TURBULENT FLOW ENHANCEMENT BY POLYELECTROLYTE ADDITIVES: MECHANISTIC IMPLICATIONS FOR DRAG REDUCTION

by

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B.S.Ch.E., U.C. Berkeley

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ABSTRACT

The drag reduction phenomenon was experimentally studied in two pipes, of diameters 1.46 and 1.02 cm, using seven polyelectrolytic HPAM additives, with molecular weights from 1 to 20×10^6 g/mole and degree of backbone hydrolysis from 8 to 60%, at concentrations from 1 to 1000 wppm, in saline solutions containing from 0.3 to 0.00001 N NaCl.

Both laminar and turbulent flow behavior were greatly influenced by salinity-induced changes in the initial conformation of the HPAM additives. Initially collapsed, random-coiling conformations exhibited Newtonian laminar flow and Type-A turbulent drag reduction, while initially extended conformations exhibited shear-thinning in laminar flow and Type-B turbulent drag reduction. The gross-flow physics of Type-B drag reduction were delineated. A characteristic "ladder" structure prevailed, with polymeric regime segments that were roughly parallel to, but shifted upward from, the Prandtl-Karman line.

In the polymeric regime, both Type-A fan and Type-B ladder structures were essentially independent of pipe diameter, and were scaled by the wall shear stress. The wall shear stress also scaled degradation during drag reduction. New onset and slope increment correlations were presented for Type-A drag reduction by HPAM additives. In Type-B drag reduction, flow enhancement was found proportional to additive concentration, and the intrinsic slip, $\Sigma = S'/(c/M_w)$, varied roughly as the third power of backbone chain links N_{bb}. New intrinsic slip and retro-onset correlations were presented for Type-B drag reduction by HPAM additives. Analysis of Type-B literature revealed a wide range of additive efficacies, with specific slips S'/c from 0.0001 to 4. For the most effective additives, HPAM and asbestos fibers, the additive-pervaded volume fraction per unit flow enhancement, $X_v/S' \approx 3000$, implied that these additives align during drag reduction.

The slip ratio R_{sc}, which is the relative flow enhancement induced in Type-A and Type-B drag reduction at constant additive concentration, was found to be a universal function of the normalized turbulent flow strength ($Re_*\sqrt{f}/Re_*\sqrt{f^*}$). The extension of initially

collapsed, random-coiling, HPAM macromolecules by the turbulent flow field thus seems independent of additive parameters and absolute wall shear stress levels. Gross flow additive equivalence was detected at iso-slip points, where different polymer solutions induced equal flow enhancements. At numerous such points, the collapsed to extended slip ratio at constant concentration, R_{sc}, was essentially equal to the extended to collapsed concentration ratio at constant slip, R_{cs}. Thus, for fixed total additive concentration, the R_{sc} observed at any $Re_s\sqrt{f}$ simply represents the fraction of originally collapsed macromolecules that have become extended in the flow, and thence effective in drag reduction.

Thesis Supervisor: Dr. Preetinder Singh Virk
Title: Professor of Chemical Engineering

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"Science increases our power in proportion as it lowers our pride."

Claude Bernard, 1928

"Wisdom entereth not into a malicious mind, and science without conscience is but the ruin of the soul."

François Rabelais, 1534

CONTENTS

CONTENTS(continued)

CONTENTS(continued)

CONTENTS(continued)

ILLUSTRATIONS

ILLUSTRATIONS(continued)

ILLUSTRATIONS(continued)

ILLUSTRATIONS(continued)

ILLUSTRATIONS(continued)

ILLUSTRATIONS(continued)

ILLUSTRATIONS(continued)

TABLES page

CHAPTER I

SUMMARY

1.1 Objectives and Approach

The thesis' objective was to examine the influence of macromolecular conformation on drag reduction in turbulent flow. This was achieved by exploring the drag reduction induced by dilute solutions of polyelectrolytic additives in both their collapsed and extended macromolecular conformations, as exhibited in solvents of high and low ionic strengths, respectively.

The experimental investigation comprised gross-flow, that is, pressure drop versus flow rate, measurements in two pipes, of diameters 1.021 and 1.458 cm, using aqueous solutions of seven partially hydrolyzed polyacrylamides(HPAM) at several salinities. The HPAM additives varied in molecular weights from 1×10^6 to 20×10^6 g/mole and had degrees of hydrolysis from 8 to 60%; they were employed at concentrations from 1 to 1000 wppm, in aqueous solutions with salinities from 0.00001 N to 0.3 N NaCl. Turbulent drag reductions induced by the additives varied from zero to the asymptotic maximum possible, about 80%.

1.2 Motivation

The present work was motivated by the observation(Virk, 1975a) of striking differences between the gross-flow drag-reduction behavior of collapsed and extended polyelectrolytes. On Prandtl-Karman(PK) coordinates, turbulent-flow trajectories for the collapsed polyelectrolytes, in common with other initially random-coiling macromolecules, were characterized by an abrupt onset of drag reduction, beyond which they departed upward from the Newtonian friction-factor relation, into a regime with drag reduction, with slopes significantly greater than Newtonian. In contrast, trajectories of extended polyelectrolytes, in common with those of fiber suspensions, exhibited no clear onset of drag reduction, but rather exhibited relatively constant drag reduction, with slopes roughly parallel to the Newtonian friction-factor relation. These two distinct types of flow trajectories, respectively named Type A and Type B, suggested that drag reduction was inherently dependent upon the conformation, that is, the actual shape, of the additive in solution, and the present work was undertaken to delineate this dependence. Polyelectrolyte additives were particularly suited to the present study because their static conformations could be altered greatly by changing solvent salinities while maintaining the identical backbone length, which is perhaps the single most important of the macromolecular parameters known to affect drag reduction. Finally, it was hoped that the systematic delineation of drag-reduction Types A and B, and the quantitative comparisons between them, might also provide fresh physical insights into the role of the additive in the mechanism of the phenomenon.

1.3 Background

Since Toms(1948) first observed the drag-reduction phenomenon, an extensive literature has accumulated on the subject, driven by industrial, military, and scientific interests.

Methods to reduce turbulent drag involve alteration of either the wetted surfaces or the flowing fluid. Surface modifications, while permanent, provide relatively little flow enhancement. Fluid modifications, by additives such as polymers, fibers, small solid particles, and air bubbles, can provide significant flow enhancement, polymeric additives having proven the most successful. For example, in the Trans-Alaskan pipeline from Prudhoe Bay to Valdez, part per million quantities of polyolefinic additives have been used for the last decade to increase oil throughput without the costly installation of additional pumping stations.

1.3.1 Previous Work

Drag reduction work prior to 1977 has been considered in several reviews, including Hoyt(1972), Lumley(1973), and Virk(1975b). The last-named reference provided a comprehensive review of polymer-induced drag reduction, with attention primarily on the behavior of homogeneous solutions of linear, random-coiling polymers, such as polyethylene oxide(PEO) in turbulent pipe flows. Table 1.3.1 illustrates the numerous experimental variables that exist for drag reduction, as well as provides references for those who have investigated these experimental aspects.

Table 1.3.1
Parameters in Drag-Reduction Experiments

<table>
<tr><th colspan="5">PARAMETER</th></tr>
<tr><td rowspan="15"></td><td colspan="4">flow cross-section(Del Villar et al., 1984)</td></tr>
<tr><td colspan="4">smooth vs. rough surface(Virk, 1971a)</td></tr>
<tr><td rowspan="13">Additive Type</td><td rowspan="13">polymers</td><td colspan="3">molecular weight M_w (Gramain & Borreill, 1978)</td></tr>
<tr><td colspan="3">backbone structure (Ting, 1982)</td></tr>
<tr><td colspan="3">side groups (McCormick et al., 1990a)</td></tr>
<tr><td rowspan="2">conformation</td><td colspan="2">coiled vs. uncoiled
(Parker & Hedley, 1972)</td></tr>
<tr><td colspan="2">preextended vs. collapsed
(Virk, 1975a)</td></tr>
<tr><td colspan="3">flexibility vs. rigidity
(Rochefort & Middleman, 1984)</td></tr>
<tr><td rowspan="2">rheology</td><td colspan="2">elasticity(relaxation)
(Bewersdorff & Berman, 1988)</td></tr>
<tr><td colspan="2">viscosity
(Pinho & Whitelaw, 1990)</td></tr>
<tr><td rowspan="4">behavior in solvent</td><td colspan="2">homogeneous dispersal
(Oliver & Bakhtiyarov, 1983)</td></tr>
<tr><td rowspan="3">heterogenous disperal</td><td>aggregates
(Dunlop & Cox, 1977)</td></tr>
<tr><td>micelles
(Ohlendorf et al., 1988)</td></tr>
<tr><td>networks
(Inge et al., 1979)</td></tr>
<tr><td colspan="4">fibers and fibers/polymers (McComb & Chan, 1981)</td></tr>
<tr><td colspan="4">gas bubbles (Madavan et al., 1985)</td></tr>
</table>

PARAMETER		
Solvent Type	highly vs. poorly dispersing(good solvent vs. Θ solvent) (Zakin & Hunston, 1980)	
	high vs. low pH (White & Gordon, 1975)	
	high vs. low ionic strength (Banijamali et al., 1974)	
Flow Conditions	transition vs. full turbulence (Ogawa & Kuroda, 1986)	
	single vs. multiple pass (Kowalik et al., 1987)	
Method of additive introduction	premixed solution (Kulicke et al., 1989)	
	flow injection	centerline($y^+ = R^+$) (Hoyt & Sellin, 1988)
		near wall($y^+ \approx 20$) (Frings, 1988)
		wall($y^+ = 0$) (Wells & Spanger, 1967)

Table 1.3.2
Themes of Recent Drag Reduction Studies

A. Gross Flow	
1. Effect of Polymer Structure	
Berman(1977)	•Type-A behavior with PEO, PAM.
Berman et al.(1978)	•Type-B behavior with DNA, Collagen.
2. Importance of Polymer Solution Preparation Methods	
Stenberg et al.(1977)	•For same polymer, DR depended on mixing methods.
Kwack et al.(1980)	•For same PEO polymer and pipe, 3 labs obtained widely different DR levels.
3. Effect of Pipe Diameter	
Burger et al.(1980)	•10 wppm CDR additive(olefinic) in Crude Oil in pipes, 26 mm < D < 1194 mm.
Sellins & Ollis(1983)	•10 wppm HPAM and 10 wppm PEO in H_2O in pipes with 2 mm < D < 50 mm.
Interthal & Wilski(1985)	•30 wppm HPAM in river water in pipes with 3 mm < D < 750 mm.
4. Effect of Additive Concentration	
Gramain & Borreill (1978)	•Polystyrene/Toluene; 6.25 wppm < c < 500 wppm, Re = 2×10^4.
Oliver & Bakhtiyarov (1983)	•Extremely dilute HPAM; 0.02 wppm < c < 0.5 wppm, Re = 15.5×10^3.
5. Drag Reduction vs. Downstream Distance: Polymer Diffusion	
Frings(1984)	•Annularly injected HPAM @ 80 < y^+ < 93, C_p = 0.2%, <C> = 50 wppm, Re = 3×10^4.

B. Mean and Turbulent Flow Structure	
1. Injected Additive	
McComb & Rabie(1982a, b)	•Centerline and wall injection of PEO, C_p = 0.3%, <C> = 10.8 wppm in 0.2% aqueous NaCl, Re = 4×104, D = 26 mm. •Coordinated measurements of DR vs x/D; polymer and salt diffusion; mean-velocity profiles; axial turbulent intensity profiles; turbulent shear stress; and axial auto-correlation data.
Bewersdorff(1984)	•Centerline injection of HPAM; C_p = 0.5%; <C> = 20 wppm; Re = 4×10^4, 6×10^4 and 8×10^4. •Axial DR vs x/D; mean velocity and turbulent intensity profiles.
Willmarth et al.(1987)	•Noted "stress deficit" during DR, with turbulent shear stress from measured <uv> correlation significantly less than estimated from the wall shear stress and mean-velocity profile.
2. Premixed Additive	
Bartels et al.(1984)	•50 < c < 320 wppm HPAM solutions; Re = 2×104 in pipes of ID = 16 and 44 mm. •Mean velocity; turbulent intensity; and shear stress profiles.
McComb & Chan(1985)	•300 wppm asbestos fiber and some fiber/HPAM mixtures in pipe flow, single and multiple passes. •Mean velocity; axial and azimuthal turbulent intensity profiles at $15\times10^3 \leq Re \leq 50\times10^3$.
Oldaker & Tiederman(1977)	•HPAM in a 2D channel, D_h = 45.45 mm, Re < 23000. •Streak dying; spacing, z^+, from streak pictures.

Table 1.3.2 encapsulates some themes examined in recent studies of drag reduction, after 1977.

No systematic study of Type B drag reduction has yet been reported in the literature.

1.3.2 HPAM Polymer Characterization

The synthetic HPAM additives used in the present work were characterized by means of intrinsic viscosity-molecular weight relationships reported in the literature, summarized in Table 1.3.3. The correlation of Kulicke et al.(1982) best approximated the data in Table 1.3.3 over the range of present interest, $10^5 < M_w < 10^8$ g/mole, and also well represented the independently gathered data of Clarke(1970) and McCormick et al.(1990). The final equation was:

$$[\eta] = 1.00\times10^{-2} M_w^{0.755} \qquad (2.4\text{-}10)$$

An experimental R_G-M_w relation derived from the same data was:

$$R_G \equiv \langle R^2 \rangle_w^{1/2} = 1.5\times10^{-2} M_w^{0.59} \qquad (2.4\text{-}11)$$

When used with the Flory-Fox equation, the above two correlations result in a reasonable value of the universal constant $\Phi = 2.96\times10^{23}$ mole^{-1}, showing that they are self-consistent.

Table 1.3.3
Summary of MHKS Equations for Aqueous PAM Solutions

Source	$[\eta] = K'M_w^a$		Experimental Conditions	M_w Range
	K'	a		
	(cm^3/g)			(10^6 g/mole)
Scholtan(1954)	6.31×10^{-3}	0.80	H_2O, 25°C	< 5.0
American Cyanamid Co.(1955)	3.73×10^{-2}	0.66	1.0N $NaNO_3$, 30°C	?
Collinson et al.(1956)	6.8×10^{-2}	0.66	H_2O, 25°C(?)	?
Klein & Conrad (1978, 1980)	4.9×10^{-3}	0.80	H_2O, 25°C	0.5-5.5
Klein & Conrad (1978, 1980)	7.19×10^{-3}	0.77	0.5 N NaCl, 25°C	0.5-5.5
Munk et al.(1980)	3.09×10^{-2}	0.67	H_2O, 20°C	< 3.0
Munk et al.(1980)	3.02×10^{-2}	0.68	0.2 N NaCl, 20°C	< 3.0
Munk et al.(1980)	2.88×10^{-2}	0.69	1.0 N NaCl, 20°C	< 3.0
Kulicke et al.(1982)	1.00×10^{-2}	0.755	H_2O, 20°C	0.038-9.0
Kulicke et al.(1982)	7.90×10^{-2}	0.5	Θ solvent, 25°C	0.5-6.0

1.4 Experimental Apparatus

The majority of experimental measurements were made using the pump-driven flow system, shown schematically in Figure 3.2, in plan view. The large diameter test-pipe shown consisted of four sections of tubing, each with a pressure-tap, cut from a single length of ¾"-OD, 0.574"-ID, 316-stainless-steel tubing. A small diameter test-pipe was also used, made from four sections cut from a single length of ½"-OD, 0.402"-

ID, low carbon, stainless-steel, microsmooth tubing. The pressure drop between any pair of taps could be measured by any one of the 0.1, 1.0, and 10 psid pressure transducers mounted on the PT board. The flow system was fed from two elevated 55-gallon, stainless-steel tanks, used for mixing, heating, and holding experimental solutions. An electronically-controlled positive-displacement Moyno 3L4-SSQ-AAA pump provided flow rates between 3.2 and 19.2 gpm. The pump discharge connected to the test pipe through a 2" flexible stainless-steel hose, a reducer, a 1" union cross, and an entrance ball valve. Three 2"-OD × ⅛"-cell × 3"-long pieces of honeycomb were inserted into the flexible hose to calm the flow. A pump-bypass loop, from the pump suction to the cross downstream of the pump, permitted gravity-driven flow through the test pipe, with the pump off and valves B2 and B3 open. The apparatus described was capable of measuring both flow rates and pressure drops to within about $\pm 1\%$ of their absolute values over their respective ranges.

1.5 Results

The experimental results are presented in three sections, dealing respectively with solvent runs, polymer-solution runs, and flow parameters extracted from the data.

1.5.1 Solvent Runs

Numerous solvent runs were conducted before and after polymer-solution runs. Fully-developed, Newtonian, Poiseuille flow(L) and turbulent flow(N) in smooth pipes

respectively obey the equations:

$$\frac{1}{\sqrt{f}} = \frac{Re_s\sqrt{f}}{16} \qquad (2.3\text{-}1)$$

$$\frac{1}{\sqrt{f}} = A_n \log(Re_s\sqrt{f}) - B_n \qquad (5.1\text{-}1)$$

where f is the Fanning friction factor, Re is the Reynolds Number, and subscript s implies the use of solvent physical properties. In Equation 5.1-1, the universal Prandtl-Karman(PK) relation results when $(A_n, B_n) = (4, 0.4)$. Solvent runs have been arranged in five sets, shown in Table 5.1.1.

In Figure 5.1.2, solvent data set 2, for the 1.021-cm pipe, is plotted in semilogarithmic PK coordinates, the ordinate and abscissa of which are $1/\sqrt{f}$ and $Re_s\sqrt{f}$, respectively. The lowest flow rate, with $Re_s\sqrt{f} \approx 40 (Re_s \approx 100)$, is in the laminar regime L. As $Re_s\sqrt{f}$ increases, the data follow L until $Re_s\sqrt{f} \approx 180 (Re_s \approx 2000)$. Here, the flow begins a transition to turbulence, the data dropping from L towards the turbulent PK line. At $Re_s\sqrt{f} \approx 400 (Re_s \approx 4000)$, the flow has become fully turbulent; thereafter the data continue along PK up to the highest flow rate, which corresponds to $Re_s\sqrt{f} \approx 10000 (Re_s = 160000)$. It is evident that the Newtonian laminar and turbulent flow relations were both closely obeyed.

Figure 5.1.7 is a PK plot of solvent data obtained in the turbulent regime using various pressure tap pairs in the 1.021-cm pipe. A solid line, 1.00PK, and two dotted lines, 1.01PK and 0.99PK, have been drawn into the figure, the latter two representing respectively $\pm 1\%$ deviations from the PK relation. Comparison between the results for

Table 1.5.1
Solvent Data Set Parameters

Solvent Set Number	System	Pipe ID	Pipe Aspect Ratio	Number of runs	Turbulent Flow Parameters	
		(cm)	L/D		A_n	B_n
1	Pump	1.458	183.0	33	4.0	0.4
2	Pump	1.021	203.2	11	4.0	0.4
3	Gravity	1.458	209.8	9	4.0	0.4
4	Gravity	1.458	209.8	10	2.98	-2.00
5	Gravity	1.458	209.8	7	3.54	-0.79

all pressure tap pairs shows that the differences between tap pairs were insignificant relative to the inherent data scatter, which is approximately $\pm 1\%$ around the PK correlation. It is evident that fully-developed turbulent flow in a smooth pipe was achieved with the solvent.

1.5.2 Polymer-Solution Runs

Polymer-solution results are grouped in three sets: (1) the high molecular-weight polymer additives C832A and B1120 in the pump-driven system; (2) the low molecular-weight polymer additives P500, A507, and D1438 in the pump-driven system; and (3) the high molecular-weight polymer additives C837A, C836A, and C832A in the gravity-driven system. Additives C832A and P500 in sets 1 and 2, respectively, were each studied separately in two pipes of inner diameters 1.458 and 1.021 cm, to infer the effect of flow scale.

Figure 5.2.1 illustrates the experimental grids executed. For each polymer, a logarithmic series of polymer concentrations was used, and each polymer concentration was studied at both high and low salinities. The columns in Figure 5.2.1 reflect the actual experimental procedure in that a polymer solution of given concentration, once made up, was used for the entire [NaCl] range to be studied; this revealed the effect of salinity-induced conformational changes while maintaining both the additive amount and its molecular-weight distribution constant.

Gross Flow Physics: Introduction. Aspects of the observed polymer-solution flow behavior are introduced in Figure 5.2.4, a PK plot of experiments in the pump-driven system using 10-wppm solutions of additive B1120, an HPAM of high molecular-weight and high backbone charge, in, respectively, 0.3(▾) and 0.0001(▿) N NaCl.

In this figure, lines L and N respectively represent Newtonian laminar and turbulent flows, whereas the line M represents the maximum drag reduction(MDR) asymptote(Virk et al., 1970):

$$\frac{1}{\sqrt{f}} = 19.0 \log(Re_s\sqrt{f}) - 32.4 \qquad (2.3\text{-}7)$$

Lines N and M envelop the region of turbulent drag reduction, called the "polymeric regime" because, within it, the extent of drag reduction depends on additive parameters.

Consider first the data at high salinity(▾), which typify results obtained with initially-collapsed conformations of HPAM additives. At low $Re_s\sqrt{f} < 150$, the polymer-solution data closely follow Poiseuille's law L. At $Re_s\sqrt{f} \approx 150$, the data deviate downward from L and then drop toward N, which is reached at $Re_s\sqrt{f} \approx 350$. The laminar-to-turbulent transition observed here is similar to that seen with solvent in

Figure 5.1.2. For $350 < Re_s\sqrt{f} < 500$, the polymer-solution data follow the solvent turbulent-flow line N. Then at $Re_s\sqrt{f} \approx 500$ the data abruptly lift up from N at the "onset" point, hereafter denoted by an asterisk, which marks the onset of flow enhancement; i.e., for any fixed $Re_s\sqrt{f} > Re_s\sqrt{f}^*$, $1/\sqrt{f_p} > 1/\sqrt{f_n}$. For $Re_s\sqrt{f} > 500$ the data exhibit flow enhancement, rising into the polymeric regime along a near-linear segment P, with slope and intercept $(A_p, B_p) = (17.2, 36.1)$ for $500 < Re_s\sqrt{f} < 3500$. At the highest $Re_s\sqrt{f} \approx 4000$ the data depart slightly downward from the line segment, possibly because of polymer degradation within the test pipe. The flow enhancements achieved are measured by the apparent slip, $S' = (1/\sqrt{f_p} - 1/\sqrt{f_n})$ at fixed $Re_s\sqrt{f}$. At $Re_s\sqrt{f} = 1000$, $1/\sqrt{f_p} = 15.6$, $1/\sqrt{f_n} = 11.6$, and $S' = 4.0$, corresponding to fractional flow enhancement $S_F = S'/(1/\sqrt{f_n}) = 0.34$ relative to solvent; at $Re_s\sqrt{f} = 3000$, $S' = 10.2$ and $S_F = 0.76$.

The flow trajectory observed for 10 wppm of B1120 in 0.3 N NaCl thus contains three segments: laminar flow, L; turbulent flow without drag reduction, N; and turbulent flow with drag reduction, P; a distinct onset of drag reduction separates the N and P segments. Such LNP trajectories are commonly exhibited by solutions of random-coiling macromolecules and are termed "Type A" drag-reduction behavior. The polymeric-regime segment P observed during Type-A drag reduction can be quantitatively characterized by the onset wall shear stress, T_w^*, which is related to $Re_s\sqrt{f}^*$, and the slope increment $\delta = A_p - A_n$. In this example, $Re_s\sqrt{f}^* = 450$, $T_w^* = 4.1$ dyne/cm^2, and $\delta = 17.2 - 4.0 = 13.2$.

Consider next the low salinity data(▽), which typify results obtained with initially extended conformations of HPAM additives. For $60 < Re_s\sqrt{f} < 400$ the data are

displaced rightwards from Poiseuille's law L, to higher $Re_s\sqrt{f}$ at fixed $1/\sqrt{f}$; this "viscosity shift", reflects the relative viscosity η_r of the polymer solution. Note that in this region of low $Re_s\sqrt{f}$, the polymer-solution is drag-enhancing, its data being displaced downwards from L. For $60 < Re_s\sqrt{f} < 400$, the data follow a Poiseuille-like path, but as $Re_s\sqrt{f}$ increases, the viscosity shift decreases, corresponding to shear-thinning behavior with power law index $n' = 0.81$. The data pass through the Newtonian turbulent-flow baseline N, at $Res\sqrt{f} \approx 220$, and enter the polymeric regime without exhibiting the laminar-to-turbulent transition observed in the 0.3-N data. For $400 < Re_s\sqrt{f}$ 1500, the data ascend toward, and lie nearly parallel to, the MDR asymptote M. At $Re_s\sqrt{f} \approx$ 1500, they depart downwards from M into the polymeric regime at a "retro-onset" point, denoted by an octathorpe(#). The retro-onset point separates the region of asymptotic maximum drag reduction, which is independent of additive properties, from the polymeric regime, within which drag reduction is dependent on additive properties; in this sense, retro-onset is the converse of onset, which separates Newtonian flow, with no drag reduction, from the polymeric regime. For $1500 < Re_s\sqrt{f} < 3400$, the data continue into the polymeric regime along a near-linear segment P with slope and intercept $(A_p, B_p) = (8.0, -1.2)$. At the highest $Re_s\sqrt{f} \approx 4000$, the data descend slightly from segment P, possibly because of polymer degradation within the test pipe. The following flow enhancements are observed: At $Re_s\sqrt{f} = 1000$, $1/\sqrt{f_p} = 1/\sqrt{f_m} = 24.6$, corresponding to $S' = 13.0$ and $S_F = 1.1$; and at $Re_s\sqrt{f} = 3000$, $S' = 14.7$, and $S_F = 1.09$.

The trajectory observed for 10 wppm of B1120 in 0.0001 N NaCl thus has three segments: drag-enhanced laminar flow with relative viscosity $\eta_r > 1$ and shear-thinning;

maximum drag reduction along the MDR asymptote, M; and turbulent drag reduction, P, with a retro-onset that separates the M and P segments. Such LMP trajectories have been previously observed with solutions of extended macromolecules and constitute "Type B" drag-reduction behavior. A feature of Type-B behavior is that the polymeric-regime segment P is almost parallel to N.

Comparisons between the two sets of data in Figure 5.2.4 reveal the influence of additive conformation. In laminar flow for $Re_s\sqrt{f} < 200$, both conformations enhance drag relative to solvent, the extended conformation more so than the collapsed conformation. In turbulent flow, however, for $Re_s\sqrt{f} > 400$, the extended conformation reduces drag relative to solvent more than does the collapsed conformation. It is instructive to follow S'_A/S'_B, the ratio of the flow enhancement induced by the collapsed conformation during its Type-A behavior to that induced by the expanded conformation exhibiting Type-B behavior. For $Re_s\sqrt{f} < Re_s\sqrt{f}^*$, $S'_A/S'_B = 0$, the collapsed conformation providing no flow enhancement before onset, while the extended conformation does. For $Re_s\sqrt{f} \geq Re_s\sqrt{f}^*$, S'_A/S'_B increases with increasing $Re_s\sqrt{f}$, approaching unity at higher $Re_s\sqrt{f}$; also, after onset, S'_A increases faster than does S'_B with increasing $Re_s\sqrt{f}$, because the Type-A P segment has a steeper slope than the Type-B P segment. In this example, at $Re_s\sqrt{f} = 500$, 1000, and 3000, $S'_A/S'_B = 0$, 0.31, and 0.69, respectively.

A second illustration of polymer-solution flow behavior is given in Figure 5.2.5, a PK plot of experiments in the gravity-driven system using 20.6-wppm solutions of additive C836A, an HPAM of high molecular-weight and moderate backbone charge, at two salinities, respectively, 0.1(◆) and 0.001(◇) N NaCl.

The data at high salinity, for an initially-collapsed conformation of C836A, exhibit an LNP trajectory typical of Type-A behavior. Parameters of the polymeric-regime segment P are: $Re_s\sqrt{f}^* \approx 770$ and $T_w^* \approx 13.7$ dyne/cm^2 , slope increment δ = 15.1; also, at $Re_s\sqrt{f} = 1000$, S' = 1.4, with $S_P = 0.12$. These data exhibit some curvature in the the vicinity of the onset point. Thus, as indicated in the figure, the visually determined onset point, $Re_s\sqrt{f}^* \approx 660$, where the data first depart significantly from N, does not coincide with the regressed onset point, $Re_s\sqrt{f}^* \approx 770$, where the linear segment P, extrapolated backward, intersects N.

Data at low salinity illustrate the behavior of an initially expanded conformation of the C836A macromolecule. At low flowrates, $80 < Re_s\sqrt{f} < 300$, the data follow a laminar path that is almost parallel to, but shifted rightward from, Poiseuille's law L, corresponding to relative viscosity $\eta_r = 1.8$, with slight shear thinning, n' = 0.91. Between $350 < Re_s\sqrt{f} < 550$, the polymer solution undergoes a laminar-to-turbulent transition, the data abruptly shifting horizontally rightward from their laminar-flow path to a turbulent flow segment P that lies in the polymeric regime. The observed transition is noteworthy because the polymer-solution exhibits drag reduction immediately upon attaining turbulent flow. For $550 < Re_s\sqrt{f} < 1100$, the polymer-solution data rise into the polymeric regime along a linear segment P, of slope and intercept $(A_p, B_p) = (19.8, 38.9)$, with slope increment $\delta = 15.8$. At $Re_s\sqrt{f} = 1000$, S' = 9.0 and $S_P = 0.79$. The flow trajectory has two distinct segments: drag-enhanced laminar flow, with relative viscosity $\eta_r \approx 1.8$, amidst slight shear thinning, and drag-reduced turbulent-flow along a linear polymeric-regime segment P. This LP trajectory evidently differs from both the LNP and LMP types of trajectories seen in earlier examples, lacking a central turbulent-

flow segment along either N or M, and displaying neither onset nor retro-onset. The behavior of 20.6-wppm C836A in 0.001 N NaCl is classified Type A, not Type B, because the polymeric-regime segment possesses a slope similar to, not much shallower than, that of the 20.6-wppm C836A in 0.1 N NaCl, which was clearly Type-A.

Figure 5.2.5 shows that, relative to the collapsed conformation, the expanded conformation of C836A causes greater drag in laminar flow, but yet induces the greater drag reduction in turbulent flow. Despite differences in their drag reduction extents, both conformations of C836A exhibit the Type-A behavior associated with random-coiling macromolecules.

Gross Flow Physics: Details. Detailed results for additive B1120 at $1 \leq c$, wppm ≤ 100 in 0.3 N and 0.0001 N NaCl, respectively, are presented in Figures 5.2.10 and 5.2.11.

In Figure 5.2.10, at high salinity, for the initially-collapsed conformation of B1120, the flow trajectories observed at all concentrations are akin to the Type-A trajectory earlier described for c = 10 wppm B1120 in 0.3 N NaCl (Figure 5.2.4), with the following elaboration. LNP trajectories are exhibited by c = 1, 2, 5, 10 and 20 wppm; however, c = 50 and 100 wppm trace LPM trajectories, the data remaining above N after transition, and attaining the MDR asymptote at the highest $Re\sqrt{f}$. Laminar-flow paths for $c \leq 20$ wppm are virtually indistinguishable from the solvent line L and both 50 and 100 wppm solutions also exhibit Newtonian viscosities, even though they show $\eta_r > 1$. In turbulent flow, the P segments for $1 \leq c \leq 20$ wppm have slopes, and slope increments, that increase with increasing concentration, δ = 0.9, 3.7, 8.4, 13.2, and 18.0, respectively, the corresponding $Re\sqrt{f^*} \approx$ 960, 580, 640, 510, and

480. These five segments appear to radiate from a narrow band on the turbulent baseline N, forming a Type-A "fan" characteristic of drag reduction by solutions of random-coiling additives.

Figure 5.2.11 shows data at low salinity, for the initially-extended conformation of B1120. The flow trajectories observed here are related to the Type-B trajectory earlier described for c = 10 wppm B1120 in 0.0001 N NaCl. For c = 1 and 2 wppm the trajectories are respectively LNP and LP; for c = 5 and 10 wppm both LMP; and for c = 20, 50, and 100 wppm all LM. In laminar flow, these solutions exhibit high relative viscosities, with shear-thinning. In turbulent flow, the polymeric-regime segments P are approximately parallel to, but displaced upwards from, the turbulent baseline N; thus, for c = 1, 2, 5, and 10 wppm, the respective P segment slopes are A_p = 4.0, 7.4, 5.3, and 8.0, with flow enhancements S' = 1.0, 4.4, 9.5, and 14.7 at $Re_s\sqrt{f}$ ≈ 3000. The resulting polymeric-regime structure resembles a "ladder", the rungs of which are the ascending parallel linear P segments; this Type-B "ladder" is characteristic of drag reduction by solutions of extended additives.

Figure 5.3.4 summarizes turbulent flow enhancements S' obtained at $Re_s\sqrt{f}$ ≈ 1000(○ ●) and 3000(△ ▲) in the Type-A fan(open points) and Type-B ladder(closed points) respectively exhibited by the collapsed and extended conformations of B1120. At $Re_s\sqrt{f}$ ≈ 1000 for c = 1, 2, 5, and 10 wppm, S'_A = 0.3, 0.5, 1.1, and 4.0, whereas S'_B = 0.5, 3.0, 8.8, and 13.0; thus, S'_A/S'_B = (0.52, 0.15, 0.12, and 0.31), respectively. At $Re_s\sqrt{f}$ ≈ 3000, S'_A = 0.45, 2.7, 5.3, and 10.2, S'_B = 1.0, 4.4, 9.5, and 14.7, and S'_A/S'_B = 0.47, 0.61, 0.56, and 0.69. The preceding show that, for fixed $Re_s\sqrt{f}$ and c, $S'_A < S'_B$, always. At any fixed c, S'_A/S'_B increases toward unity as $Re_s\sqrt{f}$

is increased, with S'_A increasing strongly but S'_B only weakly. This suggests that, as $Re_s\sqrt{f}$ increases, initially collapsed macromolecules are progressively stretched toward their extended conformations. Further, at both the chosen $Re_s\sqrt{f}$, S'_B increases roughly tenfold over the tenfold range of c from 1 to 10 wppm, suggesting an approximately linear relationship between S'_B and c at low concentrations. At the highest concentrations, 50 and 100 wppm, it is found that $S'_A = S'_B = S'_M$, the asymptotic maximum drag reduction being attained at both $Re_s\sqrt{f}$, independent of additive parameters.

Detailed results for additive D1438, an HPAM of low molecular weight and moderate backbone charge, at $30 \leq c$, wppm ≤ 1000 in 0.3 N and 0.0001 N NaCl, respectively, are presented in Figures 5.2.16 and 5.2.17.

In Figure 5.2.16, at high salinity, for the initially-collapsed conformation of D1438, all solutions display LNP trajectories. Relative viscosities in laminar flow are small, $\eta_r < 1.5$, with Newtonian behavior. The observed laminar-to-turbulent transitions are all akin to those seen in normal Newtonian flows. In turbulent flow with drag reduction, for all c, from 30 to 997 wppm, P segments rise from onset points in the vicinity of $Re_s\sqrt{f}^* \approx 1500$, with increasing respective slope increments δ, from 1.4 to 11.4, forming a Type-A fan.

In Figure 5.2.17, at low salinity, for the initially-expanded conformation of D1438, all solutions display LNP trajectories. In laminar flow, the relative viscosities increase greatly as concentration increases, upto $\eta_r \approx 5$, but the behavior remains Newtonian, with no shear thinning. Evidently, the lowered salinity increases the size of the macromolecular coils but does not distort their shape enough to allow significant

orientation in laminar flow. The observed laminar-to-turbulent transitions are all Newtonian in nature. In turbulent flow, all solutions possess N segments, without drag reduction. For c from 30 to 300 wppm, onsets occur in a narrow band, $Re_s\sqrt{f^*} \approx 1200$, and beyond onset, P segment slope increments increase with increasing concentration, with δ from 1.7 to 9.3, describing an imperfect Type-A fan.

Both collapsed and expanded conformations of D1438 exhibit Type-A drag reduction behavior, the fan for the expanded conformation showing onset at lower $Re_s\sqrt{f}$ than that for the collapsed conformation. These results suggest that even the expanded conformation of D1438 retains random-coiling character.

1.5.3 Flow-Parameter Summary

Experimental conditions, turbulent-flow parameters, and laminar-flow parameters for all 122 runs made are summarized in Tables 5.2.1, 5.2.2, and 5.2.3, respectively, from which abbreviated Tables 1.5.2a, 1.52b, and 1.52c for additive B1120 are taken.

Table 1.5.2a summarizes the experimental conditions in seven columns: Entry; Run; Concentration, c; Salinity, [NaCl]; Solvent Turbulent Baseline Constants, A_n and B_n; and Temperature Range. Table 1.5.2b summarizes the turbulent-flow parameters extracted from each run and contains eight columns: Entry; Polymeric-Regime Constants, A_p and B_p; Apparent Slips, S'_1 and S'_3; Slope Increment δ; Onset & Retro-Onset Wall Shear Stresses, T_w^* and $T_w^\#$. Table 1.5.2c summarizes the laminar-flow parameters extracted from each run and contains five columns: Entry; Arithmetic-Mean and Geomtric-Mean Estimated Intrinsic Viscosities, η_{sp}/c^a and η_{sp}/c^g, and Pseudo-Power-Law

Coefficient and Exponent, K' and n'. The Entry columns common to each of Tables 1.5.2a, 1.52b, and 1.5.3c link their rows.

Polymer Characterization from Laminar Flow Parameters. Figure 5.4.3 is a representative double-logarithmic plot of the estimated intrinsic viscosity η_{sp}/c versus concentration c, for additive P500, obtained from the present experimental laminar flow parameters. Data for η_{sp}/c at high salinity, [NaCl] $\geq$ 0.01 N, and high polymer concentration, c $\geq$ 30 wppm, were averaged, to obtain the estimated intrinsic viscosity of P500 in its collapsed conformation, as quoted in the figure. Data for η_{sp}/c at low salinity, [NaCl] $\leq$ 0.001 N, were separately averaged, to obtain the estimated intrinsic viscosity of P500 in its extended conformation, along with the ratio of extended to

Table 1.5.2a
Experimental Conditions for B1120 Runs

Entry	Run	Concentration	Salinity	Solvent Turbulent Baseline Constants		Temperature Range
		c	[NaCl]	A_n	B_n	
		(wppm)	(N)			(°C - °C)
Betz 1120 = B1120; Pump-Driven System; Pipe ID = 1.458 cm						
27	B1P01496	1.00	1.00×10^{-4}	4	0.4	25.05-25.5
28	B2P01494	2.02	1.00×10^{-4}	4	0.4	24.4-25.1
29	B5P01490	5.07	1.00×10^{-4}	4	0.4	24.4-25.05
30	B1P11486	9.96	1.00×10^{-4}	4	0.4	24.0-24.9
31	B2P11483	20.0	1.00×10^{-4}	4	0.4	23.5-24.7
32	B5P11480	49.9	1.00×10^{-4}	4	0.4	23.9-25.2
33	B1P21477	100	1.00×10^{-4}	4	0.4	24.4-24.9
34	B1P03197	1.00	3.00×10^{-1}	4	0.4	24.5-25.1
35	B2P03195	2.02	3.00×10^{-1}	4	0.4	24.2-25.1
36	B5P03191	5.07	3.00×10^{-1}	4	0.4	24.6-25.3
37	B1P13187	9.96	3.01×10^{-1}	4	0.4	24.1-25.1
38	B2P13184	20.0	3.00×10^{-1}	4	0.4	23.8-25.2
39	B5P13181	49.9	3.00×10^{-1}	4	0.4	23.7-24.9
40	B1P23178	100	3.00×10^{-1}	4	0.4	24.3-25.1

Table 1.5.2b
Turbulent Flow Parameters for B1120 Runs

Entry	Polymeric-Regime Constants		Apparent Slips[a]		Slope Increment	Onset & Retro-Onset Wall Shear Stresses[b]	
	A_p	B_p	S'_1	S'_3	δ	T_w^*	$T_w^\#$
						(dyne/cm^2)	
Betz 1120 = B1120; Pump-Driven System; Pipe ID = 1.458 cm							
27	4.01	-0.57	0.5	1.0	~0	3.3(3.8?)	
28	7.43	7.69	3.0	4.4	3.43		
29	5.29	-4.76	8.8	9.5	1.29		
30	7.98	-1.18	13.0	14.7	3.98		23.4(38)
31			11.8	18.2			MDR
32			10.8	19.1			MDR
33			9.7	18.6			MDR
34	4.92	3.14	0.3	0.5	0.92	17.8(22?)	
35	7.70	10.6	0.5	2.7	3.70	6.5(13.5)	
36	12.4	23.9	1.3	5.4	8.40	7.4(6.1)	
37	17.2	36.1	4.0	10.2	13.2	5.1(4.1)	
38	22.0	48.8	5.6	14.5	18.0		
39			11.0	19.0			MDR
40			11.2	18.6			MDR

(a) S'_1 and S'_3 denote S' evaluated at $Re_s\sqrt{f}$ = 1000 and 3000, respectively.
(b) ( ) = visual value.
† = before onset; ‡ = highest $Re_s\sqrt{f} < 1000$.

Table 1.5.2c
Laminar Flow Parameters for B1120 Runs

Entry	Arithmetic- and Geometric-Mean Estimated Intrinsic Viscosities		Pseudo-Power-Law Coefficient and Exponent	
	η_{sp}/c [a]	η_{sp}/c [g]	K'	n'
	(cm^3/g)		($s^{n'} \cdot dyne/cm^2$)	
Betz 1120 = B1120; Pump-Driven System; Pipe ID = 1.458 cm				
27	26869	24388	0.0090	1.006
28	84479	80687	0.0119	0.956
29	123199	113391	0.0210	0.861
30	113990	109283	0.0300	0.814
31	54709	52839	0.0296	0.847
32	116809	109491	0.2150	0.543
33	111709	104565	0.4176	0.490
34	0	0	0.0090	1.007
35	0	0	0.0093	0.997
36	7703	7689	0.0097	0.998
37	3658	3585	0.0096	1.002
38	2470	2357	0.0098	1.002
39	3398	3373	0.0109	1.004
40	4001	3993	0.0131	1.000
Superscripts: a = arithmetic mean; g = geometric mean.				

collapsed intrinsic viscosities, termed the coil expansion factor α^3, the cube of the linear expansion factor α.

Table 1.5.3 lists the intrinsic viscosities, η_{sp}/c, estimated at high salinity for each HPAM additive. These were used, with equations 2.4-10 and 2.4-11 from the literature, to infer the molecular weight and rms radius of gyration of each additive, and thence the associated number of backbone chain links and contour lengths quoted in the table. Additional information is also provided about the present HPAM additives, including manufacturers' estimates of their molecular weights and extents of backbone hydrolysis, estimated intrinsic viscosities derived in the present work at low salinities, and apparent coil expansion factors.

1.6 Discussion

The present experimental results are discussed in five sections, concerning the influence of pipe diameter, the effect of additive conformation, the analysis of each of Type-A and Type-B drag reduction, and comparisons between them.

1.6.1 Influence of Pipe Diameter

The influence of pipe diameter upon both Types A and B of turbulent drag reduction was sought from the experiments with additives P500 and C832A in each of the 1.458- and 1.021-cm pipes.

Table 1.5.3
Inferred Polymer Characteristics†

Polymer	Manufacturer's Data‡		Estimated Intrinsic Viscosity at High Salinity	Parameters Inferred from Equations 2.4-10 and 2.4-11	
	Molecular Weight	Degree of Hydrolysis		Molecular Weight	Radius of Gyration
	$M_w \times 10^{-6}$		η_{sp}/c	$M_w \times 10^{-6}$	R_G
	(g/mole)	(%)	(cm^3/g)	(g/mole)	(nm)
C832A	14 - 17	50(?)	3000±600	18.0±5.0	280±50
B1120	8 - 10	High(?)	3300±800	20.1±6.4	300±60
P500	2 - 3	30	1850±500	9.5±3.5	190±40
A507	1 - 2	60	340±80	1.0±0.3	50±10
D1438	2 - 4	10	440±150	1.4±0.6	60±20
C837A	14 - 17	8(?)	2700±900	15.7±6.7	260±70
C836A	14 - 17	15(?)	2700±1450	15.5±11.0	260±110

Polymer	Number of Backbone Chain Links	Contour Length	Estimated Intrinsic Viscosity at Low Salinity	Coil Expansion Ratio	Linear Expansion Factor
	$N_{bb} \times 10^{-5}$	L_c	η_{sp}/c	α^3	α
		(μm)	(cm^3/g)		
C832A	5.0±1.4	64±18	97000±2000	32.4	3.2
B1120	5.6±1.8	71±23	97000±3000	29.6	3.1
P500	2.7±1.0	34±12	72000±2000	38.7	3.4
A507	0.3±0.1	3.6±1.1	7000±500	20.3	2.7
D1438	0.4±0.2	5.0±2.2	5800±400	13.0	2.4
C837A	4.4±1.9	56±24	31000±2000	11.4	2.2
C836A	4.4±3.1	55±39	48000±4000	17.9	2.6

† ± values are average standard errors.
‡ The accuracy of manufacturers' data is unknown.

Figure 6.1.1 shows the direct superposition, on PK coordinates, of all the original data for additive P500 at high salinity in the 1.458- and 1.021-cm pipes. In the polymeric-regime, at every concentration, the data in the 1.021-cm pipe lie systematically somewhat higher than the corresponding data in the 1.458-cm pipe. Figure 6.1.2 shows the same results after a transformation wherein the original 1.458-cm data are left intact while the 1.021-cm pipe data are translated rightward and upward, along line N, by an abscissa factor of 1.458/1.021, the pipe-diameter ratio. All of the transformed 1.021-cm pipe polymeric-regime data are simultaneously superimposed upon the corresponding data in the 1.458-cm pipe. The transformation described above also serves to superimpose all the data for P500 at low salinity in both pipes, as shown by Figures 6.1.3 and 6.1.4. This remarkable coincidence of the entire Type-A fan and Type-B ladder structures in both pipes suggests that, in the polymeric regime, both types of drag reduction are independent of pipe diameter and are scaled by the wall shear stress. Theoretically, this result implies that drag reduction in the polymeric regime is relatively unaffected by the large scales of turbulence, imposed by the pipe diameter, and is instead controlled by the finer wall-turbulence scales related to the wall shear stress.

Polymeric-regime data for additive C832A at both high and low salinities in both the 1.458- and 1.021-cm pipes, Figures 6.1.5 - 6.1.8, are also found to scale with wall shear stress rather than pipe diameter, reinforcing the results shown for additive P500.

Additive Degradation. The aforementioned superposition of polymeric regimes further succeeds in superposing the degradation-induced maxima and downward departures from P segments observed in both pipes at the highest $Re\sqrt{f}$. Thus the wall shear stress also appears to scale polymer degradation during drag reduction. Perusal

of Figures 6.1.2 and 6.1.4 shows that for additive P500 at both high and low salinities, degradation becomes significant beyond a characteristic "falloff" wall shear stress, $T_w^{\wedge}$ $\approx$ 690 dynes/cm^2, corresponding to $Re_*\sqrt{f}^{\wedge} \approx 6000$ in the 1.458-cm pipe. Note also that the Type-A fans in Figure 6.1.2 exhibit onset at $Re_*\sqrt{f}^{*} \approx 700$, where $T_w^{*} \approx 9.5$ dynes/cm^2. For P500, a 70 fold range of wall shear stress thus separates onset from the degradation falloff; this is the region within which its initially-collapsed conformation can effectively reduce turbulent drag. The C832A data exhibited degradation falloffs at $T_w^{\wedge}$ $\approx$ 170 dynes/cm^2, corresponding to $Re_*\sqrt{f}^{\wedge} \approx 3000$ in the 1.458 cm pipe, and Type-A onsets at $Re_*\sqrt{f}^{*} \approx 550$, where $T_w^{*} \approx 5.7$ dynes/cm^2; in this case only a 30-fold range of wall shear stress separated onset from the degradation falloff. Lastly, the molecular weights of additives P500 and C832A are in the ratio 9.5/18 $\approx$ 0.5 while their falloff shear stresses are in the ratio 690/170 $\approx$ 4; this provides the following dimensional inverse-square relation for degradation of HPAM additives in the present pipes:

$$T_w^{\wedge} \approx 5.9\times10^{16} M_w^{-2} \qquad (6.1\text{-}2)$$

with $T_w^{\wedge}$ and M_w in dyne/cm^2 and g/mole, respectively.

1.6.2 Effect of Additive Conformation

The effects of macromolecular additive conformation on gross flow physics are summarized in the central kernel of Figure 6.2.1. Observations with any additive and salinity fell into one of three sets: (i), laminar flow that was Newtonian with relative viscosities near unity, and turbulent flow with Type-A drag reduction; (ii), laminar flow

that was Newtonian but with relative viscosities appreciably greater than unity, and turbulent flow with Type-A drag reduction; and (iii), laminar flow with shear-thinning and relative viscosities greatly in excess of unity, and turbulent flow with Type-B drag reduction. The preceding are associated with each of three initial conformations of the additive: (i) collapsed random-coil, (ii) expanded random-coil, and (iii) the extended macromolecule. The observed examples actually used to derive the above classification are given in the bottom row of Figure 6.2.1. Comparisons between these and the HPAM characterization data in Table 1.5.3 show that, while Type-A drag reduction behavior is achieved by the initially-collapsed conformations of all additives, Type-B drag reduction behavior, associated with the initially-extended macromolecular conformation, is only accessible to additives of the highest molecular weight and backbone charge. The lowest molecular weight additives, D1438 and A507, each with $M_w \approx 1\times10^6$ g/mole, did not exhibit Type-B behavior, despite the latter possessing a highly charged backbone, with nominal degree of hydrolysis $\approx$ 60%. The highest molecular weight additives, B1120 and C832A, with $M_w \approx 20\times10^6$ g/mole, and high backbone charge $\approx$ 50%, both exhibited Type-B drag reduction. However, P500, with $M_w \approx 10\times10^6$ g/mole, and backbone charge $\approx$ 30% achieved Type-B behavior, whereas C837A and C836A, with $M_w \approx 16\times10^6$ g/mole, and backbone charges $\approx$ 8 and 15%, did not. These data suggest that, at any given molecular weight, a threshold backbone charge must be exceeded to induce Type-B behavior; for our $M_w\times10^{-6} \approx$ 1, 10, 16, and 20, these threshhold charges are, respectively, $>$60%, $<$30%, $>$15%, and $<$50%.

Figure 6.2.3 details the dependence of turbulent drag reduction behavior on salinity as actually observed with the present HPAM additives. In the columns of the

figure, each of the two broad categories, the Type-A fan and the Type-B ladder, are amplified into their perfect, observed, and imperfect counterparts, respectively representing their idealized, typical, and distorted (but still recognizable) forms. Thus the perfect Type-A fan emanates from a single onset point on N, with P segments radiating into the polymeric regime, their slope increments increasing as the square-root of additive concentration. The perfect Type-B ladder has P segments that come off M at retro-onset points and lie parallel to N, but shifted upwards therefrom, by amounts that are proportional to additive concentration. The rows in the figure represent the HPAM additives studied, with the salinities exhibiting a given behavior noted in the appropriate column. All the kinds of turbulent flow behavior listed, except the perfect Type-A fan, were observed, the widest range with additive C832A.

1.6.3 Type-A Drag Reduction

Type-A drag reduction has been known for long, and here the focus is exclusively on the present new results for HPAM additives in their variously random-coiling conformations. A Type-A fan is defined by the wall shear stress at its onset point, and by the slope increments of the P segments emanating therefrom; we consider the dependence of these parameters on molecular properties.

Onset. Figure 6.3.1 illustrates a direct relationship between macromolecular coil size and onset for 20.6-wppm solutions of additive C836A at salinites from 0.1 to 0.0003 N. The onset $Re_*\sqrt{f^*}$, obtained from the intersection of the observed P segments with the solvent line N, decreases monotonically as the intrinsic viscosity η_{sp}/c increases, the

conformational expansion here induced by decreasing salinity.

More generally, the onset wall shear stress T_w^* is found to correlate inversely with the rms radius of gyration R_G of the additive. All the present onset data are presented in this standard form in Table 1.6.1. Part A of the table contains the more reliable data, using average values of T_w^* from the Type-A fans observed at high salinity and R_G data from Table 1.5.3; part B of the table contains individual values of T_w^* at various salinities, with R_G estimated from the corresponding η_{sp}/c via coil expansion factors.

Figure 6.3.2 is an onset correlation for collapsed HPAM additives, displaying the data in Table 1.6.1 on doubly logarithmic coordinates of T_w^* vs R_G. The solid line of slope -2 drawn through the experimental data represents the equation:

$$T_w^* = 5.79\times10^5 R_G^{-2} \qquad (6.3\text{-}5)$$

where T_w^* and R_G are in dyne/cm^2 and nm, repsectively. The proportionality constant in equation 6.3-5 corresponds to a nondimensional "length-based" onset constant $\Omega_L = R_G u_\tau/\nu_s = 8.3\times10^{-3}$, which is of the same order as that, $\Omega_L = (8.2\pm0.4)\times10^{-3}$, previously quoted for PAM additives in the literature(Virk, 1975b).

Slope Increments. Figure 6.3.3 illustrates a direct relationship between macromolecular coil size and slope increment for 20.6-wppm solutions of additive C836A at salinites from 0.1 to 0.0003 N. The slope increment remains essentially constant, $\delta = 15.3\pm0.7$, over a 25-fold range of the intrinsic viscosity η_{sp}/c, which increases from 2500 to 70000 cm^3/g with decreasing salinity. Thus, in Type-A drag reduction, the slope increment is essentially independent of coil size, in contrast to the onset wall shear stress, which decreases markedly with increasing coil size.

Table 1.6.1
Onset Data for Type-A Drag Reduction by HPAM Additives†

HPAM	Concen-tration Range	Salinity	Esti-mated Intrin-sic Visco-sity	Radius of Gyration	Onset Wall Shear Stress[1]	Length-Based Onset Constant
	c	[NaCl]	η_{sp}/c	R_G	T_w^*	$\Omega_L \times 10^3$
	(wppm)	(N)	(cm^3/g)	(nm)	(cm^3/g)	
Part A: Average Values						
C832A[2]	20-100	0.3	3000	280±50	7.7±2.2	8.5±2.7
B1120	10-100	0.3	3300	300±60	6.4±1.2	8.3±2.4
P500[2]	30-100	0.3	1850	190±40	9.5±4.6	6.5±3.1
A507	300-1000	0.3	340	50±10	50.4±20.1	4.0±1.5
D1438	100-1000	0.3	440	60±20	41.0±19.2	4.4±2.2
C837A	50	0.1	2700	260±70	13.7±7.9	10.8±5.9
C836A	20	0.1	2700	260±110	15.2±4.6	11.2±6.5
Part B: Other Individual Values						
C836A[3]	20.6	0.0003	69170	715	0.77(190)	7.1
C836A[3]	20.6	0.001	36330	580	1.6(270)	8.3
C836A	20.6	0.01	8190	350	5.8(510)	9.4
C836A[4]	20.6	0.1	2820	250	10.8(690)	9.0
C836A[4]	20.6	0.1	2560	240	13.7(770)	9.8
P500	30	0.01	8480	300	2.9	5.8
P500[4]	30	0.3	1630	170	8.4	5.4
A507	30-300	0.0001	7000	135	23.7[5]	8.6
A507[4]	30-300	0.3	330	49	45.6	4.0

HPAM	Concen-tration Range	Salinity	Esti-mated Intrin-sic Visco-sity	Radius of Gyration	Onset Wall Shear Stress[1]	Length-Based Onset Constant
	c	[NaCl]	η_{sp}/c	R_G	T_w^*	$\Omega_L \times 10^3$
	(wppm)	(N)	(cm^3/g)	(nm)	(cm^3/g)	
D1438	30-300	0.0001	5800	140	30	10.1
D1438[4]	30-300	0.3	440	60	46.5	4.4

†All solvent physical properties are evaluated at 25°C.
1 Values in parentheses are the corresponding $Re_s\sqrt{f^*}$.
2 Data are included from both pipes.
3 T_w^* and $Re_s\sqrt{f^*}$ are virtual values regressed via (A_p, B_p) data.
4 Data are incorporated into Part-A averages.
5 T_w^* average value is visual.

More generally, the slope increment is found to increase with the square root of additive concentration; this leads to a specific slope increment, $\delta/\sqrt{c}$, and thence an intrinsic slope increment $\Pi = \delta/\sqrt{(c/M_w)}$. For many polymer-solvent systems, the molecular quantity Π is found to correlate with the 3/2 power of the number of backbone chain links, N_{bb}, their proportionality constant being called the slope modulus, κ. The present slope increment data are presented in this standard form in Table 1.6.2, using average values of $\delta/\sqrt{c}$ from the Type-A fans observed at high salinity and N_{bb} data from Table 1.5.3.

Figure 6.3.6 shows intrinsic slope increments for collapsed HPAM additives, displaying the data from Table 1.6.2 on doubly logarithmic coordinates of Π vs N_{bb}. The solid line of slope 3/2 drawn through the experimental data represents the equation:

Table 1.6.2
Specific and Intrinsic Slope Increment Data

Polymer	Molecular Weight	Number of Backbone Chain Links	Average Specific Slope Increment	Average Intrinsic Slope Increment	Slope Modulus†
	$M_w \times 10^{-6}$	$N_{bb} \times 10^{-5}$	$\delta/\sqrt{c}$	$\Pi \times 10^{-3}$	$\kappa \times 10^{6}$
	(g/mole)				
C832A	18.0±5.0	5.0±1.4	4.1±0.7	17.2±5.3	47.9
B1120	20.1±6.4	5.7±1.8	3.6±0.6	16.2±5.4	38.3
P500	9.5±3.5	2.7±1.0	2.3±0.2	7.0±2.0	51.1
A507	1.0±0.3	0.3±0.1	0.16±0.02	0.16±0.04	42.8
D1438	1.4±0.6	0.4±0.2	0.29±0.05	0.35±0.14	56.4
C837A	15.7±6.7	4.4±1.9	2.8±0.6	1.1±0.5	38.1
C836A	15.5±11.0	4.4±3.1	2.5±0.6	9.9±5.9	34.4

† Slope moduli are averages; uncertainties in N_{bb} cause very large uncertainties in the slope moduli.

$$\Pi = 43.5 \times 10^{-6} N_{bb}^{3/2} \qquad (6.3\text{-}7)$$

The slope modulus, $\kappa = 43.5 \times 10^6$ found from equation 6.3-7 is of the same order as that, $\kappa = (80 \pm 20) \times 10^6$ previously quoted for PAM additives in the literature(Virk, 1975b).

1.6.4 Type-B Drag Reduction

Type-B drag reduction has hitherto been little studied. Here we focus mainly on our new results for HPAM additives in their extended conformations, and also attempt

to discuss (the few) other data available in the literature. A Type-B ladder is primarily defined by the flow enhancements induced by its P segment rungs at a known, high, $Re_s\sqrt{f}$; and secondarily by the wall shear stresses at its retro-onset points, where the rungs intersect the MDR asymptote. The dependence of both these parameters on the molecular properties of the additive are considered.

Flow Enhancement. The present results, §1.5.2, indicates that in Type-B drag reduction, the nondimensional flow enhancement or apparent slip, S', is only weakly dependent on flow parameters, such as $Re_s\sqrt{f}$ and pipe diameter, but is strongly dependent on additive parameters, such as concentration and molecular weight.

Figure 6.6.1 depicts the flow enhancement by six HPAM additives, including both the present data for additives C832A, B1120, and P500, as well as literature data from three sources (Clarke, 1970; Oliver & Bakhtiyarov, 1983; Interthal & Wilski, 1985). With all polymers, an approximately linear relationship between S' and c is observed at all $c < 50$ wppm (the highest concentrations, $c > 50$ wppm, attain the MDR asymptote, so $S' = S_M$, independent of c). We can now define the specific slip, S'/c, characteristic of additive efficacy in Type-B drag reduction, and also the intrinsic slip $\Sigma = S'/(c/M_w)$, a measure of flow enhancement per molecule. Since the intrinsic slip Σ is a molecular quantity, one might expect it to depend upon a molecular attribute of the additive, of which N_{bb}, the number of backbone chain links, is the most basic.

Figure 6.6.3 shows the intrinsic slip for extended HPAM additives on doubly logarithmic coordinates of Σ vs N_{bb}. It is found that Σ increases roughly as N_{bb}^3 along the solid line shown in the figure, which represents the approximate relation:

$$\Sigma = 2.21 \times 10^{-10} N_{bb}^{3} \qquad (6.6\text{-}2)$$

The proportionality constant between Σ and N_{bb}^3 is termed the "slip modulus", λ, with average value 2.2×10^{-10} g/mole/wppm; slip moduli for individual entries are shown in the legend of Figure 6.6.2.

Type-B flow enhancement data from the present work and all available literature are summarized in Table 1.6.3, which provides both additive characterization information as well as specific and intrinsic slip data.

Figure 6.6.3 depicts the flow enhancement by various additives in Type-B drag reduction, showing all entries from Table 1.6.3; these include the six HPAM additives shown in Figure 6.6.2, as well as additional results for xanthan gum (Rochefort & Middleman, 1985), asbestos fibers (Sharma et al., 1979; McComb & Chan, 1985), nylon fibers (Bobkowicz & Gauvin, 1965) and paper fibers (Lee & Duffy, 1976). All the additional data also show apparent slips roughly proportional to additive concentration.

Table 1.6.3
Flow-Enhancement Data in Type-B Drag Reduction for Various Additives

Additive†	Molecular Weight	Number of Backbone Chain Links	Contour Length	Pipe Diameter
	$M_w \times 10^{-6}$	$N_{bb} \times 10^{-5}$	$L_c \times 10^3$	D
	(g/mole)		(cm)	(cm)
HPAM Additives				
C832A	18.0±5.0	5.0±1.4	6.4±1.8	1.021, 1.458
B1120	20.1±6.4	5.7±1.8	7.1±2.3	1.458
P500	9.5±3.5	2.7±1.0	3.4±1.2	1.021, 1.458
AP30[1]	9.2	2.6	3.2	1.03
MagE10[2]	23	6.5	8.1	0.597
HSB125[3]	16.5	4.6	5.8	1.4
Xanthan[4]	2.0?	0.02?	0.25?	0.238

Stress Level of Data	Specific Slip	Intrinsic Slip	Volume Fraction Per wppm	Volume Fraction Per Unit Slip
$Re_*\sqrt{f}$	S'/c	$\Sigma \times 10^{-6}$	X_v/c	X_v/S'
	($wppm^{-1}$)	(g/mole/wppm)	($wppm^{-1}$)	
3000	1.87	33.6±9.4	4500	2410
3000	1.62	32.5±10.4	5640	3490
3000	0.58	5.45±2.02	1250	2180
3000	0.31	2.85	7380	1800
1600	4.1	94.3	3800	4180
3000	0.91	15.0	1180	3812
450	0.067	0.134?	2.5?	40?

Additive†	Fiber Diameter	Aspect Ratio	Fiber Length	Pipe Diameter
	$d_f \times 10^3$	l_f/d_f	l_f	D
	(cm)		(cm)	(cm)
Fiber Additives				
Asbestos[5]	0.003	40000	0.14	1.9
Asbestos[6]	0.005	28000	0.14	1.95
Paper[7]	3.0	90	0.27	10.0
Nylon[8]	2.0	51	0.10	4.98

Stress Level of Data	Specific Slip	Intrinsic Slip	Volume Fraction Per wppm	Volume Fraction Per Unit Slip
$Re_a\sqrt{f}$	S'/c	$\Sigma \times 10^{-6}$	X_v/c	X_v/S'
	($wppm^{-1}$)	(g/mole/wppm)	($wppm^{-1}$)	
1600	0.03	n/a	420	13900
1300	0.041	n/a	205	4980
3000	0.0015	n/a	0.006	4.1
5800	0.00021	n/a	0.0015	7.1

† Note the wrap-around nature of this table in both the HPAM- and Fiber-Additive sections.
1 — Clarke(1970); 2 — Oliver & Bakhtiyarov(1983); 3 — Interthal & Wilski (1985); 4 — Rochefort & Middleman(1984); 5 — Sharma et al.(1979); 6 — McComb & Chan(1985); 7 — Bobkowicz & Gauvin(1965); 8 — Lee & Duffy (1976).
n/a = not applicable

The specific slips seen in the figure span nearly five orders of magnitude, from S'/c = 0.00016 for nylon fibers to S'/c ≈ 4.1 for the highest molecular weight HPAM. To help interpret this wide variation in additive efficacy, the last two columns of Table 1.6.3 respectively list the additive-pervaded volume fraction per unit concentration, X_v/c, derived from either the macromolecular contour length L_c or the fiber length l_f and aspect ratio l_f/d_f, and then the additive-pervaded volume fraction required to induce unit slip, X_v/S'. For the most effective additives, HPAMs and asbestos fibers, $X_v/S' \approx 3000$, implying, since X_v cannot physically exceed unity, that these additives must be significantly aligned during drag reduction.

Retro-Onset. From the geometry of a perfect Type-B ladder, the rung for concentration c, with flow enhancement S', should exhibit retro-onset at $\log Re_s\sqrt{f^\#} = \log Re_s\sqrt{f^\#_o} + S'/15$, where $\log Re_s\sqrt{f^\#_o}$ refers to the intersection of the MDR asymptote M with the Prandtl-Karman line N. Since $Re_s\sqrt{f}$ is formed with T_w, and S' is proportional to polymer concentration, we should expect a linear relationship between $\log T_w^\#$ and c.

Figure 6.6.4 presents a retro-onset correlation for extended HPAM additives, using coordinates of $\log T_w^\#$ vs c. The present data for additives C832A and B1120 in the 1.458-cm pipe are fitted by the line:

$$\log T_w^\# = -0.436 + 0.134c \qquad (5.3\text{-}1)$$

with $T_w^\#$ and c in dyne/cm^2 and wppm, respectively. The ordinal intercept $T_{w\,o}^\# = 0.37$ dyne/cm^2 is close to the value $T_{w\,o}^\# = 0.35$ dyne/cm^2 at the intersection of N(c = 0) with M; the slope of the line corresponds to an apparent S'/c = 1, somewhat lower than the

observed S'/c ≈ 1.7 for these additives. The same form of correlation also applies to the data for P500, after adjustment for its lower S'/c and different pipe diameter. Retro-onset results from the literature are also accommodated by the correlation.

1.6.5 Comparisons Between Type-A and Type-B Drag Reduction

Relative Flow Enhancements. Data calculated from the flow trajectories of 30-wppm P500 solutions at salinities of 0.3, 0.01, 0.001, and 0.0001 N in the 1.021-cm pipe are presented in Figure 6.5.1, as a plot of the "slip ratio", $S'_{[N]}/S'_{0.0001}$, vs $Re_s\sqrt{f}$. The ordinate is the ratio of S' induced at any salinity relative to the S'induced by the lowest salinity, that is, by the most extended initial conformation of the additive, at the same $Re_s\sqrt{f}$. For the initially collapsed conformation, at the highest salinity of 0.3 N NaCl, the slip ratio increases monotonically from near zero at $Re_s\sqrt{f} \approx 500$ to almost unity at $Re_s\sqrt{f} \approx 5000$; this physically reflects the progressive extension of the initially collapsed macromolecular conformation with increasing turbulent flow strength. For the next lower salinity of 0.01 N, the slip ratio is ≈ 0.6 at $Re_s\sqrt{f} \approx 500$ and then increases monotonically to unity at $Re_s\sqrt{f} \approx 5000$. Finally, at salinity 0.001 N, the slip ratio is essentially unity over the entire range of $Re_s\sqrt{f}$ from 500 to 5000. These results suggest that the extended conformations of the additive induce drag reduction, and thence the more closely an initial conformation resembles the active extended form, the more effective it is in drag reduction. For additives that exhibit Type-A behavior at high salinity and Type-B behavior at low salinity, we can define the special slip ratio, $R_{sc} = [S'_A/S'_B]_c$, that is, the ratio of Type-A to Type-B flow enhancements at fixed

concentration and $Re_s\sqrt{f}$. Since $S'_A = 0$ for $Re_s\sqrt{f} < Re_s\sqrt{f}^*$, and $S'_A < S'_B$, always, we expect $0 \leq R_{sc} \leq 1$ for $(Re_s\sqrt{f}/Re_s\sqrt{f}^*) \geq 1$.

Figure 6.5.3 is a semilogarithmic plot of the slip ratio R_{sc} versus the normalized turbulent flow strength $(Re_s\sqrt{f}/Re_s\sqrt{f}^*)$ for 10 pairs of Type-A and Type-B data exhibited by two concentrations each of three HPAM additives in two pipes. The data scatter around a single, universal, curve that rises monotonically, but with decreasing slope, from $R_{sc} = 0$ at $(Re_s\sqrt{f}/Re_s\sqrt{f}^*) = 1$ to $R_{sc} = 0.8$ at $(Re_s\sqrt{f}/Re_s\sqrt{f}^*) = 10$, being well represented by the equation:

$$R_{sc} = 1 - \left[\frac{Re_s\sqrt{f}}{Re_s\sqrt{f}^*} \right]^{-2/3} \qquad (6.5\text{-}2)$$

Equation 6.5-2 physically represents the extension of initially collapsed, random-coiling, HPAM macromolecules towards their fully extended conformations by the turbulent flow field. It is interesting that this process seems relatively independent of additive parameters and absolute wall shear stress levels.

Additive Equivalence and Isoslip Points. Figure 6.5.4 is a PK plot of data obtained with additive C832A in the 1.458 cm pipe, specifically showing results for three solutions, namely 5.6-wppm in 0.00001 N NaCl(□, abbr 5.6B), 20.9-wppm in 0.00001 N NaCl(◇, abbr 20.9B), and 20.7-wppm in 0.1 N NaCl(◆, abbr 20.7A). The former two trajectories are part of a Type-B ladder, while the third belongs to a Type-A fan. It is seen that trajectory 20.7A intersects 5.6B at coordinates $(Re_s\sqrt{f}, 1/\sqrt{f}) = (975, 15.2)$. This is termed an "isoslip" point, since both solutions here exhibit the identical flow enhancement, $S' = 3.6$. At this isoslip point, 20.7 wppm of the initially collapsed

conformation and 5.6 wppm of the extended conformation are evidently equivalent in the ability to reduce drag. The term "additive equivalence" is used to describe such a case, where two different additive solutions cause the same drag reduction. Continuing, at the isoslip $Re_s\sqrt{f} = 975$, the trajectory 20.9B exhibits S' = 12.7, generating a "slip triad" (20.9B, 20.7A, 5.6B) with associated S'(12.7, 3.6, 3.6). Within this triad, the collapsed to extended slip ratio at constant concentration is $R_{sc} = 3.6/12.7 = 0.28$, while the extended to collapsed concentration ratio at constant slip is $R_{cs} = 5.6/20.9 = 0.27$. The essential equality between R_{sc} and R_{cs} is striking, and warrants elaboration.

Figure 6.5.10 presents data for additive B1120 in the 1.458 cm pipe, showing five additional isoslip points, where the trajectory 5A intersects the trajectories 1B and 2B, and where 20A intersects 2B, 5B, and 10B.

A total of 42 isoslip points, along with their associated slip triads, were identified in the present data for additives C832A, B1120, and P500. Figure 6.5.14 is a plot of the slip ratio R_{sc} versus the concentration ratio R_{cs} among all slip triads. It is evident that $R_{sc} = R_{cs}$, reinforcing the earlier observation in Figure 6.5.4. This result offers a noteworthy physical insight. Namely, that for fixed total additive concentration, the collapsed to extended slip ratio R_{sc} observed at any $Re_s\sqrt{f}$ simply represents the fraction of originally collapsed macromolecules that have become extended in the flow, and thence effective in drag reduction. Further, if the extended additive states are the active species responsible for drag reduction, then Type-B behavior should emerge as the fundamental feature of the phenomenon, with the better known Type-A behavior viewed as a special case wherein the initially randomly-coiled and ineffective macromolecules are extended, and hence activated, by the turbulent flow field.

1.7 Modelling Types A and B Drag Reduction

From the correlations in §1.6.3 and §1.6.4, perfect Type-A fans and perfect Type-B ladders, respectively, may be qualitatively modelled.

In modelling a perfect Type-A fan, equation 2.4-11 provides an estimated rms radius of gyration R_G from molecular weight. Equation 6.3-5 is then used to calculate the onset wall shear stress, T_w^*, and thus $Re_s\sqrt{f^*}$, from the estimated R_G. Next, equation 6.3-7 yields the specific slope increment $\delta/\sqrt{c}$, and thus δ, with $N_{bb} = M_w/m$. For any concentration c, the polymeric-regime segment P is given by

$$\frac{1}{\sqrt{f_p}} = 4.0\log(Re_s\sqrt{f}) - 0.4 + \sqrt{c}\left[\frac{\delta}{\sqrt{c}}\right]\log\left[\frac{Re_s\sqrt{f}}{Re_s\sqrt{f}^*}\right] \qquad (6.7\text{-}1)$$

Equation 6.7-1 is subject to lower and upper bounds on $Re_s\sqrt{f}$: The former is $Re_s\sqrt{f^*}$; the latter, degradation-falloff $Re_s\sqrt{f^\wedge}$, via equation 6.1-2.

In modelling a perfect Type-B ladder, equation 6.6-2 gives the intrinsic slip Σ, and thus S'/c, from molecular weight and mass per backbone chain link. For any concentration c, the corresponding ladder rung is described by equation 6.4-7:

$$\frac{1}{\sqrt{f_p}} = 4.0\log Re_s\sqrt{f} - 0.4 + c\left[\frac{S'}{c}\right] \qquad (6.4\text{-}7)$$

The valid range of $Re_s\sqrt{f}$ in equation 6.4-7 is bounded below by $Re_s\sqrt{f^\#}$, via equation 6.4-8, and above by $Re_s\sqrt{f^\wedge}$, via equation 6.1-2.

These models agree best with B1120 data at intermediate $5 < c < 10$ wppm.

1.8 Conclusions

1. The drag reduction phenomenon was experimentally studied in two pipes, of diameters 1.46 and 1.02 cm, using seven polyelectrolytic HPAM additives, with molecular weights from 1 to 20×10^6 g/mole and degree of backbone hydrolysis from 8 to 60%, at concentrations from 1 to 1000 wppm, in saline solutions containing from 0.3 to 0.00001 N NaCl.

2. Both laminar and turbulent flow behavior were greatly influenced by salinity-induced changes in the initial conformation of the HPAM additives. Initially collapsed, random-coiling conformations exhibited Newtonian laminar flow and Type-A turbulent drag reduction, while initially extended conformations exhibited shear-thinning in laminar flow and Type-B turbulent drag reduction.

3. The gross-flow physics of Type-B drag reduction were delineated. A characteristic "ladder" structure prevailed, with polymeric regime segments that were roughly parallel to, but shifted upward from, the Prandtl-Karman line and intersected the maximum drag reduction asymptote at retro-onset points.

4. In the polymeric regime, both Type-A fan and Type-B ladder structures were essentially independent of pipe diameter, and were scaled by the wall shear stress. Thus both types of drag reduction are insensitive to the large turbulence scales imposed by pipe diameter, and are controlled instead by the finer wall-turbulence scales associated with the wall shear stress. The wall shear stress also scaled incipient degradation during drag reduction.

5. New correlations were presented for Type-A drag reduction by HPAM additives, as follows:

(Onset Correlation) $$T_w^* = 5.79\times10^5 R_G^{-2} \qquad (6.3\text{-}5)$$

(Slope-Increment Correlation) $$\Pi = 43.5\times10^{-6} N_{bb}^{3/2} \qquad (6.3\text{-}7)$$

6. In Type-B drag reduction it was found that the flow enhancement S' was proportional to additive concentration, and that the intrinsic slip, $\Sigma = S'/(c/M_w)$, varied roughly as the third power of backbone chain links N_{bb}. New correlations were presented for Type-B drag reduction by HPAM additives:

(Intrinsic-Slip Correlation) $$\Sigma = 2.21\times10^{-10} N_{bb}^3 \qquad (6.6\text{-}2)$$

(Retro-Onset Correlation) $$\log T_w^{\#} = -0.436 + 0.134c \qquad (5.3\text{-}1)$$

7. Analysis of available literature for Type-B drag reduction by polyelectrolytic and fiber additives revealed a wide range of additive efficacies, with specific slips S'/c from 0.0001 to 4. For the most effective additives, HPAM and asbestos fibers, the additive-pervaded volume fraction per unit flow enhancement, $X_v/S' \approx 3000$, implied that these additives align during drag reduction.

8. The slip ratio R_{sc}, which is the relative flow enhancement induced in Type-A and Type-B drag reduction at constant additive concentration, was found to be a universal function of the normalized turbulent flow strength ($Re_s\sqrt{f}/Re_s\sqrt{f^*}$), as follows:

$$R_{sc} = 1 - \left[\frac{Re_s\sqrt{f}}{Re_s\sqrt{f}^*} \right]^{-2/3} \qquad (6.5\text{-}2)$$

The extension of initially collapsed, random-coiling, HPAM macromolecules by the turbulent flow field thus seems independent of additive parameters and absolute wall shear stress levels.

9. Gross flow additive equivalence was detected at iso-slip points, where different polymer solutions induced equal flow enhancements. At numerous such points, the collapsed to extended slip ratio at constant concentration, R_{sc}, was essentially equal to the extended to collapsed concentration ratio at constant slip, R_{cs}. Thus, for fixed total additive concentration, the collapsed to extended slip ratio R_{sc} observed at any $Re_s\sqrt{f}$ simply represents the fraction of originally collapsed macromolecules that have become extended in the flow, and thence effective in drag reduction.

10. If extended additive states are the active species responsible for drag reduction, as appears likely, then Type-B behavior should underlie the basic mechanism of additive-turbulence interaction.

CHAPTER II

INTRODUCTION

This chapter sets forth the objective of, and the motivation behind, the present work. A brief background is given of the drag-reduction phenomenon, followed by a review of pertinent previous drag-reduction literature, and a summary of macromolecular characterization data for the polyelectrolyte additives used in this work.

2.1 Objective and Motivation

The thesis' objective was to examine the influence of macromolecular conformation on drag reduction in turbulent flow. This was achieved by exploring the drag reduction induced by dilute solutions of polyelectrolytic additives in both their collapsed and expanded macromolecular conformations, as exhibited in solvents of high and low ionic strengths, respectively.

The experimental investigation comprised gross-flow, that is, pressure drop versus flow rate, measurements in two pipes, using aqueous solutions of seven partially hydrolyzed polyacrylamide, HPAM, additives at several salinities. The following ranges of flow and additive parameters were: pipes of inner diameter and length-to-diameter ratios, (D, L/D) = (1.021 cm, 203) and (1.458 cm, 183); laminar- and turbulent-flow regimes with Reynolds numbers from 1×10^{2} to 2×10^{5}; and wall shear stresses from 1×10^{-2} to 1×10^{3} dyne/cm^{2}. The HPAM additives used varied in molecular weights from

1×10^6 to 20×10^6 g/mol and had degrees of hydrolysis from 8 to 60%; they were employed at concentrations from 1 to 1000 weight-parts per million, in aqueous solutions with salinities from 0.00001 N to 0.3 N NaCl. Turbulent drag reductions induced by the additives varied from zero to the asymptotic maximum possible.

The present work was motivated by the observation(Virk 1975a) of striking differences between the gross-flow drag-reduction behavior of collapsed and extended polyelectrolytes. On Prandtl-Karman(PK) coordinates, turbulent-flow trajectories for the collapsed polyelectrolytes, in common with other initially random-coiling macromolecules, were characterized by an abrupt onset of drag reduction, beyond which they departed upward from the Newtonian friction-factor relation, into a regime with drag reduction, with slopes signifcantly greater than Newtonian. In contrast, trajectories of extended polyelectrolytes, in common with those of fiber suspensions, exhibited no clear onset of drag reduction, but rather exhibited relatively constant drag reduction, with slopes roughly parallel to the Newtonian friction-factor relation. These two distinct types of flow trajectories, respectively named Type A and Type B, suggested that drag reduction was inherently dependent upon the conformation, that is, the actual shape, of the additive in solution, and the present work was an undertaking to delineate this dependence. Polyelectrolyte additives were particularly suited to the present study because their static conformations could be altered greatly by changing solvent salinities while maintaining the identical backbone length, which is perhaps the single most important of the macromolecular parameters known to affect drag reduction. Finally, it was hoped that the systematic delineation of drag-reduction Types A and B, and the quantitative comparisons between them, might also provide fresh physical insights into

the role of the additive in the mechanism of the phenomenon.

2.2 Introduction

After Toms(1948) observed and reported the drag-reduction phenomenon, later to be called the "Toms Effect", engineers have sought to take advantage of it in real world applications.

From the beginning, most drag reduction research has been driven by industrial and military interests. For various additives, percent drag reduction achieved, degradation resistance, and ease of application were investigated. Correlations were sought for design and scale-up, and to increase the efficiency, of flow systems. The friction reduction at constant flow rates, that is, at a constant Reynolds number Re, was of particular interest, as a %DR was defined as the difference in pressure drop between solvent-flow and polymer-solution flow, respectively, at the same volumetric flow rate Q(or $<\overline{U}>$), expressed as a percentage of the solvent flow pressure drop:

$$\%DR = \frac{\Delta P_n - \Delta P_p}{\Delta P_n} \qquad (2.2\text{-}1)$$

where the subscripts p and n denote polymer and solvent(Newtonian) conditions, respectively. From equations defining the Fanning friction factor f and representing a force balance on a length of pipe D × L, respectively,

$$f \equiv \frac{2T_w}{\rho <\overline{U}>^2} \qquad (2.2\text{-}2)$$

$$T_w = \frac{D}{4}\left[\frac{-\Delta P}{L}\right] \tag{2.2-3}$$

the percent drag reduction can be rewritten:

$$\%DR = 1 - \frac{f_p}{f_n} \tag{2.2-4}$$

The features of the mean and turbulent velocity fields were also uncovered and quantified. Standard double-logarithmic friction-factor plots of f vs. Re soon gave way to semilogarithmic Prandtl-Karman(PK) plots of $1/\sqrt{f}$ vs. $Re_s\sqrt{f}$ because drag-reduction data in PK coordinates invariably follow straight lines and are easier to interpret. In PK coordinates, the ordinate and abscissa, respectively, are:

$$\frac{1}{\sqrt{f}} = \frac{\langle U \rangle}{\sqrt{2}\,u_\tau} \tag{2.2-5}$$

$$Re_s\sqrt{f} = \frac{\sqrt{2}\,Du_\tau}{\nu_s} = 2\sqrt{2}\left[\frac{Ru_\tau}{\nu_s}\right] = 2\sqrt{2}\,R^+ \tag{2.2-6}$$

where the subscript s refers to solvent and the friction velocity $u_\tau \equiv (T_w/\rho)^{1/2}$. In these coordinates, the apparent slip S' provides a measure of flow enhancement:

$$S' \equiv \left[\frac{1}{\sqrt{f_p}} - \frac{1}{\sqrt{f_n}}\right]_{u_\tau} = \left[\frac{1}{\sqrt{f_p}} - \frac{1}{\sqrt{f_n}}\right]_{Re_s\sqrt{f}} \tag{2.2-7}$$

The apparent slip S' represents the upward shift from the PK law and provides a more intuitive measure of drag reduction than does percent drag reduction. The advantage of this method is that S' can be mathematically related to the mean velocity profile; thus,

reporting S' indicates something about flow structure. In the literature review that follows, S' was found to correlate the various facets of drag reduction better than does %DR.

Methods that have been employed to reduce turbulent drag involve alteration either the wetted surfaces or the flowing fluid. Contoured surfaces, while offering a permanent solution for reducing drag, provide relatively little flow enhancement and, thus, are the least used. Adding small amounts of various substances to the fluid, in concentrations on the order of tens of weight-parts per million, has been the easiest and most popular method to reduce drag. Additives, in order of decreasing popularity, include polymers, fibers, small particles, and bubbles. The latter two are difficult to apply.

In systems which have a fixed configuration(i.e. have permanent pumps and ducts) additives can be especially advantageous with the improved performance and lower pumping costs offsetting the cost. For example, in the Alaskan oil pipline at Prudhoe Bay, drag-reducing additives increase the throughput without the costly installation of additional pumping stations. Ideally, the additive should not degrade. However, in closed-looped systems, additive degradation is a real problem and limits the extent and duration of drag reduction. In open systems, such as piplines, firehoses, drains and sewers, and hulls of water vessels, additives are continuously lost; thus, to be effective, additives must be easy to apply, inexpensive, and durable.

After Toms' discovery, most of the research has focussed on drag reduction in turbulent pipe flow by dilute solutions of long-chained polymers (macromolecules) dissolved in a Newtonian solvent. From this basic framework the variety of experiments

conducted is immense, as illustrated by Table 2.1.

The experiments in this project are limited to smooth circular-pipe geometries, polymeric additives, good solvents with varying ionic strengths, fully developed turbulent flow in a single-pass system, and premixed homogeneous solutions. The molecular weight M_w and conformation are the independent polymer-additive variables of interest.

Table 2.1
Parameters in Drag-Reduction Experiments

<table>
<tr><th colspan="5">PARAMETER</th></tr>
<tr><td rowspan="2"></td><td colspan="4">flow cross-section(Del Villar et al., 1984)</td></tr>
<tr><td colspan="4">smooth vs. rough surface(Virk, 1971a)</td></tr>
<tr><td rowspan="13">Additive Type</td><td rowspan="13">polymers</td><td colspan="3">molecular weight M_w (Gramain & Borreill, 1978)</td></tr>
<tr><td colspan="3">backbone structure (Ting, 1982)</td></tr>
<tr><td colspan="3">side groups (McCormick et al., 1990a)</td></tr>
<tr><td rowspan="2">conformation</td><td colspan="2">coiled vs. uncoiled
(Parker & Hedley, 1972)</td></tr>
<tr><td colspan="2">preextended vs. collapsed
(Virk, 1975a)</td></tr>
<tr><td colspan="3">flexibility vs. rigidity
(Rochefort & Middleman, 1984)</td></tr>
<tr><td rowspan="2">rheology</td><td colspan="2">elasticity(relaxation)
(Bewersdorff & Berman, 1988)</td></tr>
<tr><td colspan="2">viscosity
(Pinho & Whitelaw, 1990)</td></tr>
<tr><td rowspan="4">behavior in solvent</td><td colspan="2">homogeneous dispersal
(Oliver & Bakhtiyarov, 1983)</td></tr>
<tr><td rowspan="3">heterogenous dispersal</td><td>aggregates
(Dunlop & Cox, 1977)</td></tr>
<tr><td>micelles
(Ohlendorf et al., 1988)</td></tr>
<tr><td>networks
(Inge et al., 1979)</td></tr>
<tr><td colspan="4">fibers and fibers/polymers (McComb & Chan, 1981)</td></tr>
<tr><td colspan="4">gas bubbles (Madavan et al., 1985)</td></tr>
</table>

PARAMETER		
Solvent Type	highly vs. poorly dispersing(good solvent vs. Θ solvent) (Zakin & Hunston, 1980)	
	high vs. low pH (White & Gordon, 1975)	
	high vs. low ionic strength (Banijamali et al., 1974)	
Flow Conditions	transition vs. full turbulence (Ogawa & Kuroda, 1986)	
	single vs. multiple pass (Kowalik et al., 1987)	
Method of additive introduction	premixed solution (Kulicke et al., 1989)	
	flow injection	centerline($y^+ = R^{+)}$ (Hoyt & Sellin, 1988)
		near wall($y^+ \approx 20$) (Frings, 1988)
		wall($y^+ = 0$) (Wells & Spanger, 1967)

2.3 Drag-Reduction Literature Review

In "Drag Reduction Fundamentals", Virk(1975b) provided a comprehensive review of polymer-induced drag reduction, with attention primarily on the behavior of homgeneous solutions of linear, random-coiling polymers, such as polyethylene oxide(PEO). The review also delineated three echelons of flow structure during drag reduction — gross flow, mean flow, and turbulence structure — which will be used to describe the latest literature developments.

2.3.1 Gross Flow

In pipe flows, when $Re_s < 2000$, the friction factor data follow Poiseuille's law for laminar flow(L):

$$\frac{1}{\sqrt{f}} = \frac{Re_s\sqrt{f}}{16} \qquad (2.3\text{-}1)$$

for both solvent and polymer solution flows. For $Re_s > 2000$, both solvent and polymer flows exhibit intermittency or transition. For $Re_s > 4000$, both flows, in general, obey the PK equation(N):

$$\frac{1}{\sqrt{f}} = 4.0\log(Re_s\sqrt{f}) - 0.4 \qquad (2.3\text{-}2)$$

which is the universal Prandtl-Karman correlation for Newtonian fully turbulent flow. The polymer flow continues to adhere to N until onset occurs. Onset describes a sudden

divergence from N of the polymer solution's friction-factor trajectory into the "polymeric" regime with drag reduction. Onset is characterized by the onset friction velocity, u_τ^*, or, equivalently, the onset wall shear stress, T_w^*. According to the time-based onset hypothesis, onset occurs when the polymer relaxation time, λ_p, and the critical wall flow time, $[(u_\tau^*)^2/\nu s]^{-1}$, are of equal magnitude, that is, $\lambda_p(u_\tau^*)^2/\nu_s \approx 1$. From theoretical polymer mechanics, which predicts that $\lambda_p \propto M[\eta] \propto R_G^3$, and the onset criterion, a time-based onset relation arises:

$$\Omega_T = R_G^3 T_w^* \tag{2.3-3}$$

On the other hand, the length-based onset hypothesis asserts that at onset that the product of the characteristic polymer length, R_G, and the inverse turbulent length scale u_τ^*/ν_s(or wavenumber W^*) is constant:

$$\Omega_L = \frac{R_G u_\tau^*}{\nu_s} = R_G W^* \tag{2.3-4}$$

After onset, the slope increment δ, the difference between the polymeric-regime slope and the N slope both in PK coordinates, depends empirically on the molecular weight M_w and $\sqrt{c}$:

$$\Pi = \delta \left[\frac{M}{c} \right]^{1/2} \tag{2.3-5}$$

Because data suggest that $\Pi = \kappa N_{bb}^{3/2}$, another relationship for δ arises:

$$\delta = \frac{\kappa N_{bb}^{3/2} c^{1/2}}{M^{1/2}} \tag{2.3-6}$$

where κ is the slope modulus and N_{bb} is the number of backbone links. As c, hence δ,

factor relation, into a regime with drag reduction, with slopes significantly greater than Newtonian. This was termed Type-A behavior. In contrast, trajectories of solutions of extended polyelectrolytes, in common with fiber suspensions, exhibited no clear onset of drag reduction, but rather exhibited relatively constant drag reduction , with slopes roughly parallel to the Newtonian friction-factor relation. This was termed Type-B behavior.

Examples of Type-A and Type-B behavior can be seen in subsequent literature. Figures 2.3.1 and 2.3.2 from Berman(1977) show typical Type-A behavior for PEO, a random coiling polymer, and the quasi-Type-A behavior of Separan NP-10, a collapsed polyelectrolyte in this instance. Berman et al.(1978) studied DNA and collagen solutions, and these stiff additives exhibited "Type-B" behavior, as seen in Figures 2.3.3 and 2.3.4. No onset was observed. Their "Type-B" behavior likely resulted from the extension of collagen and DNA additives in solution, respectively.

Kwack et al.(1981) compared three nominally identical drag reduction experiments, a 70 wppm PEO/tap water solution flowing in a 1-cm $\times$ 1-cm duct, from three different laboratories. These data are presented in Figure 2.3.5. Different onset points and levels of drag reduction were obtained in each laboratory despite the nominal similarity of their polymer solutions. Profound differences existed in the ionic character of the tap water used in two of the three experiments, and the widely differing results were attributed to the pH and electrolyte content of the tap water. Even though the tap water likely played a role neither the polymer polydispersity nor the method of preparation of the PEO solutions, which can cause the observed large differences, were examined. Stenberg et al.(1977) noted great differences in the drag-reducing ability of

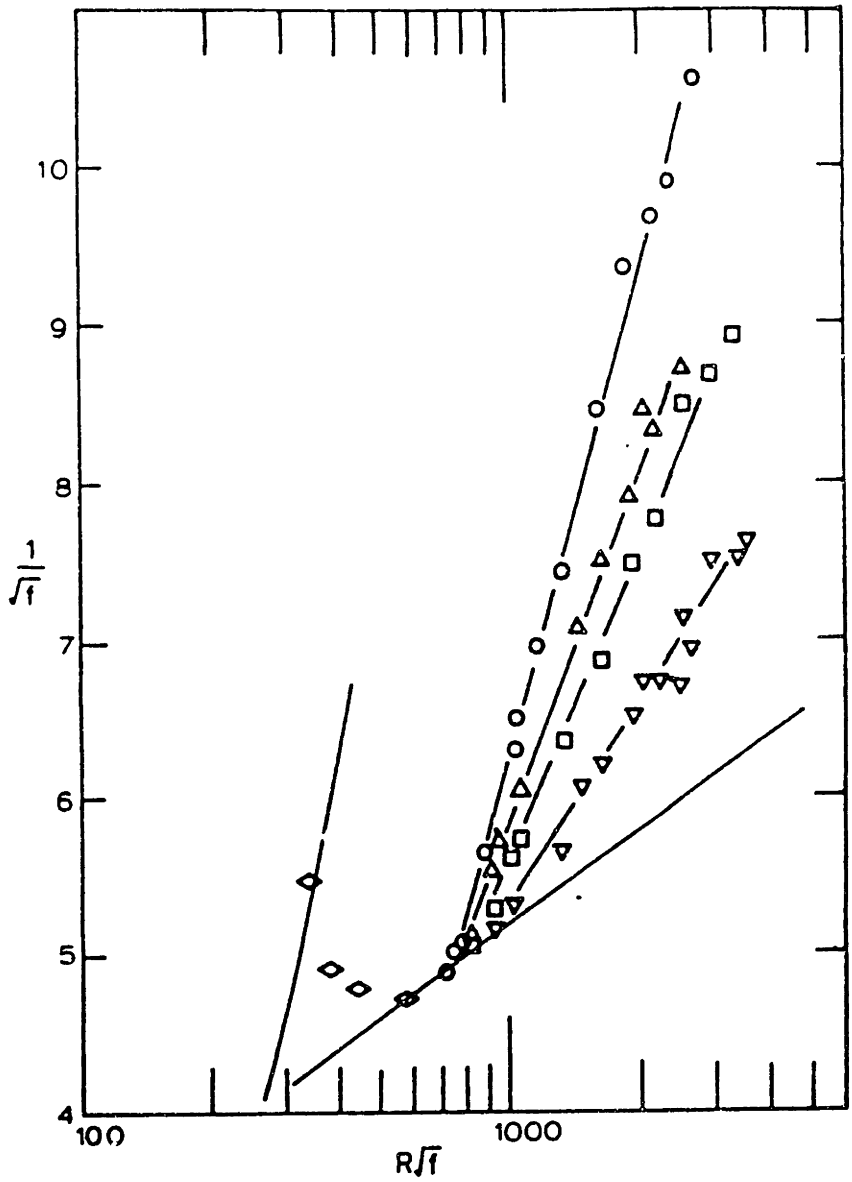

FIG. 2. Concentration dependence of drag reduction for Polyox WSR 205 in a 0.554 cm diam tube. Concentrations are 10 ppm, ▽; 20, □; 30, △; and 50, ○. The symbol ◇ illustrates points representative of all concentrations.

Figure 2.3.1: Example of Type-A Behavior from Berman(1977)

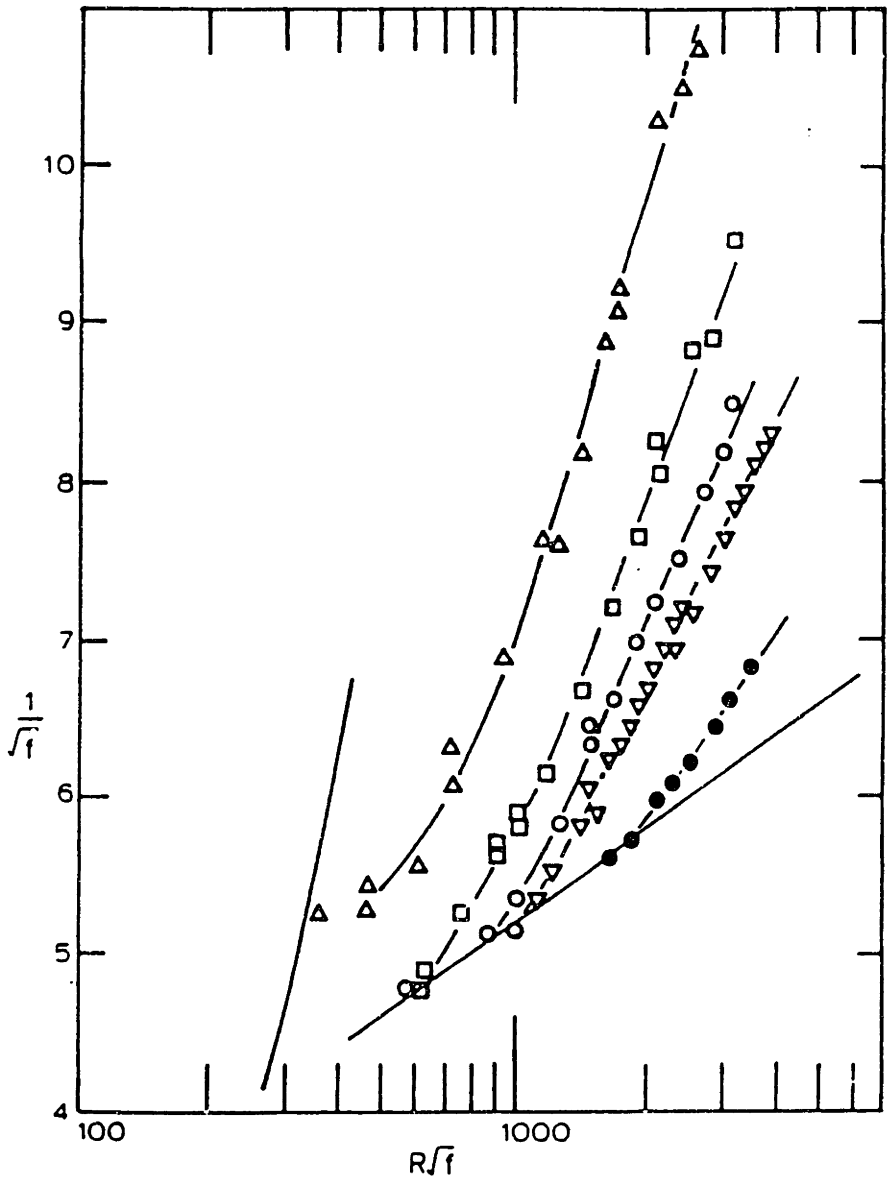

FIG. 3. Concentration dependence of drag reduction for Separan NP-10 dissolved in tap water in a 0.554 cm diam tube. Concentrations are 20 ppm, o; 50, ▽; 100, o; 200, □; and 400, △.

Figure 2.3.2: Example of Quasi-Type-A Behavior from Berman(1977)

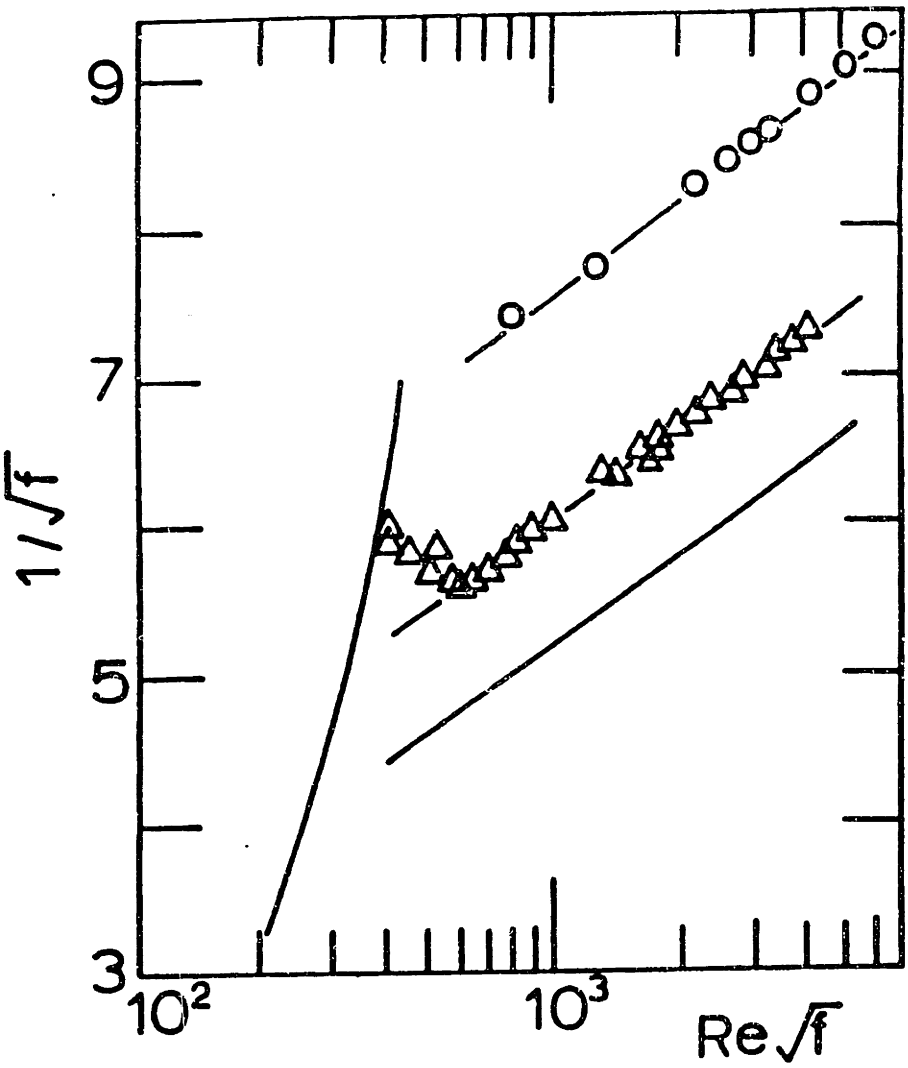

Fig. 3. Drag reduction trajectories for 50 ppm solution of DNA in 5.54 mm tube △ and 14.94 mm tube ○.

Figure 2.3.3: Example of Type-B Behavior from Berman et al.(1978)

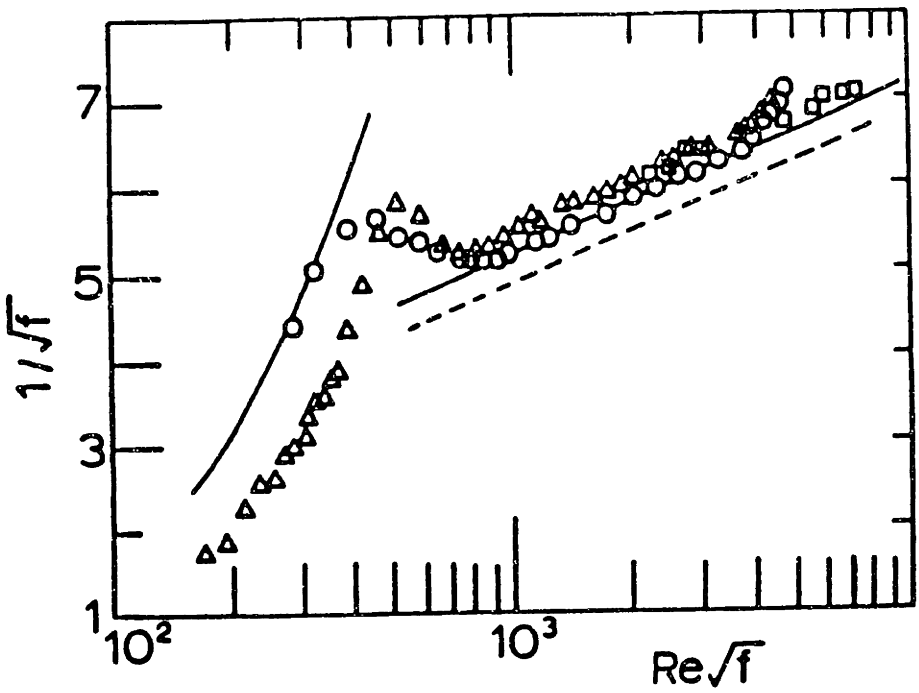

Fig. 4. Drag reduction of 200 ppm collagen in 0.01 M acetic acid. Data corresponding to the list in Table I are for run 1, △; runs 2 and 3, □; and run 4, ○. The points are based on the viscosity of the solvent. The dashed line represents Newtonian turbulent flow at the viscosity of the solution for run 1 points.

Figure 2.3.4: Example of Type-B Behavior from Berman et al.(1978)

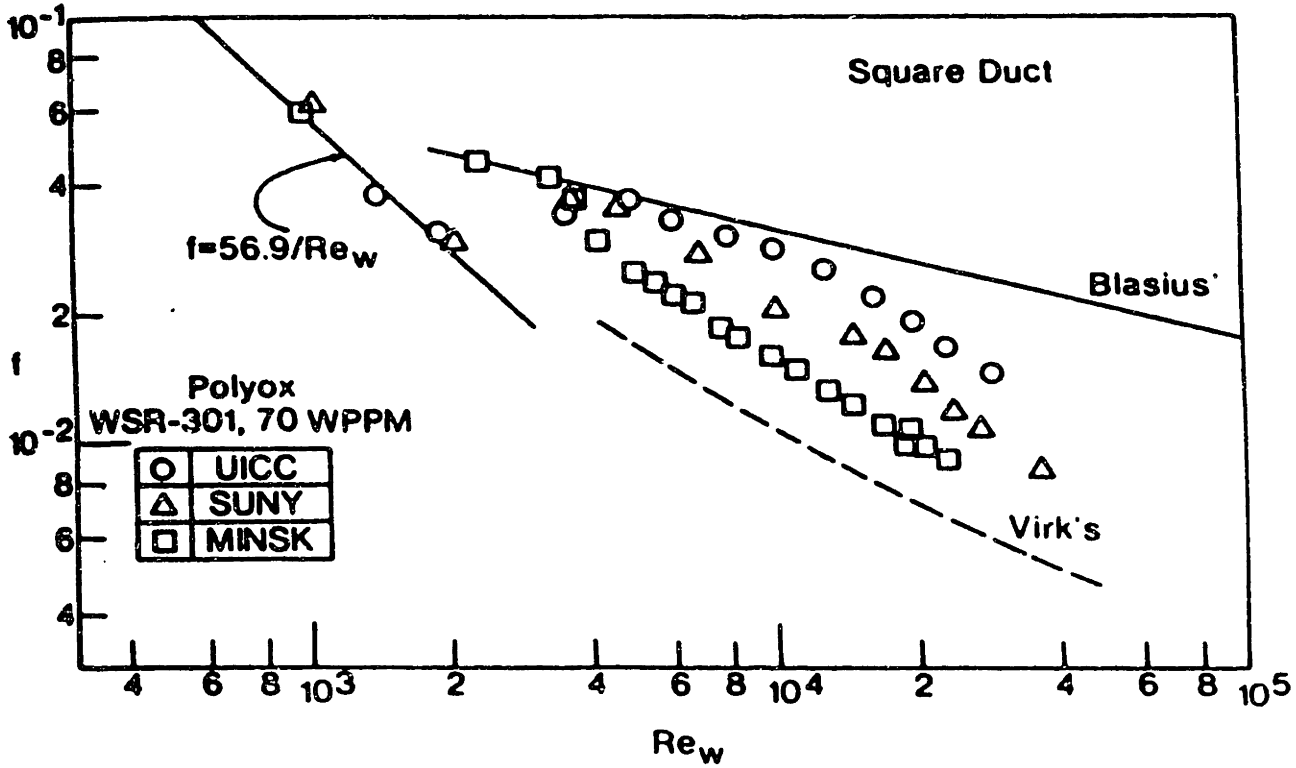

Fig. 4. Friction factor vs. Reynolds number for 70 wppm Polyox solution in 1 cm × 1 cm square duct.

Figure 2.3.5: Effect of Tap-Water Differences from Kwack et al.(1981)

PEO as a function of the mixing rate during solution preparation. These differences are displayed in Figure 2.3.6. Moderate mixing resulted in lower drag than did no mixing and high speed mixing. Apparently, mixing greatly influences the molecular state and often permits supramolecular structures to exist throughout an otherwise homogeneous fluid. These structures were deemed responsible for the flow enhancements observed. Figures 2.3.5 and 2.3.6 emphasize how truly precarious drag reduction comparisons are and how careful delineation of all experimental procedures, no matter how seemingly trivial, is required to avoid discrepancies.

Other additives, such as fibers, surfactants, and micellar solutions, also have been reported to cause drag reduction. Elson & Garside(1983) investigated the drag reducing behavior of cationic soap solutions and found that the friction factor data followed M closely even at low Reynolds numbers, as shown in Figure 2.3.7. Unlike Type-A additives, there was no onset. The solutions exhibited what Virk(1975a) called "retro-onset", meaning that drag reduction starts along the M and then reverts to the polymeric regime. Interestingly, there was also an "offset" point (for lack of a better symmetric term) at which the flow reverted all the way back to the N line of no drag reduction. Disruption of the micellar structures by too great a shear stress was though to explain these observations.

Table 2.3.1 outlines additional gross-flow themes investigated by various authors, giving some important experimental parameters; these merit further discussion.

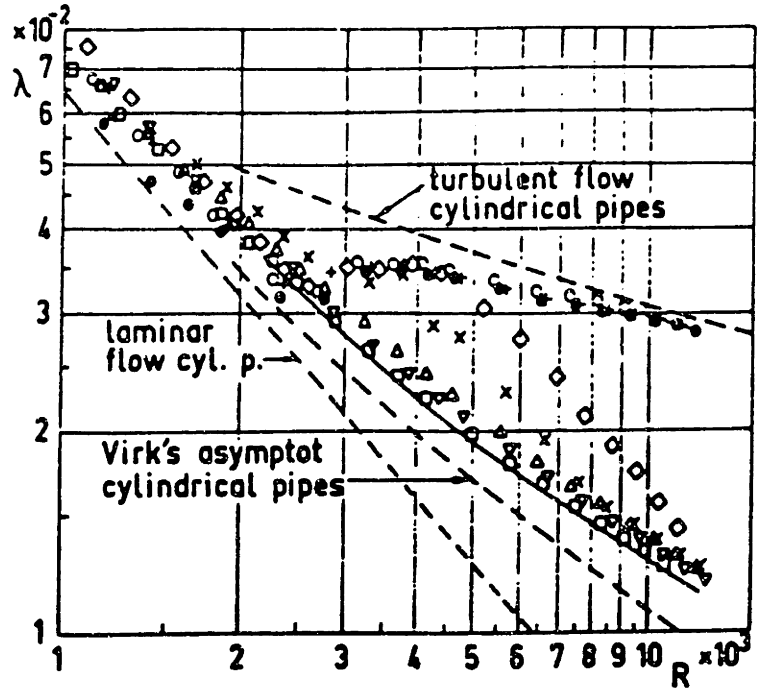

FIG. 3. Flow experiments with water and water plus 50 ppm additive of Polyox WSR 301 maintained by injection of 1% parent suspension. o water; mixer not in operation. ● water; mixer working at 20 r/sec. + water; mixer working at 40 r/sec. ▲ water +50 ppm additive; mixer not in operation. ▫ water +50 ppm additive; mixer working at 10 r/sec. ▽ water +50ppm additive; mixer working at 20 r/sec. × water +50 ppm additive; mixer working at 30 r/sec. ◇ water +50 ppm additive; mixer working at 40 r/sec.

Figure 2.3.6: Effect of Mixing on Drag Reduction from Stenberg et al.(1977)

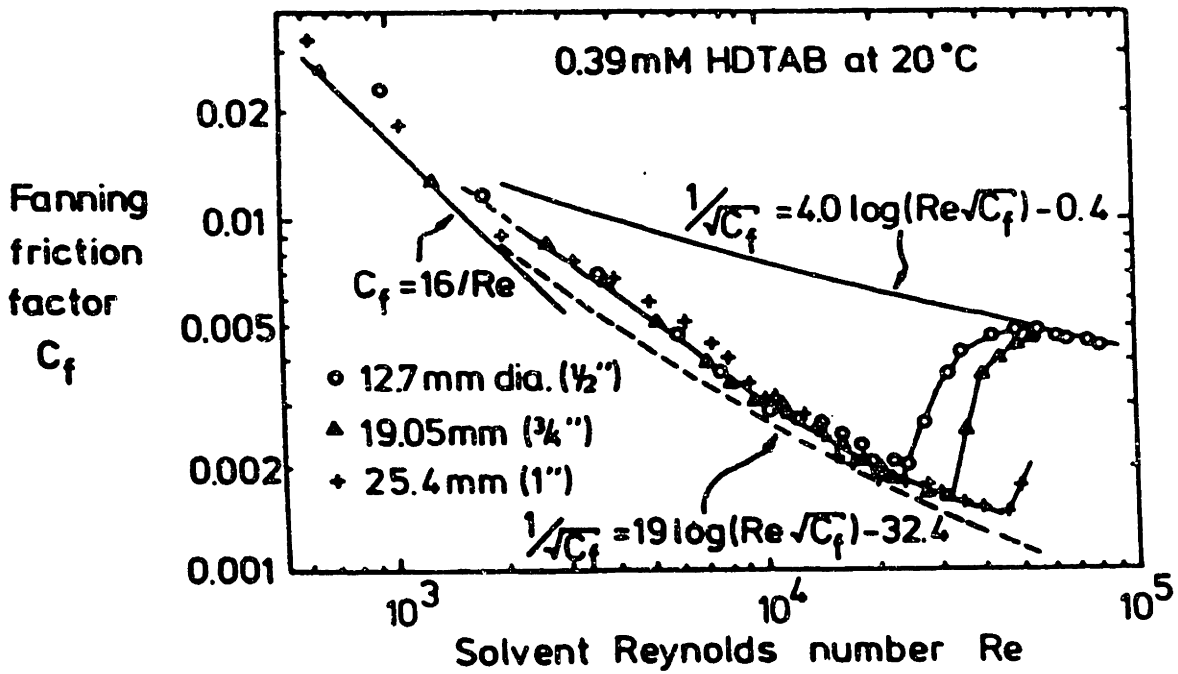

Fig. 2. Effect of pipe diameter on friction factors of equimolar 0.39 mM HDTAB, 1-naphthol solutions. The accepted Newtonian laminar and turbulent lines are illustrated as is Virk's [6] maximum drag-reduction asymptote (— — —).

Figure 2.3.7: Drag Reduction by Cationic Soap Solutions from Elson & Garside(1983)

Table 2.3.1
Gross Flow Themes and Sources

I. Order of Magnitude Effect of Pipe Diameter	
Burger et al.(1980)	10 wppm CDR additive(olefinic) in Crude Oil in pipes, 26 mm < D < 1194 mm
Sellins & Ollis(1983)	10 wppm HPAM and 10 wppm PEO in H_2O in pipes with 2 mm < D < 50 mm
Interthal & Wilski(1985)	30 wppm HPAM in river water in pipes with 3 mm < D < 750 mm
II. Drag Reduction versus Concentration	
Sharma et al.(1979)	Wall and centerline injection of fiber and fiber/HCMC solutions in H_2O pipeflow; 21 wppm < [fiber] < 64 wppm and 250 wppm HPMC; 2×10^4 < Re < 6×10^4
Gramain & Borreill(1978)	Polystyrene/Toluene; 6.25 wppm < c < 500 wppm; Re = 2×10^4
Oliver & Bakhtiyarov(1983)	Extremely dilute HPAM; 0.02 wppm < c < 0.5 wppm; Re = 15.5×10^3
Interthal & Wilski(1985)	HPAM/H_2O; 2.5 wppm < c < 30 wppm; Re = 1×10^4 and 2×10^4
III. Drag Reduction vs. Downstream Distance: Polymer Diffusion	
Frings(1984)	Annularly injected HPAM @ 80 < y^+ < 93; C_p = 0.2%; <C> = 50 wppm; Re = 3×10^4
McComb & Rabie(1982a)	Centerline PEO injection; C_p = 0.3%; <C> = 10.8 wppm in 0.2% aqueous NaCl; Re = 4.5×10^4
Bewersdorff(1984)	Centerline HPAM; C_p = 0.5%; <C> = 20 wppm; Re = 4×10^4, 6×10^4 and 8×10^4

2.3.1.1 The Effect of Pipe Diameter

Since most practical applications for drag reduction involve pipelines, much research has gone toward scale-up methods for industrial use. Typically, higher levels of drag reduction are reported in small pipes than in larger pipes, with scale-up not straightforward.

In the first group of studies, gross flow data from three investigations are compared. Burger et al.(1980) studied scale-up methods from drag reduction under lab conditions to that under conditions at Prudhoe Bay. Pipe diameters ranged from 26.64 to 1194 millimeters in single pass systems, both in the lab and field. A plot of %DR vs. ν_s/u_τ, the turbulent length scale, from experiments in pipes of different diameters gave distinct lines for each pipe diameter at all solution concentrations; a similar plot of %DR vs. ν_s/u_τ^2, the turbulent time scale, yielded a single for all pipe diameters at low concentrations, with distinct lines for each diameter becoming more apparent at higher concentrations. A viscoelasticity-based correlation, which had two flow parameters and one polymer-solvent parameter but no explicit pipe-diameter dependence, gave good agreement with measured quantities. Converting their data for 10 wppm CDR in crude oil into PK coordinates, as shown in Figure 2.3.8, reveals no diameter effect since all the data scattered about the line for which $S' \approx 2$.

Sellin & Ollis(1983) studied the effect of diameter on drag reduction in an attempt to derive a universal scaling law. They investigated the drag-reducing characteristics of 10 wppm solutions of PEO, HPAM(Magnifloc-1011® in coarse-powder form), and HPAM (Alcomer 110-L® in an oil-based emulsion) in pipes ranging from 2 to 50

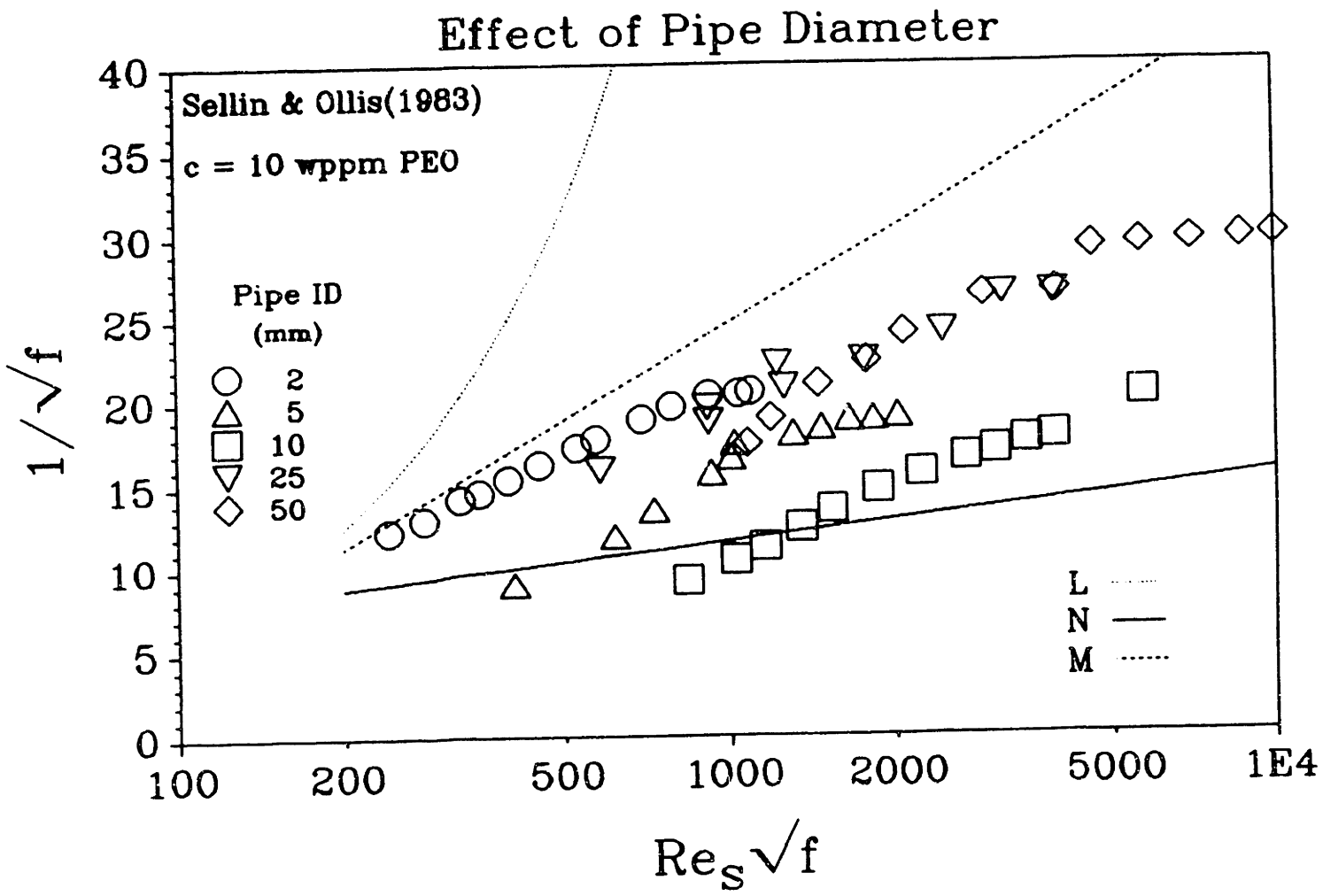

Figure 2.3.9: Effect of Pipe Diameter with 10 wppm PEO Powder(Sellin & Ollis, 1983)

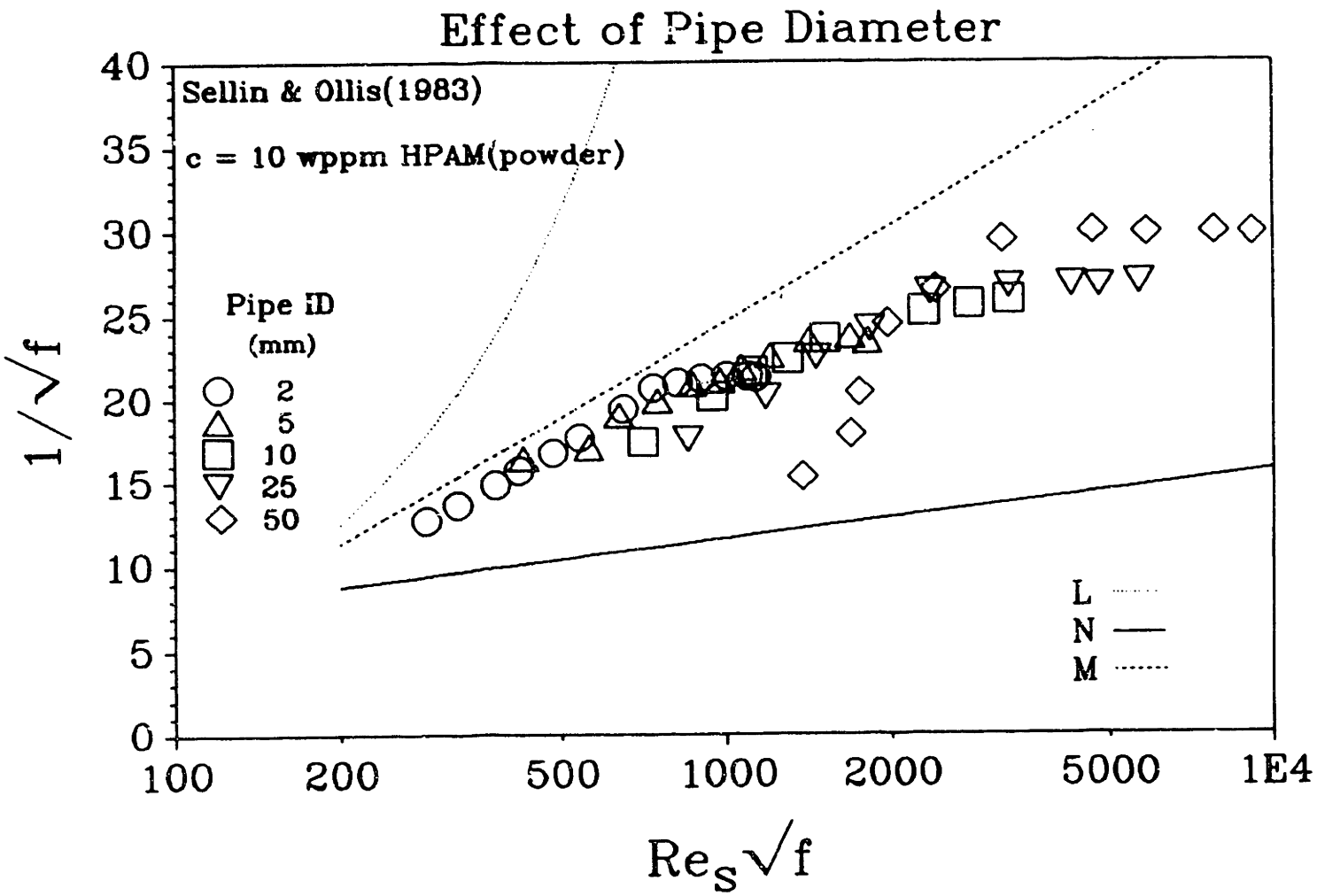

Figure 2.3.10: Effect of Pipe Diameter with 10 wppm HPAM Powder(Sellin & Ollis, 1983)

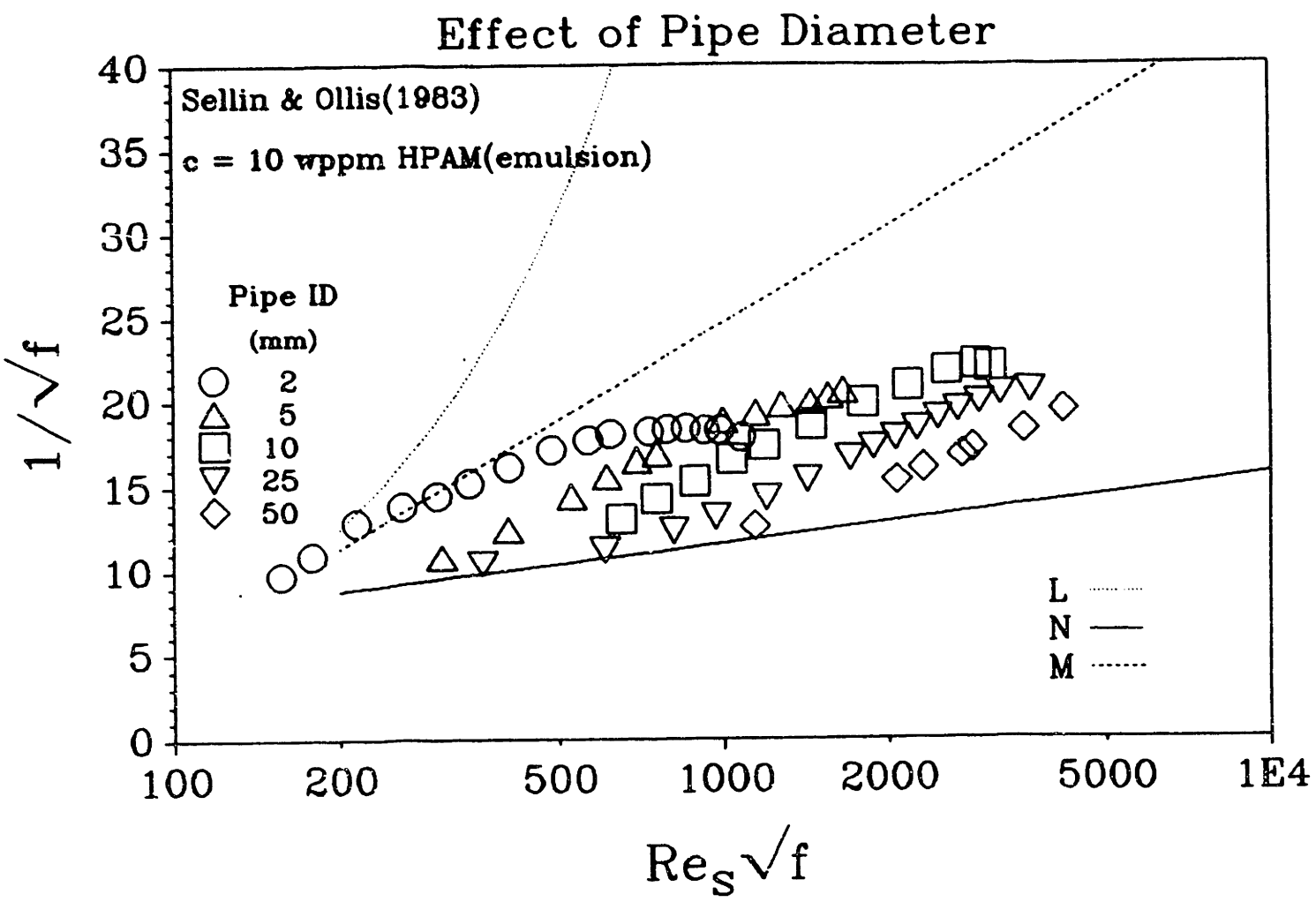

Figure 2.3.11: Effect of Pipe Diameter with 10 wppm HPAM Emulsion(Sellin & Ollis, 1983)

millimeters in diameter. Figures 2.3.9, 2.3.10, and 2.3.11 show the gross flow data for these three solutions, respectively. The PEO data were split into two groups: the 2, 5, and 10 mm pipes and the 25 and 50 mm pipes. In either set, effectiveness grew with decreasing diameter, but there were inexplicable inconsistencies between sets, with the 2 and 25 mm pipes, the smallest in each set, showing similar results. The HPAM-powder solutions exhibited flow enhancement near M at low $Re_s\sqrt{f}$ for all but the largest pipe size. In the largest pipe, $Re_s\sqrt{f} \approx 1100$ was required to reach significant flow enhancement, but its data then rapidly joined those for all other pipes by $Re_s\sqrt{f} \approx 3000$. The data revealed no clear dependence on pipe diameter. The HPAM-emulsion solution exhibited increasing drag reduction with decreasing pipe size at a given $Re_s\sqrt{f}$; however, scale-up was hampered because the $Re_s\sqrt{f}$ range that exhibited significant drag reduction for each pipe was different.

An important point is that the two HPAM solutions, while both 30% hydrolysed, differed in their premixed form, powder vs. emulsion, and in their preparation. The differences in form and preparation likely accounted for the great differences in flow behavior. Such a lack of additive reproducibility makes scale-up difficult.

Interthal & Wilski(1985) investigated drag reduction in industrial pipelines, several thousand meters in length, using 30-wppm solutions of HPAM. Their data, which have been transformed into PK coordinates, are given in Figure 2.3.12 and exhibited similar differences between small pipes and large pipes. In their smallest four laboratory pipes, with tap-water solvent, all data were either on or close to M. In the four largest pipes, with river-water solvent, the real industrial set-up consisted of large winding kilometer-long pipes, which exhibited about only half the flow enhancement seen in the

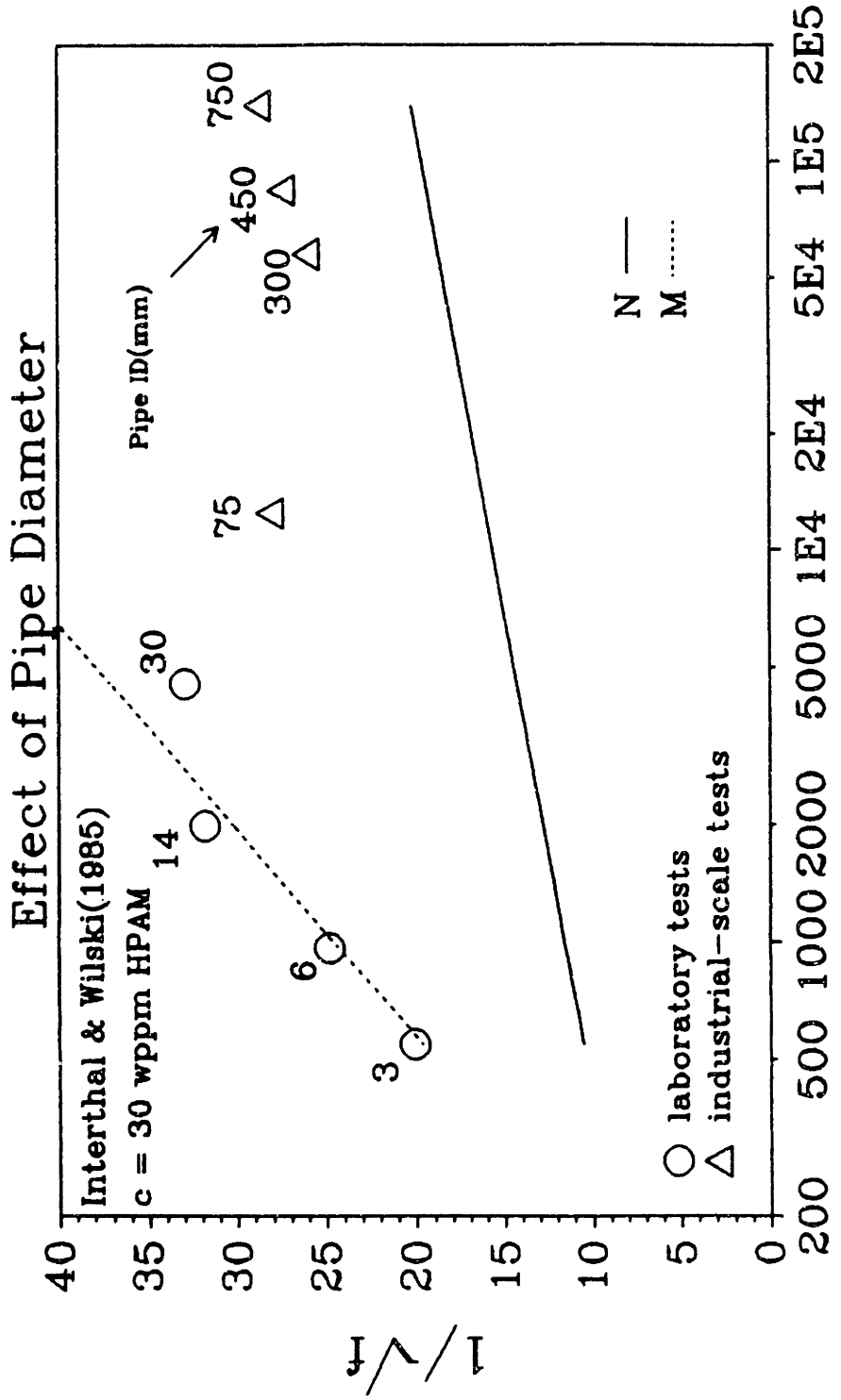

Figure 2.3.12: Effect of Pipe Diameter(Interthal & Wilski, 1985)

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smaller pipes. Thus, the drag-reducing effectiveness of HPAM in the field could not be well estimated from the lab data.

What these three p[illegible]ers emphasize is that the scaling of drag reduction is difficult at best. One must ensure [illegible]ducibility at every phase of solution preparation, from polymer polydispersities to solvent properties, and operate the experiment at low drag reduction where the MDR asymptote does not interfere with the sought-after diameter effect.

2.3.1.2 Drag Reduction vs. Concentration

The efficiency of several different additive-solvent pairs introduced into the turbulent flow in various ways is compared in Figure 2.3.13 on log-log coordinates of flow enhancement S' vs. additive concentration c, in wppm.

Data derived from Sharma et al.(1979) show the differences between wall and centerline injection of fibers and fiber suspensions at fixed $Re = 2\times10^4$ in a 19-mm pipe. Wall injection was generally more efficient than centerline injection, giving about twice the flow enhancement at fixed (final) concentration.

Data are also shown for polystyrene in toluene at $Re_s = 2\times10^4$ (Gramain & Borreill, 1978) and for aqueous HPAM at $Re_s = 1\times10^4$ and 1×10^5 in a 14-mm pipe and at $Re_s \approx 2.0\times10^4$ in a 5.97-mm pipe(Oliver & Bakhtiyarov, 1983). Evidently, HPAM in water was more effective than polystyrene in toluene which was, in turn, more effective than the asbestos fiber suspensions. Quantitatively, Oliver & Bakhtiyarov's (1983) data for the extremely dilute solution show their HPAM additive to provide

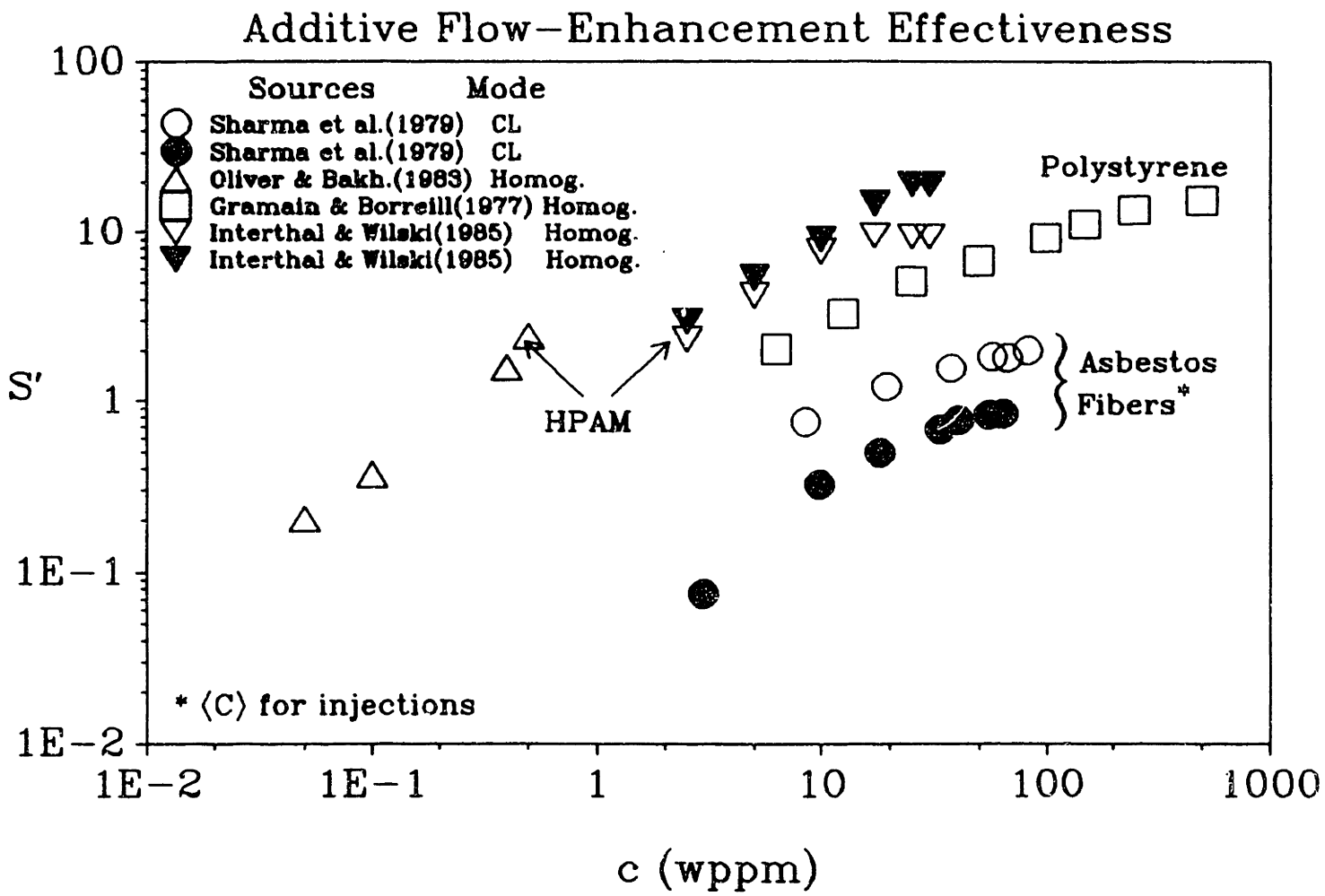


Figure 2.3.13: Additive Flow-Enhancement Effectiveness

S' $\approx$ 0.4 at c $\approx$ 0.1 wppm, whereas Sharma's(1979) data for asbestos fibers show S' $\approx$ 1 at c $\approx$ 10 to 50 wppm; thus, the HPAM polymer was about 2 to 3 orders of magnitude more effective than the asbestos fibers on a weight basis.

2.3.1.3 Drag Reduction vs. Downstream Distance from Injector

Polymer diffusion can be measured by the increase in flow enhancement S' as a function of downstream x/D during an injection experiment. Figure 2.3.14 presents data from the three authors listed in Table 2.3.1. Annular injection data from Frings(1984, 1988) show a much sharper initial rise in S' than other centerline-injection data even though Frings' data were taken at the lowest Re. This is likely due to polymer being injected directly into the buffer layer, the radial location where drag reduction is believed to originate. Thus, little diffusion was required before the onset of drag reduction. The characteristic development length, the x/D where the initial gradient in S' vs. x/D intercepts the asymptotic S' value, for the annular injection was $\sim$60 while that for all centerline-injection data was $\sim$120. The characteristic development lengths derived from the data of McComb & Rabie(1982a) and Bewersdorff(1984) agreed well, despite the great variation in Re and drag reduction. This suggests that polymer diffusion in the core does not depend significantly on the flow strength.

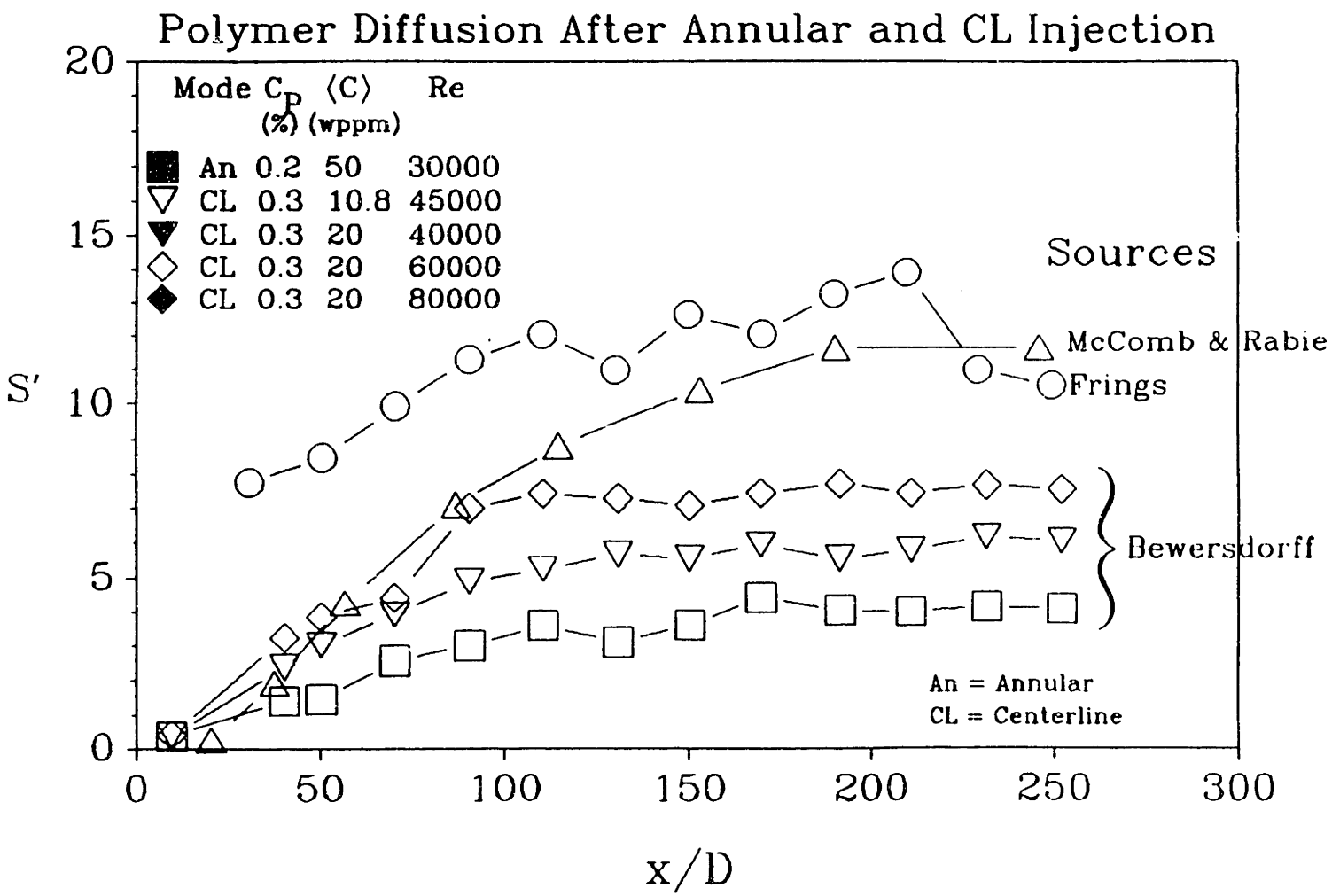


Figure 2.3.14: Axial Flow-Enhancement Development via Polymer Diffusion

2.3.2 Mean-Velocity Profiles

Starting with the Navier-Stokes equations and employing scaling arguments, the following mean velocity profiles for turbulent pipe flows of Newtonian fluids can be derived:

$$(\textit{viscous sublayer}) \quad \overline{U}^+ = y^+ \qquad 1 < y^+ < 5 \tag{2.3-9}$$

$$(\textit{buffer layer}) \quad \overline{U}^+ = 10\tan^{-1}\left[\frac{y^+}{10}\right] + 1.2, \qquad 5 < y^+ < 30 \tag{2.3-10}$$

OR

$$(\textit{buffer layer}) \quad \overline{U}^+ = 5\ln(y^+) - 3.05, \qquad 5 < y^+ < 30 \tag{2.3-11}$$

$$(\textit{log layer}) \quad \overline{U}^+ = 2.5\ln(y^+) + 5.5, \qquad 30 < y^+ < R^+ \tag{2.3-12}$$

Of the two buffer layer equations, the lower is a simple fit to the zone boundaries whereas the upper is based on the physics of the buffer layer, where most of the turbulent production occurs. This zone is of great import and interest in the study of drag reduction. Drag-reducing additives tend to thicken the buffer layer into what Virk called the "elastic layer"; the elastic layer separates the viscous sublayer from the Newtonian core and gives rise to an "effective slip". Thus, the intercept of the log layer equation becomes greater than 5.5 while the slope remains the same. The log layer extends from the outer edge(nearer the wall) of the buffer layer to the pipe axis or core. The constant slope 2.5 is the inverse of the Newtonian Von Karman constant $\kappa_n \approx 0.4$.

Virk(1971a) collected much data on mean flow and proposed a three zone "elastic sublayer model"(ESM) for the mean velocity profile of drag-reducing flow. These three

equation comprise the ESM model:

$$\textit{(viscous sublayer)} \qquad \overline{U}^+ = y^+ \qquad y^+ < y^+_v \tag{2.3-13}$$

$$\textit{(elastic sublayer)} \qquad \overline{U}^+ = 11.7\ln(y^+) - 17.0 \qquad y^+_v < y^+ < y^+_e \tag{2.3-14}$$

$$\textit{(Newtonian plug)} \qquad \overline{U}^+ = 2.5\ln(y^+) + 5.5 + 9.2\ln\left[\frac{y^+_e}{y^+_v}\right] \qquad y^+_e < y^+ < R^+ \tag{2.3-15}$$

where the $9.2\ln(y^+_e/y^+_v)$ term is also known as ΔB.

Implicitly, the scheme requires that an M profile exists in the elastic sublayer for even the smallest amount of drag reduction. As the polymer concentration increases, the drag reduction increases, and with it the thickness of the elastic layer. The M profile of slope 11.7, extends over a larger portion of the pipe in real and reduced distances with increasing drag reduction. Low radial momentum transport in the elastic layer is a feature associated with drag reduction and is indicated by a reduced Von Karman constant $\varkappa_m = 1/11.7 \approx 0.085$. At the outer edge of the elastic layer, the profile slope changes to the Newtonian value with larger $\varkappa_n \approx 0.4$; however, the intercept value in the Newtonian plug is much greater than the Newtonian value, 5.5. The difference between this value and 5.5 is known as the "effective slip" or ΔB. Since the ESM was proposed, much mean flow data has been generated to verify it. The following table summarizes some of the major contributions.

Table 2.3.2
Sources of Mean Flow Data

Investigators	Experimental Conditions
Kale & Metzner(1976)	•Homogeneous fiber and fiber/HPAM solutions; [fiber] = 1000 wppm and 2000 wppm; c = 150 wppm.
Sharma et al.(1979)	•Injected 0.3-% fiber solutions into H_2O and 250-wppm polymer solution; $1\times10^4 < Re < 1\times10^5$. •Wall and centerline injection; [fiber] < 71 wppm; $2\times10^4 < Re < 4\times10^4$.
McComb & Rabie(1982b)	•Centerline PEO injection into H_2O; $<C> < 20$ wppm; $Re = 3.5\times10^4$.
Bartels et al.(1984)	•Homogeneous HPAM solutions; $c < 320$ wppm; $Re = 2\times10^4$.
Bewersdorff(1984)	•Homogeneous 20-wppm and 50-wppm PAM solutions and centerline-injected PAM with $0.1\% < C_p < 1.0\%$ into H_2O; $Re < 8\times10^4$.
McComb & Chan(1985)	•Homogeneous 300-wppm fiber and 300/150- wppm fiber/PAM solutions; $1.4\times10^4 < Re < 5.3\times10^4$.

Figure 2.3.15 displays velocity profiles from Kale & Metzner(1976) of concentrated fiber and fiber-HPAM solutions at high Re. These profiles were consistent with the Newtonian-plug equation 2.3-15, showing "effective slip". The addition of polymer to the fiber solution results in greater ΔB. The 1000-wppm asbestos-fiber solution had an upshift per wppm $\Delta B/c = 0.007$. Adding 150 wppm PAA to that fiber solution resulted $\Delta B/c = 0.02$. Clearly, HPAM is a much more effective additive than asbestos fiber.

Sharma et al.(1979) injected fibers into turbulent pipe flows of water and HPMC solutions. Injections were made into the centerlines and at the wall. The resulting average

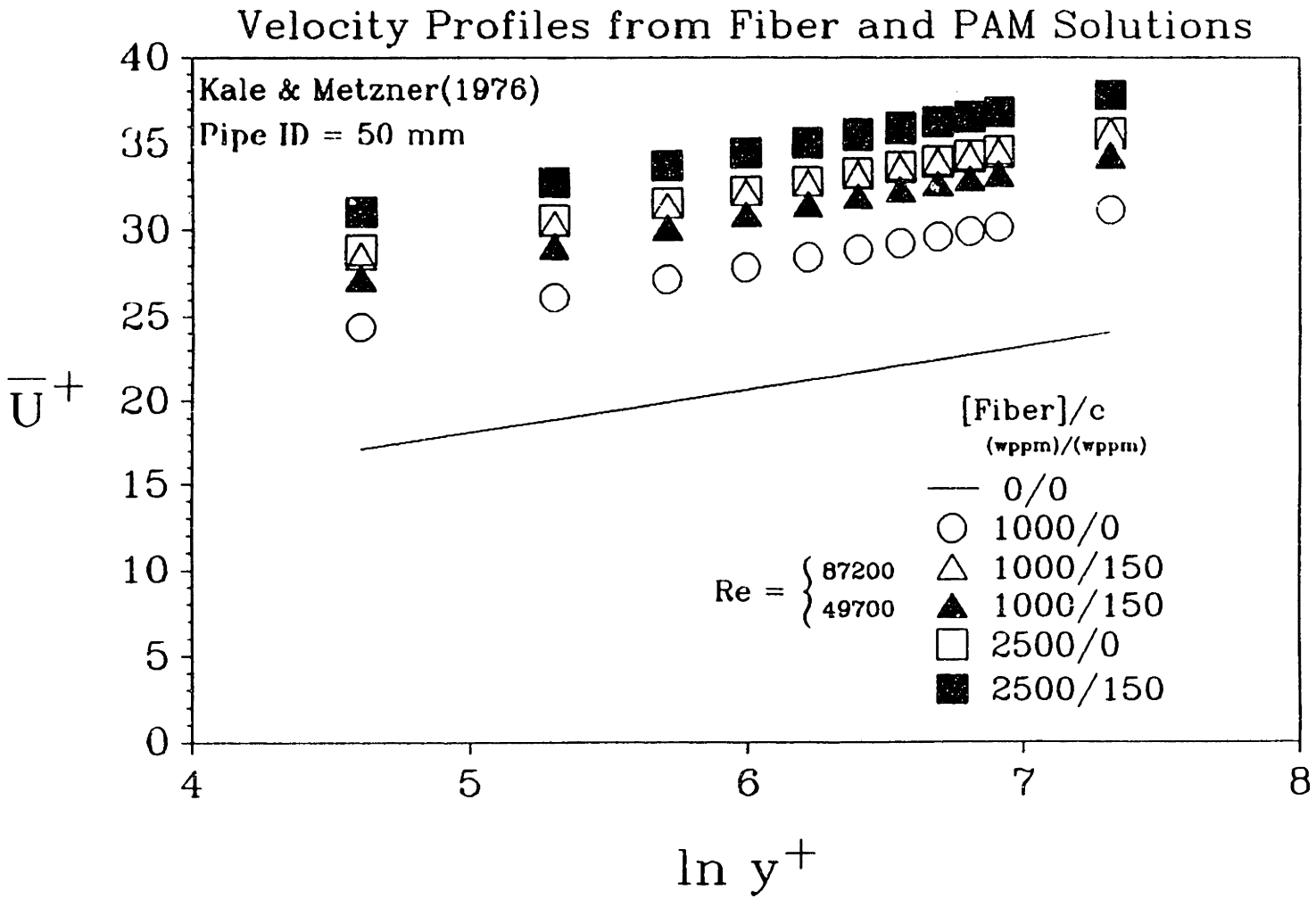


Figure 2.3.15: Velocity Profiles from Asbestos-Fiber Solutions(Kale & Metzner, 1976)

concentrations <C> were nearly two orders of magnitude lower than those of Kale & Metzner(1976). The behavior of mixed solutions, fiber and HPMC, is depicted in Figure 2.3.16 for both wall and CL injections, with the former more effective than the latter. Although still well below M, these profiles show that the presence of polymer increases ΔB for the same fiber concentration; however, $\Delta B/c$ is less for the mixed than for the fiber-only case. In these data, the fibers are more efficient than polymer, contrary to the results of Kale & Metzner(1976).

McComb & Rabie(1982b) injected PEO solutions into the centerline of a water pipe flow and measured the profiles at successive distances down the pipe, x/D, in order to observe the development of drag reduction in an already turbulent Newtonian flow. Figure 2.3.17 exhibits how the profile lifts off the Newtonian line. The profiles show that the three-zone model does not quite hold in that the profile slope in the elastic layer is somewhat less than M but greater than Newtonian; however, the core profile seems nearly parallel to the Newtonian line. In successive profiles, the growth of the elastic layer is clear. As the polymer diffuses into the elastic layer with downstream distance, $8 \leq x/D \leq 214$, the thickening layer in the region $30 < y^+ < 100$ gives rise to a velocity profile in the core that lies increasingly closer to M, with the flow enhancement S' rising from ~ 0 to 10.8 Only when the elastic layer is saturated and its extent restricted by pipe geometry rather than polymer availability, does the profile approach that of maximum drag reduction.

Bartels et al.(1984) investigated pipe flows of premixed HPAM solutions. Their results, shown in Figure 2.3.18, concur with those of McComb & Rabie(1982b) and display the similar differences among profiles of increasing polymer concentration at

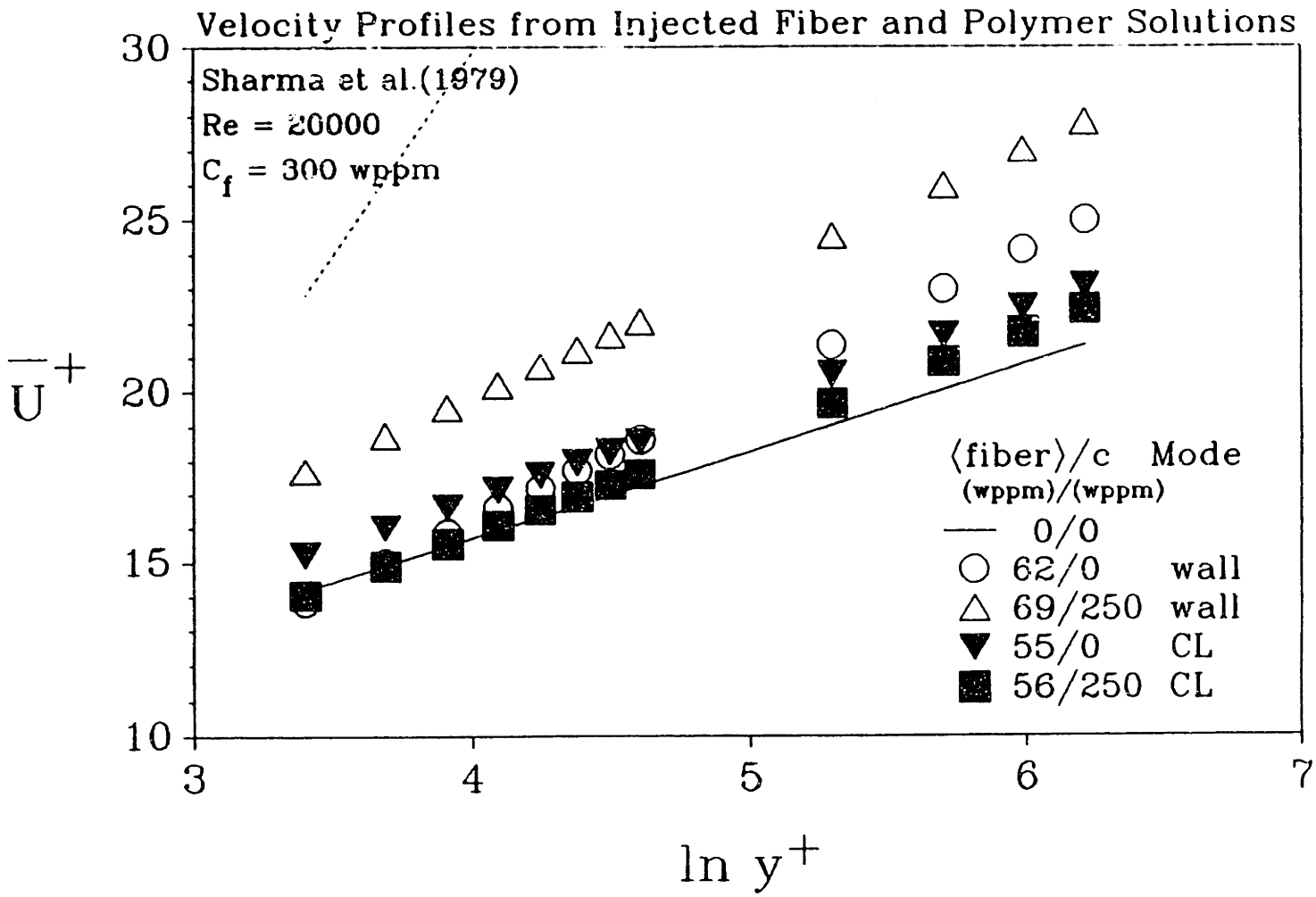


Figure 2.3.16: Velocity Profiles from Fiber-Solution Injection(Sharma et al., 1979)

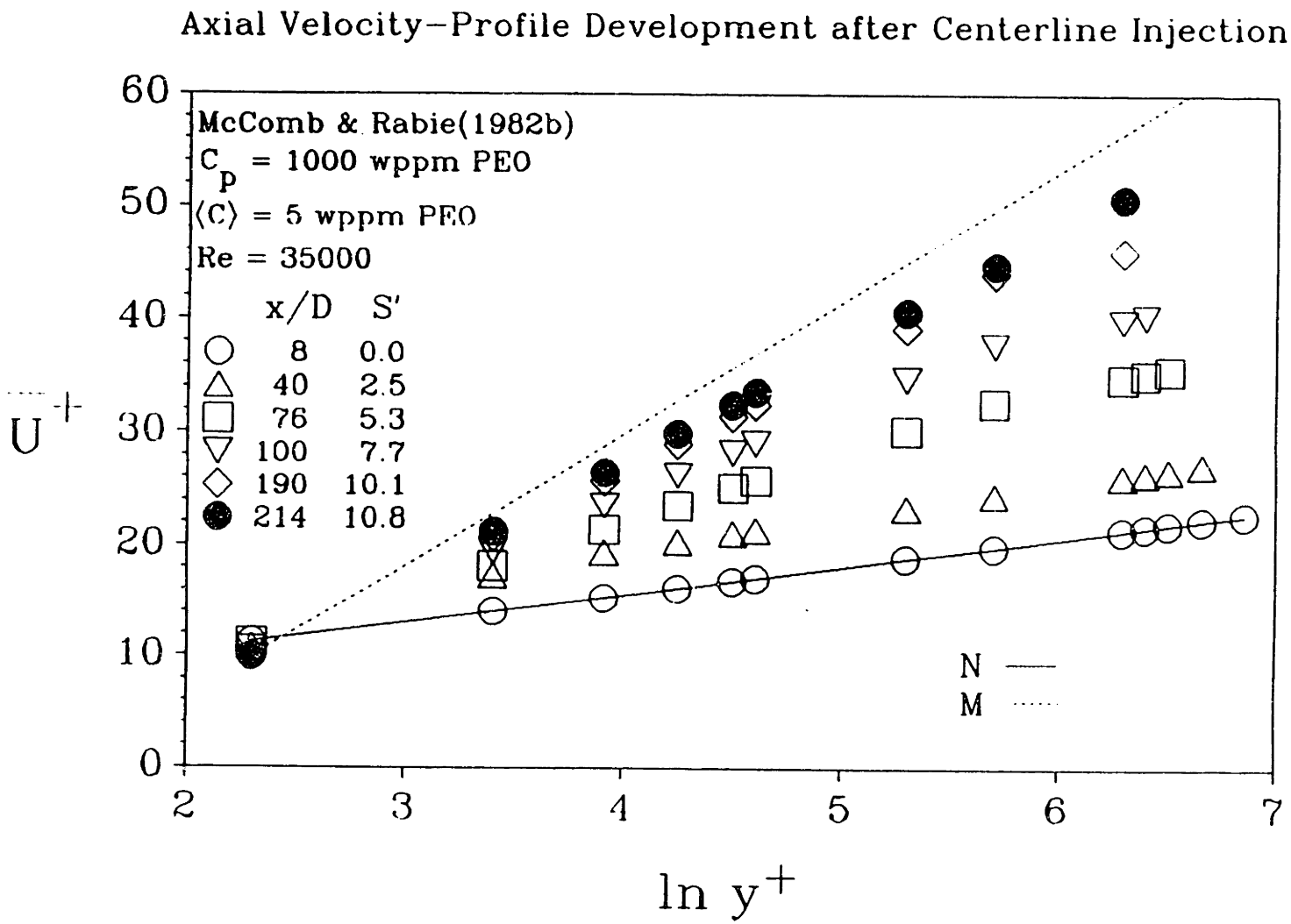


Figure 2.3.17: Velocity Profiles from PEO-Solution Injection(McComb & Rabie, 1982b)

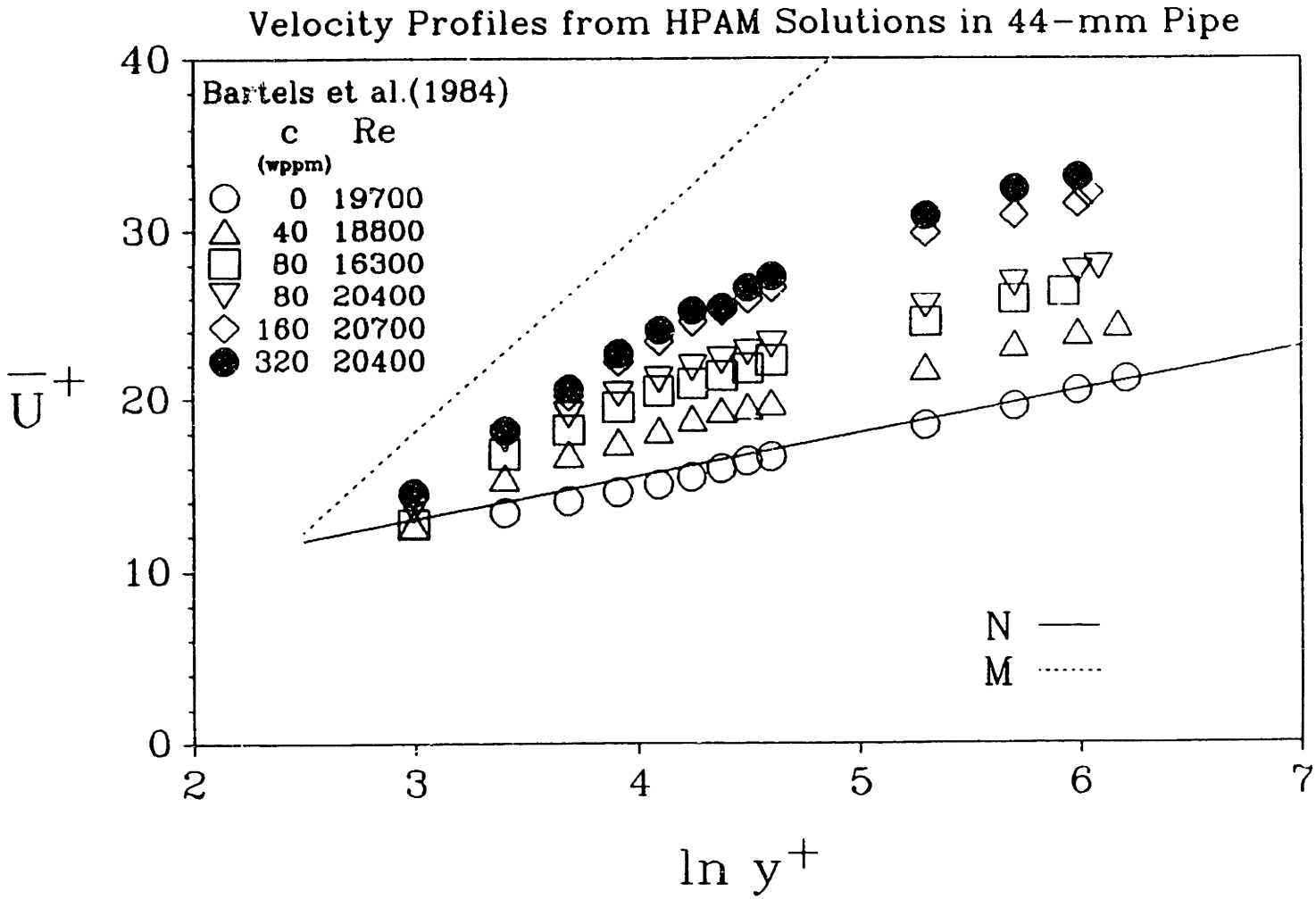


Figure 2.3.18: Velocity Profiles from Premixed HPAM Solutions in 44-mm Pipe(Bartels et al., 1984)

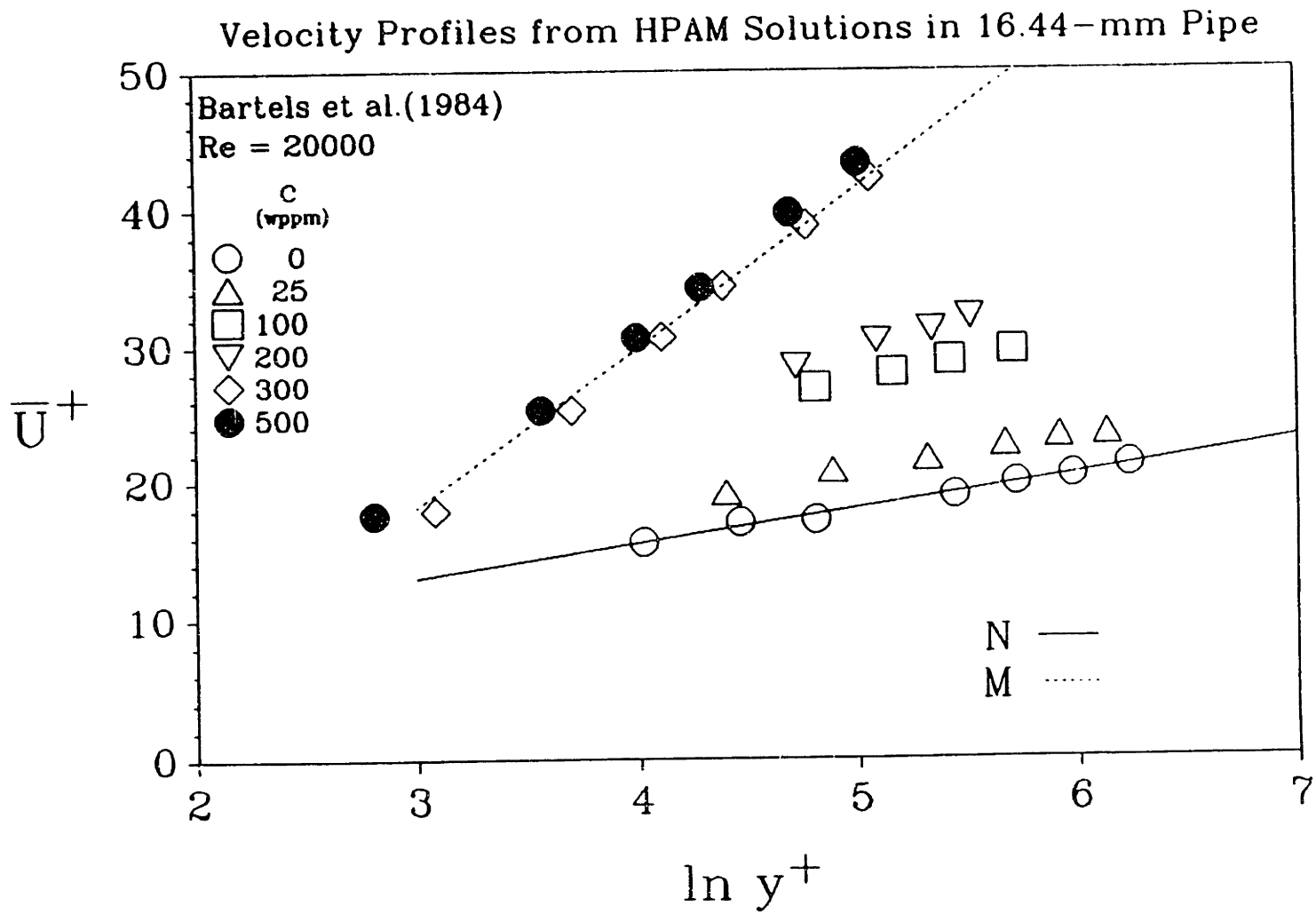


Figure 2.3.19: Velocity Profiles from Premixed HPAM Solutions in 16-mm Pipe(Bartels et al., 1984)

nearly identical conditions in a 44-mm pipe. Figure 2.3.19 exhibits the same trend in a 16-mm pipe, wherein several of the higher concentrations achieve maximum drag reduction.

Bewersdorff(1984) injected very concentrated HPAM solutions into the centerline of turbulent pipe flow, so concentrated in fact that the polymer threads remained intact as a single thick undulating cord along the centerline. Figure 2.3.20 shows that at a fixed Re, or a near-constant R^+, the less concentrated injections gave greater ΔB even though the final average concentration $<C> = 20$ wppm for each C_p. Again this indicates the importance of polymer diffusion from the central cord that forms when concentrations are as high as 10000 wppm. Polymer diffusion may account for this strange trend. Figure 2.3.21, taken from Bewersdorff(1984), demonstrates the interesting development of the velocity profile under his conditions. The profile looks as if it were representing two fluids. From the wall, the flow is Newtonian perhaps because the polymer has not diffused to that region. At some point, $y^+ > 50$, where the profile diverges from the water line, it behaves similarly to the profiles from McComb & Rabie(1982b) and Bartels et al.(1984). At greater y^+ from the divergence, a small region shows a profile of slope about half that of M and greater than that of N. Towards the core, the profile flattens and become nearly parallel to the Newtonian line. Bewersdorff & Berman(1988) observed similar "bifurcating" velocity profiles using surfactant solutions. No completely satisfactory explanation has yet been offered for these curious observations.

McComb & Chan(1985) measured profiles in pipe flows of fiber and fiber-PAA solutions at various Re. Figure 2.3.22 shows that in their flow loop at $Re = 1.4\times10^4$, a 300-wppm fiber solution exceeded M on its first two passes. Subsequent passes

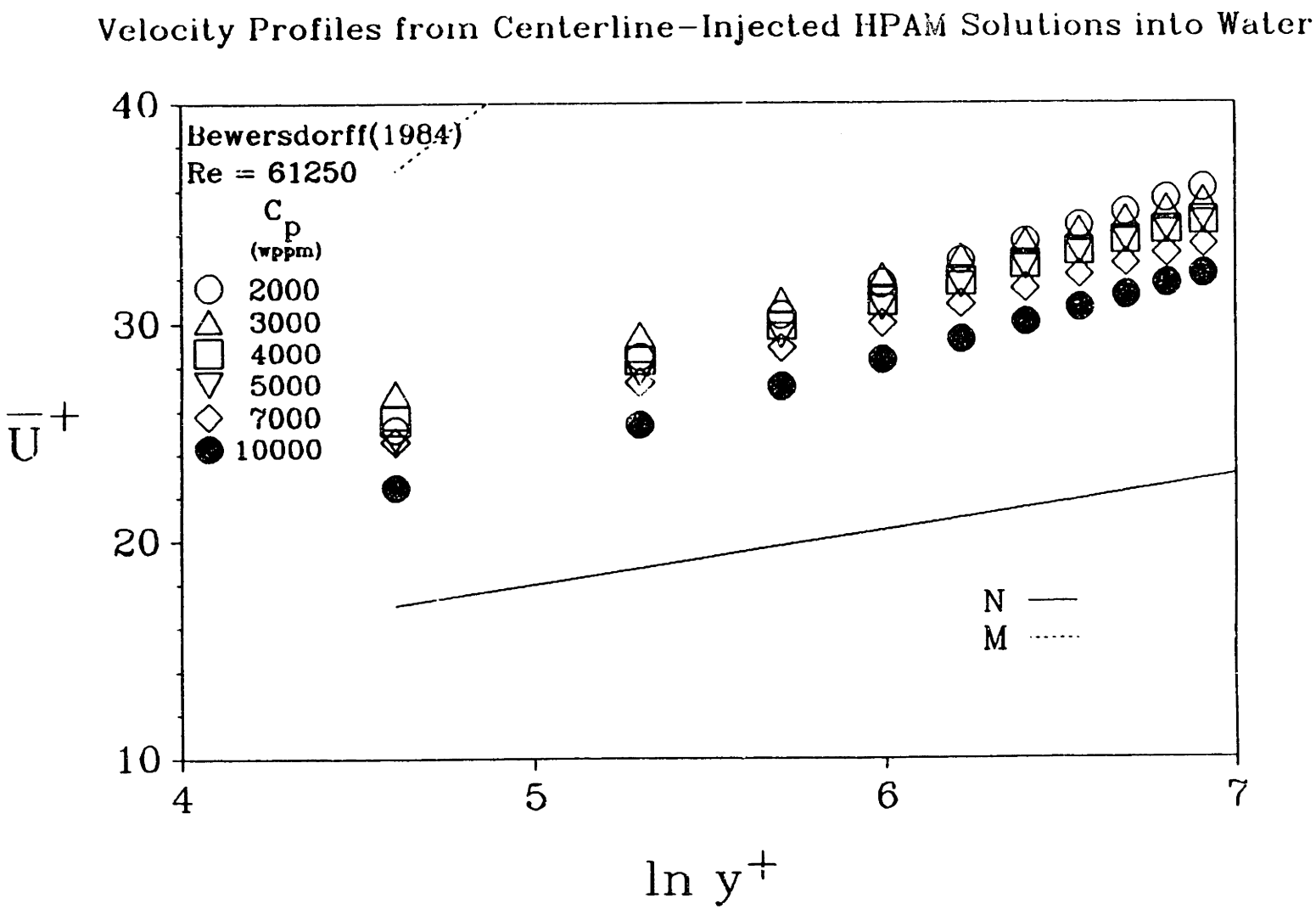


Figure 2.3.20: Velocity Profiles from HPAM-Solution Injection(Bewersdorff, 1984)

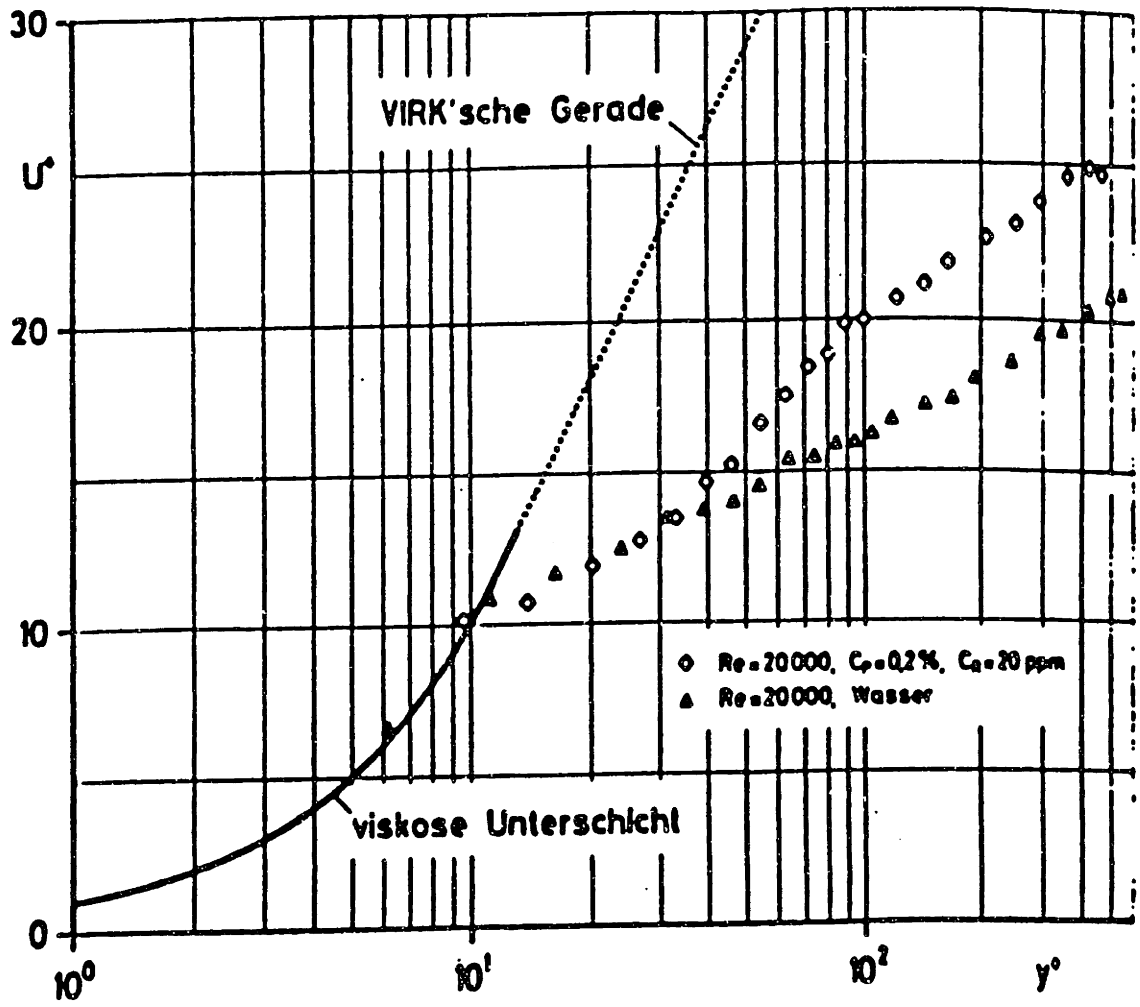


Abb. 16. Geschwindigkeitsprofil bei Injektion von Polymeren ($Re = 20000$)

Figure 2.3.21: Two-Fluid Profile from Bewersdorff(1984)

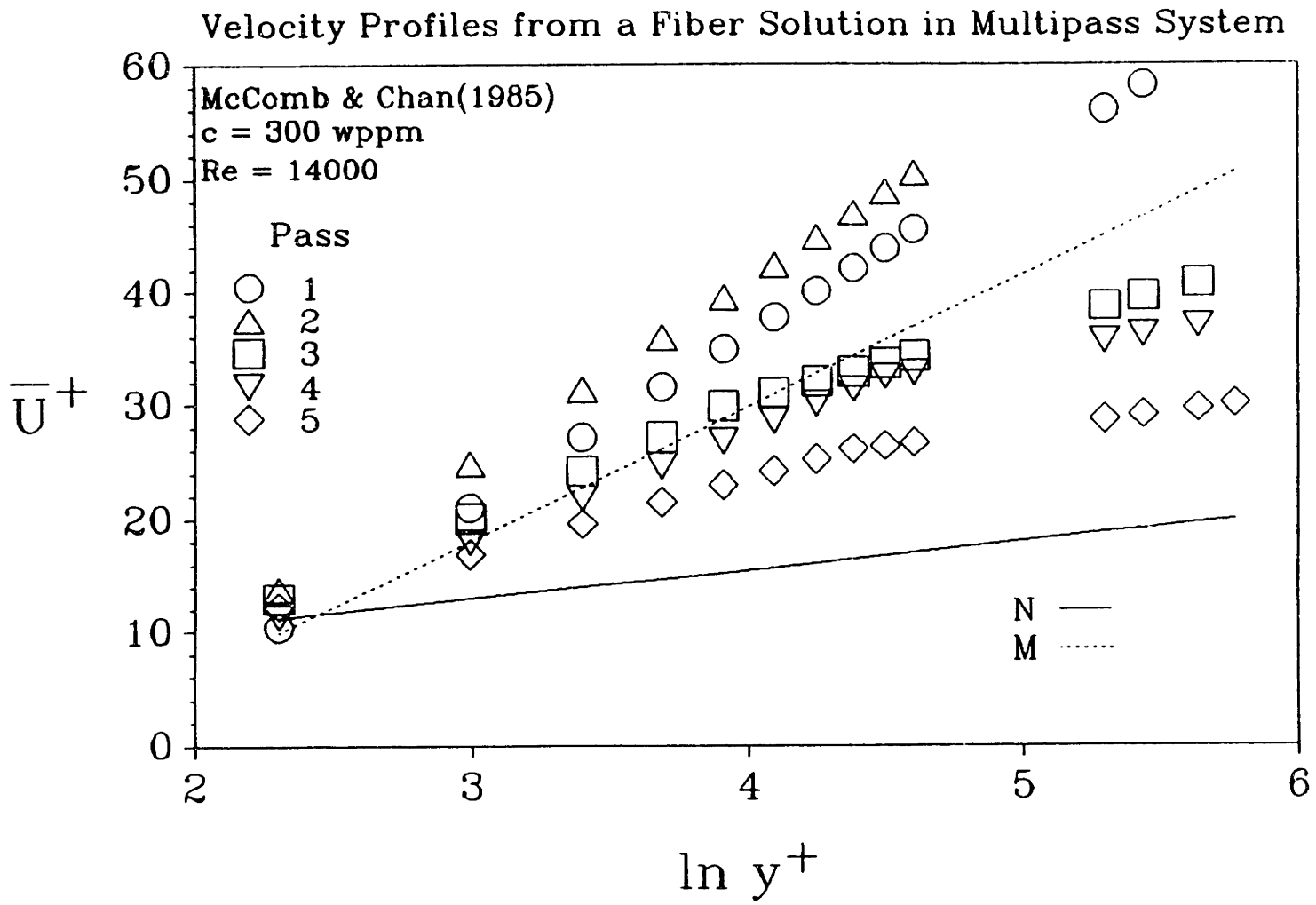


Figure 2.3.22: Velocity Profiles from Fiber Solutions in Multipass System(McComb & Chan, 1985)

behaved similarly to polymer flows. Since the MDR asymptote was first discovered, no data exist which exceed M(in either mean or gross flow) after entering the fully turbulent envelope between N and M.The profiles from passes 1 and 2 likely did not become fully developed. Thus, the authors called them "fiber-like" suggesting that fiber agglomeration rather than the individual fibers themselves may account for this behavior. Similar experiments were performed at Re = 3.2×10^4 and 5.3×10^4. The profile trend for successive passes at these Re concurred with the earlier findings of McComb & Rabie(1982b) and Bartels et al.(1984), and showed no unusual features, only the usual effect of degradation as the drag reduction decreased with increasing number of passes.

2.3.3 Turbulence Structure I: Intensities and Stresses

An understanding of Newtonian turbulence structure is required to appreciate how additives alter the turbulent-flow structure.

In pipe flow, laminar flow prevails for $Re_s < 2100$. When $2100 < Re_s < 4000$, a transition region occurs with zones of intermittent turbulence which arise from certain points along the pipe. With increasing Re_s, these zones pervade all space, leading to fully-developed turbulence when $Re > 4000$.

In a fully-turbulent pipe flow, pairs of counter-rotating rolls, also called streamwise vortices, exist near walls with a mean azimuthal spacing $z^+ \approx 100$. Their axes are separated by $\sim 50\ z^+$ units, and the average axial length of a single roll is $\sim 1000\ z^+$ units. Vortex pairs "pump" low speed fluid from the wall region and create low speed zones between the axes. This gives rise to the so called streaky structure. In

the low speed zones, shear instabilities intermittently occur which are involved in a ring-vortex mechanism and which commence events called "bursts".

Lift-up, oscillation, and break-up events characterize bursts. The bursting process disrupt the rolls' identities every ~ 1000 units such that zones of high and low velocities appear to be randomly distributed in space and time. Fluid elements in the viscous sublayer are lifted into the buffer layer. Lift-up is associated with the ring-vortex mechanism, but the exact relationship is unclear. In the low speed zones, inflectional instabilities in the mean velocity profile initiate oscillations which amplify as they are advected downstream. After travelling some characteristic lengths, these oscillations break-up, and the process begins anew. Associated with "bursts" are "ejections" which occur twice as frequently on average but with less strength. What starts the ejection process is unclear, but lift-up appears to be related. Low momentum fluid elements leave the wall area and act as sinks in higher momentum regions; thus, the Reynolds stress $-\langle uv \rangle$ associated with ejection is positive. The frequency of bursts and ejections correlate with the wall shear stress and fluid viscosity. The ejection process ends via the sweep. Sweeps also contribute a positive Reynolds stress, but in the opposite sense. Fluid elements from the higher-momentum outer flow move wallward, create high shear layers with the low- speed fluid, and initiate instabilities. The lateral extent of a sweep is ~ 80 units, while its velocity is about 75 percent of the maximum mean velocity. A newer flow structure, designated "pocket" by Falco(1977), is similar to a sweep, only penetrating more deeply into the near-wall region. They are ~ 100 by ~ 100 units in the lateral and axial directions. Again, the causes of pocket formation are unknown.

Visual and tracer studies have identified structures and described their

characteristics, but they can not attribute causality among these events. Constant formation and destruction of these structures randomly in space and time do not permit one to ascribe a "beginning" and an "end". Studying the transition to turbulence might permit causality among these structures to be established. Visual and tracer studies may be less important than reliable mean flow and velocity fluctuation data in that the latter may yield better, less-subjective data than the former. More in-depth discussions of classical turbulence may be found in Monin & Yaglom(1971), Hinze(1975), and Schlichting(1979) and of flow structure in Laufer(1954), Kline et al.(1967), Lumley(1973), and Blackwelder & Kaplan(1976). Laufer(1954) presented the first detailed measurements of turbulence fluctuations. The intensities and Reynolds stresses, u'^{+}, v'^{+}, and, w'^{+} and $-<uv>^{++}$, were carefully determined for air flow in a nominal 10-inch pipe(9.72 inches ID) at Re $= 5\times10^{4}$ and 5×10^{5}. Skewness and flatness, the third and fourth moments of the velocity fluctuations, respectively, as well as production, dissipation, and one-dimesional energy spectra were calculated. Since intensities and Reynolds stresses are easier to obtain and usually provide more mechanistic insight than the skewness, flatness, production, dissipation, and one-dimensional energy spectrum, the latter five quantities have not been widely measured. The intensities u'^{+}, v'^{+}, and, w'^{+} and Reynolds stress $-<uv>^{++}$, and correlation coefficient C_{uv} at $Re_s = 5\times10^{4}$ and 5×10^{5} are presented in Figures 2.3.23 and 2.3.24. To measure turbulence stretchiness and isotropy, an analogy with shear-free polymer flows can be used in which the Reynolds-stress tensor components $-\rho<u_iu_j>$ replace the stress-tensor components τ_{ij}; thus, first and second turbulence normal-stress ratios and kinetic energy can be defined:

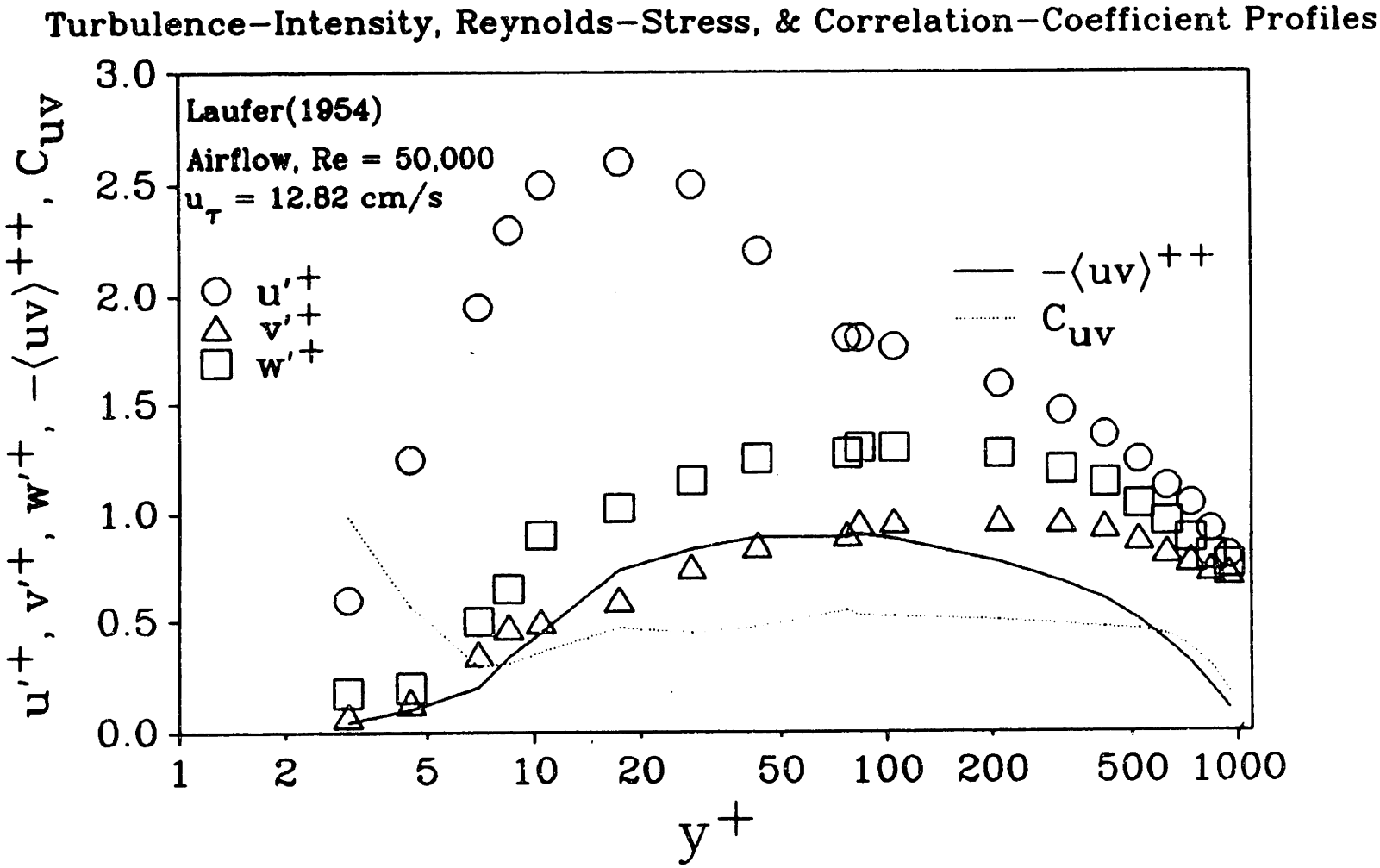


Figure 2.3.23: Newtonian-Turbulence Data at $Re_s = 5\times10^4$ (Laufer, 1954)

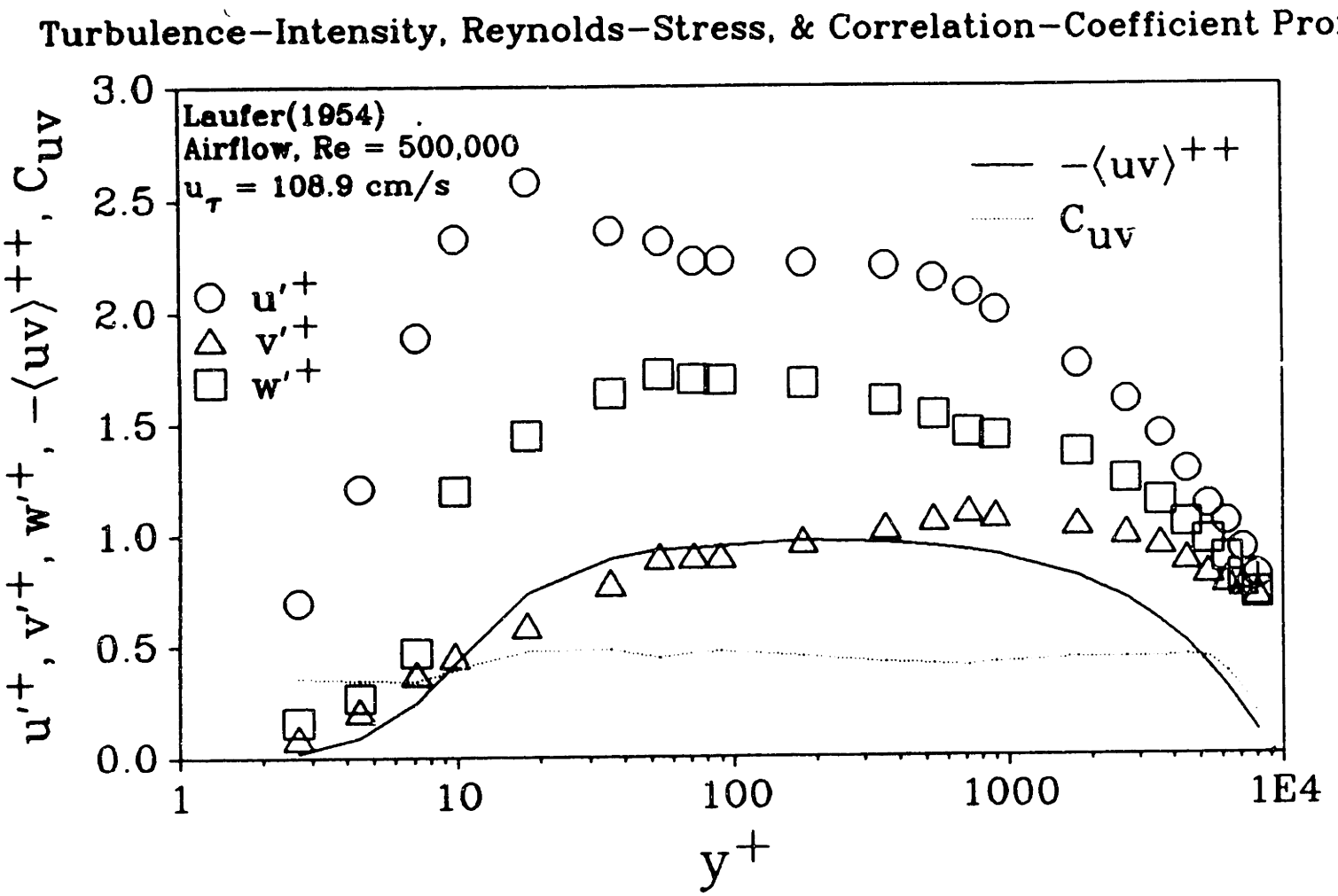


Figure 2.3.24: Newtonian-Turbulence Data at $Re_s = 5\times10^5$ (Laufer, 1954)

$$N_{11} = \frac{<uu> - <vv>}{<uv>} \qquad (2.3\text{-}16)$$

$$N_{22} = \frac{<vv> - <ww>}{<uv>} \qquad (2.3\text{-}17)$$

$$q^{++} = \frac{(u^2 + v^2 + w^2)}{2u_\tau^2} = \tfrac{1}{2}\,(u'^{+})^2 + \tfrac{1}{2}\,(v'^{+})^2 + \tfrac{1}{2}\,(w'^{+})^2 \qquad (2.3\text{-}18)$$

From Laufer's data, N_{11}, N_{22}, and q^{++} can be calculated; their profiles for Re = 5×10^4 and 5×10^5 are shown in Figures 2.3.25 and 2.3.26, respectively. To date, the analogy between fluid rheology and turbulence has not been used to characterize either Newtonian or non-Newtonian turbulence. These data are still the most extensive turbulence measurements for Newtonian turbulence and offer the best estimates for N_{11}, N_{22}, and q^{++} for Newtonian fluids. Differences in N_{11}, N_{22}, and q^{++} between Newtonian and drag-reducing flows may offer insight into the kinematic aspects of turbulence structure during drag reduction.

Virk(1975b) characterized the normalized axial intensity, u'^{+}, profiles for Newtonian and drag-reducing flows as similar. The latter has a greater u'^{+} at every y^{+}. The axial intensity u'^{+}_{max} occurs at y^{+}_{max}, in the buffer-elastic sublayer. Both values are greater than those for Newtonian profiles. Both profiles have an equal initial slope which extend to the coordinates (y^{+}_{max}, u'^{+}_{max}) and then drop off sharply. At the centerline, both u'^{+} are equal. For the radial intensity v'^{+}, the relative trend is reversed with the Newtonian always slightly larger at every y^{+}; the Newtonian v'^{+} profile has a shallow maximum in the log layer. The drag-reducing v'^{+} profile shows no local maximum and just increases from the wall to the core where its value equals that for the Newtonian

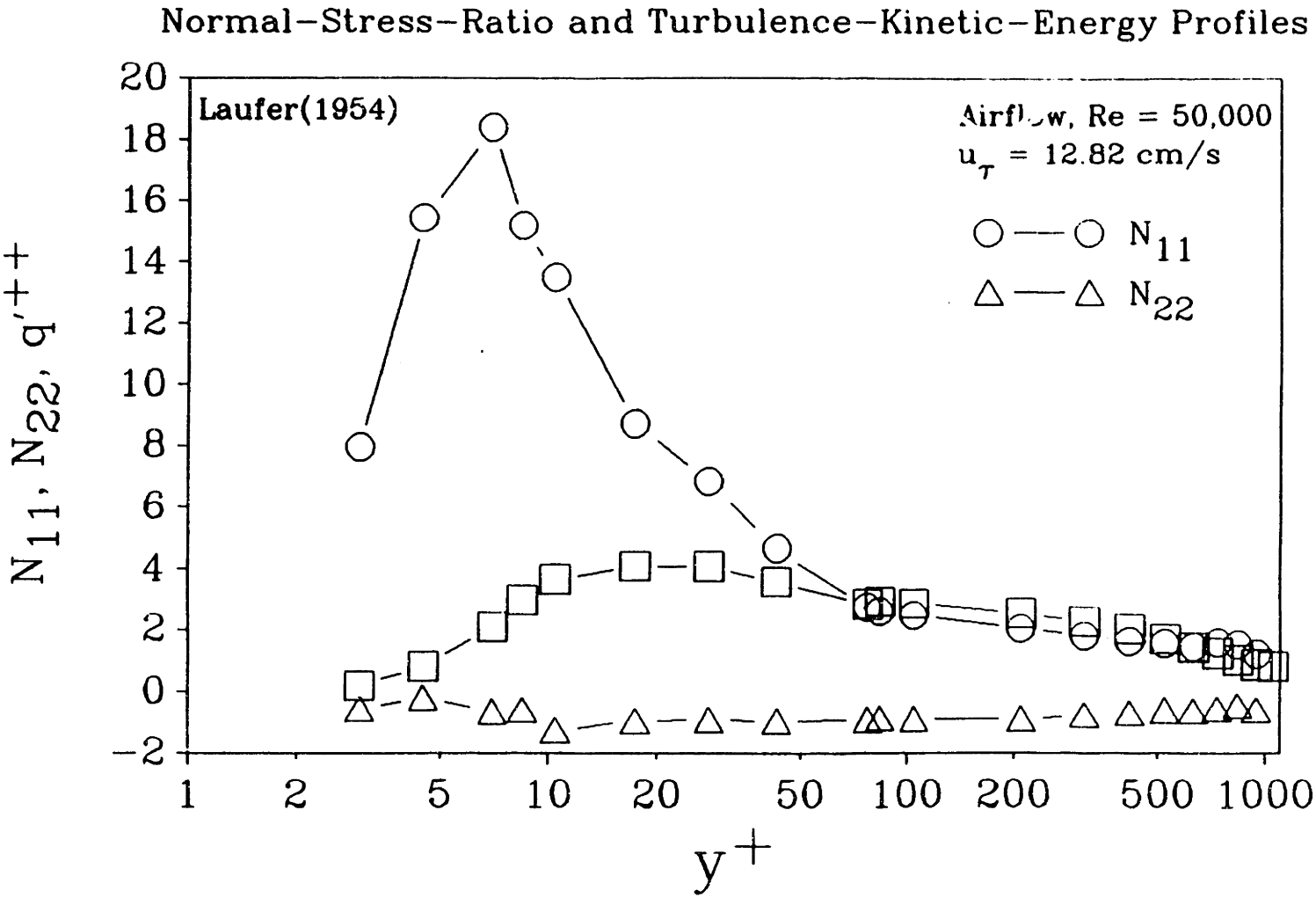


Figure 2.3.25: Turbulent Normal Stresses and Kinetic Energy at $Re_s = 5\times10^4$ (Laufer, 1954)

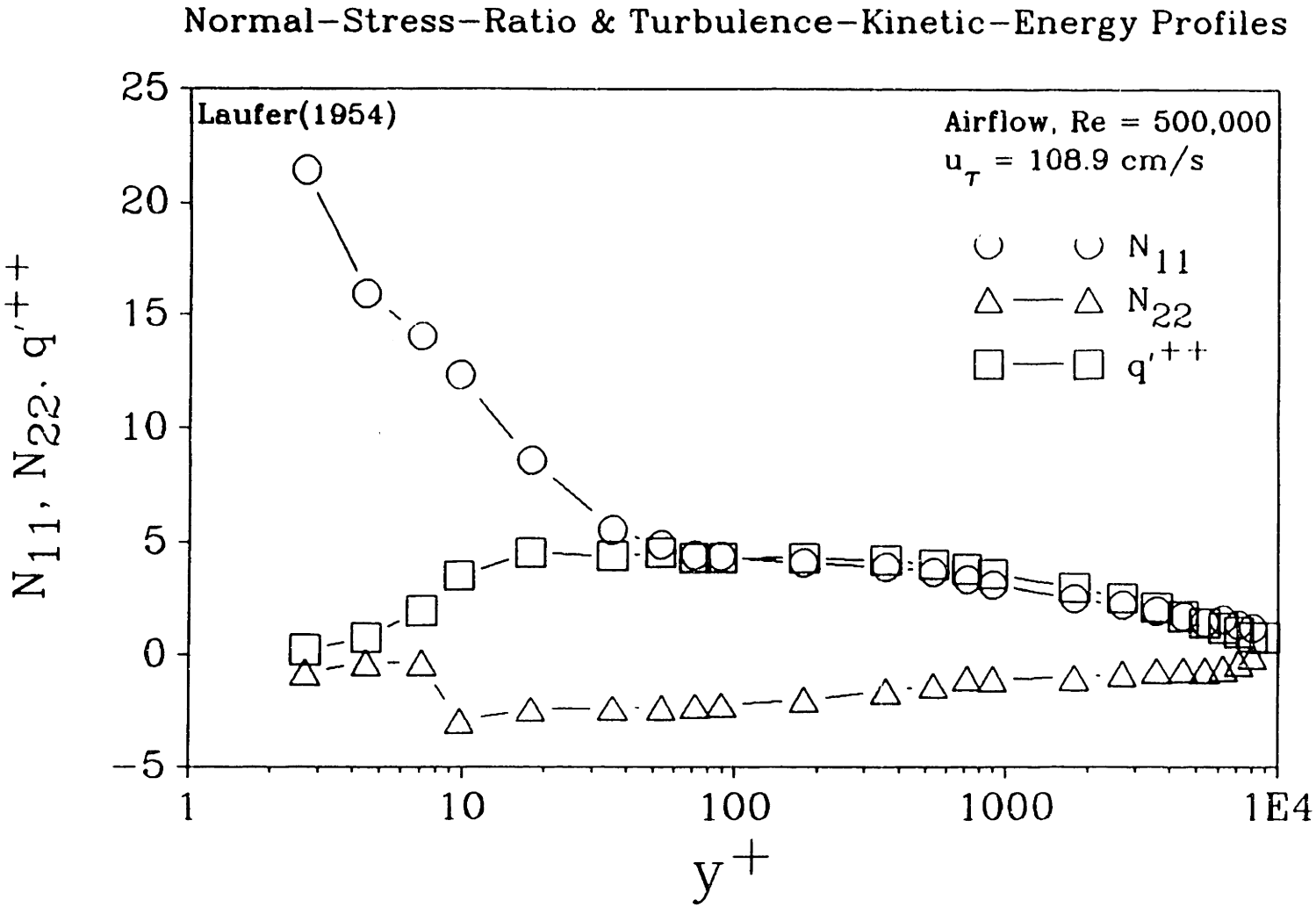


Figure 2.3.26: Turbulent Normal Stresses and Kinetic Energy at $Re_s = 5\times10^5$ (Laufer, 1954)

case. Trends for the Reynolds stress, $-\langle uv\rangle^{++}$, and the correlation coefficient, $C_{uv} = -\langle uv\rangle^{++}/(u'^{+}v'^{+})$, follow those for v'^{+}. The following table summarizes some recent turbulence-intensity measurements during drag reduction.

Table 2.3.3
Sources of Turbulence Intensity I Data

Investigators	Experimental Conditions
McComb & Rabie(1982b)	•CL and wall PEO injection into H_2O pipe flow. •u'^{+}, $-\langle uv\rangle^{++}$ vs. y^{+} at single C_p and $\langle C\rangle$.
Bartels et al.(1984)	•homogeneous HPAM solution in pipes of ID = 16 mm and 44 mm. •u'^{+}, v'^{+}, w'^{+}, $-\langle uv\rangle^{++}$ vs. y/R at several c.(Note: u'^{+}, v'^{+}, and w'^{+} were not obtained simultaneously, and $-\langle uv\rangle^{++}$ was inferred from $\overline{U}^{+}$ vs. y^{+} and the N-S equations.)
Bewersdorff(1984)	•CL HPAM injection in H_2O pipe flow at several Re and $\langle C\rangle$. •u'^{+}, v'^{+}, $-\langle uv\rangle^{++}$ vs. y/R.
McComb & Chan(1985)	•homogeneous fiber and fiber/HPAM solutions in pipe flow. •u'^{+} and w' vs. y/R at several Re and c.

McComb & Rabie(1982b) performed drag reduction experiments by injecting a PEO solution into the centerline and near-wall region of fully developed turbulent pipe flow. Figure 2.3.27 shows their measurements of u'^{+} for CL injection with $C_p = 0.1\%$, which yielded $\langle C\rangle = 5$ wppm. The graphs show that u'^{+} generally increases, the location of u'^{+}_{max} moves away from the wall, as drag-reduction increases. The region of the profile where u'^{+} exceeds solvent can be associated with the elastic sublayer.

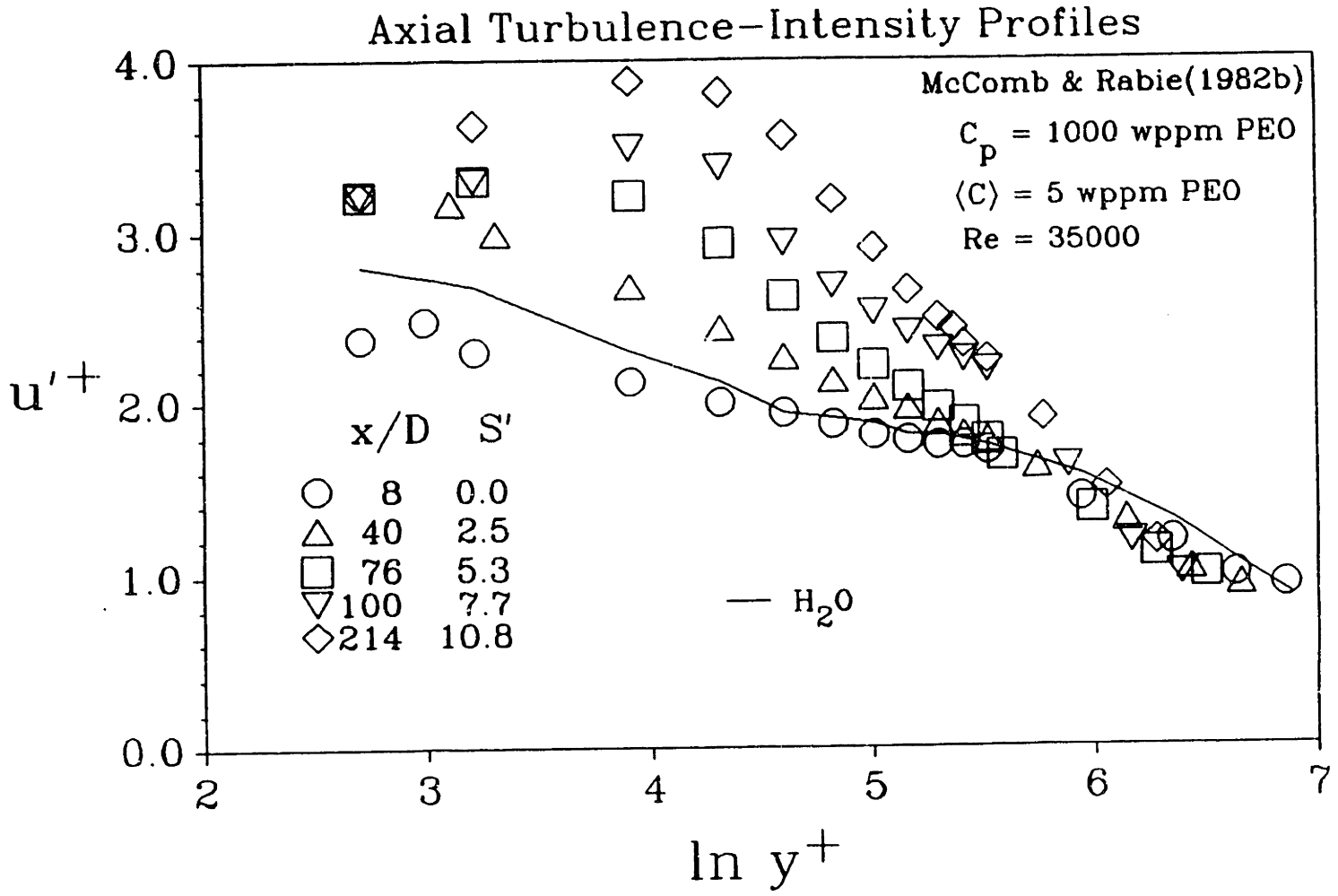


Figure 2.3.27: Axial Turbulence-Intensity Profiles(McComb & Rabie, 1982b)

Bartels et al.(1984) examined the intensity structure of HPAM-solution flows in 16.44- and 44-mm pipes. In the smaller pipe, u'^+, v'^+, and w'^+ were measured; however, all three were not thoroughly measured for all concentrations. Figures 2.3.28, 2.3.29, and 2.3.30 show data for u'^+ & v'^+, $-<uv>^{++}$ & C_{uv}, and N_{11} & N_{22}, respectively, from flows with c = 0, 200, and 300 wppm in a 16.44-mm pipe. Unfortunately, u'^+, v'^+, and w'^+ were not measured in the same flow for a given concentration, rather they were taken at nearly the same S'(%DR) at a given concentration. Thus, the conclusions drawn from these data may not be exactly correct and must be considered tentative since the intensities seem sensitive to S'. In Figure 2.3.28, the concentration dependence for u'^+ and v'^+ are $u'^+(200) \approx u'^+(300) > u'^+(0)$ and $v'^+(200) \approx v'^+(300) < v'^+(0)$. Near the wall, u'^+ levels were raised, and v'^+ levels were lowered relative to solvent. In the core, the u'^+ level for polymer-solution flows was ~ 0.81, slightly larger than Laufer's(1954) value of 0.76, while the v'^+ core value was ~ 0.63, less than the 0.72 from Laufer(1954). The profiles for $-<uv>^{++}$ and C_{uv}, displayed in Figure 2.3.29, confirm Virk's observation(1975b) that these trends should follow that of v'^+; however, the C_{uv} values are elevated relative to earlier results. This may arise because the u'^+ and v'^+ were not determined under identical conditions and because $-<uv>++$ was derived from mean velocity profiles. The first and second normal-stress ratios, N_{11} and N_{22}, are given in Figure 2.3.30. Their patterns should follow those of u'^+ and v'^+, respectively. The N_{11} and N_{22} values observed in solvent are below those of Laufer(1954), but both quantities increase dramatically during drag reduction. Figures 2.3.31 and 2.3.32 show u'^+ and v'^+ profiles in the 44-mm pipe(Bartels et al., 1984); they monotonically increased and decreased, respectively, with

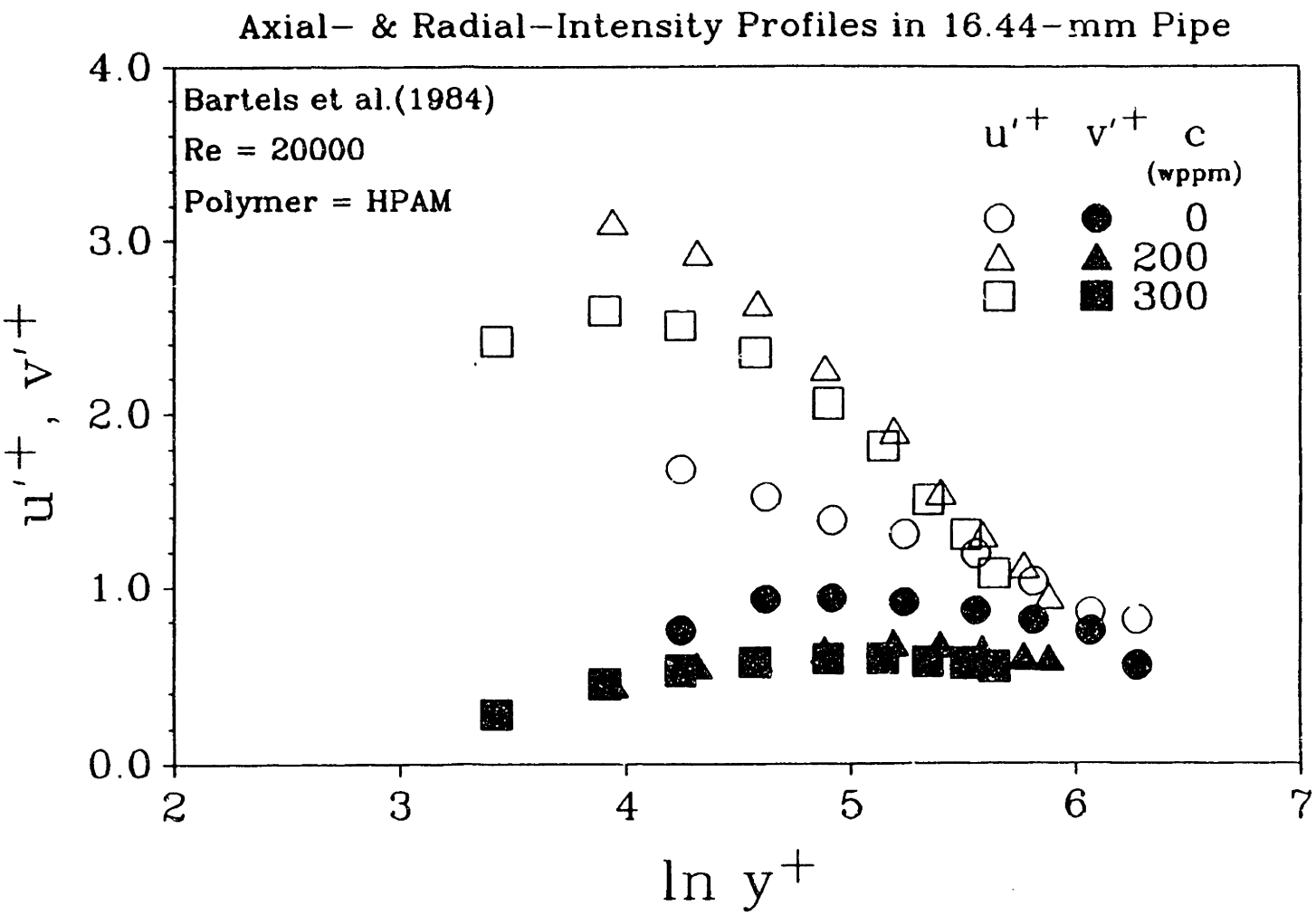


Figure 2.3.28: Axial- and Radial-Intensity Profiles in 16-mm Pipe(Bartels et al., 1984)

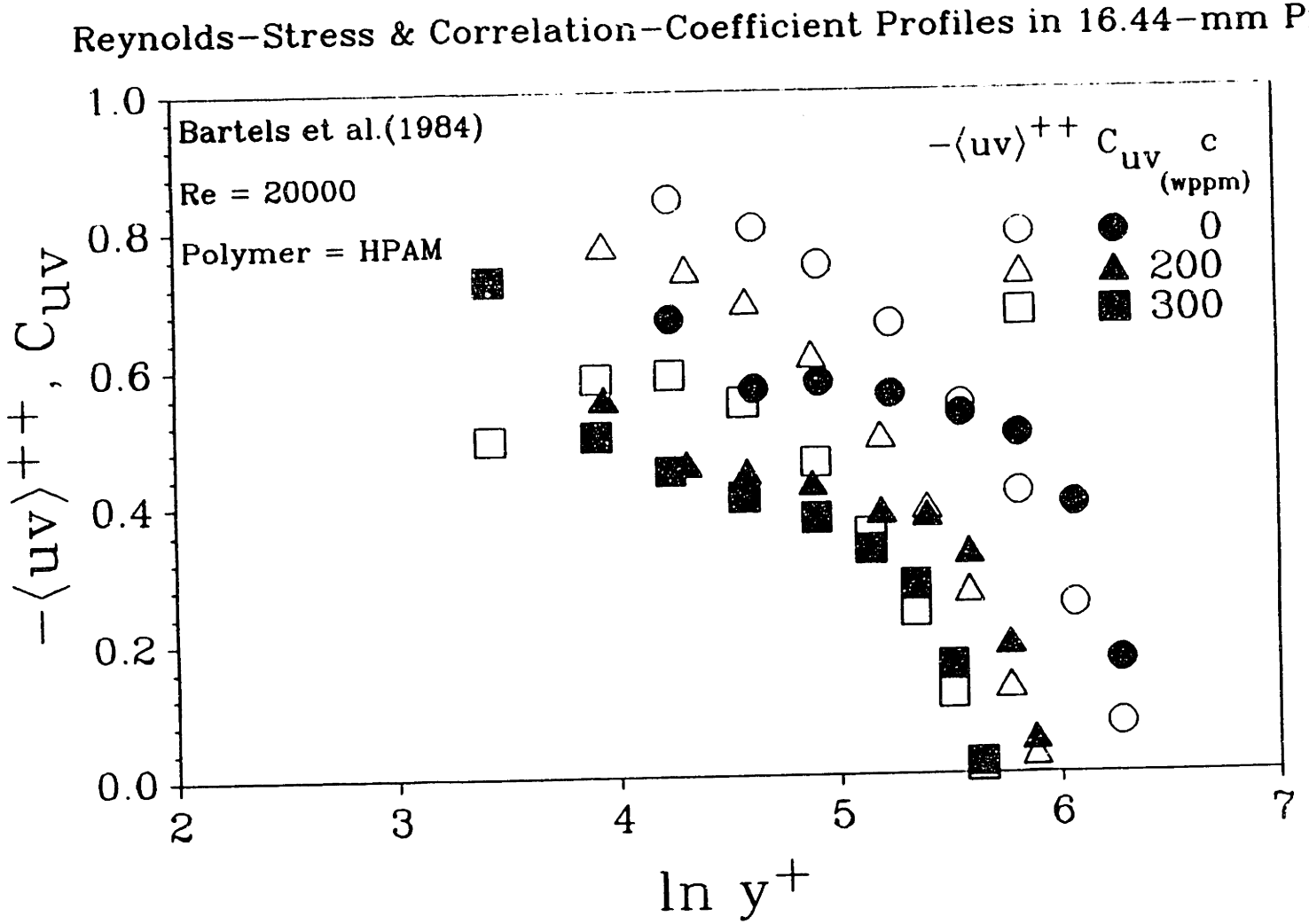


Figure 2.3.29: Reynolds-Stress Profile in 16-mm Pipe(Bartels et al., 1984)

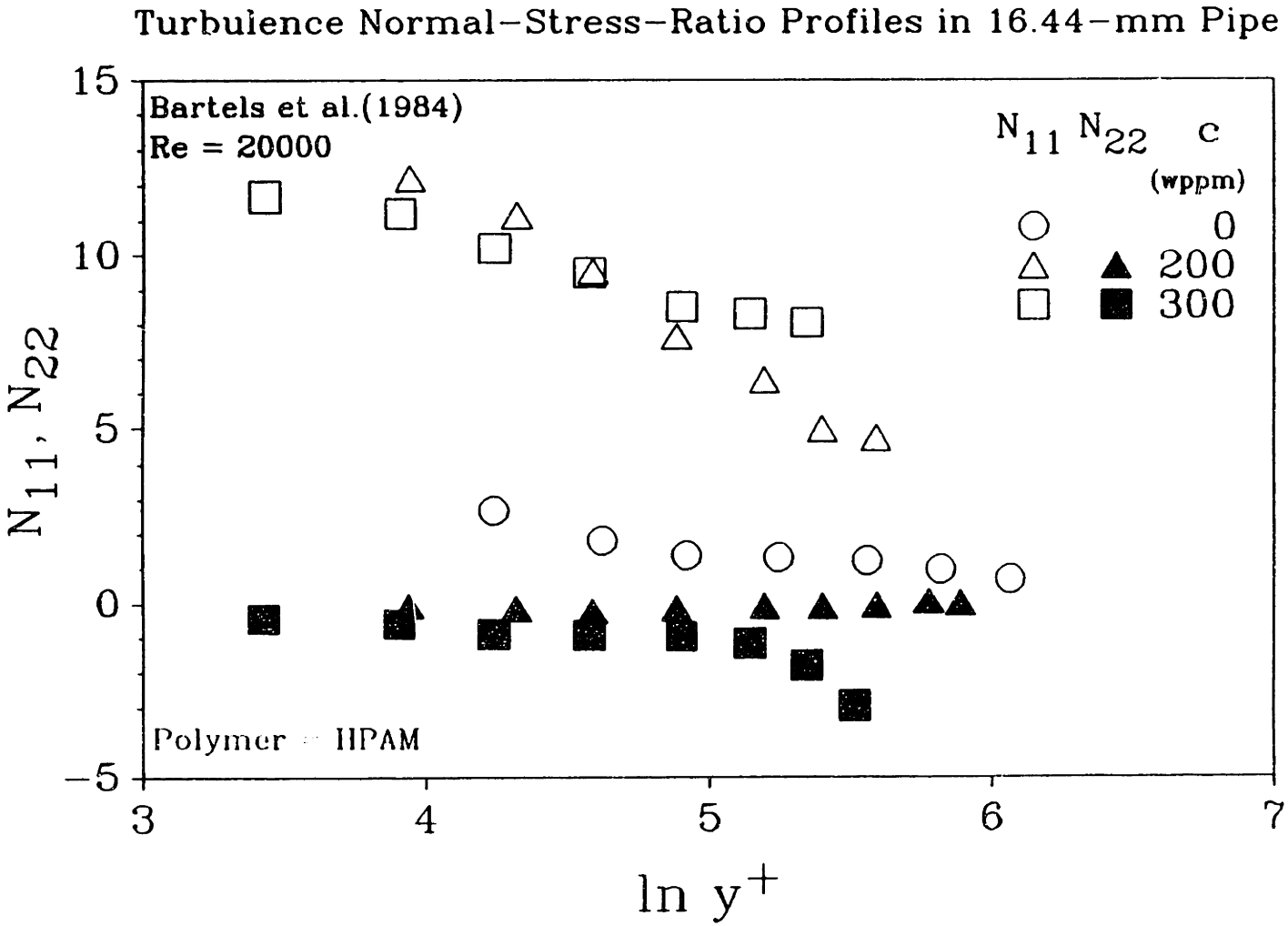


Figure 2.3.30: Turbulence Normal-Stress Ratios in 16-mm Pipe (Bartels et al., 1984)

increasing S'. The u'^{+}_{max} and v'^{+}_{max} values also displayed the same trends, with their loci moving coreward as S' increased. However, these maximum-intensity loci never extended much beyond $y^{+} = 30$, and did not move with elastic-sublayer thickening, as seen in the corresponding mean profiles. In this respect, the present data differ from those of McComb & Rabie(1982b). However, the u'^{+}_{max} values as a function of S' coincide with those from Laufer(1954)(solvent) and McComb & Rabie(1982b)(polymer solution). The data for Newtonian and homogeneous-polymer solutions(open symbols) are compared in Figure 2.3.33; the best-fit line has an intercept and slope of ~ 2.74 and ~ 0.113, respectively. A similar plot of v'^{+}_{max} vs. S' appears in Figure 2.3.34, and v'^{+}_{max} decreases linearly with S' with an intercept and slope of ~ 0.99 and ~ -0.041, respectively. Coincidentally, the ratios of the respective u'^{+}_{max} and v'^{+}_{max} intercepts, $2.74/0.99 = 2.75$, has the same magnitude as the ratio of the respective slopes, $0.11/-0.041 = -2.76$. This suggests powerful similarities in the scaling of axial and radial turbulence intensities, regardless of the level of drag reduction. A new picture of the elastic layer emerges from the u'^{+} and v'^{+} profiles. The y^{+} range bounded by the loci of u'^{+}_{max} and v'^{+}_{max} defines the most-active portion of the elastic layer. Based on this observation, an alternative definition for the elastic layer might be the region bounded by the y^{+} where the wallward maximum in u+' occurs to the y^{+} where the peak in v'^{+} occurs. Some of the v'^{+} profiles show that v'^{+}_{max} occurs at the centerline; that is, the elastic layer has penetrated to the core, implying that M has been reached. Figures 2.3.35 and 2.3.36 respectively show profiles of $-\langle uv \rangle^{++}$ and C_{uv} vs. ln y^{+}. Both quantities have been derived from mean-flow and turbulence-intensity data of Bartels et al.(1984). It can be seen that the profiles of $-\langle uv \rangle^{++}$, and especially C_{uv}, during drag

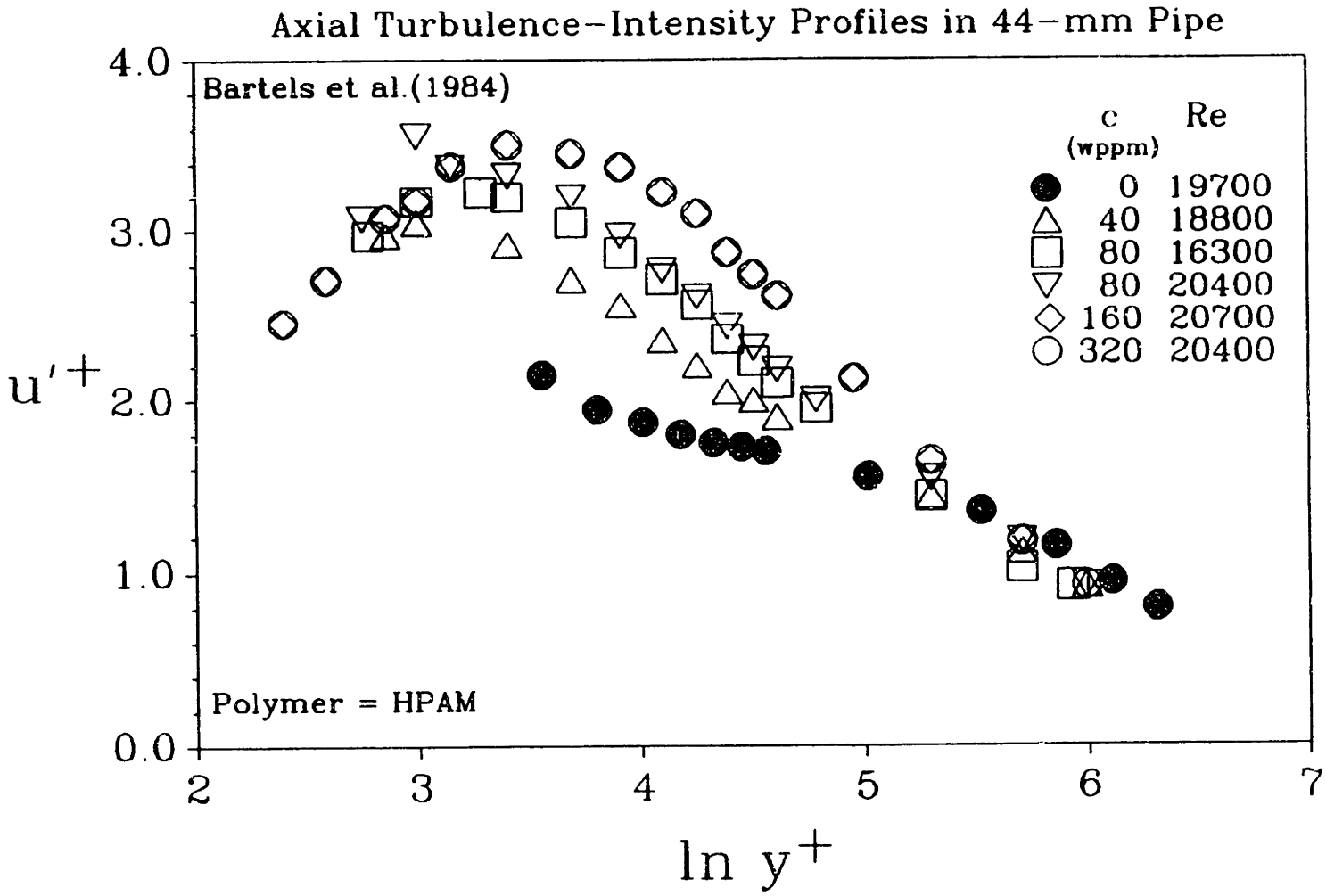


Figure 2.3.31: Axial Turbulence-Intensity Profiles in 44-mm Pipe(Bartels et al., 1984)

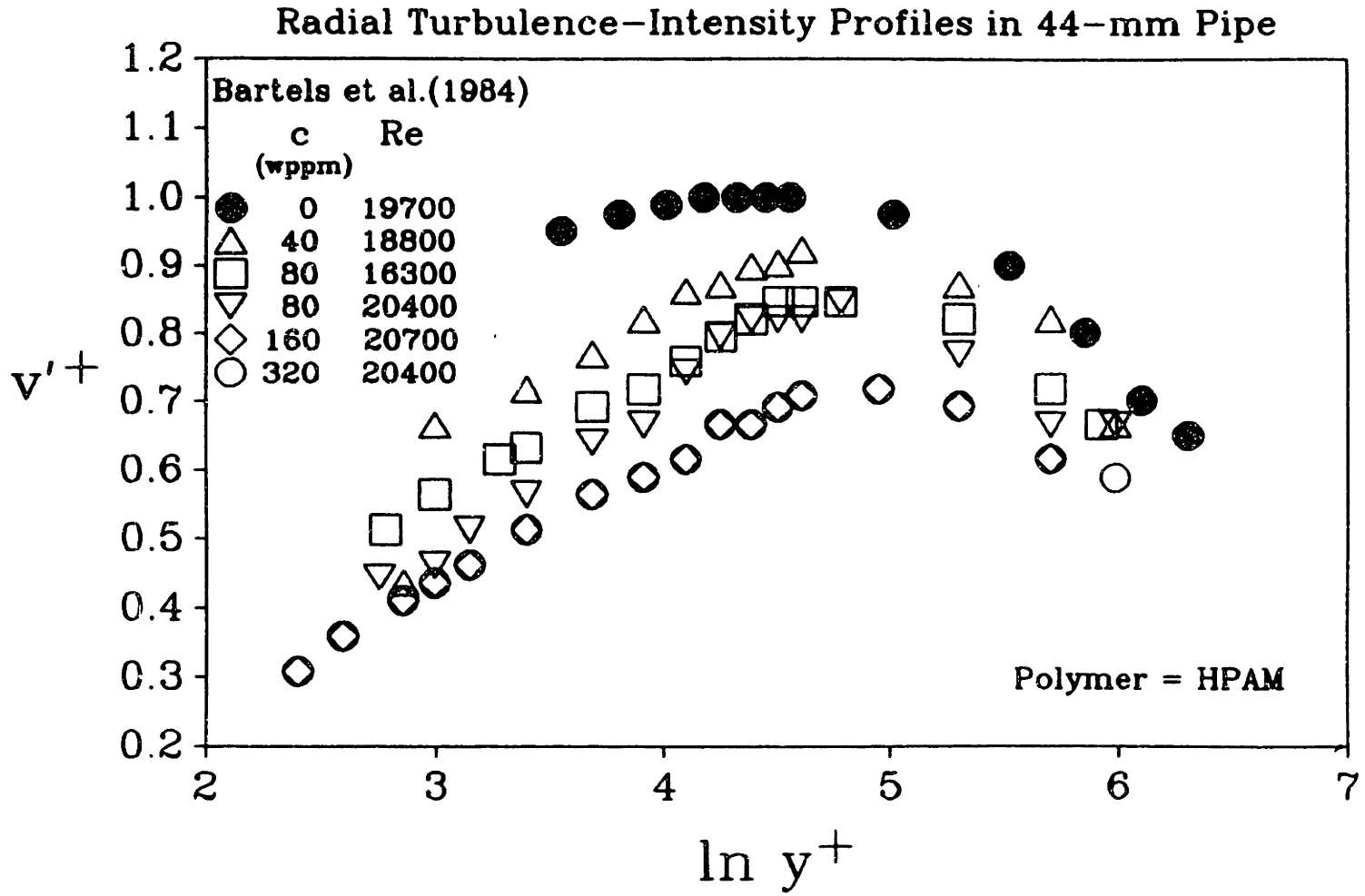


Figure 2.3.32: Radial Turbulence-Intensity Profiles in 44-mm Pipe(Bartels et al., 1984)

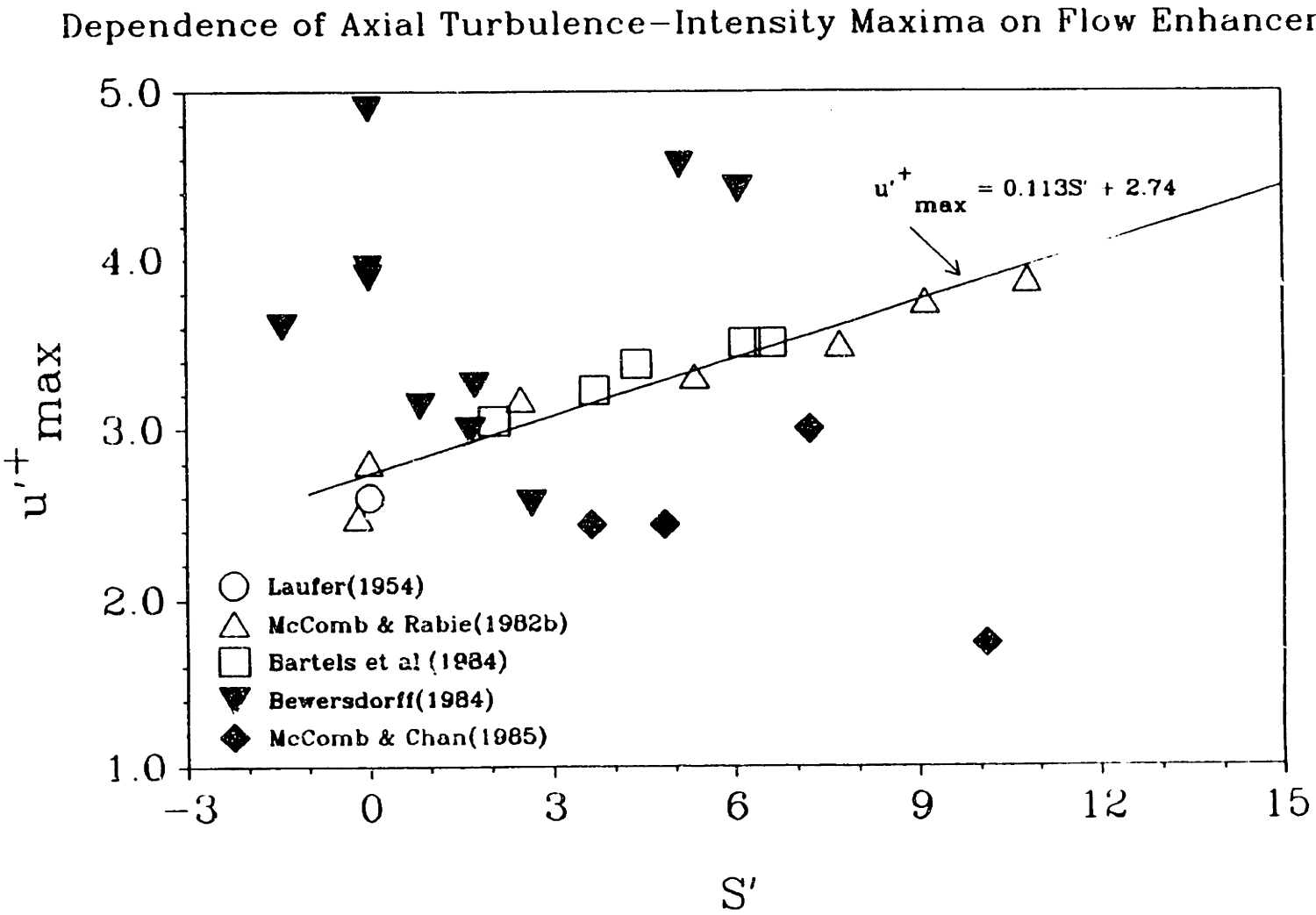


Figure 2.3.33: Axial Turbulence-Intensity Maxima from Various Studies

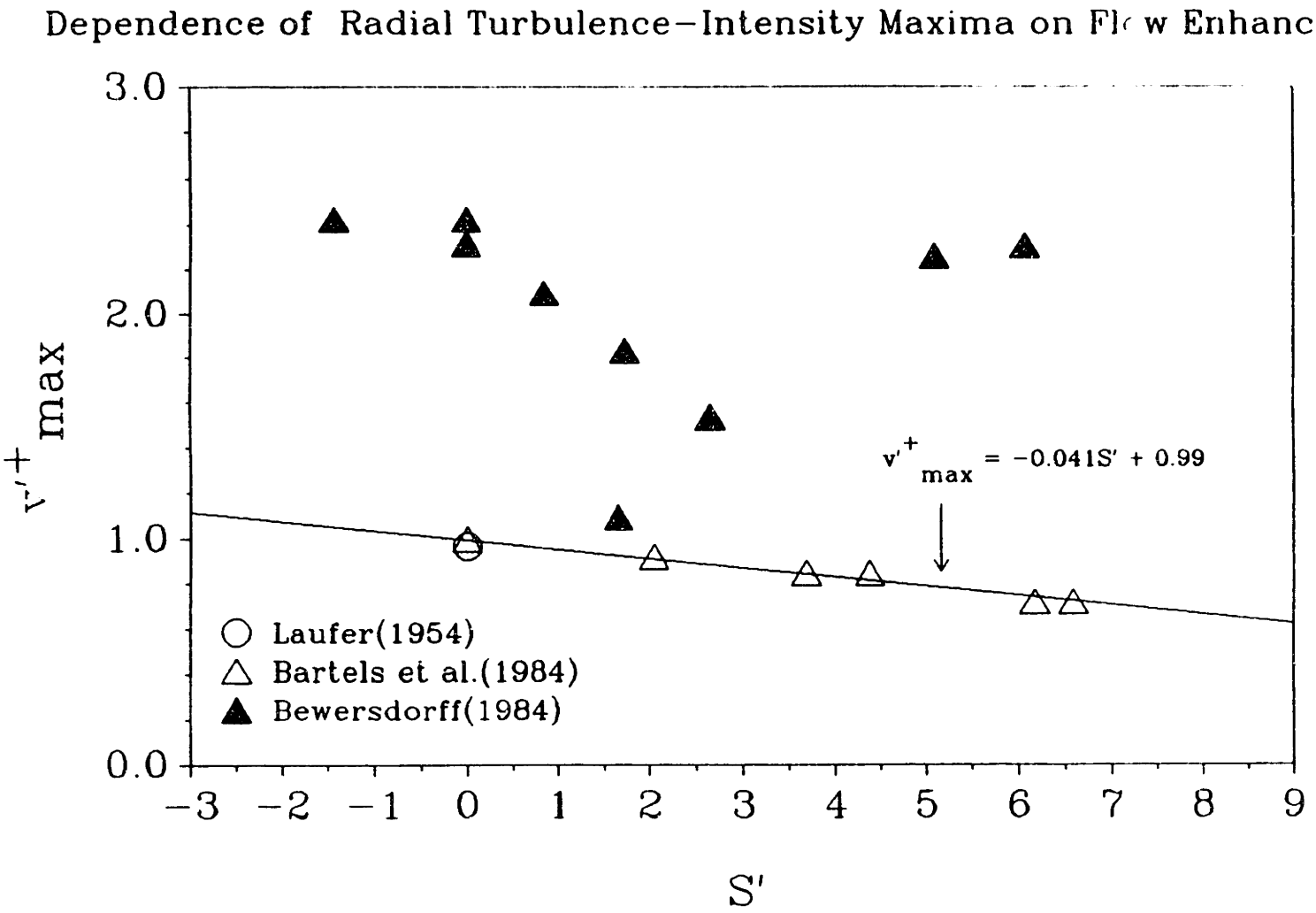


Figure 2.3.34: Radial Turbulence-Intensity Maxima from Various Studies

reduction are lower than Newtonian profiles. Also, the maxima of both $-<uv>^{++}$ and C_{uv} appear to lie in the elastic sublayer region defined by the axial and radial turbulence-intensity maxima. In these examples of both Newtonian and homogeneous polymer-solution flows, the total stress T_w near and at the core was equal to $-\rho<uv>^{++}$ and governed by the dimensionless equation derivable from Navier-Stokes:

$$-<uv>^{++} = 1 - \frac{y^+}{R^+} - \frac{d\overline{U}^+}{dy^+} \qquad (2.3\text{-}19)$$

More recently, Willmarth et al.(1987), Bewersdorff & Berman(1988) and Usui et al.(1988) observed a "stress deficit" in polymer-thread-injection experiments. The first group noted that $-<uv>^{++}$ calculated via equation 2.3-19 was about 1.5 times the measured value across the pipe diameter. Attributing the deficit to a varying local viscosity, the second group introduced an "elastic modulus" term G into equation 2.3-19 and then lumped G into an effective viscosity to get a new governing equation:

$$-<uv>^{++} = 1 - \frac{y^+}{R^+} - \frac{d\overline{U}^+}{dy^+} - G = 1 - \frac{y^+}{R^+} - \frac{\nu_{eff}}{\nu_s}\left[\frac{d\overline{U}^+}{dy^+}\right] \qquad (2.3\text{-}20)$$

Via this equation "bifurcated" mean-velocity profiles were shifted onto M; thus, what the effective-viscosity function must have been was inferred. Despite this rheological manipulation, it was concluded that the drag-reduction mechanism does not depend on rheology. The third group hypothesized that a third, viscoelastic momentum-transfer mechanism might exist in polymer-injection experiments.

Bewersdorff(1984) took extensive $\overline{U}^+$, u'^+, and v'^+ data for centerline injection of HPAM solutions into turbulent pipe flows of water. These u'^+ and v'^+ data are

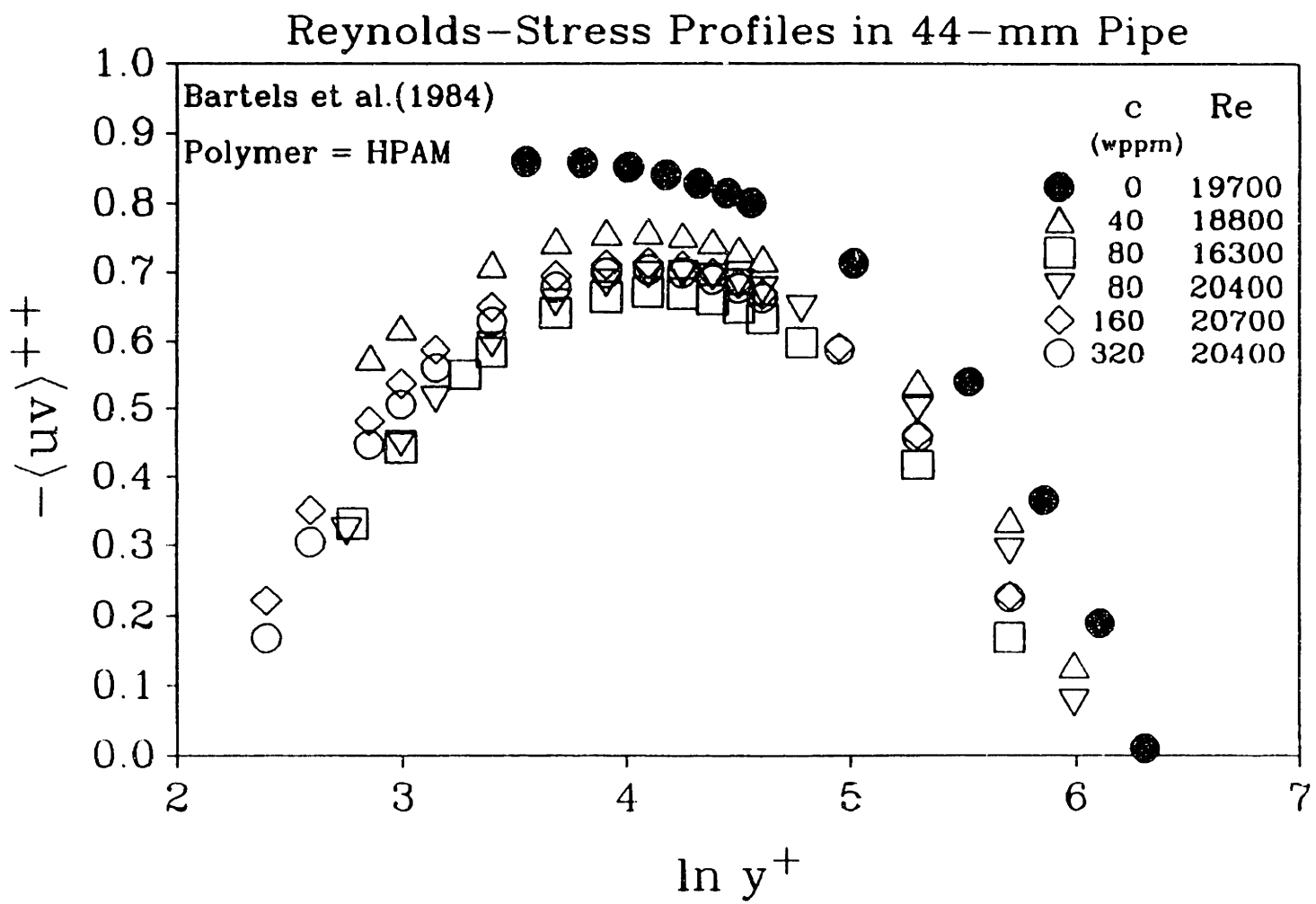


Figure 2.3.35: Reynolds-Stress Profiles in 44-mm Pipe(Bartels et al., 1984)

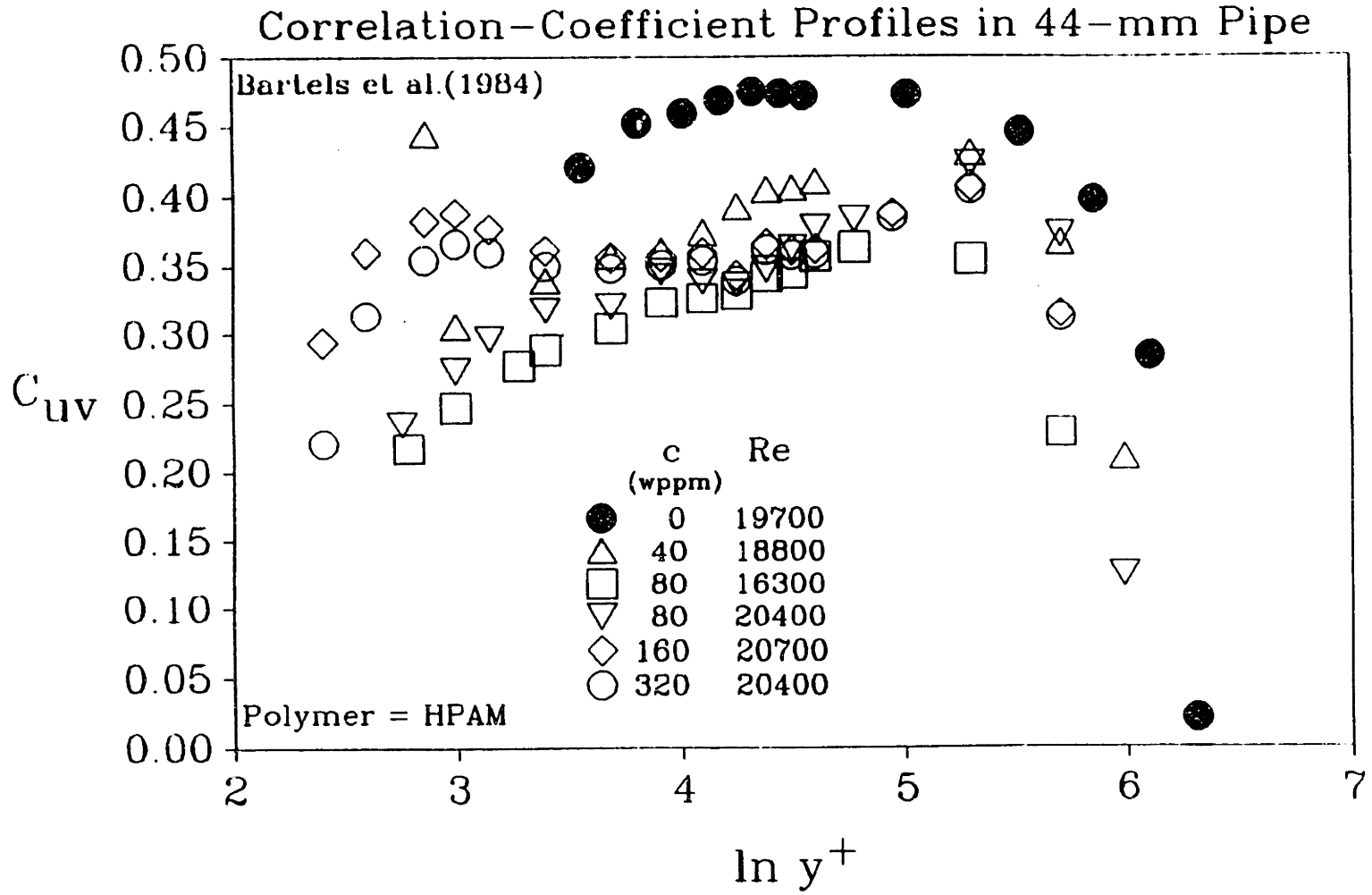


Figure 2.3.36: Correlation-Coefficient Profiles in 44-mm Pipe(Bartels et al., 1984)

anomalous when compared with the data of other investigators, as shown respectively in Figures 2.3.37 and 2.3.38, which compare some of his intensity data with those of others at similar conditions. In both figures, the data from Laufer(1954), Bartels et al.(1984), and McComb & Rabie(1982b) have a great degree of similarity over a range of R^+ while Bewersdorff's data differ markedly. An essential experimental difference between Bewersdorff and the others lies in that the injected polymer formed a large thread which remained intact down the centerline under flow conditions, possibly forming another phase in the flow that affected the LDA measurements of the turbulence intensities.

McComb & Chan(1985) investigated flows of asbestos-fiber suspensions at various Re and measured u'^+(and a few w'). At Re = 32000, the u'^+ trends for 300-wppm fiber-suspension flows coincided with those reported by others. Figure 2.3.39 shows how the u'^+ profile changed with the number of passes. In the first pass, unusual "fiber-like" behavior was observed, as indicated by a suppressed u'^+ profile.

In summary, profiles of u'^+, v'^+, $-<uv>^{++}$, and C_{uv} have provided a wealth of information about the inner structure of both Newtonian and non-Newtonian turbulent flow. Turbulence normal-stress ratios N_{11} and N_{22} derived from intensity measurements also offer valuable insights into drag reduction. Intensity maxima correlate well with S' at low drag reduction. Better measurement of u'^+ and v'^+, especially at MDR, are necessary to characterize and to understand how flow-enhancing additives alter flow structure.

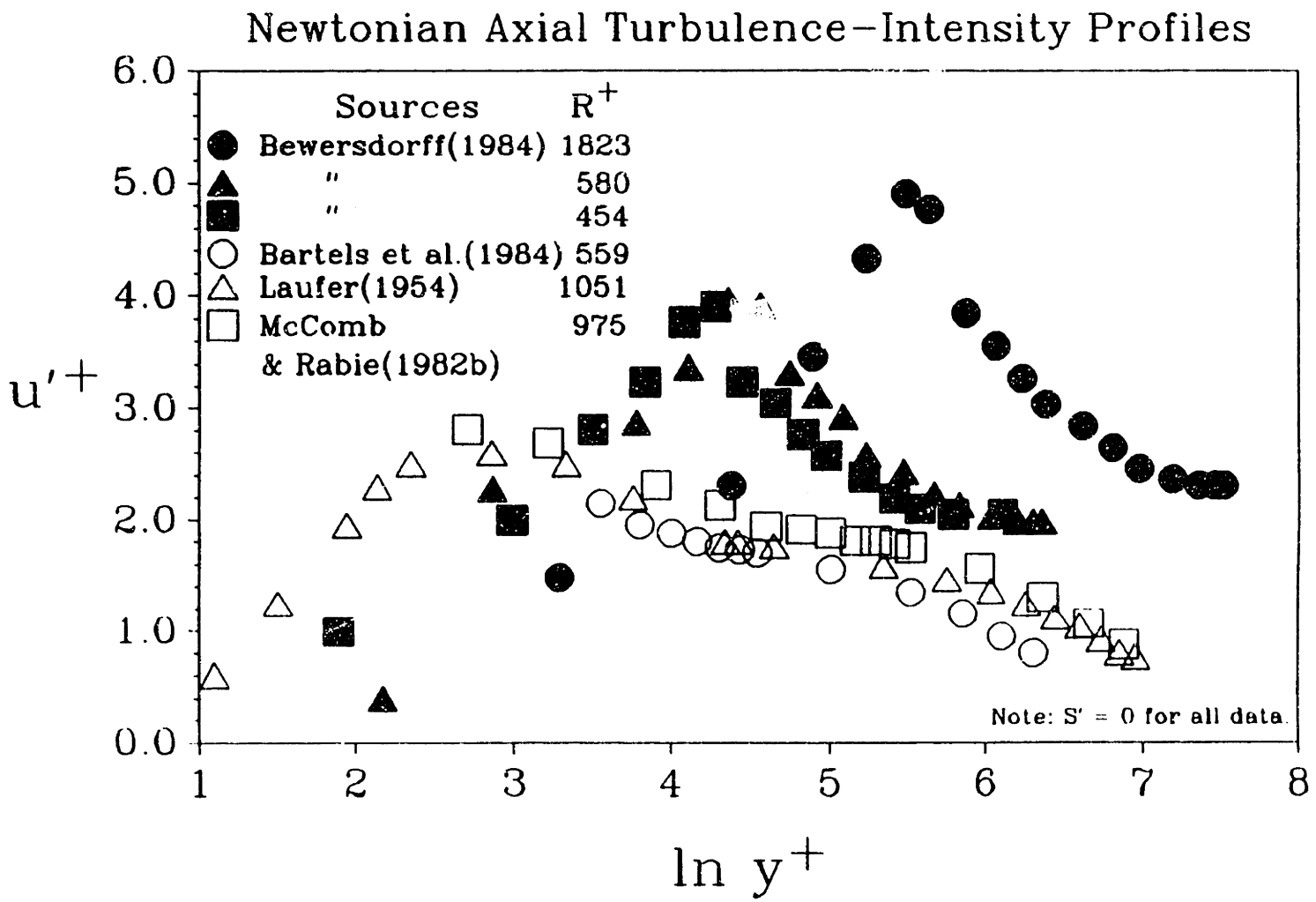


Figure 2.3.37: Axial Turbulence-Intensity Profiles from Various Sources

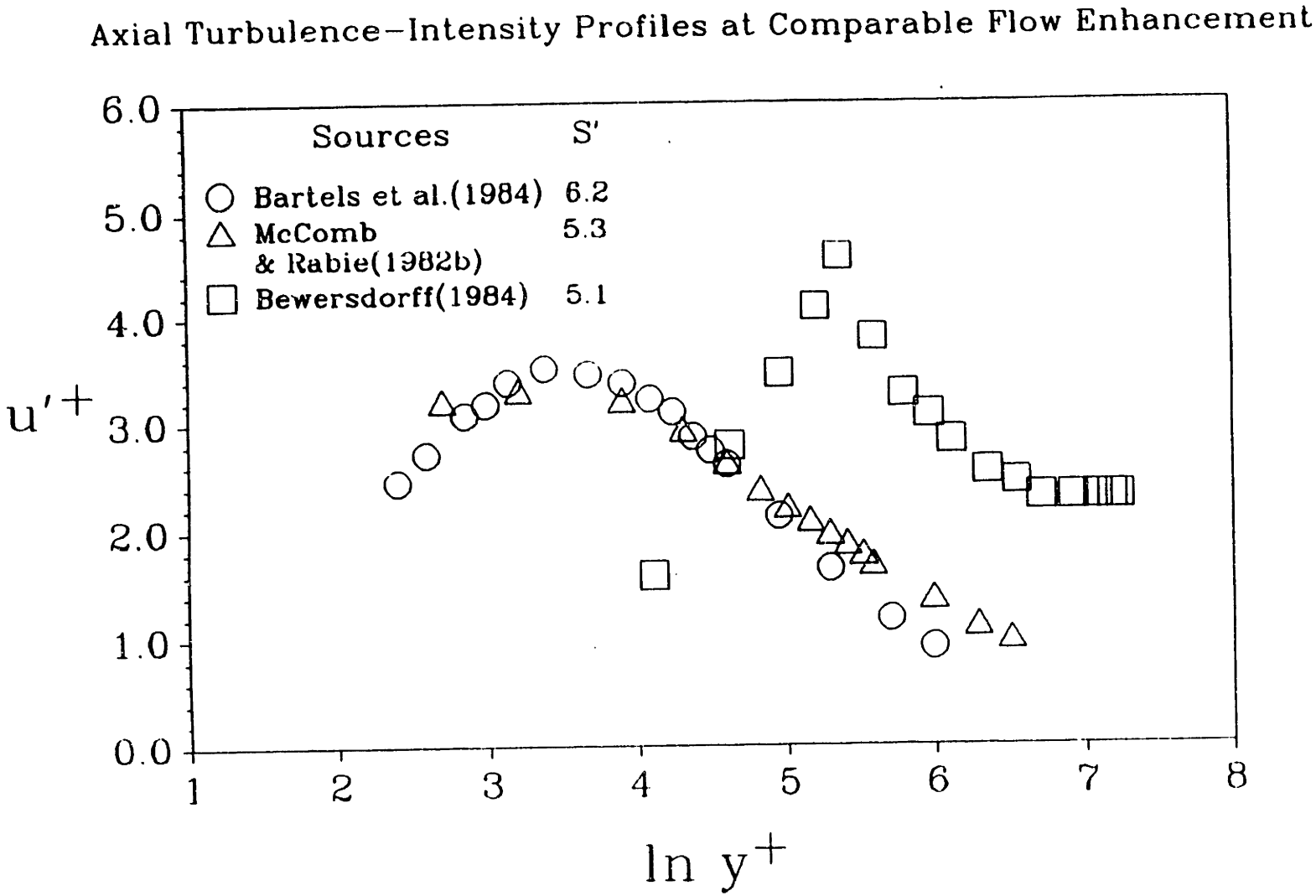


Figure 2.3.38: Axial Turbulence-Intensity Profiles from Various Sources

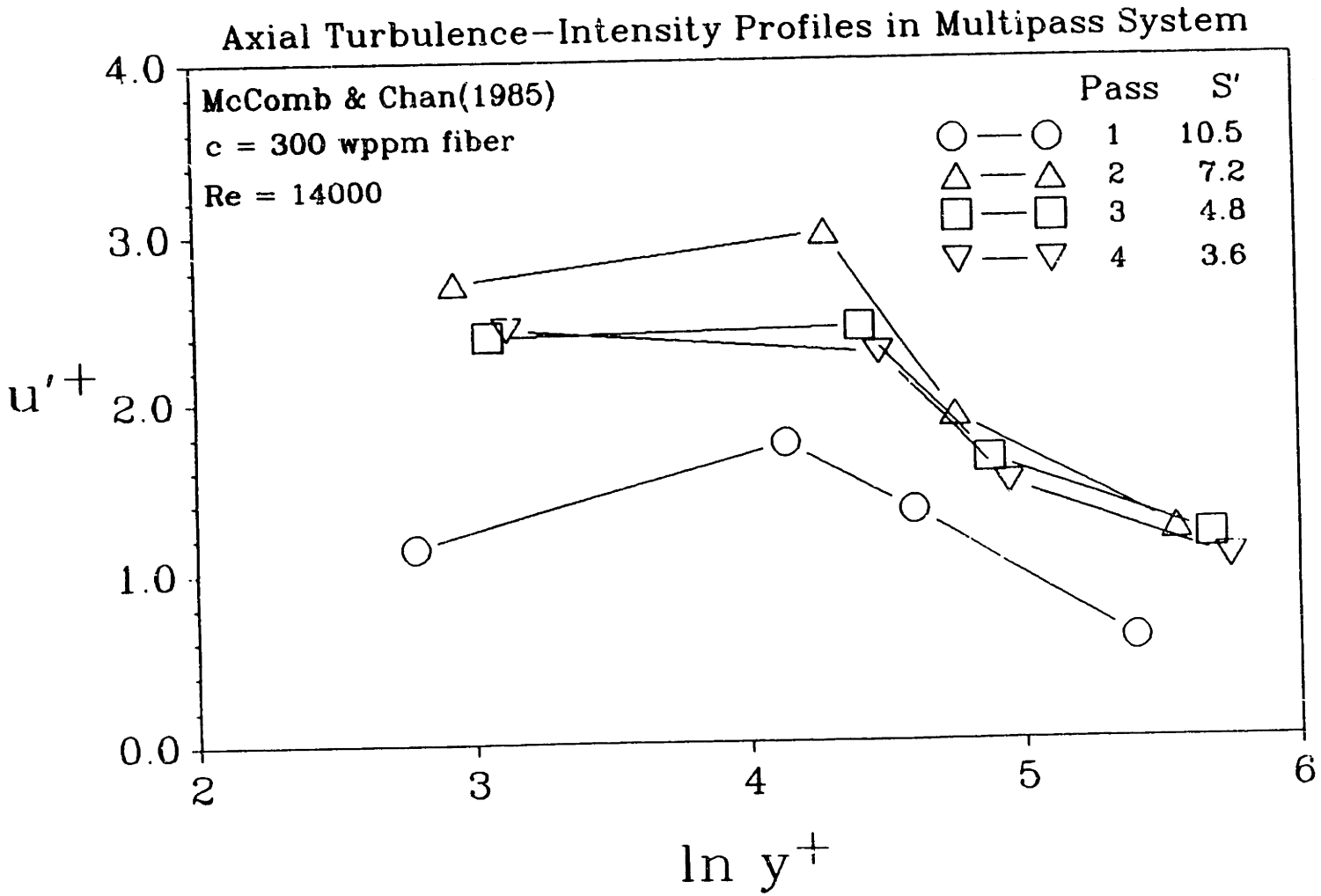


Figure 2.3.39: Axial Turbulence-Intensity Profiles from a Fiber Solution(McComb & Chan, 1985)

2.3.4 Turbulence Structure II: Bursting and Spanwise Spacing

Either time- or ensemble-averaged velocity(or pressure) fluctuations provide information about the structure of turbulent flow. Characteristic lengths and times can be inferred from spatial and temporal auto-correlations. Among the first researchers to record and to calculate these scales were Kline et al.(1967). Visual dye-tracer and hydrogen-bubble experiments on turbulent water (Newtonian)flows yielded average azimuthal spacings, bursting times, and streak lifetimes under various flow conditions. It was shown the low-speed(low-momentum) streaks begin to oscillate at $8 < y^+ < 12$, to amplify as they moved coreward, and then to break-up at $y^+ < 30$. This break-up and ejection process was considered a major mode of energy transfer from the boundary region to the outer flow.

Virk(1975b) collected data from various authors on azimuthal spacings, z^+, and the time between bursts, T_{bb+}. Azimuthal spacings in drag-reducing flows, when normalized by the Newtonian $z_{n+} \approx 100$, depended exponentially on the apparent slip S':

$$\ln\left[\frac{z_p^+}{z_n^+}\right] = 0.156S' \qquad (2.3\text{-}21)$$

where p and n denote polymer and Newtonian, respectively. Because spatial turbulence structure depended on S', temporal turbulence structure, characterized by T_{bb+}, was likely to follow similar trends, but not enough data were available then.

Investigators have since measured z^+ and T_{bb}^+ for both Newtonian and non-

Newtonian flows. Determining z^+ has depended mostly on subjective examinations of video recordings of tracer experiments; thus, there have been discrepancies among researchers who use different criteria in their analyses. On the other hand, $T_{bb}{}^+$ may be derived more objectively from auto-correlations; however, even here some subjectivity results from cut-off criteria and threshhold levels. Also, measuring $T_{bb}{}^+$ from video recordings by combining streak frequency per unit width, F^+, and z^+ has been attempted but seems prone to even greater uncertainty. The following table lists the major contributions to z^+ and $T_{bb}{}^+$ information.

Table 2.3.4
Sources of Turbulence Structure II Data

Investigators	Experimental Conditions
Donohue et al.(1972)	•streak dying, H_2 bubble tracing. •z^+ and F^+ from streak pictures. •$T_{bb+} = (z^+F_+)^{-1}$. •Re < 22800. •PEO-FRA •2D channel, D_h = 74.4 mm.
Eckelman et al.(1972)	•mass transfer probes to detect S_x and S_z. •z^+ derived from $<S_x>$, S_x wavelength, and viscosity. •pipe ID = 25 mm.
Achia & Thompson(1977)	•interferometric methods. •z^+ and F^+ from $R_c(z)$. •$R_c(z)$ from video frames. •$T_{bb}{}^+ = (z^+F_+)^{-1}$. •Re < 11000. •HPAM(Separan AP30). •pipe with flat wall, ID = 26.3 mm.

Investigators	Experimental Conditions
Mizushina & Usui(1977)	●Laser-Doppler Anemometry(LDA). ●T_{bb}^+ from rerises in $R_c(t)$. ●Re < 40000. ●PEO(Alcox E-160). ●Tbb assumed constant for $10 < y^+ < 100$. ●pipe ID = 25.3 mm.
Oldaker & Tiederman(1977)	●streak dying. ●z^+ from streak pictures. ●stringent z^+ criteria: 3σ test & valid $z^+ \geq x^+/4$ with no minimum. ●z^+ assumed constant for $y^+ < 8$. ●Re < 50000. ●HPAM(Separan AP273). ●2D channel, D_h = 71.7 mm.
McComb & Rabie(1982b)	●LDA. ●T_{bb}^+ from $R_c(t)$. ●Re = 35000. ●PEO(WSR-301). ●pipe ID = 26 mm.
Usui et al.(1984)	●LDA. ●T_{bb}^+ from short-sampled $R_c(t)$. ●Re < 10000. ●PEO(WSR-301). ●pipe ID = 25.4 mm.
Tiederman et al.(1985)	●streak dying. ●z^+ from streak pictures. ●stringent z^+ criteria: 3σ test & valid $z^+ \geq x^+/4$ with no minimum. ●Re < 23000. ●HPAM(Separan AP273). ●2D channel, D_h = 45.45 mm.

Of these authors only Eckelman et al.(1972), Oldaker & Tiederman(1977), Achia & Thompson(1977), Donohue et al.(1982), and Tiederman et al.(1985) measured z^+ for both Newtonian and drag-reducing flows. All authors agree that $z_n^+ = 100 \pm 20$. Such consistency arises from the universal structure of Newtonian turbulent flow. Recently,

Lyons et al.(1988) calculated via a model relating z^+ to a mechanical-energy balance that turbulence production and dissipation are balanced when $z^+ \approx 93$ and that this balance was sensitive to relatively small perturbations about $z^+ \approx 100$.

Because viscous- and elastic-sublayer thickening are associated with drag reduction, changes in z^+ are not a priori predictable. Equation 2.3-21 implies that the real physical extent, z, increases since S' measures the differences between drag-reduced and Newtonian flow at the same u_τ. If the fluid viscosity remains the same(only small viscosity increases occur at low c), then z^+ will represent the azimuthal extent of the vortex rolls, an important feature of the turbulence structure.

Eckelman et al.(1972) probably had the best technique, associating z^+ with the velocity gradient S_z and its wavelength in the azimuthal direction. In Figure 2.3.40, their z^+ data aligned with equation 2.3-21 at the highest S'. At lower S', z^+ data from Donohue et al.(1972), Achia & Thompson(1977), and Tiederman et al.(1985) scattered about the correlation. Data from Oldaker & Tiederman(1977) straddled the line with high and low z^+ at low and high S', respectively. Their method of confining the streak dying region to $y^+ < 8$ may account for their wide scatter.

The time between bursts T_{bb}^+ was measured by Donohue et al.(1972), Achia & Thompson(1977), Mizushina & Usui(1977), McComb & Rabie (1982b), and Usui et al. (1984). These data are shown in Figures 2.3.41 and 2.3.42. The former shows the normalized time T_{bb}^+/T_{bbn}^+ versus S', whereas the latter shows the absolute T_{bb}^+ versus S'. Agreement among investigators is hampered by their use of different sampling methods. The data of McComb & Rabie(1982b) obeyed accord well with the spanwise-spacing relation, equation 2.3-21, suggesting that both the spacing and frequency scales

with elastic-sublayer thickness. The data of Mizushina et al.(1977) and those of Usui et al.(1984) also show that T_{bb}^+/T_{bbn}^+ increases with S', but at a smaller rate than equation 2.3-21. Donohue et al.(1972) and Achia & Thompson(1977) both derived T_{bb}^+ by combining z^+ with the reduced bursting frequency per unit width F^+. Inconsistencies between the established F^+ and z^+ may account for the apparent decrease of T_{bb}^+ from T_{bbn}^+ at a given R^+. New approaches that can cleanly separate the additive and turbulent contributions to the changes in T_{bb}^+ with S' and R^+ are required.

2.3.5 Summary of Literature

A comprehensive review of drag-reduction literature since 1975 has been presented. Gross flow, mean-velocity profiles, and turbulence-flow-structure data have all been separately considered and analyzed. The elastic sublayer model(ESM), with parameter "apparent slip", S', shows promise in unifying and correlating aspects of the mean-flow and turbulence structure during drag reduction. From close examination of the limited reliable u'^+, v'^+, and $-<uv>^{++}$ data, a relationship between S' and each of u'^+_{max} and v'^+_{max} was inferred. The mean spacing z^+, and time between bursts T_{bb}^+ still comprise the least consistent aspects of drag-reduction data, being widely scattered. However, it is exciting to note that the relationship found between u'^+_{max} and S' agrees in form with the earlier empirical dependence of azimuthal streak spacings. The physics of the inner flow also support some connection between these different forms of turbulence-structure data, and further attempts to link them are warranted.

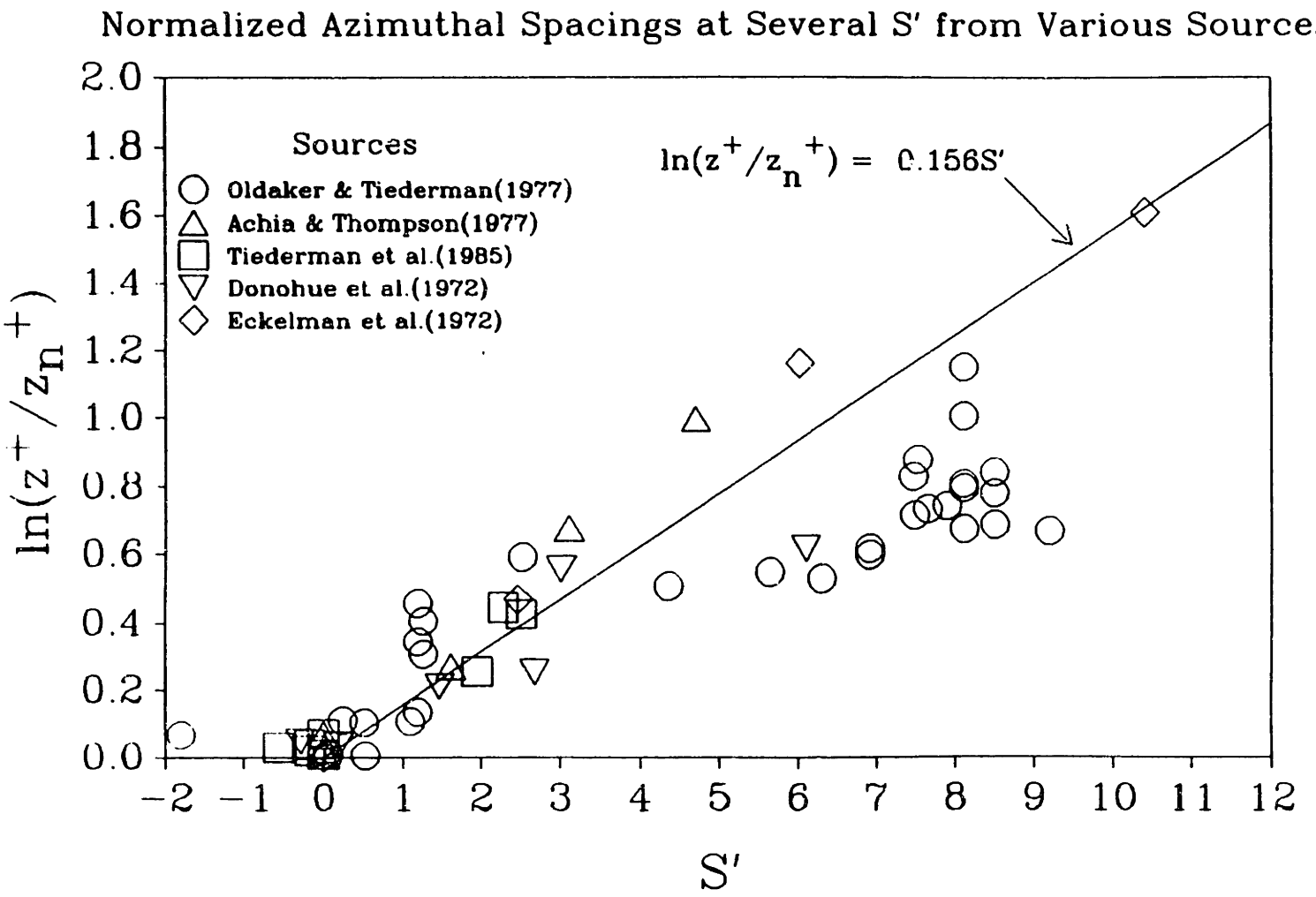


Figure 2.3.40: Normalized Azimuthal Spacings from Various Studies

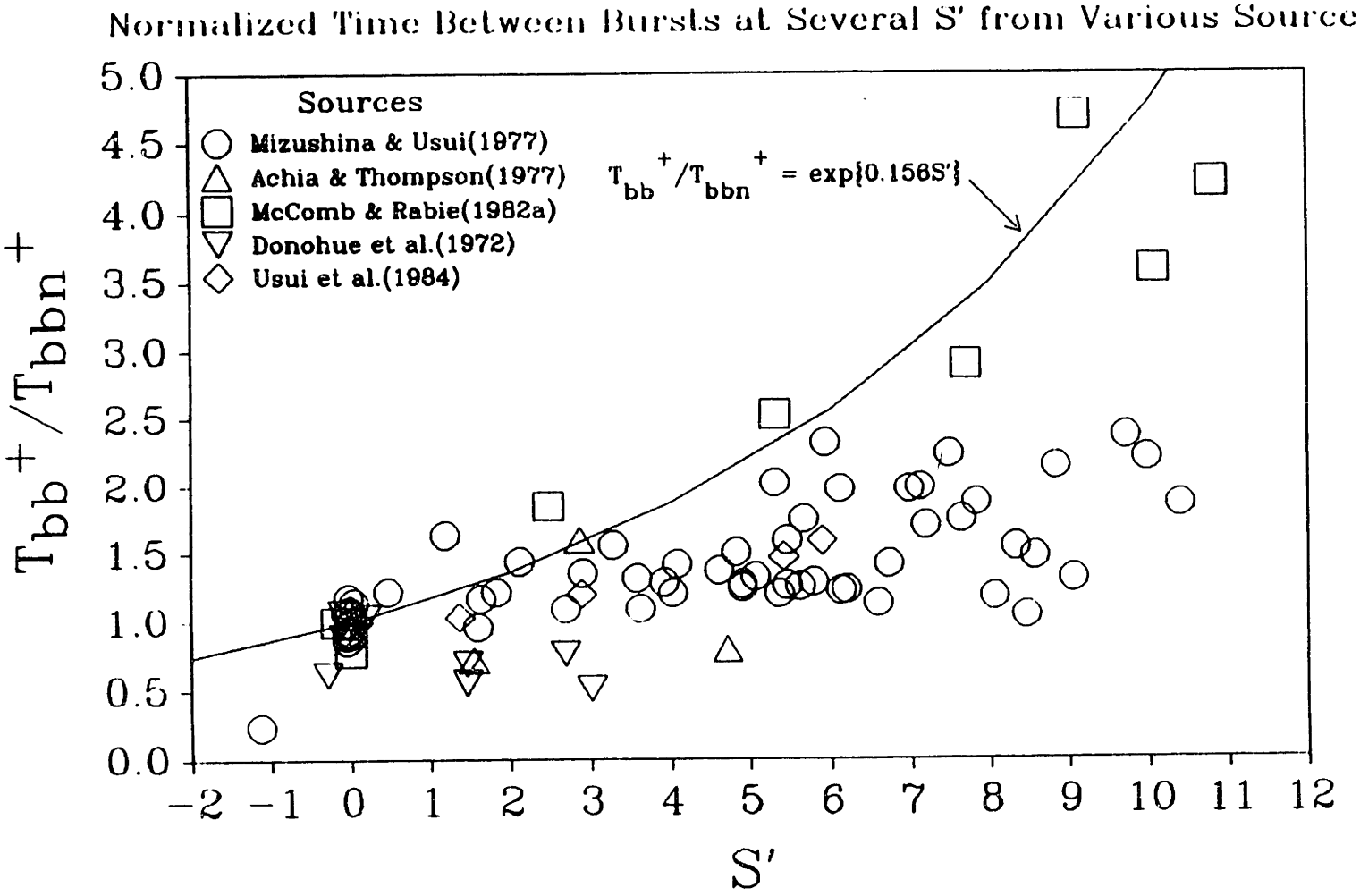


Figure 2.3.41: Normalized Time Between Bursts from Various Studies

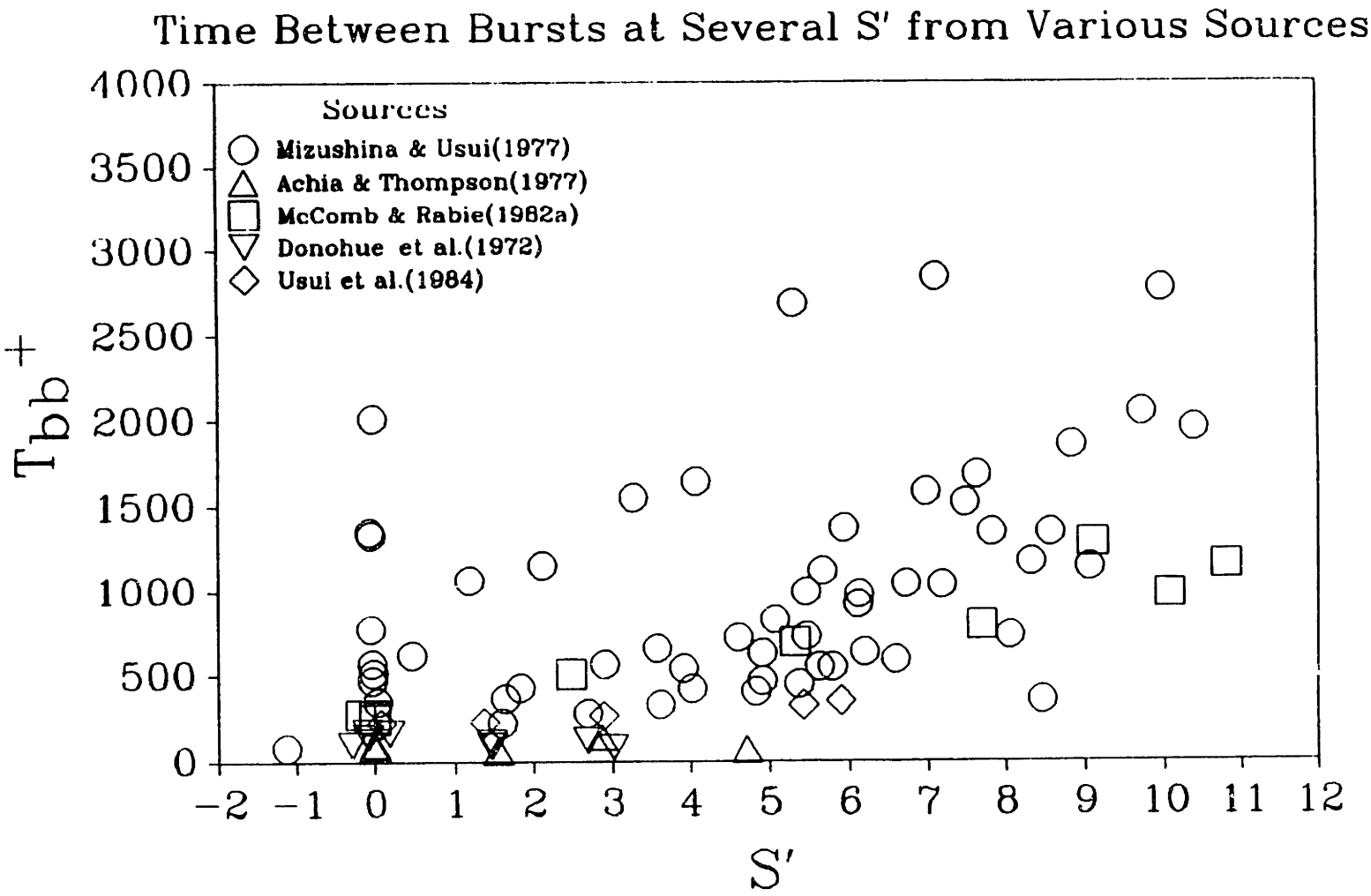


Figure 2.3.42: Time Between Bursts from Various Studies

2.4 PAM and HPAM Polymers

High-molecular-weight polymers are widely used in industry as flocculants, coagulants, clarifiers, and flow enhancers. Synthetic polyacrylamides(PAM) are popular drag-reduction additives, on account of their effectiveness and resistance to mechanical degradation. Hydrolyzing the acrylamide residues to sodium acrylate or acrylic acid makes the resulting HPAM more hydrophilic and drastically changes its static and dynamic properties. PAM and its derivative polymers have been studied widely, with an extensive literature. Some fundamental theoretical equations and empirical correlations required in the present work are presented in this section.

An overview of the theoretical and experimental literature for PAM characterization is provided in Appendix A.

2.4.1 Static and Dynamic Properties of PAM and HPAM

In this section, several Mark-Houwink-Kuhn-Sakurada(MHKS) equations are presented for aqueous PAM solutions under various conditions and summarized in Table 2.4.1. These equations are plotted at various M_w values in Figure 2.4.1. Figure 2.4.2 presents the best MHKS equation and includes some independent data that are unrelated to the equation's development. A correlation for the radius of gyration, $R_G \equiv <R^2>^{1/2}$, also has been developed and is shown in Figure 2.4.3 with some independently obtained data. Before the necessary MHKS equations for PAM and HPAM are given, the theory and assumptions underlying the MHKS equations are briefly reviewed.

2.4.2 Theoretical Background

In a dilute polymer solution, the average conformation of individual polymer chains determines its transport properties, of which $[\eta]$ is the most important here. Each chain, described as either random-flight or random-coiling, is modelled as an ensemble of unconnected segments which behaves statistically as if the segments were linearly connected; the solution is considered an ensemble of identical, noninteracting polymer chains, that is, monodisperse. How each chain distributes itself in space can be calculated given some simplifying assumptions: infinitely thin, noninteracting bonds; equal bond lengths; freely rotating bonds; short-range intramolecular forces only; perfect chain solvation; homogeneity; and isotropy. The radius of gyration, R_G, can be calculated given the bond length, ℓ, and the number of bonds, N:

$$R_G \equiv \langle R^2 \rangle^{1/2} = \ell \left[\frac{N}{6} \right]^{1/2} \qquad (2.4\text{-}1)$$

Despite idealizations, it qualitatively characterizes real chains. Under more realistic assumptions, how a real chain deviates from ideality can be determined from the temperature, the length or M of the chain, and some thermodynamic properties. This deviation is characterized by the linear-expansion factor:

$$\alpha \equiv \frac{R_G}{R_{Go}} \qquad (2.4\text{-}2)$$

in which the o subscript indicates random-flight conditions.

If a laminar flow field is imposed on this dilute solution, the frictional properties

of the solution can be derived for any polymer and solvent. The intrinsic viscosity, $[\eta]$, was defined to quantify the polymer contribution to the solution viscosity:

$$[\eta] = \lim_{c \to 0} \frac{\eta_{sp}}{c} = \lim_{c \to 0} \frac{\eta_r - 1}{c} = \lim_{c \to 0} \frac{\eta - \eta_s}{c\eta_s} \qquad (2.4\text{-}3)$$

in which the subscript s indicates solvent. It was later observed that for "random-flight" polymers, the slope of the η_{sp}/c curve varied with $[\eta]^2$, yielding the Huggins'equation:

$$\frac{\eta_{sp}}{c} = [\eta] + k'[\eta]^2 c, \qquad (2.4\text{-}4)$$

in which the Huggins' coefficient k' varies with M_w and is typically between 0.35 and 0.40, although experimental values widely vary. Its physical significance has yet to be elucidated.

Theories of intrinsic viscosity have successfully derived an equation that correlates $[\eta]$, R_G, and M for polymers that exhibit some random-coiling behavior. The Flory-Fox equation followed from these theories:

$$[\eta] = \frac{\Phi \langle h^2 \rangle^{3/2}}{M} = \frac{6^{3/2} \Phi \, R_G^3}{M} \qquad (2.4\text{-}5)$$

in which the universal constant Φ ranges between 1.5×10^{23} and 3.0×10^{23} $mole^{-1}$ both theoretically and experimentally, depending respectively upon the model and the experimental method used. The "best" value for Φ is 2.5×10^{23} $mole^{-1}$; however, to account for good solvents being used instead of ideal Θ solvents, to which the Flory-Fox equation applies, a coefficient of 0.8 is introduced. It follows that $\Phi' \equiv 0.8\Phi = 2.0 \times 10^{23}$ $mole^{-1}$, which is used here.

To account for real-chain deviations from ideal random-flight behavior, the Flory-

Fox equation can be modified to include the linear-expansion factor, $\alpha \equiv R_G/R_{Go}$:

$$[\eta] = 6^{3/2}\,\Phi'\left[\frac{<R^2>_o}{M}\right]^{3/2} M^{1/2}\alpha^3 = KM^{1/2}\alpha^3 \qquad (2.4\text{-}6)$$

in which $<R^2>_o/M$ is constant, in theory. For $\alpha = 1$, Θ conditions obtain, and $[\eta]_\Theta = KM^{1/2}$, which has been experimentally verified. Since experiments also indicate that log $\alpha^3 \propto$ log M, the intrinsic viscosity can expressed in terms of M:

$$[\eta] = K'M^a \qquad (2.4\text{-}7)$$

If the polymer in solution is polydisperse, this equation can be transformed theoretically to incorporate polydispersity:

$$[\eta] = K'M_v^{\,a} \qquad (2.4\text{-}8)$$

in which K' is some constant and M_v is the viscosity-averaged molecular weight. Because M_w, the weight-averaged molecular weight, and M_v do not differ too much; M_w may substituted into the above equation. Thus, the empirical MHKS equation,

$$[\eta] = K'M_w^{\,a} \qquad (2.4\text{-}9)$$

also can be defended theoretically in its application to polymer-solvent systems, if the polymer behaves somewhat like a random-coil.

2.4.3 Empirical MHKS Relations

Over the past 40 years, the properties of PAM have been exhaustively investigated. The following reviews chronologically the most widely cited relations and

sources, which are listed in Table 2.4.1.

Scholtan(1954) polymerized acrylamide(AM) and performed ultracentrifugation on seven PAM fractions in aqueous solution. For PAM of $M_w \leq 5\times10^6$ g/mole in solution at 25°C, the MHKS parameters, K' and a, were 6.31×10^{-3} cm^3/g and 0.80, respectively. (According to convention, K' assumes the dimensions of $[\eta]$ while a is considered a pure number.) American Cyanamid Co.(1955) published a MHKS correlation for high-molecular-weight PAM in 1.0 N aqueous $NaNO_3$ at 30°C; K' and a were given as 3.73×10^{-2} cm^3/g and 0.66, respectively. Collinson et al.(1956) polymerized AM in aqueous solution by radical initiation and measured the viscosities of unfractionated PAM in aqueous solution at 25°C(?). From chemical-kinetics calculations, K' and a were determined to be 6.8×10^{-2} cm^3/g and 0.66 ± 0.05, respectively, with M_n replacing M_w in the MHKS relationship. Klein & Conrad(1978, 1980) investigated PAM with $M_w \leq 5.5\times10^6$ g/mole via light-scattering and viscometry. For solvents of water and 0.5-N aqueous NaCl at 25°C, K' and a were 4.9×10^{-3} cm^3/g & 0.8 and 7.19×10^{-3} cm^3/g & 0.77, respectively. Munk et al.(1980) synthesized PAM of Mw $\leq 3\times10^6$ g/mole by radical initiation and measured intrinsic viscosities. For solvents of water, 0.2-N aqueous NaCl, and 1.0-N aqueous NaCl at 20°C, K' and a were 3.09×10^{-2} cm^3/g and 0.67, 3.02×10^{-2} cm^3/g and 0.68, and 2.88×10^{-2} cm^3/g and 0.69, respectively. In a survey of PAM, Kulicke et al.(1982) investigated polymerization, dilute-solution characterization and properties, and solution rheology. For aqueous solutions of PAM with $3.8\times10^4 \leq M_w \leq 9\times10^6$ g/mole at 25°C, K' and a were 1.00×10^{-2} cm^3/g and 0.755, respectively; for PAM with $5\times10^6 \leq M_w \leq 6\times10^6$ g/mole in a Θ solvent at 25°C, K' and a were 7.90×10^{-2} cm^3/g and 0.50, respectively.

Table 2.4.1
Summary of MHKS Equations

Source	$[\eta] = K'M_w^a$		Experimental Conditions	M_w Range
	K'	a		
	(cm^3/g)			(10^6 g/mole)
Scholtan(1954)	6.31×10^{-3}	0.80	H_2O, 25°C	< 5.0
American Cyanamid Co.(1955)	3.73×10^{-2}	0.66	1.0N $NaNO_3$, 30°C	?
Collinson et al.(1956)	6.8×10^{-2}	0.66	H_2O, 25°C(?)	?
Klein & Conrad (1978, 1980)	4.9×10^{-3}	0.80	H_2O, 25°C	0.5-5.5
Klein & Conrad (1978, 1980)	7.19×10^{-3}	0.77	0.5 N NaCl, 25°C	0.5-5.5
Munk et al.(1980)	3.09×10^{-2}	0.67	H_2O, 20°C	< 3.0
Munk et al.(1980)	3.02×10^{-2}	0.68	0.2 N NaCl, 20°C	< 3.0
Munk et al.(1980)	2.88×10^{-2}	0.69	1.0 N NaCl, 20°C	< 3.0
Kulicke et al.(1982)	1.00×10^{-2}	0.755	H_2O, 20°C	0.038-9.0
Kulicke et al.(1982)	7.90×10^{-2}	0.5	Θ solvent, 25°C	0.5-6.0

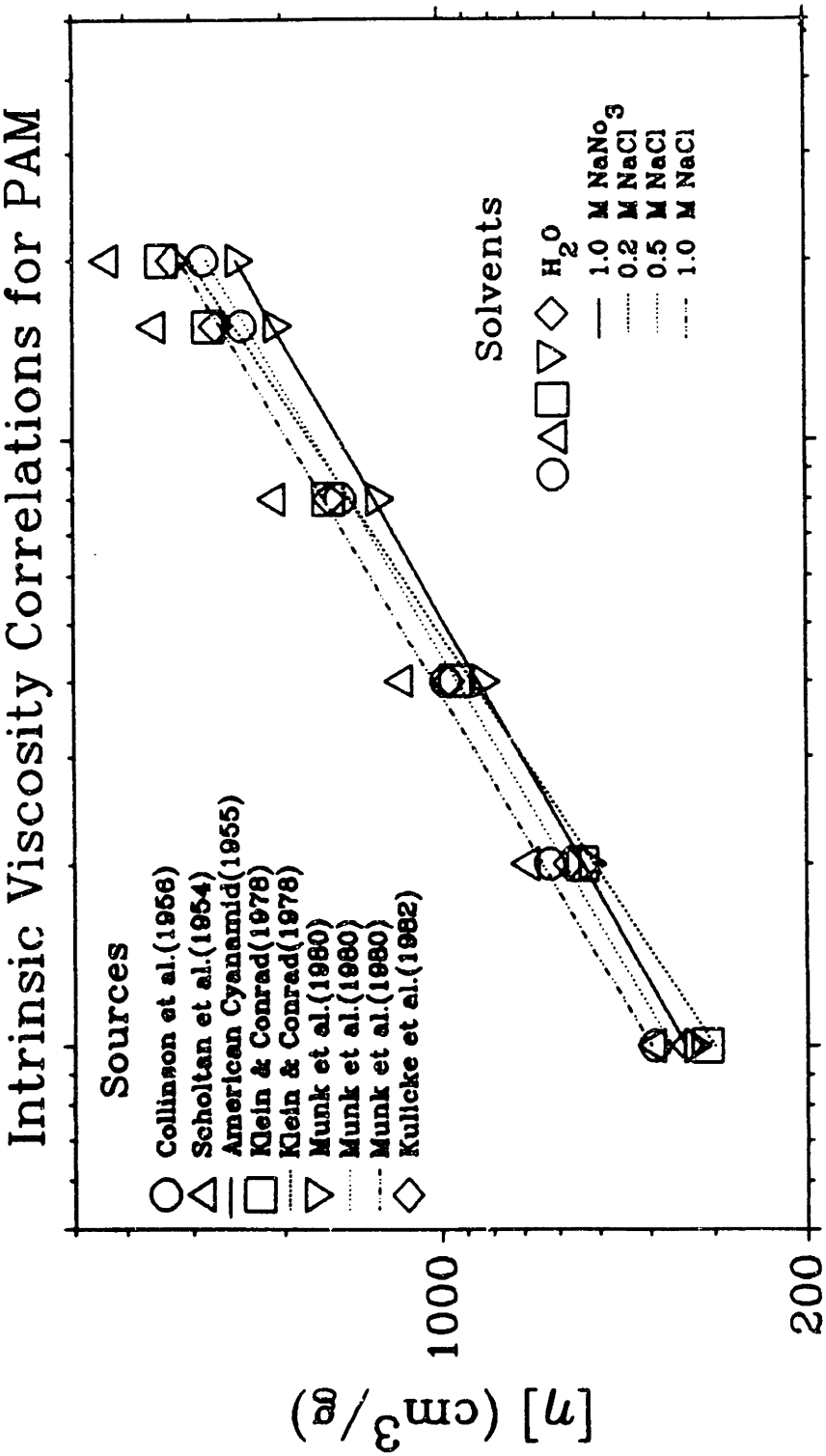


Figure 2.4.1: Intrinsic-Viscosity Correlations for HPAM from Various Studies

Because it best approximates these literature correlations, especially in the range of present interest, $M_w > 1\times10^6$ g/mole, the correlation from Kulicke et al.(1982),

$$[\eta] = 1.00\times10^{-2} M_w^{0.755} \qquad (2.4\text{-}10)$$

is used to interpret the laminar-flow data. Figure 2.4.2 shows this correlation and the data from which it was ultimately derived. The closed symbols represents independently gathered data from Clarke(1970) and McCormick et al.(1990). These data match the correlation quite well. If the independent data are included in the regression, the coefficient and exponent become 8.1×10^{-3} cm^3/g and 0.769, respectively; these two sets of parameters yield intrinsic viscosities that differ by less than five percent in the range 1.0×10^5 g/mole $< M_w <$ 1.0×10^8 g/mole. Table 2.4.2 provides the dependent and independent data shown in Figure 2.4.2. When M_w, $[\eta]$, and R_G are available, Φ has been calculated via the Flory-Fox equation to show how well it is obeyed. That Φ fluctuates about a value $\sim2.0\times10^{23}$ mole^{-1} indicates that the Flory-Fox equation holds for PAM in water and HPAM in brine.

Table 2.4.2
Data Shown in Figures 2.4.2 and 2.4.3

Source	M_w	$[\eta]$	R_G	Φ
	(g/mole)	(cm^3/g)	(nm)	(10^{23}/mole)
Klein & Conrad (1978)	490000	183	29.6	2.35
	550000	209	39.2	1.30
	770000	263	32.0	4.20
	1050000	246	49.2	1.48
	1100000	345	50.1	2.05
	1250000	412	55.3	2.07
	2020000	606	71.7	2.26
	2660000	740	88.3	1.94
	2860000	738	84.2	2.41
	5510000	1360	131.8	2.23
Kulicke et al(1982)	813000	331	48.2	1.64
	4240000	950	110.7	2.02
	4314000	1109	134.4	1.34
	4950000	1067	129.6	1.65
	5044000	1400	145.5	1.56
	5050000	1500	143.9	1.73
	7560000	1458	163.6	1.71
Clarke(1970)	7800000	1490	170.0	1.61
	9200000	1640	193.7	1.41

Source	M_w	$[\eta]$	R_G	Φ
	(g/mole)	(cm^3/g)	(nm)	(10^{23}/mole)
McCormick et al.(1990)	3900000	840	--	--
	6000000	930	--	--
	6900000	1600	--	--
	7500000	1800	--	--
	24000000	3400	--	--
	25000000	5200	--	--
	28000000	4700	--	--
Muller et al.(1979)	3700000	--	133.6	--
	3800000	--	113.8	--
	3800000	--	124.9	--
	4000000	--	118.6	--
	4400000	--	131.2	--

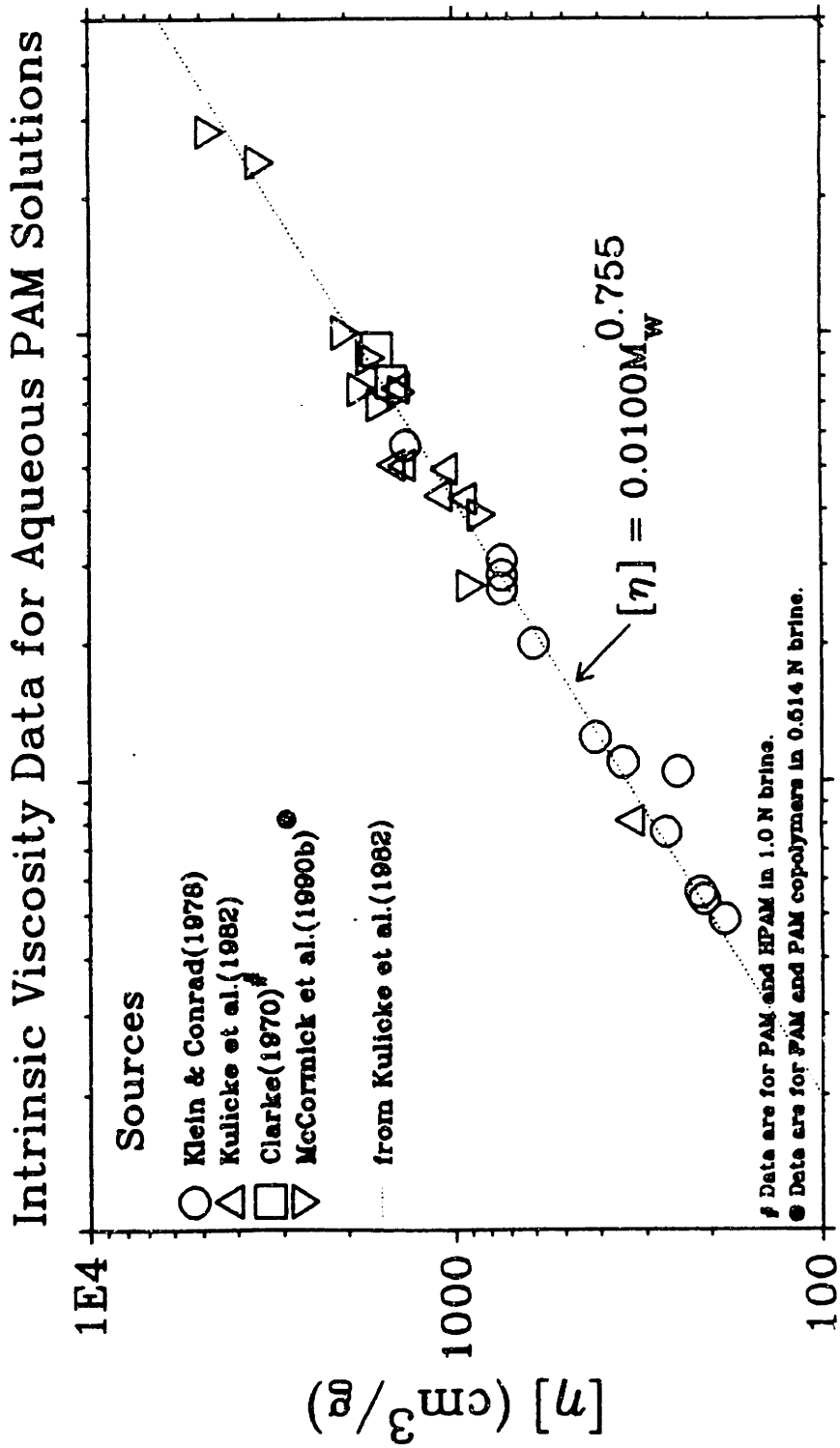


Figure 2.4.2: Intrinsic-Viscosity Correlation for PAM(Kulicke et al., 1982) and Data

In addition to $[\eta]$-M_w correlations, cross-correlations for polymer-coil size have also been determined. Klein & Conrad(1978, 1980) developed a $<h^2>_z^{1/2}$-M_w correlation with analogous K' and a of 4.9×10^{-2} nm and 0.59, respectively. Kulicke et al(1982) developed a $<h^2>_w^{1/2}$-M_w correlation using their own data and those from Klein & Conrad(1978, 1980). The $<R^2>_z^{1/2}$ and $<h^2>_z^{1/2}$ data obtained from light scattering were converted to $<R^2>_w^{1/2}$(or R_G) and $<h^2>_w^{1/2}$ via assumptions about polydispersity.(See Kulicke et al.(1982)) The resulting $<h^2>_w^{1/2}$-M_w correlation had analogous K' and a of 3.9×10^{-2} nm and 0.59, respectively. Via the same correction technique, a R_G-M_w correlation emerges:

$$R_G \equiv <R^2>_w^{1/2} = 1.5\times10^{-2} M_w^{0.59} \qquad (2.4\text{-}11)$$

in which R_G is in nm. Figure 2.4.3 shows this cross-correlation and the data from which it was ultimately derived. The closed symbols represent independently gathered data from Clarke(1970) and Muller et al.(1979). The independent data agree well with the cross-correlation; thus, this equation is used in interpretting the laminar-flow data. If these data are included in the regression, the resulting coefficient and exponent are 1.2×10^{-2} nm and 0.60, respectively. In the range $1.0\times10^5 < M_w < 1.0\times10^8$ g/mole, the two sets of parameters estimate radii of gyration that differ by about five percent. Table 2.4.2 lists the data shown in Figure 2.4.3.

To check the consistency of the MHKS correlation and the R_G-M_w correlation, the MHKS correlation can be inserted into the Flory-Fox equation to yield another R_G-M_w correlation; theoretically, the original and the derived correlations should be identical. It follows that the exponent in the R_G-M_w cross-correlation must be $(a+1)/3$. In addition,

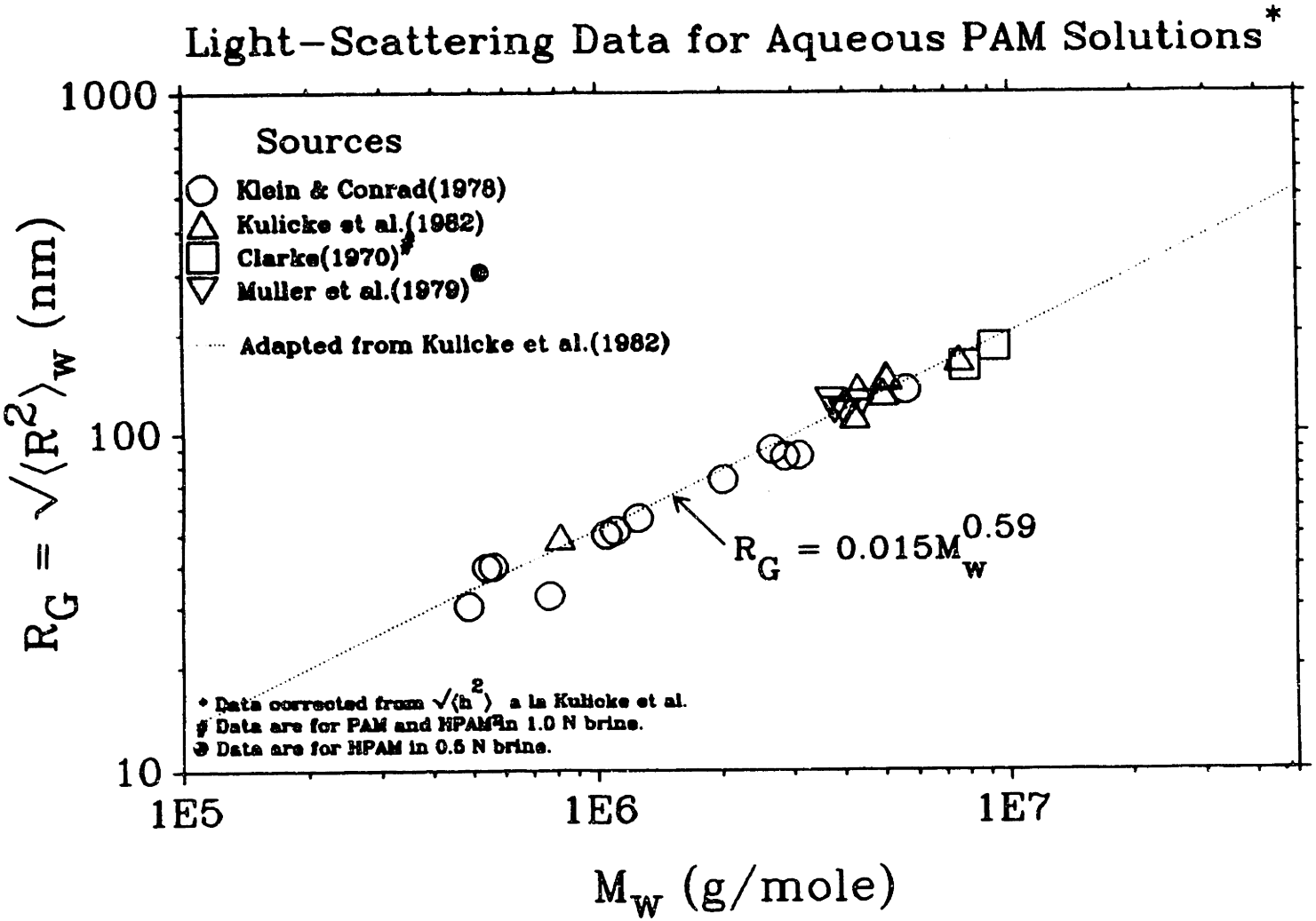


Figure 2.4.3: Radius-of-Gyration Correlation for PAM(Kulicke et al., 1982) and Data

by matching coefficients, Φ can be calculated. From the correlations shown in Figures 2.4.2 and 2.4.3, the exponents of the original and derived correlations are 0.59 and 0.585, respectively; the calculated Φ is 2.02×10^{23} mole^{-1}. (If the two correlations that include the independent data are used with the Flory-Fox equation, the original and derived exponents are 0.60 and 0.59, respectively, and the calculated Φ is 2.96×10^{23} mole^{-1}.) That the exponents match, with Φ having a very reasonable values, provides a high degree of confidence in using the two correlations, equations 2.4-10 and 2.4-11, in interpretting the laminar-flow data.

It must be remembered that these correlations apply to PAM solutions in which the macromolecules are somewhat random-coiling, i.e. not very aspherical. Thus, HPAM solutions must contain enough counterions(i.e. salt) to collapse the macromolecules through the mutual screening of backbone charges. Because HPAM solutions with small counterion concentrations contain mostly expanded macromolecules, neither the Flory-Fox nor the MHKS equation obtains. Experimentally for such solutions, $[\eta]$ depends not only on M_w, but also on c and [NaCl]. Equations reflecting these dependencies differ markedly from MHKS-type equations. Under certain conditions, two general equations describe intrinsic-viscosity data for expanded macromolecules:

$$\frac{\eta_{sp}}{c} = \frac{A}{1 + Bc^{1/2}} \qquad (2.4\text{-}12)$$

$$[\eta] = [\eta]_{s\infty} + k_{s\infty}[salt]^{-1/2} \qquad (2.4\text{-}13)$$

the coefficients of which depend on both polymer-solvent pair and temperature. Equation 2.4-14 has some basis on excluded-volume theory, but available data do not bear out its

universality. Several arguments against equation 2.4-13 have been made(Bohdanecký & Kovář, 1982), such as negative extrapolated values of $[\eta]_{s\infty}$ and applicability only at intermediate salinities.

A more recent experiment using aqueous solutions of HPAM suggests that $[\eta]$ is quadratic in $[NaCl]^{-½}$(Tam & Tiu, 1989) with the following relationship

$$[\eta] = [\eta]_\theta + 760[NaCl]^{-½} + 48[NaCl]^{-1} \qquad (2.4\text{-}14)$$

in which $[\eta]$ and [NaCl] are in cm^3/g and N, respectively. In Figure 2.4.4 η_{sp}/c is plotted against $[NaCl]^{-½}$ for additives C836A and P500. The solid line represents the best-fit line according to equation 2.4-13, with $[\eta]_{s\infty} \approx 2700\pm4100$ cm^3/g and $k_{s\infty} \approx 730\pm50$ $N^{½}\bullet cm^3/g$. While a linear relationship is apparent, the large uncertainty in $[\eta]_{s\infty}$ demonstrates the limited usefulness of equation 2.4-13. The dotted and dashed lines in Figure 2.4.4 represent the values predicted by equation 2.4-14 for additives C836A and P500, respectively, for which $M_w \approx 15.5\times10^6$ and 9.5×10^6 g/mole and $[\eta]_\theta \approx 310$ and 240 cm^3/g, the latter estimated by the last equation in Table 2.4.1 from Kulicke et al.(1982). Equation 2.4-14 not only overpredicts the intrinsic viscosity, but its quadratic form does not obtain for the C836A and P500 data. An equation that correctly predict the behavior of a wide range of polyelectrolytes has yet to be found.

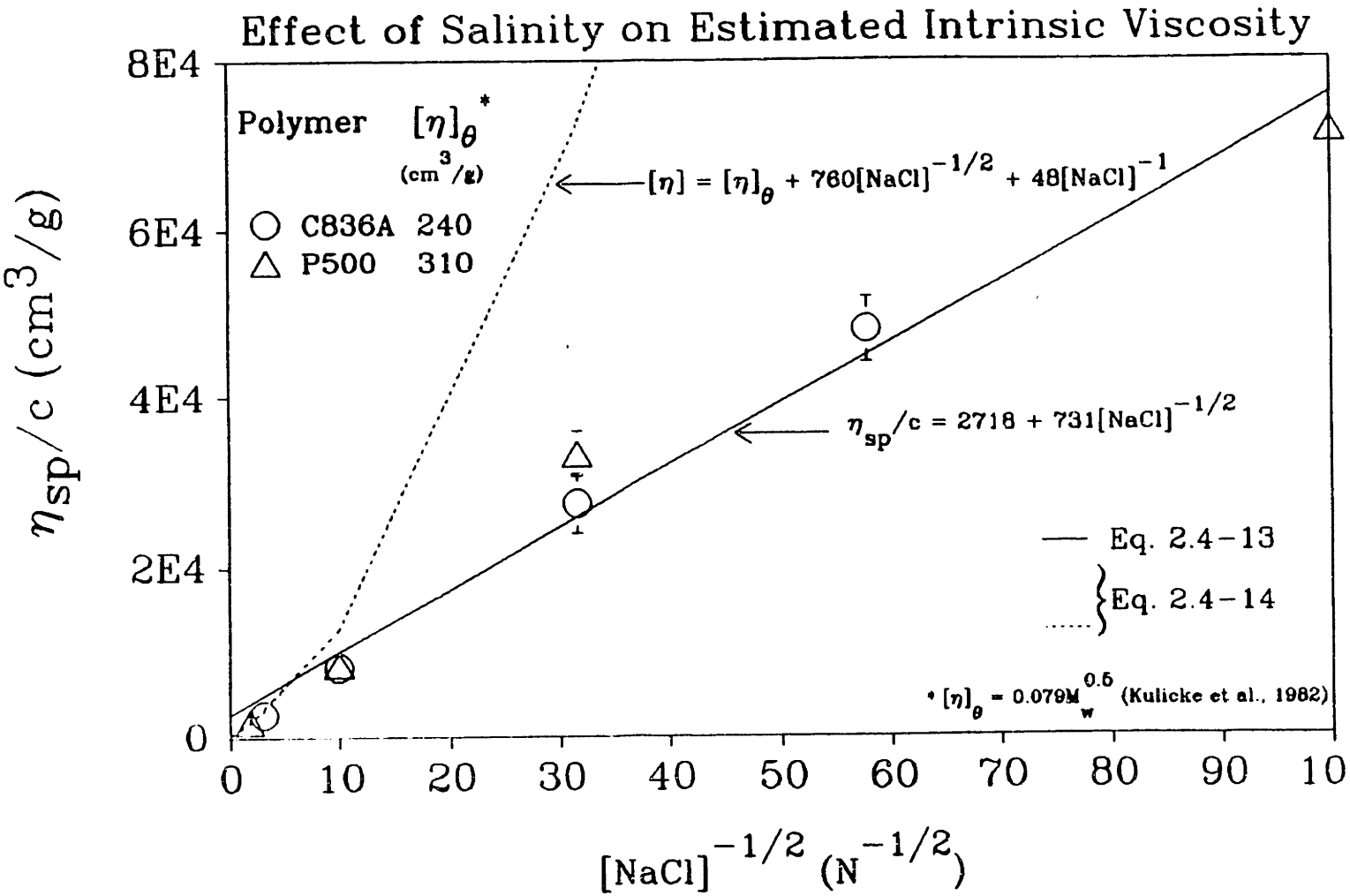


Figure 2.4.4: Effect of Salinity on Estimated Intrinsic Viscosity for Additives C836A and P500

CHAPTER III

EXPERIMENTAL APPARATUS

This chapter provides detailed descriptions of the experimental equipment and apparatus. Items include the gravity-driven and pump-driven flow systems, system modules, individual pieces of equipment, and chemicals. Table B3.0 in Appendix B contains a list of equipment and vendors.

3.1 Gravity-Driven Flow System

Figure 3.1 shows a schematic of the gravity-driven flow system. The test-pipe section included four lengths of tubing, each with a pressure-tap hole for measuring the pressure gradient. The four lengths were cut from a single length of 0.574"-ID(1.458-cm-ID), 316-stainless-steel tubing. Bored-through, ¾", stainless-steel unions held together and aligned adjacent lengths. A bored-through, ¾", stainless-steel, union tee fitted over each 0.025"-ID tap hole; its branch run received the pressure tap line from the pressure-transducer(PT) board. The 0.1- and 1.0-psid PTs mounted on the PT board and measured the pressure drop between any two of the four tap holes. Four ball valves connected to the tap holes via pressure-tap lines and could be adjusted to access any tap-hole pair. The flow was moderated by the flow-control unit. The flow-control unit contained a ¾", stainless-steel, ball valve and a ¾", stainless-steel, 10-turn, needle valve in parallel. Downstream of the flow-control unit, a mass-flow meter measured and displayed the flow

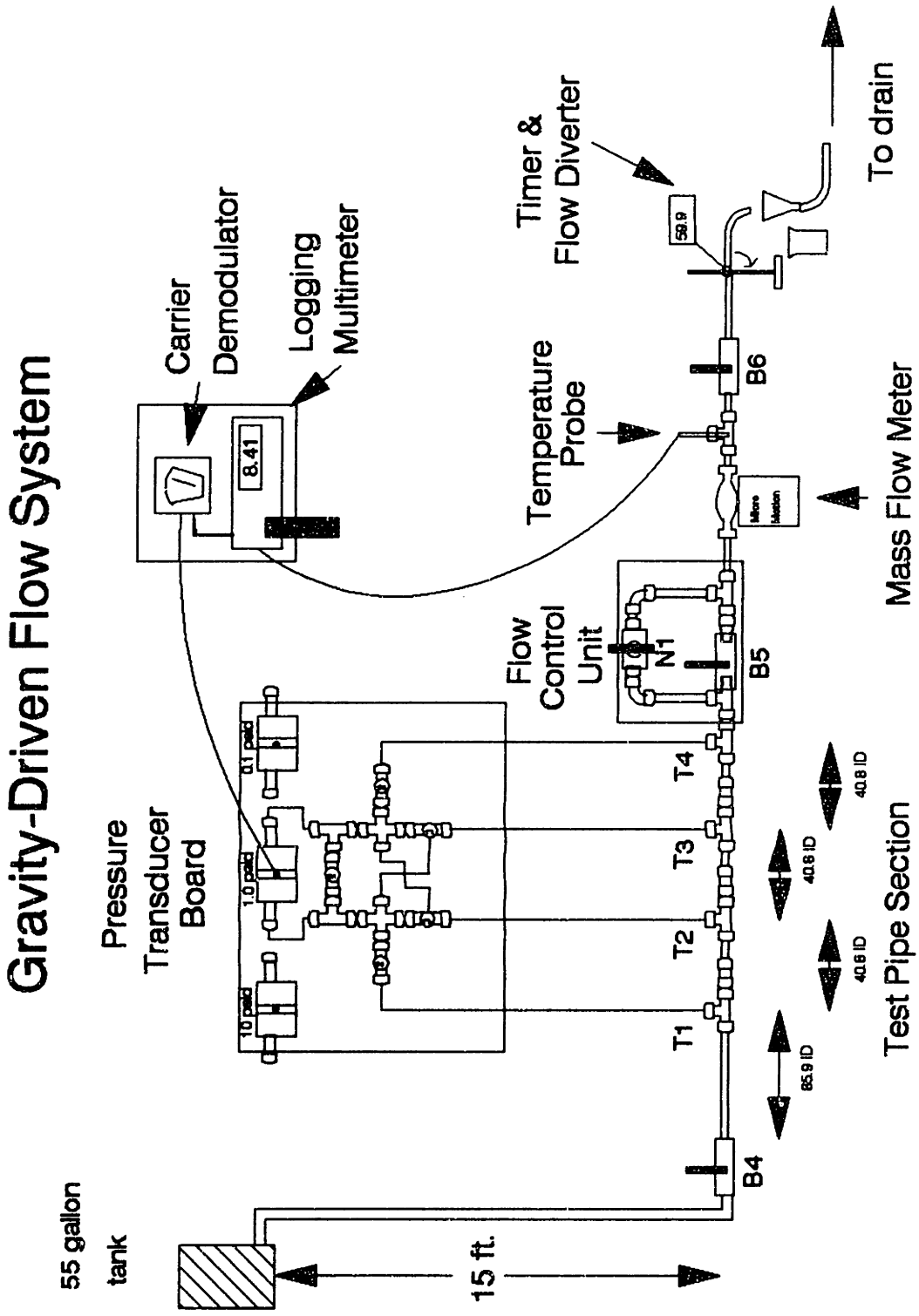


Figure 3.1: Gravity-Driven Flow System

rate. Further downstream, the temperature-probe unit, via its 5k-Ω thermistor, measured the temperature of the exiting flow. After the probe, a ¾", stainless-steel, ball valve was used to start and to stop the flow. At the system's end, a timer and flow diverter alternately measured the flow rate for low rates and discharged the effluent to the drain. A HP-3467A Logging Multimeter monitored, displayed, and printed out the PTs' output voltage; it also converted the thermistor's resistance output to temperature and displayed it.

At the most upstream position, a single 55-gallon, stainless-steel tank was used for mixing and holding the experimental solutions. The tank was located on a second-floor balcony about 15' above the first-floor laboratory space. A 1" flexible tube delivered distilled water up to the tank from the distilled-water spigot on the first-floor laboratory space. The tank had an old 2", stainless-steel, ball valve attached to its nipple. A 2" PVC elbow with a 2"-to-1" PVC reducer followed the valve. A 1¼" flexible tube connected the PVC reducer to a ¾", stainless-steel, male tube adapter on the front end of the FNPT-ended, ¾", stainless-steel, ball valve(B4) that preceded the test-pipe section.

A long stretch of a unistrut double channel(P1001C) supported valve B4, the test-pipe section, the PT board, and the flow-control unit. Several floor-anchored posts upheld the P1001C. Valve B4 mounted flat onto an 9" × 12" × ⅛" aluminum plate that mounted vertically onto the side of the P1001C. This suspended the test pipe just above the P1001C and maintained it level as determined by a bubble level. A ¾" stainless-steel male connector joined the back of valve B4 to the entry length of the test-pipe section. The next three segments of this section followed along the surface of the P1001C until

the ending length reached the flow-control unit. A bored-through ¾" stainless-steel union sealed adjacent lengths together. A bored-through ¾" stainless-steel union tee provided a seal over each tap hole and connected the tap hole hydraulically to its pressure-tap line. Four tap lines fed into the four ball valves on the PT board. The board bolted onto the side of the P1001C, adjacent to the middle lengths of the test-pipe section. The ending length inserted directly into the flow-control unit. A short length of ¾" stainless-steel tubing and a ¾"-port-to-⅜"-NPT stainless-steel male connector in series joined the flow-control unit to the mass-flow meter. Another short length of ¾" stainless-steel tubing connected the mass-flow meter to the temperature probe. A short length of ¾" stainless-steel tubing and a ¾" stainless-steel male connector followed the temperature probe and led to the FNPT-ended ¾" stainless-steel rear ball valve(B6).

A ¾" stainless-steel male tube adapter installed into the back of valve B6. Beyond this two flow configurations were used. At high flow rates when the mass-flow meter operated alone, one end of a 1" flexible tube was clamped to the tube adapter by a wormhose clamp. The other end went into the drain. At flow rates which required the timer and flow diverter, the ¾"-port-to-½"-stub reducer of the flow diverter was attached to the tube adapter. The end of the 1" flexible tube that had been clamped onto the tube adapter was placed over the tip of the flow diverter's funnel. The other end remained in the drain.

3.2 Pump-Driven Flow System

Figure 3.2 provides a plan view of the pump-driven flow system. The test-pipe section included four lengths of tubing, each with a pressure-tap hole for measuring the pressure drop. These four lengths were cut from a single length of ¾"-OD, 0.574"-ID(1.458-cm-ID), 316-stainless-steel tubing. In later experiments, four lengths cut from a single length of ½"-OD, 0.402"-ID(1.021-cm-ID), low carbon, stainless-steel, microsmooth tubing were used in this section. Bored-through, ¾"(½"), stainless-steel unions held together and aligned adjacent lengths. On each length a bored-through, ¾"(½"), stainless-steel, union tee fitted over the 0.025"-ID tap hole; its branch run received the pressure-tap line from the PT board. The 0.1-, 1.0-, and 10-psid PTs mounted on the PT board and measured the pressure drop between any two of the four tap holes. Four ball valves connected to the tap holes via pressure-tap lines and could be adjusted to access any pair of taps. A positive-displacement Moyno 3L4-SSQ-AAA pump provided flow rates between 3.2 gpm(0.2 l/s) and 19.2 gpm(1.2 l/s). A pump-bypass loop emerged from the pump's suction housing and connected to the 1" union cross downstream; it permitted gravity-driven flow when valves B2 and B3 were open. The gravity-driven flow was moderated by the flow-control unit. The flow-control unit contained a ¾", stainless-steel, ball valve and a ¾", stainless-steel, 10-turn, needle valve in parallel. Further downstream, the temperature-probe unit, via its 5k-Ω thermistor, measured the effluent temperature. After the probe, a ¾", stainless-steel, ball valve was used to start and to stop the flow. At the system's end, a timer and flow diverter alternately measured the flow rate for low rates and discharged the effluent to

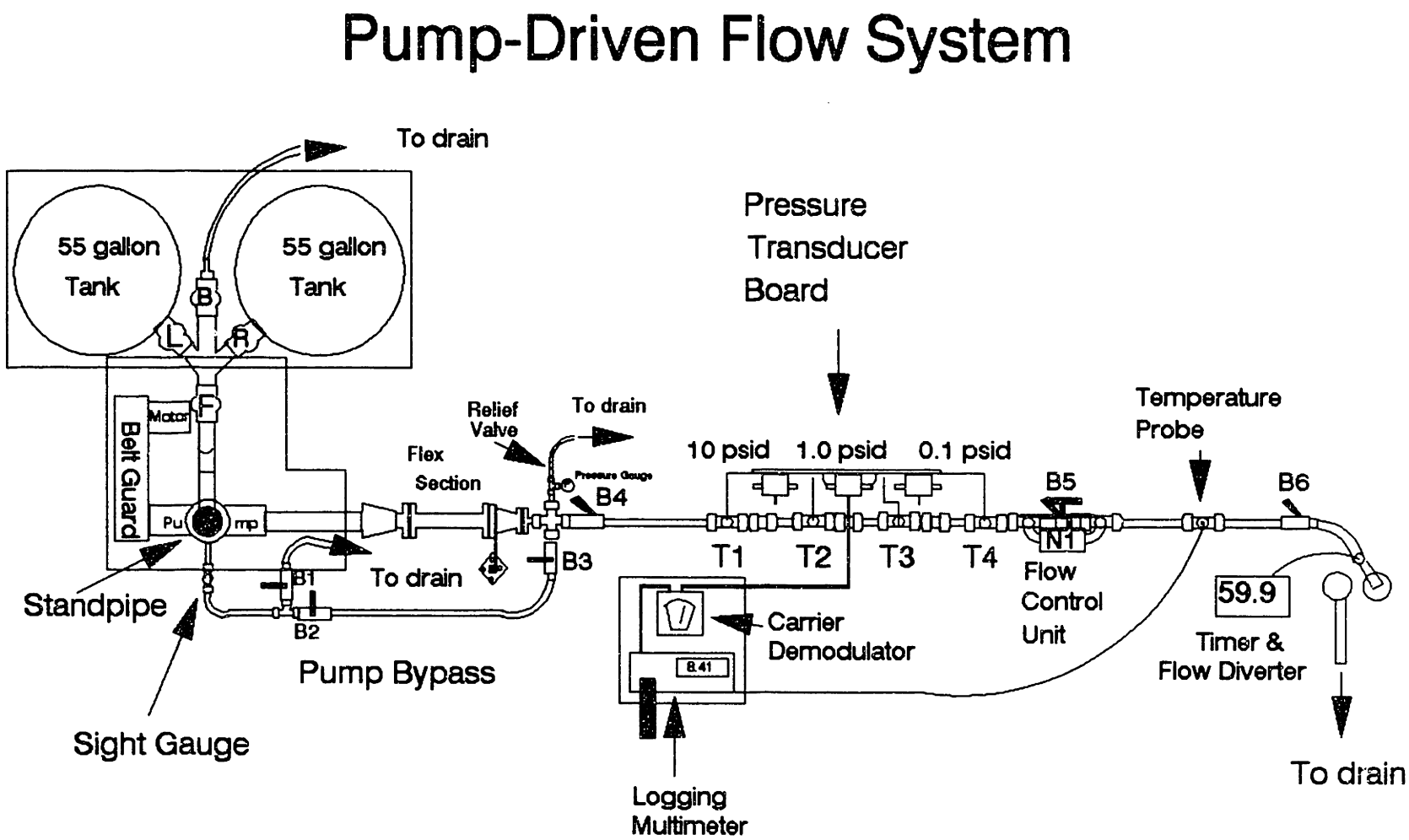


Figure 3.2: Pump-Driven Flow System

the drain. A HP-3467A LoggingMultimeter monitored, displayed, and printed out the PTs' output voltage; it also converted the thermistor's resistance output to temperature and displayed it.

At the most upstream position, two 55-gallon, stainless-steel tanks were used for mixing, heating, and holding experimental solutions. These tanks were elevated atop a reinforced unistrut frame about five feet above the laboratory floor. A hose connected to a distilled-water spigot provided the large volumes(up to 380 liters) necessary for most runs. A Model-10 Lightnin mixer that clamped onto the rim of either tank mixed the solutions, and a drum heater around each tank warmed the solutions before use. A FNPT-ended, 2", ball valve attached directly onto the 2" MNPT nipple of each tank. Valves L and R on the left and right tanks were stainless steel and PVC, respectively. A schedule-80, MNPT-ended, 2", PVC double nipple joined each ball valve with a schedule-80, 2", PVC ring flange. The ring valves provided convenient removal of both tanks from the system. From either ring flange, another schedule-80, MNPT-ended, 2", PVC double nipple connected indirectly to a 2" PVC double wye via a FNPT-to-socket, 2", PVC adapter. Socket-ended, 2", PVC ball valves F and B attached onto both the front and the back socket of the double wye, respectively, via a short length of schedule-40, 2" PVC pipe. Attached to valve B, a schedule-40, 2" × 1¼" spigot-to-female-bushing connected to an adjustable wrench, 1¼" adapter. Clamped onto this adapter, a long 1¼" flexible tube led to and emptied into the drain. Via a short length of schedule-40, 2", PVC pipe, valve F connected to a schedule-40, 2", PVC elbow that pointed downwards. From the elbow, another short length of pipe led into a vertical length of 3"-OD, 2½"-ID flexible tubing. The lower end of the flexible tubing attached onto

another identical elbow via a short pipe length. From the elbow, another pipe length led into a schedule-40, 2½" × 2", PVC bushing which in turn connected to the branch run of a 2½" PVC socket tee. In the upper run of the tee, an eight-foot length of schedule-40, 2½", PVC pipe served as a stand pipe. From the lower run, a length of 2½" pipe inserted into a 2½" PVC socket flange that directly bolted onto the suction end of the Moyno pump.

Two separate flow paths emerged from the pump and then rejoined downstream at the 1" stainless-steel union cross. One path flowed through the pump discharge; the other bypassed the pump elements and flowed through the suction-housing drain plug.

A 2" flange assembly screwed directly into the pump discharge. The 2" flange assembly consisted of a 2" length of 2" stainless-steel pipe with one MNPT end welded onto a 2" stainless-steel neck-weld flange. With an intervening silicone gasket, the flange assembly bolted onto the "flex section." The flex section consisted of a flange-ended 2" flexible stainless-steel hose with a 16" total length. Three 2"-OD × ⅛"-cell × 3"-long pieces of honeycomb were inserted into the flexible hose to calm the flow. With another intervening silicone gasket, the flex section bolted onto a 2"-to-1" reducer assembly. The 2"-to-1" reducer assembly consisted of a 2" stainless-steel flange, a 2"-to-1" stainless-steel concentric reducer, and a 1" stainless-steel flange. These were welded together serially. Due to intervening equipment and the long distance from pump discharge to the test-pipe section, the reducer assembly required support. A thin rectangular metal plate with a large U-shape cut into it attached both onto the 2" flange of the reducer assembly and onto a floor-anchored post. A 1" flange assembly bolted onto the reducer assembly with an intervening silicone gasket. The 1" flange assembly consisted of a 2" length of

1" stainless-steel pipe with one MNPT end welded to a 1" stainless-steel flange. A 1" stainless-steel female tube adapter connected the flange unit to the 1" stainless-steel union cross.

In the second flow path, a ½" stainless-steel male elbow fit into the suction-housing drain plug so that the elbow pointed away from the tanks and 90° from the pump discharge direction. The elbow connected to the run of a ½" stainless-steel union tee via a length of ½" stainless-steel tubing. Nylon ferrules were used with all stainless-steel fittings for easy maintenance. Pointing upwards, the branch run of the tee held an eight-foot length of ½" clear rigid PVC tubing. This length consisted of two-foot and six-foot lengths sealed together by a ½" brass union and served as a sight gauge of the tanks' fluid levels. The other tee run held a long length of ½" stainless-steel tubing that bent 90° in the pump-discharge direction. A ½"-port-to-1"-stub stainless-steel reducer joined the ½" stainless-steel tubing to the run of a 1" stainless-steel union tee. From the branch run of the tee, a 1" stainless-steel male tube adapter inserted into a FNPT-ended 1" stainless-steel ball valve(B1). Another 1" stainless-steel male tube adapter installed into the back of vaive B1. Clamped into the adapter, a long 1¼" flexible tube led to and emptied into the drain. The following pieces linked in series the other run end of the tee with an arm of the 1" union cross: a 1 stainless-steel male tube adapter; a FNPT-ended 1" stainless-steel ball valve(B2); a second 1" stainless-steel male tube adapter; a length of 1¼" flexible tubing; a third 1" stainless-steel male tube adapter; another FNPT-ended 1" stainless-steel ball valve (B3); and a fourth 1", stainless-steel male tube adapter.

The two remaining arms of the 1" stainless-steel union cross led to the drain as an overpressure release and to the test-pipe section. The relief arm opposed the bypass

arm. A 1"-stub-to-½"-port stainless-steel reducer and a ½" stainless-steel port connector joined the relief arm to a ½" stainless-steel female branch tee. A ½"-to-¼" stainless-steel reducing bushing connected a 0-160-psig pressure gauge(P) to the female branch run. The tee run joined to a 100-psig spring-loaded relief valve(SS-CH-S8-100) via a ½" stainless-steel port connector. Another ½" stainless-steel port connector inserted into the other end of the relief valve. Clamped onto the port connector by a wormhose clamp, a long ½" flexible tube led to and emptied into the drain.

Inserted into the union arm opposite the pump-discharge arm, a 1"-stub-to-¾"-NPT male tube adapter installed directly into the FNPT-ended ¾" stainless-steel ball valve(B4) preceding the test-pipe section. The test-pipe sections with the ¾" and ½" stainless-steel tubing and fittings and the two flow configurations used beyond B6 were the same as those in the Gravity-Driven flow system.

3.3 System Modules

(1) Test-Pipe Sections

In the first, larger test-pipe section, the pipe was a 316-stainless-steel, seamless tube with a ¾" OD and a nominal 0.584" ID. Measurements of the inner diameter with a dial caliper indicated that the real pipe ID was 0.574 inch(1.458 cm). This accorded with the hydraulic diameter(D_h) determined from subsequent solvent run data.

Cut from a single length of tubing, the test-pipe section consisted of an entry length, two middle lengths, and an ending length. For the gravity-driven flow system,

they had lengths of 49 5/16", 23⅜", 23⅜", and 24⅜", respectively; these corresponded to 85.9 ID, 40.7 ID, 40.7 ID, and 42.5 ID, respectively. For the pump-driven flow system, the entry section was shortened to 33 15/16"(59.1 ID) to accomodate the pump.

For the entry length, a 0.025" ID pressure-tap hole was located 2 19/32" from the downstream end. For the middle lengths and ending length, the 0.025" ID pressure-tap holes were drilled at locations 2 9/16" and 3 9/16" from the downstream end, respectively. This allowed the ending length to insert directly into the flow-control unit. The sequential intertap distances were 23 13/32"(41.4 ID), 23⅜"(40.7 ID), and 23⅜"(40.7 ID). Care was taken to drill all tap holes with their axes normal the tube axis. The inner surface of each length was manually smoothed with a gun barrel cleaning brush and fine sandpaper. Providing a more uniform polish, a milling machine rotated the tube while a brush and sandpaper, with some lubricating oil, were moved back and forth inside the tube. Next, a manually-rotated, 0.025" drill bit(size 72) was moved in and out of each tap hole to ensure that the tap hole was perfectly circular and unobstructed. The spot where the tap hole penetrated the inner tube wall was sanded with a jeweler's file to remove burrs and debris. Inside the tube, each tap hole was virtually invisible.

Figure 3.3.1 depicts the test-pipe section junction. Where the faces of adjacent lengths met, a ¾" bored-through stainless-steel union held the two ends and matched the two abutting faces almost seamlessly. Fitted with nylon ferrules, the tightened union nuts gripped the tubes, both creating a fluid-tight seal and permitting disassembly and reassembly without causing damage. With its branch run centered over each tap hole, a ¾" bored-through stainless-steel union tee created a fluid-tight volume above the hole

Test-Pipe Section Interface

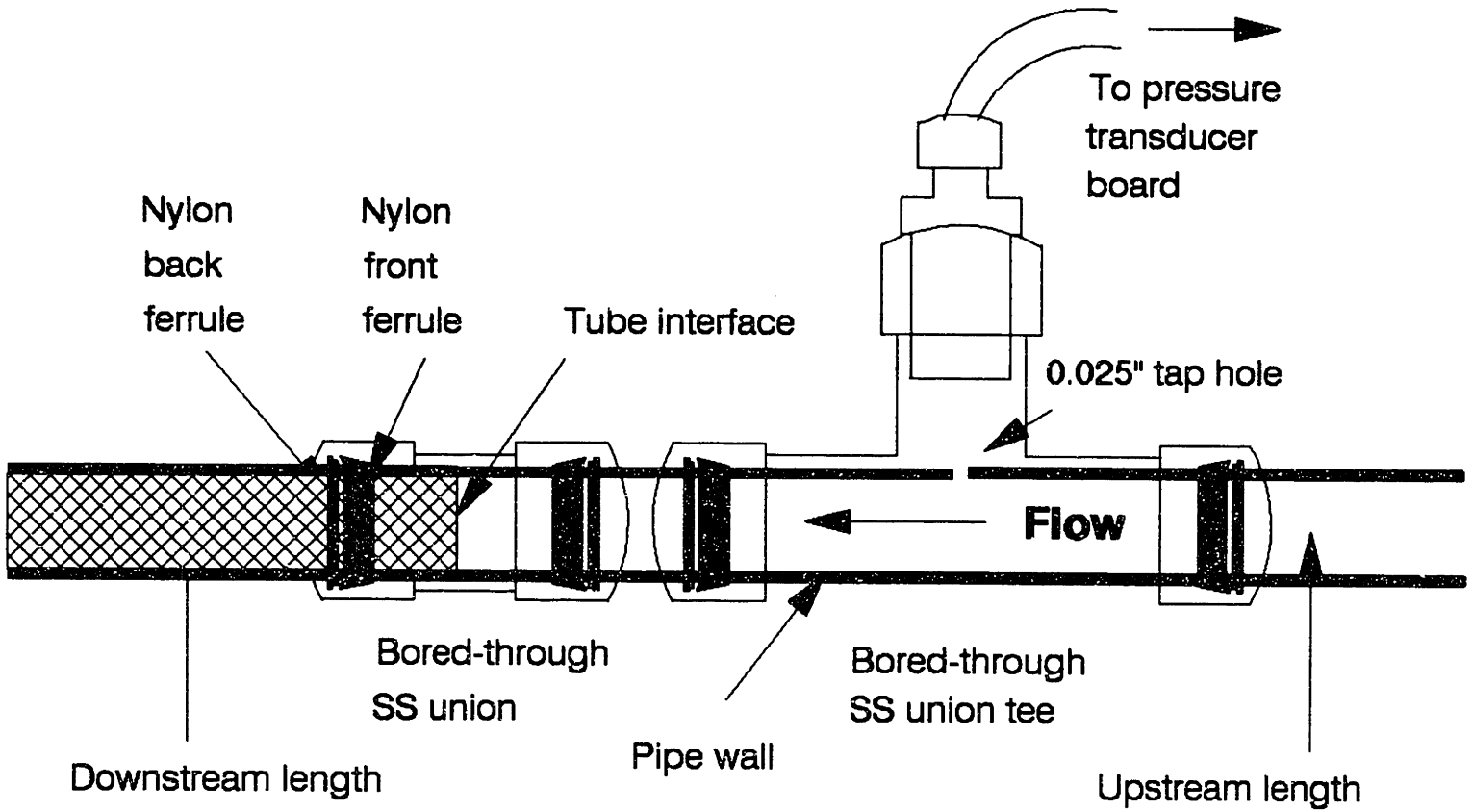


Figure 3.3.1: Test-Pipe Section Interface

with its tightened nuts and nylon ferrules providing seals. Its branch run served as the port for the pressure-tap line leading to the PT board. Placed into each branch run, a ¾"-stub-to-¼"-port reducer accommodated the ¼" OD pressure tap line. The entire test-pipe section rested atop a stretch of P1001C about a foot above the floor.

In the second, smaller test-pipe section, the pipe was a low-carbon, 316-stainless-steel, seamless tube with a ½" OD and and with an electro-polished ID of 0.402 ± 0.000005 inch(1.021 cm). Dial caliper measurements of the ID and flow data accorded with the given ID value.

Cut from a single length of tubing, the test-pipe section had an entry length, two middle lengths, an ending length. They had lengths of 33 53/64", 15 5/8", 15 39/64", and 16 5/8", respectively; these corresponded to 84.1 ID, 38.9 ID, 38.8 ID, and 41.4 ID, respectively. For the entry and middle lengths, a 0.025"-ID, pressure-tap hole was drilled at a location approximately 2¾" from the downstream end. The 0.025"-ID, pressure-tap hole in the ending length was drilled at a location approximately 3¾" from the downstream end. This allowed the ending length to insert directly into the flow-control unit via a ¾"-stub-to-½"-port reducer. The four tap-hole-to-end distances were 2.743", 2.747", 2.741", and 3.746", respectively, as measured with a dial caliper. The sequential intertap distances were 15.62"(38.86 ID), 15.62"(38.84 ID), and 15.62"(38.86 ID). Care was taken to drill these holes with their axes normal to the tube axis. Next, a manually-rotated, 0.025" drill bit(size 72) was moved in and out of each tap hole to ensure that the tap hole was perfectly circular and unobstructed. Then the spot where the tap hole penetrated the inner tube wall was sanded delicately with a jeweler's file to remove burrs and debris. Inside the tube, each tap hole was virtually invisible. The ends

of these lengths, where the saw blade had passed, required polishing. To polish the inner ends, a 0.40" OD metal rod and very fine sandpaper, with some lubricating oil, were moved back and forth inside the tube while it was rotated on a milling machine.

Just as with the ¾" tubing, ½" bored-through stainless-steel unions with nylon ferrules sealed the faces between adjacent lengths of the smaller tubing. Similarly, ½" bored-through stainless-steel union tees provided fluid-tight volumes above the tape holes; their ports accomodated the pressure-tap lines that lead to the PT board with ½"-stub-to-¼"-port reducers. The entire test-pipe section rested upon a stretch of P1001C about a foot above the floor.

(2) The Pump Unit

The following components comprised the pump unit: an L-shaped steel base; a Moyno 3L4-SSQ-AAA Pump; timing belts, pulleys, and belt guard; and a Reliance 2-Hp TEFC-XE motor controlled remotely by a T. B. Woods 2-Hp variable-frequency E-trAC AC Inverter.

Figure 3.3.2 presents the vendor-supplied pump-unit schematic. An L-shape steel base served as both a platform and an anchor for the motor, the timing belts, pulleys, and belt guard, and the pump. While the base height was about three inches, its edges bent downwards and met the floor. Around its periphery about a three-inch-wide strip of metal pressed flush against the floor. The base bolted directly onto the laboratory floor via the bolt holes in the strip around the base periphery.

The pump was designed to operate between 100 rpm and 940 rpm. Its discharge

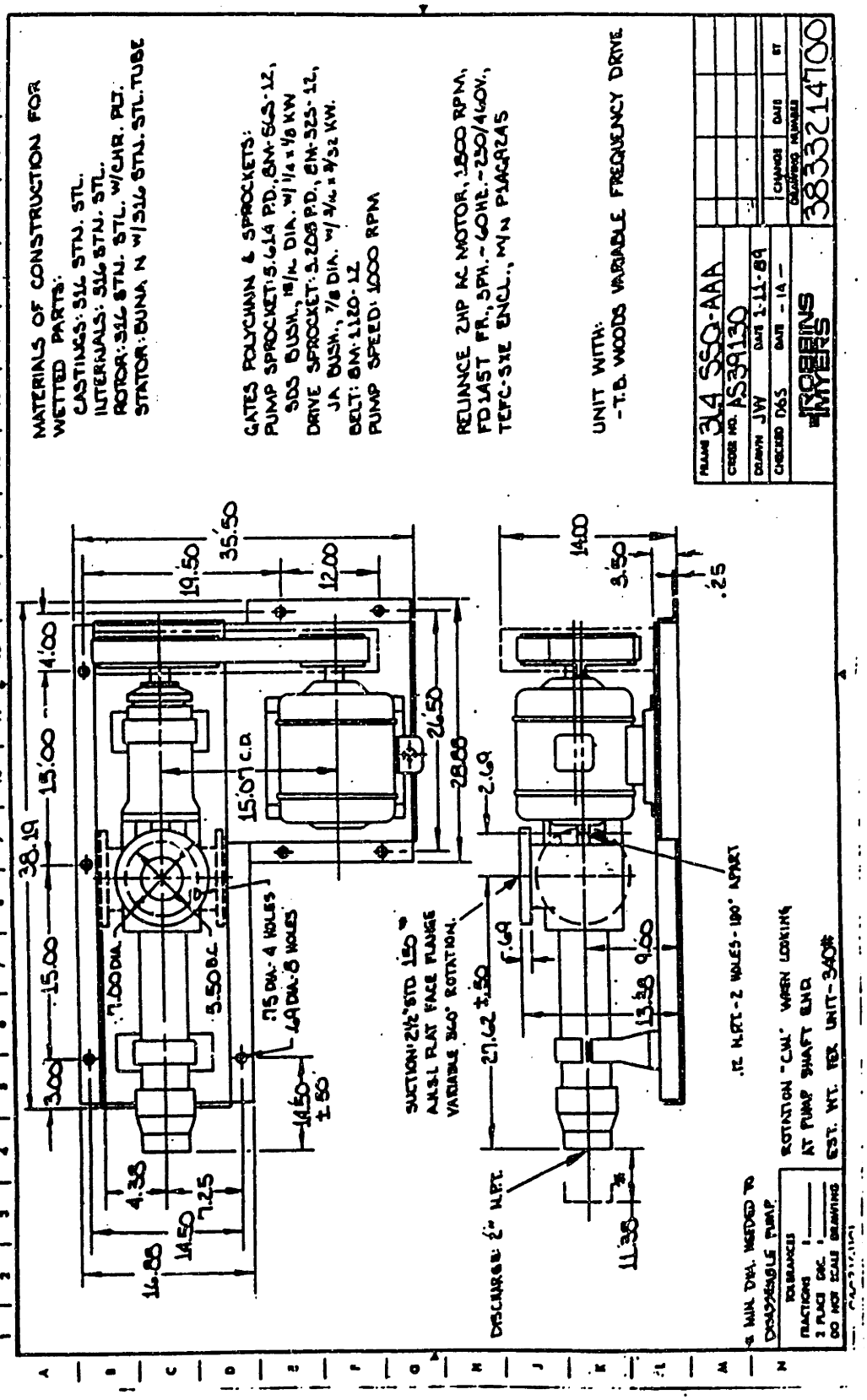


Figure 3.3.2: Moyno-Pump Schematic

pressure range was rated from 10 psig to 100 psig, and its designated capacity was rated from 2 gpm(0.13 l/s) to 17 gpm(1.07 l/s). The pumping capacity actually realized was 3.2 gpm(0.2 l/s) to 19.2 gpm(1.21 l/s). The pump had size-4 pumping elements and originally three stages. Because the 2-Hp motor could not turn over the 3L4 rotor frame, a 2L4 rotor frame was used while the 3L4 stator frame remained. The SSQ designation indicated that the body casting and all wetted internal parts were 316 stainless steel and that the stator material was Buna "N" 100, 700 Durometer. The AAA designation identified the sealing, internal, and rotor variations as braided teflon & graphite packing, standard plated shaft, and standard size with chrome plating, respectively. The discharge end came fitted with a 2" NPT female thread; the suction end came fitted with a 2½" flange. The timing belt provided the mechanical connection between the pump's rear pulley and the drive pulley of the Reliance 2-Hp TEFC-XE motor. The removable belt guard covered both pulleys and the timing belt, protecting them from being accidently contacted. The Reliance, 2-Hp, TEFC-XE, Model- P14G9245 motor had a 145T frame and was placed atop the base parallel to and opposite from the pump. The three-phase motor was designed to operate 230 VAC, 60 Hz current. Its rated speed was 1800 rpm.

A T. B. Woods 2-Hp variable-frequency E-trAC AC Inverter, Model- AFC2002-0B2, controlled the Reliance motor remotely. The drive unit was located above and near the test-pipe section, where other instruments were located. A long, well-protected, well-insulated conduit housed the wires electrically connecting the inverter and the motor. The inverter provided adjustable frequencies and constant torque to the motor. The inverter delivered up to 2-Hp to the motor. The CPU was the "brain" of the inverter and consisted of a 16-bit microprocessor and a custom Large Scale Integrated(LSI)

circuit.The inverter was programmable via a soft-touch membrane keypad on the front panel. Eight snap-dome switches, a four-digit, seven-segment, LED display, and a 10-segment LED bargraph comprised the keypad.

(3) Pressure-Transducer Board

The pressure-transducer(PT) board shown in Figure 3.3.3 supported the three PTs, the valves, fittings, and tubing that hydraulically connected the PTs to the pressure-tap lines. A 14" × 19" × ⅛" aluminum plate bolted onto two foot-long pieces of unistrut channel. These two channels bolted upright onto the P1001C at their lower ends. The board stood in front of and adjacent to the test-pipe section. As seen from behind the board, the 10-psid, 1.0-psid, and 0.1-psid PTs mounted from left to right across the top of the aluminum plate at 5½" intervals. The pressure equalizing(PE) valve was a ¼" brass 2-way ball valve and was located about two inches below the 1.0-psid PT. To either end of the PE valve connected the branch run of a ¼" brass union tee via a ¼" brass port connector. From the top run of each of these two tees emerged a short length of ⅛" flexible tubing with a ⅛" nut and ⅛" nylon ferrules on its free end. Each ⅛" nut attached directly onto a PT arm, connecting the PT and the board. To the bottom run of each tee attached a ¼" brass union cross via a ¼" brass port connector. A ¼" brass 2-way ball valve connected to the outer arm of each cross. On the left cross, nearer the 10-psid PT, the 2-way ball valve received the tap line from tap 1(T1). On the right cross, nearer the 0.1-psid PT, the 2-way ball valve received the tap line from T4. A ¼" brass 3-way ball valve connected to the lower arm of each cross. On the left cross, a 3-way

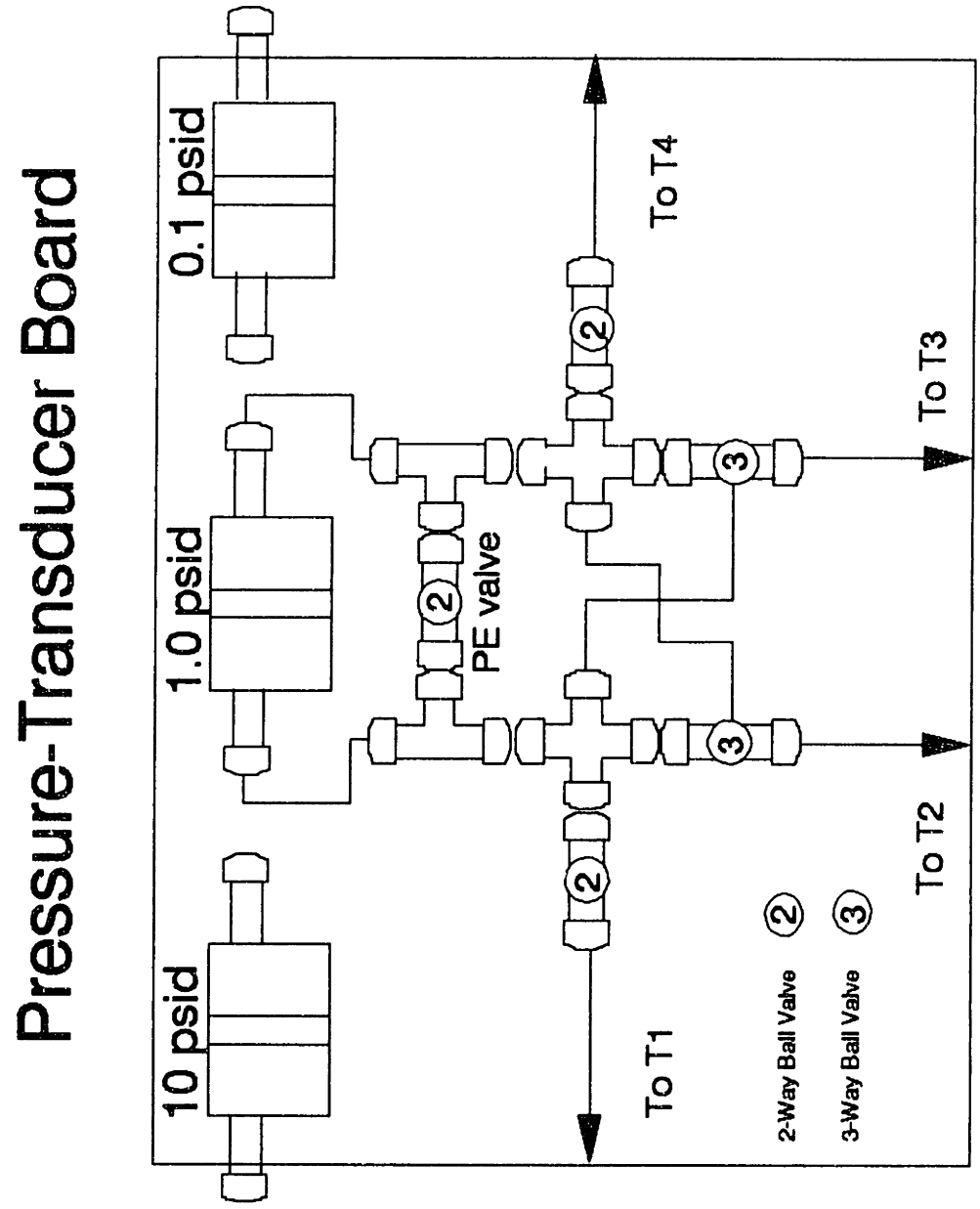


Figure 3.3.3: Pressure-Transducer Board

ball valve received the tap line from T2 on its lower run. Out of the right arm of the left cross, a ¼" flexible tube plugged into the left arm of the right cross. On the right cross, the 3-way ball valve received the tap line from T3 on its lower run. Out of the left arm of the right cross a, ¼" flexible tube plugged into the right arm of the left cross.

With the PE valve closed, the pressure drop across any tap pair could be determined by the proper positioning of the four valves. To test the integrity of the board, the two open valves, the others already closed, were suddenly closed while measuring the pressure drop. The pressure drop reading remained constant for several minutes, indicating that the board had no pressure leaks.

(4) Flow-Control Unit

A 10" × 12" × ⅛" aluminum plate served as the platform for the flow-control unit. A schematic is presented in Figure 3.3.4. Two 9/16" holes were drilled along the bottom plate to fasten the plate to the P1001C that supported this part of the flow system. Just above these bolt holes smaller holes were made to install a ¾" stainless-steel ball valve(B5) with ¾" female NPT fittings. About 6" higher on the plate, a large hole was cut from the plate to accommodate a ¾" stainless-steel 10-turn needle valve(N1) with ¾" port fittings. A ¾" stainless-steel male run tee installed directly into the upstream female fitting of the ball valve. The most downstream end of the test-pipe section entered directly into this tee. A ¾" stainless-steel male connector fit into the valve's downstream female fitting. Via a ¾" stainless-steel port connector, the ¾" stainless-steel male connector joined to a ¾" stainless-steel union tee, through which fluid exited the flow-

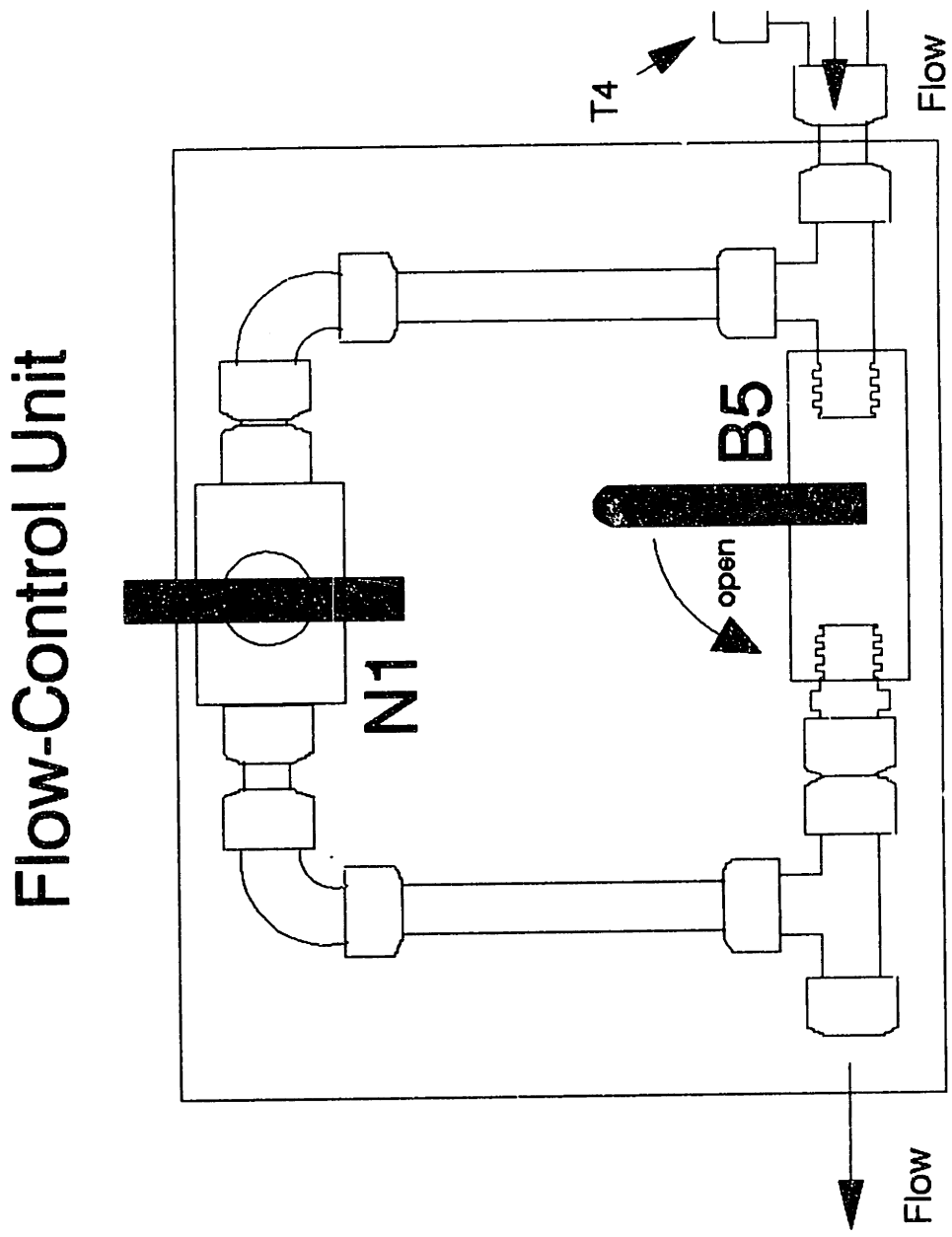


Figure 3.3.4: Flow-Control Unit

control unit. The needle-valve bypass loop began from the male branch run of the upstream tee. An extra length of ¾" stainless-steel tubing, a ¾" stainless-steel elbow, and a very short piece of ¾" stainless-steel tubing in series linked the male branch run with the upstream end of the needle valve. The same arrangement in reverse order connected the downstream end of the needle valve with the branch run of the downstream tee. The plate bolted directly onto the P1001C, just downstream of the test-pipe section.

(5) The Timer and Flow-Diverter Unit

Under gravity-driven flow conditions, this unit measured the time interval that elapsed while collecting a volume of system effluent. Its main components were an electronic timer, a switch box, a ring-stand-mounted rotating arm with snap switch, and a ring-stand-mounted funnel as shown in Figure 3.3.5. A large vessel received the diverted flow for later volumetric measurement.

A DX100 Solid State Time/Count Totalizer measured the elapsed time and provided a visual reading on a 4½-digit, ½"-high, LCD display. It required 120 VAC, 60 Hz cuurent. Proper wiring was necessary to activate the 1999.9-second timing range and to create a remote reset switch. A 2¼" × 2¼" × 5" aluminum switch box housed the reset switch. On the box, red and green lights signaled the open and closed condition, respectively, of the timing circuit. Mounted near the pivoting arm, a snap switch toggled the timing circuit as the arm's trip screw would either press or release the snap switch.

A straight length of ½" copper tubing with a gentle 90°-bend at the discharge end comprised the pivoting arm. The copper tube's straight end fit tightly into and passed

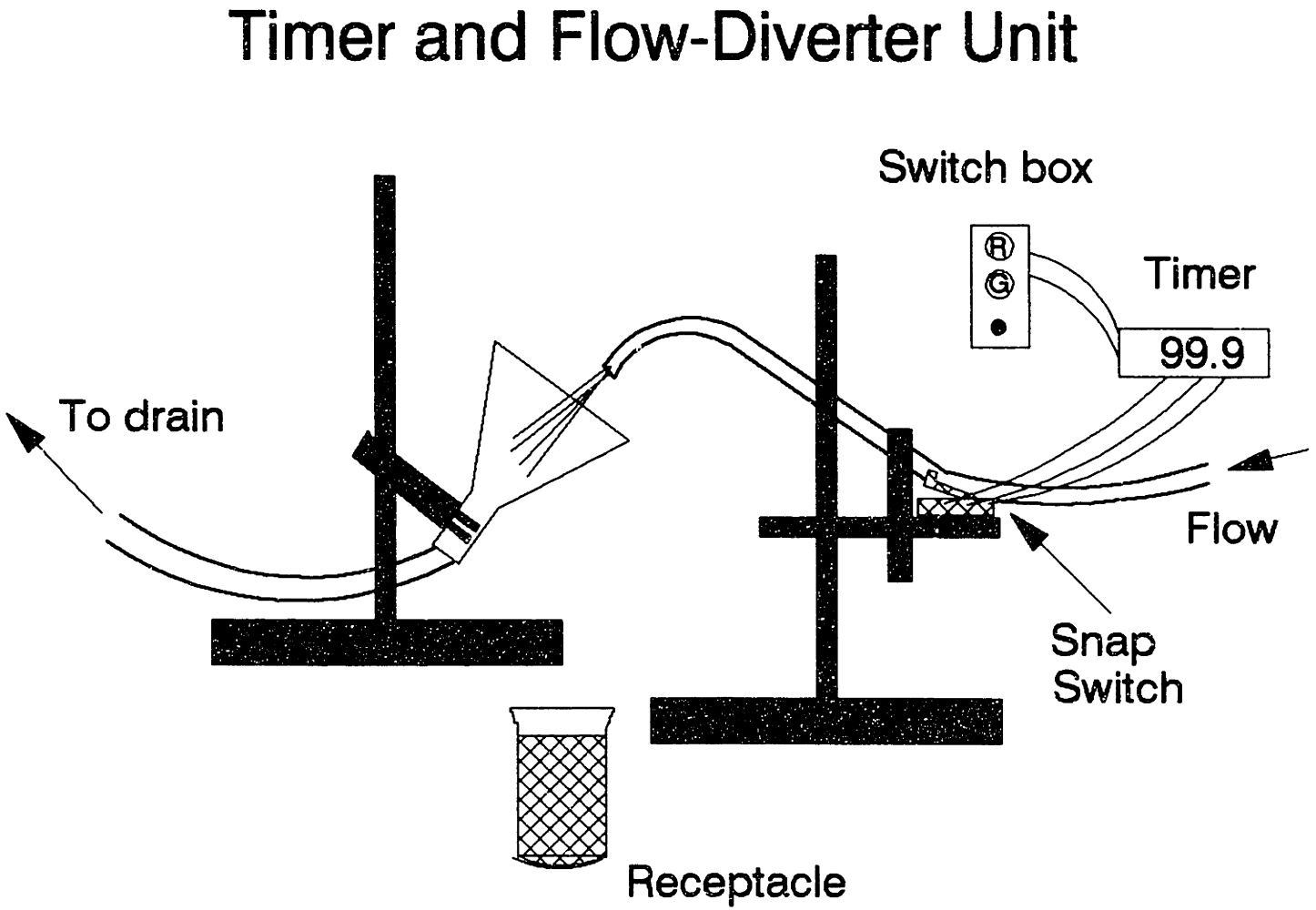


Figure 3.3.5: Timer and Flow-Diverter Unit

through a bored-through rod-end connector. One end of a ½" flexible tube attached onto the copper tube by a wormhose clamp; its other end attached onto a ½"-stub-to-¾"-port reducer. This reducer joined onto the ¾" stainless-steel male tube adapter on the rear valve(B6). The other hole of the bored-through rod-end connector was perpendicular to the first hole and loosely held an aluminum rod to permit rotation of the arm about the rod. This aluminum rod fit tightly into another bored-through rod-end connector, which held a second aluminum rod perpendicularly. The snap switch attached to the second rod by a screw. A ring stand supported this second aluminum rod at one end via a regular clamp holder.

A ring-stand-mounted funnel received the undiverted flow from the arm's bent discharge end. Gripping the ring stand, a regular holder clamped onto a three-prong clamp. This three-prong clamp gripped the large powder funnel just below its cone. One end of a long 1" flexible tube fitted over the funnel's tip while its other end went into the drain.

(6) Temperature-Probe Unit

The temperature probe measured the temperature of the fluid leaving the system. A ¾" stainless-steel union tee, a 5kΩ thermistor in a ⅛" stainless-steel casing, a ¾"-tube-to-½"-NPT female tube adapter, and a ½"-NPT-to-⅛"-port male connector comprised the unit, as shown in Figure 3.3.6. Long wires connected the thermistor's two wire leads to the input terminals of the HP-3467A, which was internally configured to calculate the temperature in °C from the thermistor resistance. The thermistor had an

accuracy of 0.1 °C.

(7) Flexible-Pipe Section

The "flex section" consisted of a 2", braided, flexible, stainless-steel, metal-hose assembly with coupled 2" stainless-steel fixed flanges. Three pieces of honeycomb were placed inside as shown in Figure 3.3.7. The hose's corrugated inner surface had 30 "convolutions" per foot. Without the honeycomb, the extreme roughness caused a large pressure gradient along the section. The pressure drop could be calculated from the equation

$$\Delta P = \frac{NCV^2 R_o}{9256} \qquad (3.1\text{-}1)$$

The equation variables are: the pressure drop ΔP in psid/ft, the number of convolutions per foot N, the loss coefficient C = 0.05514, the velocity V in ft/s, and the Reynolds number R_o. At the maximum flow rate, Q_{max} = 19.2 gpm, ΔP/L = 23.6-psid/ft, and ΔP = 23.6 psid.

To calm the flow, three pieces of Spiral Wrap Tricomb Honeycomb were inserted into the flexible hose. That the presence of honeycomb was vital can not be overemphasized. Installing the three pieces erased flow artifacts created by the pump and corrugated inner-surface of the flexible pipe. Each 3"-long, 2"-OD cylindrical piece was a tightly-rolled sheet of ¼"-cell honeycomb encased in a stainless-steel sleeve. In each cell, which was closer to ⅛" in size, Re_{max} = 2120 with T_w = 13.6 dyne/cm^2. This compared to Re_{max} = 33900 with T_w = 67800 dyne/cm^2 in the empty hose.

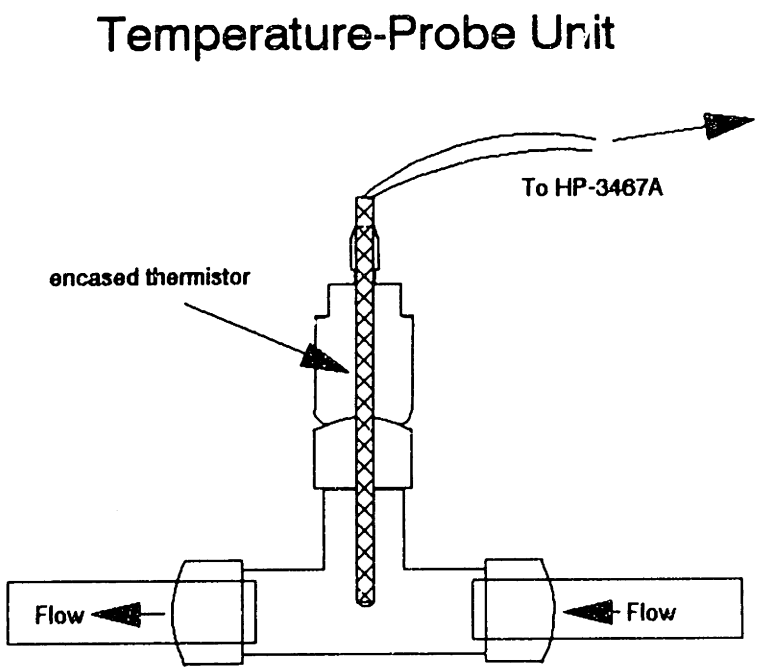


Figure 3.3.6: Temperature-Probe Unit

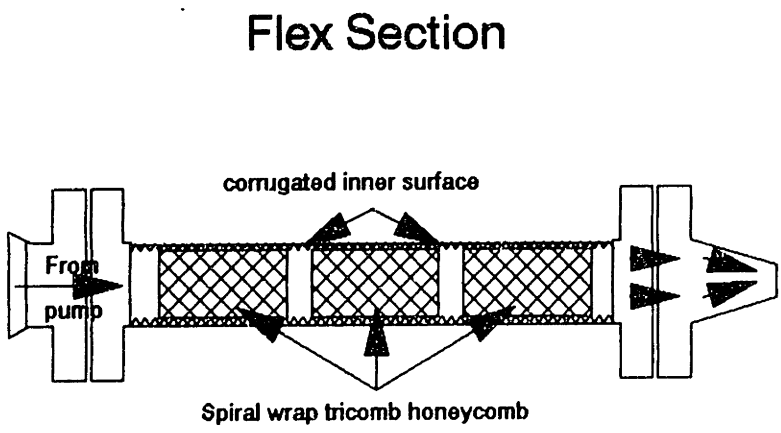


Figure 3.3.7: Flex Section

3.4 Experimental Equipment

(1) Pressure Transducers and Carrier Demodulator

Three differential pressure transducers(PT) with range maxima of 0.1-psid, 1.0-psid and 10-psid were used to measure the pressure drop in the test-pipe section. All were Model CJ3D Differential Pressure Transducers made by C. J. Enterprises. They operated on the variable reluctance principle. Their VDC output was linear with imposed pressure differential to within $\pm 0.5\%$ of full scale. Hysteresis was 0.5% of full scale(FS), and overpressure was 200% of range with less than 0.5% FS zero shift. Their stainless-steel diaphragms and pressure cavities resisted corrosion from brine. Stainless-steel ½" fittings, called arms, screwed into the pressure ports of the PTs and accepted the two small tubes from the PT board. The maximum temperature errors were 3% FS for ranges above 1.0-psid and 5% FS for ranges below 0.1-psid.

A Model CJCD-4111M Carrier Demodulator was used to convert reluctance output from the PT to an electric DC signal. The demodulator operated on unregulated 115 VAC, 60 Hz current and provided FS output of ± 10 VDC. In practice, however, the FS scale output was about ± 13.5 VDC, depending upon the PT in use. Its maximum output could be adjusted from ± 1 VDC to ± 10 VDC by setting the span dial(S) between zero and ten. Its zero level could be adjusted up to $\pm 75\%$ FS by setting a zero dial(Z) between zero and ten. Its linearity and drift varied less than $\pm 0.5\%$ FS. Its temperature error was less than 0.017% FS per °C.

(2) Mass-Flow Meter Unit

In the gravity-driven flow system at high flow rates, the mass-flow meter measured and displayed the flow rate in ml/s and the cumulative fluid volume in liters. Three major components comprised this unit: a Model D40 S-SS Mass-flow Element(MFE), a Model DUL115-AF Remote Electronics Unit(REU), and a Model FMS-3 Flow Monitoring System(FMS).

Externally, the MFE consisted of a 8¾" × 7½" × 2¼" hermetically-sealed, stainless-steel, sensor housing and a 7" stainless-steel cylinder having tapered ends with ⅜" NPT male fittings. The housing encased two parallel U-tubes, two position detectors, a temperature sensor, and a drive coil. The drive coil received signals from the REU, processd the input, and vibrated the tubes accordingly. The flow entered one end of the cylinder, flowed through both vibrating U-tubes, and emerged from the cylinder's other end as a single stream.

The MFE measured from 12 ml/s(0.19 gpm) to 900 ml/s(14.3 gpm) with a ±0.22% error at full scale. While the MFE provided non-invasive measurements, it incurred a large ΔP penalty. In the gravity-driven flow system, at $Q_{max} \approx$ 250 ml/s(3.96 gpm), the $\Delta P_{MFE} \approx$ 4.4 psid, or about 70% of the available pressure head! In the pump-driven flow system, at $Q_{max} \approx$ 1210 ml/s(19.2 gpm), the ΔP_{MFE} would have been about 95 psid and would have consumed almost all of the pump's rated discharge pressure! Operating the pump at moderate Q with the MFE on-line caused vibrational feedback between the pump and MFE. The resultant surging flow and large ΔP penalty made using the MFE in the pump-driven flow system unfeasible.

A teflon cable electrically connected the MFE to the REU. The REU required 115 VAC and operated in the 0 - 900 Hz frequency and 4 to 20 mA ranges. Its five basic components were drive, signal, isolation, analog, and frequency boards. Measuring the coriolis force generated in the vibrating tubes, the REU calculated the mass flow rate. The output from the REU were sent, via two wires, to the FMS-3. On the back of its 5.66" × 5.66" × 6.50" housing, a junction box received the power cable and wires from the REU. The front panel contained a two-digit LED mode display, a six-digit LED setup/rate display, an eight-digit LED totalizer display, and a six-key, membrane, function panel. The FMS-3 was programmable and could display flow rates and volumes in various common units.

As shown in Figure 3.4.2, a unistrut frame held the three components in close proximity. Separated by 22½", two floor-anchored, five-foot-high posts supported three cross beams. From lowest beam, two short arms held the MFE level with the test-pipe section, at a height just enough for the sensor housing to hang down without touching the floor. Between the two upper beams, the FMS-3 and REU mounted onto a 12¼" × 19" × ¼" aluminum plate that spanned the beams. The FMS-3 inserted into a square hole cut into the upper half of the plate so that its front panel was flush with the plate. Just beneath, the REU mounted horizontally across the lower half of the plate.

(3) Water and Mercury Manometers

The 0.1-psid and 1.0-psid PTs were calibrated with a water-filled manometer constructed from two glass tubes, a meter stick, two ring stands, a small separation

Mass-Flow Meter Unit

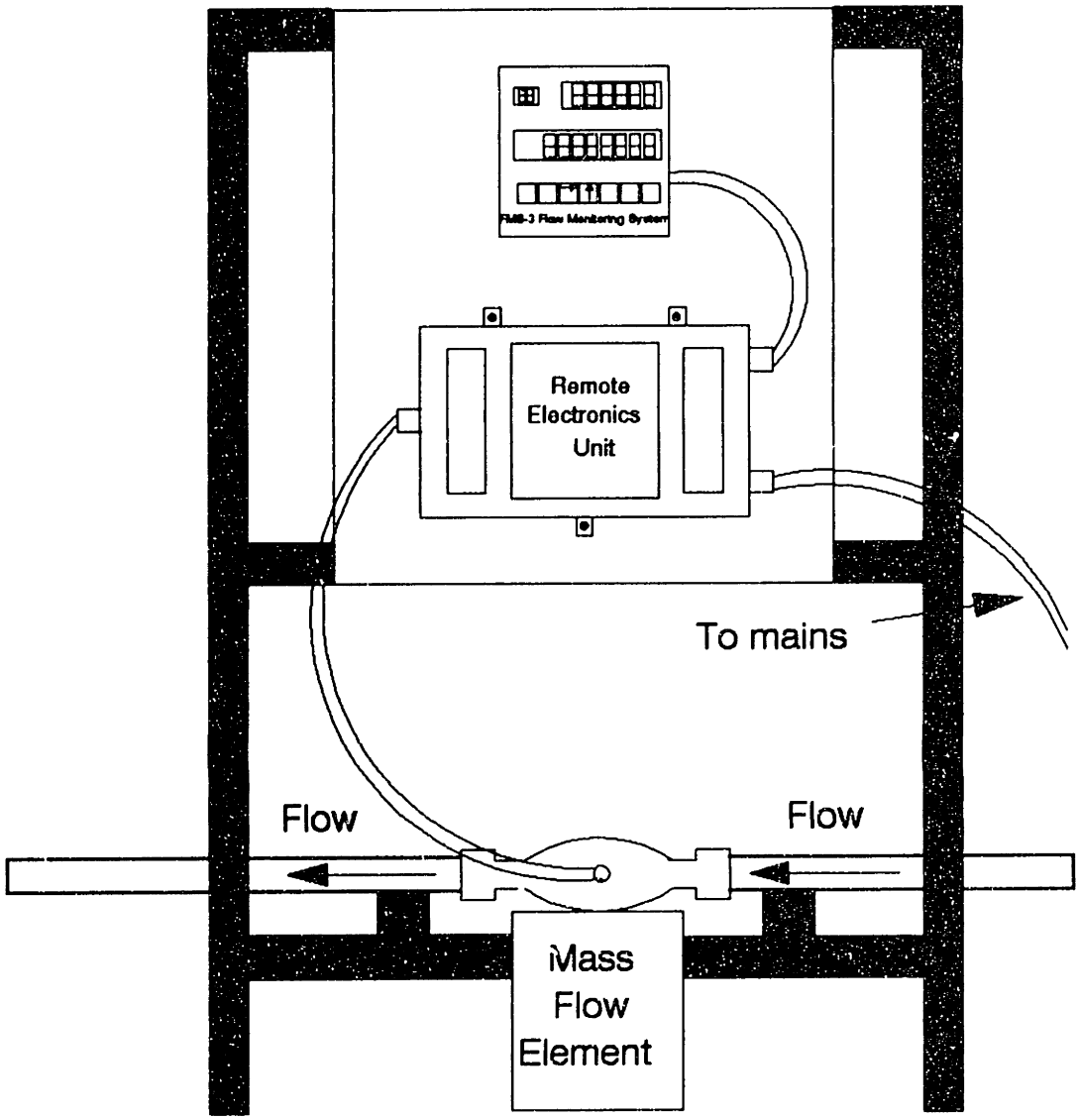


Figure 3.4.2: Mass-Flow Meter Unit

funnel, tubing, valves, and fittings. The 10-psid PT was calibrated with a mercury-filled manometer comprised of a U-tube with meter stick, mercury, a ring stand, a compressed air cylinder with regulating valve, a mercury trap, tubing, valves, and fittings. More detailed descriptions and Figures C3.4.3a and C3.4.3b are provided in §C3.4 in Appendix C.

(4) Digital Multimeters

A Hewlett-Packard Model 3467A Logging Multimeter displayed and printed the output signals from the carrier demodulator and the temperature probe. The HP-3467A had four channels, a 4½-digit LED readout, and a 4-function printing multimeter. The four-channel scanner read sequentially from all four channels and sent sequentially the input to the logging multimeter. The four functions were DC volts, AC volts, ohms, and temperature. The thermal printer created a hardcopy of the channel data and elapsed time with up to 16 characters per line and could be initiated manually or by a timer. A monolithic, 8-bit, parallel microprocessor and a Motorola MC6802 MPU with a 6k-byte ROM Operating System controlled the display, the printing, the internal data transfers, and the mathematical operations. The HP-3467A had accuracies of $\pm$(0.03% of the VDC input + 1 count) and $\pm$0.3°C.

During the experimental runs, a HP-3467A received input from the carrier demodulator and the temperature probe. It displayed the output voltage from the carrier demodulator on its LED readout in real time. Scanning these data every four seconds, it printed the results on thermal paper. The HP-3467A also measured the esistance in

the temperature probe's 5kΩ thermistor and converted it internally into a temperature reading in °C.

In calibrating the 0.1- 1.0-psid PTs, the HP-3467A provided visual readings from the carrier demodulator output. A small Hewlett-Packard 34702A Digital Multimeter displayed the output during the calibration of the 10-psid PT only.

3.5 Chemicals

The flow-enhancement additives were commercial polymers obtained directly from the manufacturer as one pound samples. The precise chemical composition, weight- or number-averaged molecular weight, polydispersity, and backbone charge were not known. Table D3.5 in Appendix D reports the best available data. Most of the polymers were polyacryalamide-based. Usually, "pure" polyacrylamide was partially hydrolyzed to create sodium acrylate or acrylic acid residues randomly along the backbone; however, some samples were co-polymers of polyacrylamide and sodium acrylate.

To alter the equilibrium conformation of polyelectrolytes in solution, pure NaCl crystals(Mallinckrodt and Fisher), having less than 0.0001% impurities, were added to experimental solutions. Besides their affect on polyelectrolytic polymers, aqueous Na^+ and Cl^- ions, even at 0.00001 N concentrations, overwhelmed the ions contributed by aqueous H_2CO_3, arising from the small solubility of CO_2 in water. A 5% solution of NaCl at 25°C had a pH of 6.9, nearly neutral.

CHAPTER IV

PROCEDURES

This chapter describes in detail the various procedures performed in the course of this thesis work. The procedures are presented in the following order: polymer preparation, system calibrations, experimental technique, and data reduction.

4.1 Polymer Master Batch Preparation

Two related methods were used in this thesis. The first requires a vacuum oven while the second does not; both yielded reproducible, consistent results.

4.1.1 Master Batch Preparation: Method #1

1.1) A five-liter, baffled, stainless-steel vessel was filled with about four liters of distilled water.

2.1) The mixer speed was initially set at 400 rpm to ensure rapid polymer dispersal without degradation.

3.1) About 15 grams of polymer were slowly added into the churning water.

4.1) The mixer speed was maintained for another 10 minutes after the polymer had been added completely.

5.1) The speed was lowered to about 200 rpm for about three hours. Polymer networks and lumps were broken up manually with a stirring rod or spatula.

6.1) The speed was further reduced to about 120 rpm for another three hours.

7.1) The mixer was stopped, the impeller was removed, and the vessel was covered with Saran Wrap™.

8.1) After a day or two, the master batch was decanted successively into four or five clean, one-quart, suitably labelled, glass jars with screw lids.

9.1) For each jar at least three aluminum weighing boats were labelled for use in determining the average weight concentration of the polymer solution in each jar. To reduce the chances of contamination by foreign matter, the boats always were placed on clean tissue, except when in the oven, and were handled only with forceps.

10.1) An empty boat was weighed on an analytical balance and then filled with about 15 grams of fluid. It was immediately weighed and placed in the vacuum oven.

11.1) The samples were desiccated in the vacuum oven at about 60°C and 40

mm Hg absolute for at least 10 hours.

12.1) After desiccation, the oven was turned off and left to cool to ambient temperature.

13.1) The polymer-residue encrusted boats were weighed. The average weight concentration, c, as well as the standard deviation, σ_c, for the fluid in each jar was determined from these data. Table 4.1.1 lists c and σ_c for all the polymer characterizations performed by Method #1.

Table 4.1.1
Polymer Characterization Data for Method #1

Date	Polymer	c	σ_c	σ_c/c
		(wppm)	(wppm)	(%)
12/20/88	C832A	2449.9	24.3	0.99
12/20/88	C832A	2579.0	35.8	1.39
12/20/88	C832A	2656.8	25.5	0.96
12/20/88	C832A	2840.7	81.0	2.85
01/28/89	C837A	2679.6	27.2	1.02
01/28/89	C837A	2706.3	14.5	0.54
01/28/89	C837A	2773.6	40.6	1.46
01/28/89	C837A	2768.7	43.9	1.59
01/28/89	C837A	2996.6	23.5	0.78
02/25/89	C836A	2766.1	28.0	1.01
02/25/89	C836A	2765.2	36.4	1.32
02/25/89	C836A	2835.6	53.8	1.90
02/25/89	C836A	2918.2	58.5	2.00
05/01/90	C832A	2730.0	25.6	0.94
05/01/90	C832A	2692.0	38.3	1.42
05/01/90	C832A	2742.1	50.0	1.82
05/01/90	C832A	2714.9	27.2	1.00
05/01/90[a]	C832A	2739.3	58.2	2.12

(a) The oven became unreliable soon after. Method #2 was adopted for the remainder of the investigation.

4.1.2 Master Batch Preparation: Method #2

1.2) From the polymer solution concentration desired in an experiment and the solvent volume, the mass of polymer required was calculated.

2.2) A baffled five-liter stainless-steel vessel was filled with about four liters of distilled water. When the stainless-steel vessel was in use, a one-gallon glass jar filled with about three liters of distilled water was used.

3.2) An empty boat was weighed on an analytical balance. The required amount of polymer was put into the boat, which was reweighed. For maximum precision the boats were handled only with forceps.

4.2) With the impeller going at about 400 rpm, the polymer was added slowly into the water. Special care was taken to prevent water from splashing onto the boat.

5.2) The empty boat was weighed on the analytical balance. The solvent volume for the experimental run was adjusted for any difference between the calculated required polymer mass and actual polymer mass in the vessel.

6.2) A wash bottle containing distilled water was used to remove undissolved polymer stuck to various surfaces.

7.2) The mixer speed was maintained at 400 rpm for another 10 minutes after the polymer had been added completely.

8.2) The speed was lowered to about 200 rpm for about three hours and then further reduced to about 120 rpm for another three hours. To facilitate thorough mixing, from time to time the impeller speed was increased, and more distilled water was added.

9.2) After the mixing, the impeller was lifted out of the solution, while remaining suspended above it, and its shaft and blades were rinsed thoroughly free of polymer, the washings falling back into the vessel. Thus, all the polymer added remained in the vessel.

10.2) The vessel was covered immediately with Saran Wrap™.

11.2) This solution was used within two days.

Table 4.1.2 lists the following data for solutions prepared by Method #2 from each experimental run: the mass of polymer deposited into the left and right tanks, the total fluid volume in both tanks, and the best c for the solution in each tank.

Table 4.1.2
Polymer Characterization Data for Method #2

Run(s)	Polymer Mass Per Tank		Solvent Volume Per Tank		c_{Left}	c_{Right}
	Left	Right	Left	Right		
	(g)	(g)	(ml)	(ml)	(wppm)	
Q2P11456/3157	3.5996	3.6145	180526	181158	20.00	20.01
B1P21477/3178	17.66	17.68	177000	177400	100.1	99.95
B5P11480/3181	8.94	9.06	179474	182211	49.96	49.87
B2P11483/3184	3.5902	3.5971	179895	180316	20.02	20.01
B1P11486/3187	1.8027	1.8029	181368	181579	9.969	9.958
B5P01401(a)		1.7810		178632		5.00
A1P21403/3104	17.68	17.70	177400	177600	99.95	99.95
A3P21406/3107	53.35	53.82	178632	179895	299.5	300.0
A3P11409/3110	5.13	5.29	171474	177200	30.01	29.94
A1P31412/3113	166.31	169.59	166667	170000	999.8	999.6
D1P21415/3116	17.45	17.63	175400	177000	99.77	99.89
D3P11418/3119	5.15	5.13	172316	171474	29.97	30.00
D3P21421/3122	53.48	53.55	179053	179053	299.5	299.9
D1P31424/3125	141.33[b]	139.41	141789	140600	1000.	993.5
U1P21427/3128	17.57	17.67	176200	177200	100.0	100.0
V1P21431/3132	17.58	17.60	176000	176400	100.2	100.1
V1P11434/3135	1.7791	1.7869	177400	179895	10.06	9.962
V3P11437/3138	5.3630	5.3685	179474	179474	29.97	30.00
Y1P01443/3144	0.1690	0.1831	169556	183684	1.000	1.000
Y2P01446/3147	0.3430	0.3538	172105	177400	1.999	2.000
Y5P01449/3150	0.8825	0.9141	177000	183263	5.001	5.003
Y1P11452/3153	1.8010	1.7798	180737	178421	9.994	10.00
Y1P11455/3156	3.5879	3.5968	179895	180316	20.00	20.01

Run(s)	Polymer Mass Per Tank		Solvent Volume Per Tank		c_{Left}	c_{Right}
	Left	Right	Left	Right		
	(g)	(g)	(ml)	(ml)	(wppm)	
Y1P1DEGL		1.7935		179895		10.00
Y1P1DEGH		1.8173		182211		9.83
Y5P11459/3160	8.9988	9.0056	180526	180526	49.99	50.03
W1P11462/3163	1.8069	1.8035	181158	180947	10.00	9.997
W3P11465/3166	5.4151	5.3992	180947	180526	30.01	30.00
W3P11468/3169	17.9968	18.0025	180737	180526	99.56	100.0
W3P11371/1272	5.3817	5.3960	179895	180316	30.00	30.01

(a) This tank was split in subsequently.
(b) Maximum amount due to small losses.

4.2 Transducer Calibration

The 0.1- and 1.0-psid differential pressure transducers (PTs) were calibrated with a water-filled manometer; the 10-psid differential PT was calibrated with a mercury-filled manometer.

The calibration procedure for the 0.1- and 1.0-psid transducers was:

1.1) The PTs were connected to the water-filled manometer via the long ⅛" flexible vincon tubes with ⅛", stainless-steel nuts and nylon ferrules. The bleed screws were opened to fill the diaphragm chamber entirely with fluid and to remove trapped gas.

2.1) The electrical connections between the PT and carrier demodulator and between the carrier demodulator and HP-3467A Logging Multimeter were made.

3.1) Before turning on the demodulator, the span(S) and zero(Z) dials were set at the values to be used during the experiment. The span setting changed very little except after the PT was repaired; the zero setting invariably required adjustment.

4.1) The arms of the manometer were hydraulically isolated by closing the stopcock. The initial water column heights, which were arbitrary but approximately equal, and PT output, which was close to zero volts, were recorded.

5.1) The water reservoir was lowered incrementally down the ring stand by adjusting the clamp supporting the reservoir. After the reservoir had been in place for 30 seconds, the water-column heights and output voltage were recorded. This greatly reduced, but did not eliminate, the problem of voltage drift. As seen in Figures 4.2.1 and 4.2.2, data taken as the pressure differential was increased did not exactly coincide with those taken when the pressure differential was decreased. This constituted voltage drift. Still, precise calibration constants were obtained. As seen from the r2 column in Table 4.2, the square of the correlation coefficient for each calibration was better than 0.999, indicating high linearity.

6.1) When either the PT output topped -10 volts or the imposed pressure differential exceeded -0.1 or -1.0 psid, the reservoir was no longer lowered. It was then

incrementally raised stopping at levels between those during lowering. In Figures 4.2.1 and 4.2.2 the alternating "up"(□) and "down"(+) symbols illustrate intermeshing h_l and h_r columns. Experimental liquid-column heights are listed in the data sheets corresponding to each figure.

7.1) Linear regression of these data provided the calibration constant in volt/psid, equal to the slope of the best-fit line of the output voltage versus differential pressure data. Figures 4.2.1 and 4.2.2 illustrate the regression of DP vs. V data; these data are listed in the DP and D<V> columns in the corresponding data sheet.

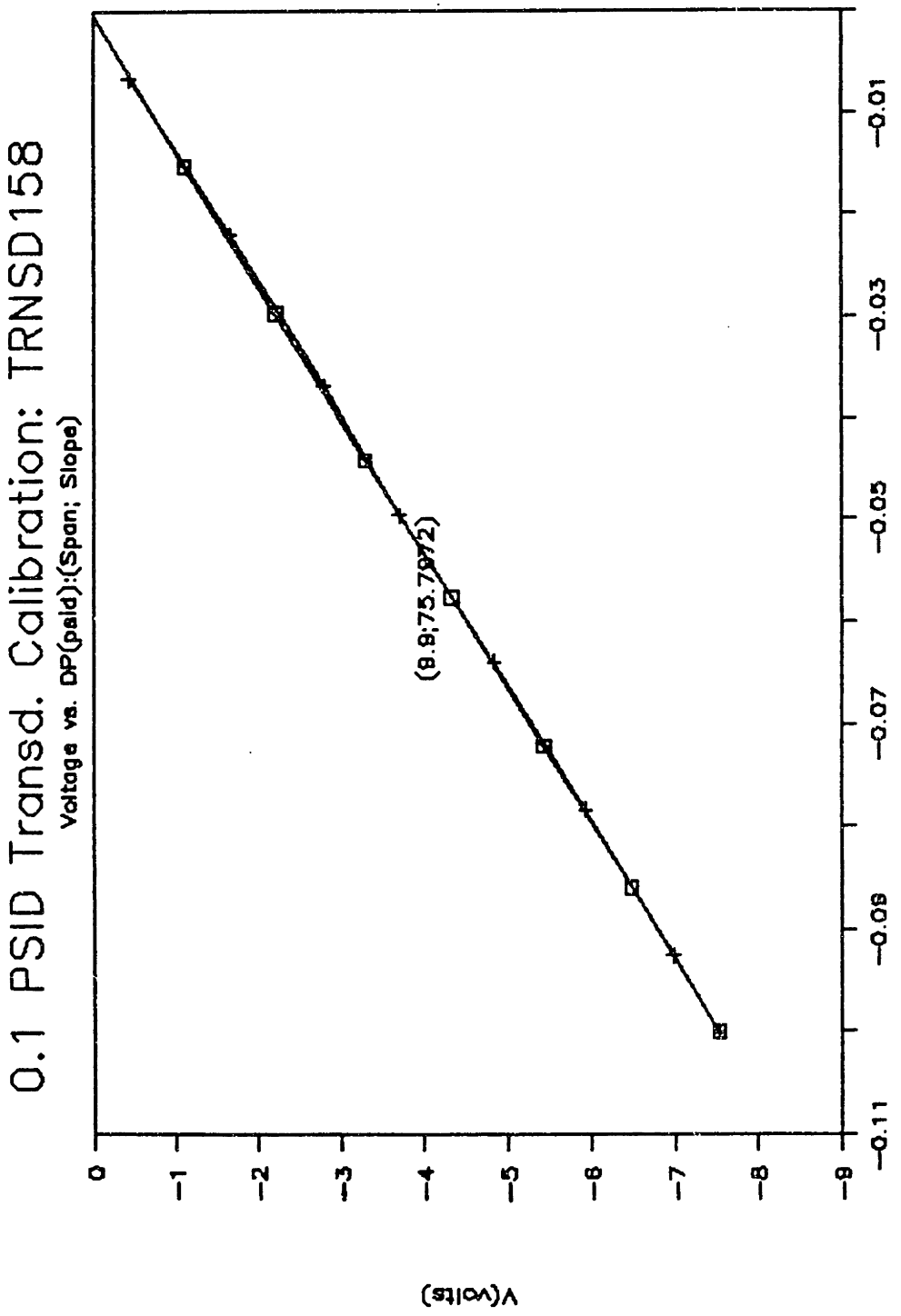


Figure 4.2.1: 0.1-psid Pressure-Transducer Calibration

Page 1 Typical Calibration Data for the 0.1 PSID Transducer

TRNSD158 Pressure Transducer Calibrations 5/15/90 16:06

0.1 PSID S = 9.9 Z = 7.45 t(deg C)= 23.8

	hl(mm)	hr(mm)	V)low	V)high	Dh	DP(psid)	D<V>
	471	471	0.027	0.028	0	0	0.0275
	471	460.2	-1.111	-1.11	-10.8	-0.01531	-1.1105
	471	450	-2.206	-2.205	-21	-0.02978	-2.2055
	471	439.8	-3.307	-3.306	-31.2	-0.04424	-3.3065
(9.9;75.7	470.9	430.2	-4.339	-4.338	-40.7	-0.05771	-4.3385
	470.9	420	-5.421	-5.42	-50.9	-0.07218	-5.4205
	470.9	410.3	-6.473	-6.472	-60.6	-0.08593	-6.4725
	470.9	400.3	-7.536	-7.535	-70.6	-0.10012	-7.5355
	470.9	405.6	-6.974	-6.973	-65.3	-0.09260	-6.9735
	470.9	415.6	-5.922	-5.921	-55.3	-0.07842	-5.9215
	470.9	425.8	-4.832	-4.831	-45.1	-0.06395	-4.8315
	470.9	435.9	-3.713	-3.712	-35	-0.04963	-3.7125
	470.9	444.9	-2.784	-2.783	-26	-0.03687	-2.7835
	470.9	455.3	-1.669	-1.668	-15.6	-0.02212	-1.6685
	470.9	466.2	-0.428	-0.427	-4.7	-0.00666	-0.4275

Data Sheet for Figure 4.2.1

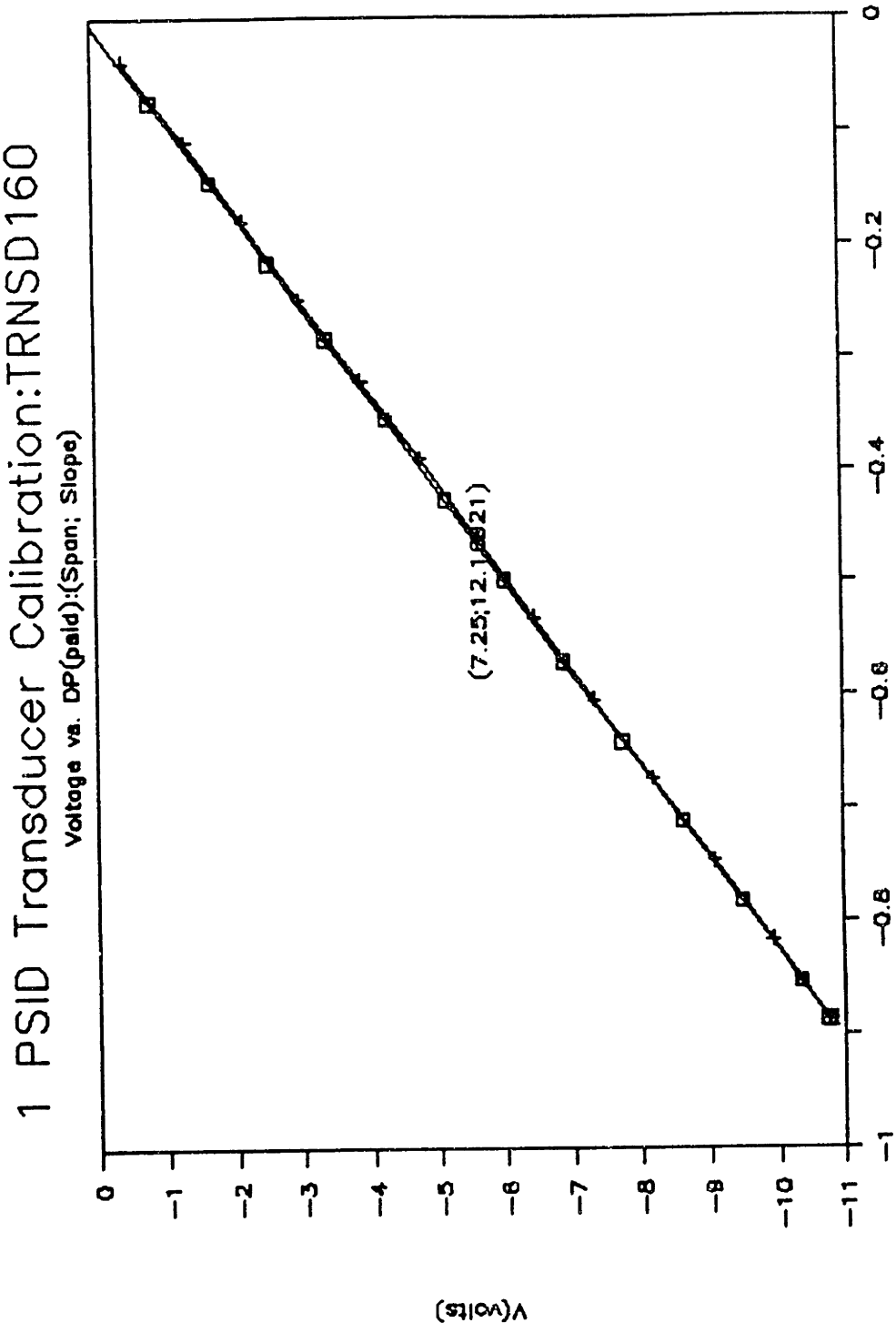


Figure 4.2.2: 1.0-psid Pressure-Transducer Calibration

Page 1 Typical Calibration Data for the 1.0 PSID Transducer

TRNSD160 Pressure Transducer Calibrations 5/20/90 15:44

1.0 PSID S = 7.25 Z = 8.25 t(deg C)= 23.1

	hl(mm)	hr(mm)	V)low	V)high	Dh	DP(psid)	D<V>
	702	702.3	0.07	0.071	0	0	0.0705
	701.9	650.1	-0.842	-0.841	-52.1	-0.07389	-0.8415
	701.9	600.1	-1.701	-1.7	-102.1	-0.14481	-1.7005
	701.9	549.9	-2.564	-2.563	-152.3	-0.21602	-2.5635
	701.9	501.5	-3.4	-3.399	-200.7	-0.28467	-3.3995
	701.9	451.5	-4.267	-4.266	-250.7	-0.35559	-4.2665
	701.9	400.8	-5.14	-5.139	-301.4	-0.42750	-5.1395
	701.8	350.3	-6.013	-6.012	-351.8	-0.49898	-6.0125
(7.25;12.	701.7	299.4	-6.897	-6.896	-402.6	-0.57104	-6.8965
	701.7	250	-7.753	-7.754	-452	-0.64111	-7.7535
	701.7	200.3	-8.615	-8.614	-501.7	-0.71160	-8.6145
	701.7	150.4	-9.47	-9.469	-551.6	-0.78238	-9.4695
	701.7	100.3	-10.337	-10.336	-601.7	-0.85344	-10.3365
	701.7	76.9	-10.755	-10.754	-625.1	-0.88663	-10.7545
	701.7	126.7	-9.905	-9.904	-575.3	-0.81599	-9.9045
	701.7	175.8	-9.069	-9.068	-526.2	-0.74635	-9.0685
	701.7	226.8	-8.197	-8.196	-475.2	-0.67401	-8.1965
	701.7	276.2	-7.349	-7.348	-425.8	-0.60394	-7.3485
	701.7	327.3	-6.47	-6.469	-374.7	-0.53147	-6.4695
	701.7	376.2	-5.636	-5.635	-325.8	-0.46211	-5.6355
	701.7	426.2	-4.773	-4.772	-275.8	-0.39119	-4.7725
	701.7	476.1	-3.911	-3.91	-225.9	-0.32041	-3.9105
	701.8	526.6	-3.028	-3.027	-175.5	-0.24892	-3.0275
	701.8	576	-2.184	-2.183	-126.1	-0.17885	-2.1835
	701.8	625	-1.339	-1.338	-77.1	-0.10935	-1.3385
	701.8	675.8	-0.448	-0.449	-26.3	-0.03730	-0.4485

Data Sheet for Figure 4.2.2

8.1) Due to its extreme sensitivity, the 0.1-psid PT was calibrated before and after each experiment. The calibration constant of the 1.0-psid PT was fairly stable($\pm$ 2%) over a month, but weekly calibrations were done. Table 4.2 provides the calibration historics for these PTs.

In calibrating the 10-psid PT, the general procedure was:

1.2) One PT arm was connected first to the compressed air supply via the long ⅛", flexible vincon tube with a ⅛", stainless-steel nut and nylon ferrules; the other arm was exposed to the atmosphere.

2.2) The electrical connections between the PT and carrier demodulator and between carrier demodulator and HP-34702A multimeter were made.

3.2) Before turning on the demodulator, the span(S) and zero(Z) dials were set at the values to be used during the experiment. The span setting changed very little except after the PT was repaired; the zero setting invariably required adjustment.

4.2) After the initial height and voltage data were recorded, the pressure release valve was **SLOWLY** opened, forcing the mercury from the right arm into the left arm of the glass U-tube. Then the pressure release valve was closed, trapping the compressed air and keeping the mercury elevated. After the mercury levels had been stable for about 30 seconds, the height and voltage data were recorded. This greatly reduced, but did not

eliminate, the problem of voltage drift. As seen in Figure 4.2.3, data taken as the pressure differential was increased did not coincide with those taken as the pressure differential was decreased. This constituted voltage drift. Still, a precise calibration constant was obtained. In the r^2 column of Table 4.2, high precision and linearity are indicated by $r^2 \geq 0.999$.

5.2) When the imposed pressure differential reached 10 psid, the pressure was released incrementally, stopping at levels between those during the pressure increase. The alternating "up"(□) and "down"(+) symbols in Figure 4.2.3 illustrate intermeshing h_l and h_r columns. Experimental liquid-column heights are listed in the data sheet corresponding to Figure 4.2.3.

6.2) Linear regression of these data provided the calibration constant in volt/psid equal to the slope of the best-fit line of the output voltage versus differential pressure data. Figure 4.2.3 illustrates the regression of the DP vs. V data; these data are listed in the DP and D<V> columns in the corresponding data sheet.

7.2) The calibration constant of the 10-psid PT was fairly stable($\pm$ 2%) over months. Monthly calibrations were done, unless a solvent run indicated that the calibration constant had changed. Table 4.2 also provides the calibration history of the 10-psid PT.

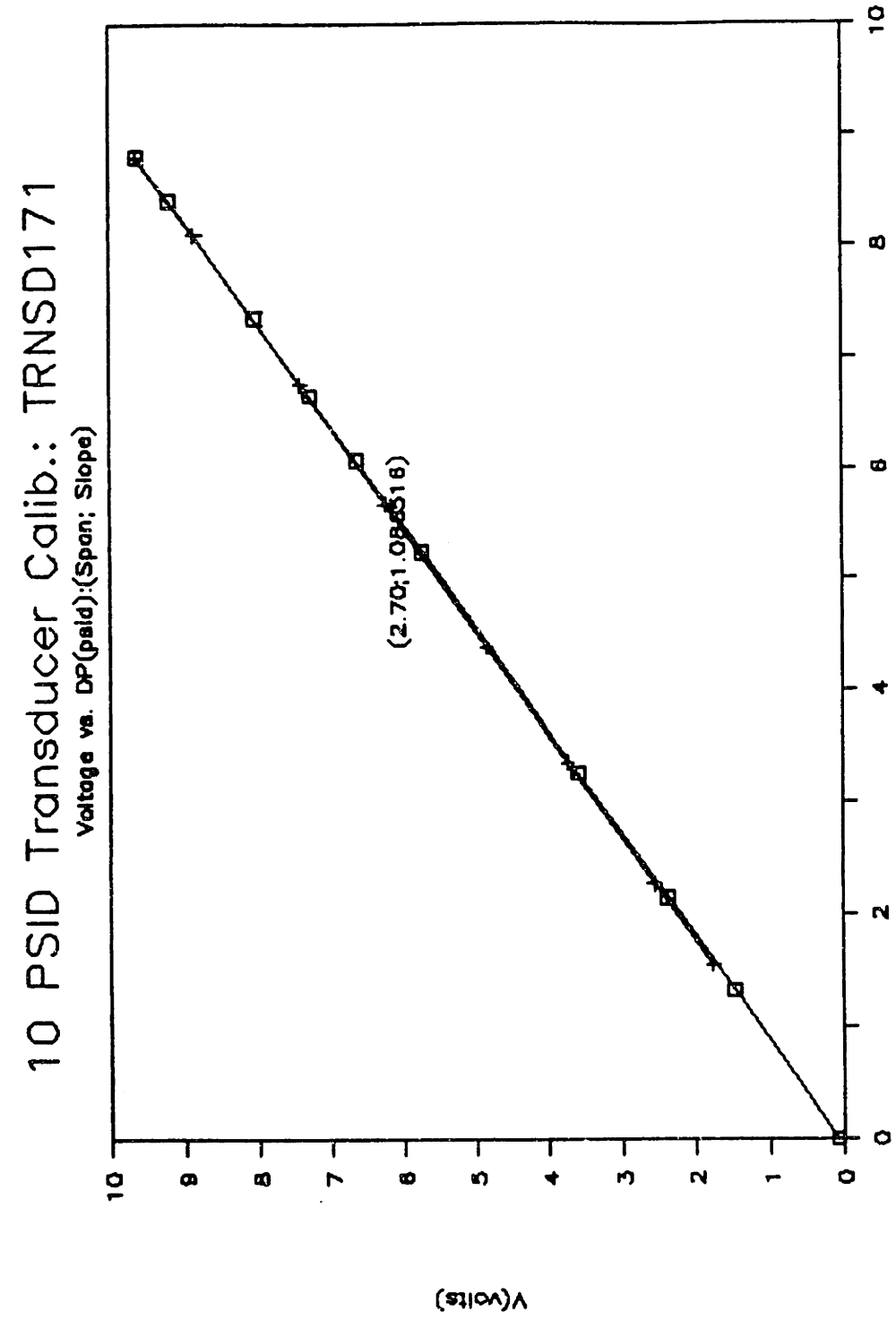


Figure 4.2.3: 10-psid Pressure-Transducer Calibration

Page 1 Typical Calibration Data for the 10 PSID Transducer

TRNSD171 Pressure Transducer Calibrations 7/6/90 10:50

10 PSID S = 2.70 Z = 2.7 t(deg C)= 24

	hl(mm)	hr(mm)	V)low	V)high	Dh	DP(psid)	D<V>
	333.2	333.2	0.0912	0.0913	0	0	0.09125
	359.8	291	1.4809	1.481	68.8	1.329364	1.48095
	376	264.7	2.3824	2.3825	111.3	2.150556	2.38245
	398	229.2	3.566	3.5661	168.8	3.261580	3.56605
(2.70;1.0	437.3	166	5.7217	5.7218	271.3	5.242102	5.72175
	453.9	139.9	6.6269	6.627	314	6.067158	6.62695
	465.3	121.2	7.2705	7.2706	344.1	6.648755	7.27055
	479.2	99	8.0378	8.0379	380.2	7.346285	8.03785
	500.5	65.4	9.1899	9.19	435.1	8.407071	9.18995
	508.3	53.1	9.6307	9.6308	455.2	8.795447	9.63075
	494.2	75.1	8.86	8.8601	419.1	8.097917	8.86005
	467.3	118.1	7.3946	7.3947	349.2	6.747298	7.39465
	446	152.4	6.2362	6.2363	293.6	5.672986	6.23625
	420.4	193.3	4.8347	4.8348	227.1	4.388062	4.83475
	400	226.3	3.7057	3.7058	173.7	3.356259	3.70575
	378.2	260.6	2.5623	2.5624	117.6	2.272286	2.56235
	364.2	283.5	1.7709	1.771	80.7	1.559298	1.77095
	349.9	307	0.9881	0.9882	42.9	0.828920	0.98815
	333.3	333.2	0.0889	0.089	0.1	0.001932	0.08895

Data Sheet for Figure 4.2.3

Table 4.2
Transducer Calibration Constants

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
10/11/88	TRNSD001	0.1	7.93	7.17	48.86	0.99996
10/11/88	TRNSD001	0.1	9.94	7.18	72.81	0.999964
10/20/88	TRNSD002	0.1	9.94	7.26	72.62	0.9997
10/20/88	TRNSD002	0.1	7.93	7.26	49.058	0.999755
11/09/88	TRNSD006	0.1	9.94	7.14	68.526	0.999963
11/09/88	TRNSD006	0.1	10.05	7.19	70.314	0.999971
11/20/88	TRNSD009	0.1	10.15	7.21	66.5048	0.999978
12/10/88	TRNSD013	0.1	10.05	6.88	57.79140	0.999885
12/15/88	TRNSD014	0.1	10.05	7.21	61.46408	0.999702
12/17/88	TRNSD016	0.1	10.05	6.72	60.9112	0.99996
01/08/89	TRNSD018	0.1	10.05	6.43	60.22719	0.999991
01/13/89	TRNSD022	0.1	10.05	7.23	81.30932	0.999908
01/13/89	TRNSD022	0.1	5.11	7.23	38.12897	0.999927
01/17/89	TRNSD023	0.1	10.05	7.27	83.35598	0.999972
01/17/89	TRNSD025	0.1	10.05	7.27	83.83672	0.99998
01/22/89	TRNSD028	0.1	10.05	7.27	82.21182	0.999716
01/24/89	TRNSD030	0.1	8.00	4.90	75.0614	0.999655
01/29/89	TRNSD032	0.1	10.05	7.27	83.22382	0.999979
01/29/89	TRNSD033	0.1	8.00	4.90	84.19413	0.999796
02/06/89	TRNSD036	0.1	8.00	4.90	85.14261	0.999836
03/03/89	TRNSD041	0.1	10.05	4.92	73.79766	0.999995
03/07/89	TRNSD042	0.1	10.05	4.92	73.94846	0.999821
04/06/89	TRNSD045	0.1	10.05	4.60	84.25618	0.999894
04/12/89	TRNSD047	0.1	10.05	4.60	84.25618	0.999866

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
05/01/89	TRNSD048	0.1	10.05	4.96	81.83694	0.9997
05/10/89	TRNSD051	0.1	10.05	4.90	81.72632	0.999798
08/09/89	TRNSD053	0.1	10.05	5.00	58.47773	0.999475
08/09/89	TRNSD053	0.1	7.18	5.00	33.51341	0.999743
08/18/89	TRNSD056	0.1	10.05	7.12	76.63642	0.999722
08/21/89	TRNSD058	0.1	10.05	7.11	76.20957	0.999657
08/23/89	TRNSD060	0.1	10.05	7.00	76.31588	0.99978
08/28/89	TRNSD064	0.1	10.05	6.97	76.40294	0.999769
09/10/89	TRNSD067[a]	0.1	10.05	6.62	79.56422	0.999579
09/11/89	TRNSD068	0.1	10.05	3.44	98.07934	0.999797
09/11/89	TRNSD069	0.1	10.05	3.44	98.28819	0.999816
09/22/89	TRNSD074	0.1	10.05	4.11	98.41659	0.999867
09/27/89	TRNSD076	0.1	10.05	4.22	96.3605	0.999828
10/02/89	TRNSD079	0.1	10.05	4.40	95.11395	0.999795
10/07/89	TRNSD082[b]	0.1	7.85	3.58	102.07	0.994751
10/10/89	TRNSD084	0.1	10.05	6.10	97.17752	0.999887
10/12/89	TRNSD087	0.1	10.05	5.50	113.1092	0.999739
10/13/89	TRNSD089	0.1	10.05	7.60	79.99924	0.999754
10/13/89	TRNSD089	0.1	10.05	6.85	82.88132	0.999775
10/14/89	TRNSD089[b]	0.1	10.05	7.60	83.53885	0.999750
10/15/89	TRNSD090	0.1	10.05	7.10	78.83565	0.999657
10/18/89	TRNSD092	0.1	10.05	7.35	78.37642	0.999870
10/23/89	TRNSD096	0.1	10.05	7.75	90.88766	0.999892
10/25/89	TRNSD097	0.1	10.05	7.67	76.32052	0.999733
10/25/89	TRNSD097	0.1	10.05	7.60	74.01564	0.999740
10/28/89	TRNSD099	0.1	10.05	7.72	76.42426	0.999631

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
10/30/89	TRNSD099	0.1	10.05	7.50	73.36316	0.999938
11/13/89	TRNSD102	0.1	10.06	7.80	69.8097	0.999681
11/11/89	TRNSD102	0.1	10.05	7.75	68.28726	0.999676
11/15/89	TRNSD105	0.1	10.05	7.90	70.83384	0.999759
11/14/89	TRNSD105	0.1	10.05	7.85	69.9713	0.999589
11/15/89	TRNSD105	0.1	10.05	7.90	70.40149	0.999771
11/19/89	TRNSD107[a]	0.1	10.05	5.60	88.37565	0.999818
11/21/89	TRNSD108[b]	0.1	10.05	7.80	126.1543	0.999309
11/22/89	TRNSD108	0.1	8.80	7.80	99.68092	0.999525
11/22/89	TRNSD108	0.1	8.80	7.85	98.61889	0.999552
11/27/89	TRNSD109	0.1	8.80	8.85	98.01992	0.999139
12/04/89	TRNSD112[b]	0.1	9.60	8.25	95.66494	0.999769
12/05/89	TRNSD114	0.1	9.60	8.1	98.39966	0.999811
12/05/89	TRNSD114	0.1	9.60	8.15	98.9334	0.999867
12/09/89	TRNSD115[a]	0.1	8.50	5.90	99.02889	0.998326
12/18/89	TRNSD117	0.1	8.50	9.10	98.57166	0.999764
12/21/89	TRNSD121	0.1	8.50	9.15	98.39153	0.999834
12/25/89	TRNSD122	0.1	8.50	9.70	96.43758	0.999839
12/30/89	TRNSD125	0.1	8.50	9.95	95.03889	0.999882
01/03/90	TRNSD126	0.1	9.90	9.97	80.83505	0.999749
01/02/90	TRNSD126	0.1	9.90	7.50	97.48596	0.999732
01/19/90	TRNSD128	0.1	9.90	6.80	72.74352	0.999782
02/01/90	TRNSD130	0.1	9.90	6.65	77.51999	0.999822
02/04/90	TRNSD131	0.1	9.90	6.65	78.59397	0.999862
02/06/90	TRNSD132	0.1	9.90	6.60	78.75403	0.999859
02/07/90	TRNSD132	0.1	9.90	6.60	79.34951	0.999905

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
02/08/90	TRNSD133	0.1	9.90	6.80	79.81819	0.999638
02/12/90	TRNSD133	0.1	9.90	6.80	78.02002	0.999865
02/22/90	TRNSD136	0.1	9.90	7.10	80.03842	0.999805
03/19/90	TRNSD139	0.1	9.90	7.35	78.17769	0.999862
04/04/90	TRNSD142	0.1	9.90	7.25	76.80585	0.99994
04/12/90	TRNSD143	0.1	9.90	7.40	76.33338	0.999787
04/11/90	TRNSD143	0.1	9.90	7.40	77.98275	0.999863
04/17/90	TRNSD145	0.1	9.90	7.35	75.55558	0.999887
04/19/90	TRNSD145	0.1	9.90	7.45	74.23541	0.999871
04/23/90	TRNSD147	0.1	9.90	7.55	75.54508	0.999912
04/26/90	TRNSD149	0.1	9.90	7.60	75.75206	0.999897
05/01/90	TRNSD153	0.1	9.90	7.60	76.04142	0.99992
05/07/90	TRNSD155	0.1	9.90	7.65	74.66555	0.999841
05/09/90	TRNSD157	0.1	9.90	7.40	76.33526	0.999923
05/15/90	TRNSD158	0.1	9.90	7.45	75.79972	0.999938
05/20/90	TRNSD161	0.1	9.90	7.45	75.61796	0.999999
06/13/90	TRNSD163	0.1	9.90	7.45	78.07879	0.999866
06/25/90	TRNSD166	0.1	9.90	7.35	78.98393	0.999872
07/02/90	TRNSD169	0.1	9.90	7.20	79.06431	0.999813
07/20/90	TRNSD174	0.1	9.90	7.10	81.57181	0.999992
07/23/90	TRNSD175	0.1	9.90	7.05	82.0894	0.999819
07/30/90	TRNSD177	0.1	9.90	7.05	79.63686	0.999827
08/01/90	TRNSD179	0.1	9.90	7.00	78.70749	0.999981
08/03/90	TRNSD179	0.1	9.90	6.90	79.55358	0.999926
08/08/90	TRNSD181	0.1	9.90	6.85	80.93545	0.999843
08/12/90	TRNSD183	0.1	9.90	6.90	79.89031	0.99983

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
08/14/90	TRNSD185	0.1	9.90	6.90	79.71477	0.999923
08/24/90	TRNSD187	0.1	9.90	6.85	80.1597	0.999985
08/30/90	TRNSD188	0.1	9.90	6.85	79.692	0.999934
08/30/90	TRNSD189	0.1	9.90	6.85	79.79777	0.999987
09/07/90	TRNSD191	0.1	9.90	6.85	79.42137	0.999919
09/15/90	TRNSD194	0.1	9.90	6.85	80.92975	0.999897
09/22/90	TRNSD195	0.1	9.90	6.85	80.63355	0.999897
09/21/90	TRNSD195	0.1	9.90	6.80	78.34361	0.999901
09/26/90	TRNSD196	0.1	9.90	6.90	78.91503	0.999932
09/26/90	TRNSD196	0.1	9.90	6.90	78.67313	0.999749
10/04/90	TRNSD197	0.1	9.90	6.85	79.72605	0.999553
10/25/90	TRNSD199	0.1	9.90	6.90	79.91174	0.999878
10/29/90	TRNSD201	0.1	9.90	6.90	79.89385	0.99989
10/31/90	TRNSD203	0.1	9.90	6.90	81.82122	0.999938
11/04/90	TRNSD205	0.1	9.90	6.90	83.13996	0.999877
11/07/90	TRNSD207	0.1	9.90	6.90	82.43988	0.999914
11/14/90	TRNSD212	0.1	9.90	6.90	82.65572	0.999909
11/15/90	TRNSD212	0.1	9.90	6.90	81.50076	0.999815
11/21/90	TRNSD216	0.1	9.90	6.90	84.29793	0.99993
11/24/90	TRNSD218	0.1	9.90	6.80	82.65316	0.999866
11/28/90	TRNSD219	0.1	9.90	6.95	82.54038	0.999952
11/28/90	TRNSD219	0.1	9.90	6.85	83.38349	0.999919
12/04/90	TRNSD222	0.1	9.90	6.90	84.98972	0.999985
12/04/90	TRNSD222	0.1	9.90	6.90	83.99103	0.999895
12/11/90	TRNSD224	0.1	9.90	6.85	83.85071	0.999913
12/11/90	TRNSD224	0.1	9.90	6.90	84.78139	0.999902

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
12/22/90	TRNSD225	0.1	9.90	6.95	84.54326	0.999904
12/22/90	TRNSD225	0.1	9.90	6.95	82.58022	0.999924
12/25/90	TRNSD226	0.1	9.90	6.95	82.52987	0.99995
12/25/90	TRNSD226	0.1	9.90	6.90	82.56793	0.999962
10/11/88	TRNSD001	1.0	8.00	5.27	9.52	0.99993
10/11/88	TRNSD001	1.0	5.00	5.28	6.49	0.99996
10/20/88	TRNSD002	1.0	8.00	5.30	9.492	0.999879
10/20/88	TRNSD002	1.0	8.00	5.33	6.446	0.999983
10/24/88	TRNSD003	1.0	8.00	5.20	9.5358	0.999981
11/10/88	TRNSD007	1.0	8.00	5.17	9.4525	0.999999
11/15/88	TRNSD008	1.0	8.00	5.14	9.44895	0.999998
12/10/88	TRNSD012	1.0	8.00	5.14	9.251516	0.999976
12/15/88	TRNSD015	1.0	8.00	5.05	9.5666	0.999985
12/19/88	TRNSD017	1.0	8.00	5.05	9.637244	0.999997
01/13/89	TRNSD020	1.0	8.00	5.14	9.407184	0.999949
01/13/89	TRNSD021	1.0	8.00	4.94	9.581598	0.999997
01/17/89	TRNSD024	1.0	8.00	4.90	9.4676	0.999959
01/20/89	TRNSD026	1.0	8.00	4.90	9.481430	0.999963
01/22/89	TRNSD027	1.0	8.00	4.90	9.3928	0.999968
01/24/89	TRNSD031	1.0	10.05	7.27	9.4644	0.999975
02/02/89	TRNSD034	1.0	8.00	4.90	9.402316	0.999904
02/02/89	TRNSD035	1.0	10.05	7.27	9.483509	0.999995
02/06/89	TRNSD036	1.0	10.05	4.90	9.525949	0.999966
02/12/89	TRNSD037	1.0	10.05	4.90	14.25395	0.999999
02/19/89	TRNSD038	1.0	10.05	4.92	14.2489	0.99998

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
02/19/89	TRNSD039	1.0	10.05	4.82	14.28768	0.999935
02/26/89	TRNSD040	1.0	10.05	4.90	14.23522	0.999951
03/07/89	TRNSD043	1.0	10.05	4.90	14.25176	0.999998
04/06/89	TRNSD044	1.0	10.05	4.86	13.87506	0.999973
04/12/89	TRNSD046	1.0	10.05	4.70	13.97521	0.99999
05/01/89	TRNSD049	1.0	10.05	4.43	14.08113	0.999994
05/10/89	TRNSD050	1.0	10.05	4.40	14.213	0.99994
08/08/89	TRNSD052	1.0	10.05	4.00	13.93282	0.999949
08/15/89	TRNSD054	1.0	10.05	4.11	13.94509	0.999953
08/17/89	TRNSD055	1.0	10.05	4.11	14.12357	0.999994
08/18/89	TRNSD057	1.0	10.05	4.11	13.9635	0.999991
08/23/89	TRNSD059	1.0	10.05	4.12	13.9196	0.999986
08/28/89	TRNSD063	1.0	10.05	4.10	13.92606	0.999981
09/06/89	TRNSD065	1.0	10.05	4.31	13.556	0.99955
09/09/89	TRNSD066	1.0	10.05	4.95	17.35183	0.999821
09/11/89	TRNSD070	1.0	10.05	5.04	17.50439	0.999969
09/22/89	TRNSD073	1.0	10.05	5.04	17.71172	0.999896
09/27/89	TRNSD075	1.0	10.05	5.31	17.65151	0.999944
10/02/89	TRNSD078	1.0	10.05	5.34	17.83705	0.999975
10/07/89	TRNSD081	1.0	7.25	5.36	10.19435	0.999977
10/08/89	TRNSD083	1.0	7.25	5.43	10.12039	0.999910
10/12/89	TRNSD086	1.0	7.25	6.10	10.1462	0.999946
10/15/89	TRNSD091	1.0	7.25	6.25	10.08697	0.999983
10/15/89	TRNSD091	1.0	7.50	6.10	10.53907	0.999952
10/18/89	TRNSD093	1.0	7.25	5.50	10.10833	0.999868
10/26/89	TRNSD098	1.0	7.25	5.90	10.09309	0.999979

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
10/25/89	TRNSD098	1.0	7.25	5.95	10.08204	0.99998
10/29/89	TRNSD100	1.0	7.25	5.90	11.85022	0.999875
10/30/89	TRNSD100	1.0	7.25	6.25	11.88974	0.999905
11/11/89	TRNSD103	1.0	7.25	6.60	11.85364	0.999785
11/15/89	TRNSD106	1.0	7.25	6.65	11.86867	0.999767
11/27/89	TRNSD110	1.0	7.25	6.90	11.89484	0.999853
12/03/89	TRNSD111	1.0	7.25	7.05	11.92289	0.999745
12/18/89	TRNSD118	1.0	7.25	7.25	12.0867	0.999685
12/21/89	TRNSD120	1.0	7.25	7.25	12.09851	0.999997
12/25/89	TRNSD123	1.0	7.25	7.30	12.073	0.999534
12/29/89	TRNSD124	1.0	7.25	7.35	12.10268	0.999595
01/19/90	TRNSD129	1.0	7.25	7.55	12.19997	0.999982
02/08/90	TRNSD134	1.0	7.25	7.60	12.31038	0.999729
02/22/90	TRNSD135	1.0	7.25	7.75	12.28248	0.999996
03/19/90	TRNSD140	1.0	7.25	7.85	12.19433	0.999676
04/12/90	TRNSD144	1.0	7.25	7.90	12.26293	0.999771
04/19/90	TRNSD146	1.0	7.25	7.95	11.68401	0.999755
04/23/90	TRNSD148	1.0	7.25	8.00	11.76185	0.999752
04/27/90	TRNSD150	1.0	7.25	8.00	11.93037	0.999991
05/01/90	TRNSD152	1.0	7.25	8.10	11.96208	0.99976
05/09/90	TRNSD156	1.0	7.25	8.15	12.03909	0.999862
05/15/90	TRNSD159	1.0	7.25	8.15	12.09069	0.999878
05/20/90	TRNSD160	1.0	7.25	8.25	12.16921	0.999915
06/13/90	TRNSD164	1.0	7.25	8.75	12.37189	0.99993
06/25/90	TRNSD167	1.0	7.25	8.90	12.48441	0.999996
07/02/90	TRNSD170	1.0	7.25	8.90	12.40044	0.999814

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
07/13/90	TRNSD173	1.0	7.25	8.95	12.56699	0.999868
07/24/90	TRNSD176	1.0	7.25	9.05	12.79437	0.999918
07/30/90	TRNSD178	1.0	7.25	9.05	12.56946	0.999776
08/08/90	TRNSD180	1.0	7.25	9.10	12.75206	0.999865
08/12/90	TRNSD184	1.0	7.25	9.05	12.77237	0.999981
08/17/90	TRNSD186	1.0	7.25	9.05	12.75147	0.999971
08/30/90	TRNSD190	1.0	7.25	9.05	12.8687	0.999953
09/07/90	TRNSD192	1.0	7.25	9.10	12.85295	0.999965
10/26/90	TRNSD200	1.0	7.25	9.00	13.29777	0.999983
10/29/90	TRNSD202	1.0	7.25	9.05	13.19632	0.999965
11/07/90	TRNSD206	1.0	7.25	9.25	13.45545	0.999951
11/14/90	TRNSD211	1.0	7.25	9.10	13.4881	0.999965
11/21/90	TRNSD217	1.0	7.25	9.30	13.84841	0.99998
11/28/90	TRNSD220	1.0	7.25	9.20	13.79691	0.999907
08/24/89	TRNSD061	10.0	10.05	3.39	0.208574	0.995124
08/24/89	TRNSD061	10.0	10.05	3.33	0.221723	0.999274
08/25/89	TRNSD062	10.0	10.05	3.41	0.20675	0.991471
09/14/89	TRNSD071	10.0	2.70	2.93	1.071034	0.999752
09/14/89	TRNSD071	10.0	10.05	2.91	3.075481	0.999612
09/19/89	TRNSD072	10.0	2.70	2.80	1.080677	0.999891
09/29/89	TRNSD077	10.0	2.70	2.80	1.06711	0.999957
10/02/89	TRNSD080	10.0	2.70	2.90	1.078322	0.999957
10/10/89	TRNSD085	10.0	2.70	2.65	1.069926	0.999522
10/12/89	TRNSD088	10.0	2.70	2.80	1.071837	0.999862
10/22/89	TRNSD094	10.0	2.70	2.70	1.078165	0.999749

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
10/22/89	TRNSD095	10.0	2.70	2.70	1.072608	0.999758
10/29/89	TRNSD101	10.0	2.70	2.70	1.06504	0.9998
11/11/89	TRNSD104	10.0	2.70	2.70	1.076613	0.999836
12/04/89	TRNSD113	10.0	2.70	2.70	1.076645	0.99972
12/10/89	TRNSD116	10.0	2.70	2.70	1.086647	0.999218
02/25/90	TRNSD137	10.0	2.70	2.70	1.106182	0.999535
03/07/90	TRNSD138	10.0	2.70	2.70	1.088082	0.999898
03/31/90	TRNSD141	10.0	2.70	2.70	1.088684	0.999949
04/03/90	TRNSD141	10.0	2.70	2.70	1.089026	0.999935
04/29/90	TRNSD151	10.0	2.70	2.70	1.097177	0.999867
05/01/90	TRNSD151	10.0	2.70	2.70	1.094631	0.999926
05/06/90	TRNSD154	10.0	2.70	2.70	1.083886	0.999928
05/21/90	TRNSD162	10.0	2.70	2.70	1.088055	0.999956
06/17/90	TRNSD165	10.0	2.70	2.70	1.091023	0.999942
06/25/90	TRNSD168	10.0	2.70	2.70	1.085095	0.999975
07/06/90	TRNSD171	10.0	2.70	2.70	1.086052	0.999958
07/12/90	TRNSD172	10.0	2.70	2.70	1.08859	0.999774
08/09/90	TRNSD182	10.0	2.70	2.70	1.077888	0.999967
09/09/90	TRNSD193	10.0	2.70	2.70	1.085877	0.99987
10/24/90	TRNSD198	10.0	2.70	2.70	1.078748	0.999649
10/31/90	TRNSD204	10.0	2.70	2.70	1.098348	0.999936
11/14/90	TRNSD210	10.0	2.70	2.85	1.440286	0.999657
11/18/90	TRNSD214	10.0	2.70	2.70	1.445043	0.999911
11/19/90	TRNSD215	10.0	2.70	2.70	1.450513	0.999794
11/19/90	TRNSD215[a]	10.0	1.00	5.75	1.180945	0.999615
11/30/90	TRNSD221	10.0	1.00	5.00	1.186618	0.999721

Date	File	Trans-ducer	Span	Zero	K (V/psid)	r^2
12/10/90	TRNSD223	10.0	1.00	4.60	1.161491	0.999775

(a) Its diaphragm was removed, cleaned, and reinstalled.
(b) A new diaphragm was installed.

4.3 Tank Calibration

While the 55-gallon tanks used in the experimental apparatus were apparently cylindrical, their bottoms bowed upwards. The height difference between the axis and the edge of the bottom was about two inches. Assuming a cylindrical shape of volume $\pi/4 \times (\text{tank diameter})^2 \times (\text{tank height})$ overestimated the volume by about five percent and, thus, underestimated the polymer and salt concentrations by about five percent. This underestimation can be seen from the apparent-tank-diameter data in Figures 4.3.1 and 4.3.2.

During the initial polymer runs in the gravity-driven flow system, this problem was not recognized; the reported concentrations were retroactively corrected.

In the pump-driven flow system, both the left and right tanks were calibrated as follows:

1) When the tank was completely empty, a metal yardstick was clamped in an upright position against the inside wall of the empty tank. The yardstick's position became permanent for all subsequent fluid measurements in that tank.

2) Into this initially empty, isolated tank, distilled water was added in 2000 ml increments. The liquid level was read from the yardstick. The incremental volume, cumulative volume, and height were recorded.

3) Step 2 was repeated. When the cumulative volume reached 50000 ml, the

increments increased to 4000 ml.

4) When the tank was nearly full, the calibration stopped.

5) The cumulative volume and fluid level data were tabulated; this "look-up" table was used in the experiments to convert measured heights into volumes by linear interpolation. Figures 4.3.1 and 4.3.2 show the height-versus-volume data for the right and left tanks, respectively; the corresponding data sheets are also presented.

4.4 Pump Calibration

1) Initially, the left tank was completely empty. Valves L and B were closed. The right tank was filled to about 90% capacity with the distilled-water hose. The hose's valve was closed, and the hose set aside. The metal yardstick was clamped against the wall inside the tank at its proper position to indicate the fluid level.

2) The system as shown in Figure 3.2 was altered by closing valves B2 and B3 and removing the tubing between them. The 1¼" flexible vincon tubing connected onto valve B was detached and was clamped onto valve B3; the last few feet of its other end was put inside the left tank on the bottom. To prevent the tubing from slipping out of the tank when the pump operated, two C clamps were used to hold the tubing against the tank's inner rim.

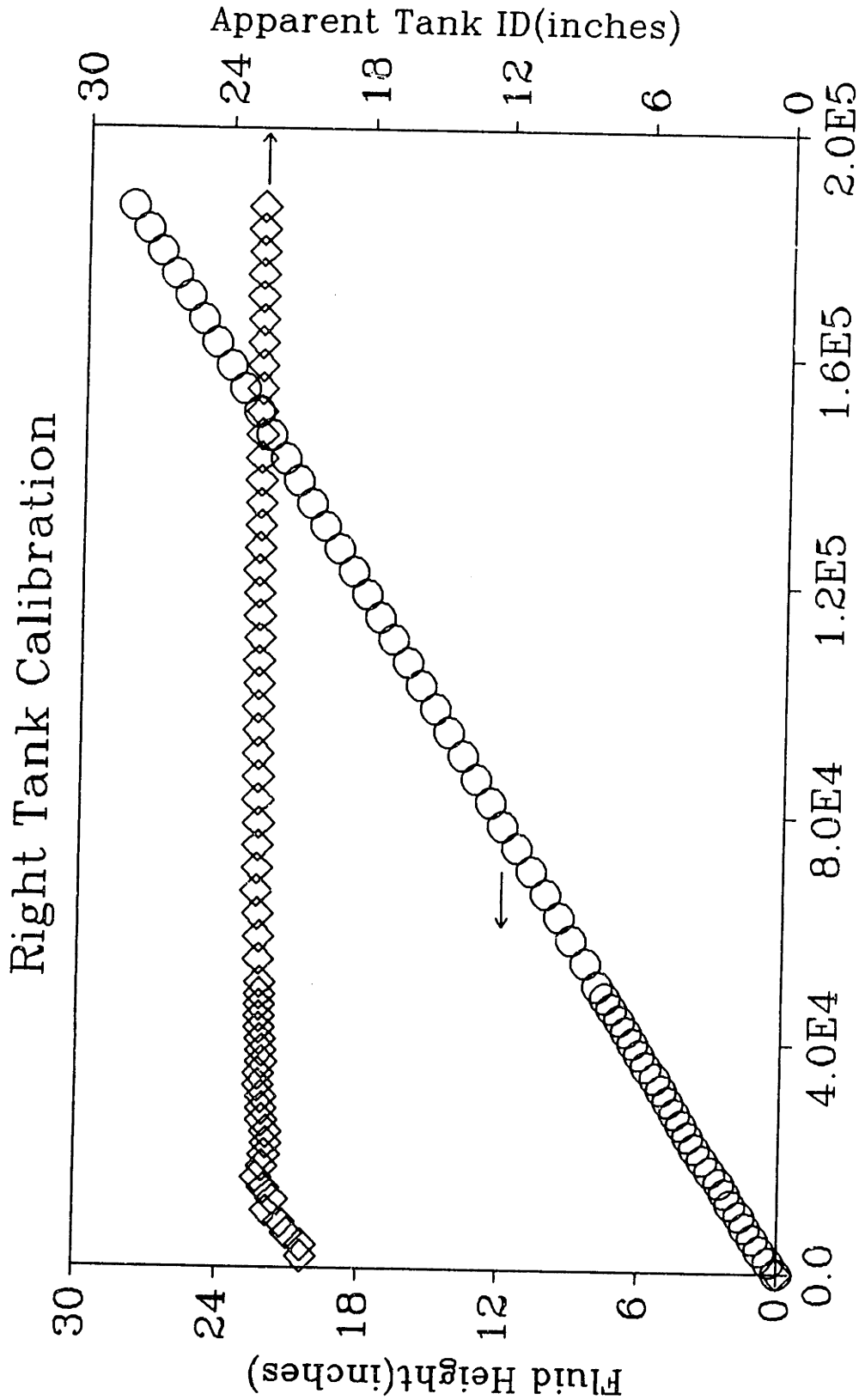


Figure 4.3.1: Right-Tank Calibration

Right Tank Calibration Summary Sheet

Right Tank Calibration 9/23/89 13:05

	Total Volume (ml)	Total Volume (cu. in.)	Height (inches)	Height Deltas (inches)	Corrected Height (inches)	Apparent ID) tank (inches)	Corrected Apparent ID) tank (inches)
	0	0	0		0		
	2000	122.0474	0.375		0.375	20.34089	20.34089
	4000	244.0949	0.75		0.75	20.34089	20.34089
	6000	366.1424	1.0625		1.0625	20.93149	20.93149
	8000	488.1899	1.375		1.375	21.24673	21.24673
	10000	610.2374	1.625		1.625	21.85186	21.85186
	12000	732.2849	2		2	21.57661	21.57661
	14000	854.3324	2.25		2.25	21.97308	21.97308
	16000	976.3799	2.5		2.5	22.28518	22.28518
	18000	1098.427	2.875		2.875	22.04131	22.04131
	20000	1220.474	3.1875	0.03125	3.21875	22.06534	21.95782
	22000	1342.522	3.5625		3.5625	21.89021	21.89021
	24000	1464.569	3.875		3.875	21.92233	21.92233
	26000	1586.617	4.125		4.125	22.11549	22.11549
	28000	1708.664	4.4375		4.4375	22.12749	22.12749
	30000	1830.712	4.75		4.75	22.13789	22.13789
	32000	1952.759	5		5	22.28518	22.28518
	34000	2074.807	5.3125		5.3125	22.28518	22.28518
	36000	2196.854	5.6875		5.6875	22.16224	22.16224
	38000	2318.902	6		6	22.16866	22.16866
	40000	2440.949	6.25	0.03125	6.28125	22.28518	22.22961
	42000	2562.997	6.5625		6.5625	22.28518	22.28518
	44000	2685.044	6.875		6.875	22.28518	22.28518
	46000	2807.092	7.1875		7.1875	22.28518	22.28518
	48000	2929.139	7.5		7.5	22.28518	22.28518
	50000	3051.187	7.8125		7.8125	22.28518	22.28518
	54000	3295.282	8.375		8.375	22.36829	22.36829
	58000	3539.377	9		9	22.36253	22.36253
	62000	3783.472	9.5625		9.5625	22.43055	22.43055
	66000	4027.567	10.125		10.125	22.49084	22.49084
	70000	4271.662	10.75		10.75	22.47894	22.47894
	74000	4515.757	11.375		11.375	22.46833	22.46833
	78000	4759.852	12		12	22.45883	22.45883
	82000	5003.947	12.5625		12.5625	22.50611	22.50611
	86000	5248.041	13.1875		13.1875	22.49569	22.49569
	90000	5492.136	13.8125	-0.03125	13.78125	22.48621	22.51172
	94000	5736.231	14.375		14.375	22.52642	22.52642
	98000	5980.326	15	-0.03125	14.96875	22.51642	22.53994
22.76056	102000	6224.421	15.625	-0.03125	15.59375	22.50721	22.52978
	106000	6468.516	16.1875		16.1875	22.54216	22.54216
	110000	6712.611	16.8125		16.8125	22.53266	22.53266
	114000	6956.706	17.375	0.03125	17.40625	22.56436	22.54407
	118000	7200.801	18	-0.03125	17.96875	22.55473	22.57436
	122000	7444.896	18.5625		18.5625	22.58371	22.58371
	126000	7688.991	19.1875		19.1875	22.57404	22.57404

Data Sheet 1 for Figure 4.3.1

Right Tank Calibration Summary Sheet

130000	7933.086	19.8125		19.8125	22.56499	22.56499
134000	8177.181	20.375	0.03125	20.40625	22.59109	22.57377
138000	8421.276	21	-0.03125	20.96875	22.58205	22.59889
142000	8665.371	21.5625	0.03125	21.59375	22.60626	22.58987
146000	8909.466	22.1875		22.1875	22.59728	22.59728
150000	9153.561	22.75		22.75	22.61983	22.61983
154000	9397.656	23.375		23.375	22.61094	22.61094
158000	9641.751	24	-0.03125	23.96875	22.60252	22.61727
162000	9885.846	24.5625		24.5625	22.62329	22.62329
166000	10129.94	25.1875		25.1875	22.61496	22.61496
170000	10374.03	25.75		25.75	22.63448	22.63448
174000	10618.13	26.375	-0.03125	26.34375	22.62627	22.63970
178000	10862.22	26.9375	0.03125	26.96875	22.64469	22.63155
182000	11106.32	27.5625		27.5625	22.63660	22.63660
186000	11350.41	28.125	0.03125	28.15625	22.65403	22.64144
190000	11594.51	28.75		28.75	22.64607	22.64607

Volume vs. Hc

Regression Output: 22.27760

Constant	-112.315
Std Err of Y Est	10.28576
R Squared	0.999988
No. of Observations	45
Degrees of Freedom	43
X Coefficient(s)	406.8703
Std Err of Coef.	0.208219

ID)tank= 22.76056

Data Sheet 2 for Figure 4.3.1

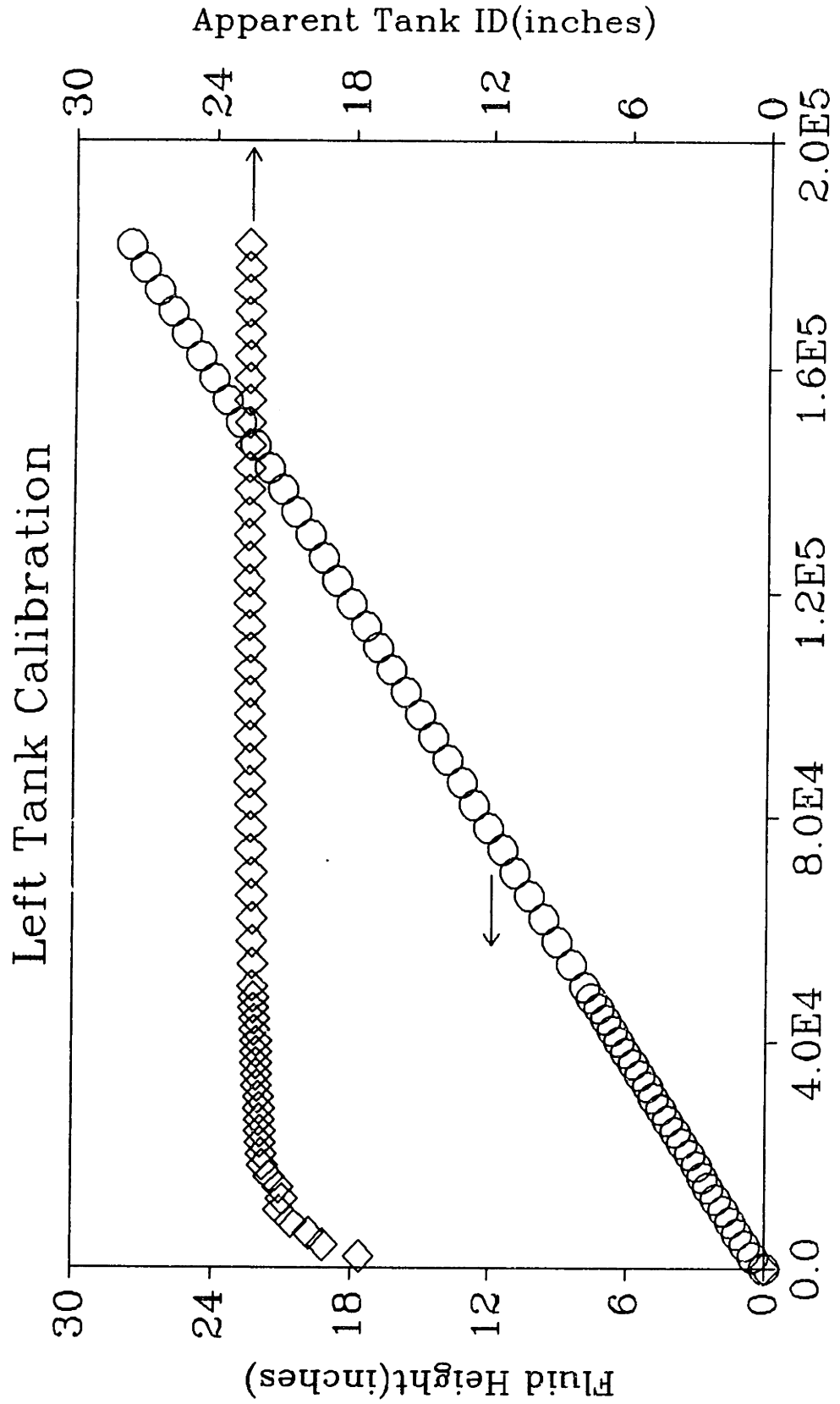


Figure 4.3.2: Left-Tank Calibration

Left Tank Calibration 9/24/89 10:55

	Total Volume (ml)	Total Volume (cu. in.)	Height (inches)	Height Deltas (inches)	Corrected Height (inches)	Apparent ID) tank (inches)	Corrected Apparent ID) tank (inches)
	0	0	0		0		
	2000	122.0474	0.5		0.5	17.61121	17.61121
	4000	244.0949	0.875	-0.03125	0.84375	18.82959	19.17573
	6000	366.1424	1.1875		1.1875	19.79752	19.79752
	8000	488.1899	1.5	-0.03125	1.46875	20.34089	20.55647
	10000	610.2374	1.75		1.75	21.05590	21.05590
	12000	732.2849	2.125		2.125	20.93149	20.93149
	14000	854.3324	2.4375		2.4375	21.10990	21.10990
	16000	976.3799	2.6875		2.6875	21.49271	21.49271
	18000	1098.427	2.9375		2.9375	21.80525	21.80525
	20000	1220.474	3.25		3.25	21.85186	21.85186
	22000	1342.522	3.5625		3.5625	21.89021	21.89021
	24000	1464.569	3.875		3.875	21.92233	21.92233
	26000	1586.617	4.1875		4.1875	21.94961	21.94961
	28000	1708.664	4.5		4.5	21.97308	21.97308
	30000	1830.712	4.8125		4.8125	21.99348	21.99348
	32000	1952.759	5.125	-0.03125	5.09375	22.01138	22.07889
	34000	2074.807	5.4375	-0.03125	5.40625	22.02721	22.09086
	36000	2196.854	5.6875	0.03125	5.71875	22.16224	22.10153
	38000	2318.902	6	0.03125	6.03125	22.16866	22.11108
	40000	2440.949	6.3125	0.03125	6.34375	22.17444	22.11969
	42000	2562.997	6.625		6.625	22.17968	22.17968
	44000	2685.044	6.9375		6.9375	22.18444	22.18444
	46000	2807.092	7.25	-0.03125	7.21875	22.18879	22.23683
	48000	2929.139	7.5	0.03125	7.53125	22.28518	22.23884
	50000	3051.187	7.8125		7.8125	22.28518	22.28518
	54000	3295.282	8.4375		8.4375	22.28518	22.28518
	58000	3539.377	9	0.03125	9.03125	22.36253	22.32375
	62000	3783.472	9.625	0.03125	9.65625	22.35751	22.32126
	66000	4027.567	10.25		10.25	22.35311	22.35311
	70000	4271.662	10.875		10.875	22.34921	22.34921
	74000	4515.757	11.4375		11.4375	22.40678	22.40678
	78000	4759.852	12.0625		12.0625	22.40050	22.40050
	82000	5003.947	12.6875		12.6875	22.39483	22.39483
	86000	5248.041	13.25		13.25	22.44251	22.44251
	90000	5492.136	13.875		13.875	22.43544	22.43544
	94000	5736.231	14.5	-0.03125	14.46875	22.42899	22.45323
	98000	5980.326	15.0625		15.0625	22.46960	22.46960
22.68871	102000	6224.421	15.6875		15.6875	22.46228	22.46228
	106000	6468.516	16.3125		16.3125	22.45552	22.45552
	110000	6712.611	16.875	0.03125	16.90625	22.49084	22.47002
	114000	6956.706	17.5	-0.03125	17.46875	22.48353	22.50366
	118000	7200.801	18.125	-0.03125	18.09375	22.47672	22.49615
	122000	7444.896	18.6875		18.6875	22.50795	22.50795
	126000	7688.991	19.3125		19.3125	22.50078	22.50078

Data Sheet 1 for Figure 4.3.2

130000	7933.086	19.875		19.875	22.52944	22.52944
134000	8177.181	20.5		20.5	22.52203	22.52203
138000	8421.276	21.0625	0.03125	21.09375	22.54848	22.53175
142000	8665.371	21.6875		21.6875	22.54093	22.54093
146000	8909.466	22.3125		22.3125	22.53381	22.53381
150000	9153.561	22.9375		22.9375	22.52707	22.52707
154000	9397.656	23.5		23.5	22.55065	22.55065
158000	9641.751	24.125	-0.03125	24.09375	22.54382	22.55845
162000	9885.846	24.6875		24.6875	22.56587	22.56587
166000	10129.94	25.3125		25.3125	22.55898	22.55898
170000	10374.03	25.875		25.875	22.57968	22.57968
174000	10618.13	26.5	-0.03125	26.46875	22.57277	22.58611
178000	10862.22	27.0625	0.03125	27.09375	22.59226	22.57922
182000	11106.32	27.6875		27.6875	22.58538	22.58538
186000	11350.41	28.3125		28.3125	22.57879	22.57879

Volume vs. Hc

22.05260

Regression Output:

Constant	-107.291
Std Err of Y Est	18.27117
R Squared	0.999972
No. of Observations	60
Degrees of Freedom	58
X Coefficient(s)	404.3054
Std Err of Coef.	0.276862

ID)tank= 22.68871

Data Sheet 2 for Figure 4.3.2

3) Valve B4 was closed, and the power switch for the E-trAC inverter was engaged.

4) Via the inverter keypad, the pump speed was set to the maximum 60 Hz. Valve B3 was fully open to provide the least back pressure, indicated by the pressure gauge(P). A hand-held stopwatch was set to zero.

5) The pump was started.

6) As the dropping fluid level in the right tank(feed tank) was observed, starting and stopping levels for nmeasuring the elapsed time were chosen arbitrarily, but quickly; a five-inch drop was chosen to give about a 30-second elapsed-time interval at the highest flow rate.

7) Before the pump was stopped, the back pressure was read from gauge P. The starting and stopping heights, the elapsed time, and the back pressure were recorded.

8) The stopwatch was reset. Valve B3 was slightly closed to make the back pressure about 20 psig. Subsequent back pressures at a given flow rate were 40 psig, 60 psig and 80 psig. After the 80 psig run, the flow rate was lowered by 10 Hz on the keypad, and valve B3 was opened fully again. The lowest flow rate was 20 Hz.

9) Steps 5 through 8 were repeated. When the right tank(feed tank) was

nearly empty, the pump was run until the fluid level could be seen in the 3" OD clear tubing between the 2" PVC elbows.

10) Valve R was closed, and valve L was opened. The tubing and clamps were removed from the left tank(the new feed tank) and set up on the right tank(now empty). The calibration could now continue.

11) Step 9 was repeated.

12) When the last data point, 20 Hz at 80 psig, was taken, the flow system was returned to its normal operating configuration as depicted in Figure 3.2.

13) The height interval data were converted to volume from the tank calibration data. From the volume change and the elapsed time, the flow rate at a given pump speed and back pressure was calculated. The relationship between flow rate and speed was linear.

Figures 4.4.1 - 4.4.4 present data from four pump calibrations. Figure 4.4.1 presents the results from the first pump calibration. Water-flow-rate data in l/s are plotted against the pump-frequency setting in Hz. The different symbols indicate the applied back pressure; the dotted line represents the regression used to calculate flow rates in subsequent experiments. Figure 4.4.2 presents results from the second pump calibration; this verified the first pump calibration after questionable turbulent polymer-solution data were obtained. Figure 4.4.3 presents results from the third pump calibration. Using a 50-

wppm solution of C832A eliminated shear-thinning effects as causing the questionable data. Among the three calibrations, the average calibration constant $<q>$ and its standard deviation σ_q were 0.020242 and 0.000030 l/s/Hz, respectively, for which $\sigma_q/<q>$ was 0.15 percent. After the third calibration, the absence of honeycomb was related to the turbulent-flow data problems.

Figure 4.4.4 presents results from the fourth pump calibration. This calibration differed from the previous three in that the flow passed through the test-pipe section rather than being rerouted through valve B3. With the small tube comprising the test-pipe section, the back pressure at top pump speed with valve B4 fully open was ~ 80 psid. With the large tube under the same conditions, the back pressure never got exceeded ~ 20 psid. The calibration constant was 0.019693 l/s/Hz, lower than before by about three percent.

Because high back pressures were unavoidable, instead of dismantling the pump-bypass loop, a long piece of 1" flexible tubing was clamped onto valve B6. The last few feet of its other end was put inside the left tank on the bottom. The tube was clamped as described in Step 2. Valve B3 remained closed, and valve B4 was left fully opened, allowing the back pressure to be what it may. The other aspects of calibration were identical to those previously described.

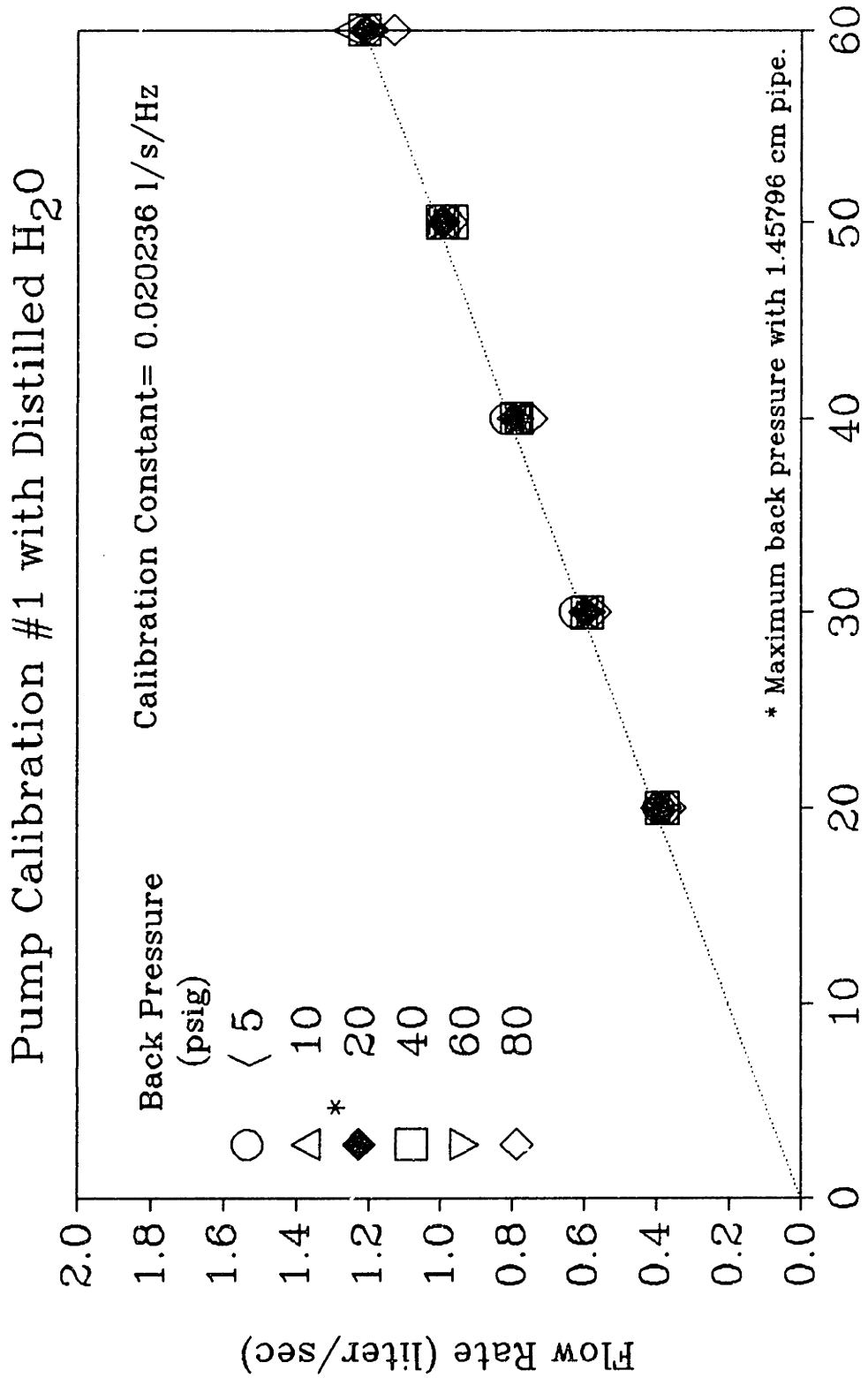


Figure 4.4.1: Pump Calibration #1 with Distilled H_2O

Pump Calibration 1 with Distilled Water

Flow System Calibration 9/27/89 & 9/28/89
14:55 11:09

H) left begin	H) left end	H) right begin	H) right end	DP (psid)	Freq. (Hz)	tf - to (sec)
20	15.0625			10	60	25.8
12	5.875			20	60	33.5
		23	18	40	60	27.5
		14.5	10.5	60	60	22.7
		7	4	80	60	17.5
23	18			80	60	27.7
12.875	7.875			100	60	33.9
		24	19	10	50	33.4
		16	11	20	50	33.3
		6.5	3.5	40	50	20.5
24	19			40	50	33.5
16	11			60	50	33.3
8	4			80	50	27.2
		24	19	5	40	40.7
		16	11	10	40	41.9
22	17			15	40	41.5
14	9			20	40	41.5
		23.5	18.5	40	40	42.1
		16.5	11.5	60	40	42.5
		9	4.5	80	40	39.5
23.5	19.5			5	30	42.7
17.5	13.5			10	30	44.1
11.5	7.5			20	30	44.7
		24	20	40	30	45.5
		18	14	60	30	46.1
		12	8	80	30	46.7
		7	4	5	20	50.3
23.5	20.5			10	20	49.7
19	16			20	20	50.5
14.5	11.5			40	20	51.7
10	7			60	20	53.9
5.5	3.5			80	20	35.9

Data Sheet 1 for Figure 4.4.1.

begin V) left (ml)	end V) left (ml)	begin V) right (ml)	end V) right (ml)	Flow Rate (l/s)	Flow Rate (gpm)
130631.5	98000			1.259906	19.96992
77600	37000			1.211940	19.20964
		151600	118210.5	1.214162	19.24487
		94842.10	68400	1.185744	18.79443
		44800	25000	1.131428	17.93350
150444.4	117400			1.192940	18.90848
83333.33	50400			0.971484	15.39834
		158210.5	124800	1.000315	15.85531
		104736.8	71600	0.995100	15.77266
		41555.55	21636.36	0.971667	15.40125
157368.4	124000			0.996072	15.78806
104000	70888.88			0.994327	15.76041
51200	24800			0.970588	15.38413
		158210.5	124800	0.820897	13.01148
		104736.8	71600	0.790855	12.53531
144000	110666.6			0.803212	12.73118
90842.10	57800			0.796195	12.61995
		154842.1	121578.9	0.790098	12.52332
		108000	74800	0.781176	12.38189
		58000	28400	0.749367	11.87771
154000	127333.3			0.624512	9.898718
114200	87600			0.603174	9.560512
74400	47777.77			0.595575	9.440063
		158210.5	131263.1	0.592249	9.387351
		118210.5	91473.68	0.579974	9.192789
		78000	51333.33	0.571020	9.050862
		44800	25000	0.393638	6.239292
154000	134000			0.402414	6.378399
124000	104000			0.396039	6.277355
94210.52	74400			0.383182	6.073563
64315.78	44444.44			0.368670	5.843548
34600	21600			0.362116	5.739671

Data Sheet 2 for Figure 4.4.1.

Freq. (Hz)	Flow Rate (l/s)
40	0.820897
30	0.624512
20	0.393638
60	1.259906
50	1.000315
40	0.790855
40	0.803212
30	0.603174
20	0.402414
60	1.211940
50	0.995100
40	0.796195
30	0.595575
20	0.396039
60	1.214162
50	0.971667
50	0.996072
40	0.790098
30	0.592249
20	0.383182
60	1.185744
50	0.994327
40	0.791176
30	0.579974
20	0.368670
60	1.131428
60	1.192940
50	0.970588
40	0.749367
30	0.571020
20	0.362116

Flow Rate (l/s) vs. Freq. (Hz)

Regression Output:

Constant	-0.01820
Std Err of Y Est	0.023612
R Squared	0.993462
No. of Observations	31
Degrees of Freedom	29
X Coefficient(s)	0.020236
Std Err of Coef.	0.000304

Data Sheet 3 for Figure 4.4.1.

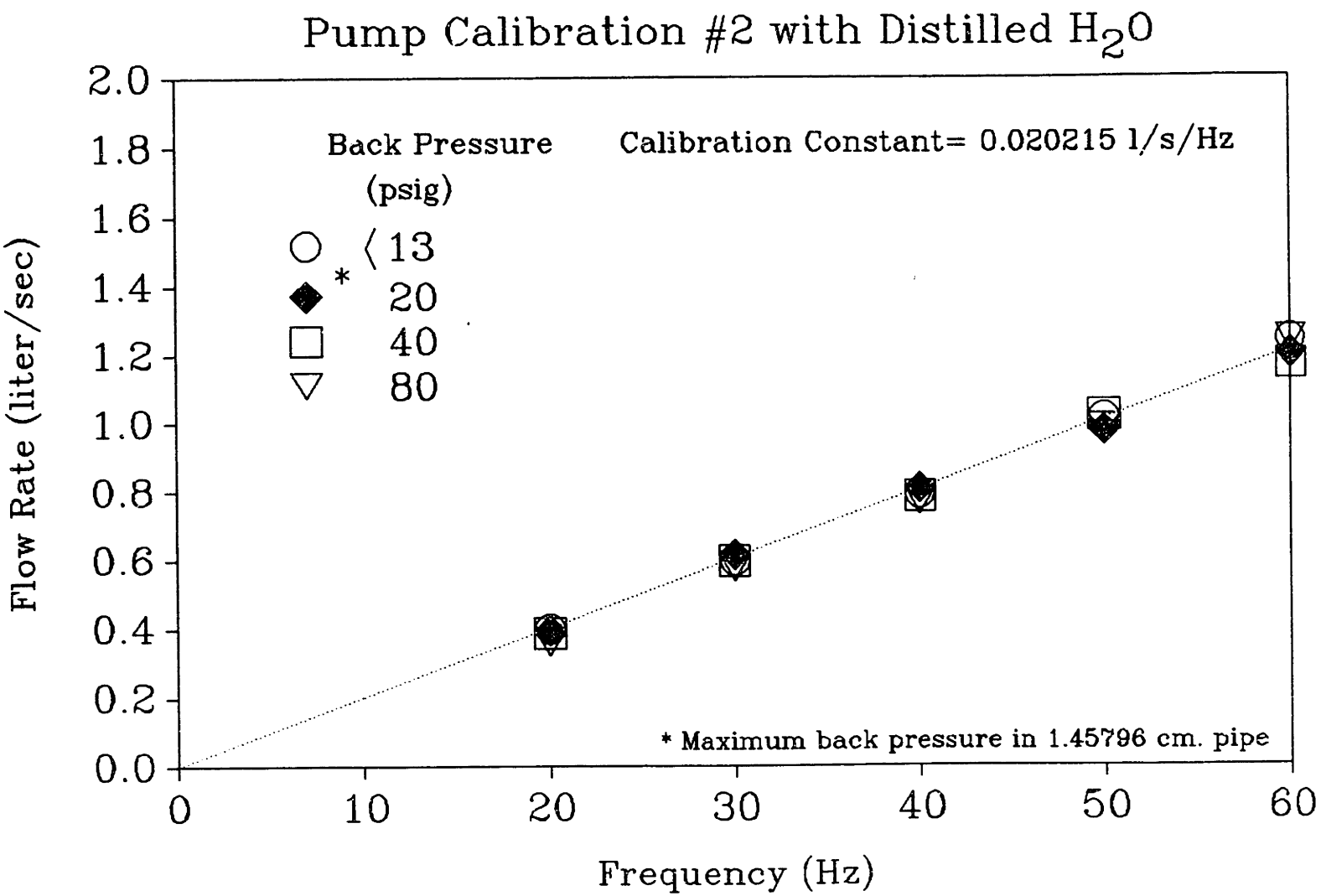


Figure 4.4.2: Pump Calibration #2 with Distilled H_2O

Flow System Calibration 10/22/89
14:09

H)left begin	H)left end	H)right begin	H)right end	DP (psid)	Freq. (Hz)	tf - to (sec)
		26	21	12.5	60	26.97
		16.5	11.5	20	60	27.7
		8.5	3.5	40	60	28.4
25	20			80	60	26.75
18	13			6	50	32.7
10.5	5.5			20	50	33.77
		25.5	20.5	40	50	32.64
		18	13	80	50	33.84
		11.5	6.5	5	40	41.97
25	20			20	40	41.04
18	13			40	40	42.28
10.5	5.5			80	40	42.72
		26	21	5	30	56.2
		19	14	20	30	54.14
		12.5	7.5	40	30	56.2
26	21			80	30	57.99
20	16			5	20	66.97
14	11			20	20	50.66
10	7			40	20	51.44
6	3			80	20	53.86

Data Sheet 1 for Figure 4.4.2.

begin V) left (ml)	end V) left (ml)	begin V) right (ml)	end V) right (ml)	Flow Rate (l/s)	Flow Rate (gpm)
		171684.2	138200	1.241535	19.67873
		108000	74800	1.198555	18.99749
		54800	21636.36	1.167733	18.50895
164000	130800			1.241121	19.67217
117400	84222.22			1.014610	16.08191
67600	34600			0.977198	15.48891
		168000	134666.6	1.021241	16.18701
		118210.5	84800	0.987308	15.64916
		74800	41555.55	0.792100	12.55504
164000	130800			0.808966	12.82238
117400	84222.22			0.784715	12.43799
67600	34600			0.772471	12.24392
		171684.2	138200	0.595804	9.443693
		124800	91477.68	0.615558	9.756794
		81555.55	48000	0.597073	9.463814
170842.1	137368.4			0.577232	9.149313
130800	104000			0.400179	6.342969
90842.10	70888.88			0.393865	6.242892
64315.78	44444.44			0.386301	6.123002
37800	18400			0.360193	5.709176

Data Sheet 2 for Figure 4.4.2.

Pump Calibration 2 with Distilled Water

Freq. (Hz)	Flow Rate (l/s)
60	1.241535
60	1.241121
60	1.198555
60	1.167733
50	1.021241
50	1.014610
50	0.987308
50	0.977198
40	0.808966
40	0.792100
40	0.784715
40	0.772471
30	0.615558
30	0.597073
30	0.595804
30	0.577232
20	0.400179
20	0.393865
20	0.386301
20	0.360193

Flow Rate (l/s) vs. Freq. (Hz)

Regression Output:

Constant	-0.01237
Std Err of Y Est	0.019074
R Squared	0.995568
No. of Observations	18
Degrees of Freedom	16
X Coefficient(s)	0.020215
Std Err of Coef.	0.000337

Data Sheet 3 for Figure 4.4.2.

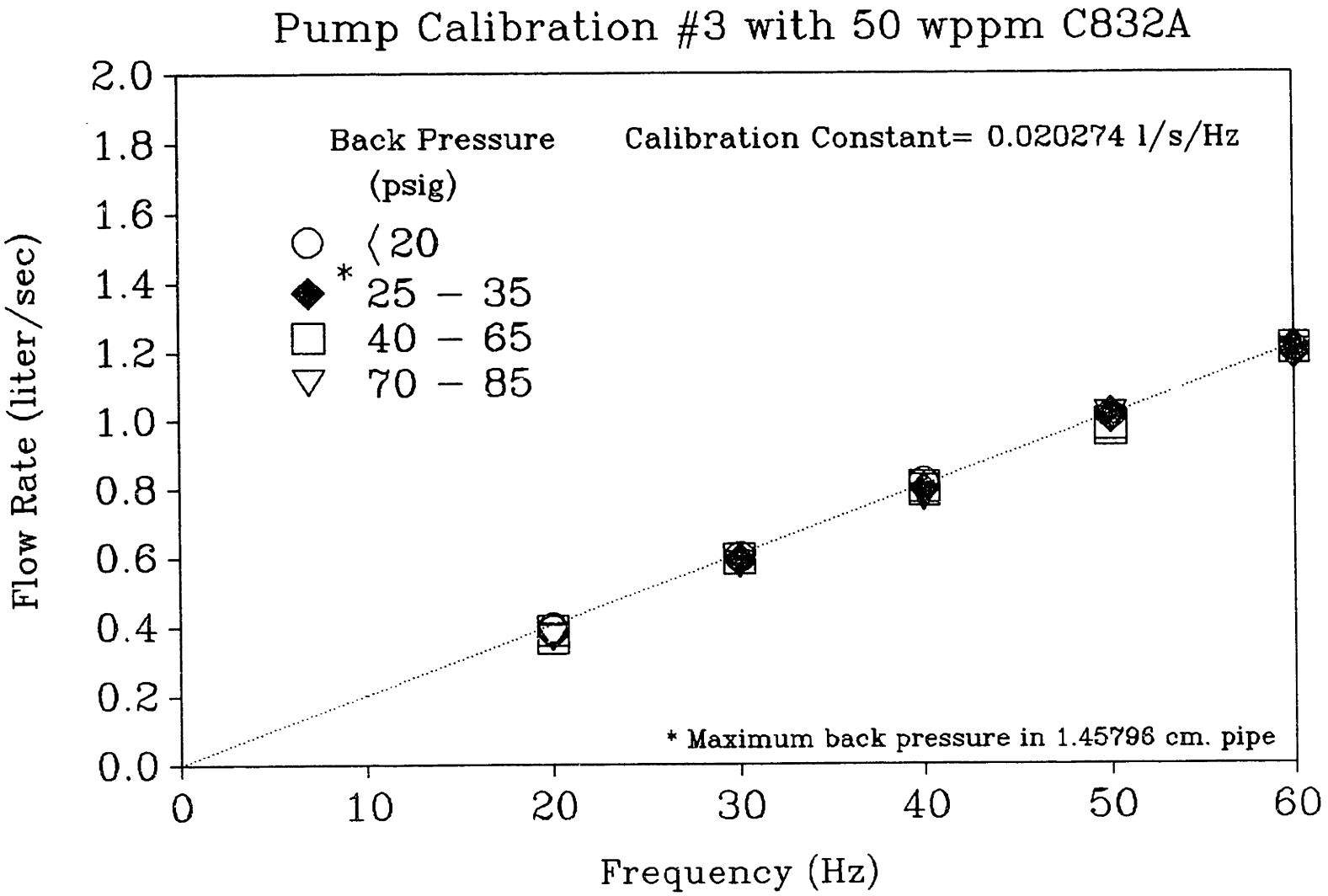


Figure 4.4.3: Pump Calibration #3 with 50-wppm C832A

Pump Calibration 3 with 50 ppm C8?2A in 1E-4 N NaCl

Flow System Calibration 1/6/90
With 50 ppm C8?2A in 1E-4N NaCl

H)left begin	H)left end	H)right begin	H)right end	DP (psid)	Freq. (Hz)	tf - to (sec)
				?0	60	
				?0	60	
		17.5	12.5	?0	60	27.3
		10.5	5.5	?5	60	28.1
				55	60	
22.375	17.5			5?	60	26.7
15	10			85	60	27.9
8	?			28	50	?2.7
				?8	50	
		22.5	17.5	?2	50	?2.9
		15.5	10.5	47	50	?4.1
		8	?	65	50	?3.1
				80	50	
22	17			75	50	?2.9
15	10			17.5	40	40.7
8.5	?.5			25	40	41.1
					40	
		22.5	17.5	50	40	41.7
		16	11	55	40	41.7
		9.5	4.5	80	40	42.9
				10	?0	
22	17			12	?0	55.5
15	10			27	?0	55.9
8.5	?.5			40	?0	55.1
				65	?0	
		22.5	17.5	70	?0	57.9
		16	11	7.5	20	83.5
		10	5	15	20	84.9
				40.	20	
23	18			40	20	85.1
17	12			65	20	90.3
9	4			85	20	89.5

Data Sheet 1 for Figure 4.4.3.

Pump Calibration 3 with 50 ppm C832A in 1E-4 N NaCl

Temp	begin V) left (ml)	end V) left (ml)	begin V) right (ml)	end V) right (ml)	Flow Rate (l/s)	Flow Rate (gpm)
23.6						
23.6						
23.6			114666.6	81555.55	1.212861	19.22424
23.6			68400	35000	1.188612	18.83988
23.5						
23.6	146400	114222.2			1.205160	19.10217
23.6	97578.94	64315.78			1.192227	18.89719
23.5	51200	18400			1.003058	15.89879
23.5						
23.6			148222.2	114666.6	1.019925	16.16615
23.6			101400	68400	0.967741	15.33902
23.6			51333.33	18727.27	0.985077	15.61379
23.5						
23.6	144000	110666.6			1.013171	16.05909
23.5	97578.94	64315.78			0.817276	12.95409
23.5	54421.05	21600			0.798565	12.65752
23.4						
23.5			148222.2	114666.6	0.804689	12.75458
23.5			104736.8	71600	0.794648	12.59543
23.5			61555.55	28400	0.772856	12.25002
23.1						
23.4	144000	110666.6			0.600600	9.519713
23.4	97578.94	64315.78			0.595047	9.431695
23.4	54421.05	21600			0.595663	9.441457
23.4						
23.4			148222.2	114666.6	0.579543	9.185948
			104736.8	71600	0.396848	6.290175
			65111.11	32000	0.390001	6.181646
	150444.4	117400			0.388301	6.154701
	110666.6	77600			0.366186	5.804178
	57789.47	24800			0.368597	5.842389

Data Sheet 2 for Figure 4.4.3.

Freq. (Hz)	Flow Rate (l/s)
60	1.212861
60	1.205160
60	1.192227
60	1.188612
50	1.003058
50	1.019925
50	0.967741
50	0.985077
50	1.013171
40	0.817276
40	0.798565
40	0.804689
40	0.794648
40	0.772856
30	0.600600
30	0.595047
30	0.579543
30	0.595663
20	0.396848
20	0.390001
20	0.388301
20	0.366186
20	0.368597

Flow Rate (l/s) vs. Freq. (Hz)

Regression Output:

Constant	-0.01679
Std Err of Y Est	0.014472
R Squared	0.997386
No. of Observations	21
Degrees of Freedom	19
X Coefficient(s)	0.020274
Std Err of Coef.	0.000238

Data Sheet 3 for Figure 4.4.3.

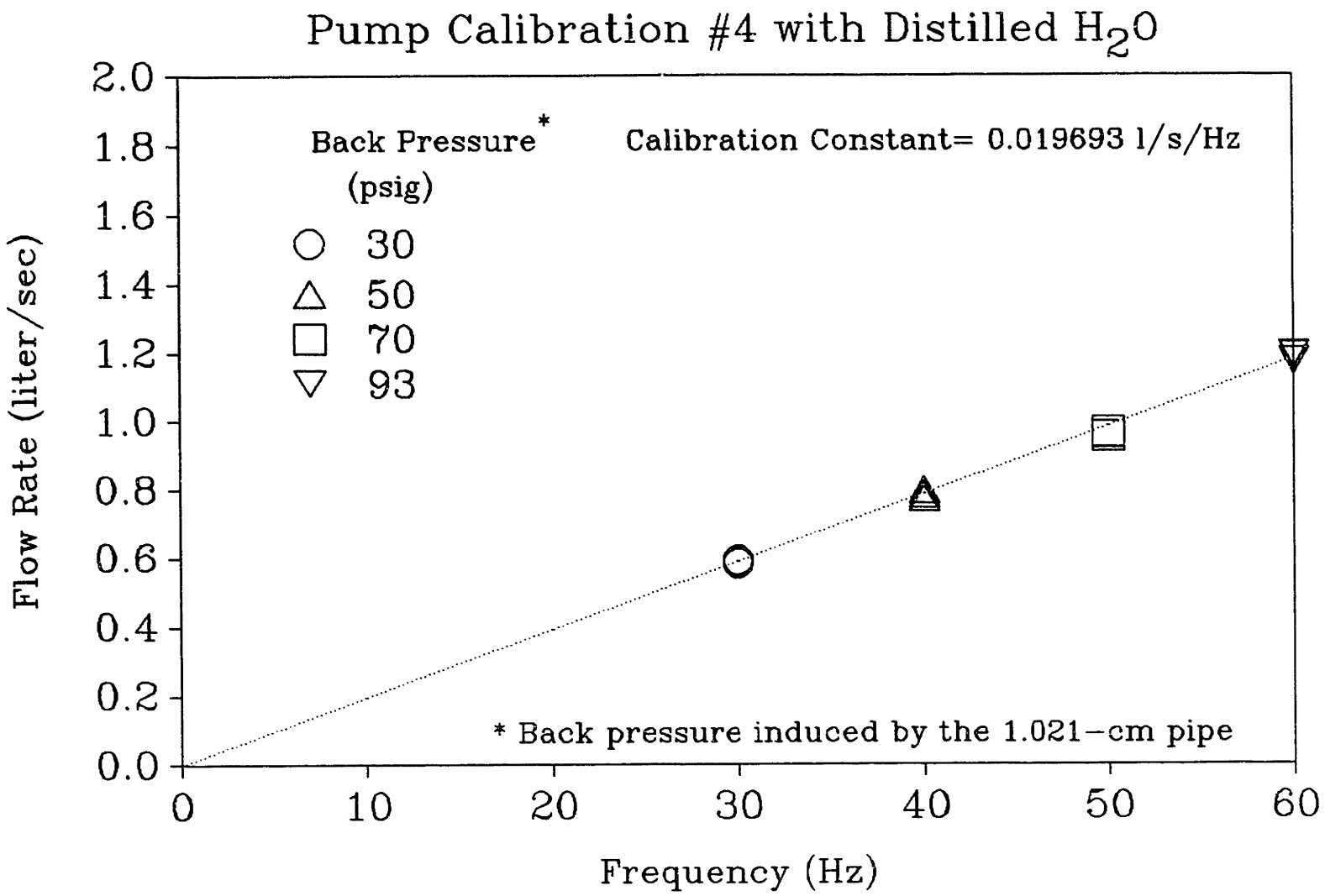


Figure 4.4.4: Pump Calibration #4 with Distilled H_2O

Pump Calibration 4 with H20 in the 0.402"-ID Pipe

Flow System Calibration 11/2/90
9:43 - 10:55

H)left begin	H)left end	H)right begin	H)right end	DP (psid)	Freq. (Hz)	tf - to (sec)
		24	18	93	60	34.1
		16.5	10.5	70	50	40.9
25	19			50	40	50.2
17.5	12.5			32	30	56.3
		25.5	19.5	93	60	33.8
		17.5	11.5	70	50	41.3
		10	5	50	40	42.7
25	20			30	30	56.5
18	12			93	60	33.4
10	4			70	50	41.4
		24	18	50	40	51.7
		16	11	30	30	56.7
		10	4	50	40	51.1

Regression Output:

Constant	-0.00618
Std Err of Y Est	0.012658
R Squared	0.997023
No. of Observations	13
Degrees of Freedom	11
X Coefficient(s)	0.019688
Std Err of Coef.	0.000324

93	60
93	60
93	60
70	50
70	50
70	50
50	40
50	40
50	40
50	40
32	30
30	30
30	30

Regression Output:

Constant	-0.00651
Std Err of Y Est	0.013326
R Squared	0.998171
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	0.019693
Std Err of Coef.	0.000595

60
50
40
30

Data Sheet 1 for Figure 4.4.4.

begin V)left (ml)	end V)left (ml)	begin V)right (ml)	end V)right (ml)	Flow Rate (l/s)	Flow Rate (gpm)
		158210.5	118210.5	1.173020	18.59275
		108000	68400	0.968215	15.34652
164000	124000			0.796812	12.62973
114200	80800			0.593250	9.403211
		168222.2	128000	1.190006	18.86198
		114666.6	74800	0.965294	15.30023
		65111.11	32000	0.775435	12.29090
164000	130800			0.587610	9.313818
117400	77600			1.191616	18.88751
64315.78	24800			0.954487	15.12893
		158210.5	118210.5	0.773694	12.26330
		104736.8	71600	0.584424	9.263309
		65111.11	25000	0.784953	12.44176

1.173020	60	1.173020
1.190006	50	0.968215
1.191616	40	0.796812
0.968215	30	0.593250
0.965294	60	1.190006
0.954487	50	0.965294
0.796812	40	0.775435
0.775435	30	0.587610
0.773694	60	1.191616
0.784953	50	0.954487
0.593250	40	0.773694
0.584424	30	0.584424
0.587610	40	0.784953

1.184881
0.962665
0.782724
0.588428

Data Sheet 2 for Figure 4.4.4.

4.5 Set-Up Procedure for the Gravity-Driven Flow System

In this description of the procedure, it is assumed that both the 0.1- and 1.0-psid PTs had been calibrated recently, that the Micro Motion mass-flow meter was in working order, and that the system had been adequately flushed with distilled water. Figure 3.1 shows a schemtic of the gravity-driven flow system.

1) The mass-flow meter was turned on, and vaive B6 was opened to flush out any air inside the flow meter. The FMS-3 was checked to make certain that it was displaying the flow rate in ml/s and the cumulative fluid volume in liters. Valve B6 was closed again.

2) All the valves on the PT board were shut. The ends of the two small connecting tubes from the board were placed in a beaker. Each valve was opened individually to release trapped air in the board and in the pressure-tap lines. The valves were shut again, and the two small tubes were attached to the arms of the 1.0-psid PT. The valves corresponding to the desired pair of taps were opened. The PE valve was opened to remove any pressure differentials across the transducer. The PT bleed screws were opened to release any trapped air and then were closed. The PT cable was connected to the carrier demodulator. The span and zero dials on the demodulator were set to their appropriate values. The HP-3467A Logging Multimeter and the carrier demodulator then were turned on. The FMS-3 was reset. If the multimeter was not displaying a near zero voltage from the carrier demodulator, the zero setting was changed. If that seemed

insufficient, the PT bleed screws were reopened. If the problem still persisted, then the tap lines were degassed again.

3) With valve B6 closed and valves B5 and N1 open, the tank was filled to near capacity. The water level was not so high as to cause spillage over the sides when the mixer operated. The height was measured, and the volume was calculated.

4) Given the volume of distilled water in the tank, the master batch concentration, and the target salt and polymer concentrations, the required masses of salt and of master batch were calculated.

5) A clean, small plastic boat was weighed. On an analytical balance, the boat was filled with the required amount of salt. The salt-laden boat was reweighed and then carried to the tank. Forceps were used to handle the boat. The boat was inverted above the tank, dumping the salt into the fluid. The now-empty boat was reweighed. The actual amount of added salt was calculated.

6) In adding the master batch, a beaker with a pouring lip was placed on a top-loading balance and weighed. Master batch from its jar was poured into the beaker. A small glass stirring rod was used to control and to guide the fluid because of its viscoelastic properties. Because the fluid tended to stick to the walls of the beaker, more master batch than that calculated was poured into the beaker. The fluid-filled beaker was reweighed and was carried over to the tank. The fluid was added by inverting the beaker

over the tank. The beaker was held above the tank until the last diaphanous streamers of fluid between the beaker and water surface had broken. The beaker was reweighed. The actual amount of master batch added was calculated. If the beaker had to be used again, this procedure was repeated. In this instance, because the walls of the beaker were already wetted, no "stickage" compensation was necessary.

7) Clamped to the side of the tank, the stirrer was positioned so that its impeller blades were well under water. The stirrer was turned to the lowest speed setting and was left running for at least one hour. The actual time depended upon the target polymer concentration. During this time, the actual salt and polymer concentrations were determined.

8) After the mixing period, the stirrer was stopped. The first part of the experiment then was performed.

9) After the first part was finished, the height of fluid in the tank was measured, and the remaining volume was calculated. Given the target salt concentration for the next part, the required amount of additional salt was calculated. Depending upon the required mass of salt, either a large plastic boat or an empty plastic salt bottle was weighed on a top-loading balance, filled with salt, and reweighed. Due to the larger salt masses involved, no special handling was needed. After the salt was added to the fluid, the fluid was stirred for another hour to dissolve the salt crystals completely and to allow solution equilibration. The new salt concentration was determined.

10) After the mixing period, the stirrer was turned off. The valves on the PT board were shut, and the carrier demodulator was turned off. The two small connecting tubes from the PT board were removed from the 0.1-psid PT and attached to the 1.0-psid PT. The cable belonging to the 0.1-psid PT was removed from the carrier demodulator and that belonging to the 1.0-psid PT was inserted. The span and zero dials were set to the appropriate values, and the carrier demodulator was turned on again. Two valves on the PT board were opened. The bleed screws of the 1.0-psid PT were opened to flush out any trapped air and then were closed.

11) The second part of the experiment was performed.

12) After the second part had ended, steps 9 and 10 were repeated. Then the third and final part of the experiment was performed.

13) After the experiment was finally over, step 10 was repeated. To remove any residual salt and polymer from the system, the system was flushed with distilled water by simultaneously filling the tank and keeping valve B6 open. At some point valve B5 was closed to flush fluid from the needle-valve bypass. During this flushing period, the 1.0-psid PT measured the pressure drop, and the mass-flow meter displayed the flow rate. When the pressure drop and the flow rate reached higher and lower constant values, respectively, the flushing could be stopped as very little drag reduction remained. During this time, both PTs were flushed with water from the water manometer to remove any polymer or salt that might have entered into the diaphragm chambers. After the

system and the PTs were flushed, the water supply valve and valve B6 were closed. The carrier demodulator, logging multimeter, and the mass-flow meter were shut off. Valves B5 and N1 were left fully open.

4.6 Experimental Run in the Gravity-Driven Flow System

1) After the set-up was complete and when the solution was fully mixed, the flow-totalizer display on the FMS-3 was set to zero. Valves B4, B5, and N1, as shown in Figure 3.1, were fully open.

2) The initial "zero voltage" of the 1.0-psid PT was recorded. The HP-3467A printer was started, and valve B6 was opened.

3) When the flow reached steady state, the flow rate displayed by the FMS-3 was recorded. Valve B6 was closed after about six liters had passed, as indicated by the flow totalizer. This corresponded to about six printed output scans per data point, the usual minimum.

4) The HP-3467A printer was stopped, the PT data channel was disengaged, and the temperature-probe data channel was engaged. The temperature was recorded, and then the data channels were switched back. The final "zero voltage" PT output was recorded. The paper in the printer was advanced to leave a blank between data points.

5) The flow-control valves were adjusted for the next data point. As long as the mass-flow meter measured the flow, steps 2 through 4 were repeated. For the next two data points, valve B5 was half-open and fully closed with N1 fully open. With valve B6 closed, valve N1 was closed gradually before each data point. With the 1.0-psid PT on line, the usual turn sequence was 3, 6, and 7.

6) At turn 7, the flow rate was ~40 ml/s; this corresponded to $Re_s \approx 3600$, at the high end of the transitional flow regime. At this point, the 0.1-psid PT replaced the 1.0-psid PT and resumed sensing the pressure drop.

7) The long 1" flexible vincon tube on the back end of valve B6 was removed and was attached to the tip of the funnel in the flow-diverter unit. The ¾"-port-to-½"-stub reducer attached to the pivoting arm was connected to the end of valve B6. Before proceeding, the locations of the ring-stand-mounted pivoting arm and funnel were adjusted to the proper positions; when the arm just crossed over to the receptacle from the funnel, the timer just began to count. On the switch box, the green light illuminated just as the red light went dark. Then the timer was reset to zero via the reset button on the switch box. Valve N1 was not adjusted.

8) The initial "zero voltage" of the 0.1-psid PT was recorded. The HP-3467A printer was started, and valve B6 was opened.

9) After steady state, the arm of the flow diverter was moved over the

receptacle, starting the timer. The arm was moved back to the funnel after either 30 seconds had elapsed or ~ 1000 ml of solution had been collected, whichever took longer. During this time, the flow rate displayed by the FMS-3 was recorded. After the arm was moved back, valve B6 was closed. The elapsed time was recorded, and then the timer was reset.

10) Step 4 was repeated.

11) The volume of fluid collected in the receptacle was determined by pouring the fluid into graduated cylinders. The solution was discarded down the sink drain.

12) Steps 8 through 11 were repeated. Both the mass-flow meter and the timer-and-flow-diverter unit measured the flow rate independently. The subsequent N1 turn sequence was 7½, 8, 8½, 8¾, 9, 9¼, and 9½ turns. Below a flow rate of ~ 13 ml/s, the mass flow meter could not measure, and its display went dark. After 9½ turns, at a flow rate of ~ 10 ml/s, valve N1 was closed just enough to halve the PT output from the previous data point. This dimunition continued until the flow was slow small that the flow diverter actually impeded the flow. This point usually ended this part of the experiment, but more data points could be taken at higher flow rates if so desired.

13) After the set-up for the next part, the procedure began again at step 1. If the last part had been completed, the system was washed out as described in step 13 in §4.5.

4.7 Set-Up Procedure for the Pump-Driven Flow System

In this description of the procedure, it is assumed that the 0.1-, 1.0-, and 10-psid PTs had been calibrated recently and that the system had been adequately flushed with distilled water. Figure 3.2 shows a schematic of the pump-driven flow system.

1) Valve B was closed, and valve B3 was opened to permit gravity-driven flow through the system. The rest is the same as Step 1 in §4.5 but with no FMS-3.

2) The E-trAC inverter was switched on. Via the keypad, the pump speed was set to the value that caused the PT to give full-scale output under Newtonian flow conditions for a given tap pair. The PE valve was closed. The pump was started, and the PT output was monitored visually for about a minute. This ensured both a clean system and properly operating PT as well as warmed up the pump. Then the pump was stopped.

From this point the set-up procedure for filling the tanks and for preparing the solutions diverged due to the two different methods used to make the master batch; the procedures converge after step 10.

3.1) Under method #1, the tanks were filled to near capacity via the distilled-water hose. Valves L and R were shut. The water levels were measured in both tanks with a metal yardstick. From the "look-up" tables the volumes in both tanks were interpolated.

4.1) Step 4 in §4.5 was done for each tank.

5.1) Step 5 in §4.5 was done for each tank.

6.1) Step 6 in §4.5 was done for each tank.

7.1) Clamped to the side of one tank, the stirrer was positioned with its impeller blades well under water; it operated at its lowest speed for about 15 minutes. To guard against degradation, the stirrer was stopped whenever a large vortex formed. Over about 90 minutes, the stirrer alternated between the tanks at about 15 minute intervals.

8.1) Because the desired solution temperature was 25°C, heating was generally required, but this was not always the case. The ambient laboratory temperature ranged between 18°C and 26°C, depending mostly upon laboratory ventilation. Also, the temperature of the distilled water coming from the spigot reached temperatures as high as 29°C; thus, the amount of warming varied widely. A 0°C-to-30°C thermometer was used to monitor the solution temperature in both tanks about every five minutes. As needed, a drum heater on either tank warmed the solution at a low heating rate. The warming continued intermittently until the solution temperature reached about 25°C.

9.1) During the mixing and heating period, valves B and B3 were opened to remove most of the hold-up fluid between the tanks and the pump's suction flange. When

the hold-up fluid had been drained away, these two valves were closed.

3.2) Under method #2, the tanks were filled to heights of about 24 inches, corresponding to volumes of ~ 160,000 ml per tank, via the distilled-water hose. Valves L and R were closed.

4.2) Given the amount of polymer in the master batch vessel and the target salt and polymer concentrations, the required mass of salt and volume of distilled water were calculated for each tank. The tank volumes were converted to heights from the "look-up" tables.

5.2) See Step 5.1.

6.2) Due to the elevated tanks and cumbersome mixing vessels, a ladder was used when adding master batch to the tanks. The metal yardstick was placed inside the tank at its proper position and was clamped in an upright position against the wall to provide continuous height readings. One of the master batch vessels was uncovered and was placed on the bucket rack of the ladder. A wash bottle filled with distilled water also was placed on the bucket rack. A master batch vessel was held above its corresponding tank and then tipped to empty its contents into the tank. When almost all the master batch had been decanted, the vessel was returned slowly to its upright position to break the last diaphanous streamers of fluid between the vessel and the water surface. The wash bottle washed any master batch drops that stuck on the vessel lip back into the vessel. The

inner surfaces of the vessel were rinsed free of master batch fluid, which collected in the bottom of the vessel. After the vessel was filled partially with distilled water, it was moved in a gyrating manner to cause the liquid inside to swirl over the interior surface. This action removed master batch fluid that adhered to the interior surface. Care was taken not to lose any fluid inadvertantly. After this swirling, the vessel was filled to near capacity with more distilled water, and then its contents were emptied into the tank. The rinsing, gyrating, filling, and emptying steps were repeated until the fluid height in the tank reached the target height.

7.2) Clamped to the side of one tank, the stirrer was positioned with its impeller blades well under water; it operated at its lowest speed for about 15 minutes. As the fluid was mixed, the yardstick was unclamped from the tank wall and held upright in the swirling liquid to wash away any master batch fluid stuck onto it. When no master batch fluid remained on the yardstick and when the solution seemed fairly homogeneous, the yardstick was removed. After the yardstick was rinsed with distilled water and dried, it was clamped to the inner wall of the other tank at the permanent position.

8.2) Step 6.2 was repeated for the other tank. During this time, the stirrer was mixing the solution in the other tank. To guard against degradation, the stirrer was stopped whenever a large vortex formed. The other solution was simultaneously mixed and warmed up to the desired 25°C. Heating was generally required, but this was not always the case. The rest is the same as Step 8.1.

9.2) When the master batch fluid had been transferred entirely into the second tank, step 7.2 was done for the second tank. The solution in the second tank also was warmed as described in step 8.2. Over about 90 minutes, the stirrer alternated between the tanks at about 15 minute intervals, and solution temperature in both were monitored about every five minutes.

10) After the warming and mixing period ended, the heaters and stirrer having been stopped, the system was ready for the first half of the experiment to commence.

11) After the first part was finished, valves L and R were shut. The height of fluid in both tanks were measured, and the remaining volumes were determined. Given the target salt concentration for the next part, the required amount of additional salt was calculated. A top-loading scale capable of weighing more than 3000 g was required. A empty large plastic bottle was weighed, filled with salt, and reweighed. With such large salt masses no special handling was needed. After its contents were dumped into the tank, the empty bottle was reweighed.

12) When ~2000 g NaCl was added to each solution, the salt did not easily dissolve, rather it remained mostly as crystals on the bottom of the tank. Instead of clamping the stirrer to the tank as before, the stirrer was held manually during mixing. For at least five minutes, the stirrer was moved to apply direct agitation to the "salt drifts" on the tank bottom. Only when the "salt drifts" had disappeared did the mixing stop. Each solution was treated in this way. During this step, that the stirring became

markedly easier as the salt dissolved evidenced the profound affect of salt on the polyelectrolyte solution. The solutions sat for about an hour to dissolve completely the salt crystals and to allow solution equilibration. The new salt concentrations were determined.

13) The temperature of the solutions were monitored with a 0°C-to-30°C thermometer during the equilibration period. After initial temperature readings, the drum heaters were used judiciously to warm the solutions back to about 25°C. Because the 10-psid PT was used at the end of the first half and at the start of the second half, switching PTs and degassing the lines were generally unnecessary.

14) Valves B and B3 were opened to release any fluid held up between the tanks and the pump's suction flange. These valves were closed when the hold-up fluid had been drained.

15) After the warming period with the heaters shut off, the second half of the experiment was performed.

16) The experiment usually ended with the 10-psid PT on line. If this was not the case, the carrier demodulator was turned off, and the cable of the on-line PT was removed from the carrier demodulator. Step 1 was done, but using the 10-psid PT instead. The valves on the PT board were adjusted to access the desired tap pair. The PE valve was closed, readying the PT for pressure drop measurements.

17) Valve B6 was closed, and the valve B3 was opened. Valves B5 and N1 were opened fully, if they were not already. The nozzle of the distilled-water hose was opened, and the hose was clamped to the inside of the right tank. The distilled-water valve was opened, filling the tanks. When the water could be seen filling the 3"-OD clear tube, valve B6 was opened to permit gravity-driven flow through the system. As the residual salt and polymer was washed from the system, the pressure drop noticeably increased. At some point the valve B5 was closed to flush the needle-valve bypass. Valve B5 was reopened. When the pump bypass seemed relatively free of polymer and salt, valve B3 was closed.

18) While the tanks were being filled, the pump was started and jogged up to maximum speed via the "shift" and "▲" keys. Again, as the salt and polymer were removed from the system, the pressure drop would rise towards its Newtonian value. The water level was watched constantly to avoid running the pump "on empty," a certain way to damage it. The pump was stopped often to allow the tanks to refill. The pump was operated a few more times to ensure that most of the salt and polymer had been removed. The distilled water valve was closed, the pump was stopped, and the power to the E-trAC inverter was cut. It often required several days to purge the system completely.

19) The valves on the PT board were closed. The two connecting tubes from the PT board were removed from the 10-psid PT, and the ends were placed in a beaker. The carrier demodulator and logging multimeter were shut off. Finally, the 0.1-, 1.0-,

and 10-psid PTs were flushed with water from the water manometer to remove any polymer or salt that might have entered into their diaphragm chambers.

4.8 Experimental Run in the Pump-Driven Flow System

1) After the set-up was complete and when the solution was fully mixed, valves L and R, as shown in Figure 3.2, were opened to fill the volume between the tanks and the pump's suction flange with solution.

2) With the 1.0-psid PT on line, valve B3 was opened to allow gravity-driven flow through the pump bypass. As the new solution displaced the old, the PT output dropped and took time to reach steady state. At this point valve B3 was closed. Valves B5 and N1 were fully open.

3) The initial pump speed was set on the keypad of the E-trAC inverter. This setting was 15 Hz, corresponding to that speed at which the 1.0-psid PT gave full-scale output. The initial "zero voltage" of the PT was recorded.

4) The HP-3467A printer was started, and the pump was started.

5) Due to the "old" hold-up in the pump, the PT output dropped and took more time to reach steady state. After steady state, the pump continued running at this speed until four scans had been printed out, the usual minimum.

6) After an initial setting of 15 Hz, the pump was jogged up to a higher speed via the "shift" and "▲" keys on the inverter. This higher speed depended upon the level of drag reduction, i.e. how much the pressure drop had fallen from the Newtonian value at this same flow rate. For example, if the initial output was 6 V and the transducer's full-scale output was 10 V, the next setting would be that which gave an 8 V output. After at least four scans, the pump speed was increased to that at which the PT output was full-scale. After four scans, the pump setting was reduced to 10 Hz, after which the pump was stopped.

7) See Step 4 in §4.6.

8) With the pump idle, valve B3 was opened, temporarily permitting gravity-driven flow. Valve B6 was closed quickly after. The rest is the same as Step 7 in §4.6.

9) At this point, if the tap pair needed changing, then the PE valve was opened, the appropriate valves on the PT board were adjusted, and the PE valve was closed.

10) The initial "zero voltage" was recorded. The printer was started, and valve B6 was opened. After steady state, the arm of the flow diverter was moved over the receptacle, starting the timer. After 15 seconds the arm was moved back to the funnel. At lower flow rates, at least 1000 ml was collected, unless the elapsed time exceeded 150 seconds. Valve B6 was closed. The elapsed time was recorded, and then the timer was

reset.

11) Step 7 was repeated.

12) See Step 11 in §4.6.

13) Valve B5 was closed. For the subsequent data points, valve N1, a 10-turn valve, was closed gradually at each data point. With the 1.0-psid PT on line, the usual turn sequence was 3, 6, 7, and 8. Steps 10 through 12 were repeated.

14) At this point, the 0.1-psid PT replaced the 1.0-psid PT and resumed sensing the pressure drop.

15) The subsequent turn sequence for valve N1 was 8, 8½, 8¾, 9, 9¼, and 9½ turns. After 9½ turns, at a flow rate of ~ 10 ml/s, valve N1 was closed just enough to halve the PT output from the previous data point. This dimunition continued until the flow was slow small that the flow diverter actually impeded the flow. At this point valve N1 was opened sequentially to record more data points. This turn sequence was 7, 6, 3, and 0. Steps 10 through 12 were repeated for all these turn settings.

16) After valve N1 was fully open, the 10-psid PT replaced the 0.1-psid PT. Valve B5 was opened. The flow diverter was disengaged from valve B6. The tube end was removed from the funnel and clamped onto valve B6.

17) Valve B3 was closed, and valve B6 was opened. The pump speed was set at 60 Hz.

18) The initial "zero voltage" of the PT was recorded. The printer was started, and then the pump was started. After an initial setting of 60 Hz, the pump was jogged down to the next setting via the "shift" and "▼" keys on the inverter. The subsequent settings were 50, 40, 30 , 20, 15, and 10 Hz, after which the pump was stopped. (Note: Jogging the pump and stopping on a targetted setting with 0.01 Hz precision required considerable practice. Because conserving solution was most important, the actual pump settings only approximated the settings given here. For example, an acceptable sequence was 60.00, 49.00, 41.00, 31.00, 22.00, 15.00, and 9.00 Hz.)

19) The first part ended, and the second part was set up.

20) After the set-up for the second half, the procedures for this part were nearly identical. The order of PT use was 10, 1.0, and 0.1 psid rather than 1.0, 0.1, and 10 psid. Steps 3 and 6 differed slightly. With the 1.0-psid PT on line, the initial pump speed was that which gave near full-scale output under experimental conditions. Subsequently, the pump would be jogged down to 10 Hz in regular increments.

4.9 Data Reduction

Figure 4.9 presents a flow-chart diagram for reducing the data. The data recorded in the laboratory notebook and that printed out on thermal paper were entered into a LOTUS-123™ spreadsheet. It contained all the calibration constants, intertap distances, and physical properties of H_2O and aqueous salt solutions to convert the flow rate, pressure drop, and temperature data into derived variables that could be analyzed. The final derived variables were T_w in dyne/cm2, Q in cm^3/s, $Re_s\sqrt{f}$, and $1/\sqrt{f}$.

The PT output, a sequence of voltage readings, was corrected by the initial and final "zero" readings to obtain the corrected output. The pressure drop in psid between the tap pair, ΔP, was calculated by dividing the corrected output by the appropriate PT constant. The wall shear stress in $dyne/cm^2$, T_w, was calculated by multiplying ΔP by the quantity D/4L, where D and L are the pipe ID and intertap distance, respectively. The flow data, both pump- and gravity-driven, were converted to give Q in ml/s. If the pump frequency in Hz was given, it was simply multiplied by the pump calibration constant and by 1000; if the data were the sample volume and time in ml and seconds, respectively, Q was calculated by dividing the time into the volume. The average velocity $<U>$ in cm/s was calculated from $4Q/\pi D^2$, the flow rate in cm^3/s divided by the pipe cross-sectional area in cm^2. From the temperature in °C and the salt concentration of the experimental solution, the density ρ, viscosity η, and the kinematic viscosity ν of the solvent were determined(CRC Handbook of Chemistry and Physics; Chemical Engineers' Handbook). Multiplying D and $<U>$ together and dividing that by ν gave Re_s, the solvent-based Reynolds number. The friction velocity u_τ in cm/s equalled $\sqrt{(T_w/\rho)}$. The

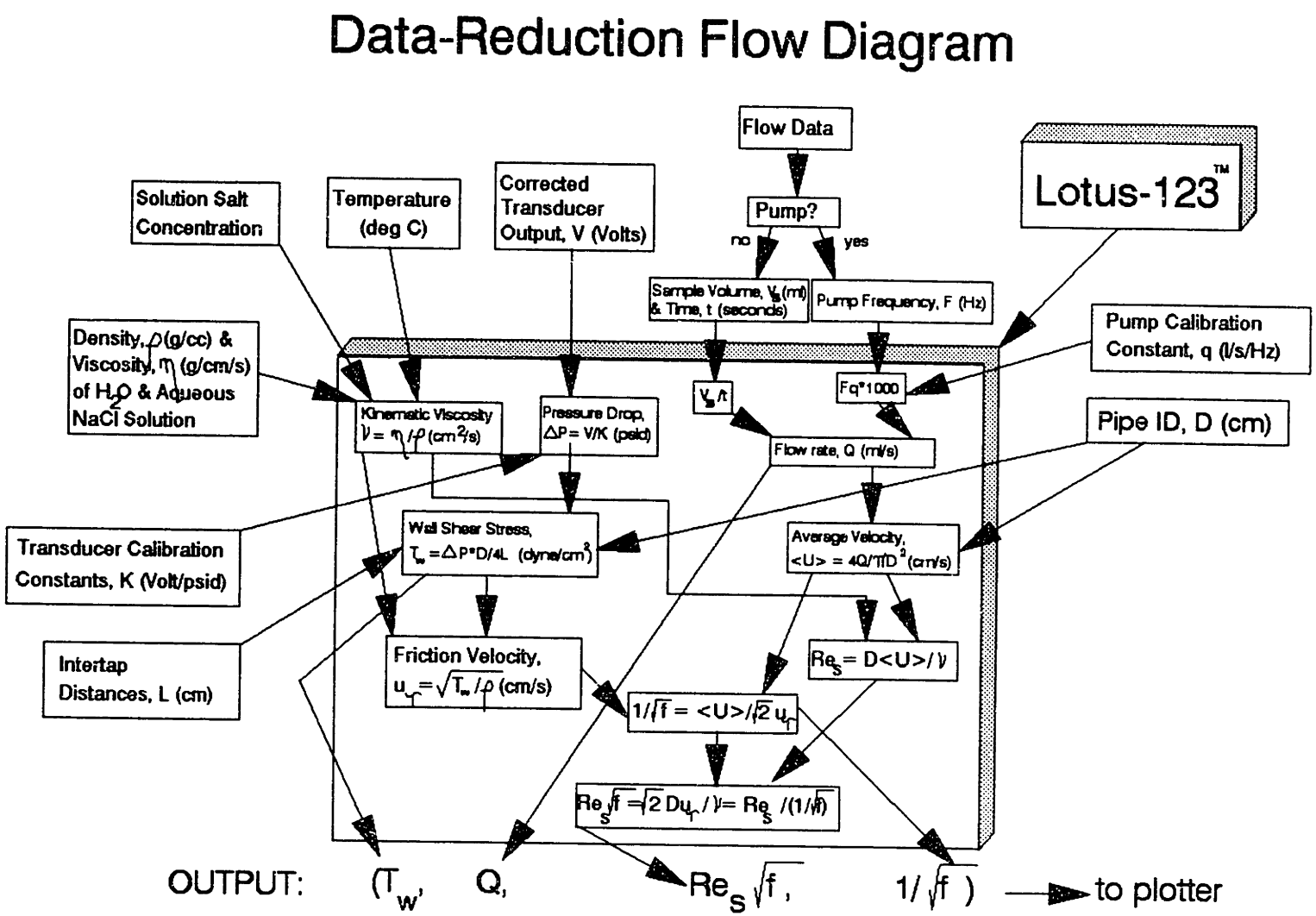


Figure 4.9: Data-Reduction Flow Diagram

ordinate of a Prandtl-Karman plot, $1/\sqrt{f}$, was derived by dividing $<U>$ by $\sqrt{2}u_\tau$; its abscissa, $Re_s\sqrt{f}$ (actually $\log_{10}Re_s\sqrt{f}$), was derived by dividing Re_s by $1/\sqrt{f}$. The four final derived variables were used in plots to display the experimental trends. Further analysis is given in the Discussion in Chapter VI.

CHAPTER V

RESULTS

Drag-reduction experiments were conducted with saline solutions of seven polyelectrolytic hydrolyzed-polyacrylamide(HPAM) additives, ranging in molecular weight from 1×10^6 to 20×10^6 g/mole, in two pipes of inner diameters 1.458 and 1.021 cm.

The experimental results are presented in three sections, dealing respectively with solvent runs, polymer-solution runs, and flow parameters extracted from the data.

5.1 Solvent Runs

Numerous solvent runs were conducted before and after polymer-solution runs. Adherence of the solvent to Poiseuille flow(L) and Newtonian turbulent flow(N) ensured that the system was free of flow artifacts and contained no residual polymer. For pipe flow, the general equations for the Newtonian baselines L and N are, respectively:

$$\frac{1}{\sqrt{f}} = \frac{Re_s\sqrt{f}}{16} \qquad (2.3\text{-}1)$$

$$\frac{1}{\sqrt{f}} = A_n \log(Re_s\sqrt{f}) - B_n \qquad (5.1\text{-}1)$$

where f is the Fanning friction factor, Re is the Reynolds Number, and subscript s

implies the use of solvent physical properties. In Equation 5.1-1, the universal Prandtl-Karman(PK) correlation for turbulent pipe flow results when (A_n, B_n) = (4, 0.4), equation 2.3-2. (A minus sign is put before B_n to render it positive in most cases.)

Solvent runs have been arranged in five sets as shown in Table 5.1.1, which cites the number of runs and the average turbulent flow parameters. Solvent runs in the 1.458- and 1.021-cm pipes were respectively designated S00000??? and T00000??? with the last three places(???) as follows: Data Set #1 contained runs 243, 245, 248, 251, 252, 255, 258, 261, 264, 267, 270, 272, 276, 279, 282, 285, 288, 293, 298, 300, 302, 305, 308, 311, 314, 317, 320, 323, 326, 329, 333, 336, and 339 taken in the pump-driven system with the 1.458-cm pipe. Data Set #2 contained runs 341, 342, 345, 348, 351, 354, 358, 361, 364, 367, and 370 taken in the pump-driven system with the 1.021-cm pipe. Data Sets #3, #4, and #5 were taken in the gravity-driven system with the 1.458-cm pipe and consisted of the following runs: 011 - 013, 016, 022, 025, 034, 038, and 042; 065-069, 072, 077, 081, and 085; and 089, 093, 100, 116, 117, 125, and 131.

Table 5.1.1
Solvent Data Set Parameters

Solvent Data Set Number	System	Pipe ID	Pipe Aspect Ratio	Number of runs	Turbulent Flow Parameters	
		(cm)	L/D		A_n	B_n
1	Pump	1.458	183.0	33	4.0	0.4
2	Pump	1.021	203.2	11	4.0	0.4
3	Gravity	1.458	209.8	9	4.0	0.4
4	Gravity	1.458	209.8	10	2.98	-2.00
5	Gravity	1.458	209.8	7	3.54	-0.79

In Figure 5.1.1, solvent data set 1 is plotted in semilogarithmic PK coordinates, the ordinate and abscissa of which are $1/\sqrt{f}$ and $Re_s\sqrt{f}$, respectively. At the lowest flow rate, $Re_s\sqrt{f} \approx 40$, which corresponds to $Re_s \approx 100$ in the laminar flow regime L. As $Re_s\sqrt{f}$ increases, the data follow L until $Re_s\sqrt{f} \approx 180(Re_s \approx 2000)$. Here, the flow begins a transition to turbulence. The data drop down from L towards the PK baseline. At $Re_s\sqrt{f} \approx 400(Re_s \approx 4000)$, the flow has become fully turbulent; thereafter the data continue along PK up to the highest flow rate, which corresponds to $Re_s\sqrt{f} \approx 9000(Re_s = 140000)$.

Figures 5.1.2 - 5.1.5 contain the four composite PK plots corresponding to solvent data sets 2 - 5 and demonstrate how well L and PK were established in these cases.

Figures 5.1.6 and 5.1.7 present additional PK plots of solvent data in the turbulent regime using various different pairs of pressure taps in each of the 1.458- and 1.021-cm pipes, respectively. In both figures, a solid line, 1.00PK, and two dotted lines, 1.01PK and 0.99PK, have been drawn in, the latter two representing respectively $\pm 1\%$ deviations from the PK correlation. Comparison between the results for all pressure tap pairs shows that the differences between tap pairs were insignificant relative to the inherent data scatter, which is approximately $\pm 1\%$ around the PK correlation. These figures show that fully-developed turbulent flow in smooth pipes was achieved with the solvent.

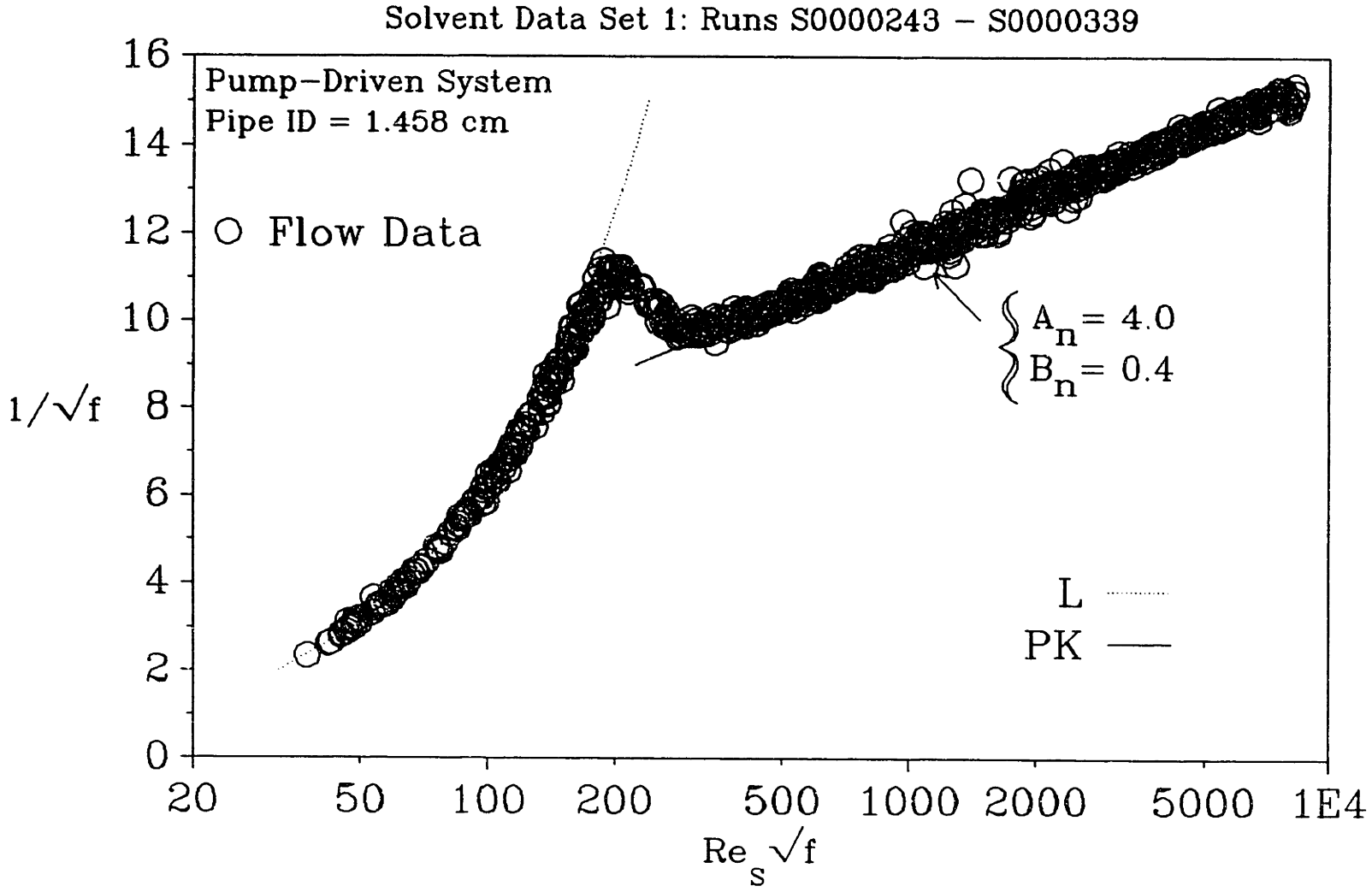


Figure 5.1.1: Solvent Data Set 1, Runs S0000243 - S0000339

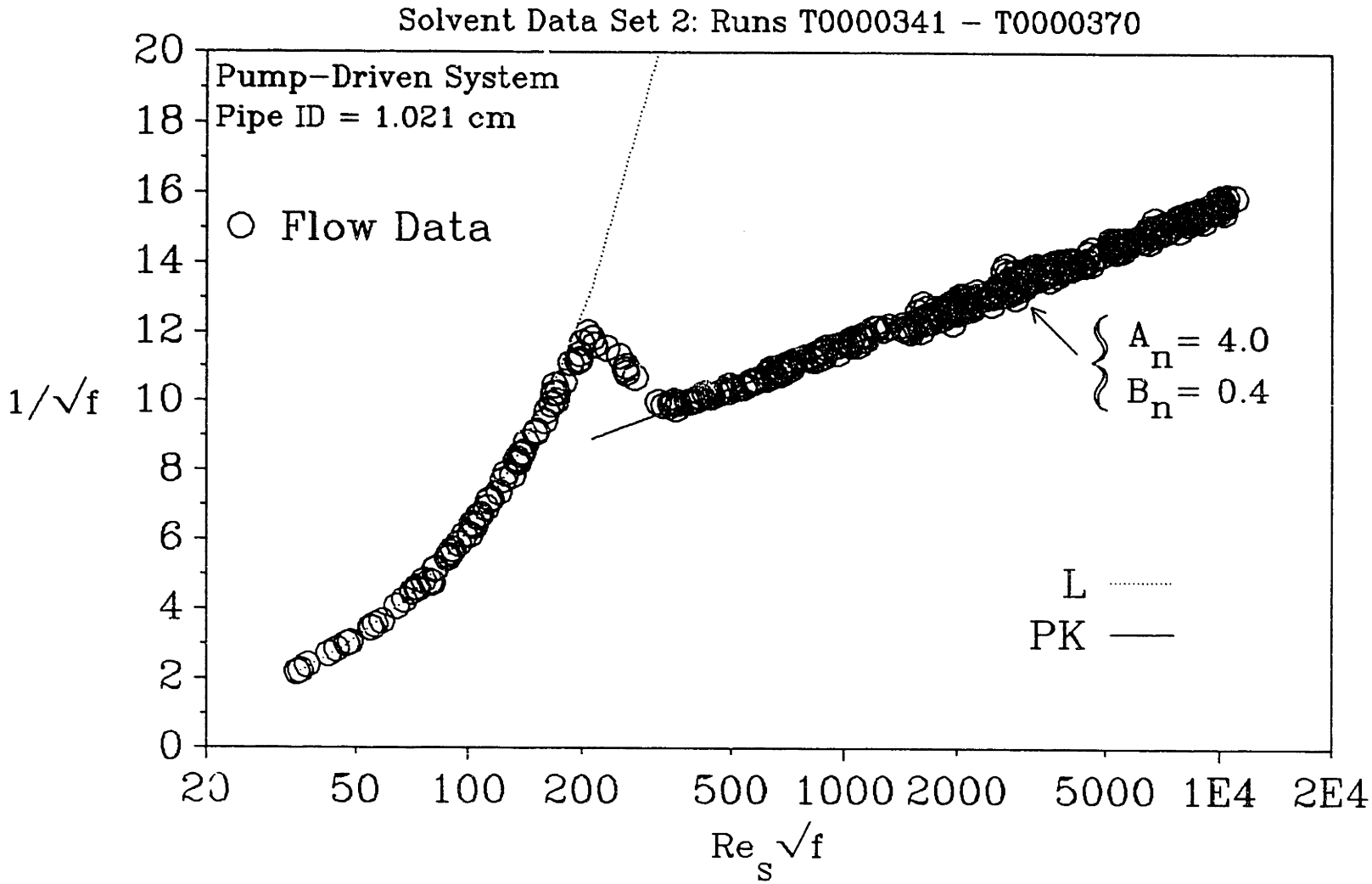


Figure 5.1.2: Solvent Data Set 2, Runs T0000341 - T0000370

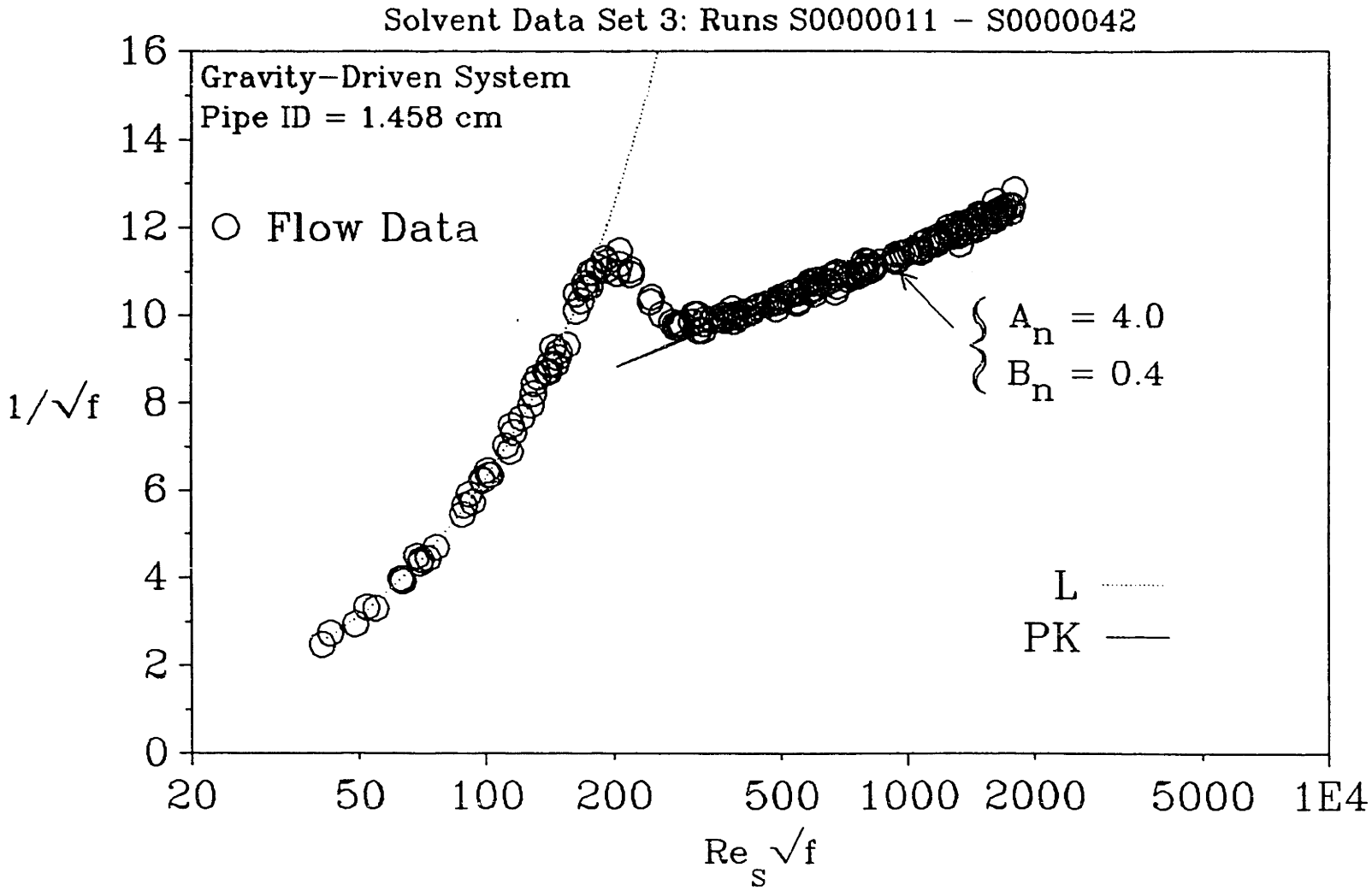


Figure 5.1.3: Solvent Data Set 3, Runs S0000011 - S0000042

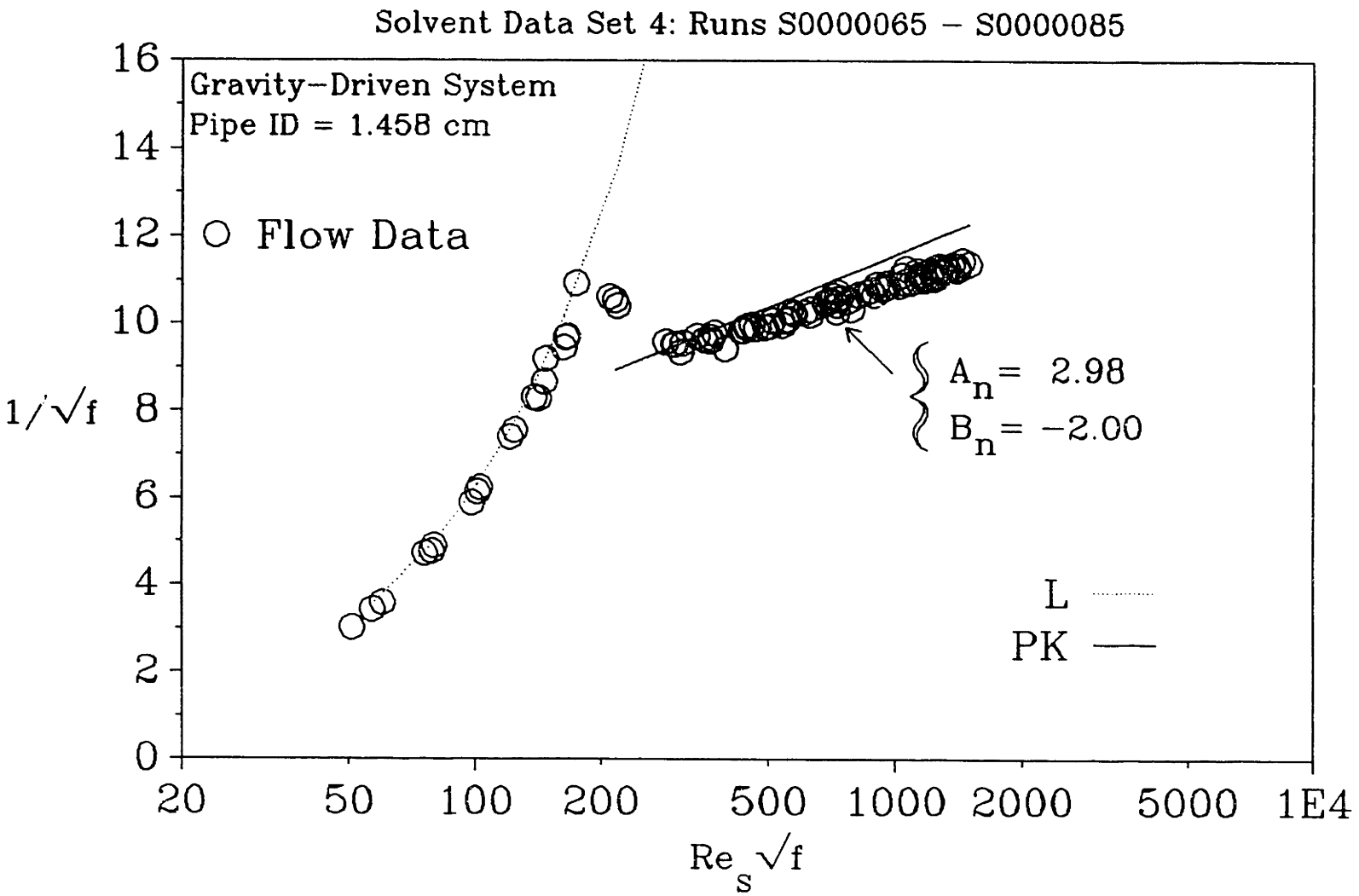


Figure 5.1.4: Solvent Data Set 4, Runs S0000065 - S0000085

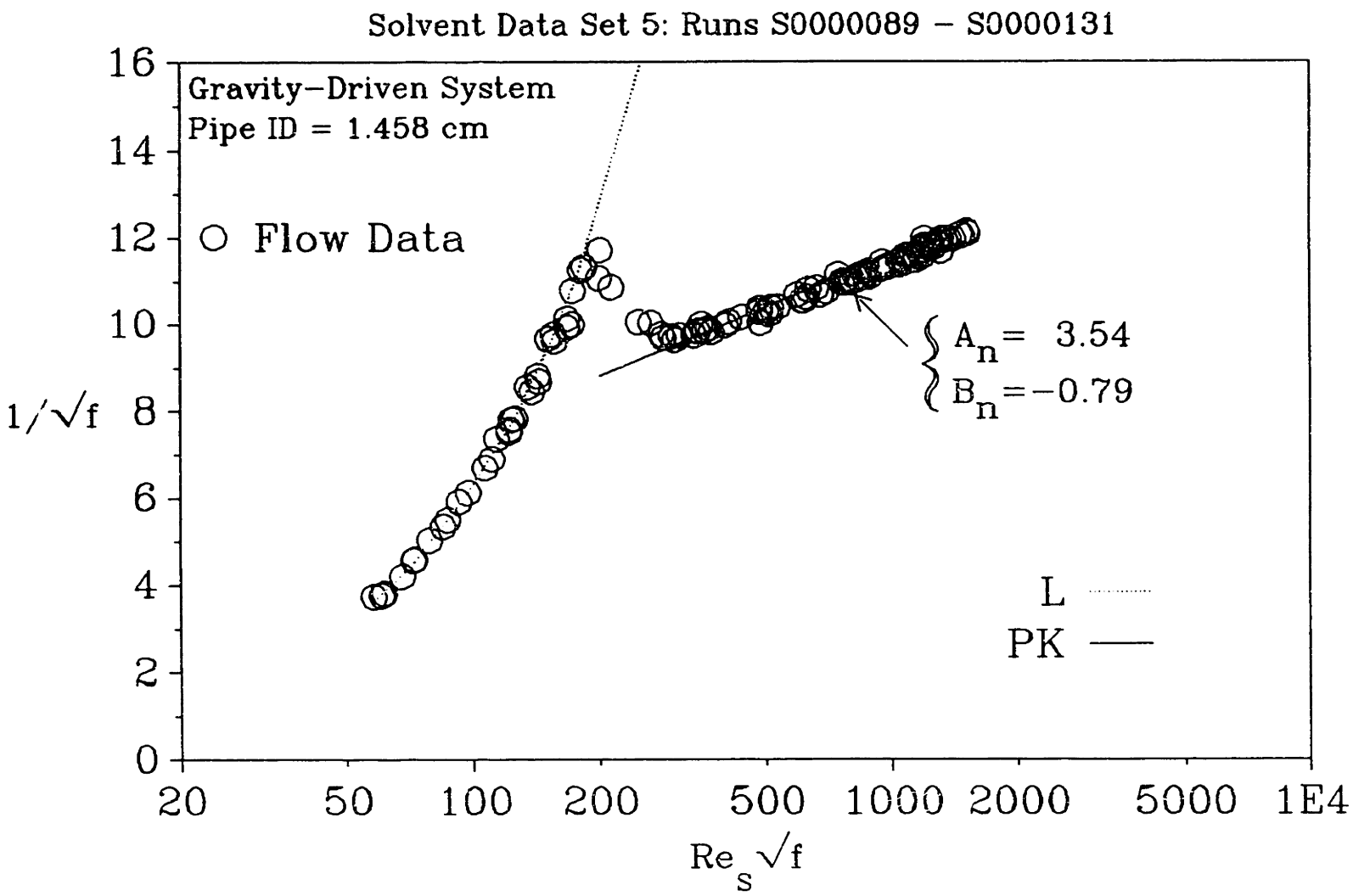


Figure 5.1.5: Solvent Data Set 5, Runs S0000089 - S00000131

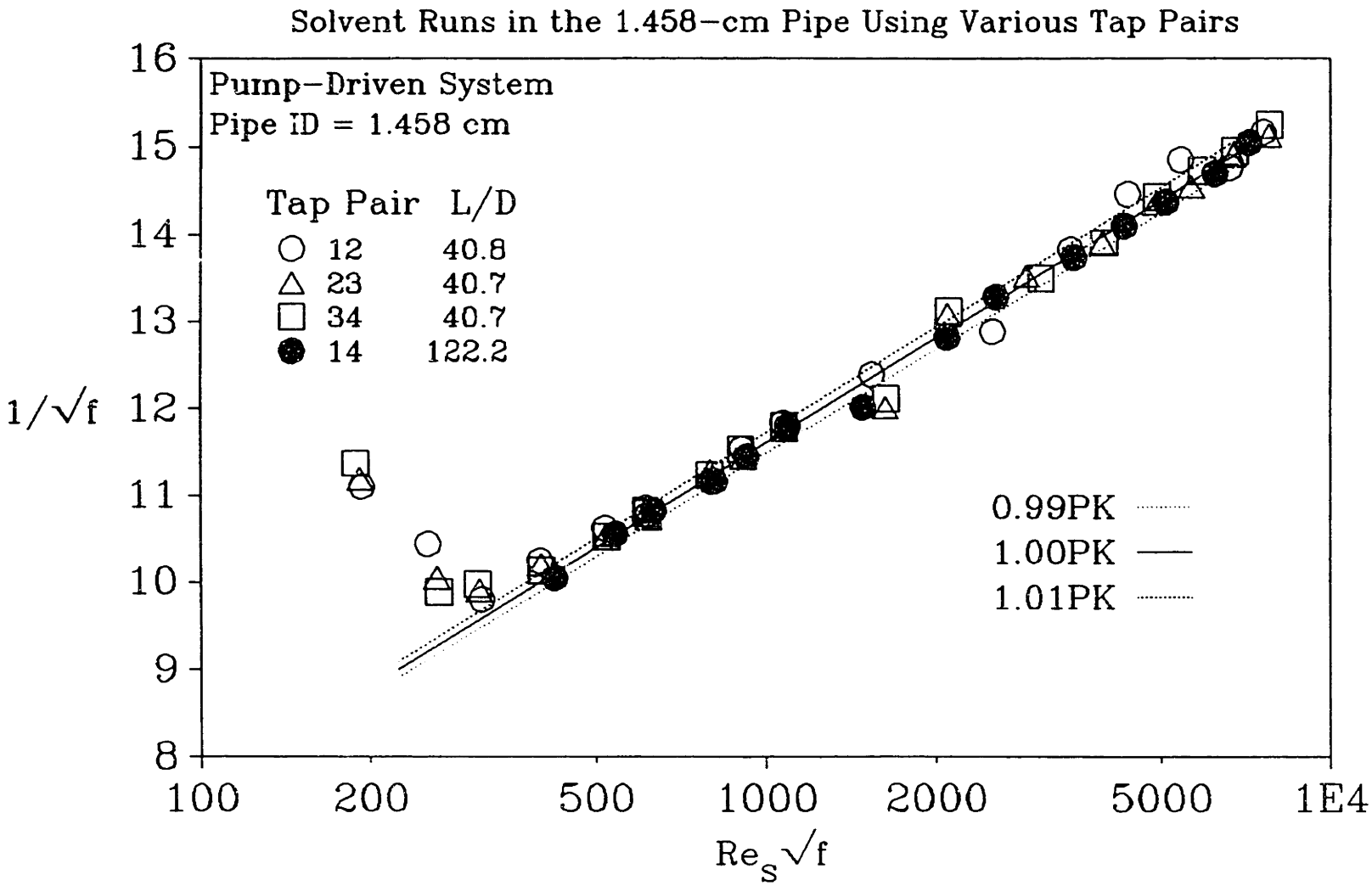


Figure 5.1.6: Solvent Runs in the 1.458-cm Pipe Using Various Tap Pairs

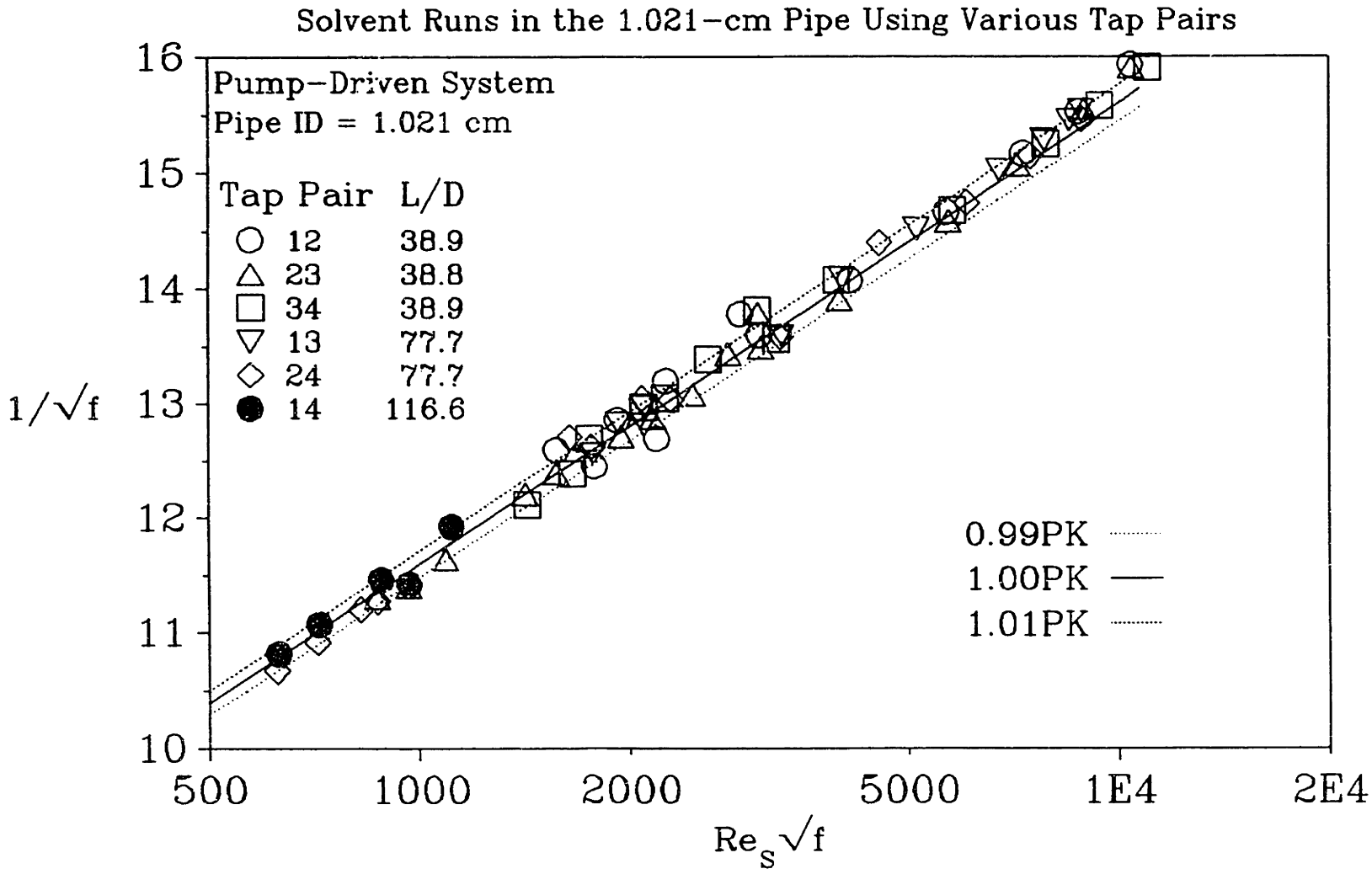


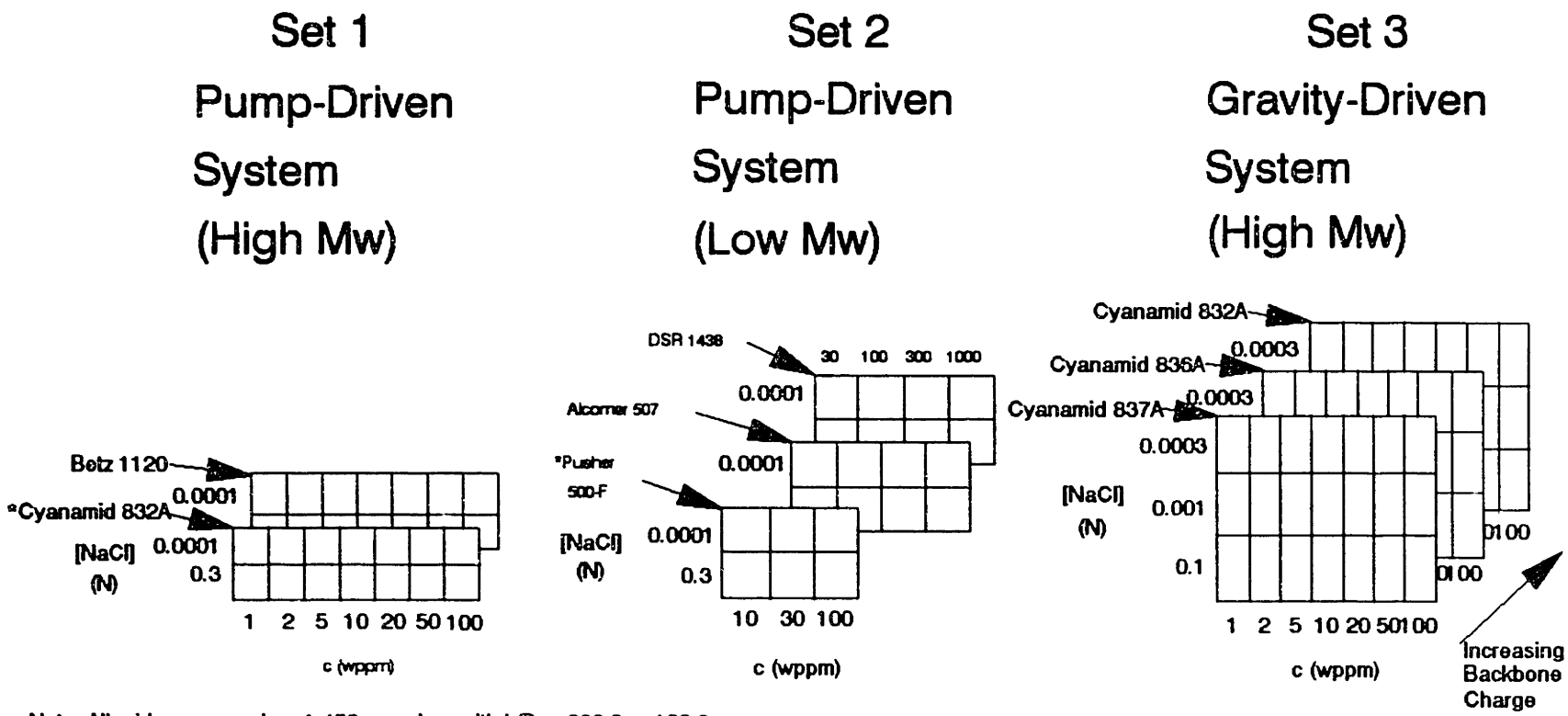
Figure 5.1.7: Solvent Runs in the 1.021-cm Pipe Using Various Tap Pairs

5.2 Polymer-Solution Runs

Polymer-solution results are presented in three sets: (1) the high molecular-weight polymer additives C832A and B1120 in the pump-driven system; (2) the low molecular-weight polymer additives P500, A507, and D1438 in the pump-driven system; and (3) the high molecular-weight polymer additives C837A, C836A, and C832A in the gravity-driven system. The first two sets sought the influence of additive molecular weight and conformation on flow enhancement, while the third set qualitatively explored how the backbone charge of a high molecular-weight polymer additive affected flow enhancement. Additives C832A and P500 in sets 1 and 2, respectively, were each studied separately in two pipes of inner diameters 1.458 and 1.021 cm to infer the effect of flow scale.

Figure 5.2.1 shows the actual experimental grids executed. For high molecular-weight polymers, a logarithmic series of polymer concentrations c = (1, 2, 5, 10, . . .) wppm was used. For low molecular-weight polymers, the logarithmic series used was (10, 30, 100, . . .) wppm. In the pump-driven system, each polymer concentration was studied at two salinities, [NaCl] = 1.0×10^{-4} and 3×10^{-1} N. In the gravity-driven system, each polymer concentration was studied at three salinities, [NaCl] = 3.0×10^{-4}, 1.0×10^{-3}, and 1.0×10^{-1} N. The columns in Figure 5.2.1 reflect the actual experimental procedure. Each polymer solution was used for the entire [NaCl] range studied to reveal the effect of salinity-induced conformational changes while maintaining both the additive amount and molecular-weight distribution constant.

Experimental Grids



Note: All grids were run in a 1.458 cm. pipe, with L/D = 209.8 or 183.0
* entries were also run in a 1.021-cm pipe, with L/D = 203.2

Figure 5.2.1: Experimental Grids

5.2.0 Turbulent-Flow Development in Polymer Solutions

Variations in the pressure drop at a constant flow rate measured by different pairs of pressure taps indicate simultaneously the inherent scatter among the polymer-solution data and the severity of axial polymer degradation. Even though separating the two phenomena may not be possible, measuring such variations provides some estimate of the uncertainty in the data from polymer-solution experiments.

Figure 5.2.2 shows the variations in data measured by tap pairs 12, 23, and 34 in the pump-driven system using the 1.458-cm pipe for turbulent flows of a solution having 5-wppm B1120 and 0.0001 N NaCl. The line M, provided for reference, represents the MDR asymptote. In PK coordinates, a variation in the measured pressure drop at a constant flow rate shifts both the abscissa $Re_s\sqrt{f}$ and the ordinate $1/\sqrt{f}$.

At the highest $Re_s\sqrt{f} \approx 5500$, tap pairs 12, 34, and 23 respectively measure increasing pressure drops at a constant flow rate, as indicated by increasing $Re_s\sqrt{f}$ and decreasing $1/\sqrt{f}$ in Figure 5.2.2, with the data from all taps lying within one ordinate unit. Because axial polymer degradation alone should cause tap pairs 12, 23, and 34 to measure increasing pressure drops, the observed differences among taps probably reflect the inherent data uncertainty. As $Re_s\sqrt{f}$ decreases, the average $1/\sqrt{f}$ of the data increases slightly, reaches a plateau for $4400 > Re_s\sqrt{f} > 3000$, and then declines roughly linearly. The plateau region strongly suggests that polymer degradation within the pipe becomes important at $Re_s\sqrt{f} > 4000$. At lower $Re_s\sqrt{f} \approx 2000$, the inherent data scatter remains about one unit of $1/\sqrt{f}$.

In experiments using the 1.458-cm pipe, the pressure drop was measured by tap

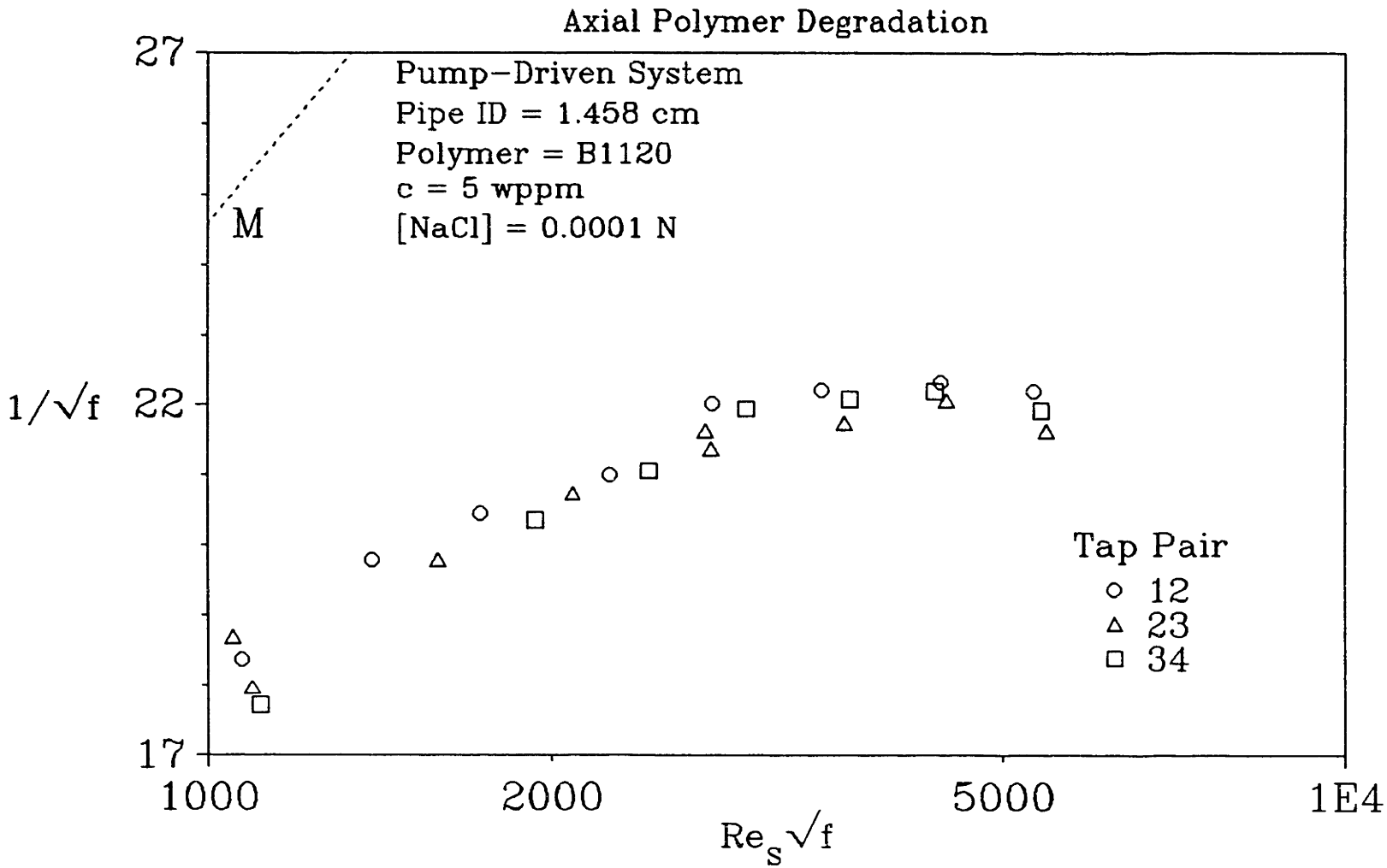


Figure 5.2.2: Axial Polymer Degradation in the 1.458-cm Pipe

pair 14, which provided the largest transducer signal. The experimental reported data, thus, reflect an average pressure drop across tap pairs 12, 23, and 34.

Figure 5.2.3 presents data measured by tap pairs 12, 23, and 34 for turbulent flows of a 10-wppm solution of C832A in 0.0001 N NaCl over five passes through the pump-driven system using the 1.021-cm pipe. The line M represents the MDR asymptote, which offers some perspective.

At the highest $Re_s\sqrt{f} \approx 7000$ in pass 1, tap pairs 12, 23, and 34 measure increasingly higher pressure drops, respectively, with the data from all taps lying within one ordinate unit. As $Re_s\sqrt{f}$ decreases, the average $1/\sqrt{f}$ increases and reaches a plateau at $Re_s\sqrt{f} \approx 3000$. The spread among the data measured by the tap pairs at the same flow rate also increases with decreasing $Re_s\sqrt{f}$, but remains within about one unit of $1/\sqrt{f}$. There is no entirely consistent pattern of tap measurements, but the $1/\sqrt{f}$ from pair 12 is always slightly greater than $1/\sqrt{f}$ from either 23 or 34, suggestive of polymer degradation in axial flow through the pipe.

In pass 2, the absolute levels of drag reduction are much lower than in pass 1, showing that the ancillary equipment needed to recycle the fluid degraded the polymer solution much more than a single pass through the system. At the highest $Re_s\sqrt{f} \approx 7300$, tap pairs 12, 23, and 34 respectively measure increasingly larger pressure drops. The data-scatter among them, $\sim$½ unit of $1/\sqrt{f}$, is less than that in the first pass. As $Re_s\sqrt{f}$ decreases, the data measured by all tap pairs increase, peak at $Re_s\sqrt{f} \approx 5500$, and then decline down to $Re_s\sqrt{f} \approx 2500$. This observation likely reflects polymer degradation. Furthermore, not only does the scatter decrease among the data measured by the tap pairs at a constant flow rate, but the order in which they measure increasing pressure drops

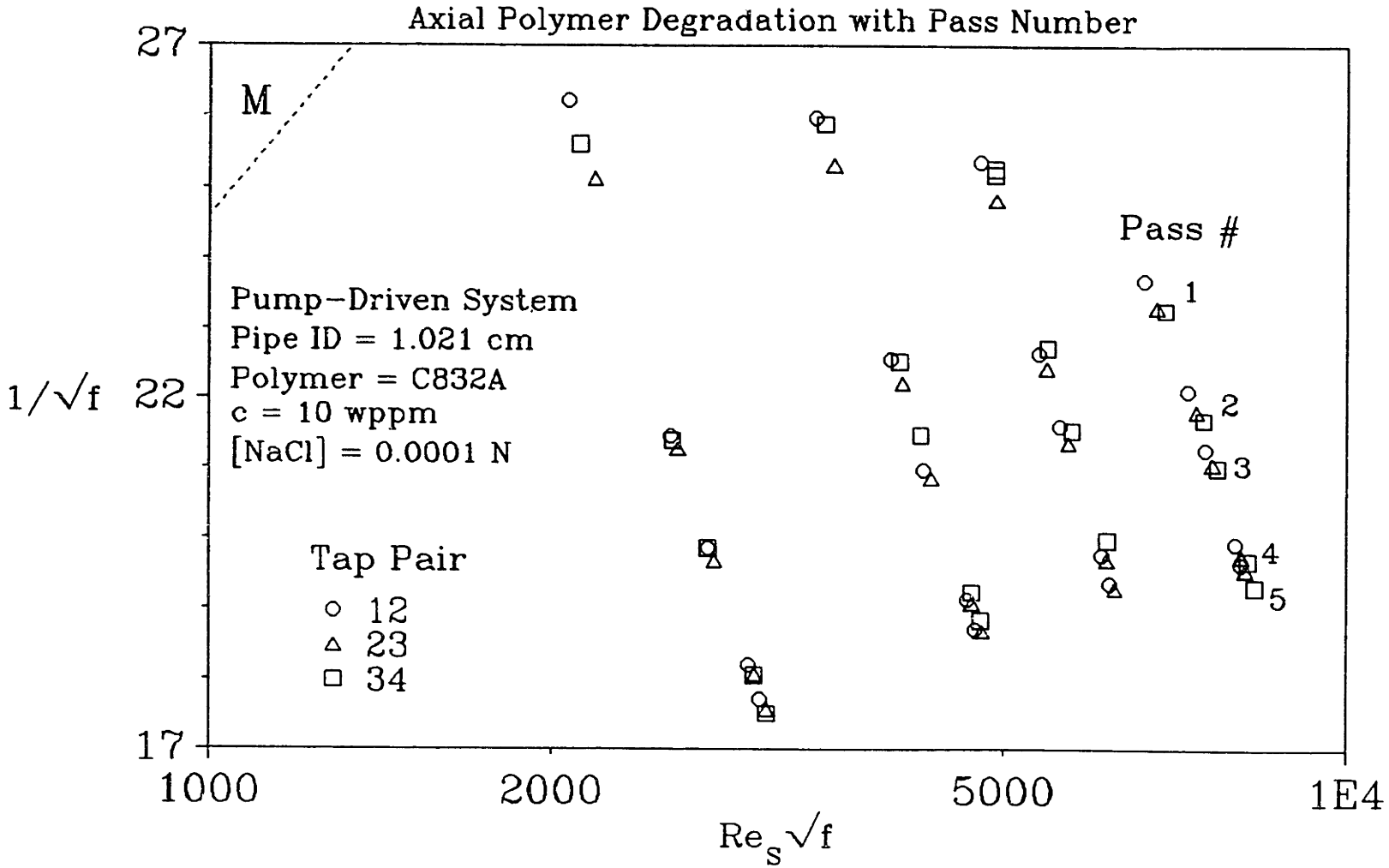


Figure 5.2.3: Axial Polymer Degradation with Pass Number in the 1.021-cm Pipe

appears more random. Thus, polymer degradation has a relatively less profound effect in pass 2 than in pass 1.

In passes 3, 4, and 5, the absolute drag-reduction levels fall further with each pass. The data-scatter appears to diminish, the tap-pair order becomes less regular, and the peak in the average $1/\sqrt{f}$ shifts to higher $Re\sqrt{f}$.

In experiments using the 1.021-cm pipe, tap pair 12 was used to measure the pressure drop at these high flow rates. Using tap pair 13, 24, or 14 would have saturated and very likely damaged the carrier demodulator needed to process the pressure-transducer signal. Tap pair 14 was used when the flow was gravity driven; at such lower stresses, polymer degradation was likely not a problem, especially in laminar flow. As seen in Figure 5.2.3, tap pair 12 consistently measures the lowest pressure drop in turbulent flows of fresh polymer solutions and probably provides the data least affected by polymer degradation.

5.2.1 Introductory Examples: Representative Flow Trajectories

Aspects of polymer-solution flow behavior are introduced in Figure 5.2.4, a PK plot of experiments in the pump-driven system using two 10-wppm solutions of additive B1120 in, respectively, 0.3(▾) and 0.0001(▿) N NaCl.

In this figure, lines L and N represent respectively the Newtonian laminar-flow and turbulent-flow baselines, equations 2.3-1 and 5.1-1, whereas the line M represents the empirically established maximum drag reducing(MDR) asymptote(Virk et al., 1970):

$$\frac{1}{\sqrt{f}} = 19.0 \log(Re_s\sqrt{f}) - 32.4 \qquad (2.3\text{-}7)$$

Lines N and M envelop the region of turbulent drag reduction; this region is called the "polymeric regime" because within it the extent of drag reduction depends on additive parameters.

Consider first the data at high salinity, 0.3 N NaCl (▾), which typify results obtained with initially collapsed conformations of HPAM additives. At low $Re_s\sqrt{f} < 150$, the polymer-solution data closely follow Poiseuille's law L. At $Re_s\sqrt{f} \approx 150$, the data deviate downward from L and then drop toward N, which is reached at $Re_s\sqrt{f} \approx 350$. The laminar-to-turbulent transition observed here is similar to that observed in solvent runs, such as those in Figure 5.1.1, described earlier. For $350 < Re_s\sqrt{f} < 500$, the polymer-solution data follow the Newtonian turbulent-flow line N. Then at $Re_s\sqrt{f} \approx 500$ the data abruptly lift up from N at the "onset" point, denoted by an asterisk and so named because it marks the onset of flow enhancement; i.e., for any fixed $Re_s\sqrt{f} > Re_s\sqrt{f}^*$, $1/\sqrt{f_p} > 1/\sqrt{f_n}$. For $Re_s\sqrt{f} > 500$ the data exhibit flow enhancement rising into the polymeric regime along a near-linear segment P with slope and intercept $(A_p, B_p) = (17.2, 36.1)$ for $500 < Re_s\sqrt{f} < 3500$. At the highest $Re_s\sqrt{f} \approx 4000$ the data depart slightly downward from the line segment, possibly because of polymer degradation within the test pipe as seen in Figure 5.2.3. The flow enhancements achieved are also of interest, as measured by the apparent slip $S' = (1/\sqrt{f_p} - 1/\sqrt{f_n})$ at fixed $Re_s\sqrt{f}$. In Figure 5.2.4, at $Re_s\sqrt{f} = 1000$, $1/\sqrt{f_p} = 15.6$, $1/\sqrt{f_n} = 11.6$, and $S' = 4.0$, corresponding to fractional flow enhancement $S_F = 0.34$ relative to the solvent. At $Re_s\sqrt{f} = 3000$, $1/\sqrt{f_p} = 23.7$, $1/\sqrt{f_n} = 13.5$, and $S' = 10.2$ and $S_F = S'/(1/\sqrt{f_n}) = 0.76$ relative to the

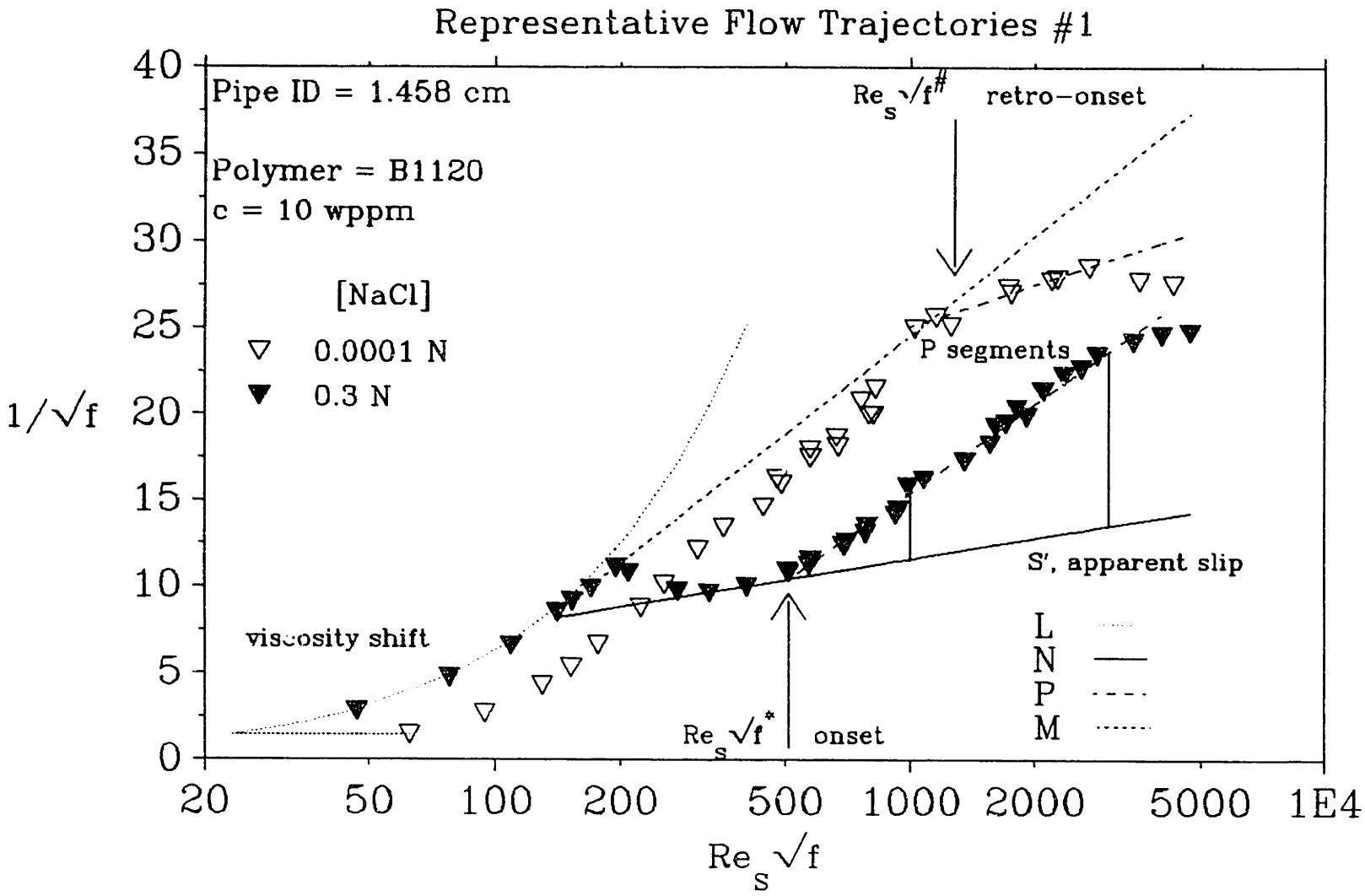


Figure 5.2.4: Representative Flow Trajectories #1

solvent. Note that S' increases from 4.0 to 10.2 as $Re_s\sqrt{f}$ increases from 1000 to 3000, respectively.

The flow trajectory observed for 10 wppm of B1120 in 0.3 N NaCl in Figure 5.2.2 thus contains three segments: laminar flow, L; turbulent flow without drag reduction, N; and turbulent flow with drag reduction, P, with a distinct onset of drag reduction that separates the N and P segments. Such LNP trajectories are commonly exhibited by solutions of random-coiling macromolecules and are termed "Type A" drag-reductien behavior. The polymeric-regime segment P observed during Type-A drag reduction can be quantitatively characterized by the onset wall shear stress, T_w^*, which is related to $Re_s\sqrt{f^*}$, and the slope increment $\delta = A_p - A_n$. In this example, $Re_s\sqrt{f^*} = 450$, $T_w^* = 4.1$ dyne/cm^2, and $\delta = 17.2 - 4.0 = 13.2$.

Next consider the second set of data in Figure 5.2.4 at low salinity, 0.0001 N NaCl(▽), which is representative of results obtained with initially extended conformations of HPAM additives. For $60 < Re_s\sqrt{f} < 400$ the data are displaced rightwards from Poiseuille's law L, to higher $Re_s\sqrt{f}$ at fixed $1/\sqrt{f}$; this displacement, labelled "viscosity shift" in Figure 5.2.4, reflects the relative viscosity η_r of the polymer solution. Note that in this region of low $Re_s\sqrt{f}$, the data being displaced downwards from L to lower $1/\sqrt{f}$, the polymer-solution is drag-enhancing. For $60 < Re_s\sqrt{f} < 400$, the data follow a Poiseuille-like path, but as $Re_s\sqrt{f}$ increases, the viscosity shift decreases, indicating shear-thinning behavior. The data pass through the Newtonian turbulent-flow baseline N, at $Res\sqrt{f} \approx 220$, and enter the polymeric regime without exhibiting the laminar-to-turbulent transition observed in the 0.3-N data. For $400 < Re_s\sqrt{f}$ 1500, the data ascend toward, and lie nearly parallel to, the maximum drag-reducing(MDR) asymptote M. At $Re_s\sqrt{f} \approx$

1500, the data depart downwards from M into the polymeric regime at a "retro-onset" point, denoted by an octathorpe(#). The retro-onset point separates the region of asymptotic maximum drag reduction, which is independent of additive properties, from the polymeric regime, within which drag reduction is dependent on additive properties; in this sense, retro-onset is the converse of onset, which separates Newtonian flow, with no drag reduction, from the polymeric regime. For $1500 < Re_s\sqrt{f} < 3400$, the data continue into the polymeric regime along a near-linear segment P with slope and intercept $(A_p, B_p) = (8.0, -1.2)$. At the highest $Re_s\sqrt{f} \approx 4000$, the data descend slightly from segment P, possibly because of polymer degradation within the test pipe. The following flow enhancements are observed: At $Re_s\sqrt{f} = 1000$, $1/\sqrt{f_p} = 1/\sqrt{f_m} = 24.6$, $1/\sqrt{f_n} = 11.6$, and $S' = 13.0$, corresponding to $S_F = 1.1$, the maximum achievable at $Re_s\sqrt{f} = 1000$; and at $Re_s\sqrt{f} = 3000$, $1/\sqrt{f_p} = 28.2$, $1/\sqrt{f_n} = 13.5$, and $S' = 14.7$, corresponding to a fractional flow enhancement $S_F = S'/(1/\sqrt{f_n}) = 1.09$ relative to the solvent.

The flow trajectory observed for 10 wppm of B1120 in 0.0001 N NaCl in Figure 5.2.4 thus has three parts: drag-enhanced laminar flow with a relative viscosity $\eta_r > 1$; maximum drag reduction along the MDR asymptote, M; and turbulent drag reduction, P, with a retro-onset that separates the M and P segments. Such LMP trajectories have been previously observed with solutions of extended macromolecules and constitute "Type B" drag-reduction behavior. Note the important feature of Type-B behavior: that the polymeric-regime segment P is almost parallel to N.

Finally, it is interesting to compare the two sets of data in Figure 5.2.4 to infer the effects of additive conformation. In laminar flow for $Re_s\sqrt{f} < 200$, the expanded conformation, in 0.0001 N NaCl, enhances drag relative to solvent more than does the

collapsed conformation, the former showing higher $1/\sqrt{f}$ than the latter by ~ 3.5 units. In turbulent flow, however, for $Re_s\sqrt{f} > 400$, the expanded conformation reduces drag relative to solvent more than does the collapsed conformation, the former always attaining higher $1/\sqrt{f}$ than the latter. Thus, the ratio of S' of the Type-A collapsed conformation to that of the Type-B expanded conformation, S'_A/S'_B increases with increasing $Re_s\sqrt{f}$. For $Re_s\sqrt{f} < Re_s\sqrt{f}^*$, $S'_A/S'_B = 0$, the collapsed conformation providing no flow enhancement before onset, at which $Re_s\sqrt{f}^*$ the extended conformation does. For $Re_s\sqrt{f} \geq Re_s\sqrt{f}^*$, S'_A/S'_B increases with increasing $Re_s\sqrt{f}$, approaching unity at higher $Re_s\sqrt{f}$; after onset, S'_A increases faster than does S'_B with increasing $Re_s\sqrt{f}$ because the Type-A P segment has a steeper slope than does the Type-B P segment. In this example, at $Re_s\sqrt{f} = 500$, 1000, and 3000, $S'_A/S'_B = 0$, 0.31, and 0.69, respectively.

A second illustration of polymer-solution flow behavior is given in Figure 5.2.5, a PK plot of experiments in the gravity-driven system using 20.6-wppm solutions of additive C836A, an HPAM of high molecular-weight and moderate backbone charge, at two salinities, 0.1(◆) and 0.001(◇) N NaCl, respectively.

Lines L, N, and M respectively represent Poiseuille's law for laminar flow, the Newtonian turbulent-flow baseline, and the MDR asymptote, the latter two envelop the polymeric regime P.

Data at high salinity, 0.1 N NaCl(◆), exemplify results obtained with an initially collapsed conformation of the C836A additive. At low $Re_s\sqrt{f} < 150$, the polymer-solution data closely follow L. At $Re_s\sqrt{f} \approx 180$, the data depart downward from L and then drop toward N, which is reached at $Re_s\sqrt{f} \approx 350$. This laminar-to-turbulent

transition is much like that seen with solvent alone in Figure 5.1.1. For 350 < $Re_s\sqrt{f}$ < 600, the polymer-solution data adhere closely to N, exhibiting no drag reduction. At $Re_s\sqrt{f} \approx 700$, the data rise weakly from N at an "onset" point, indicated on the figure, beyond which $1/\sqrt{f_p} > 1/\sqrt{f_n}$. For 700 < $Re_s\sqrt{f}$ < 900, the polymer-solution data initially ascend into the polymeric regime along a shallow knee that shortly joins a well-developed linear segment P, of slope and intercept $(A_p, B_p) = (18.6, 42.8)$ for 900 < $Re_s\sqrt{f}$ < 1400. As shown in Figure 5.2.5, the visually determined onset point, $Re_s\sqrt{f^*} \approx 660$, where the data along N first appear to depart significantly from N, does not necessarily coincide with the regressed onset point, $Re_s\sqrt{f^*} \approx 770$, where the linear segment P, extrapolated backward, would intersect the baseline N. At $Re_s\sqrt{f} = 1000$, the apparent slip S' = (12.9 - 11.5) = 1.4, corresponding to a fractional flow enhancement $S_F = 0.12$ relative to the solvent.

The preceeding flow trajectory comprises three distinct segments, namely: laminar flow, L; turbulent-flow without drag reduction, N; and turbulent flow with drag reduction, P, with an onset point separating the N and P segments. This LNP trajectory exemplifies the Type-A drag-reduction flow behavior typically exhibited by solutions of random-coiling macromolecules. Characteristic parameters of the polymeric-regime segment P are: $T_w^* \approx 13.7$ dyne/cm^2 and $Re_s\sqrt{f^*} \approx 770$, and the slope increment δ = 15.1.

Data at low salinity, 0.001 N NaCl(◇), in Figure 5.2.5 illustrate the behavior of an initially expanded conformation of the C836A macromolecule. At low flowrates, 80 < $Re_s\sqrt{f}$ < 350, the data follow a laminar path that is almost both parallel to, but shifted rightwards from, Poiseuille's law L. The displacement between L and the

laminar-flow data at constant $1/\sqrt{f}$, called "viscosity shift" in Figure 5.2.5, reflects the relative viscosity η_r of the polymer solution, which is thus seen to exhibit shear thinning. The polymer-solution evidently enhances drag in laminar flow, its data lying below L, with η_r decreasing from 1.9 at $Re_s\sqrt{f} = 80$ to 1.5 at $Re_s\sqrt{f} = 350$. Between $350 < Re_s\sqrt{f} < 550$, the polymer solution undergoes a laminar-to-turbulent transition, the data abruptly shifting horizontally rightward from their laminar-flow path to a turbulent flow segment P that lies in the polymeric regime. The observed transition is noteworthy because the polymer-solution exhibits drag reduction immediately upon attaining turbulent flow. For $550 < Re_s\sqrt{f} < 1100$, the polymer-solution data rise into the polymeric regime along a linear segment P, of slope and intercept $(A_p, B_p) = (19.8, 38.9)$. At $Re_s\sqrt{f} = 1000$, the apparent slip $S' = 20.5 - 11.5 = 9.0$ and fractional flow enhancement $S_F = 0.79$ relative to the solvent.

The flow trajectory observed for 20.6 wppm of C836A in 0.001 N NaCl has two distinct segments: drag-enhanced laminar flow, with relative viscosity $\eta_r \approx 1.7$, amidst some shear thinning, and drag-reduced turbulent-flow along a linear polymeric-regime segment P. This LP trajectory evidently differs from both the LNP and LMP types of trajectories seen in earlier examples, lacking a central turbulent-flow segment along either N or M, and displaying neither onset nor retro-onset. This observed behavior is classified Type A, not Type B, because the polymeric-regime segment possesses a slope similar to, not much shallower than, that of the 20.6-wppm C836A in 0.1 N NaCl, which clearly exhibited Type-A behavior.

Finally, comparing the two sets of data in Figure 5.2.5, it is seen that, relative to the collapsed conformation, the expanded conformation of C836A causes greater drag

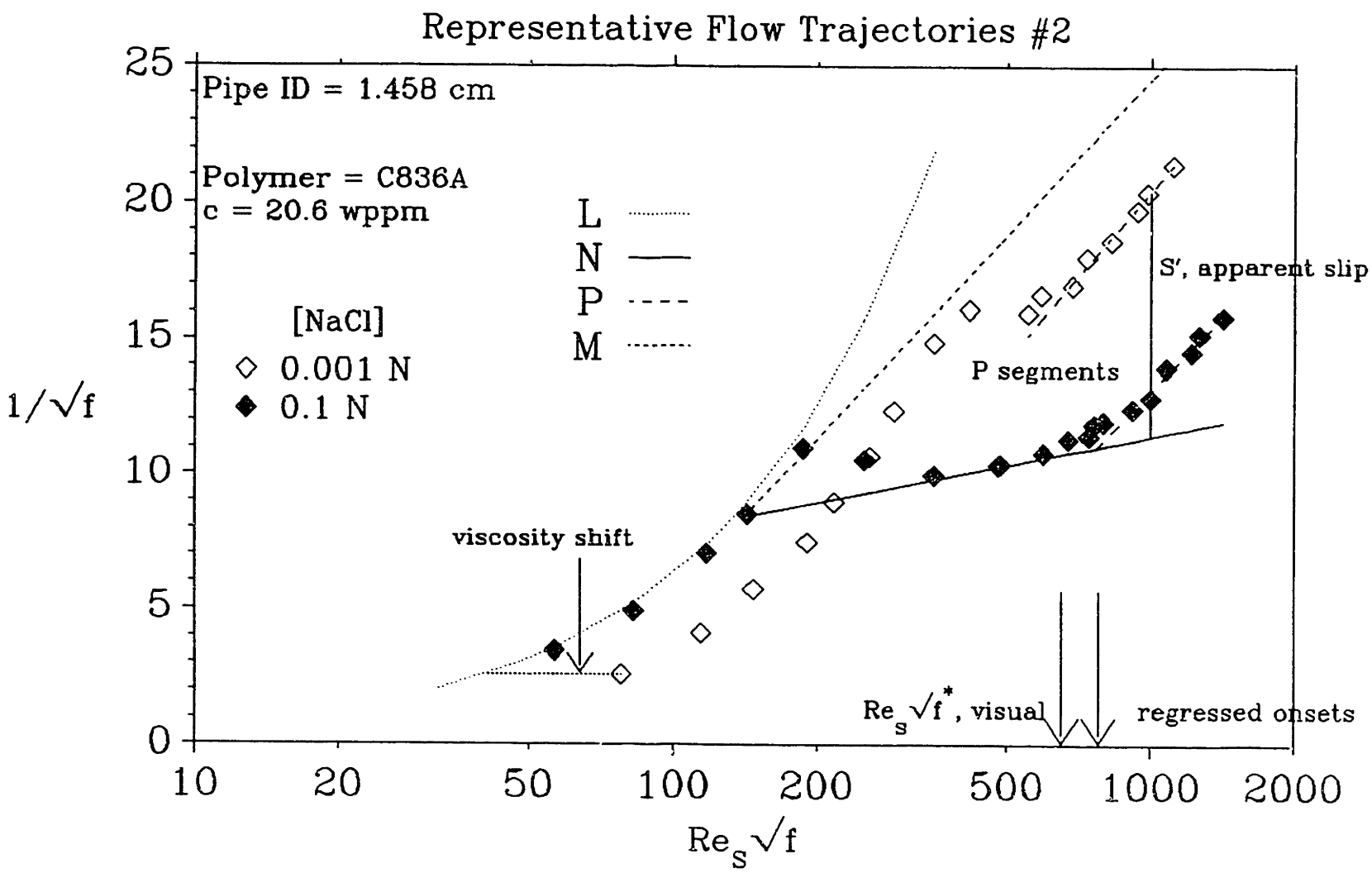


Figure 5.2.5: Representative Flow Trajectories #2

in laminar flow, but yet induces the greater drag reduction in turbulent flow. Despite differences in drag reduction extents, both conformations of C836A exhibit the Type-A drag-reduction behavior associated with random-coiling linear macromolecules.

5.2.2 Experimental Summary Tables

Experimental conditions, turbulent-flow pararmeters, and laminar-flow parameters for all runs are given in Tables 5.2.1, 5.2.2, and 5.2.3, respectively.

Table 5.2.1 summarizes the experimental conditions in seven columns: Entry; Run; Concentration, c; Salinity, [NaCl]; Solvent Turbulent Baseline Constants, A_n and B_n; and Temperature Range. The Entry column provides an identifying number for each run and serves to link Table 5.2.1 with subsequent Tables 5.2.2 and 5.2.3. The Run column shows the label assigned to each run. The label itself contains experimental information about the polymer additive, the additive concentration, and the salinity used in the run. For example, runs Q1P01465 and Q1P03166 were executed from the same experimental batch of polymer solution. The **Q** identifies the polymer as Cynanmid 832A in the pump-driven system. (In the gravity-driven system, all labels begin with P even though additives C837A, C836A, and C832A were used.) The sequence 1P0 indicates that the polymer concentration in wppm is **1** times ten to the **P**ower of **0**, c $\approx$ 1 wppm. The next pairs of digits 14 and 31 indicate salinities of 1×10^{-4} and 3×10^{-1} N, respectively. The last pairs of digits 65 and 66 merely maintain the ordering among all solvent and polymer runs; these digits ranged between 00 and 99. In addition, for run dyads in the pump-driven system and run triads in the gravity-driven system, a single

computer file contained all the experimental and reduced data and had the same label as the run using the lowest salinity. Hence, computer file Q1P01465.wk1(A Lotus-123™ Spreadsheet; see Figure 4.9 in Chapter IV) contained data for runs Q1P01465 and Q1P03166. In the third column, the polymer-solution concentration in weight parts per million(wppm) is given for each run. This was calculated by dividing the mass of polymer contained in a tankful of solution by the sum of the solvent, polymer, and salt masses composing the solution and multiplying by 1×10^6 to get wppm units. The fourth column [NaCl] gives the saline normality(N) for each run. The normality was calculated by dividing the number of equivalents of NaCl in a tankful of solution by the total solution volume. The fifth and sixth columns provide, respectively, the slope A_n and intercept B_n of the best-fit baseline through the solvent data set associated with each experimental run. Constants A_n and B_n were determined by a least-squares regression of $1/\sqrt{f}$ vs. log $Re_s\sqrt{f}$ to fit equation 5.1-1. The seventh column contains the minimum and maximum solution temperatures, in °C, measured during a run; however, solution temperature was recorded for every data point within each run to ensure accurate calculations of solvent physical properties.

Table 5.2.1
Experimental Conditions for All Runs

Entry	Run	Concen-tration	Salinity	Solvent Turbulent Baseline Constants		Temperature Range
		c	[NaCl]	A_n	B_n	
		(wppm)	(N)			(°C - °C)
Cyanamid 832A = C832A; Pump-Driven System; Pipe ID = 1.458 cm						
1	Q1P01465	1.01	1.00×10^{-4}	4	0.4	24.2-25.15
2	Q2P01462	2.02	1.00×10^{-4}	4	0.4	24.8-26.1
3	Q5P01459	4.99	1.00×10^{-4}	4	0.4	24.3-25.0
4	Q1P11453	9.97	1.00×10^{-4}	4	0.4	23.8-24.8
5	Q2P11456	20.0	1.00×10^{-4}	4	0.4	24.1-25.1
6	Q5P11449	50.0	1.00×10^{-4}	4	0.4	23.8-25.1
7	Q1P21446	100	1.00×10^{-4}	4	0.4	23.9-25.1
8	Q1P03166	1.01	3.00×10^{-1}	4	0.4	24.5-25.3
9	Q2P03163	2.02	3.00×10^{-1}	4	0.4	24.0-25.3
10	Q5P03160	4.99	3.00×10^{-1}	4	0.4	24.1-24.8
11	Q1P13154	9.97	3.00×10^{-1}	4	0.4	24.1-24.9
12	Q2P13157	20.0	3.00×10^{-1}	4	0.4	23.9-24.9
13	Q5P13150	50.0	3.00×10^{-1}	4	0.4	24.0-25.5
14	Q1P23147	100	3.00×10^{-1}	4	0.4	24.0-24.9
Cyanamid 832A = C832A; Pump-Driven System; Pipe ID = 1.021 cm						
15	Y1P01443	1.00	1.00×10^{-4}	4	0.4	23.6-24.9
16	Y2P01446	2.00	1.00×10^{-4}	4	0.4	23.1-25.2
17	Y5P01449	5.00	1.00×10^{-4}	4	0.4	23.0-25.0

Entry	Run	Concen-tration	Salinity	Solvent Turbulent Baseline Constants		Temperature Range
		c	[NaCl]	A_n	B_n	
		(wppm)	(N)			(°C - °C)
18	Y1P11452	10.0	1.00×10^{-4}	4	0.4	22.5-24.9
19	Y2P11455	20.0	1.00×10^{-4}	4	0.4	23.4-24.9
20	Y5P11459	50.0	1.00×10^{-4}	4	0.4	23.5-25.1
21	Y1P03144	1.00	3.00×10^{-1}	4	0.4	23.9-24.9
22	Y2P03147	2.00	3.00×10^{-1}	4	0.4	23.3-25.0
23	Y5P01450	5.00	3.00×10^{-1}	4	0.4	22.7-24.9
24	Y1P13153	10.0	3.00×10^{-1}	4	0.4	22.5-25.1
25	Y2P13156	20.0	3.00×10^{-1}	4	0.4	24.05-25.9
26	Y5P13160	50.0	3.00×10^{-1}	4	0.4	22.9-25.1
Betz 1120 = B1120; Pump-Driven System; Pipe ID = 1.458 cm						
27	B1P01496	1.00	1.00×10^{-4}	4	0.4	25.05-25.5
28	B2P01494	2.02	1.00×10^{-4}	4	0.4	24.4-25.1
29	B5P01490	5.07	1.00×10^{-4}	4	0.4	24.4-25.05
30	B1P11486	9.96	1.00×10^{-4}	4	0.4	24.0-24.9
31	B2P11483	20.0	1.00×10^{-4}	4	0.4	23.5-24.7
32	B5P11480	49.9	1.00×10^{-4}	4	0.4	23.9-25.2
33	B1P21477	100	1.00×10^{-4}	4	0.4	24.4-24.9
34	B1P03197	1.00	3.00×10^{-1}	4	0.4	24.5-25.1
35	B2P03195	2.02	3.00×10^{-1}	4	0.4	24.2-25.1
36	B5P03191	5.07	3.00×10^{-1}	4	0.4	24.6-25.3
37	B1P13187	9.96	3.01×10^{-1}	4	0.4	24.1-25.1

Entry	Run	Concen-tration	Salinity	Solvent Turbulent Baseline Constants		Temperature Range
		c	[NaCl]	A_n	B_n	
		(wppm)	(N)			(°C - °C)
38	B2P13184	20.0	3.00×10^{-1}	4	0.4	23.8-25.2
39	B5P13181	49.9	3.00×10^{-1}	4	0.4	23.7-24.9
40	B1P23178	100	3.00×10^{-1}	4	0.4	24.3-25.1
Pusher 500-F = P500; Pump-Driven System; Pipe ID = 1.458 cm						
41	V1P11434	10.0	1.00×10^{-4}	4	0.4	24.0-24.9
42	V3P11437	30.0	1.00×10^{-4}	4	0.4	23.2-25.0
43	V1P21431	100	1.00×10^{-4}	4	0.4	23.8-25.0
44	V1P13135	10.0	3.00×10^{-1}	4	0.4	24.2-25.3
45	V3P13138	30.0	3.01×10^{-1}	4	0.4	23.4-25.2
46	V1P23132	100	3.00×10^{-1}	4	0.4	23.7-25.2
Pusher 500-F = P500; Pump-Driven System; Pipe ID = 1.021 cm						
47	W1P11462	10.0	1.00×10^{-4}	4	0.4	23.9-25.0
48	W3P11465	30.0	1.00×10^{-4}	4	0.4	24.0-25.2
49	W1P21468	99.8	1.00×10^{-4}	4	0.4	23.4-25.0
50	W3P11371	30.0	1.00×10^{-3}	4	0.4	23.75-25.15
51	W3P11272	30.0	1.00×10^{-2}	4	0.4	24.0-25.4
52	W1P13163	10.0	3.00×10^{-1}	4	0.4	24.55-25.4
53	W3P13166	30.0	3.00×10^{-1}	4	0.4	23.7-25.2

Entry	Run	Concen-tration	Salinity	Solvent Turbulent Baseline Constants		Temperature Range
		c	[NaCl]	A_n	B_n	
		(wppm)	(N)			(°C - °C)
54	W1P23169	99.8	3.00×10^{-1}	4	0.4	23.8-25.4
Alcomer 507 = A507; Pump-Driven System; Pipe ID = 1.458 cm						
55	A3P11409	30	1.00×10^{-4}	4	0.4	23.7-24.8
56	A1P21403	99.9	1.00×10^{-4}	4	0.4	22.6-24.8
57	A3P21406	300	1.00×10^{-4}	4	0.4	22.9-24.7
58	A1P31412	1000	1.00×10^{-4}	4	0.4	23.1-24.9
59	A3P13110	30.0	3.00×10^{-1}	4	0.4	23.5-25.2
60	A1P23104	99.9	3.00×10^{-1}	4	0.4	23.2-24.8
61	A3P23107	300	3.00×10^{-1}	4	0.4	23.5-24.9
62	A1P33113	1000	3.00×10^{-1}	4	0.4	23.55-25.05
DSR 1438 = D1438; Pump-Driven System; Pipe ID = 1.458 cm						
63	D3P11418	30	1.00×10^{-4}	4	0.4	23.2-25.0
64	D1P21415	99.8	1.00×10^{-4}	4	0.4	23.6-24.9
65	D3P21421	300	1.00×10^{-4}	4	0.4	22.8-25.1
66	D1P31424	997	1.00×10^{-4}	4	0.4	23.3-24.9
67	D3P13119	30.0	3.00×10^{-1}	4	0.4	23.4-24.9
68	D1P23116	99.8	3.00×10^{-1}	4	0.4	24.25-25.7
69	D3P23122	300	3.00×10^{-1}	4	0.4	23.6-25.5
70	D1P33125	997	3.00×10^{-1}	4	0.4	23.4-25.2

Entry	Run	Concen-tration	Salinity	Solvent Turbulent Baseline Constants		Temperature Range
		c	[NaCl]	A_n	B_n	
		(wppm)	(N)			(°C - °C)
Cyanamid 837A = C837A; Gravity System; Pipe ID = 1.458 cm						
71	P1P03478	1.03	3.08×10^{-4}	2.98	-2.00	21.9-22.05
72	P2P03497	2.09	3.09×10^{-4}	3.54	-0.79	20.45-20.65
73	P5P03486	5.16	3.09×10^{-4}	2.98	-2.00	21.2-21.4
74	P1P13490	10.3	3.09×10^{-4}	3.54	-0.79	20.65-20.85
75	P2P13494	20.8	3.12×10^{-4}	3.54	-0.79	21.8-22.0
76	P5P13401	52.0	3.12×10^{-4}	3.54	-0.79	23.8-24.1
77	P1P01379	1.03	1.04×10^{-3}	2.98	-2.00	21.7-21.85
78	P2P01398	2.09	1.03×10^{-3}	3.54	-0.79	20.35-20.65
79	P5P01387	5.16	1.04×10^{-3}	2.98	-2.00	21.2-21.4
80	P1P11391	10.3	1.04×10^{-3}	3.54	-0.79	20.45-20.65
81	P1P01180	1.03	1.04×10^{-1}	2.98	-2.00	21.4-21.65
82	P2P01199	2.09	1.05×10^{-1}	3.54	-0.79	20.2-20.55
83	P5P01188	5.16	1.04×10^{-1}	2.98	-2.00	21.2-21.6
84	P1P11192	10.3	1.03×10^{-1}	3.54	-0.79	20.2-20.55
85	P2P11195	20.8	1.05×10^{-1}	3.54	-0.79	21.8-22.0
86	P5P11102	52.0	1.07×10^{-1}	3.54	-0.79	23.75-24.0
Cyanamid 836A = C836A; Gravity System; Pipe ID = 1.458 cm						
87	P1P03404	1.03	3.09×10^{-4}	3.54	-0.79	21.2-21.65
88	P2P03407	2.07	3.09×10^{-4}	3.54	-0.79	20.8-21.4

Entry	Run	Concen-tration	Salinity	Solvent Turbulent Baseline Constants		Temperature Range
		c	[NaCl]	A_n	B_n	
		(wppm)	(N)			(°C - °C)
89	P5P03410	5.16	3.09×10^{-4}	3.54	-0.79	20.1-20.35
90	P1P13413	10.3	3.09×10^{-4}	3.54	-0.79	21.0-21.45
91	P2P13426	20.6	3.09×10^{-4}	3.54	-0.79	21.5-21.6
92	P1P01305	1.03	1.04×10^{-3}	3.54	-0.79	21.1-21.5
93	P2P01308	2.07	1.04×10^{-3}	3.54	-0.79	20.9-21.45
94	P5P01311	5.16	1.04×10^{-3}	3.54	-0.79	20.0-20.3
95	P1P11314	10.3	1.04×10^{-3}	3.54	-0.79	21.0-21.45
96	P2P11327	20.6	1.04×10^{-3}	3.54	-0.79	21.4-21.4
97	P2P11229	20.6	1.03×10^{-2}	3.54	-0.79	21.2-21.2
98	P1P11106	1.03	1.06×10^{-1}	3.54	-0.79	21.0-21.5
99	P2P01109	2.07	1.05×10^{-1}	3.54	-0.79	20.9-21.4
100	P5P01112	5.16	1.06×10^{-1}	3.54	-0.79	19.9-20.25
101	P1P11115	10.3	1.05×10^{-1}	3.54	-0.79	20.7-21.1
102	P2P11128	20.6	1.06×10^{-1}	3.54	-0.79	20.9-21.0
103	P2P11130	20.6	1.04×10^{-1}	3.54	-0.79	20.95-21.05
Cyanamid 832A = C832A; Gravity System; Pipe ID = 1.458 cm						
104	P1P01556	1.04	1.00×10^{-5}	2.98	-2.00	20.8-20.8
105	P2P01570	2.09	1.00×10^{-5}	2.98	-2.00	19.9-20.25
106	P5P01573	5.63	1.00×10^{-5}	2.98	-2.00	20.4-20.9
107	P1P11574	10.2	1.00×10^{-5}	2.98	-2.00	21.1-21.3

Entry	Run	Concen-tration	Salinity	Solvent Turbulent Baseline Constants		Temperature Range
		c	[NaCl]	A_n	B_n	
		(wppm)	(N)			(°C - °C)
108	P2P11575	20.9	1.00×10^{-5}	2.98	-2.00	21.2-21.45
109	P1P03443	1.03	3.08×10^{-4}	4	0.4	20.2-22.1
110	P2P03445	2.06	3.08×10^{-4}	4	0.4	21.9-22.0
111	P5P03448	5.57	3.08×10^{-4}	4	0.4	21.4-21.5
112	P1P13451	10.0	3.08×10^{-4}	4	0.4	20.0-20.0
113	P2P13457	20.7	3.09×10^{-4}	4	0.4	20.4-20.5
114	P1P01344	1.03	1.03×10^{-3}	4	0.4	20.0-20.15
115	P2P01346	2.06	1.03×10^{-3}	4	0.4	21.65-21.7
116	P5P01349	5.57	1.03×10^{-3}	4	0.4	21.1-21.1
117	P1P11352	10.0	1.01×10^{-3}	4	0.4	19.7-19.7
118	P2P11358	20.7	1.03×10^{-3}	4	0.4	20.4-20.6
119	P2P01147	2.06	1.05×10^{-1}	4	0.4	21.2-21.3
120	P5P01150	5.57	1.04×10^{-1}	4	0.4	20.6-20.7
121	P1P11153	10.0	1.05×10^{-1}	4	0.4	19.4-19.5
122	P2P11159	20.7	1.05×10^{-1}	4	0.4	20.5-20.75

Table 5.2.2 summarizes the turbulent-flow parameters extracted from each run and contains eight columns: Entry; Polymeric-Regime Constants, A_p and B_p; Apparent Slips, S'_1 and S'_3; Slope Increment δ; Onset & Retro-Onset Wall Shear Stresses, T_w^* and $T_w^\#$. The Entry column links each row with Table 5.2.1. The second and third columns give the slope A_p and intercept B_p, respectively, of the best-fit, least-squares line through the data composing the polymeric-regime segment P of the run:

$$\frac{1}{\sqrt{f}} = A_p \log(Re_s\sqrt{f}) - B_p \qquad (5.2\text{-}1)$$

The fourth and fifth columns, S'_1 and S'_3, contain the apparent slip S' evaluated at $Re_s\sqrt{f} = 1000$ and 3000, respectively; for runs in the gravity-driven system, only S'_1 is quoted because $Re_s\sqrt{f_{max}} < 3000$. In the sixth column is given the slope increment $\delta = A_p - A_n$, the difference between the P-segment slope, A_p, and the slope of the solvent line N, A_n. The seventh column gives the onset wall shear stress T_w^*, dyne/cm^2, for each run exhibiting onset. Both regressed and visual values of T_w^* are quoted, the latter in parentheses to the right of the former. Regressed T_w^* were calculated from $Re_s\sqrt{f^*}$, determined from (A_n, B_n) and (A_p, B_p):

$$Re_s\sqrt{f^*} = 10^{\left(\frac{B_p - B_n}{A_p - A_n}\right)} \qquad (5.2\text{-}2)$$

This $Re_s\sqrt{f^*}$ obtains at the onset point where the P segment, extrapolated backward, would intersect the N baseline. By use of $Re_s\sqrt{f} = \sqrt{2}Du_\tau/\nu_s$ and $T_w = \rho u_\tau^2$, the onset wall shear stress is:

$$T_w^* = \rho \left[\frac{\nu_s Re_s \sqrt{f}^*}{\sqrt{2}\, D} \right]^2 \qquad (5.2\text{-}3)$$

In the calculating the visual T_w^*, two adjacent data points were selected in an LNP trajectory, one with the highest T_w in the N segment without drag reduction and one with the lowest T_w in the P segment with drag reduction. The visual T_w^* was the geometric mean of these two T_w values. The uncertainty in T_w^* can be as high as $\pm 100\%$ for P segments having small slope increments δ, excess curvature, or more than one linear domain. Mostly, regressed T_w^* either equals or exceeds visual T_w^* because the curvature in a P-segment was usually concave upward. The visual and regressed T_w^* values are not statistically very different and can be considered the best lower and upper bounds bracketing T_w^*. In the eighth column, the retro-onset wall shear stress $T_w^\#$, dyne/cm^2, is given for each run exhibiting retro-onset. As for T_w^*, both regressed and visual $T_w^\#$ values were calculated, with the latter given in parentheses to the right of the former. Regressed $T_w^\#$ was calculated from $Re_s\sqrt{f}^\#$, determined from (A_p, B_p) and the slope and intercept of the MDR asymptote, (19.0,32.4):

$$Re_s \sqrt{f}^\# = 10^{\left(\frac{32.4 - B_p}{19.0 - A_p}\right)} \qquad (5.2\text{-}4)$$

This $Re_s\sqrt{f}^\#$ obtains at the retro-onset point where the P segment, extrapolated backward, would intersect the MDR asymptote. The retro-onset wall shear stress $T_w^\#$ is calculated from an equation analogous to equation 5.2-3:

$$T_w^{\#} = \rho \left[\frac{\nu_s Re_s \sqrt{f}^{\#}}{\sqrt{2}\, D} \right]^2 \qquad (5.2\text{-}5)$$

In the calculating visual $T_w^{\#}$, two adjacent data points were selected in an LMP trajectory, one with the highest T_w in the M segment of additive-independent, maximum turbulent drag reduction and one with the lowest T_w in the P segment of additive-dependent turbulent drag reduction. The visual $T_w^{\#}$ was the geometric mean of these two. The uncertainty in $T_w^{\#}$ can be as high as $\pm 100\%$, especially at large $Re_s\sqrt{f}$ because T_w grows as $(Re_s\sqrt{f})^2$. Regressed $T_w^{\#}$ does not exceed visual $T_w^{\#}$ because the regression of a P segment includes the last data point on M and, thus, yields lower $Re_s\sqrt{f}^{\#}$. The two values are probably not statistically different and represent the best lower and upper values for $T_w^{\#}$. The appearance of "MDR" in this column indicates that the flow trajectory of the run attained maximum drag reduction at the highest $Re_s\sqrt{f}$, by which point retro-onset did not occur.

Table 5.2.2
Turbulent-Flow Parameters

Entry	Polymeric-Regime Constants		Apparent Slips[a]		Slope Increment	Onset & Retro-Onset Wall Shear Stresses[b]	
	A_p	B_p	S'_1	S'_3	δ	T_w^*	$T_w^{\#}$
						(dyne/cm^2)	
Cyanamid 832A = C832A; Pump-Driven System; Pipe ID = 1.458 cm							
1	4.96	1.71	1.5	2.0	0.96	0	
2	7.01	4.89	4.3	5.8	3.01		0.7(1.3)
3	10.9	13.7	7.3	10.1	6.90		0.8(1.8)
4	9.63	3.40	12.0	16.6	5.63		29.8(47)
5	1.74?	-26.1?	11.5	18.5			110?(150?)
6			7.6	18.7			MDR
7			7.6	19.1			MDR
8	4.13	0.82	0	0†	0.13		
9	9.07	14.3	~1.1	3.4	5.07	5.9(6.0)	
10	13.4	25.9	2.1	7.1	9.40	5.4(4.8)	
11	19.5	42.8	3.8	11.1	15.5		
12	21.1	45.4	6.0	14.8	17.1		
13	24.3	53.4	8.2	18.7	20.3		
14			10.2	19.7			MDR
Cyanamid 832A = C832A; Pump-Driven System; Pipe ID = 1.021 cm							
15	4.01	-1.04	1.2	1.6	0.01		
16	6.24	4.46	2.9	3.5	2.24		
17	8.15	6.37	6.6	8.2	4.15		

Entry	Polymeric-Regime Constants		Apparent Slips[a]		Slope Increment	Onset & Retro-Onset Wall Shear Stresses[b]	
	A_p	B_p	S'_1	S'_3	δ	T_w^*	$T_w^\#$
						(dyne/cm^2)	
18	11.0	8.71	11.9	15.1	7.0		31.9(66)
19	2.06	-26.3	12.7	19.5	-1.94		332(410)
20			~12	20.9			MDR
21	5.27	3.86	0.3	0.9	1.27	12.2(22.2)	
22	7.50	9.83	1.2	2.7	3.50	9.7(9.6)	
23	13.4	25.2	3.5	7.0	9.40		
24	18.5	37.1	6.7	11.4	14.5		
25	24.0	50.1	10.9	17.7	20.0		
26	22.9	44.8	12.8	20.2	18.9		MDR
Betz 1120 = B1120; Pump-Driven System; Pipe ID = 1.458 cm							
27	4.01	-0.57	0.5	1.0	~0	3.3(3.8?)	
28	7.43	7.69	3.0	4.4	3.43		
29	5.29	-4.76	8.8	9.5	1.29		
30	7.98	-1.18	13.0	14.7	3.98		23.4(38)
31			11.8	18.2			MDR
32			10.8	19.1			MDR
33			9.7	18.6			MDR
34	4.92	3.14	0.3	0.5	0.92	17.8(22?)	
35	7.70	10.6	0.5	2.7	3.70	6.5(13.5)	
36	12.4	23.9	1.3	5.4	8.40	7.4(6.1)	
37	17.2	36.1	4.0	10.2	13.2	5.1(4.1)	

Entry	Polymeric-Regime Constants		Apparent Slips[a]		Slope Increment	Onset & Retro-Onset Wall Shear Stresses[b]	
	A_p	B_p	S'_1	S'_3	δ	T_w^*	$T_w^\#$
						(dyne/cm^2)	
38	22.0	48.8	5.6	14.5	18.0		
39			11.0	19.0			MDR
40			11.2	18.6			MDR
Pusher 500-F = P500; Pump-Driven System; Pipe ID = 1.458 cm							
41	8.95	10.7	4.6	7.0	4.95		
42	5.90	-6.21	11.3	13.4	1.90		14.8(14.6)
43			7.3	18.4			MDR
44	10.8	19.7	1.0	4.56	6.80	9.5(9.6)	
45	15.7	32.4	2.5	9.0	11.7	5.9(6.2)	
46	26.2	61.8	5.0	16.0	22.2	6.5(4.1)	
Pusher 500-F = P500; Pump-Driven System; Pipe ID = 1.021 cm							
47	8.58	9.63	4.6	6.6	4.58		
48	9.00	3.35	10.4	14.8	5.00		
49			9.2	19.7			MDR
50	7.60	-1.72	10.1	15.3	3.60		
51	18.0	34.7	7.7	13.8	14.0		
52	10.6	19.0	1.1	4.8	6.60	16.0(14.4)	
53	17.2	35.6	4.2	10.8	13.2		
54	31.2	72.6	9.2	19.4	27.2		MDR

Entry	Polymeric-Regime Constants		Apparent Slips[a]		Slope Increment	Onset & Retro-Onset Wall Shear Stresses[b]	
	A_p	B_p	S'_1	S'_3	δ	T_w^*	$T_w^\#$
						(dyne/cm^2)	
Alcomer 507 = A507; Pump-Driven System; Pipe ID = 1.458 cm							
55	4.27	0.94	0.1?	0.4	0.27	0.19(25.0)	
56	5.61	4.57	0.3?	1.5	1.61	2.9(20.3)	
57	9.03	15.9	0†	2.0	5.03	27.7(25.7)	
58	15.6	39.3	-1.7!	1.4	11.6	90.0(69.3)	
59	4.43	1.78	0†	0.10	0.43	45.2(55.2)	
60	5.32	4.61	0†	0.4	1.32	46.9(68.0)	
61	6.97	9.86	0†	0.9	2.97	45.6(38.8)	
62	9.72	18.7	0†	1.7	5.27	46.8(60.7)	
DSR 1438 = D1438; Pump-Driven System; Pipe ID = 1.458 cm							
63	5.73	5.76	0†	0.6	1.73	29.4(38.8)	
64	8.12	12.7	0.4	1.9	4.12	18.3(12.2)	
65	13.3	29.4	0†	3.2	9.30	33.8(37.6)	
66	20.8	55.1	0†	3.5	16.8	60.5(58.3)	
67	5.36	4.89	0†	0.3	1.36	77.3(68.6)	
68	6.37	7.89	0†	0.8	2.37	40.9(66.4)	
69	8.84	15.3	0†	1.7	4.84	27.7(27.4)	
70	15.4	36.4	0†	3.4	11.4	40.2(38.0)	
Cyanamid 837A = C837A; Gravity-Driven System; Pipe ID = 1.458 cm							
71	3.20	-1.61	0.2		0.22	0(10.9)	

Entry	Polymeric-Regime Constants		Apparent Slips[a]		Slope Increment	Onset & Retro-Onset Wall Shear Stresses[b]	
	A_p	B_p	S'_1	S'_3	δ	T_w^*	$T_w^\#$
						(dyne/cm^2)	
72	5.97	5.87	0.6		2.43	7.0(9.5)	
73	9.02	13.7	2.4		6.05		
74	13.7	25.2	4.5		10.1		
75	25.0	54.3	9.1		21.4		
76			10.8				MDR
77	3.02	-2.02	0.1		0.05	0(6.2)	
78	5.22	3.90	0.3		1.68	8.77(9.7)	
79	8.25	12.0	1.7		5.28		
80	12.0	21.5	3.1		8.00		
81	2.77	-2.66	0		-0.20		
82	4.02	0.59	0.1		0.48	13.2(14.0)	
83	8.59	14.7	0.2†		5.62	19.4(23.2)	
84	13.5	29.2	0.2†		9.95	24.8(16.4)	
85	20.6	47.0	3.1		17.0	9.24(6.1)	
86	17.9	37.6	5.9		13.9		
Cyanamid 836A = C836A; Gravity-Driven System; Pipe ID = 1.458 cm							
87	6.02	6.32	0.4		2.48	12.1(6.4)	
88	6.51	7.65	0.5		2.97	10.8(6.5)	
89	11.1	18.6	3.1		7.52		
90	13.6	24.7	4.8		10.1		
91	18.0	32.0	10.6		14.4		

Entry	Polymeric-Regime Constants		Apparent Slips[a]		Slope Increment	Onset & Retro-Onset Wall Shear Stresses[b]	
	A_p	B_p	S'_1	S'_3	δ	T_w^*	$T_w^\#$
						(dyne/cm^2)	
92	5.01	3.43	0.2		1.47	13.1(17.6)	
93	5.44	4.62	0.3		1.90	11.3(13.7)	
94	8.22	11.3	1.8		4.68		
95	12.4	22.1	3.6		8.88		
96	19.8	38.9	9.0		16.3		
97	19.4	42.1	4.4		15.9		
98	3.94	0.40	0		0.40?	23.5(20.0)	
99	4.09	0.79	0		0.54?	17.3(20.8)	
100	8.08	12.6	0.2		4.54	20.1(14.7)	
101	10.7	20.3	0.5		7.20	16.5(15.1)	
102	18.6	42.8	1.4		15.1	13.7(6.6)	
103	18.6	42.0	2.3		15.1	10.8(6.6)	
Cyanamid 832A = C832A; Gravity-Driven System; Pipe ID = 1.458 cm							
104	3.19	-1.75	0.9		0.22		
105	4.72	1.46	1.8		1.74		
106	8.49	10.1	4.7		5.52		
107	4.64	-6.69	9.9		1.66		6.21(6.4)
108			12.8‡				MDR
109	4.78	2.53	0.2		0.78	6.18(8.7)	

Entry	Polymeric-Regime Constants		Apparent Slips[a]		Slope Increment	Onset & Retro-Onset Wall Shear Stresses[b]	
	A_p	B_p	S'_1	S'_3	δ	T_w^*	$T_w^\#$
						(dyne/cm^2)	
110	6.03	4.92	1.5		2.03		
111	9.78	14.0	3.8		5.78		
112	9.54	8.18	9.0		5.54		3.10(5.2)
113			11.2‡				MDR
114	3.97	0.40	0		0		
115	5.39	3.80	0.8		1.39		
116	8.70	12.5	2.0		4.70		
117	10.5	14.0	5.9		6.49		
118			11.3‡				MDR
119	3.98	0.38	0		0		
120	3.93	0.22	~0.1		0		
121	10.9	19.7	1.2		6.87	10.1(7.7)	
122	20.1	44.8	3.9		16.1	7.44(4.2)	

(a) S'_1 and S'_3 denote S' evaluated at $Re_s\sqrt{f}$ = 1000 and 3000, respectively.
(b) ( ) = visual value.
† = before onset; ‡ = highest $Re_s\sqrt{f} < 1000$.

Table 5.2.3 summarizes the laminar-flow parameters extracted from each run and contains five columns: Entry; Arithmetic-Mean and Geomtric-Mean Estimated Intrinsic Viscosities, η_{sp}/c^{a} and η_{sp}/c^{g}, and Pseudo-Power-Law Coefficient and Exponent, K' and n'. The Entry column links the rows to Table 5.2.1. The second and third columns both provide estimates of polymer intrinsic viscosity, $[\eta]$, by listing the arithmetic and geometric means, respectively, of η_{sp}/c in cm^3/g for each run. In laminar flow, the relative viscosity η_r at each data point was the $Re_s\sqrt{f}$ ratio of polymer solution to solvent at fixed $1/\sqrt{f}$:

$$\eta_r = \left[\frac{Re_s\sqrt{f_p}}{Re_s\sqrt{f_L}}\right]_{\downarrow \frac{1}{\sqrt{f_r}}} = \left[\frac{Re_s\, f_p}{16}\right] \qquad (5.2\text{-}6)$$

From the specific viscosity $\eta_{sp} = (\eta_r - 1)$, it follows that $\eta_{sp}/c = (\eta_r - 1)/c$. For each laminar-flow data point, η_{sp}/c was calculated, from several of which an average value, either arithmetic or geometric, could be determined. At low salinity the laminar viscosity was usually shear-thinning as η_{sp}/c decreased with increasing $Re_s\sqrt{f}$. At high salinity, shear-thinning behavior was not pronounced, and η_{sp}/c was approximately constant. Whereas an arithmetic mean was appropriate for a set of η_{sp}/c at high salinity, it was not at low salinity; thus, both arithmetic and geometrics mean were calculated for each set, their difference reflecting the severity of shear thinning. Significant differences only arose at the highest concentrations and lowest salinities. In the fourth and fifth columns, the pseudo-power-law coefficient K' and exponent n' were determined from the laminar-flow data in each run. Both are defined by the pseudo-power law for polymer-solution viscosity:

$$T_w = K' \left[\frac{8 < \overline{U} >}{D} \right]^{n'} \qquad (5.2\text{-}7)$$

where $8 < \overline{U} > /D$ is the laminar-flow shear rate in s^{-1}. At each laminar-flow data point, T_w and $8 < \overline{U} > /D$ were determined. For a set of data, the best-fit line for log T_w vs. log $8 < \overline{U} > /D$ was calculated, where the slope and intercept were n' and log K', respectively.

At the highest salinities, corresponding to the random-coiling conformation, and moderate polymer concentrations, the polymer-solutions were virtually indistinguishable from solvent in that they exhibited almost no shear thinning and had relative viscosities very close to unity; thus, their exponents n' $\approx$ 1.0, the Newtonian value, and their coefficients K' $\approx$ 0.009 g/(cm•s), about the solvent viscosity. Even at the highest concentrations for which $\eta_r \approx 1.5$; the solutions were Newtonian, having exponents n' $\approx$ 1.0. At the lowest salinities at all concentrations, the coefficient K' could be much greater than 0.009 g/(cm•s); the exponent n', much less than unity. For the most extreme example, a 100-wppm solution of additive B1120 with 0.0001 N NaCl(entry 36), K' and n' respectively reached 0.4176 $s^{0.490}$•dyne/cm^2 and a minimum of 0.490.

Table 5.2.3
Laminar-Flow Parameters

Entry	Arithmetic- and Geometric-Mean Estimated Intrinsic Viscosities		Pseudo-Power-Law Coefficient and Exponent	
	η_{sp}/c [a]	η_{sp}/c [g]	K'	n'
	(cm^3/g)		($s^{n'} \cdot dyne/cm^2$)	
Cyanamid 832A = C832A; Pump-Driven System; Pipe ID = 1.458 cm				
1	11994	11980	0.0092	0.998
2	106170	105875	0.0120	0.969
3	55215	55167	0.0120	0.989
4	110550	105733	0.0405	0.756
5	86350	79622	0.0560	0.735
6	116644	105897	0.1945	0.566
7	83039	74663	0.2383	0.595
8	0	0	0.0093	0.999
9	19722	19608	0.0099	0.995
10	13326	12818	0.0094	1.015
11	11367	11365	0.0105	0.997
12	5790	5780	0.0103	1.004
13	2547	2633	0.0108	0.994
14	3739	3667	0.0133	0.972
Cyanamid 832A = C832A; Pump-Driven System; Pipe ID = 1.021 cm				
15	62797	59371	0.0106	0.973
16	69357	66187	0.0129	0.935
17	74359	71848	0.0178	0.898
18	57649	55238	0.0209	0.882

Entry	Arithmetic- and Geometric-Mean Estimated Intrinsic Viscosities		Pseudo-Power-Law Coefficient and Exponent	
	η_{sp}/c [a]	η_{sp}/c [g]	K'	n'
	(cm^3/g)		($s^{n'} \cdot dyne/cm^2$)	
19	109219	107192	0.0739	0.679
20	59145	57253	0.0818	0.726
21	0	0	0.0092	1.005
22	0	0	0.0095	1.001
23	0	0	0.0096	0.999
24	0	0	0.0097	1.001
25	3172	3086	0.0098	1.002
26	2575	2575	0.0109	0.996
Betz 1120 = B1120; Pump-Driven System; Pipe ID = 1.458 cm				
27	26869	24388	0.0090	1.006
28	84479	80687	0.0119	0.956
29	123199	113391	0.0210	0.861
30	113990	109283	0.0300	0.814
31	54709	52839	0.0296	0.847
32	116809	109491	0.2150	0.543
33	111709	104565	0.4176	0.490
34	0	0	0.0090	1.007
35	0	0	0.0093	0.997
36	7703	7689	0.0097	0.998
37	3658	3585	0.0096	1.002
38	2470	2357	0.0098	1.002
39	3398	3373	0.0109	1.004

Entry	Arithmetic- and Geometric-Mean Estimated Intrinsic Viscosities		Pseudo-Power-Law Coefficient and Exponent	
	η_{sp}/c [a]	η_{sp}/c [g]	K'	n'
	(cm^3/g)		($s^{n'} \cdot dyne/cm^2$)	
40	4001	3993	0.0131	1.000
Pusher 500-F = P500; Pump-Driven System; Pipe ID = 1.458 cm				
41	71637	69745	0.0191	0.925
42	75338	73942	0.0695	0.732
43	99572	95219	0.2746	0.565
44	3336	3271	0.0096	1.002
45	3037	2984	0.0100	1.007
46	2091	2088	0.0113	1.001
Pusher 500-F = P500; Pump-Driven System; Pipe ID = 1.021 cm				
47	62981	62074	0.0195	0.892
48	53183	52775	0.0362	0.836
49	72353	70603	0.1683	0.653
50	33358	33143	0.0243	0.892
51	8485	8480	0.0116	0.994
52	0	0	0.0093	1.000
53	1637	1630	0.0099	1.001
54	1829	1829	0.0113	0.995
Alcomer 507 = A507; Pump-Driven System; Pipe ID = 1.458 cm				
55	5398	5385	0.0104	1.008

Entry	Arithmetic- and Geometric-Mean Estimated Intrinsic Viscosities		Pseudo-Power-Law Coefficient and Exponent	
	η_{sp}/c [a]	η_{sp}/c [g]	K'	n'
	(cm^3/g)		($s^{n'} \cdot dyne/cm^2$)	
56	32618	32566	0.0454	0.938
57	8973	8952	0.0394	0.969
58	6633	6628	0.0781	0.963
59	0	0	0.0095	0.999
60	0	0	0.0092	1.016
61	347	314	0.0100	1.011
62	360	360	0.0125	1.009
DSR 1438 = D1438; Pump-Driven System; Pipe ID = 1.458 cm				
63	3099	3085	0.0100	1.002
64	8383	8381	0.0170	0.997
65	7733	7732	0.0320	0.986
66	3825	3822	0.0480	0.972
67	0	0	0.0094	1.001
68	436	422	0.0095	1.009
69	461	458	0.0104	1.006
70	441	441	0.0133	1.007
Cyanamid 837A = C837A; Gravity-Driven System; Pipe ID = 1.458 cm				
71	34523	34508	0.0100	0.999
72	25672	25483	0.0099	1.012
73	--	--	--	--
74	--	--	--	--

Entry	Arithmetic- and Geometric-Mean Estimated Intrinsic Viscosities		Pseudo-Power-Law Coefficient and Exponent	
	η_{sp}/c [a]	η_{sp}/c [g]	K'	n'
	(cm^3/g)		($s^{n'} \cdot dyne/cm^2$)	
75	21194	21166	0.0139	1.000
76	41727	40122	0.0476	0.803
77	33211	32598	0.0101	0.999
78	7911	7864	0.0099	1.003
79	--	--	--	--
80	--	--	--	--
81	21878	19632	0.0099	0.998
82	2586	2071	0.0100	1.002
83	--	--	--	--
84	--	--	--	--
85	--	--	--	--
86	2775	2648	0.0106	0.994
Cyanamid 836A = C836A; Gravity-Driven System; Pipe ID = 1.458 cm				
87	42155	42024	0.0100	1.003
88	22247	21392	0.0101	1.001
89	49278	47947	0.0148	0.940
90	26550	26392	0.0128	0.989
91	70970	67372	0.0401	0.797
92	33501	33033	0.0098	1.008
93	18797	18391	0.0100	1.003
94	24934	24891	0.0113	1.000

Entry	Arithmetic- and Geometric-Mean Estimated Intrinsic Viscosities		Pseudo-Power-Law Coefficient and Exponent	
	η_{sp}/c [a]	η_{sp}/c [g]	K'	n'
	(cm^3/g)		($s^{n'} \cdot dyne/cm^2$)	
95	21058	20967	0.0119	0.998
96	36543	36109	0.0218	0.910
97	8204	8172	0.0115	0.996
98	0	0	0.0095	1.010
99	3957	3768	0.0098	1.004
100	0	0	0.0099	1.004
101	4395	4245	0.0094	1.027
102	2821	2811	0.0106	0.999
103	2569	2543	0.0103	1.003
Cyanamid 832A = C832A; Gravity-Driven System; Pipe ID = 1.458 cm				
104	--	--	--	--
105	116856	112141	0.0195	0.860
106	35364	34285	0.0151	0.949
107	96855	95552	0.0516	0.732
108	199918	146399	0.1158	0.617
109	--	--	--	--
110	47196	46647	0.0102	1.006
111	21957	21956	0.0110	0.997
112	47270	47125	0.0181	0.954
113	58527	58016	0.0564	0.769

Entry	Arithmetic- and Geometric-Mean Estimated Intrinsic Viscosities		Pseudo-Power-Law Coefficient and Exponent	
	η_{sp}/c [a]	η_{sp}/c [g]	K'	n'
	(cm^3/g)		($s^{n'} \cdot dyne/cm^2$)	
114	--	--	0.0100	1.001
115	17859	17518	0.0092	1.021
116	21602	21498	0.0104	1.013
117	32795	32767	0.0137	0.994
118	43424	42978	0.0415	0.806
119	--	--	--	--
120	--	--	--	--
121	--	--	--	--
122	5246	5229	0.0109	1.002

Superscripts: a = arithmetic mean; g = geometric mean.

5.2.3 Detailed Descriptions

(1) High Molecular-Weight Additives

Figures 5.2.6 and 5.2.7, each a composite PK plot, presents results from the pump-driven system using the 1.458-cm pipe for additive C832A in 0.3 N NaCl, the initially collapsed conformation, and 0.0001 N NaCl, the initially extended conformation, respectively, at c = 1, 2, 5, 10, 20, 50, and 100 wppm.

The set of runs in Figure 5.2.6 typifies Type-A drag-reduction behavior by initially collapsed HPAM macromolecules. Lines L, N, and M represent Poiseuille's Law for laminar flow, the Newtonian turbulent-flow baseline, and the MDR asymptote, respectively.

For $50 < Re_s\sqrt{f} < 150$, the 1-wppm data follow L closely and for $150 < Re_s\sqrt{f} < 350$, depart downward from L and toward N, completing a laminar-to-turbulent transition like those previously observed in solvent runs. For $400 < Re_s\sqrt{f} < 6000$, the data adhere closely to the baseline N, following an N segment of slope and intercept $(A_p, B_p) = (4.1, 0.8)$ and then appear to show a small amount of flow enhancement for $6000 < Re_s\sqrt{f} < 7000$. The 1-wppm data thus exhibit essentially an LN trajectory.

The 2-wppm and 5-wppm data display LNP trajectories, like that described for the 0.3-N data shown in Figure 5.2.4. For $50 < Re_s\sqrt{f} < 150$, the data follow L closely with viscosities $\eta_r \approx 1.0$ and for $180 < Re_s\sqrt{f} < 350$, undergo laminar-to-turbulent transitions, departing downward from L and dropping toward N. For $Re_s\sqrt{f} > 400$, the 2-wppm and 5-wppm data continue along N, onset respectively at $Re_s\sqrt{f^*} \approx 550$ and

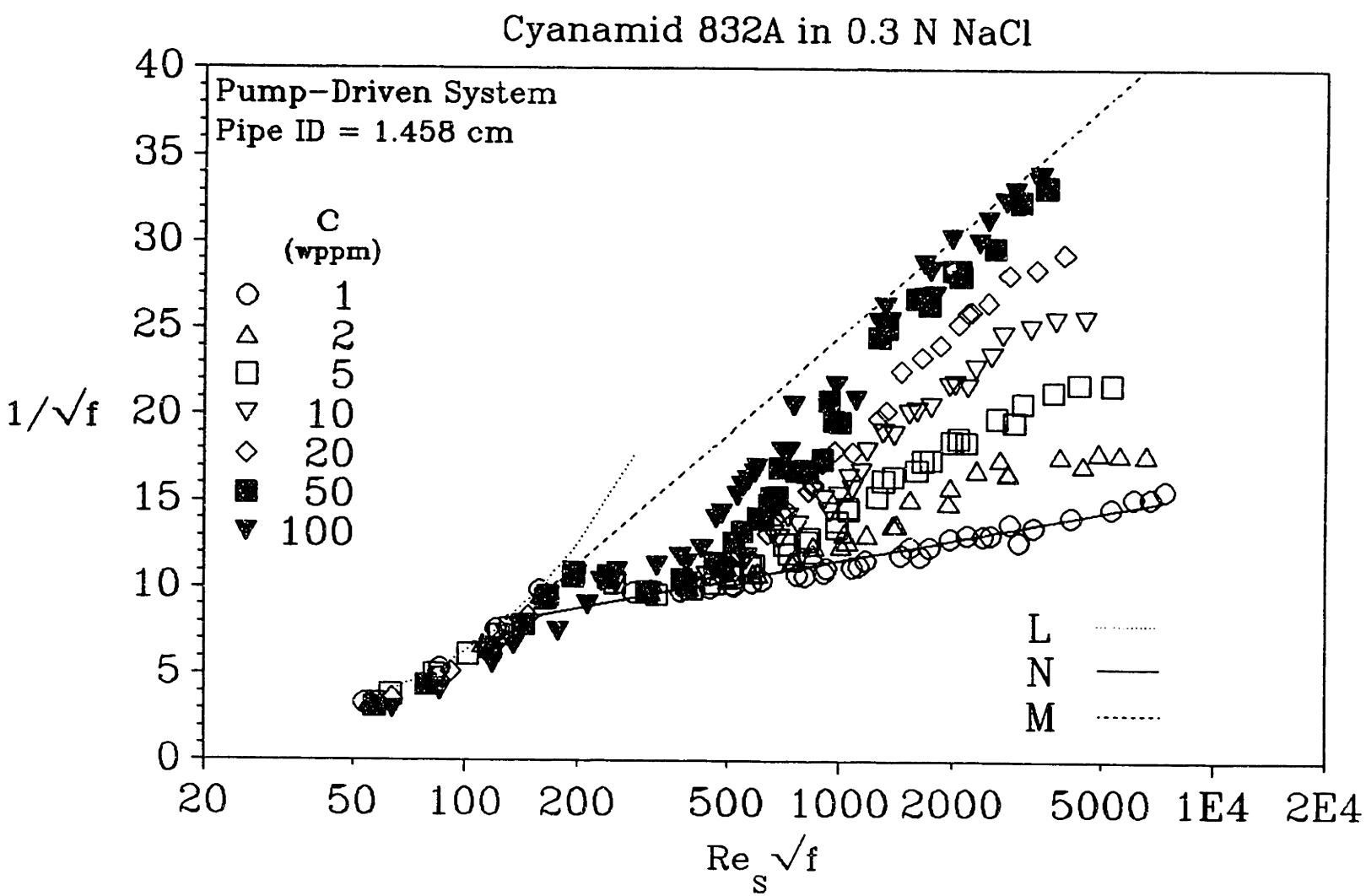


Figure 5.2.6: Cyanamid 832A in 0.3 N NaCl from the 1.458-cm Pipe

520, and ascend into the polymeric regime along linear segments P with slopes and intercepts $(A_p, B_p) = (9.1, 14.3)$ and (13.4, 25.9) and slope increments $\delta = 5.1$ and 9.4 until $Re_s\sqrt{f} \approx 3000$ and 4000, respectively. For $Re_s\sqrt{f} > 3000$, the 2-wppm data depart downward from their segment P, perhaps because of polymer degradation, and maintain constant $1/\sqrt{f}$ up to $Re_s\sqrt{f} \approx 7600$; similarly, the 5-wppm data level off from their segment P for $4000 < Re_s\sqrt{f} < 5000$.

Data for c = 10, 20, and 50 wppm display L(N)P trajectories, with ill-defined Newtonian segments. For $50 < Re_s\sqrt{f} < 150$, their data parallel L closely with $\eta_r \leq 1.1$, exhibiting slight drag enhancement relative to solvent, and at $Re_s\sqrt{f} \approx 180$, depart downward from L toward N, beginning laminar-to-turbulent transitions. Rather than dropping onto, and then following, N upon achieving turbulence, data for c = 10, 20, and 50 wppm reach $1/\sqrt{f}$ minima on or very close to N at $Re_s\sqrt{f} \approx 300$ to 400. From their minima, these data rise into the polymeric regime along respective linear segments with $(A_p, B_p) = (19.5, 42.8)$, (21.1, 45.4), and (24.3, 53.4) and $\delta = 15.5$, 17.1 and 20.3 until $Re_s\sqrt{f} \approx 3000$, 3000, and 1500. Although these data do not show clear-cut onsets, for a lack of well-defined N segments, nonetheless extrapolating their segments P back to the line N yields apparent regressed $Re_s\sqrt{f}^* \approx 540$, 420, and 410, respectively. For $Re_s\sqrt{f} > 3000$, the 10-wppm and 20-wppm data depart slightly downward from their segments P, likely on account of polymer degradation, up to $Re_s\sqrt{f} \approx 4400$ and 5100, respectively; for $Re_s\sqrt{f} > 1000$, the 50-wppm data rise steeply along their segment P toward the MDR asymptote, come closest to M at $Re_s\sqrt{f} \approx 1400$, and then approximately parallel M up to $Re_s\sqrt{f} \approx 4000$.

The 100-wppm data display an LPM trajectory. For $50 < Res\sqrt{f} < 150$, they

data follow a slightly shear-thinning, laminar path with $\eta_r \approx 1.3$ and show the greatest drag enhancement relative to solvent. At $Re_s\sqrt{f} \approx 180$, the 100-wppm data suddenly shift rightwards and begin to parallel L as if $\eta_r \approx 1.5$ until $Re_s\sqrt{f} \approx 240$. For $250 < Re_s\sqrt{f} < 400$, the 100-wppm data shift abruptly rightward and slightly upward in apparent transitional behavior and for $450 < Re_s\sqrt{f} < 1200$, rise steeply into the polymeric regime toward the MDR asymptote along a linear segment P with $(A_p, B_p) = (27.5, 59.5)$ and $\delta = 23.5$. Extrapolating the segment P back to the line N gives an apparent regressed $Re_s\sqrt{f^*} \approx 330$ for the 100-wppm data. At $Re_s\sqrt{f} \approx 1300$, the data virtually converge onto M and begin to climb along M up to $Re_s\sqrt{f} \approx 3400$.

To summarize, the flow trajectories displayed in Figure 5.2.6 are: LN by the 1-wppm data; LNP by the 2-wppm an 5-wppm data; L(N)P by the data at c = 10, 20, and 50 wppm; and LPM by the 100-wppm data. In laminar flow, all data lie close to L with $\eta_r < 1.4$, typical behavior by solutions of collapsed macromolecules. In turbulent flow, the 1-wppm data show no perceptible drag reduction; all other solutions, with c = 2, 5, 10, 20, 50, and 100 wppm exhibit drag reduction, with P segments, the slopes and slope increments of which increase as the concentration increases: $A_p = 9.1$, 13.4, 19.5, 21.1, 24.3, and 27.5, and $\delta = 5.1$, 9.4, 15.5, 17.1, 20.3, and 23.5, respectively. These P segments radiate from the turbulent baseline N at their real and apparent $Re_s\sqrt{f^*}$ in the range $330 < Res\sqrt{f} < 550$, forming the spokes of a fan-like structure. This "Type-A fan" is the characteristic drag-reduction behavior of solutions of initially collapsed, random-coiling macromolecules. Note that, in the present case, the slopes of the fan spokes are much nearer that of the MDR asymptote, $A_m = 19.0$, than that of the turbulent baseline N, $A_n = 4.0$.

In Figure 5.2.7, results for additive C832A runs at $1 \leq c \leq 100$ wppm in 0.0001 N NaCl exemplify Type-B drag-reduction behavior by initially extended HPAM macromolecules. Newtonian laminar and turbulent baselines and the MDR asymptote are shown by lines L, N, and M, respectively.

The 1-wppm data follow along L for $50 < Re_s\sqrt{f} < 150$ and then depart L beginning a laminar-to-turbulent transition at $Re_s\sqrt{f} \approx 150$. Dropping toward, but never reaching, N, the data attain a $1/\sqrt{f}$ minimum at $Re_s\sqrt{f} \approx 350$ and exhibit flow enhancement immediately. The 1-wppm data remain above and slightly diverge from N along a linear segment P with slope and in $(A_p, B_p) = (5.0, 1.7)$ for $350 < Re_s\sqrt{f} < 2000$. For $2000 < Re_s\sqrt{f} < 7500$, the data exhibit nearly constant $1/\sqrt{f} \approx 13$, weakly departing from P, towards N, perhaps as a result of polymer degradation. Thus, the 1-wppm data display an LP trajectory.

The 2-wppm and 5-wppm data both show LP trajectories; they lie parallel to the right of L for $50 < Re_s\sqrt{f} < 200$, with $\eta_r \approx 1.15$ and 1.3, respectively, the latter slightly shear-thinning and both enhancing drag relative to solvent. At $Re_s\sqrt{f} \approx 300$ data for both solutions shift sharply rightward and somewhat upward into the polymeric regime and for $Re_s\sqrt{f} > 500$ follow along respective linear segments P with $(A_p, B_p) = (7.0, 4.9)$ and $(10.9, 13.7)$ until $Re_s\sqrt{f} \approx 3000$. For $Re_s\sqrt{f} > 3000$ and up to $Re_s\sqrt{f} \approx 6400$ and 5000, respectively, the 2-wppm and 5-wppm data exhibit essentially constant $1/\sqrt{f} \approx 20$ and 24, respectively, declining from their segments P, possibly from polymer degradation.

The 10-wppm and 20-wppm data exhibit LMP trajectories. For $Re_s\sqrt{f} < 300$, the 10-wppm and 20-wppm data follow shear-thinning laminar paths with $\eta_r \approx 2.1$ and 2.7,

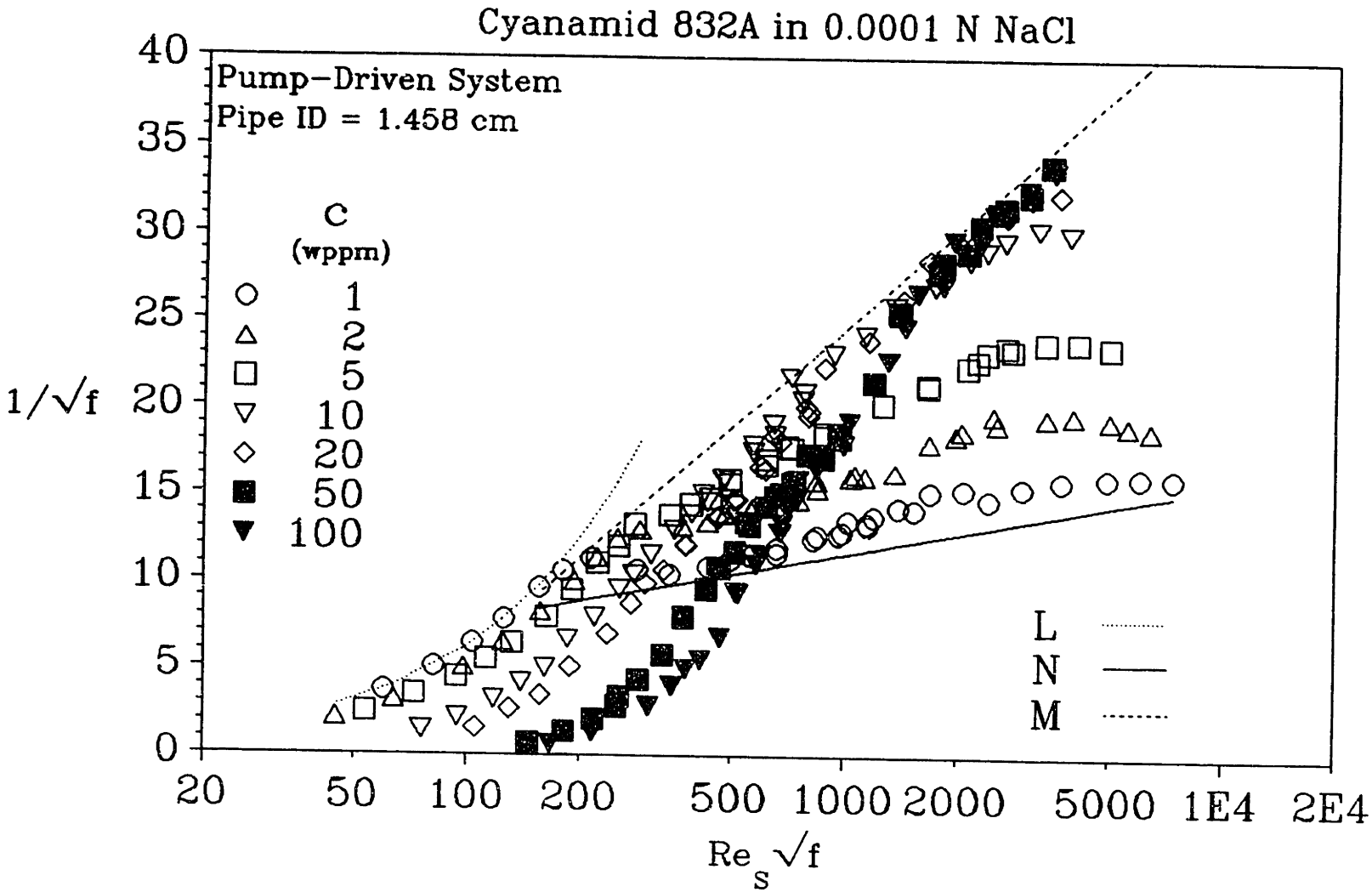


Figure 5.2.7: Cyanamid 832A in 0.0001 N NaCl from the 1.458-cm Pipe

respectively, enhancing drag relative to solvent. At $Re_s\sqrt{f} \approx 300$, these data depart from their laminar courses and ascend toward the MDR asymptote, which is approached most closely at $Re_s\sqrt{f} \approx 800$ and 900, respectively. For $800 < Re_s\sqrt{f} < 900$, the 10-wppm data are parallel and close to M, shift sharply into the polymeric regime at a retro-onset point $Re_s\sqrt{f}^* \approx 2000$, and then rise along a linear segment P with $(A_p, B_p) = (9.6, 3.4)$ for $2000 < Re_s\sqrt{f} < 3500$. Similarly, the 20-wppm data parallel M for $900 < Re_s\sqrt{f} < 3300$, and then at $Re_s\sqrt{f} \approx 3400$, the final 20-wppm data point shifts horizontally rightward into the polymeric regime, possibly a retro-onset induced by polymer degradation.

The 50-wppm and 100-wppm data display LM trajectories. For $Re_s\sqrt{f} > 150$, the 50-wppm and 100-wppm data trace respective laminar paths, well to the right of L and highly shear-thinning, with average $\eta_r \approx 6.8$ and 9.3 until $Re_s\sqrt{f} \approx 700$; the solutions enhance drag greatly relative to solvent, lying ~29 units below L at $Re_s\sqrt{f} \approx 700$, respectively. For $700 < Re_s\sqrt{f} < 1500$, the 50-wppm and 100-wppm data deviate from their apparently laminar paths, and both rise toward the MDR asymptote M, which is reached at $Re_s\sqrt{f} \approx 1500$ and closely adhere to M up to the highest $Re_s\sqrt{f} \approx 3400$.

In Figure 5.2.7, the flow trajectories exhibited are: LP by data at c = 1, 2, and 5 wppm; LMP by the 10-wppm and 20-wppm data; and LM by the 50-wppm and 100-wppm data. In laminar flow, as the concentration increases, these solutions have both increasing relative viscosities and drag enhancements relative to solvent, as the data shift farther to the right from L, and are increasingly shear thinning. In turbulent flow, as the concentration increases, these solutions increasingly enhance the flow relative to solvent, opposite to the effect observed in laminar flow. In the polymeric regime, the segments

P for c = 1, 2, 5, and 10 wppm have slopes A_p = 5.0, 7.0, 10.9, and 9.6, respectively, nearer that of the turbulent baseline N, A_n = 4.0, than that of the MDR asymptote, A_m = 19.0. Furthermore, as the concentration increases, the segments P achieve higher slips. At $Re_s\sqrt{f}$ = 1000, S' = 1.9, 4.5, 7.0, and 12.0, and at $Re_s\sqrt{f}$ = 3000, S' = 2.0, 5.8, 10.1, and 16.6, respectively. At each $Re_s\sqrt{f}$, to a rough approximation, S' increases linearly with increasing concentration. The segments P appear to extend from the MDR asymptote into the polymeric regime and to parallel the baseline N with uniform interspacings. The resulting overall structure thus resembles a "ladder", the segments P being the rungs and the MDR asymptote providing support. This "Type-B ladder" is characteristic of drag-reduction by solutions of extended additives. The Type-B ladder in Figure 5.2.7 has no rungs for c = 20, 50, and 100 wppm because the maximum $Re_s\sqrt{f}$ is not large enough to give rise to retro-onset at these concentrations. (The tiny segment P in the 20-wppm data may, in fact, be the retro-onset and incipient segment P corresponding to a degraded polymer solution that has a concentration somewhat less than 20 wppm.)

In summary, Figures 5.2.6 and 5.2.7 respectively illustrate a Type-A fan, which is characteristic of the drag-reduction behavior exhibited by solutions of initially collapsed macromolecules, and a Type-B ladder, which typifies drag-reduction behavior of solutions of initially extended macromolecules. The Type-A fan radiates into the polymeric regime from the turbulent baseline N, the lower limit of turbulent flow, at the individual onset points, which usually occur within a narrow band. The characteristic onset wall shear stress T_w^* reflects the average physical properties of the collapsed macromolecules in solution. The fan spokes have slopes A_p and slope increments δ that

increase with additive concentration. Note that the spokes emerge from the turbulent baseline N and have slopes like that of the MDR asymptote. In contrast, the Type-B ladder is characteristic of the drag-reduction behavior exhibited by solutions of initially extended macromolecules. The segments P forming the ladder rungs extend, or retro-onset, from the MDR asymptote, the upper turbulent-flow limit, into the polymeric regime and approximately parallel the turbulent baseline N, having shallow slopes near to that of N.

The Type-A fan and Type-B ladder structures exhibit some symmetry about the polymeric regime. The former has segments P which onset from N and have steep slopes whereas the latter has segments P which retro-onset from M and have shallow slopes. Both structures may contain LP trajectories, the former lacking an N segment and the latter lacking an M segment.

It is of interest to compare the turbulent flow enhancements observed in the present example of additive C832A in the 1.458-cm pipe. In the Type-A fan for c = 1, 2, 5, 10, and 20 at $Re\sqrt{f} \approx 1000$, the respective apparent slips S' = 0, 1.1, 1.8, 3.8, and 6.1; in the Type-B ladder at the same conditions, the respective S' = 1.9, 4.5, 7.1, 12.0, and 10.4. Here the respective apparent slip ratios S'_A/S'_B = 0, 0.24, 0.25, 0.32, and 0.59. The data for c = 50 and 100 wppm are excluded because they exhibit LM trajectories and do not display ladder rungs. At $Re\sqrt{f} \approx 3000$ for c = 1, 2, 5, 10, and 20 wppm, the respective apparent slips in the Type-A fan and the Type-B ladder are: S' = (0, 3.4, 7.1, 11.1, and 14.8) and (2.0, 5.8, 10.1, 16.6, and 18.5); the respective apparent slips ratios S'_A/S'_B = 0, 0.58, 0.70, 0.67, and 0.80. It is thus seen that the turbulent flow enhancement induced by the collapsed conformation never exceeds that

induced by the extended conformation at the same solution concentration. Also, as $Re_s\sqrt{f}$ increases, the flow enhancement induced by the collapsed conformation approaches that induced by the extended conformation, which suggests that initially collapsed macromolecules are transformed toward extended conformations at the higher $Re_s\sqrt{f}$.

Figures 5.2.8 and 5.2.9 present results, from the pump-driven system using the 1.021-cm pipe, for additive C832A, at c = 1, 2, 5, 10, 20, and 50 wppm, in the collapsed conformation in 0.3 N NaCl and the extended conformation in 0.0001 N NaCl, respectively. In both figures, lines L, N, and M represent the Newtonian laminar and turbulent baselines and the MDR asymptote, respectively.

In Figure 5.2.8, for $30 < Re_s\sqrt{f} < 150$, all data follow laminar paths either along, or just to the right of, L, typical of the behavior of solutions of initially collapsed macromolecules. The 20-wppm and 50-wppm laminar data lie slightly rightward, with respective relative viscosities $\eta_r \approx 1.06$ and 1.13.

The 1-wppm and 2-wppm data depart downward from L and onto N, completing a laminar-to-turbulent transition for $200 < Re_s\sqrt{f} < 400$. For $400 < Re_s\sqrt{f} < 700$, the 1-wppm data adhere to N, and then onset at $Re_s\sqrt{f}^* \approx 770$; for $700 < Re_s\sqrt{f} < 3000$, they ascend into the polymeric regime along a linear segment P with slope and intercept $(A_p, B_p) = (5.3, 3.9)$ and slope increment $\delta = 1.3$; for $4000 < Re_s\sqrt{f} < 10000$, the data become downward from the P segment, descending slightly toward N. Similarly, the 2-wppm data follow N briefly, onset at $Re_s\sqrt{f}^* \approx 500$, and then rise into the polymeric regime along a linear segment P with $(A_p, B_p) = (7.5, 9.8)$; for $4000 < Re_s\sqrt{f} < 10000$, these nearly exhibit constant $1/\sqrt{f} \approx 15$, declining slightly from their linear P segment, possibly on account of polymer degradation. The 1-wppm and 2-wppm

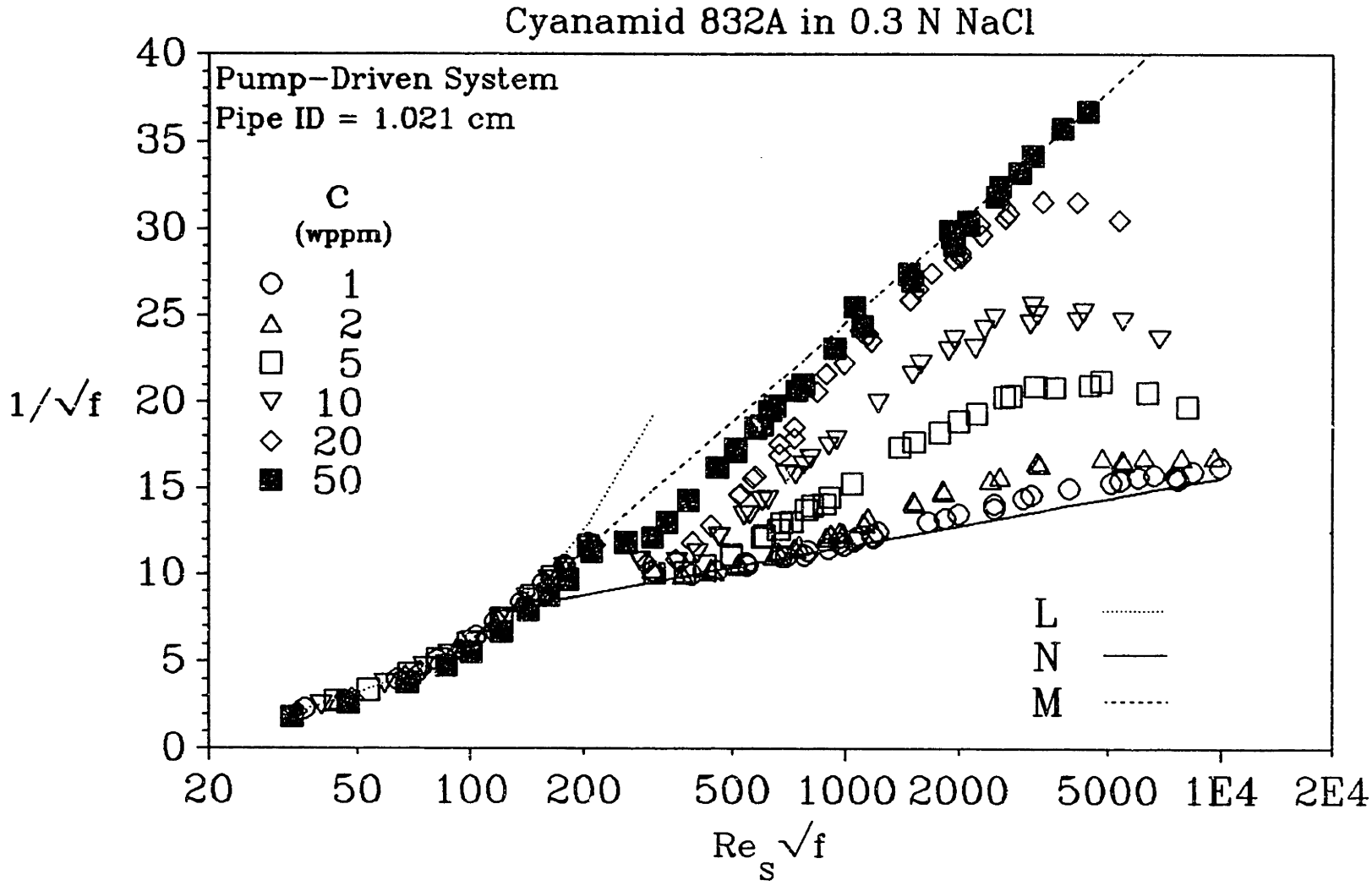


Figure 5.2.8: Cyanamid 832A in 0.3 N NaCl from the 1.021-cm Pipe

data thus exhibit LNP trajectories.

The 5-wppm and 10-wppm data depart downward from L toward N, for $200 < Re_s\sqrt{f} < 800$, in a laminar-to-turbulent transition. Yet, although both solutions either reach, or come very close to, N in the vicinity of $Re_s\sqrt{f} \approx 350$, they do not exhibit well-defined N segments. Rather, immediately after reaching $1/\sqrt{f}$ minima near N at $Re_s\sqrt{f} \approx 350$, the 5-wppm and 10-wppm solutions begin turbulent flow enhancement, rising into the polymeric regime along respective linear segments P with $(A_p, B_p) = (13.4, 25.2)$ and $(18.5, 37.1)$, and $\delta = 9.4$ and 14.5 until $Re_s\sqrt{f} \approx 3000$. Their respective apparent regressed onsets occur at $Re_s\sqrt{f}^* \approx 420$ and 340. For $Re_s\sqrt{f} > 3500$, the 5-wppm and 10-wppm data descend markedly from their linear segments P, probably on account of polymer degradation, up to $Re_s\sqrt{f} \approx 5000$ and 6500, respectively. The 5-wppm and 10-wppm data thus display L(N)P trajectories.

The 20-wppm data undergo a laminar-to-turbulent transition in the region $180 < Re_s\sqrt{f} < 300$, reaching a $1/\sqrt{f}$ minimum slightly above N at $Re_s\sqrt{f} \approx 300$. For $350 < Re_s\sqrt{f} < 750$, the data, already flow enhancing, rise further into the polymeric regime along a linear segment P with $(A_p, B_p) = (24.0, 50.1)$ and $\delta = 20.0$, with an apparent regressed onset at $Re_s\sqrt{f}^* \approx 300$. At $Re_s\sqrt{f} \approx 1000$, the 20-wppm data approach the MDR asymptote closely and for $1000 < Re_s\sqrt{f} < 3000$, lie parallel to M and about ~ 1.5 units of $1/\sqrt{f}$ beneath it; for $3500 < Re_s\sqrt{f} < 5000$, they depart rightward from M into the P regime and then descend somewhat in a possible manifestation of polymer degradation. The 20-wppm solution exhibit an LPM(P) trajectory.

The 50-wppm data depart rightward from L at $Re_s\sqrt{f} \approx 200$ and exhibit transitional behavior for $200 < Re_s\sqrt{f} < 300$, moving slightly upward into the polymeric

regime. For $300 < Re_s\sqrt{f} < 800$, the data ascend more steeply into the polymeric regime, toward M, along a linear segment with $(A_p, B_p) = (22.9, 44.8)$, $\delta = 18.9$ and apparent regressed onset at $Re_s\sqrt{f^*} \approx 200$. The 50-wppm data merge with M at $Re_s\sqrt{f} \approx 800$, and then continue along M up to the highest $Re_s\sqrt{f} \approx 5000$. The 50-wppm data, thus, trace an LPM trajectory.

In Figure 5.2.8, the flow trajectories displayed are: LNP by the 1-wppm and 2-wppm data, L(N)P by the 5-wppm and 10-wppm data, LPM(P) by the 20-wppm data, and LPM by the 50-wppm data. The laminar-flow data exemplify the behavior of solutions of initially collapsed macromolecules in that the solutions have low relative viscosities $\eta_r < 1.2$ up to the highest concentrations and show little relatively small drag enhancements relative to solvent. In turbulent flow, all segments P have slopes and slope increments that increase as concentration increases: A_p = (5.3, 7.5, 13.4, 18.5, 24.0 and 22.9) and δ = (1.3, 3.5, 9.4, 14.5, 20.0, and 18.9) for c = (1, 2, 5, 10, 20, and 50) wppm, respectively. The segments P seemingly radiate from the turbulent baseline N within a narrow range of real and apparent onset points, $220 < Re_s\sqrt{f} < 550$, and create a fan structure. This ensemble of segments P constitutes a Type-A "fan", characteristic of the drag-reduction behavior of solutions of collapsed macromolecules.

Figure 5.2.9 presents results for initially extended conformation of additive C832A in 0.0001 N NaCl.

The 1-wppm and 2-wppm data follow laminar paths for $30 < Re_s\sqrt{f} < 150$, shifted slightly rightward from L, to higher $Re_s\sqrt{f}$, corresponding to relative viscosities $\eta_r \approx 1.06$ and 1.14, respectively; these rightward shifts decrease with increasing $Re_s\sqrt{f}$ showing shear-thinning behavior. Both solutions enhance drag relative to the solvent with

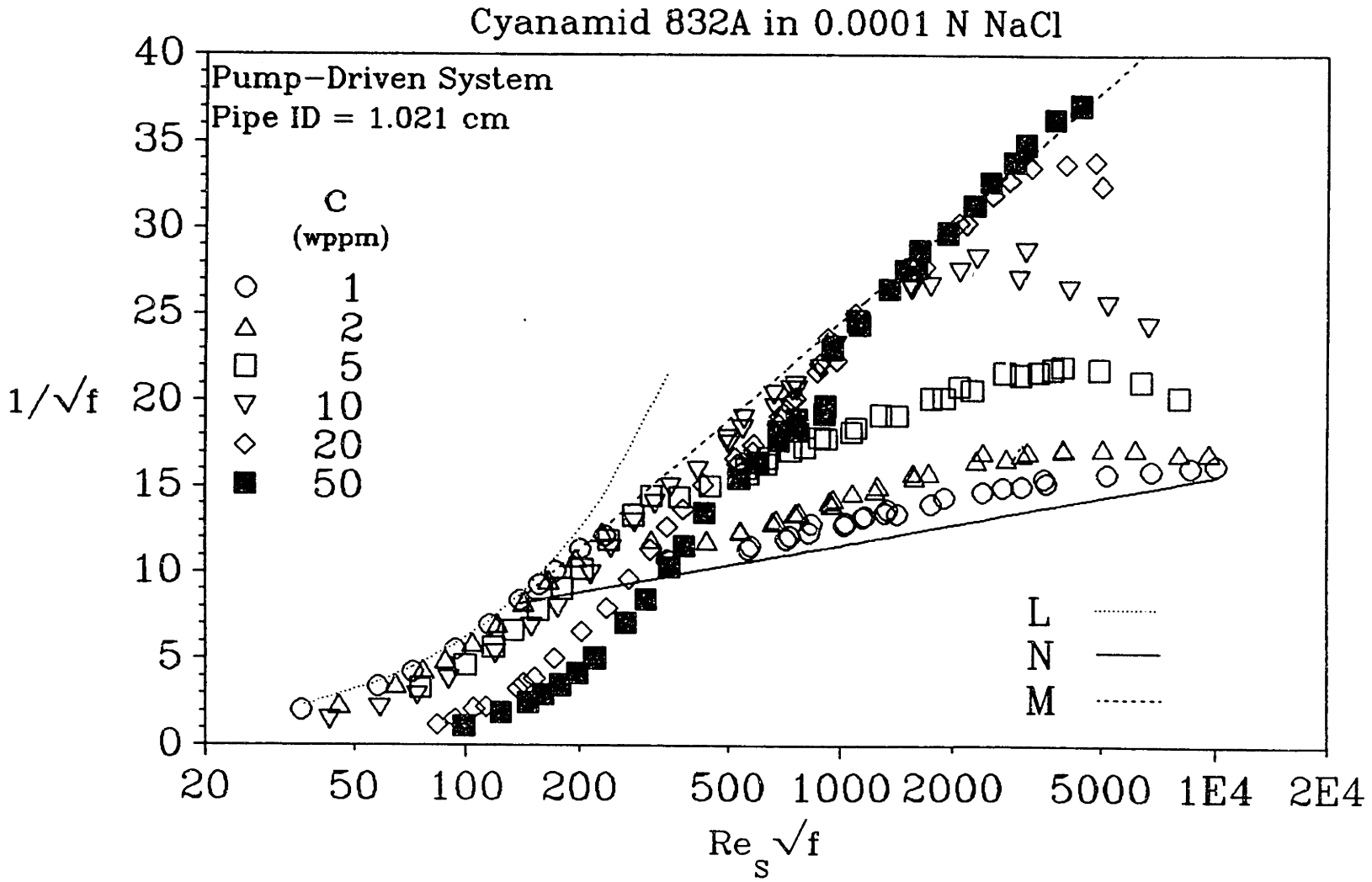


Figure 5.2.9: Cyanamid 832A in 0.0001 N NaCl from the 1.021-cm Pipe

$1/\sqrt{f_p} > 1/\sqrt{f_l}$ at constant $Re_s\sqrt{f}$. For $180 < Re_s\sqrt{f} < 350$, the 1-wppm and 2-wppm data depart downward from L, toward N, but reach $1/\sqrt{f}$ minima above N at $Re_s\sqrt{f} \approx 350$, thus exhibiting laminar-to-turbulent transitions that terminate in the polymeric regime. From these minima at $Re_s\sqrt{f} \approx 350$, the 1-wppm and 2-wppm data rise linearly into the polymeric regime along their respective P segments with slopes and intercepts $(A_p, B_p) = (4.0, -1.0)$ and $(6.2, 4.5)$, virtually parallel to N until $Re_s\sqrt{f} \approx 4000$; for $4000 < Re_s\sqrt{f} < 10000$, both solutions exhibit nearly constant $1/\sqrt{f} \approx 16$ and 17, respectively, declining from their P segments toward N. The 1-wppm and 2-wppm data thus make LP trajectories. The 5-wppm data are similar, but not identical. For $50 < Re_s\sqrt{f} < 200$, they follow a laminar path, to the right of L, corresponding to a relative viscosity $\eta_r \approx 1.4$ with some shear thinning. In the region $200 < Re_s\sqrt{f} < 300$, the data are both parallel to L and very close to M, so they could be following either an L or an M segment. At $Re_s\sqrt{f} \approx 300$, the 5-wppm data shift abruptly rightward, in a brief transition, and then, already flow enhancing, rise into the polymeric regime along a linear segment P, with $(A_p, B_p) = (8.2, 6.4)$ until $Re_s\sqrt{f} \approx 3500$. For $3500 < Re_s\sqrt{f} < 8000$, the data descend significantly from their segment P with $1/\sqrt{f}$ decreasing from 23 to 19, possibly on account of polymer degradation. The 5-wppm data thus display either an LP or an L(M)P trajectory.

The 10-wppm data follow a laminar path for $50 < Re_s\sqrt{f} < 250$ shifted rightward from L with $\eta_r \approx 1.6$ amid shear thinning. At $Re_s\sqrt{f} \approx 300$, the data approach the MDR asymptote from beneath, lie parallel and very close to M for $350 < Re_s\sqrt{f} < 1000$, and then retro-onset at $Re_s\sqrt{f} \approx 1000$. For $1000 < Re_s\sqrt{f} < 3000$, the 10-wppm data rise briefly into the polymeric regime along a linear segment P with (A_p,

B_p) = (11.0, 8.7) and for 3500 < $Re_s\sqrt{f}$ < 6500, decline from the segment P as a probable result of polymer degradation. The 10-wppm data trace an LMP trajectory.

In laminar flow for 90 < $Re_s\sqrt{f}$ < 400, both the 20-wppm and 50-wppm data exhibit shear-thinning with average $\eta_r \approx$ 3.2 and 4.0, respectively; these solutions also greatly enhance drag relative to L, lying ~10 and ~12 units below L at $Re_s\sqrt{f} \approx 400$. At $Re_s\sqrt{f} \approx 400$, both solutions exhibit inflections in their slopes, departing their laminar paths and converging upon the MDR asymptote M, with which they merge at $Re_s\sqrt{f} \approx$ 1000. For 1000 < $Re_s\sqrt{f}$ < 3000, the 20-wppm data follow along M, but then at $Re_s\sqrt{f}$ $\approx$ 3000 with $1/\sqrt{f} \approx 33$, shift sharply into the polymeric regime, following a short, nearly horizontal, segment with (A_p, B_p) = (2.1, -26.3) up to $Re_s\sqrt{f} \approx 5000$. The sudden departure from M is likely a retro-onset induced by polymer degradation. The 20-wppm data display an LMP trajectory. The 50-wppm data follow M for 1000 < $Re_s\sqrt{f}$ < 4500 to the highest $Re_s\sqrt{f}$, completing an LM trajectory.

In Figure 5.2.9, the flow trajectories displayed are: LP by data at c = 1, 2, and 5 wppm; LMP by the 10-wppm and 20-wppm data; and LM by the 50-wppm data. In laminar flow, relative viscosities and drag enhancements relative to solvent are high and increase with increasing concentration; also all solutions exhibit shear thinning. This behavior is typical of solutions of initially extended macromolecules. In turbulent flow, the data exhibit flow enhancements relative to solvent that increase with increasing concentration, the reverse of the laminar-flow observation. The segments P at c = 1, 2, 5, and 10 wppm seemingly extend(i.e. retro-onset) from the MDR asymptote into the polymeric regime and approximately parallel the Newtonian turbulent baseline N with slopes A_p = 4.0, 6.2, 8.2, and 11.0, respectively, until polymer degradation begins to

negate flow enhancement. The separation between a segment P and the baseline N, quantified by the apparent slip S', is roughly proportional to the concentration: At $Re_s\sqrt{f}$ $\approx$ 3000 for c = 1, 2, 5, and 10, S' = 1.6, 3.5, 8.2, and 15.3 and S'/c = 1.6, 1.8, 1.6, and 1.5, respectively. These uniformly-spaced and nearly-parallel P segments which extend from the MDR asymptote form the rungs of a "Type-B ladder", characteristic of drag reduction by solutions of initially extended additives. The 20-wppm data are omitted from the ladder because its segment P appears to be a manifestation of polymer degradation; the 50-wppm data, in their LM trajectory, do not contribute a ladder rung.

A comparison between the flow enhancements exhibited by the same polymer concentrations in the Type-A fan, Figure 5.2.8, and the Type-B ladder, Figure 5.2.9, is again interesting. For c = 1, 2, 5, and 10 wppm at $Re_s\sqrt{f}$ = 1000, the respective apparent slips are: S'_A = 0.3, 1.0, 3.5, and 6.7 and S'_B = 1.2, 2.9, 6.6, and 11.9, with slip ratios S'_A/S'_B = 0.28, 0.36, 0.53, and 0.56. The same concentrations at $Re_s\sqrt{f}$ = 3000 respectively provide S'_A = 0.9, 2.7, 7.0, and 11.4 and S'_B = 1.6, 3.5, 8.2, and 13.5, with slip ratios S'_A/S'_B = 0.59, 0.79, 0.86, and 0.84. It is seen that, at constant $Re_s\sqrt{f}$, for a given concentration, the flow enhancement induced by the initially collapsed conformation never exceeds that induced by the initially extended conformation. Also at each fixed concentration, the ratio of collapsed to extended flow enhancement increases toward unity with increasing $Re_s\sqrt{f}$. This suggests that, as $Re_s\sqrt{f}$ increases, initially collapsed macromolecules are progressively stretched by the flow toward their extended conformations.

The effect of flow length scale on drag reduction can be inferred by comparing turbulent flow results for additive C832A in the 1.458-cm pipe, Figures 5.2.6 and 5.2.7,

to those in the 1.021-cm pipe, Figures 5.2.8 and 5.2.9.

Data for additive C832A in 0.3 N NaCl, in the initially collapsed conformation, form Type-A fans in Figures 5.2.6 and 5.2.8. Each fan comprises the same kinds of flow trajectories, LNP, LP, and LPM at low, medium, and high concentrations. The fan from the 1.458-cm pipe, in Figure 5.2.6, contains segments P for $2 \leq c \leq 100$ wppm, the 1-wppm solution showing no perceptible drag reduction, whereas the fan from the 1.021-cm pipe, in Figure 5.2.8, contains segments P for all solutions $1 \leq c \leq 50$ wppm. The slope increments δ in the two fans at constant concentrations are similar, being for c = 2, 5, 10, 20, and 50 wppm, δ = (5.1, 9.4, 15.5, 17.1, and 20.3) and (3.5, 9.4, 14.5, 20.0, and 18.9), respectively. Also if the entire 1.021-cm-pipe fan is translated rightward, along the Newtonian line N, by a factor of ~ 1.4, then it virtually superimposes upon the 1.458-cm-pipe fan. Because the superposition factor 1.4 is roughly their pipe-diameter ratio 1.458/1.021, the structures of the two fans are essentially independent of the pipe diameter and are scaled by the wall shear stress alone. This implies that Type-A fans are essentially independent of the large scales of turbulence imposed by the pipe diameters. Moreover, the foregoing superposition of fans also causes the coincidence of the maxima exhibited by solutions of a given concentration in each pipe, suggesting that degradation, which likely causes these maxima, is also primarily dependent upon the wall shear stress.

Data for additive C832A in 0.0001 N NaCl, the initially extended conformation, create Type-B ladders in Figures 5.2.7 and 5.2.9. Each ladder comprises LP, LMP, and LM trajectories respectively at low, medium, and high concentrations. The ladders from the 1.458-cm pipe in Figure 5.2.7 and from the 1.021-cm pipe in Figure 5.2.9 have the

same qualitative appearance, showing well-developed rungs at c = 1, 2, 5, and 10 wppm with similar P-segment slopes A_p = (5.0, 7.0, 10.9, and 9.6) and (4.0, 6.2, 8.2, and 11.0), respectively. When compared at constant $Re_s\sqrt{f}$, the rungs in the 1.458-cm ladder are all somewhat higher than those in the 1.021-cm ladder: For example, at $Re_s\sqrt{f}$ = 3000, S' = (2.0, 5.8, 10.1, and 16.6) and (1.6, 3.5, 8.2, and 13.5), respectively. Yet, when compared at equal wall shear stresses, by translating the 1.021-cm rightward along N by the pipe-diameter ratio 1.458/1.021, the differences between the rungs diminish, and the ladders from both pipes roughly superimpose. Thus, Type-B ladders also appear to be scaled by wall shear stress and are roughly independent of pipe diameter.

Results for additive B1120 from the pump-driven system using the 1.458-cm pipe are shown in Figures 5.2.10 and 5.2.11 for solutions of initially collapsed and initially extended macromolecules in 0.3 N and 0.0001 N NaCl, respectively, with $1 \leq c \leq 100$ wppm. In both figures, the Newtonian laminar and turbulent baselines and the MDR asymptote are given by lines L, N, and M, respectively, the latter two enveloping the polymeric regime.

Figure 5.2.10 presents results for additive B1120 in 0.3 N NaCl at c = 1, 2, 5, 10, 20, 50, and 100 wppm from the pump-driven system using the 1.458-cm pipe. In laminar flow for $30 < Re_s\sqrt{f} < 180$, the data for c = 1, 2, 5, and 10 wppm follow L closely, with $\eta_r < 1.05$; for $180 < Re_s\sqrt{f} < 400$, they complete laminar-to-turbulent transitions, descending from L and alighting onto N. For $Re_s\sqrt{f} > 400$, these data continue along N until they onset at respective $Re_s\sqrt{f^*} \approx$ 960, 580, 640, and 510 and then rise into the polymeric regime along respective linear segments P with slopes and intercepts (A_p, B_p) = (4.9, 3.1), (7.7, 10.6), (12.4, 23.9), and (17.2, 36.1) and slope

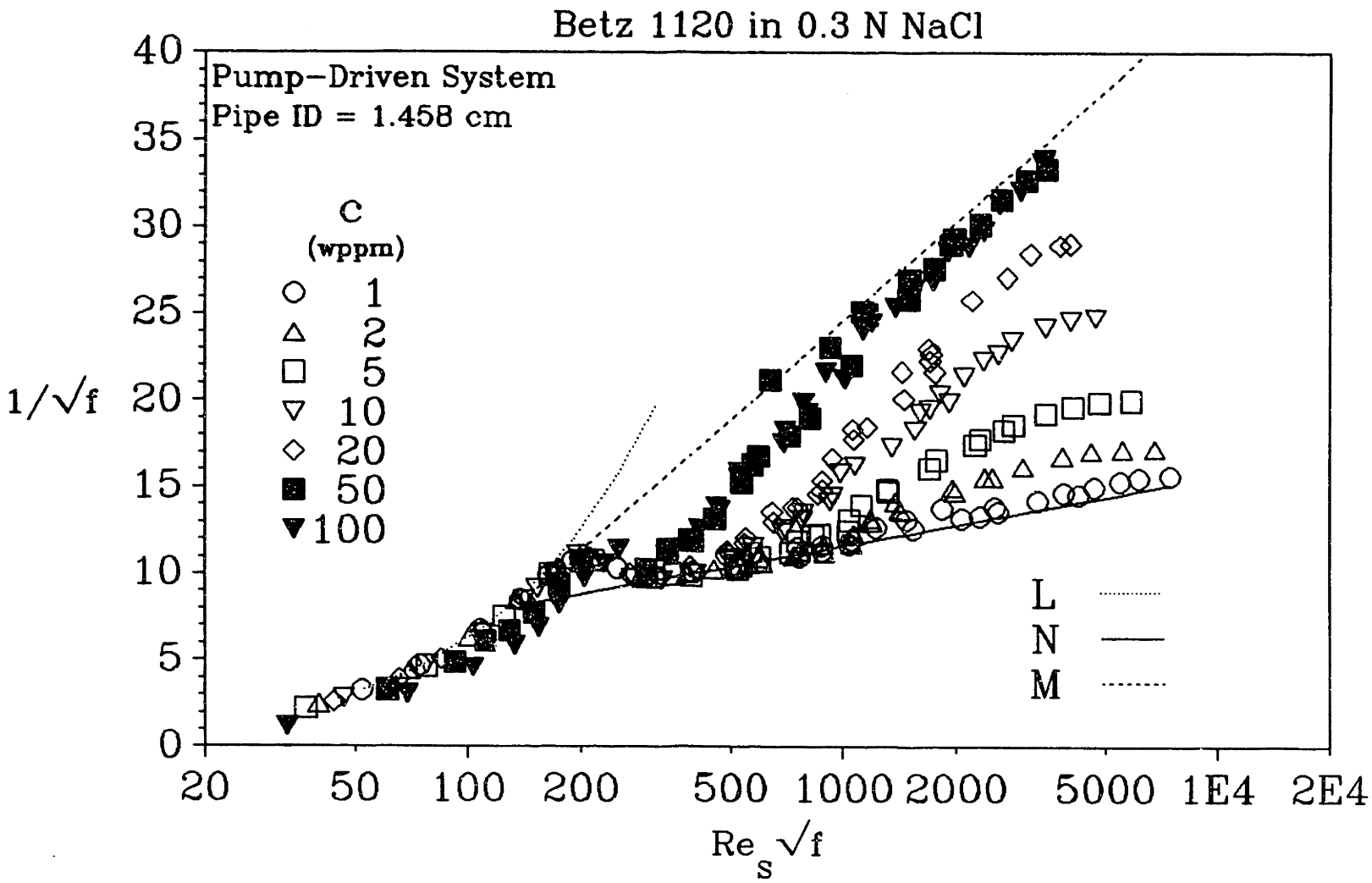


Figure 5.2.10: Betz 1120 in 0.3 N NaCl from the 1.458-cm Pipe

increments δ = 0.9, 3.7, 8.4, and 13.2 until $Re_s\sqrt{f} \approx 3000$. At $Re_s\sqrt{f} > 4000$, these data decline from their respective P segments, showing essentially constant $1/\sqrt{f} \approx$ 13, 15, 18, and 23, up to highest $Re_s\sqrt{f} \approx$ 7500, 6800, 5800 and 4700. Data for c = 1, 2, 5, and 10 wppm, thus, display LNP trajectories.

The 20-wppm data follow along L for $40 < Re_s\sqrt{f} < 150$, depart downward from L toward N at $Re_s\sqrt{f} \approx 180$, and reach a $1/\sqrt{f}$ minimum very close to N at $Re_s\sqrt{f} \approx 350\pm50$; for $400 < Re_s\sqrt{f} < 3000$, the data ascend linearly into the polymeric regime along a segment P with $(A_p, B_p) = (22.0, 48.8)$, δ = 18.0, and an apparent regressed onset at $Re_s\sqrt{f}^* \approx 480$. For $3000 < Re_s\sqrt{f} < 4000$, the data fall slightly below their segment P, likely owing to polymer degradation. The 20-wppm data complete an L(N)P trajectory.

The 50-wppm and 100-wppm data parallel L to the right with respective $\eta_r \approx 1.2$ and 1.4, until $Re_s\sqrt{f} \approx 200$. The 50-wppm and 100-wppm solutions slightly enhance laminar drag relative to the solvent in that they lie beneath L. At $Re_s\sqrt{f} \approx 220$, both solutions commence laminar-to-turbulent transitions, departing to the right and downward to reach $1/\sqrt{f}$ minima at $Re_s\sqrt{f} \approx 300$, close to, but slightly above, N. Already a bit flow enhancing at their minima, both then rise steeply into the polymeric regime toward the MDR asymptote along respective linear segments P with $(A_p, B_p) = (21.8, 44.2)$ and $(24.7, 51.9)$, δ = 17.8 and 20.7, and apparent regressed onsets at $Re_s\sqrt{f}^* \approx 290$ and 310. The 50-wppm and 100-wppm data approach M most closely at $Re_s\sqrt{f} \approx 1500$ and then begin to parallel M up to $Re_s\sqrt{f} \approx 3400$. These data, thus, follow LPM trajectories.

In Figure 5.2.10, LNP, L(N)P, and LPM trajectories are displayed at c = 1, 2, 5, and 10 wppm, at c = 20 wppm, and at c = 50 and 100 wppm, respectively. The

laminar-flow paths for $c \leq 20$ wppm are virtually indistinguishable from solvent line L and are characteristic of solutions of initially collapsed macromolecules; the 50-wppm and 100-wppm solutions also exhibit Newtonian viscosities, even though they show significant $\eta_r > 1$. In turbulent flow, the segments P for $c \leq 20$ wppm have slopes and slope increments that increase with increasing concentration: $A_p = 4.9$, 7.7, 12.4, 17.2, and 22.0 and $\delta = 0.9$, 3.7, 8.4, 13.2, and 18.0, respectively, the corresponding $Re_s\sqrt{f^*} \approx 960$, 580, 640, 510, and 480(apparent). These five segments appear to radiate from a narrow band on the turbulent baseline N, forming a fan, typical of Type-A drag-reduction behavior by an initially collapsed additive conformation.

Figure 5.2.11 shows results for the initially extended conformation of additive B1120 in 0.0001 N NaCl for $1 \leq c \leq 100$ wppm from the pump-driven system using the 1.458-cm pipe.

The 1-wppm data follow L closely for $50 < Re_s\sqrt{f} < 160$, a little to the right with $\eta_r \approx 1.02$; for $160 < Re_s\sqrt{f} < 320$, they depart downward from L onto N in a laminar-to-turbulent transition. Continuing along N for $320 < Re_s\sqrt{f} < 750$, the 1-wppm data onset at $Re_s\sqrt{f^*} \approx 750$ and then slowly diverge from N before becoming nearly parallel to N at $Re_s\sqrt{f} \approx 1000$. For $1000 < Re_s\sqrt{f} < 7500$, the data hover just above N, with slope $A_p = 4.0$, descending slightly at the highest $Re_s\sqrt{f}$. The 1-wppm data, thus, display an LNP trajectory.

The 2-wppm data follow a laminar path to the right of L for $50 < Re_s\sqrt{f} < 190$, with $\eta_r \approx 1.2$ and, thus, show drag enhancement relative to solvent. Departing rightwards from L at $Re_s\sqrt{f} \approx 200$, the 2-wppm data exhibit a transitional undulation and reach a $1/\sqrt{f}$ minimum above N at $Re_s\sqrt{f} \approx 400$. For $400 < Re_s\sqrt{f} < 3000$, the data

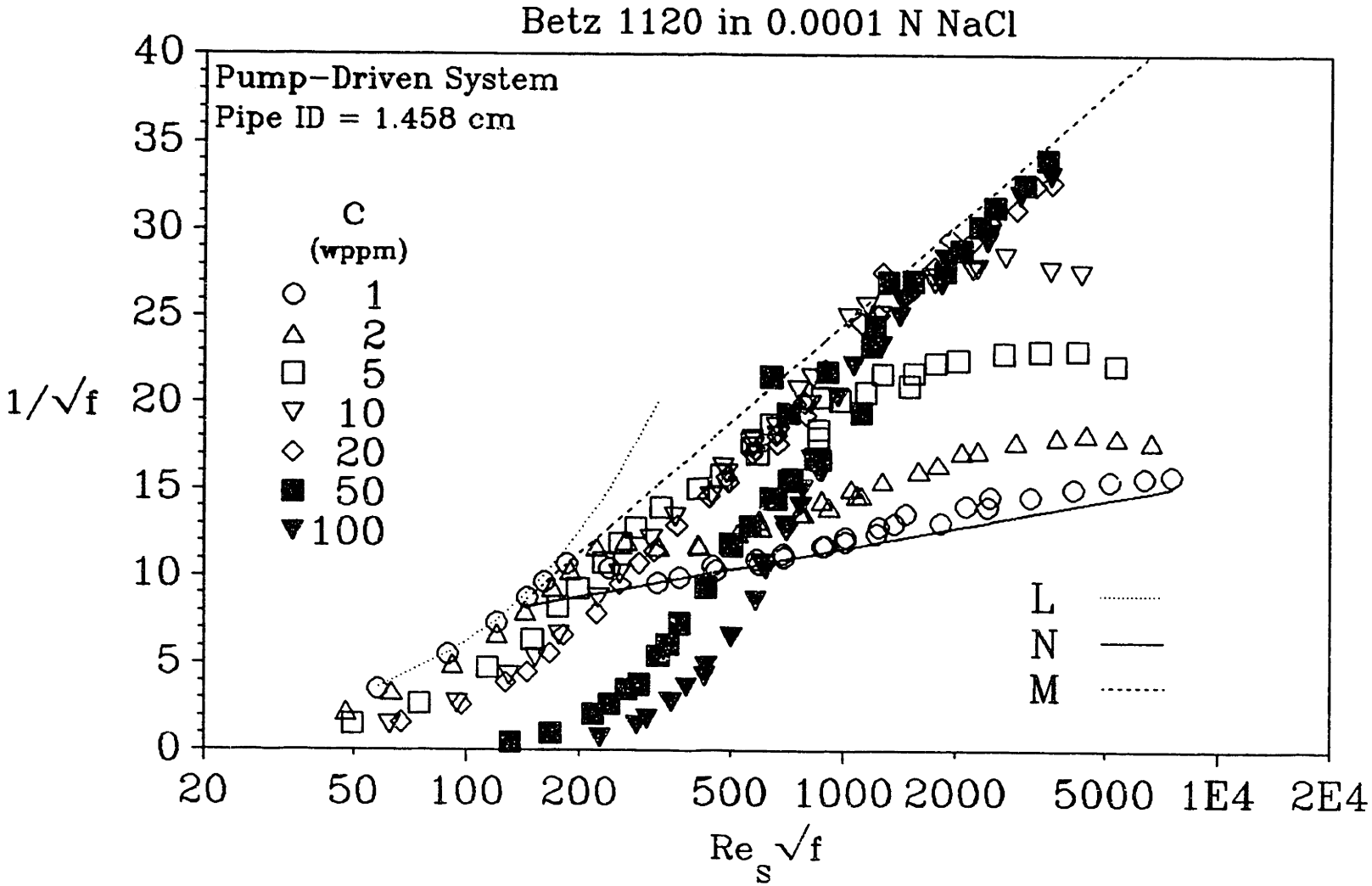


Figure 5.2.11: Betz 1120 in 0.0001 N NaCl from the 1.458-cm Pipe

rise shallowly into the polymeric regime along a linear segment P with slope and intercept $(A_p, B_p) = (7.4, 7.7)$ and for $3000 < Re_s\sqrt{f} < 6500$, decline from their segment P possibly because of polymer degradation, becoming horizontal with $1/\sqrt{f} \approx 17$. The 2-wppm solution follows an LP trajectory.

The 5-wppm data follow a laminar path still farther to the right of L for $50 < Re_s\sqrt{f} < 200$, with $\eta_r \approx 1.6$, showing greater drag enhancement relative to solvent as well, and exhibit distinct shear thinning. Departing from their laminar path at $Re_s\sqrt{f} \approx 300$, the data ascend linearly, parallel and close to M, until $Re_s\sqrt{f} \approx 800$. At $Re_s\sqrt{f^*} \approx 800$, retro-onset occurs, and the 5-wppm data sharply shift to the right, into the polymeric regime, and ascend along a shallow linear segment P with $(A_p, B_p) = (5.3, -4.8)$ until $Re_s\sqrt{f} \approx 3000$; for $4000 < Re_s\sqrt{f} < 6000$, the data decline slightly from their linear path. Thus, the 5-wppm solution follows an LMP trajectory.

The 10-wppm and 20-wppm data trace laminar paths to the right of L for $60 < Re_s\sqrt{f} < 300$, amidst shear thinning, with $\eta_r \approx 1.8$ and 2.0, respectively. Both the 10-wppm and 20-wppm solutions enhance drag relative to solvent. At $Re_s\sqrt{f} \approx 320$, these data appear to depart from their L segments, exhibit slight inflections, and then become parallel to the MDR asymptote M. The 10-wppm data retro-onset at $Re_s\sqrt{f^*} \approx 1500$, continue linearly into the polymeric regime along a segment P with $(A_p, B_p) = (8.0, -1.2)$ until $Re_s\sqrt{f} \approx 3000$, and then decay slightly from their segment P up to $Re_s\sqrt{f} \approx 4300$. The 20-wppm data run parallel to M for $600 < Re_s\sqrt{f} < 3500$. The 10-wppm and 20-wppm trace LMP and LM trajectories, respectively.

The 50-wppm data follow a laminar path far to the right of L for $120 < Re_s\sqrt{f} < 500$, with $\eta_r \approx 7.0$; they exhibit great drag enhancement relative to solvent and

distinct shear-thinning. The 100-wppm data follow a similar laminar path for 200 < $Re_s\sqrt{f}$ < 800, with $\eta_r \approx 12$, even more drag enhancement, and more severe shear-thinning behavior. For 500 < $Re_s\sqrt{f}$ < 1400, the 50-wppm data depart from their L segment, inflect, and rise toward the MDR asymptote, widely scattering in apparent transitional behavior at $Re_s\sqrt{f} \approx 1000$. At $Re_s\sqrt{f} \approx 1400$, the data approach M closely and are then parallel to M up to the highest $Re_s\sqrt{f} \approx 3500$. For 1200 < $Re_s\sqrt{f}$ < 1500, the 100-wppm data leave their L segment, inflect, and rise toward M, closely approaching it at $Re_s\sqrt{f} \approx 1400$ and continuing parallel to M up to the highest $Re_s\sqrt{f} \approx 3500$. The 50-wppm and 100-wppm data both show LM trajectories.

In Figure 5.2.11, the flow trajectories displayed are: LNP by the 1-wppm data; LP by the 2-wppm data; LMP by the 5-wppm and 10-wppm data; and LM by data for c = 20, 50, and 100 wppm. In laminar flow, these solutions exhibit high relative viscosities, as well as shear-thinning behavior, typically associated with extended macromolecules; also, as the concentration increases, the solutions increasingly enhance drag relative to solvent. In turbulent flow, the opposite holds in that increasing concentration increases flow enhancement relative to solvent. In the polymeric regime, for c = 1, 2, 5, and 10 wppm, the segments P are approximately parallel to the turbulent baseline N, with respective slopes A_p = 4.0, 7.4, 5.3, and 8.0; also, as concentration increases, the segments P achieve higher flow enhancements relative to solvent at constant $Re_s\sqrt{f}$, with, for example, S' = 1.0, 4.4, 9.5, and 14.7, respectively, at $Re_s\sqrt{f} \approx 3000$. The resulting polymeric-regime structure resembles a ladder, the rungs of which are the ascending parallel linear P segments; this Type-B ladder is characteristic of drag reduction by solutions of extended additives.

Figures 5.2.10 and 5.2.11 for additive B1120 in the initially collapsed and initially extended conformations in 0.3 N and 0.0001 N NaCl, respectively, differ significantly in both laminar and turbulent flow. In laminar flow, whereas the former data show Newtonian relative viscosities near unity and small accompanying drag enhancements relative to solvent, the latter data exhibit large, highly shear-thinning relative viscosities, $\eta_r \leq 7.0$, and concomitant large drag enhancements relative to solvent. Consequently, in laminar flow, solutions of a collapsed additive enhance flow relative to solutions of an extended additive.

In turbulent flow for $Re_s\sqrt{f} > Re_s\sqrt{f'}$, the collapsed and extended conformations exhibit a Type-A fan and a Type-B ladder, respectively. The Type-A fan is characterized by P segments radiating outward from closely clustered onsets point on the turbulent baseline N; the P-segment slope increments δ increase with increasing concentration. The Type-B ladder is characterized by P segments of shallow slope, roughly parallel to N, that appear to extend outward from the MDR asymptote at retro-onset points; the displacements S' of the P segments above N increase with increasing concentration. Note that data for c = 50 and 100 wppm exhibit LPM trajectories for the initially collapsed macromolecular conformation and LM trajectories for the initially extended macromolecular conformation. Thus, maximum drag reduction is not only independent of the additive's physical properties, it is independent of the additive's initial conformation. By comparing the Type-A fan to the Type-B ladder, it is found that solutions of initially extended macromolecules enhance flow relative to solutions of initially collapsed additive, the opposite of the laminar-flow observation. Between the establishment of turbulent flow and the onset of Type-A drag reduction, $400 < Re_s\sqrt{f}$

$< Re_s\sqrt{f^*}$, Type-B solutions enhance flow relative to solvent infinitely more than do Type-A solutions because the latter exhibit Newtonian turbulent-flow behavior, no drag reduction, prior to onset. For $Re_s\sqrt{f} > Re_s\sqrt{f^*}$, both kinds of solutions enhance flow relative to solvent, but with $S'_A < S'_B$ at equal concentration; as $Re_s\sqrt{f}$ increases further, the flow enhancements S'_A and S'_B approach each other. In Figure 5.2.10, at $Re_s\sqrt{f} \approx$ 1000 for c = 1, 2, 5, and 10 wppm, S'_A = 0.3, 0.5, 1.1, and 4.0, whereas in Figure 5.2.11, at the same $Re_s\sqrt{f}$, S'_B = 0.5, 3.0, 8.8, and 13.0; thus, S'_A/S'_B = (0.52, 0.15, 0.12, and 0.31), respectively. At $Re_s\sqrt{f} \approx$ 3000, S'_A = 0.45, 2.7, 5.3, and 10.2, S'_B = 1.0, 4.4, 9.5, and 14.7, and S'_A/S'_B = 0.47, 0.61, 0.56, and 0.69. The preceding illustrates that, for fixed $Re_s\sqrt{f}$ and c, $S'_A < S'_B$, always and that, for all c, S'_A/S'_B increases toward unity as $Re_s\sqrt{f}$ is increased.

(2) Low Molecular-Weight Additives

Figures 5.2.12 and 5.2.13 show results from the pump-driven system using the 1.458-cm and 1.021-cm pipes, respectively, for additive P500 at c = 10, 30, and 100 wppm in both the initially collapsed conformation, in 0.3 N NaCl(closed symbols), and the initially extended conformation, in 0.0001 N NaCl(open symbols). In Figures 5.2.12 and 5.2.13, the lines L, N, and M represent the Newtonian laminar and turbulent baselines and the MDR asymptote, respectively.

Consider first Figure 5.2.12, in the 1.458-cm pipe. For the initially collapsed-conformation in laminar flow, for $50 < Re_s\sqrt{f} < 150$, data for c = 10, 30, and 100 wppm parallel L with constant rightward displacements that increase as concentration

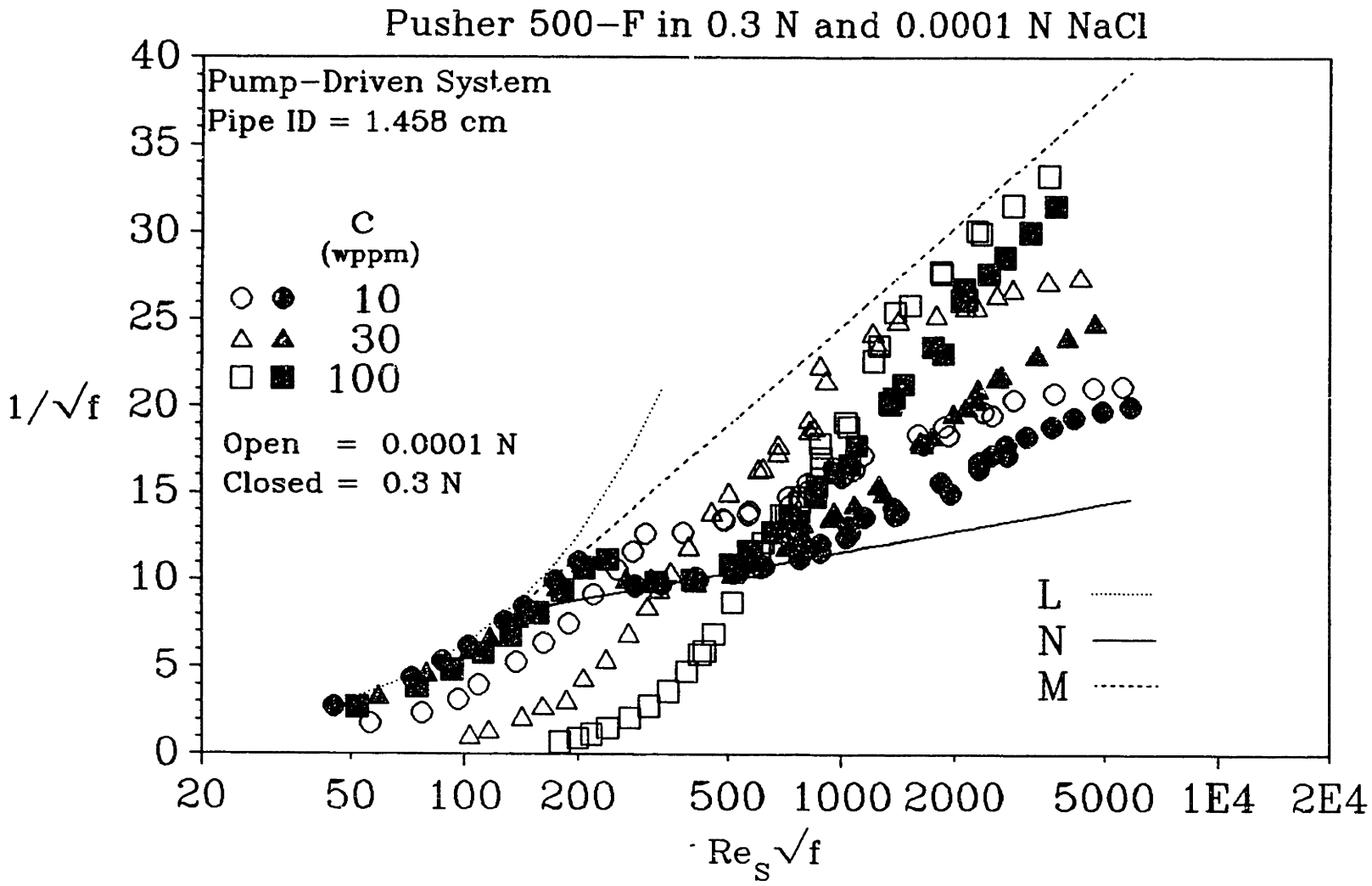


Figure 5.2.12: Pusher 500-F in 0.3 and 0.0001 N NaCl from the 1.458-cm Pipe

increases and that correspond to $\eta_r \approx 1.03$, 1.09, and 1.21, respectively; thus, these solutions slightly enhance drag relative to solvent. For $150 < Re_s\sqrt{f} < 320$, these data deviate to the right from their laminar paths and drop onto N, completing laminar-to-turbulent transitions. For $Re_s\sqrt{f} > 320$, the data for c = 10, 30, and 100 wppm continue along N until they onset at respective $Re_s\sqrt{f^*} \approx 700$, 550, and 580. For $Re_s\sqrt{f^*} < Re_s\sqrt{f} < 3500$, the 10-wppm and 30-wppm data rise into the polymeric regime along their respective linear segments P with slopes and intercepts $(A_p, B_p) = (10.8, 19.7)$ and (15.7, 32.4) and slope increments $\delta = 6.8$ and 11.7, and then for $Re_s\sqrt{f} > 3500$, they decline slightly downward from their segments P, possibly because of polymer degradation, up to $Re_s\sqrt{f} \approx 6000$ and 4700, respectively. For $600 < Re_s\sqrt{f} < 3000$, the 100-wppm data ascend into the polymeric regime showing slight initial concave-upward curvature before achieving a linear segment P with $(A_p, B_p) = (26.2, 61.8)$ and $\delta = 22.2$. As a result of the initial curvature, the regressed $Re_s\sqrt{f^*} \approx 580$ is much larger than the visual $Re_s\sqrt{f^*} \approx 450$. At $Re_s\sqrt{f} \approx 3000$, the 100-wppm data deviate slightly downward from their segment P up to the highest $Re_s\sqrt{f} \approx 4000$. The data for all three c = 10, 30, and 100 wppm exhibit LNP trajectories.

In the same Figure 5.2.12, the initially extended conformation data for c = 10, 30, and 100 wppm follow respective laminar paths with increasing rightward shifts from L that correspond to $\eta_r \approx 1.7$, 3.3, and 11.0 for $Re_s\sqrt{f} < 250$, 450, and 650; thus, lying below L, the data exhibit large drag enhancements relative to solvent, that increase with concentration. Also, because the rightward shifts from L decrease as $Re_s\sqrt{f}$ increases, these solutions exhibit shear thinning.

The 10-wppm data depart their laminar path at $Re_s\sqrt{f} \approx 300$, shift rightward in

a short transitional undulation for $300 < Re_s\sqrt{f} < 400$, and then ascend linearly into the polymeric regime until $Re_s\sqrt{f} \approx 3000$ along a segment P with slope and intercept (A_p, B_p) = (9.0, 10.7); for $3500 < Re_s\sqrt{f} < 5600$, the data decline slightly from their segment P, perhaps because of polymer degradation. The 10-wppm data exhibit an LP trajectory. Similarly, departing their laminar path at $Re_s\sqrt{f} \approx 450$, the 30-wppm data inflect and then steeply approach the MDR asymptote with some transitional scatter, reaching M at $Re_s\sqrt{f} \approx 800$; after following M briefly, they exhibit retro-onset at $Re_s\sqrt{f^\#} \approx 1000$. For $1000 < Re_s\sqrt{f} < 4300$, the 30-wppm data extend into the polymeric regime along a shallow linear segment P with (A_p, B_p) = (5.9, -6.2) without any apparent polymer degradation. The 30-wppm data display an L(M)P trajectory, with a short, ill-defined, M segment. The 100-wppm data leave their laminar path at $Res\sqrt{f} \approx 650$, inflect, and rise steeply toward the MDR asymptote, approaching M closely at $Re_s\sqrt{f} \approx 1400$, after which they are parallel to, and just beneath, M for $1500 < Re_s\sqrt{f} < 3600$. The 100-wppm data, thus, trace an LM trajectory.

Figure 5.2.12 well illustrates the striking differences in flow behavior between solutions of initially collapsed and initially extended macromolecules, the former exhibiting LNP trajectories whereas the latter exhibits LP and LM trajectories. In laminar flow, the former have relative viscosities near unity, thus enhancing drag relative to solvent very little, and show no shear-thinning behavior, whereas the latter have large relative viscosities, thus greatly enhancing drag relative to solvent, and show pronounced shear-thinning behavior. In turbulent flow, the former data have distinct N segments with no flow enhancement whereas the latter do not. The segments P of the collapsed conformation at c = 10, 30, and 100 wppm burst from closely clustered onset points

with respective $Re_s\sqrt{f} \approx 700$, 550, and 580 on the Newtonian turbulent baseline N and have respective slope increments that increase with increasing concentration, $\delta = 6.8$, 11.0, and 22.2. The resulting Type-A fan structure exemplifies the drag-reduction behavior of solutions of initially collapsed additives. For the extended conformation, the segments P at c = 10 and 30 wppm extend into the polymeric regime roughly parallel to the turbulent baseline N, having respective slopes $A_p = 9.0$ and 5.9. Their upward displacements from N, measured by the apparent slip S', are roughly proportional to concentration: At $Re_s\sqrt{f} = 1000$, S' = 4.6 and 11.3 and S'/c = 0.46 and 0.38, whereas at $Re_s\sqrt{f} = 3000$, S' = 7.0 and 13.4 and S'/c = 0.70 and 0.45. The 30-wppm data exhibit retro-onset from M into the polymeric regime. These result in a Type-B ladder structure, here comprising only two segments P and the MDR asymptote.

By comparing the Type-A fan and Type-B ladder in Figure 5.2.12, it is evident that, for fixed concentration, Type-A flow enhancement is always less than Type-B flow enhancement, with the former approaching the latter at the higher $Re_s\sqrt{f}$. In Figure 5.2.12, at $Re_s\sqrt{f} \approx 1000$, S'_A = (1.0, 2.5, and 5.0), S'_B = (4.6, 11.3, and 7.3), and the ratios S'_A/S'_B = (0.22, 0.22, and 0.69); the last ratio is oddly large because the high relative viscosity of the 100-wppm data with Type-B behavior displaces laminar flow to higher $Re_s\sqrt{f}$, thus reducing S' at $Re_s\sqrt{f} \approx 1000$. At $Re_s\sqrt{f} \approx 3000$, S'_A = (4.6, 9.0, and 16.0), S'_B = (7.0, 13.4, and 18.4), and the ratios S'_A/S'_B = (0.65, 0.67, and 0.87). The last ratio here is also oddly large, this time because the 100-wppm data in both Type-A and Type-B drag reduction closely approach the MDR asymptote at $Re_s\sqrt{f} \approx 3000$.

Figure 5.2.13 presents results for additive P500 in the 1.021-cm pipe at the same concentrations and salinities as shown in Figure 5.2.12 in the 1.458-cm pipe.

Data for the initially collapsed conformation(closed symbols) at c = 10, 30, and 100 wppm follow along or closely to L with respective $\eta_r \approx 1.00$, 1.05, and 1.18 for $30 < Re_s\sqrt{f} < 150$. At $Re_s\sqrt{f} \approx 180$, the data depart downward from L and drop toward N, commencing a laminar-to-turbulent transition, at the end of which the 10-wppm and 30-wppm data alight onto N at $Re_s\sqrt{f} \approx 350$, whereas the 100-wppm data reach a $1/\sqrt{f}$ minimum just above N at $Re_s\sqrt{f} \approx 350$. The 10-wppm data continue along N until $Re_s\sqrt{f} \approx 600$, then onset at $Re_s\sqrt{f}^* \approx 640$, and ascend into the polymeric regime along a linear segment P with slope and intercept $(A_p, B_p) = (10.6, 19.0)$ and slope increment $\delta = 6.6$ until $Re_s\sqrt{f} \approx 4000$. For $4100 < Re_s\sqrt{f} < 8000$, the 10-wppm markedly decline from their linear segment P, perhaps because of polymer degradation. The 30-wppm data reside only briefly on N, onset at $Re_s\sqrt{f}^* \approx 450$, and ascend into the polymeric regime along a P segment, for $450 < Re_s\sqrt{f} < 3000$, with slope and intercept $(A_p, B_p) = (17.2, 35.6)$ and slope increment $\delta = 13.2$; for $3500 < Re_s\sqrt{f} < 6000$, the data exhibit near-constant $1/\sqrt{f} \approx 26$, departing downward from their P segment, possibly owing to polymer degradation. From their minimum, the 100-wppm data rise further into the polymeric regime, from an apparent regressed onset at $Re_s\sqrt{f}^* \approx 460$, along a linear segment P with $(A_p, B_p) = (31.2, 72.6)$ and $\delta = 27.2$ until $Re_s\sqrt{f} \approx 1500$. The 100-wppm data, approach the MDR asymptote closely at $Re_s\sqrt{f} \approx 1500$ and are then parallel to and just below M, for $1500 < Re_s\sqrt{f} < 4500$.

Data for c = 10, 30, and 100 wppm in 0.3 N NaCl, thus, exhibit LNP, L(N)P, and LPM flow trajectories, respectively. All their laminar-flow data remain proximal to

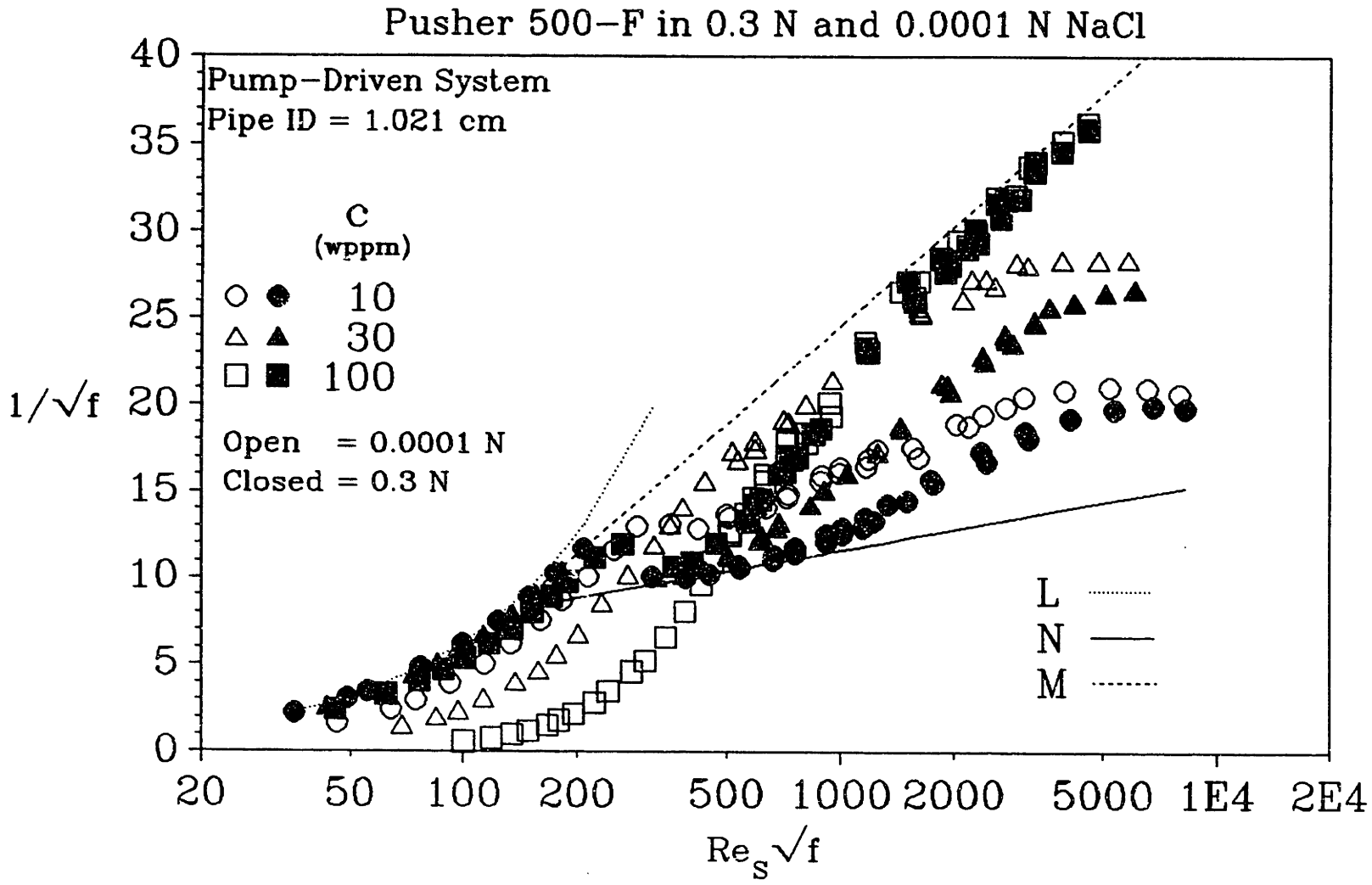


Figure 5.2.13: Pusher 500-F in 0.3 and 0.0001 N NaCl from the 1.021-cm Pipe

L with small Newtonian relative viscosities near unity, typical of solutions of initially collapsed macromolecules. In turbulent flow with drag reduction, the segments P have slope increments that increase with increasing concentration: δ = 6.6, 13.2, and 27.2, respectively. Although only the 10-wppm data show a distinct N segment and onset point, $Re_x\sqrt{f^*} \approx 640$, the 30-wppm also reach N and onset at $Re_x\sqrt{f} \approx 450$, whereas the 100-wppm data, with no N segment, have an apparent regressed onset, $Re_x\sqrt{f^*} \approx 460$, close to the others. Thus, the three P segments collectively appear to radiate from the turbulent baseline N near $Re_x\sqrt{f} \approx 500$, forming a Type-A "fan", that exemplifies drag-reduction behavior of solutions of initially random-coiling macromolecules.

For the initially extended conformation(open symbols) in Figure 5.2.13, data for c = 10, 30, and 100-wppm follow respective laminar paths that are shifted increasingly rightward from L and that correspond to increasingly shear-thinning $\eta_r \approx$ 1.6, 2.6, and 8.2 for $Re_x\sqrt{f} <$ 180, 250, and 500; the observed drag enhancements relative to solvent increase greatly as concentration increases. The 10-wppm data depart from their L segment at $Re_x\sqrt{f} \approx 250$, at which point they are also very close to the MDR asymptote; at $Re_x\sqrt{f} \approx 300$, they undergo a transition, abruptly shifting rightward from L and M, to reach a $1/\sqrt{f}$ minimum at $Re_x\sqrt{f} \approx 430$ in the polymeric regime with flow enhancement. From this minimum, the 10-wppm data rise into the polymeric regime along a shallow linear segment P with slope and intercept (A_p, B_p) = (8.6, 9.8) until $Re_x\sqrt{f} \approx 3000$; from $4000 < Re_x\sqrt{f} < 8000$, the data show nearly constant $1/\sqrt{f} \approx 20$, declining from their linear segment P, possibly because of polymer degradation. The 10-wppm data describe an I.P trajectory. The 30-wppm data depart from their L segment at $Re_x\sqrt{f} \approx 400$, exhibit an inflection, and then are parallel, and ~2 units of $1/\sqrt{f}$

below, M for $500 < Re_s\sqrt{f} < 1500$. At $Re_s\sqrt{f}^{\#} \approx 1500$, the data exhibit retro-onset, suddenly shifting away from M toward the polymeric regime, into which they ascend along a linear segment P with $(A_p, B_p) = (9.0, 3.4)$ until $Re_s\sqrt{f} \approx 3100$; for $3500 < Re_s\sqrt{f} < 5800$, the data attain a constant $1/\sqrt{f} \approx 28$, descending somewhat from their segment P, possibly on account of polymer degradation. The 30-wppm data trace an LMP trajectory. The 100-wppm data inflect away from L at $Re_s\sqrt{f} \approx 600$ and ascend steeply toward M, which is reached at $Re_s\sqrt{f} \approx 1500$ and then followed closely for $1500 < Re_s\sqrt{f} < 4500$. The 100-wppm solution follows an LM trajectory.

Data for c = 10, 30, and 100 wppm in 0.0001 N NaCl, respectively display LP, LMP, and LM trajectories. In laminar flow, the data exhibit large relative viscosities amidst shear-thinning behavior and, concomitantly, are greatly drag enhancing relative to solvent; this is the characteristic behavior of solutions of initially extended macromolecules. In turbulent flow, the segments P for c = 10 and 30 wppm appear to extend linearly from the MDR asymptote into the polymeric regime with similar shallow slopes $A_p = 8.6$ and 9.0, roughly parallel to the turbulent baseline N. Each segment P lies above N at a distance roughly proportional to its concentration, as shown by the observation that at $Re_s\sqrt{f} \approx 3000$, S' = 6.6 and 14.8 and S'/c = 0.66 and 0.49, respectively. The 30-wppm data exhibit retro-onset, from M to P, at $Re_s\sqrt{f}^{\#} \approx 1500$. The two segments P for c = 10 and 30 wppm and the MDR asymptote followed by the 100-wppm data form a Type-B ladder structure, typical of the drag-reduction behavior of extended macromolecules in solution.

Figure 5.2.13 serves to contrast the flow behaviors induced by solutions of initially collapsed and initially extended macromolecules. In laminar flow, the former,

which are less viscous and Newtonian, enhance drag relative to solvent less than the latter, which are more viscous and shear-thinning. In turbulent flow, whereas a Type-A fan, characteristic of initially collapsed macromolecules, comprises segments P that radiate upward from their closely-clustered onset points on the turbulent baseline N into the polymeric regime, a Type-B ladder, characteristic of initially extended macromolecules, comprises segments P that extend rightward from the widely spaced retro-onset points on the MDR asymptote into the polymeric regime above N. Figure 5.2.13 clearly shows that, for fixed concentration, Type-B drag reduction always exceeds Type-A drag reduction, with the latter asymptotically approaching the former as $Re_s\sqrt{f}$ is increased. These statements are illustrated by examples. At fixed c = 10 wppm, for $300 < Re_s\sqrt{f} < 400$, the solution of initially extended macromolecules exhibits $S' \approx 3$, enhancing flow infinitely better than the solution of initially collapsed macromolecules because the latter, having yet to onset, exhibits Newtonian turbulent behavior with S' = 0. At fixed c = 30 wppm and $Re_s\sqrt{f} \approx 460$, the solution of initially extended macromolecules exhibits $S' \approx 6$ and is a much better flow enhancer than the solution of initially collapsed macromolecules, which has barely reached its onset point, $S' \approx 0$. Interestingly, for fixed c = 100 wppm, for $300 < Re_s\sqrt{f} < 460$, the solution of initially extended macromolecules is in laminar flow and, thus, drag enhancing, $S' < 0$, whereas solution of initially collapsed macromolecules is slightly flow enhancing, $S' \approx 1$. For fixed c = 10, 30, and 100 wppm, at higher $Re_s\sqrt{f}$ = 1000 and 3000, the results follow: At $Re_s\sqrt{f}$ = 1000, the apparent slips are S'_A = (1.1, 4.2, and 9.3) and S'_B = (4.6, 10.4, and 9.0) with the ratio S'_A/S'_B = (0.23, 0.41, and 1.0), respectively; at $Re_s\sqrt{f}$ = 3000, S'_A = (4.8, 10.8, and 19.4), S'_B = (6.6, 14.8, and 19.7), and S'_A/S'_B = (0.72,

0.73, and 0.98). For c = 10 and 30 wppm, the results show that always $S'_A < S'_B$, and that the ratio S'_A/S'_B increases toward unity with increasing $Re_s\sqrt{f}$. For c = 100 wppm, the ratios S'_A/S'_B are about unity because both initial conformations trace the same path for $Re_s\sqrt{f} > 500$, and both are close to the MDR asymptote at $Re_s\sqrt{f} = 1000$ and 3000.

The effect of pipe diameter on both Types A and B of drag reduction by the collapsed and extended conformations of additive P500 can be inferred by comparisons between Figure 5.2.12, in the 1.458-cm pipe, and Figure 5.2.13, in the 1.021-cm pipe. Direct superposition of figures, as drawn, with identical $1/\sqrt{f}$ vs. $Re_s\sqrt{f}$ coordinates, causes all the polymeric-regime data in the 1.021-cm pipe to lie systematically somewhat higher than the corresponding data in the 1.458-cm pipe. But, if the 1.021-cm-pipe data are translated rightward along the Newtonian line N by an abscissa factor of 1.458/1.021, the pipe-diameter ratio, then all of the polymeric-regime data are simultaneously superimposed upon the corresponding data in the 1.458-cm pipe. This remarkable coincidence of the entire Type-A fan and Type-B ladder structures in both pipes strongly suggests that, in the polymeric regime, both types of drag reduction are independent of pipe diameter and are scaled only by the wall shear stress. Theoretically, this result implies that drag reduction in the polymeric regime is relatively unaffected by the large scales of turbulence, imposed by the pipe diameter, and is controlled by the finer "wall" scales related to the wall shear stress. It is further noteworthy that the aforementioned superposition of polymeric regimes in both pipes also succeeds in superposing the degradation-induced maxima and declines observed in the many trajectories at the highest $Re_s\sqrt{f}$. Thus the wall shear stress is also important in scaling polymer degradation during drag reduction.

Figures 5.2.14 and 5.2.15 present results, from pump driven-system using the 1.458-cm pipe, for additive A507 in the collapsed conformation, in 0.3 N NaCl, and in the expanded conformation, in 0.0001 N NaCl, at c = 30, 100, 300, and 1000 wppm. The Newtonian laminar and turbulent baselines and the MDR asymptote are represented by the lines L, N, and M, respectively, in both figures.

In Figure 5.2.14, for the collapsed conformation of additive A507, the data for c = 30, 100, 300, and 1000 wppm follow laminar paths either on or to the right of L with respective Newtonian $\eta_r \approx$ 1.0, 1.0, 1.1, and, 1.4 for $40 < Re_s\sqrt{f} < 150$. For $180 < Re_s\sqrt{f} < 400$, all data depart from their laminar paths and drop downward onto N in laminar-to-turbulent transitions. All data continue along N, onset respectively at $Re_s\sqrt{f^*} \approx$ 1520, 1540, 1520, and 1540, and then rise into the polymeric regime along respective linear segments P with slopes and intercepts (A_p, B_p) = (4.4, 1.8), (5.3, 4.6), (7.0, 9.9), and (9.3, 17.0) and slope increments δ = 0.4, 1.3, 3.0, and 5.3.

These data all exhibit LNP trajectories. The laminar-flow data trace paths adjacent to L with small relative viscosities and curvatures identical to that of L, as is typical behavior of solutions of random-coiling macromolecules. In turbulent flow, the long segments N, without drag reduction, and the relatively high onsets at $Re_s\sqrt{f^*} \approx$ 1530 indicate that high stresses are required to perturb the non-flow-enhancing coiled conformation, implying that the additives are either short or very tightly coiled. The segments P for all c = 30, 100, 300, and 1000 wppm radiate from a single onset point at $Re_s\sqrt{f} \approx$ 1530 on the Newtonian turbulent baseline N, with small slope increments that nevertheless increase with increasing concentration, forming a Type-A fan structure typical of drag reduction by solutions of random-coiling macromolecules.

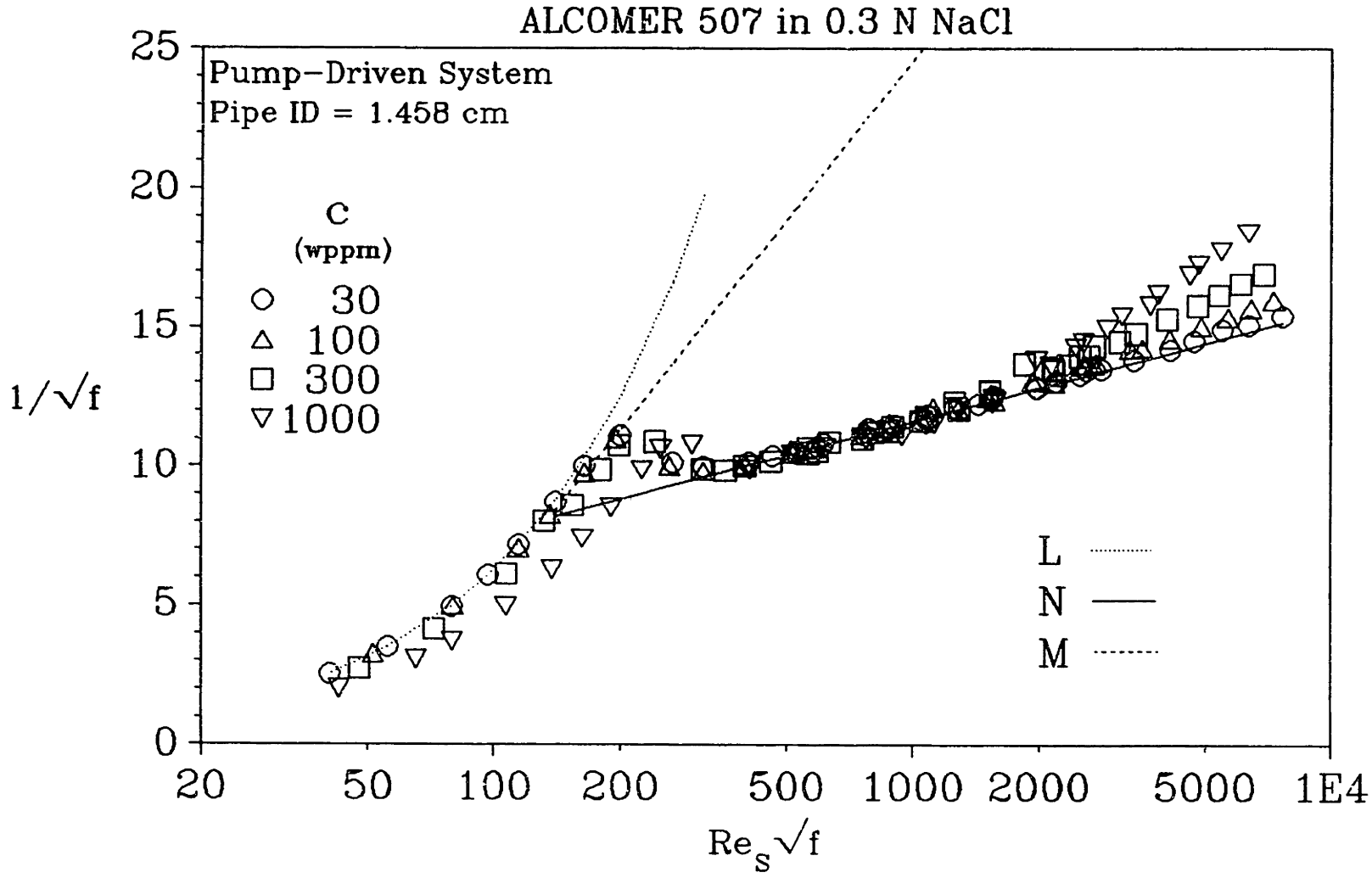


Figure 5.2.14: ALCOMER 507 in 0.3 N NaCl from the 1.458-cm Pipe

Figure 5.2.15 shows results for the expanded conformation of additive A507. The 30-wppm data parallel L for $40 < Re_s\sqrt{f} < 170$ to the right with a Newtonian $\eta_r \approx 1.2$. For $200 < Re_s\sqrt{f} < 400$, they undergo a laminar-to-turbulent transition, departing their laminar path and dropping onto N, to which they adhere for $400 < Re_s\sqrt{f} < 1100$. The data then onset at $Re_s\sqrt{f}^* \approx 1500$ and rise shallowly into the polymeric region above N along a linear segment P with slope and intercept $(A_p, B_p) = (4.3, 0.9)$ and slope increment $\delta = 0.3$ up to $Re_s\sqrt{f} \approx 7200$. The 100-wppm and 300-wppm data follow roughly the same laminar path for $70 < Re_s\sqrt{f} < 550$ far to the right of L with respective, essentially Newtonian, $\eta_r \approx 4.0$ and 4.3, both greatly drag enhancing relative to solvent. Both sets of data show similar laminar-to-turbulent transitions, $600 < Re_s\sqrt{f} < 900$, that end on N. After briefly following N, the 100-wppm and 300-wppm data onset at $Re_s\sqrt{f}^* \approx 1200$ and then ascend into the polymeric regime along respective linear segments P with $(A_p, B_p) = (5.6, 4.6)$ and $(9.0, 15.9)$ and $\delta = 1.6$ and 5.0 up to $Re_s\sqrt{f} \approx 6200$ and 6900. The 1000-wppm data trace a laminar path for $100 < Re_s\sqrt{f} < 1100$, farthest right of L, with essentially Newtonian $\eta_r \approx 7.8$; they exhibit the greatest drag enhancement relative to solvent, lying ~56 units of $1/\sqrt{f}$ below L at $Re_s\sqrt{f} \approx 1100$. For $1200 < Re_s\sqrt{f} < 1600$, the data seem to undergo laminar-to-turbulent transition, in which the data drop slightly beneath N by ~½ $1/\sqrt{f}$ unit, but then ascend immediately into the polymeric regime along a linear segment P with $(A_p, B_p) = (16.5, 42.4)$ and $\delta = 12.5$ up to $Re_s\sqrt{f} \approx 6000$. The 1000-wppm data appear to onset at $Re_s\sqrt{f}^* \approx 2000$.

In Figure 5.2.15, data for c = 30, 100, and 300 wppm display LNP trajectories similar to those in Figure 5.2.14; the 1000-wppm data display an L(N)P trajectory,

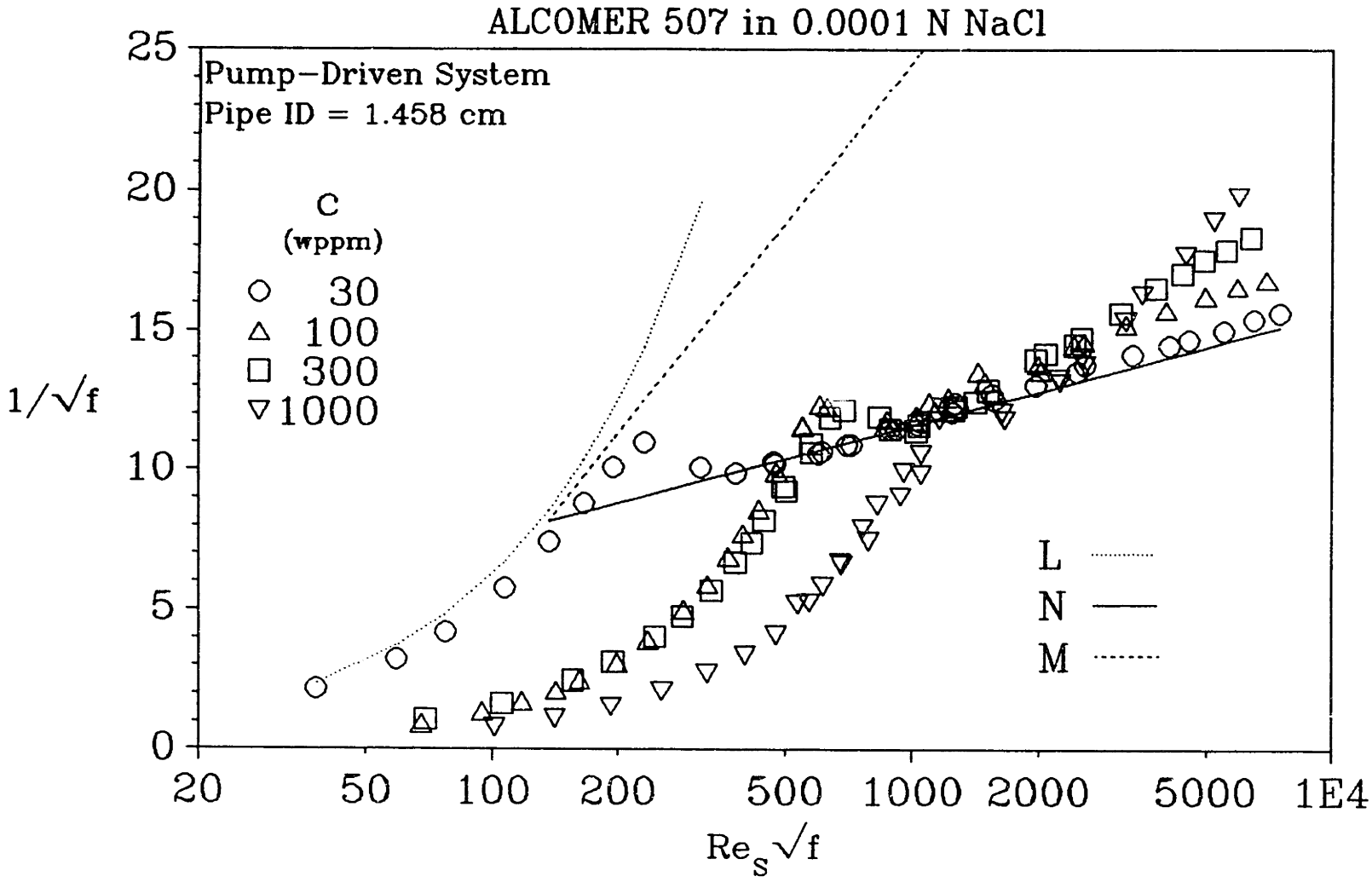


Figure 5.2.15: ALCOMER 507 in 0.0001 N NaCl from the 1.458-cm Pipe

lacking a clearly-defined segment N. The laminar-flow data exhibit only slightly shear thinning, but their relative viscosities, and concomitant drag enhancements, are large and increase as concentration increases. In turbulent flow, the solutions at c = 20, 100, and 300 wppm all exhibit N segments, without flow enhancement before onset in the vicinity of $Re_s\sqrt{f} \approx 1200$; the 1000-wppm solution does not clearly follow N between transition and onset. After onset, the segments P have respective slope increments δ = 0.3, 1.6, 5.0, and 11.6 that increase with increasing concentration. The segments P form a less-than-perfect Type-A fan, that radiates from an onset region at $Re_s\sqrt{f^*} \approx 1200$ on the turbulent baseline N.

When juxtaposed, Figures 5.2.14 and 5.2.15 show interesting behavior by additive A507. All solutions exhibit LNP trajectories with normal Newtonian laminar-to-turbulent transitions. In laminar flow, the conformation of the polyelectrolytic additive is clearly influenced by salinity, the data in 0.3 N NaCl showing low relative viscosities and lying very close to L whereas the data in 0.0001 N NaCl exhibit much higher relative viscosities and lie much farther to the right of L. For example, the 1000-wppm solution possesses a relative viscosity $\eta_r \approx 1.4$ at high salinity, whereas at low salinity, $\eta_r \approx 7.8$. Yet, unlike previous additives C832A, B1120, and P500, the high relative viscosities exhibited by A507 solutions at low salinity are not acconmpanied by significant shear thinning, which suggests that the expanded conformation has no tendency to orient, remaining approximately spherical.

In turbulent flow, the data at both salinities, for both collapsed and expanded conformations, exhibit similar Type-A fans, with respective average onset $Re_s\sqrt{f^*} \approx$ 1530 and 1200, and respective slope increments δ = (0.4, 1.3, 3.0, and 5.3) and (0.3,

1.6, 5.0, 11.6) for c = 30, 100, 300, and 1000 wppm. Thus, in turbulent flow, the additive behaves as though it were initially random-coiling at both salinities, with a somewhat larger coil-size at the lower salinity.

Evidently, both laminar and turbulent results with A507 suggest that the macromolecule retains a random-coiling conformation in 0.3 N and 0.0001 N NaCl, despite the coil expansion at lower salinity.

Figures 5.2.16 and 5.2.17 show results for additive D1438 in 0.3 N and 0.0001 N NaCl, corresponding to its collapsed and expanded conformations, respectively, at c = 30, 100, 300, and 997 wppm, using the pump-driven system with the 1.458-cm pipe. In both figures, lines L, N, and M respectively represent the Newtonian laminar and turbulent baselines and the MDR asymptote.

Figure 5.2.16 presents results for additive D1438 in 0.3 N NaCl. For $40 < Re_s\sqrt{f} < 150$, all data for c = 30, 100, 300, and 997 wppm trace laminar paths either on or slightly to the right of L with Newtonian $\eta_r \approx 1.00$, 1.05, 1.12, and 1.45, respectively. For $180 < Re_s\sqrt{f} < 400$, these data depart from their laminar paths and drop onto N, undergoing laminar-to-turbulent transitions; for $Re_s\sqrt{f} > 400$, all solutions continue along N until they onset respectively at $Re_s\sqrt{f^*} \approx 2000$, 1450, 1200, and 1450, and rise into the polymeric regime along respective linear segments P with slopes and intercepts (A_p, B_p) = (5.4, 4.9), (6.4, 7.9), (8.8, 15.3), and (15.4, 36.4) and slope increments δ = 1.4, 2.4, 4.8, and 11.4 up to $Re_s\sqrt{f} \approx 5300$, 6100, 6500, and 7200.

All solutions display LNP trajectories. Relative viscosities in laminar flow are small, $\eta_r < 1.5$, with Newtonian behavior. The observed laminar-to-turbulent transitions are all akin to those seen in normal Newtonian flows. In turbulent flow with drag

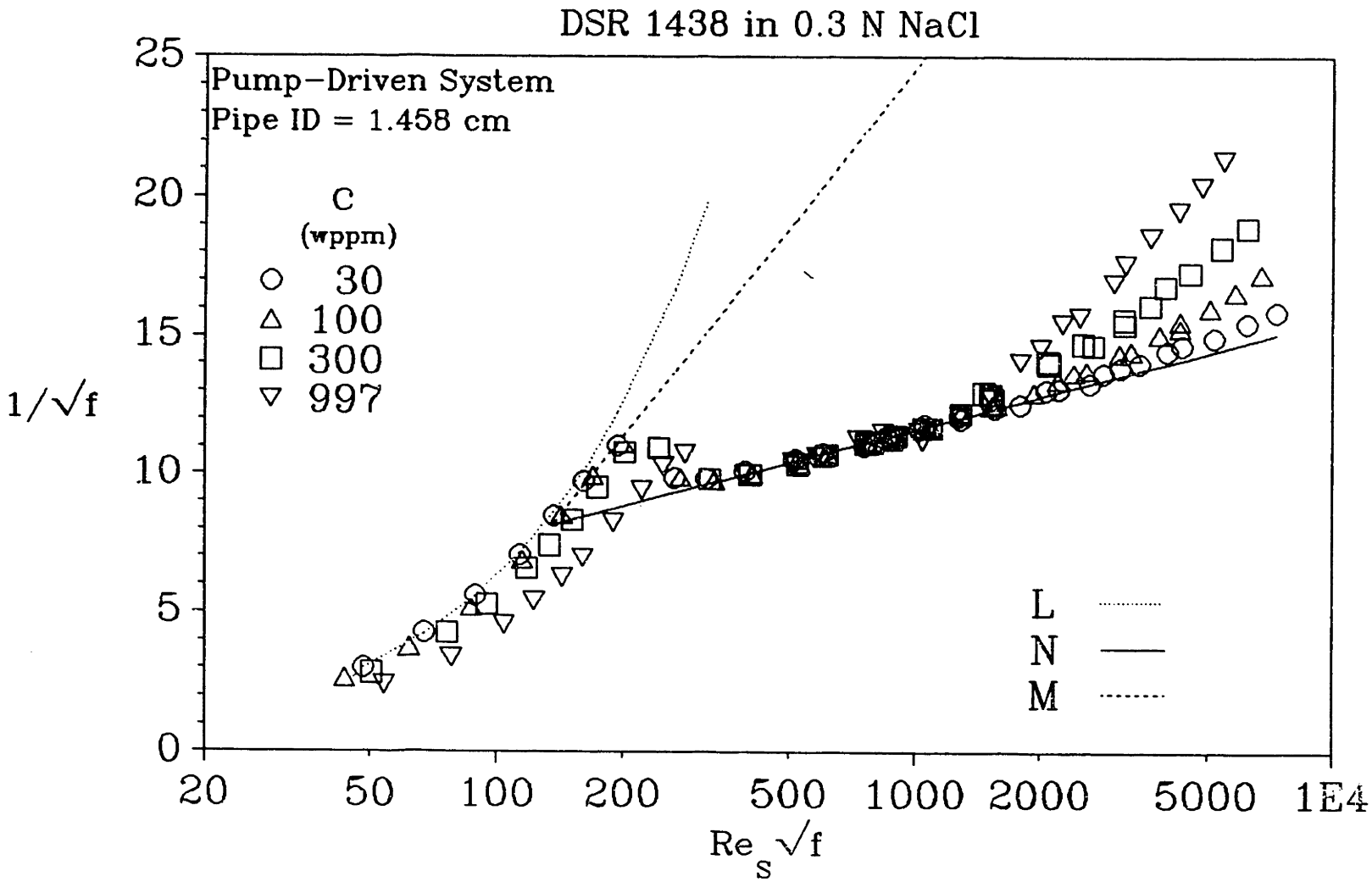


Figure 5.2.16: DSR 1438 in 0.3 N NaCl from the 1.458-cm Pipe

reduction, the segments P for c = 30, 100, 300, and 997 wppm rise from onset points in the vicinity of $Re_s\sqrt{f}^* \approx 1500$ on the Newtonian turbulent baseline N, with increasing respective slopes increments δ = 1.4, 2.4, 4.8, and 11.4. The segments P constitute a "Type-A fan" typical of drag reduction by initially random-coiling macromolecules in solution.

Figure 5.2.17 presents results for additive D1438 in the expanded conformation, in 0.0001 N NaCl. The 30-wppm data follow just to the right of L for $40 < Re_s\sqrt{f} < 150$ with $\eta_r \approx 1.08$, showing slight drag enhancement relative to solvent, and for $180 < Re_s\sqrt{f} < 380$, then undergo a laminar-to-turbulent transition, departing L and dropping onto N. Adhering to N for $400 < Re_s\sqrt{f} < 1200$, the 30-wppm data onset at $Re_s\sqrt{f}^* \approx 1250$ and ascend into the polymeric regime along a linear segment P with slope and intercept $(A_p, B_p) = (5.7, 5.8)$ and slope increment $\delta = 1.7$ up to $Re_s\sqrt{f} \approx 5100$. The 100-wppm data trace a laminar path for $45 < Re_s\sqrt{f} < 270$ rightward from L with $\eta_r \approx 1.8$ and for $300 < Re_s\sqrt{f} < 580$, depart their laminar path and drop onto N, in a laminar-to-turbulent transition. These data then follow along N for $600 < Re_s\sqrt{f} < 950$, onset at $Re_s\sqrt{f}^* \approx 1000$, and rise into the polymeric regime along a linear segment P with $(A_p, B_p) = (8.1, 12.7)$ and $\delta = 4.1$ up to $Re_s\sqrt{f} \approx 5600$. The 300-wppm data follow a laminar path for $60 < Re_s\sqrt{f} < 540$ to the right of L with Newtonian $\eta_r \approx 3.4$, enhancing drag greatly relative to solvent; they abruptly undergo a laminar-to-turbulent transition for $620 < Re_s\sqrt{f} < 890$, alighting onto N. The 300-wppm data continue along N for $900 < Re_s\sqrt{f} < 1300$, onset at $Re_s\sqrt{f}^* \approx 1350$, and rise into the polymeric regime along a linear segment P with $(A_p, B_p) = (13.3, 29.4)$ and $\delta = 9.3$ up to $Re_s\sqrt{f} \approx 6200$. The 997-wppm data trace the most drag-enhancing laminar path, farthest to the right of

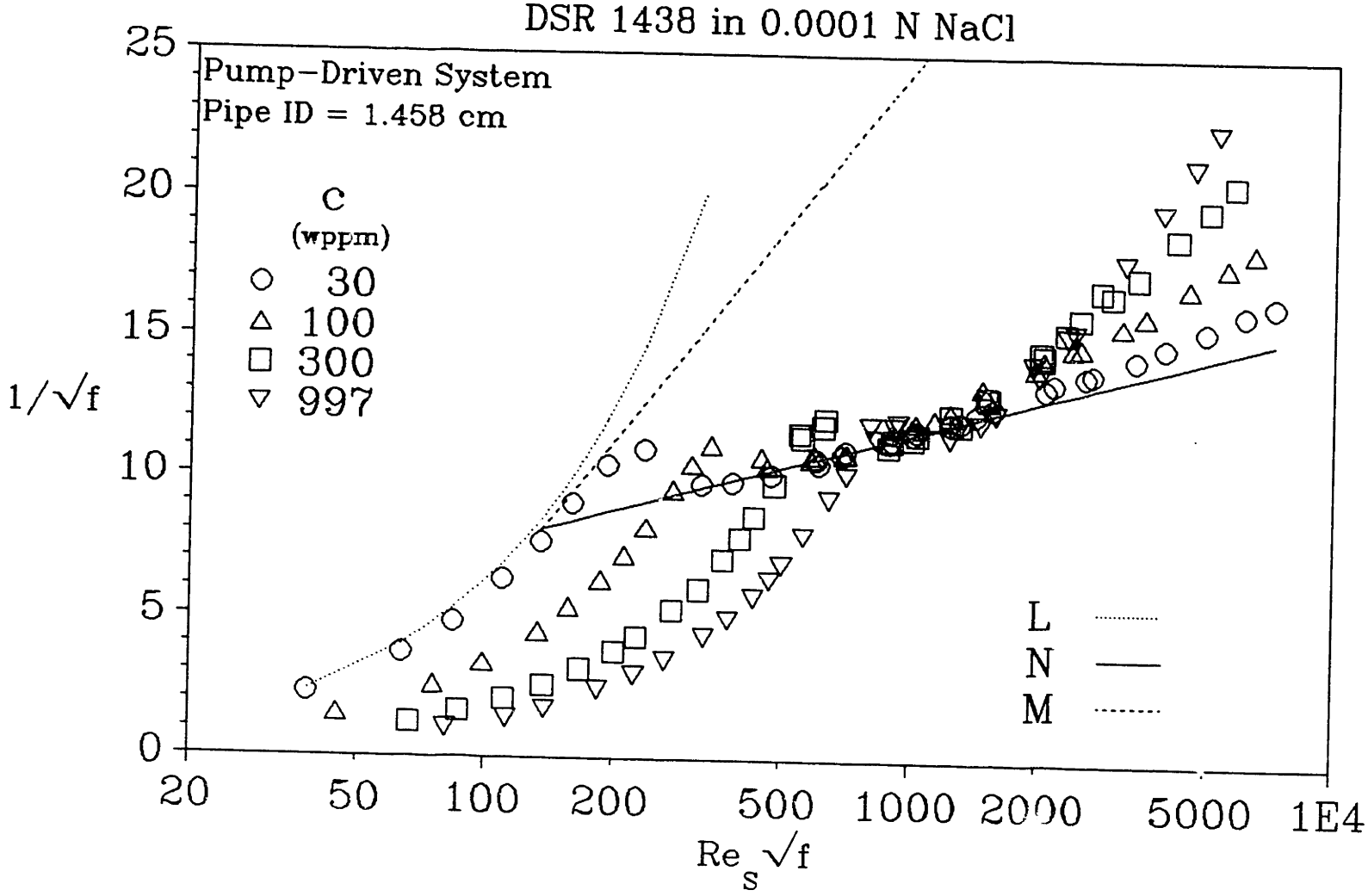


Figure 5.2.17: DSR 1438 in 0.0001 N NaCl from the 1.458-cm Pipe

L, for $80 < Re_s\sqrt{f} < 800$ with Newtonian $\eta_r \approx 5.0$. These data undergo a laminar-to-turbulent transition for $900 < Re_s\sqrt{f} < 1200$, after which they alight onto N; they continue along N for $1300 < Re_s\sqrt{f} < 1700$, onset at $Re_s\sqrt{f}^* \approx 1800$, and then rise into the polymeric regime along a linear segment P with $(A_p, B_p) = (20.8, 55.1)$ and $\delta = 16.8$ up to $Re_s\sqrt{f} \approx 7000$.

In Figure 5.2.17, data for c = 30, 100, 300, and 997 wppm all display LNP trajectories. In laminar flow, the relative viscosities and concomitant drag enhancements relative to solvent increase greatly as concentration increases, but the behavior remains Newtonian with no shear thinning. The observed laminar-to-turbulent transitions are all Newtonian in nature. In turbulent flow, all solutions possess N segments, without drag reduction. For three solutions, c = 30, 100, and 300 wppm, onsets occur in a narrow band, $Re_s\sqrt{f}^* \approx 1200$, but the 997-wppm solution, with the highest viscosity, onsets at $Re_s\sqrt{f}^* \approx 1800$. Beyond onset, the segments P have slope increments that increase with increasing concentration: $\delta = 1.7, 4.1, 9.3$, and 16.8, respectively. The segments P form an imperfect Type-A fan, that radiates from onsets at $Re_s\sqrt{f}^* \approx 1200$ on the Newtonian turbulent baseline N. This "Type-A-fan" behavior, typical of drag reduction by initially random-coiling macromolecules in solution, suggests that even the expanded conformation of additive D1438 still retains its random-coiling character.

Figures 5.2.16 and 5.2.17 together illustrate the effect of salinity-induced changes in the flow behavior of additive D1438. In laminar flow, data in 0.3 N NaCl, with the collapsed conformation, show Newtonian behavior with small relative viscosities near unity, whereas data in 0.0001 N NaCl, with the expanded conformation, display much larger relative viscosities, but continue to show Newtonian behavior. For example, the

997-wppm solution has a relative viscosity $\eta_r \approx 1.4$ in 0.3 N NaCl and a much larger relative viscosity $\eta_r \approx 5.0$ in 0.0001 N NaCl, but exhibits Newtonian behavior, without shear thinning in both cases. Thus, reduction in salinity from 0.3 N to 0.0001 N NaCl increases the size of the macromolecular coils but do not distort their shape enough to allow significant orientation.

At both salinities, both solutions of D1438 display normal Newtonian laminar-to-turbulent transitions. In turbulent flow, Type-A fans are exhibited at both high and low salinities, with somewhat different respective onsets at $Re_x\sqrt{f} \approx 1500$ and 1200, and respective slope increments δ = (1.4, 2.4, 4.8, and 11.4) and (1.7, 4.1, 9.3, 16.8). At a fixed $Re_x\sqrt{f} \approx 3000$, the fan at low salinity shows slightly more flow enhancement than that at high salinity. The turbulent-flow data suggest that at both high and low salinities, the conformation of D1438 macrmolecules retain random-coiling character, despite changes in coil size.

It is seen that salinity-induced conformational changes have similar effects on the turbulent-flow drag-reduction behavior of additives A507 and D1438. For both additives, the expanded conformations at low salinity exhibit Type-A fans with slightly lower onset and higher slope increments that the similar Type-A fans shown by the collapsed conformations at high salinity. This effect of salinity on additives A507 and D1438 contrasts with that of additives C832A, B1120, and P500, all latter of which exhibit Type-A fans at high salinity and Type-B ladders at low salinity.

5.2.4 Comparative Descriptions for Similar Additives of Varying Backbone Charge

Additives C837A, C836A, and C832A — HPAMs of approximately equal, nominal, molecular weights, $M_w \approx (15\text{-}18)\times 10^6$ g/mole — possess increasing degrees of hydrolysis ~ 8, ~ 16, and ~ 40 percent, respectively. Their drag-reduction results at salinities of 0.1, 0.001, and 0.0003 N NaCl in the 1.458-cm pipe from the gravity-driven system show the influence of backbone charge on polyelectrolytes with approximately equal backbone lengths. Figures 5.2.18 - 27 present these data and are ordered by decreasing salinity overall, corresponding to increasing coil expansions, and by increasing backbone charge at each salinity. The following descriptions focus on turbulent-flow aspects; all relevant laminar- and turbulent-flow parameters have been derived and are given in Tables 5.2.1 - 5.2.3.

Figures 5.2.18 - 5.2.20 respectively show results for the most-collapsed conformations, in 0.1 N NaCl, of additives C837A, C836A, C832A at $1 \leq c \leq 50$ wppm. Each polymer exhibits a Type-A drag-reduction fan that radiates from an onset point near $Re_s\sqrt{f^*} \approx 600$. For typical $c \approx 10$ and 20 wppm, all additives possess P segments with similar slope increments, $\delta \approx 8.5$ and 16, that attain flow enhancements of roughly the same magnitudes, $S'_1 \approx 0.7$ and 2.5, respectively. Thus, all the polymers show almost quantitatively-identical Type-A drag-reduction behavior, constituting a single fan that presumably is characteristic of the fully-collapsed, random-coiling conformation of their common backbone.

Figures 5.2.21 - 5.2.23 respectively show results for the three polymers in 0.001 N NaCl, at which salinity their conformations are all appreciably larger. Each polymer

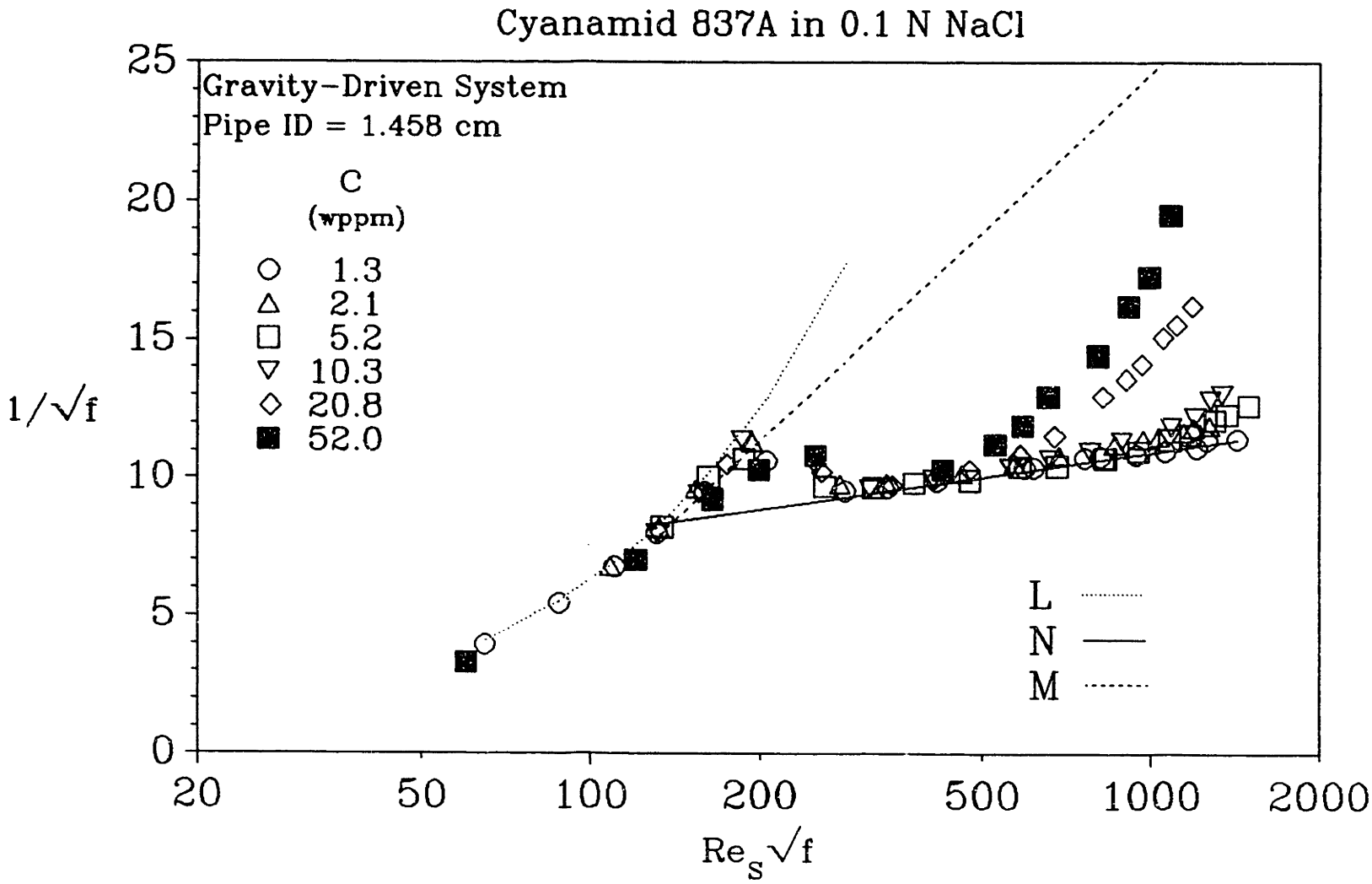


Figure 5.2.18: Cyanamid 837A in 0.1 N NaCl from the 1.458-cm Pipe

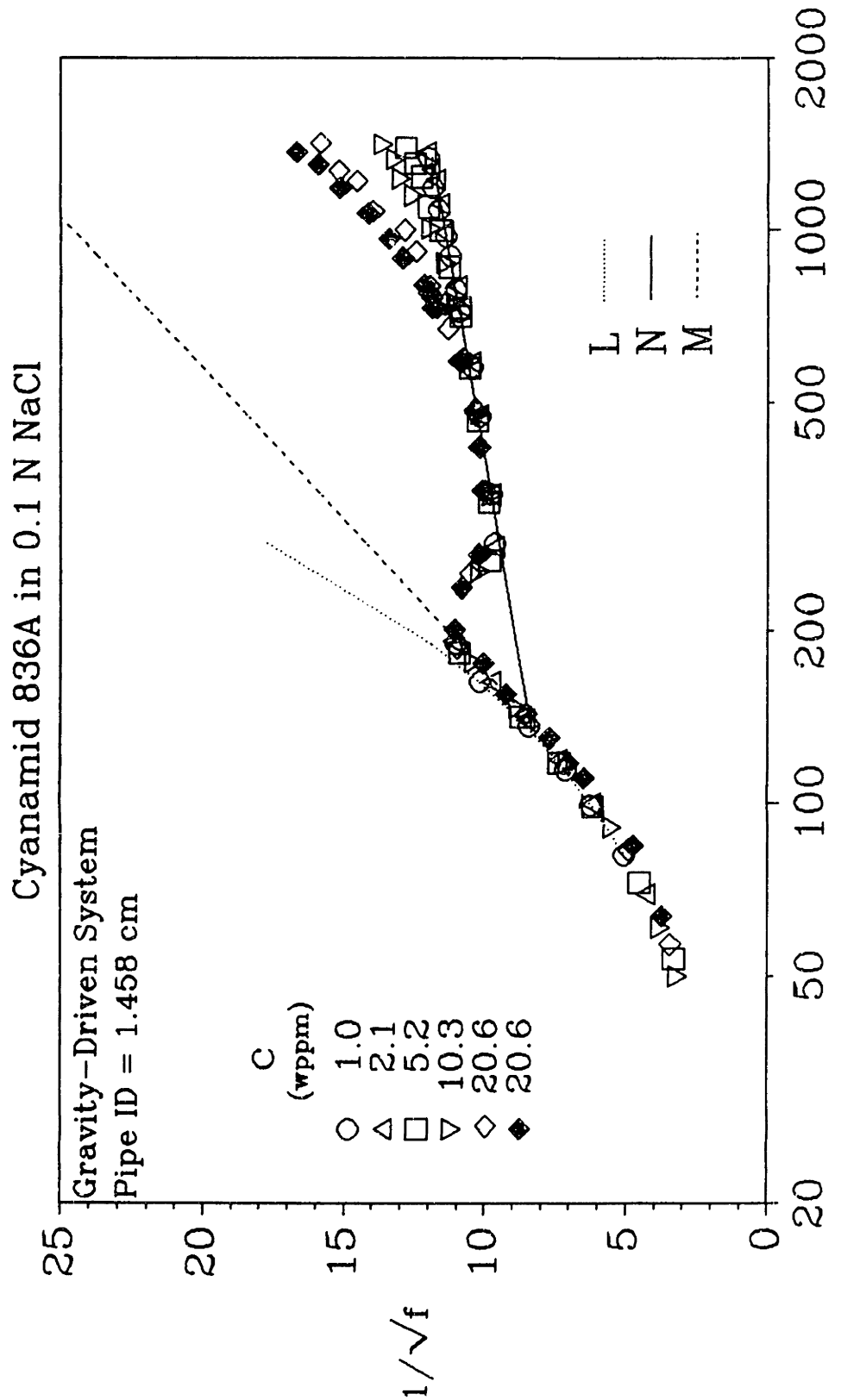


Figure 5.2.19: Cyanamid 836A in 0.1 N NaCl from the 1.458-cm Pipe

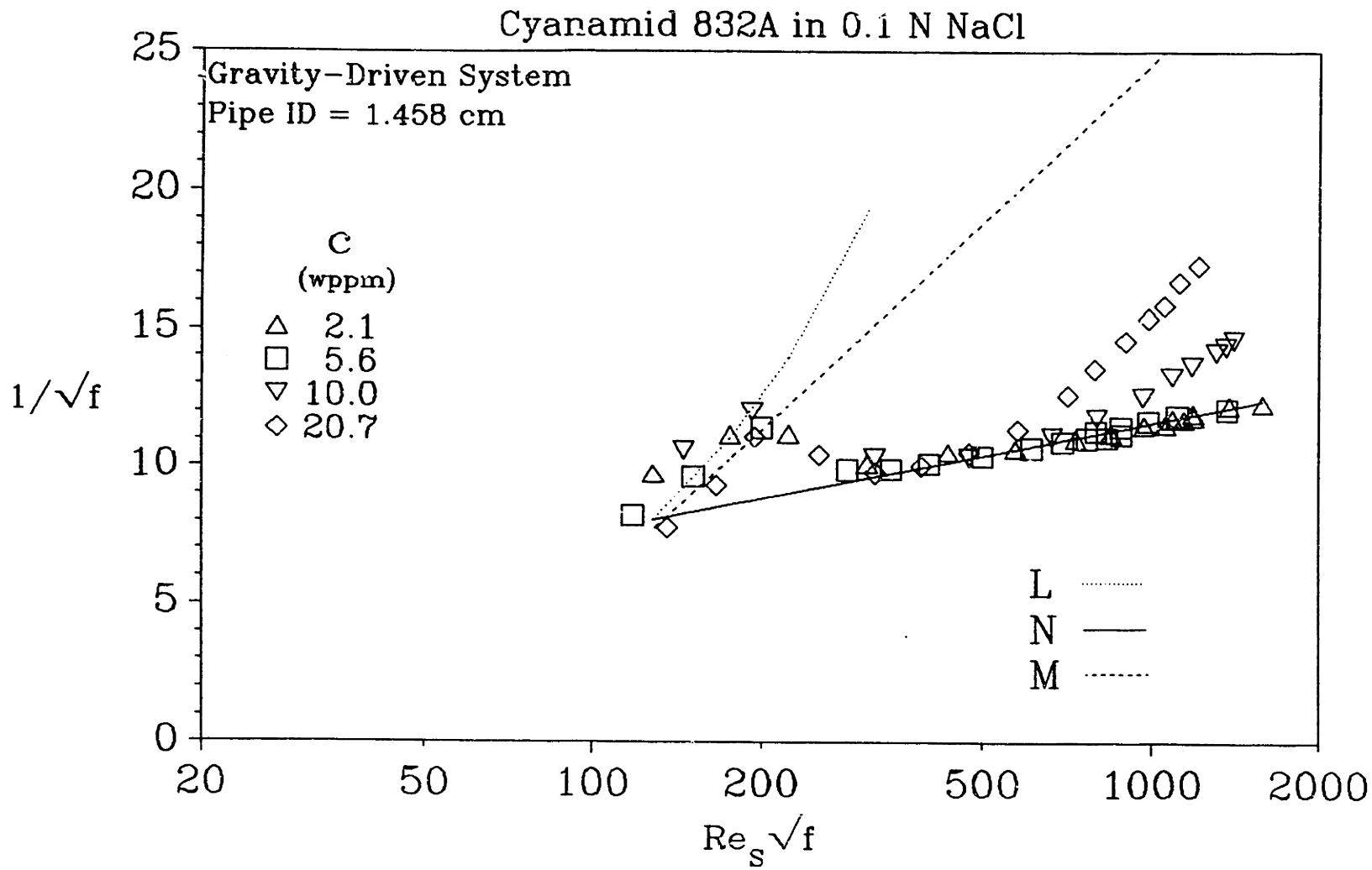


Figure 5.2.20: Cyanamid 832A in 0.1 N NaCl from the 1.458-cm Pipe

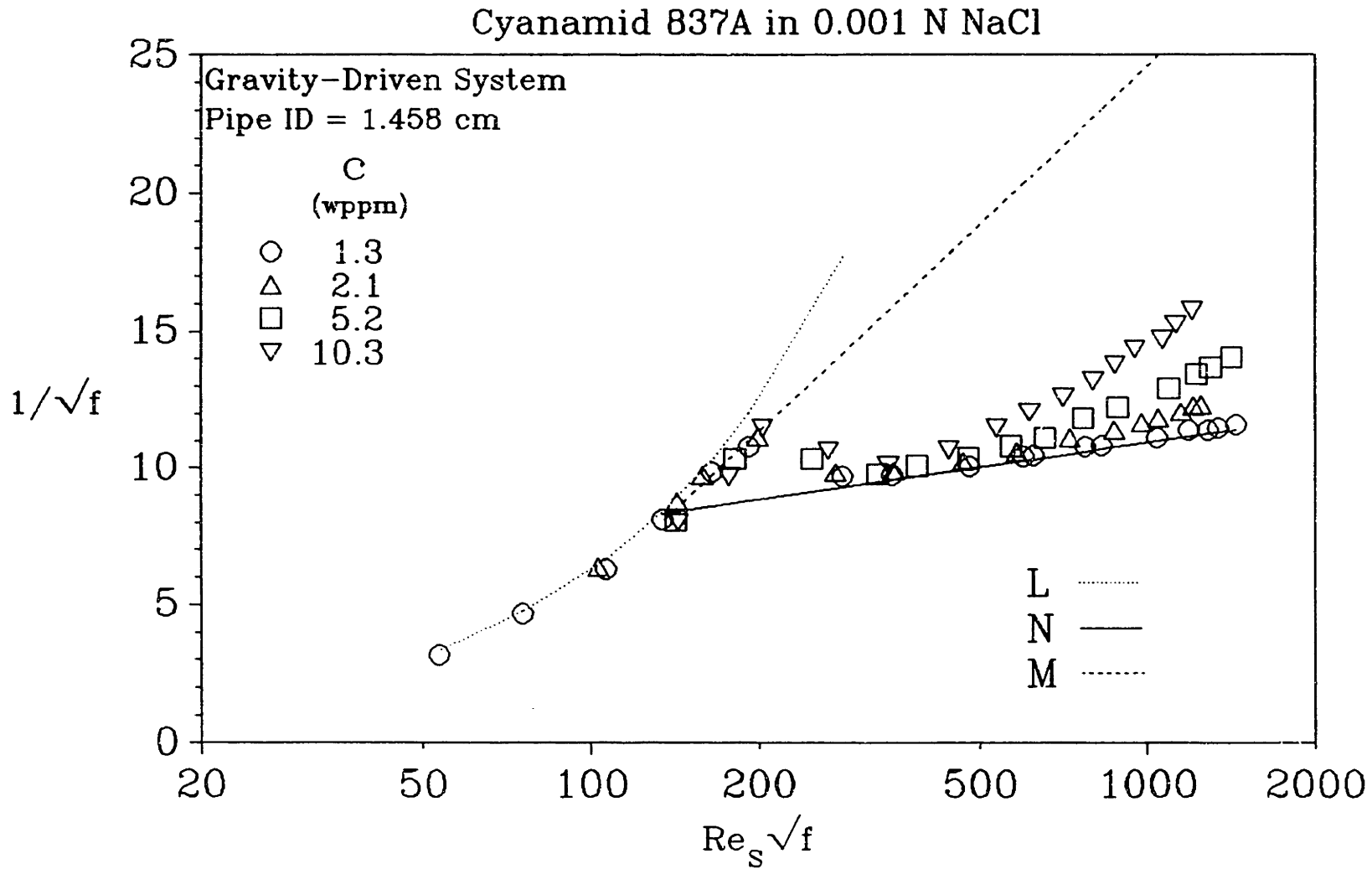


Figure 5.2.21: Cyanamid 837A in 0.001 N NaCl from the 1.458-cm Pipe

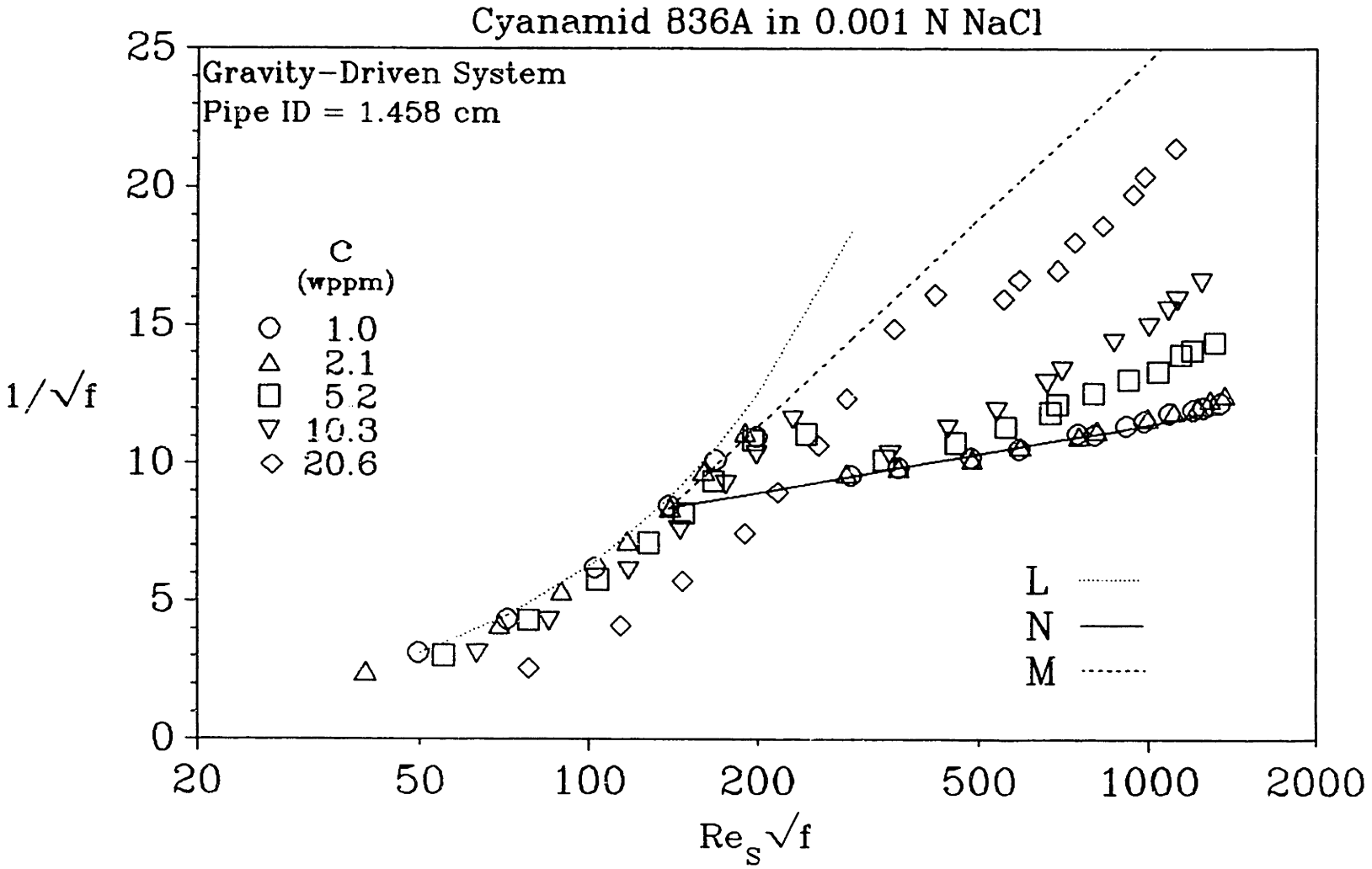


Figure 5.2.22: Cyanamid 836A in 0.001 N NaCl from the 1.458-cm Pipe

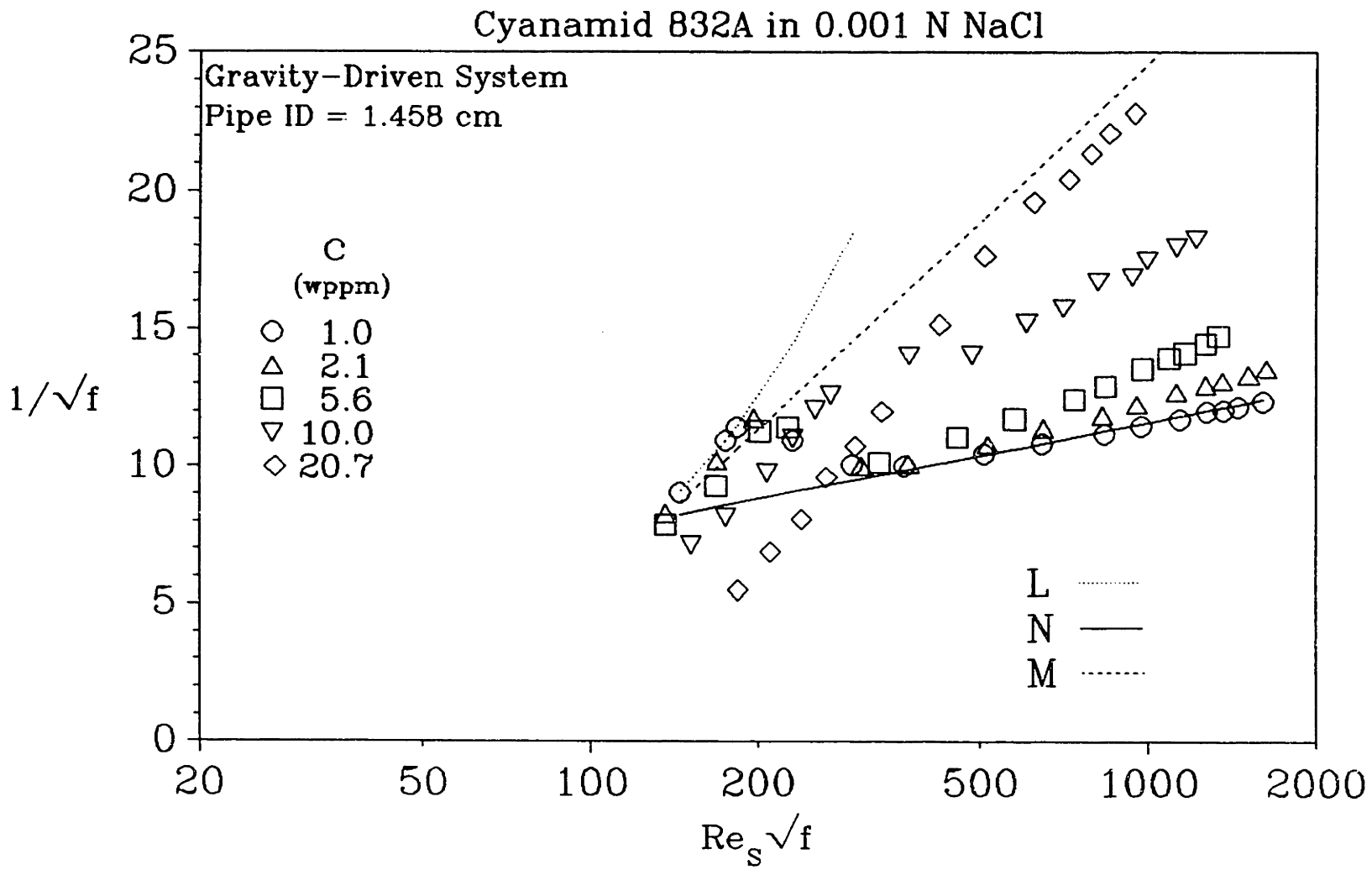


Figure 5.2.23: Cyanamid 832A in 0.001 N NaCl from the 1.458-cm Pipe

here differs from the other two in its drag-reduction behavior, and all three differ from their common collapsed fan obtained in 0.1 N NaCl. Additive C837A, with the lowest backbone charge, shows almost the same Type-A fan, which here is translated to lower $Re_s\sqrt{f}$ relative to the common collapsed fan, with onset at $Re_s\sqrt{f}^* \approx 400$. For $c \approx 10$ wppm, the P segment has roughly the same slope increment as in the collapsed fan, $\delta \approx 8$, but here achieves appreciably greater flow enhancement, $S'_1 \approx 3$, on account of its earlier onset. Next, additive C836A also continues to exhibit a Type-A fan, trnaslated to lower $Re_s\sqrt{f}$ relative to both the common collapsed fan and the preceding C837A fan, with onset at $Re_s\sqrt{f}^* \approx 300$, near the lower limit of fully turbulent flow. For $c \approx 10$ and 20 wppm, the P segments retain approximately the same slope increments as in the collapsed fan, $\delta \approx 9$ and 14, but here attain appreciably greater respective flow enhancements, $S'_1 \approx 4$ and 9, on account of their earlier onsets. Finally, additive C832A, with the highest backbone charge, displays a distorted Type-A fan structure that tends toward, but short of, a Type-B ladder structure. Onsets are visible only at the lowest $c \approx 2$ and 5 wppm, near the lowest turbulent $Re_s\sqrt{f}$. The 10-wppm solution traces an LP trajectory, with a P-segment slope increment $\delta \approx 6.5$, somewhat lower than that in the collapsed fan, whereas the 20-wppm solution follows an LM trajectory, attaining maximum drag reduction; their respective flow enhancements, $S'_1 \approx 5.9$ and 11.3, greatly exceed those observed at $c \approx 10$ and 20 wppm in the common collapsed fan.

Evidently, at this salinity of 0.001 N NaCl, drag reduction by the three polymers depends upon their backbone charges. Most directly, the flow enhancement induced by a fixed concentration increases with increasing backone charge. In terms of drag-reduction behavior, the additive with the least-charged backbone, C837A, continues to

exhibit a Type-A fan, translated to lower $Re_s\sqrt{f}$ relative to the common collapsed fan; this implies that C837A retains an initially random-coiling conformation that is more expanded than the collapsed conformation. The additive with the next-higher backbone charge, C836A, also continues to exhibit a Type-A fan, translated to lower $Re_s\sqrt{f}$ relative to both the collapsed and C837A fans, again implying an initially random-coiling conformation with a coil size larger than those for both its collapsed conformation and the C837A expanded conformation. Note that in the two Type-A fans exhibited by these expanded conformations of C837A and C836A, the P-segment slope increments at each concentration are essentially the same as those in the common collapsed fan. Finally, the additive with the highest backbone charge, C832A, exhibits a distorted Type-A fan that possesses some Type-B ladder structure, suggesting that its conformation is expanded enough to render it non-random-coiling.

Figures 5.2.24 - 5.2.26 show results for all three polymers in 0.0003 N NaCl, the lowest common salinity, which allowing the most-expanded initial conformations. Additive C837A still exhibits a Type-A fan, translated to lower $Re_s\sqrt{f}$ relative to both the common collapsed fan and the C837A fan in 0.001 N NaCl, with onset in the transitional region at $Re_s\sqrt{f^*} \approx 250$, such that several solutions display either LP or LM trajectories. For $c \approx 10$ and 20 wppm, their respective P segments retain approximately the same slope increments, $\delta \approx 9$ and 16, as in the collapsed fan and the C837A fan in 0.001 N NaCl, but attain appreciably greater flow enhancement, $S'_1 \approx 4$ and 9. Interestingly, this fan for C837A in 0.0003 N NaCl is quantitatively similar to the fan for C836A, with a more highly charged backbone, at the higher salinity of 0.001 N NaCl. Next, additive C836A also continues to exhibit Type-A behavior, translated to

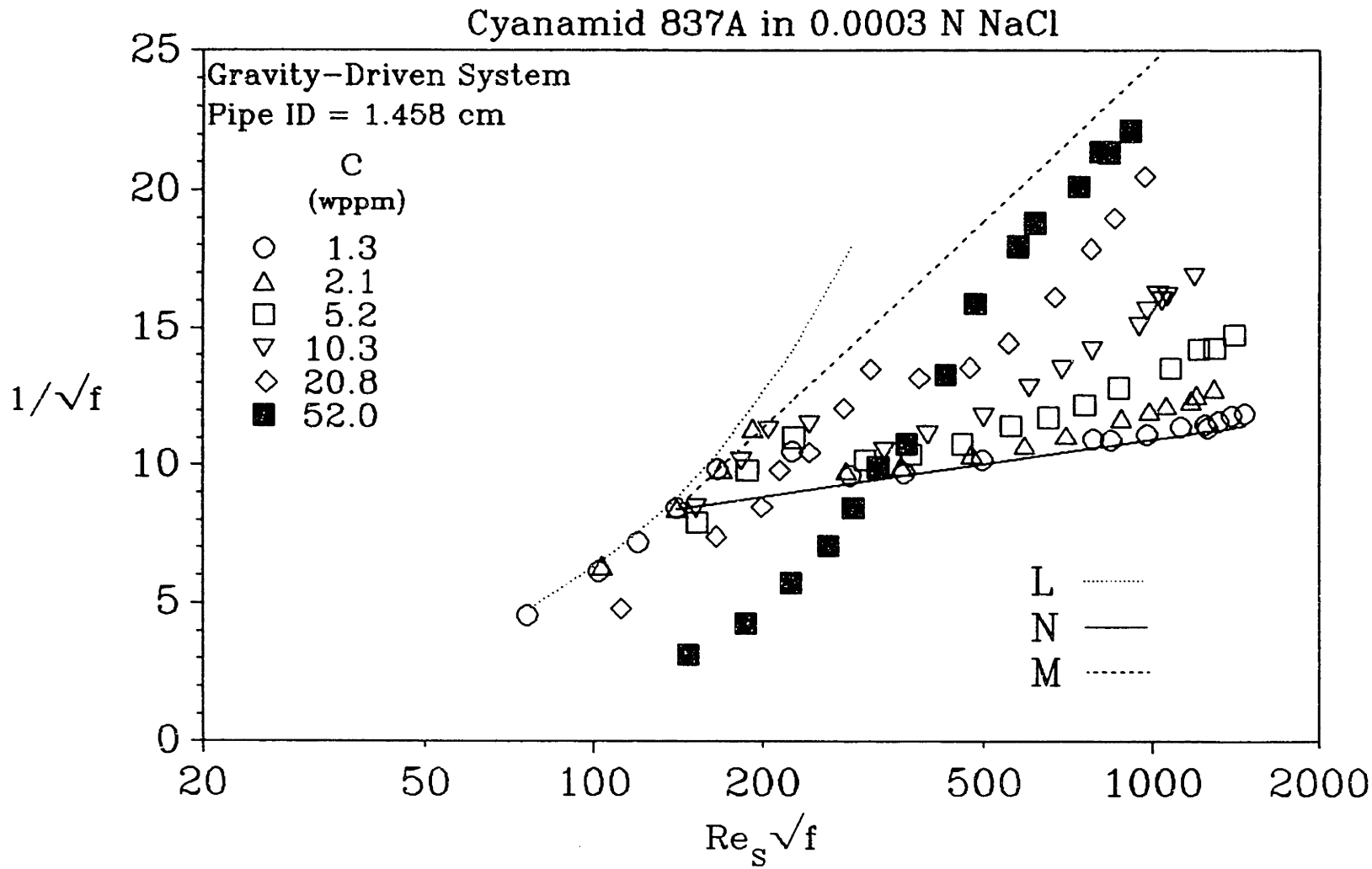


Figure 5.2.24: Cyanamid 837A in 0.0003 N NaCl from the 1.458-cm Pipe

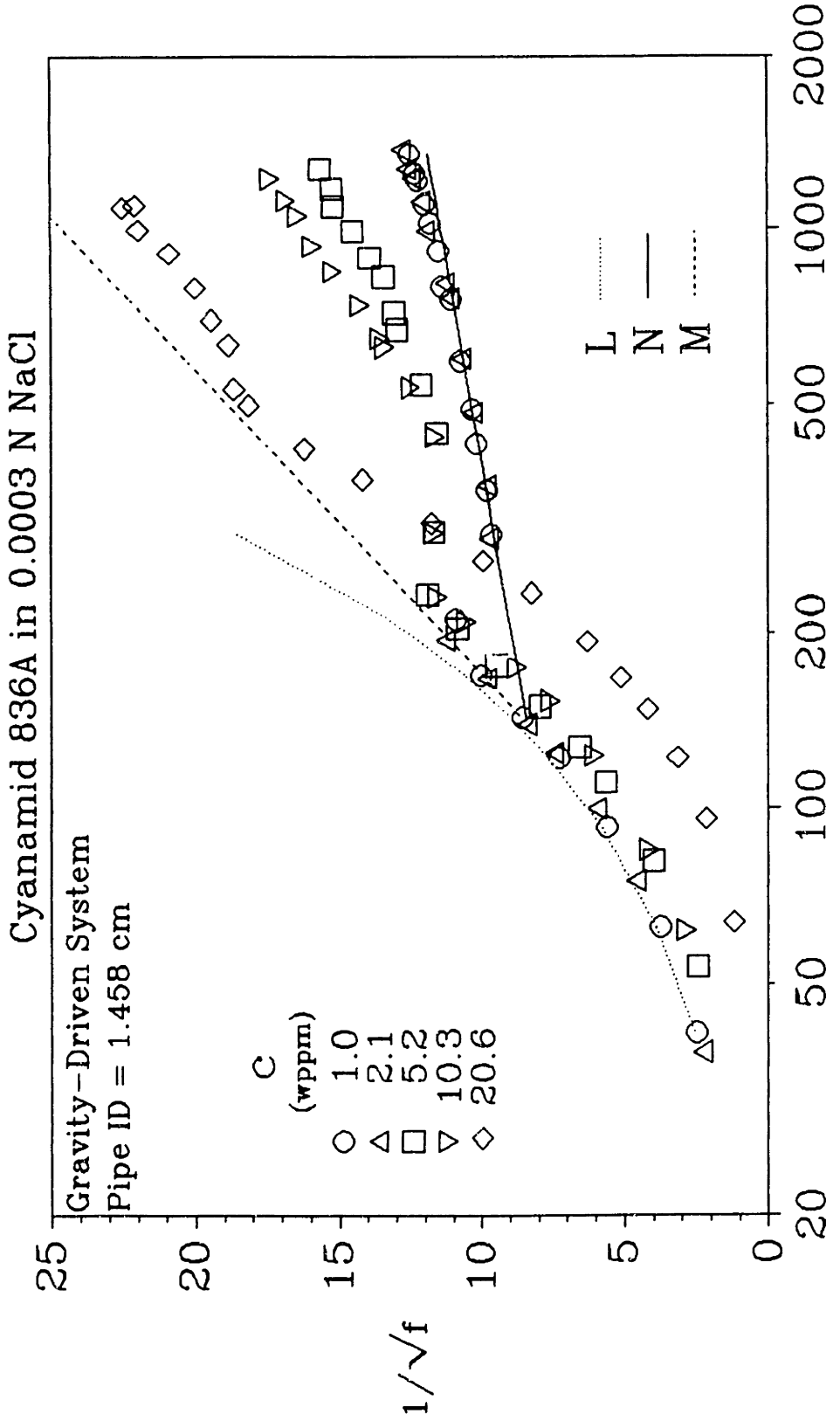


Figure 5.2.25: Cyanamid 836A in 0.0003 N NaCl from the 1.458-cm Pipe

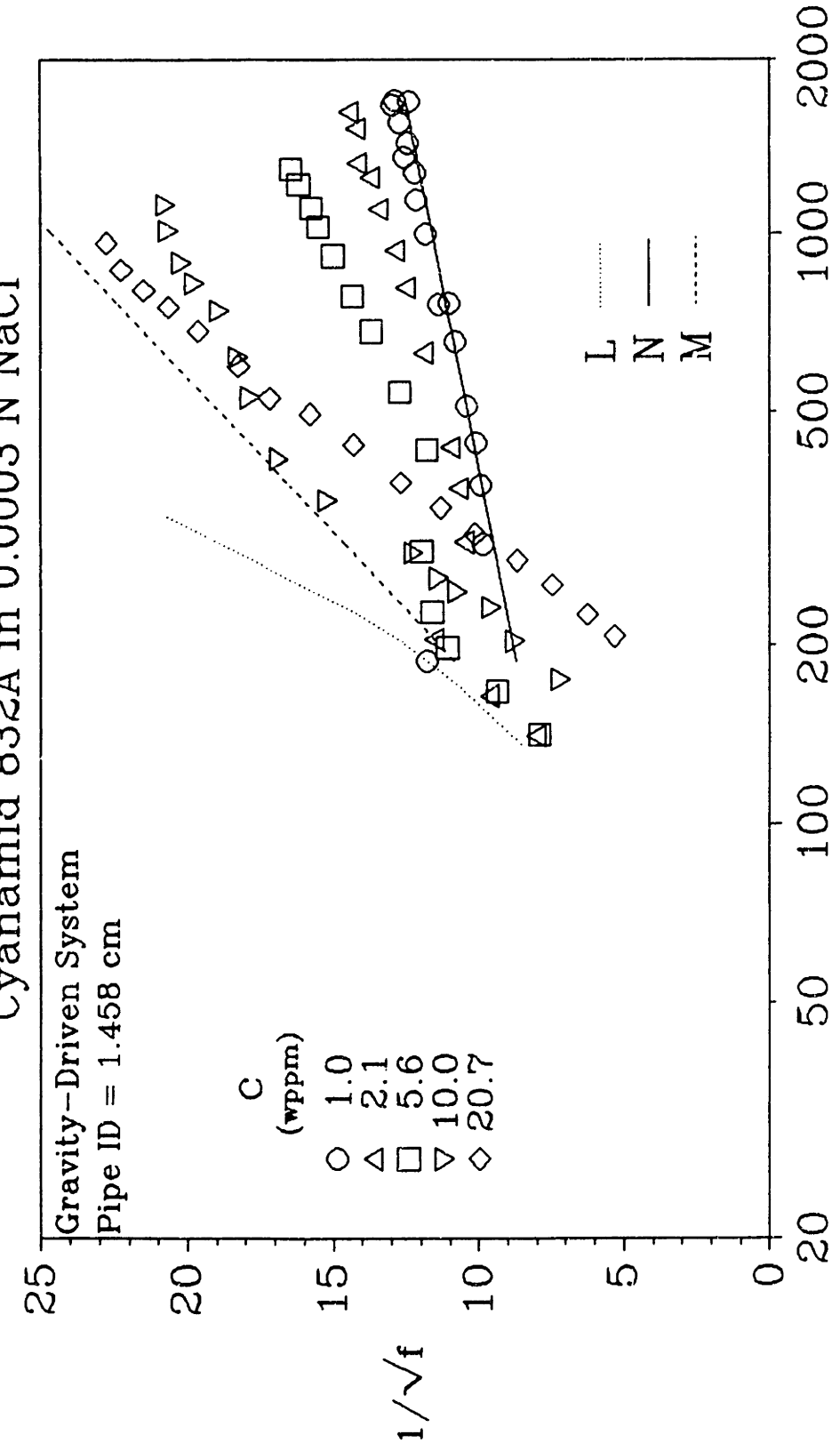


Figure 5.2.26: Cyanamid 832A in 0.0003 N NaCl from the 1.458-cm Pipe

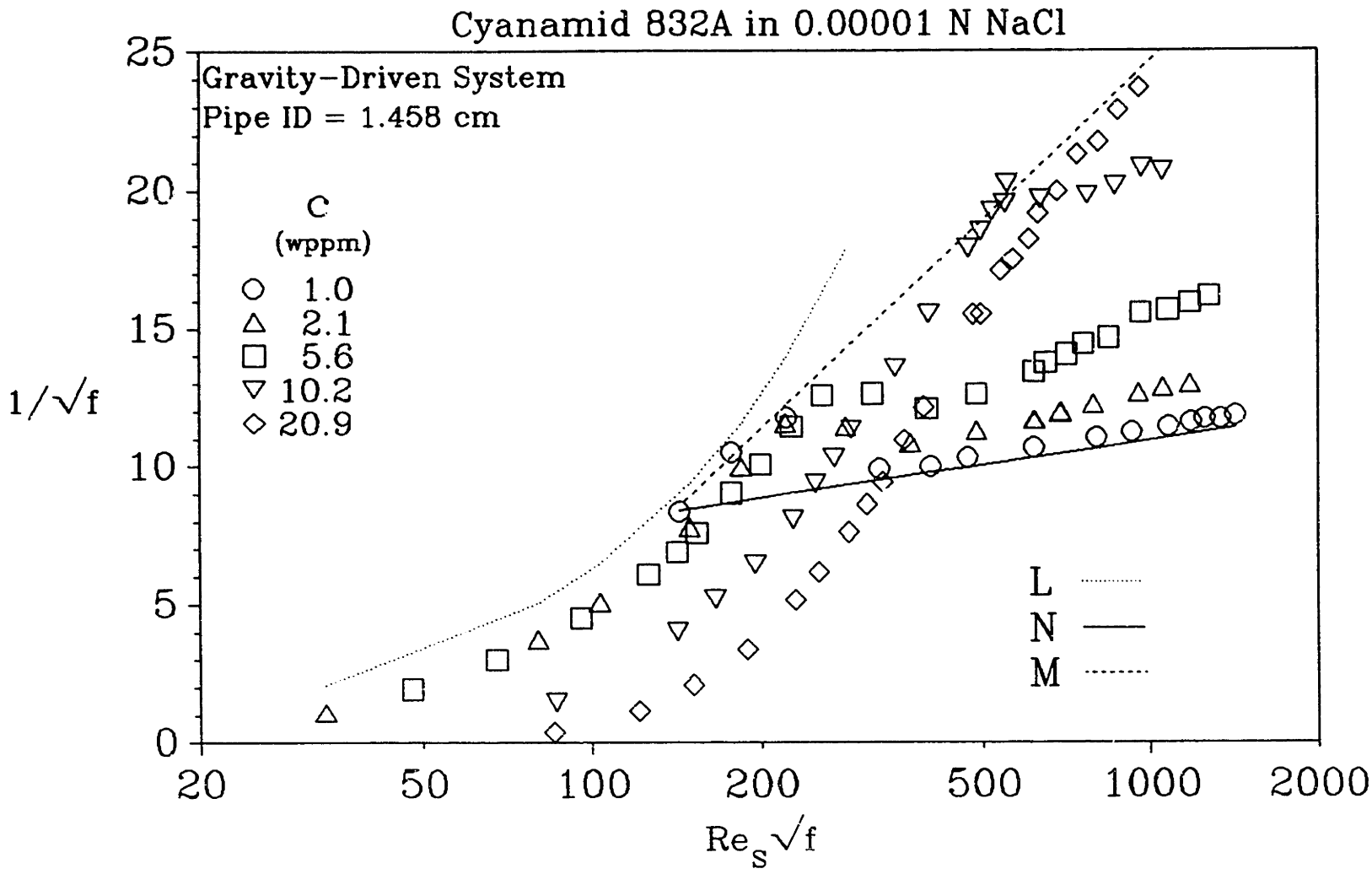


Figure 5.2.27: Cyanamid 832A in 0.00001 N NaCl from the 1.458-cm Pipe

lower $Re_s\sqrt{f}$ relative to both the common collapsed fan and the C836A fan in 0.001 N NaCl; however, only a partial Type-A fan is observed because flow transition masks the onset region of $Re_s\sqrt{f^*} < 250$. For c $\approx$ 10 and 20 wppm, the P segments retain approximately the same slope increments, $\delta \approx 10$ and 14, as in the collapsed fan and the C836A fan in 0.001 N NaCl, but achieve greater flow enhancements, $S'_1 \approx 5$ and 10.5. Finally, for additive C832A, with the highest backbone charge, a Type-B ladder emerges. No onsets are visible. The 10-wppm solution traces an LP trajectory, with a P-segment slope increment, $\delta \approx 5.5$, appreciably lower than that in the collapsed fan, and a flow enhancement, $S'_1 \approx 9$, greater than those exhibited at the same concentrations in all the previous examples. The 20-wppm solution traces an LM trajectory, achieving maximum drag reduction. The preceding description for additive C832A is reinforced in Figure 5.2.27, for additive C832A in 0.00001 N NaCl, in which a Type-B ladder is also clearly visible.

The drag-reduction behavior of each polymer at this salinity of 0.0003 N NaCl is analogous to that seen in 0.001 N, and essentially continues the progression with declining salinity established in the preceding descriptions. Additives C837A and C836A, with the lowest backbone charges, retain Type-A fan structures that are translated to lower $Re_s\sqrt{f}$ relative to both the collapsed fan and their own respective fans in 0.001 N NaCl. Additive C832A, with the highest backbone charge, exhibits Type-B ladders in both 0.0003 and 0.00001 N NaCl, constituting the final progression from the collapsed fan exhibited in 0.1 N NaCl through its intermediate behavior, between Type-A and Type-B, in 0.001 N NaCl. In summary, drag-reduction observations with additives C837A, C836A, and C832A reveal the following influence of increasing backbone

charge. In 0.1 N NaCl, all three polymers exhibit virtually identical Type-A fans, independent of backbone charge. In 0.001 N and 0.0003 N NaCl the polymers with the least backbone charges, C837A and C836A, continue to exhibit Type-A fans, but these are translated to lower $Re_x\sqrt{f}$ relative to the common fan seen in 0.1 N NaCl, the extent of translation increasing separately with increasing backbone charge and decreasing salinity. The most-charged additive, C832A, displays intermediate drag-reduction behavior between Type-A and Type-B in 0.001 N NaCl and exhibits Type-B ladders in both 0.0003 N and 0.00001 N NaCl. At a given concentration, flow enhancement at constant $Re_x\sqrt{f}$ increases monotonically, and significantly, with both increasing backbone charge and decreasing salinity; however, in Type-A fans, the slope increments at constant concentration remain essentially independent of backbone charge and salinity.

The foregoing observations suggest the following physical interpretations. The identical Type-A fans observed at the highest salinity, 0.1 N NaCl, show that all three polymers, regardless of backbone charge, effect a collapsed random-coiling conformation, characteristic of their common backbone. The prevalence of Type-A fans for additives C837A and C836A, with the two least-charged backbones, at all lower salinities, 0.001 N and 0.0003 N NaCl, implies that their conformations remain random-coiling. The observed translations of their fans to lower $Re_x\sqrt{f}$ suggests that their random coils increasingly expand with increasing backbone charge and decreasing salinity. For C832A, with the highest backbone charge, the crossover of drag-reduction behavior from Type A in 0.1 N NaCl, through an intermediate structure in 0.001 N NaCl, to Type B in 0.0003 and 0.00001 N NaCl, reflects marked conformational changes with decreasing salinity, from a collapsed coil toward full extension.

Two further inferences arise from the foregoing. First, although all three polymers exhibit conformational expansion with decreasing salinity, Type-B behavior is displayed only by additive C832A, which has the highest backbone charge; thus, the requisite non-random-coiling, fully extended type of conformation associated with Type-B behavior can only be achieved with backbone charges in excess of a minimum charge that lies between those for additives C836A and C832A, thus corresponding to a $\sim 25\%$ degree of hydrolysis. Second, as observed in all cases, drag reduction at constant concentration always increases separately with increasing backbone charge and decreasing salinity; this implies that the drag-reduction phenomenon is enhanced by macromolecular expansion and thus is intimately associated with extended conformations of the macromolecular additive.

5.2.5 Comparative Descriptions for the Effect of Salinity

Results for solutions of additives P500 and C836A at intermediate salinities, which are not shown in either §5.2.3 or §5.2.4, are presented here in Figures 5.2.28 and 5.2.29, respectively. In each figure, the intermediate results are superposed upon the previously described and shown results for solutions of these additives at the same concentrations at both high and low salinity; the lines L, N, and M represent respectively the Newtonian laminar and turbulent baselines and the MDR asymptote.

Figure 5.2.28 presents the results for solutions of 30-wppm P500 in 0.3, 0.01, 0.001, and 0.0001 N NaCl in the 1.021-cm pipe from the pump-driven system. (Data for the 0.3-N(◆) and 0.0001-N(◇) solutions are described in §5.2.3 and shown in Figure

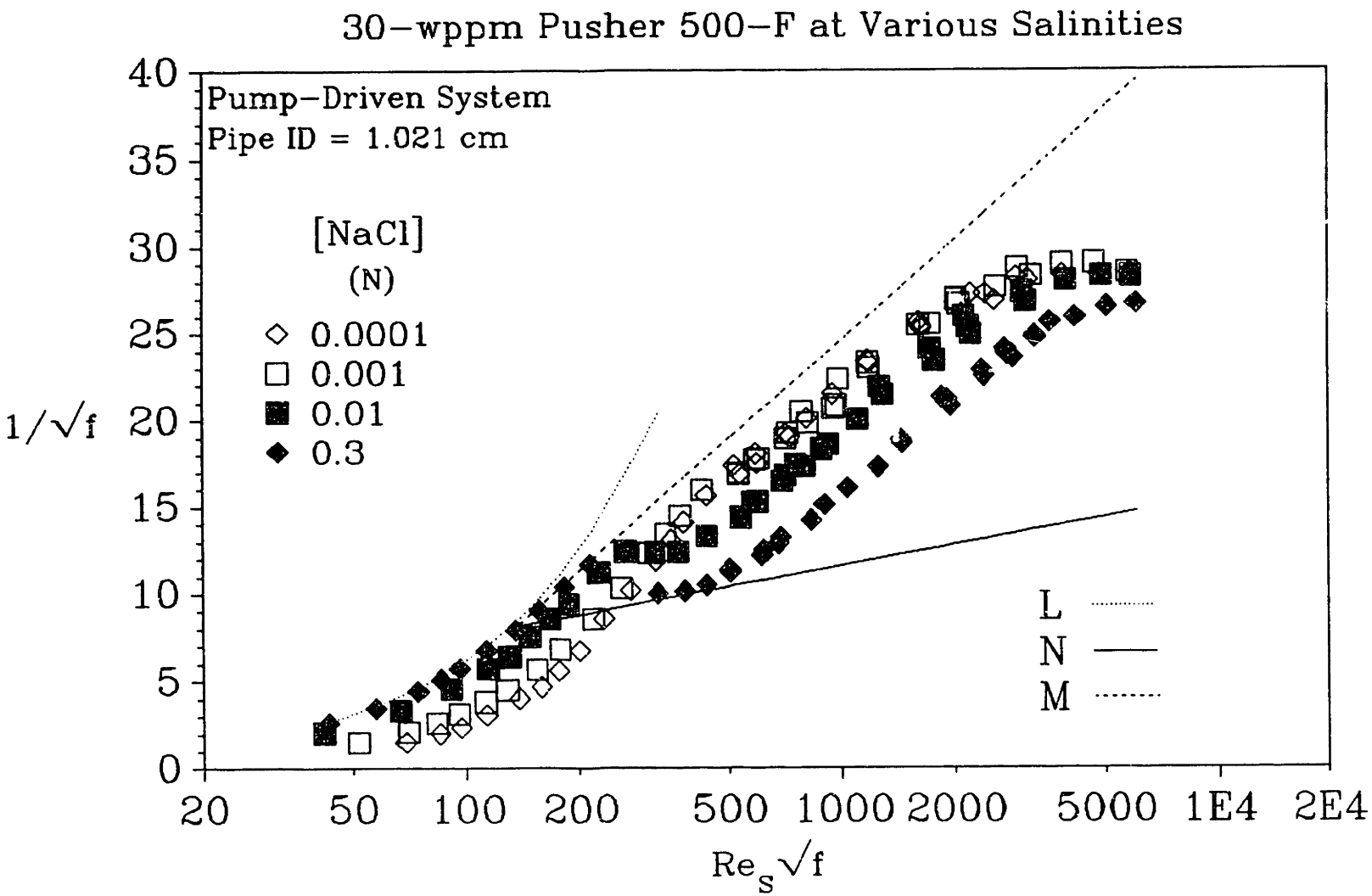


Figure 5.2.28: 30-wppm Pusher 500-F at Various Salinities

5.2.13.) In Figure 5.2.28, symbol shapes indicate polymer solutions from the same set of experimental runs; open and closed symbols denote low and high salinity, respectively.

The 0.3-N data(◆) adhere closely to L for $40 < Re_s\sqrt{f} < 150$, and then undergo a laminar-to-turbulent transition for $180 < Re_s\sqrt{f} < 350$; staying briefly on N, they onset at $Re_s\sqrt{f}^* \approx 450$ and rise linearly into the polymeric regime for $450 < Re_s\sqrt{f} < 3000$ along a P segment with slope and intercept $(A_p, B_p) = (17.2, 35.6)$ and slope increment $\delta = 13.2$. The data attain nearly constant $1/\sqrt{f} \approx 26$, declining from their P segment for $3500 < Re_s\sqrt{f} < 6000$, on account of polymer degradation. The 0.3-N solution traces an L(N)P trajectory. The 0.01-N data(■) follow a laminar path for $50 < Re_s\sqrt{f} < 150$ to the right of L with a Newtonian $\eta_r \approx 1.25$, inflect toward M for $180 < Re_s\sqrt{f} < 250$, lying just below it near $Re_s\sqrt{f} \approx 250$, and then abruptly shift horizontally rightward, away from either L or M, in an altered laminar-to-turbulent transition for $250 < Re_s\sqrt{f} < 400$. Enhancing flow immediately after transition, they rise linearly into the polymeric regime for $400 < Re_s\sqrt{f} < 2500$ along a segment P with $(A_p, B_p) = (18.0, 34.7)$ and $\delta = 14.0$. The 0.01-N data maintain a nearly constant $1/\sqrt{f} \approx 28$, declining from their P segment for $3000 < Re_s\sqrt{f} < 5800$ because of polymer degradation. The 0.01-N solution follows an LP trajectory. The 0.001-N(□) and 0.0001-N(◇) data follow adjacent laminar paths for $50 < Re_s\sqrt{f} < 250$ to the right of L with respective average $\eta_r \approx 2.0$ and 2.6 amidst some shear thinning. Both sets of data inflect toward M for $300 < Re_s\sqrt{f} < 450$ and then are about parallel to, and ~2 units of $1/\sqrt{f}$ below, M for $500 < Re_s\sqrt{f} < 1300$. At $Re_s\sqrt{f}^* \approx 1500$, the 0.001-N and 0.0001-N data retro-onset into the polymeric regime and follow respective linear P segments with $(A_p,$

B_p) = (9.0, 3.4) and (7.6, -1.7) for $1500 < Re_s\sqrt{f} < 3000$; these data maintain nearly constant $1/\sqrt{f} \approx 28.5$, declining from their respective P segments for $3100 < Re_s\sqrt{f} < 5800$. The 0.001-N and 0.0001-N solutions exhibit LMP trajectories.

In Figure 5.2.28, the 0.3-N, 0.01-N, 0.001-N, and 0.0001-N data exhibit L(N)P, LP, LMP, and LMP trajectories, respectively. In laminar flow, these 30-wppm solutions of decreasing salinity possess increasing average relative viscosities $\eta_r \approx 1.0$, 1.25, 2.0, and 2.6 and exhibit increasingly shear-thinning behavior from initial Newtonian behavior at both 0.3 N and 0.01 N NaCl. That relative viscosities and shear thinning increase with decreasing salinity suggests the following progression of initial macromolecular conformations in solution: collapsed random coils that neither increase viscosity nor give rise to shear thinning; expanded random coils that enhance viscosity without the extension and alignment necessary for shear thinning; partially extended macromolecules, the extension and alignment of which give rise to a shear-thinning, enhanced viscosity; fully extended macromolecules, the alignment of which induce a more-shear-thinning, larger viscosity than that observed for the partially extended conformation. As seen in Figure 5.2.28, this progression coincides with L segments that are displaced below the line L by greater $1/\sqrt{f}$ deficits; evidently, drag enhancement relative to solvent directly reflects the extent to which the initial additive conformation departs from the initially collapsed additive conformation.

Similarly, laminar-to-turbulent transitions are influenced by the initial conformation of the additive. The transition observed for a solution of initially collapsed macromolecules appears much like those observed for solvent flows. After transition, the N segment here is ill-defined, with onset immediately ensuing, rather than well-defined,

as for solvent flows, with no subsequent onset. At the next lower salinity of 0.01 N NaCl, in which the macromolecules are somewhat more-expanded relative to those at the highest salinity, the observed transition is altered because the expanded macromolecules interact with the transitional flow, rather than being passive "tracer particles" like the collapsed macromolecules. After commencing transition, the observed horizontal rightward shift of the 0.01-N data(■) away from either L or M, these data lie above the 0.3-N data by ~2.5 units of $1/\sqrt{f}$, but displaced to slightly lower $Re_s\sqrt{f}$. Thus, already enhancing flow, they begin to rise linearly into the polymeric regime at $Re_s\sqrt{f} \approx 350$, just to the left of the 0.3-N onset point at $Re_s\sqrt{f} \approx 450$. Moreover, the P segments of the 0.01-N and 0.3-N data possess virtually the same slope increments $\delta \approx 14.0$ and 13.2, respectively, with their subsequent declines due to polymer degradation being the same. Modest coil expansion, short of extension, evidently translates transition and the P segment with ensuing polymer degradation together toward the MDR asymptote, to higher $1/\sqrt{f}$ and lower $Re_s\sqrt{f}$. For the 0.001-N and 0.0001-N solutions, no transitional behavior is observed in that both solutions exhibit LM transitions. Interestingly, these LM transitions coincide with shear-thinning behavior in laminar flow: The 0.3-N and 0.01-N solutions are Newtonian and exhibit transitions whereas the 0.001-N and 0.0001-N solutions are shear-thinning and show no transitional behavior. (To be precise, the absence of gross-flow transition does guarantee the absence of transitional behavior in either the mean-flow or turbulent-flow structure.)

In turbulent flow, the P segment, like a vector, retains both its direction and magnitude, i.e., its slope increment and linear extent prior to polymer degradation. In Figure 5.2.28, the 0.3-N P segment is translated increasingly nearer to the MDR

asymptote as the salinity decreases to 0.001 N, during which translation it becomes a 0.01-N P segment and then a 0.001-N M segment. Evidently, in a given trajectory, laminar flow and transition determine the location, but not the subsequent behavior, of a P segment. In macromolecular terms, this observation is consistent with what is known about Type-A drag reduction. In an LNP trajectory associated with Type-A behavior, the L and N segments are governed by the initially collapsed conformation, and the P segment is governed by the subsequent departure of the additive conformation, after onset, from the initial one. In an LMP trajectory associated with Type-B behavior, the L and N segments, too, are governed by the initial conformation, but with a difference. Because of the initially extended additive conformation, an L segment often lies well to the right of Poiseuille's Law and exhibits shear thinning; because the initially extended conformation coincides with that needed for turbulent flow enhancement, flow enhancement occurs immediately following the L segment, obviating a would-be N segment and giving rise to the observed LM transition. Once both macromolecular extension and turbulent flow are achieved, the subsequent drag-reduction behavior, including flow-enhancement-related polymer degradation, is independent of the prior segments in the trajectory, notwithstanding the change in ($Re_s\sqrt{f}$, $1/\sqrt{f}$) due to translation.

It is important to note, however, that flow enhancement efficiency is influenced by salinity. Because P segments are translated to lower $Re_s\sqrt{f}$ and higher $1/\sqrt{f}$, nearer to M, with decreasing salinity, the apparent slip S' must so increase. For example, at $Re_s\sqrt{f} \approx 450$, 1000, and 3000, solutions in 0.3, 0.01, 0.001, and 0.0001 N NaCl respectively exhibit flow enhancements S' $\approx$ (0, 4.2, 10.8), (3.1, 7.7, 13.8), (5.8, 10.1,

15.3), and (5.5, 10.4, 14.8), corresponding to slip ratios, relative to the 0.0001-N solution, $S'_A/S'_B \approx$ (0, 0.40, 0.73), (0.58, 0.74, 0.93), (1.06, 0.97, 1.03), and (1.0, 1.0, 1.0). For each of the 0.3-N and 0.01-N solutions, the slip ratios increase with increasing $Re_s\sqrt{f}$, implying macromolecular extension in Type-A drag reduction; that the ratios of the latter always exceed those of the former indicates that lower salinities induce larger initial macromolecular conformations. The slip ratios for the 0.001-N and 0.0001-N solution are approximately unity at all $Re_s\sqrt{f}$, implying that their initially extended conformations are essentially the same and greater than those for the 0.3-N and 0.01-N solutions.

Figure 5.2.29 presents the results for solutions of 20.6-wppm C836A in 0.1, 0.01, 0.001, and 0.0003 N NaCl in the 1.458-cm pipe from the gravity-driven system. In Figure 5.2.29, symbol shapes indicate salinity; open and closed symbols denote solutions from the same set of experimental runs.

The 0.1-N data(▽,▼) follow closely to L for $60 < Re_s\sqrt{f} < 150$ with Newtonian $\eta_r \approx 1.05$ and undergo a laminar-to-turbulent transition for $180 < Re_s\sqrt{f} < 450$, dropping onto N. They remain along N for $500 < Re_s\sqrt{f} < 600$, onset at $Re_s\sqrt{f} \approx 700$, and then, rising into the polymeric regime, attain a linear P segment with slope and intercept $(A_p, B_p) \approx (18.6, 42.4)$ and slope increment $\delta = 15.1$. The 0.1-N solution follows an LNP trajectory. The 0.01-N data(■) trace a laminar path for $60 < Re_s\sqrt{f} < 150$, rightward of L, with a Newtonian $\eta_r \approx 1.2$, undergo transition for $180 < Re_s\sqrt{f} < 350$, but reach a $1/\sqrt{f}$ minimum slightly above N at $Re_s\sqrt{f} \approx 350$. Rising immediately into the polymeric regime, they attain a linear P segment with $(A_p, B_p) = (19.4, 42.1)$ and $\delta = 15.9$ from an apparent onset at $Re_s\sqrt{f}^* \approx 500$. The 0.01-N solution exhibits an

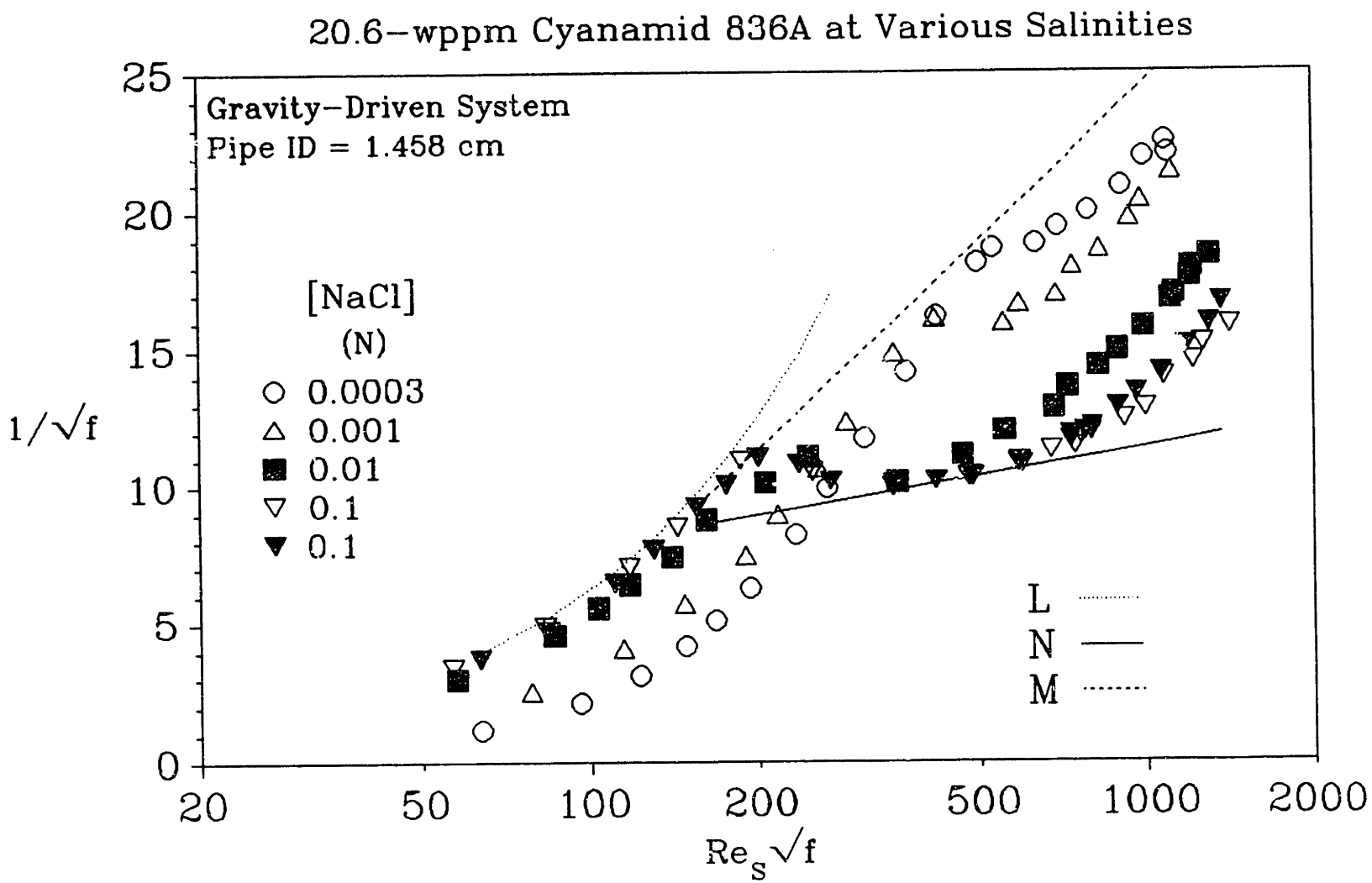


Figure 5.2.29: 20.6-wppm Cyanamid 836A at Various Salinities

L(N)P trajectory, the (N) denoting an ill-defined N segment. The 0.001-N data(▽) trace a laminar path for 70 < $Re_s\sqrt{f}$ < 350, far rightward from L, with a nearly Newtonian $\eta_r \approx 1.8$, lying just below the MDR asymptote at $Re_s\sqrt{f} \approx 350$. At $Re_s\sqrt{f} \approx 400$, they display transitional behavior as they shift rightward and slightly downward into the polymeric regime, reaching a $1/\sqrt{f}$ minimum at $Re_s\sqrt{f} \approx 500$ well above N by ~5.5 unit of $1/\sqrt{f}$. The 0.001-N data, already flow enhancing at this minimum, rise further into the polymeric regime along a linear P segment with $(A_p, B_p) = (19.8, 38.9)$ and $\delta = 16.3$. Although the 0.001-N data shift into the polymeric regime from M, they do not retro-onset because the ensuing P segment possesses a slope increment, $\delta = 16.3$, similar to those of the 0.1-N and 0.01-N P segments, $\delta = 15.1$ and 15.9, respectively. The 0.001-N solution follows an LP trajectory. The 0.0003-N data(○) follow a laminar path for 60 < $Re_s\sqrt{f}$ < 400, farthest to the right from L, with an average $\eta_r \approx 3.0$ amidst some shear thinning, lying just below M at $Re_s\sqrt{f} \approx 400$. Approaching M most-closely at $Re_s\sqrt{f} \approx 500$, they shift slightly upward into the polymeric regime, exhibiting transitional behavior, and then rise further into the polymeric regime along a somewhat-linear P segment with $(A_p, B_p) = (18.0, 32.0)$ and $\delta = 14.4$. As with the 0.001-N data, the 0.0003-N data do not retro-onset because their P segment has a slope increment, $\delta = 14.4$, similar to those for the previous P segments. The 0.0003-N solution traces an LP trajectory.

In Figure 5.2.29, the 0.1-N, 0.01-N, 0.001-N, and 0.0003-N solutions display LNP, L(N)P, LP, and LP trajectories. In laminar flow, these solutions respectively possess increasingly higher relative viscosities, $\eta_r \approx 1.0$, 1.2, 1.8, and 3.0, exhibiting some shear thinning at the two lowest salinities. Thus, as salinity decreases, the initial

conformation of additive C836A progressively departs from a collapsed random coil in 0.1 N NaCl to a highly expanded macromolecule in 0.0003 N NaCl. Moreover, as seen in Figure 5.2.29, the L segments lie farther beneath the line L, over a fixed region of $Re_s\sqrt{f}$, as the salinity decreases. Evidently, solutions of increasingly expanded macromolecules enhance drag to greater extents relative to the solvent in laminar flow.

Laminar-to-turbulent transitions are also influenced by salinity via the initial macromolecular conformation of the additive. As observed in Figure 5.2.28 for P500 solutions of decreasing salinity, such C836A solutions exhibit systematically changing transitions. The 0.1-N solution undergoes a Newtonian transition that appears no different than that for solvent; for the 0.01-N solution, transition appears generally Newtonian but its peak is translated to a higher $Re_s\sqrt{f} \approx 250$ from the lower Newtonian $Re_s\sqrt{f} \approx 200$. The 0.001-N and 0.0003-N solutions, which both contain initially highly expanded macromolecules, undergo transition only when their L segments approach the line M and only at the points of imminent intersection at respective $Re_s\sqrt{f} \approx 450$ and 500, as seen in Figure 5.2.29. These transitions are characterized by rightward horizontal shifts, away from M, into the polymeric regime at $1/\sqrt{f}$ well above N. Thus, increasing coil expansion, short of extension, with decreasing salinity essentially translates transition along the line M, as dictated by the relative viscosity in laminar flow.

In turbulent flow, decreasing salinity evidently reduces the length of an N segment in a flow trajectory, as seen in Figure 5.2.29 by the trajectory progression of LNP to L(N)P to LP. The disappearance of the N segment coincides with the translation of transition to higher ($Re_s\sqrt{f}$, $1/\sqrt{f}$) along the line M as salinity decreases. Just as the character of transition is not greatly altered by decreasing salinity, all ensuing P segments

possess approximately the same slope increments $\delta \approx$ 15.1, 15.9, 16.3, and 14.4, respectively; thus, all four initial macromolecular conformations are random-coiling, only differing in their expansions, due to decreasing salinity, away from the collapsed conformation. As observed for additive P500, the P segments exhibited by C836A solutions are vector-like in their constant direction, irrespective of their locations on the (PK) coordinate plane, which are determined by the initial conformations in the previous L segments.

Flow enhancement, unlike P segments, does vary with salinity. For example, at $Re_s\sqrt{f} \approx$ 400 and 1000, the 0.1-N, 0.01-N, 0.001-N, and 0.0003-N solutions exhibit respective $S' \approx$ (0, 1.8), (0.7, 4.4), (6.0, 9.0), and (6.1, 10.6), having slip ratios, relative to the 0.0003-N solution, $S'_A/S'_B \approx$ (0, 0.17), (0.11, 0.42), (0.98, 0.85), and (1.0, 1.0), respectively. Because these turbulent flow enhancements and slip ratios increase with decreasing salinity as do drag enhancements in laminar flow, larger initial coil sizes induce greater turbulent flow enhancements, all else being equal. It is worth noting that coil expansion produces opposite effects in laminar and turbulent flow, i.e, drag enhancement vis-a-vis flow enhancement.

5.3 Turbulent-Flow Parameters

The turbulent-flow parameters, given in Table 5.2.2, are presented pictorially for each polymer additive. The apparent slips S'_1 and S'_3 at $Re_s\sqrt{f}$ = 1000 and 3000, slope increments δ, onset wall shear stresses T_w^*, and the retro-onset wall shear stresses $T_w^\#$, respectively, are plotted against solution concentration. These summarize the drag-

reduction trends observed in the figures presented in the detailed descriptions.

5.3.1 The Apparent Slip S'

Figures 5.3.1 - 5.3.9, double-logarithmic plots of apparent slip S' vs. concentration c, illustrate the concentration dependence of the apparent slip S' for additives C832A, B1120, P500, A507, D1438, C837A, and C836A, respectively.

As shown in the previous section, Type-B drag-reduction exceeds Type-A drag-reduction at constant $Re_s\sqrt{f}$ with the latter approaching the former at high $Re_s\sqrt{f}$. The apparent slip S' observed for a polymer solution at low salinity, thus, exceeds that observed for a polymer solution at high salinity, with the two becoming closer at high $Re_s\sqrt{f}$. Moreover, as concentration increases, the asymptote of maximum drag reduction is approached; thus, the apparent slips S' for both Type-A and Type-B drag-reduction tend toward these asymptotic maximum values at high concentrations.

Figures 5.3.1 and 5.3.2, which respectively display S'_3 and S'_1 for additive C832A in both the 1.458-cm(○ ▽) and 1.021-cm(● ▼) pipes, contain three important observations: (1) pipe diameter has little effect on flow-enhancement efficiency as indicated by the virtually coinciding triangles and circles at both salinities; (2) Type-B drag-reduction is more effective than Type-A drag-reduction with their difference decreasing with increasing concentration, as the open and closed symbols become less separated and overlap; and (3) in Type-B drag reduction, both S'_3 and S'_1 initially increase about linearly with concentration at low flow enhancements and then reach respective constant values ~ 20 and ~ 13, the maxima permitted by the MDR asymptote

at $Re_s\sqrt{f} = 3000$ and 1000.

Figure 5.3.3 shows S'_1 for additive C832A from all experiments and serves to compare the results from the gravity-driven and pump-driven systems. At low concentrations, $c < 10$ wppm, data from the gravity-driven system, the 0.00001-N(○) and 0.0003-N(▽), lie below the 0.0001-N data(◇) from the pump-driven system; at high concentrations, $c \approx 10$ and 20 wppm, data from both systems at these three salinities coincide. The 0.001-N(▽) data, from the gravity-driven system, lie below those at the three lower salinities, from both systems; increasing more rapidly with increasing concentration, they nearly reach the maximum drag-reduction value, $S'_1 \approx 13$, at $c = 20$ wppm. At $c \approx 10$ and 20 wppm, the only 0.1-N data(▼) from the gravity-driven system are much less than the 0.3-N data(◆) from the pump-driven system. In summary, data from the gravity-driven system follow the same trends with respect to salinity as observed in Figures 5.3.1 and 5.3.2, the high-salinity data lying below the low-salinity data at fixed concentration, but generally exhibit less flow enhancement than data from the pump-driven system.

Figure 5.3.4 shows both S'_1 and S'_3 for additive B1120 and illustrates the initial near-linear growth of S' with increasing c at low concentrations and low salinity, the merging of the 0.3-N and 0.0001-N data as concentration increases, and the levelling of S' as maximum drag reduction is approached.

Figures 5.3.5 and 5.3.6 present S'_3 and S'_1, respectively, for additive P500 from both pipes. Pipe diameter has little influence on flow enhancement, as the 0.3-N data(▽▼) and 0.0001-N data(○ ●) separately overlap at almost every concentration. Low-salinity data, again, exceed high-salinity data, and S' appears to increase linearly

with increasing concentration. Note that additive P500 is less effective than additives C832A and B1120, the extended conformation requiring almost fourfold higher c to reach the same S'.

Figure 5.3.7 shows S'_3 for additives A507 and D1438. Additive A507 is slightly more effective than D1438, but both additives are clearly much less effective per unit-mass than additives C832A, B1120, and P500. Unlike the other additives, both A507 and D1438 exhibit Type-A drag-reduction behavior irrespective of salinity. Because the Type-A fan at low salinity is displaced to lower $Re_s\sqrt{f}$ and has steeper spokes, S' at low salinity is generally greater than that at high salinity until $c \approx 1000$ wppm when the two are nearly equal. Note that all the data are well below maximum drag reduction.

Figures 5.3.8 and 5.3.9 present S'_1 for additives C837A and C836A, respectively. As seen in both figures, S' at low salinity is greater than that at high salinity and increases almost linearly with increasing concentration at low concentrations, reaching a constant value, $S'1 \approx 13$, at high concentrations, corresponding roughly to maximum drag reduction.

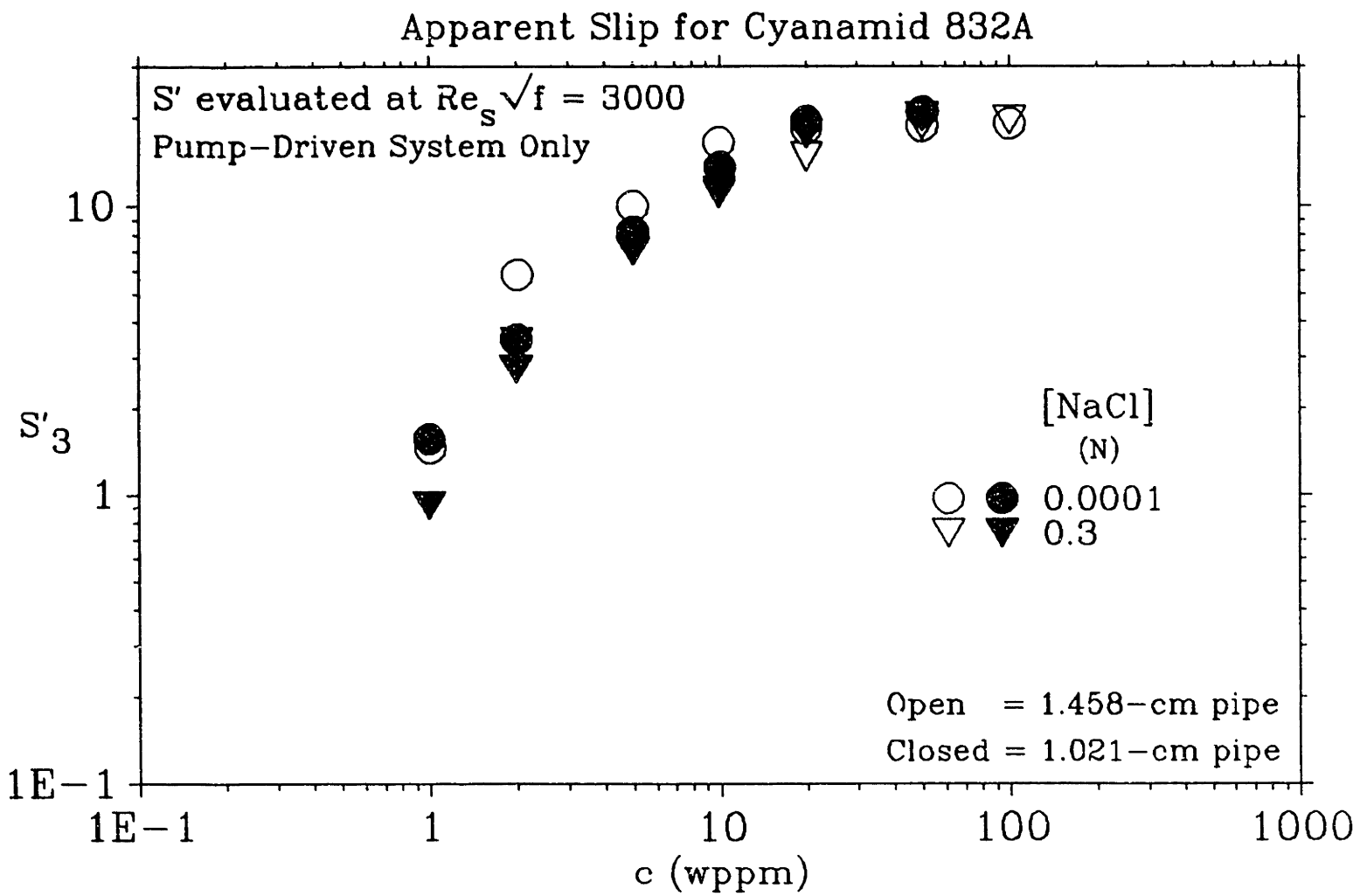


Figure 5.3.1: Apparent Slip S'_3 from the Pump-Driven System in Both Pipes for Additive C832A

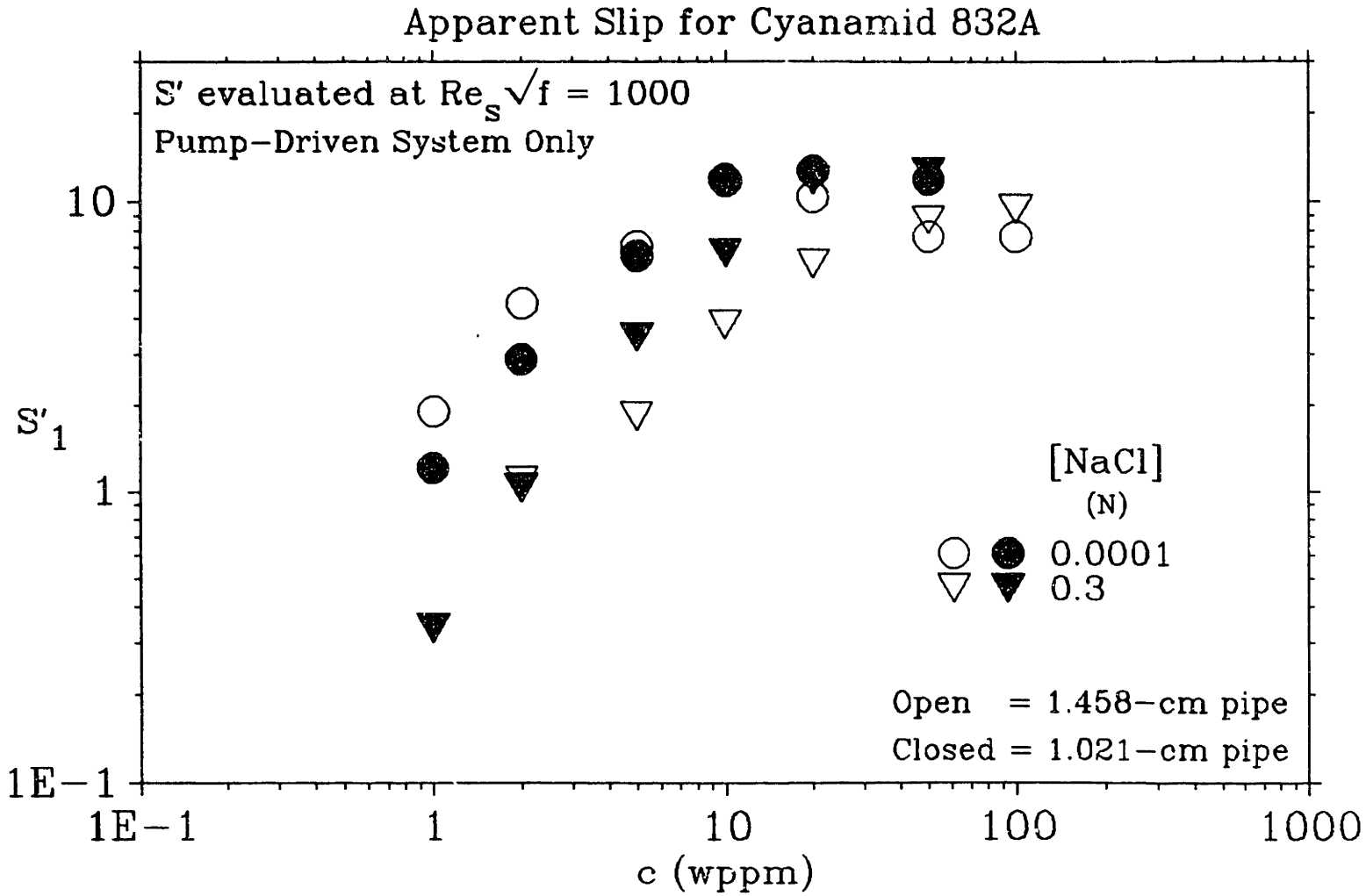


Figure 5.3.2: Apparent Slip S'_1 for Cyanamid 832A from Pump-Driven System in Both Pipes

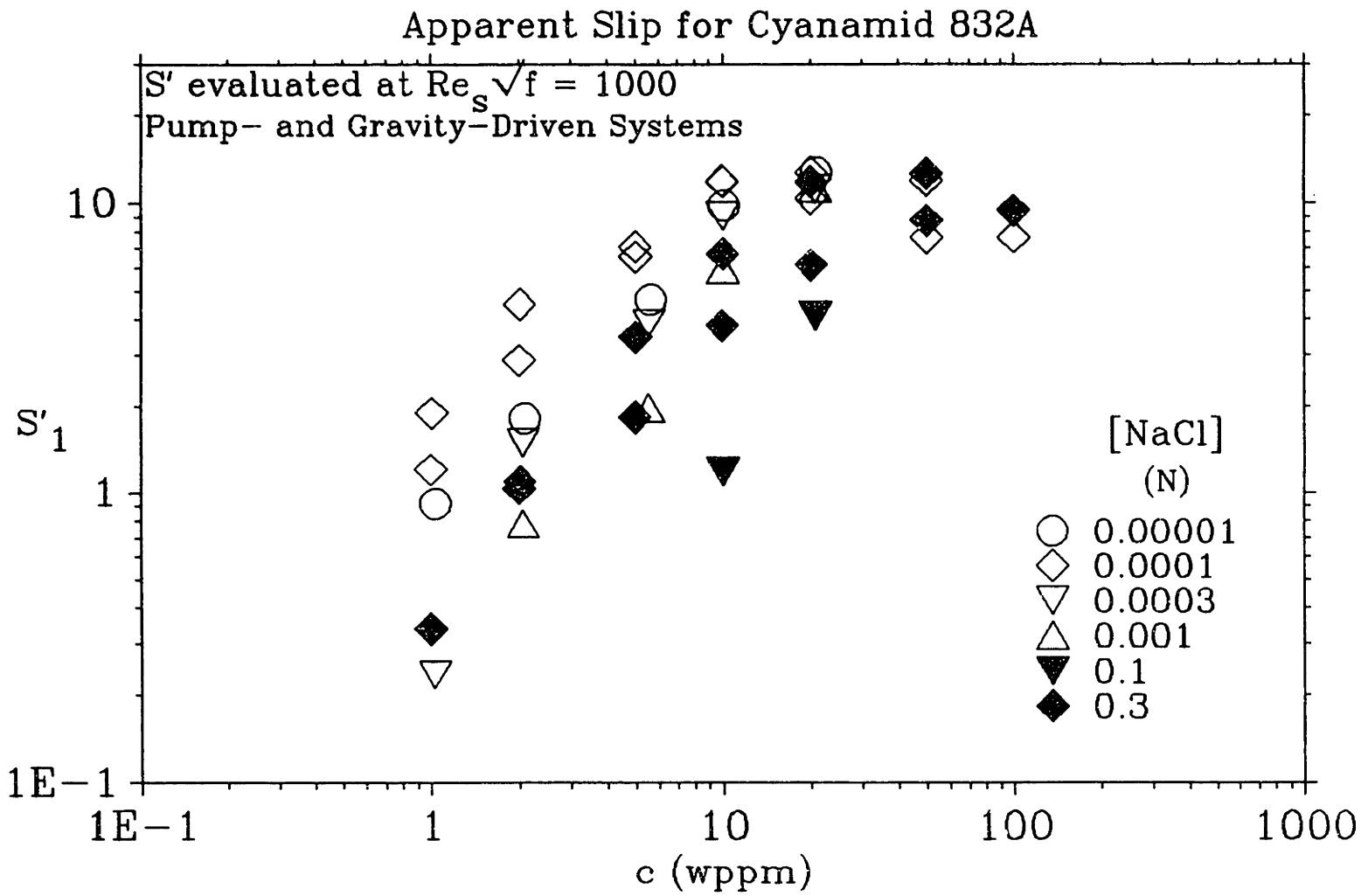


Figure 5.3.3: Apparent Slip S'_1 for Cyanamid 832A from Both Systems in the 1.458-cm Pipe

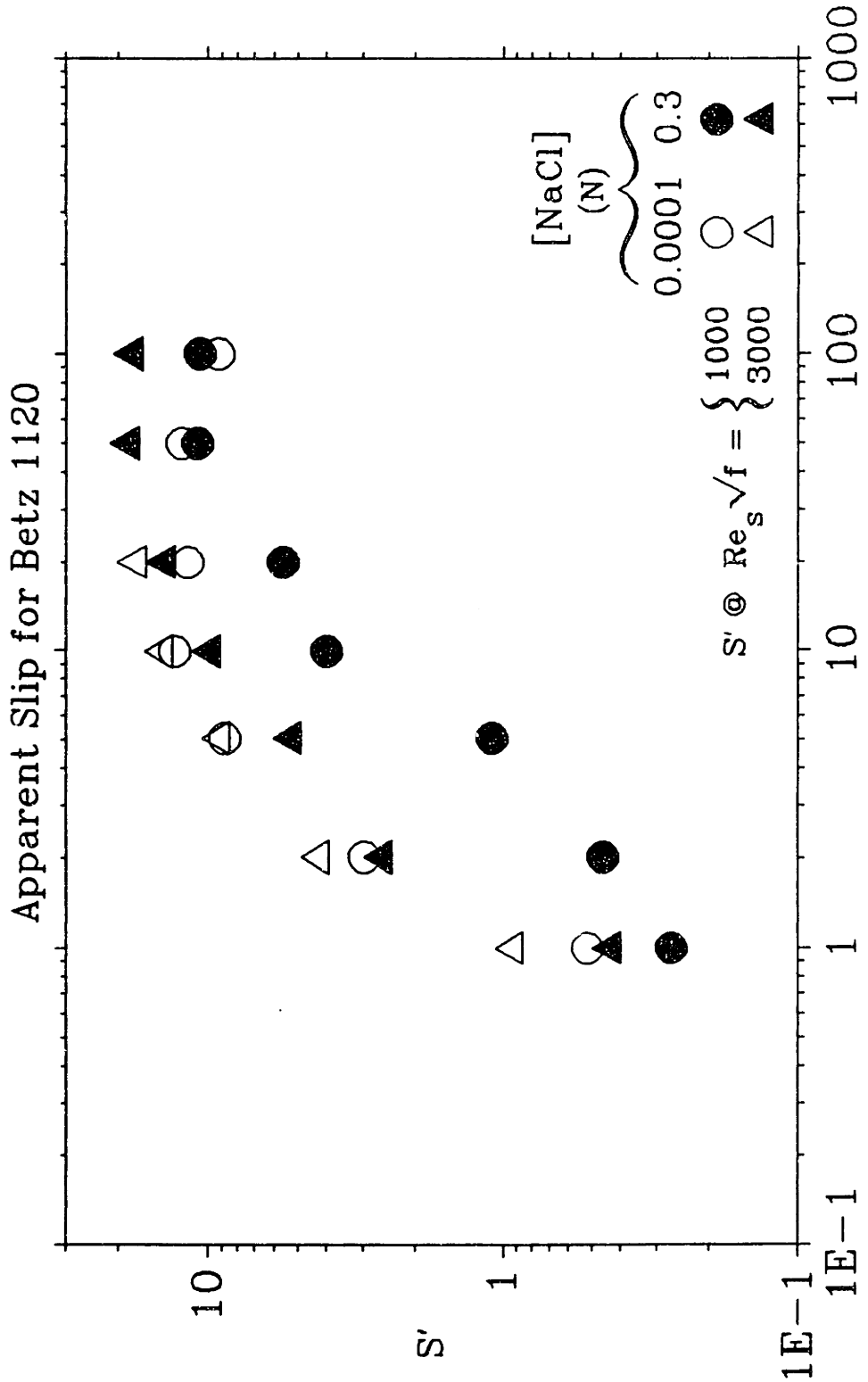


Figure 5.3.4: Apparent Slip S'_3 for Betz 1120

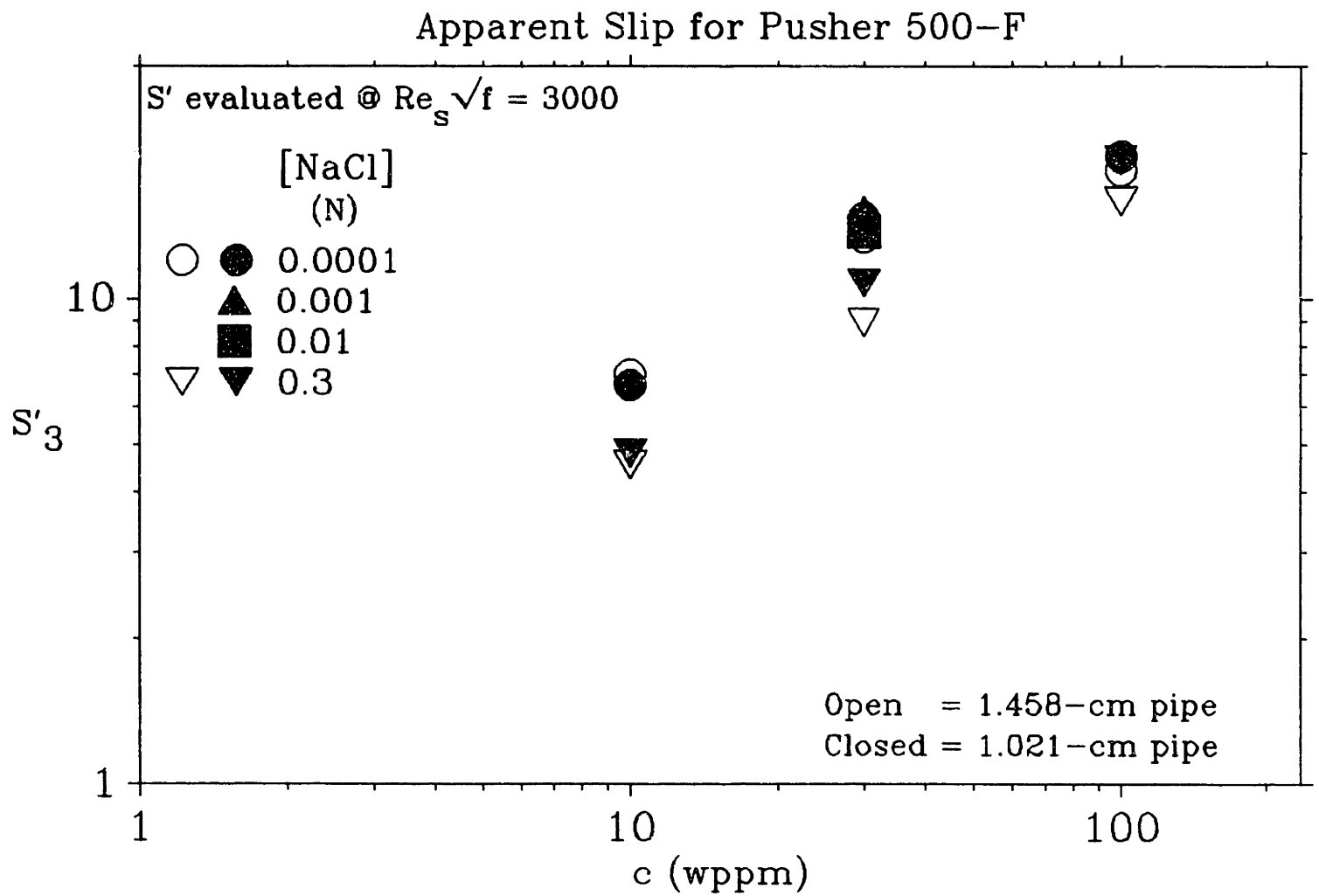


Figure 5.3.5: Apparent Slip S'_3 for Pusher 500-F in Both Pipes

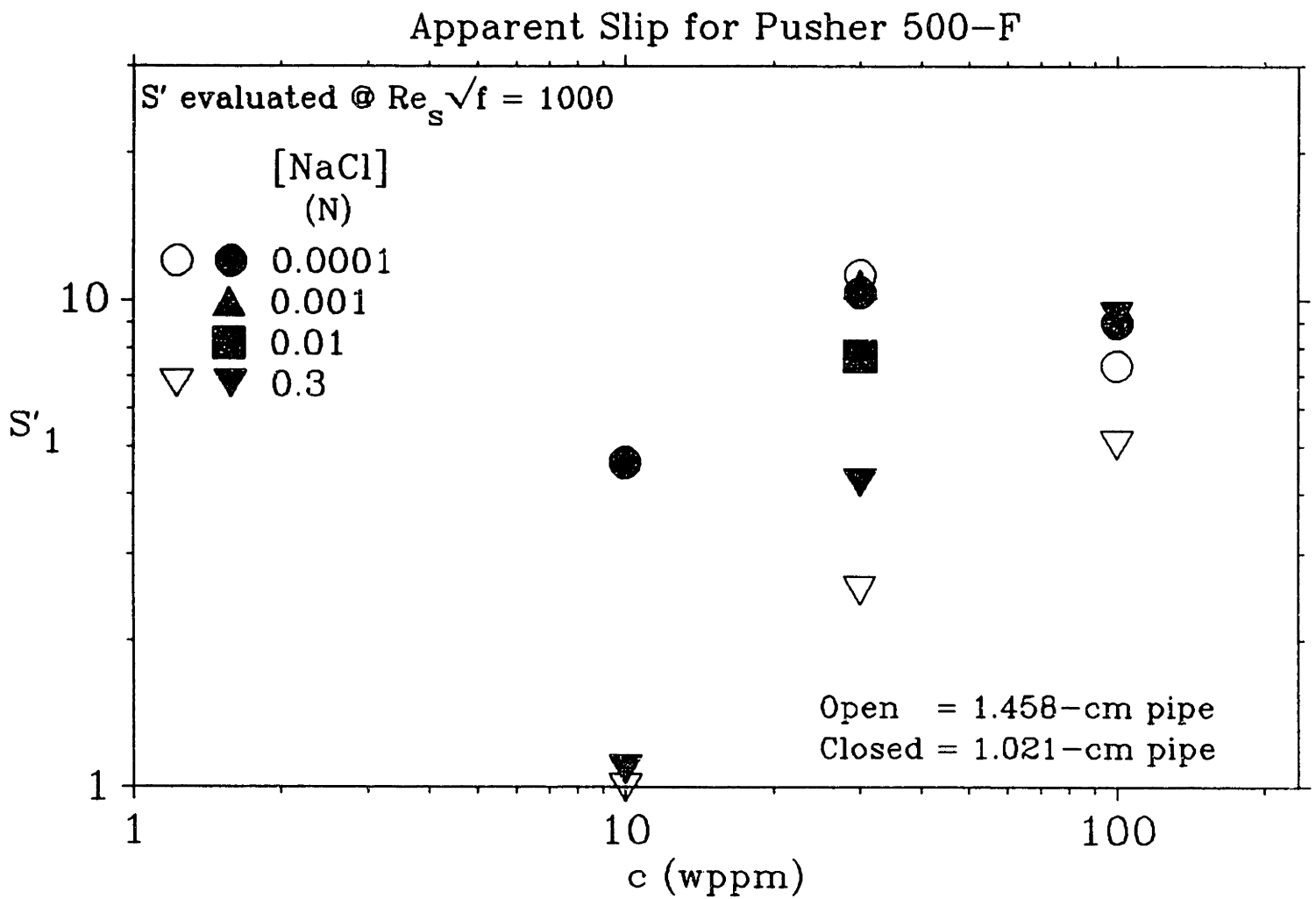


Figure 5.3.6: Apparent Slip S'_1 for Pusher 500-F in Both Pipes

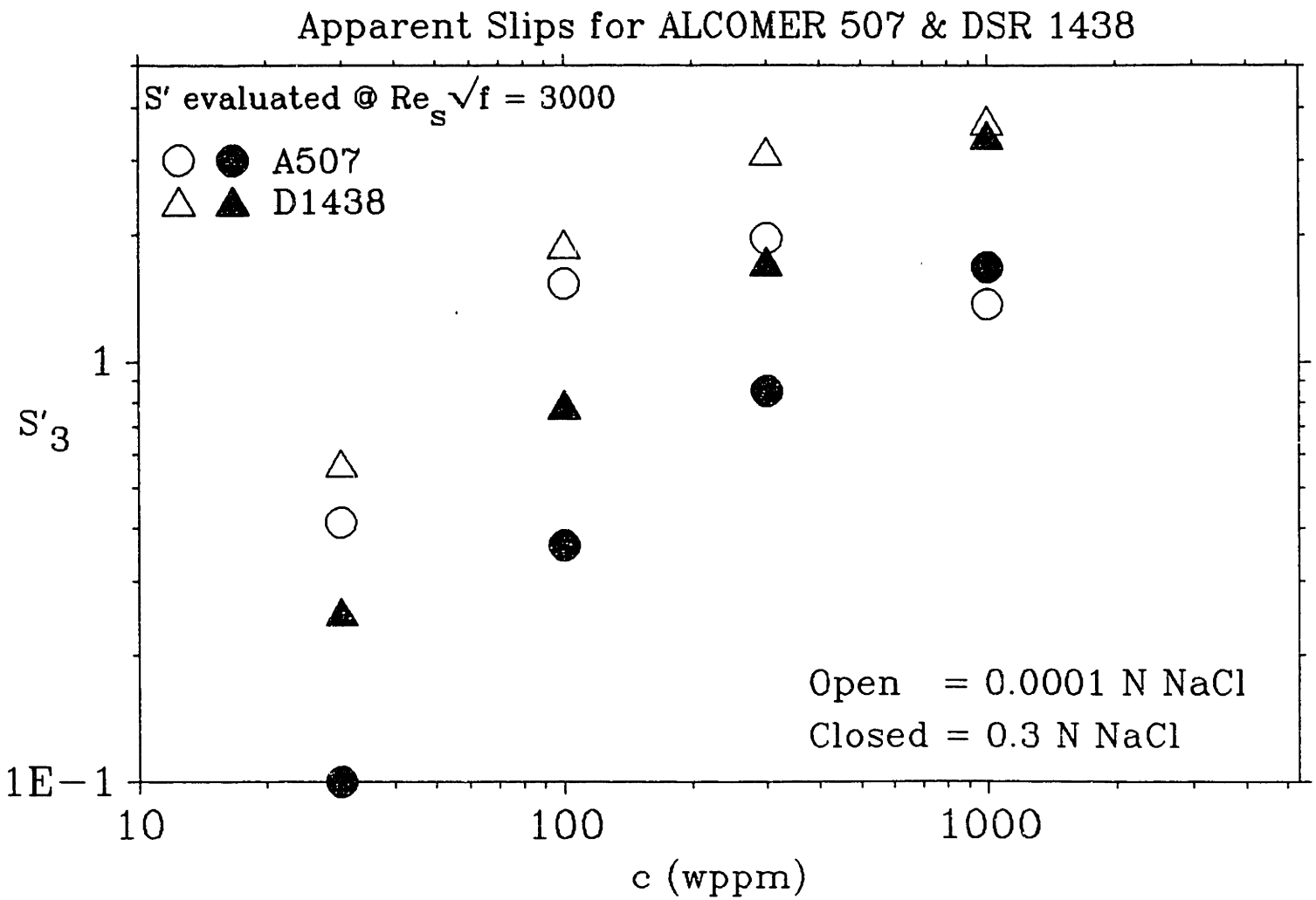


Figure 5.3.7: Apparent Slip S'_3 for Alcomer 507 and DSR 1438

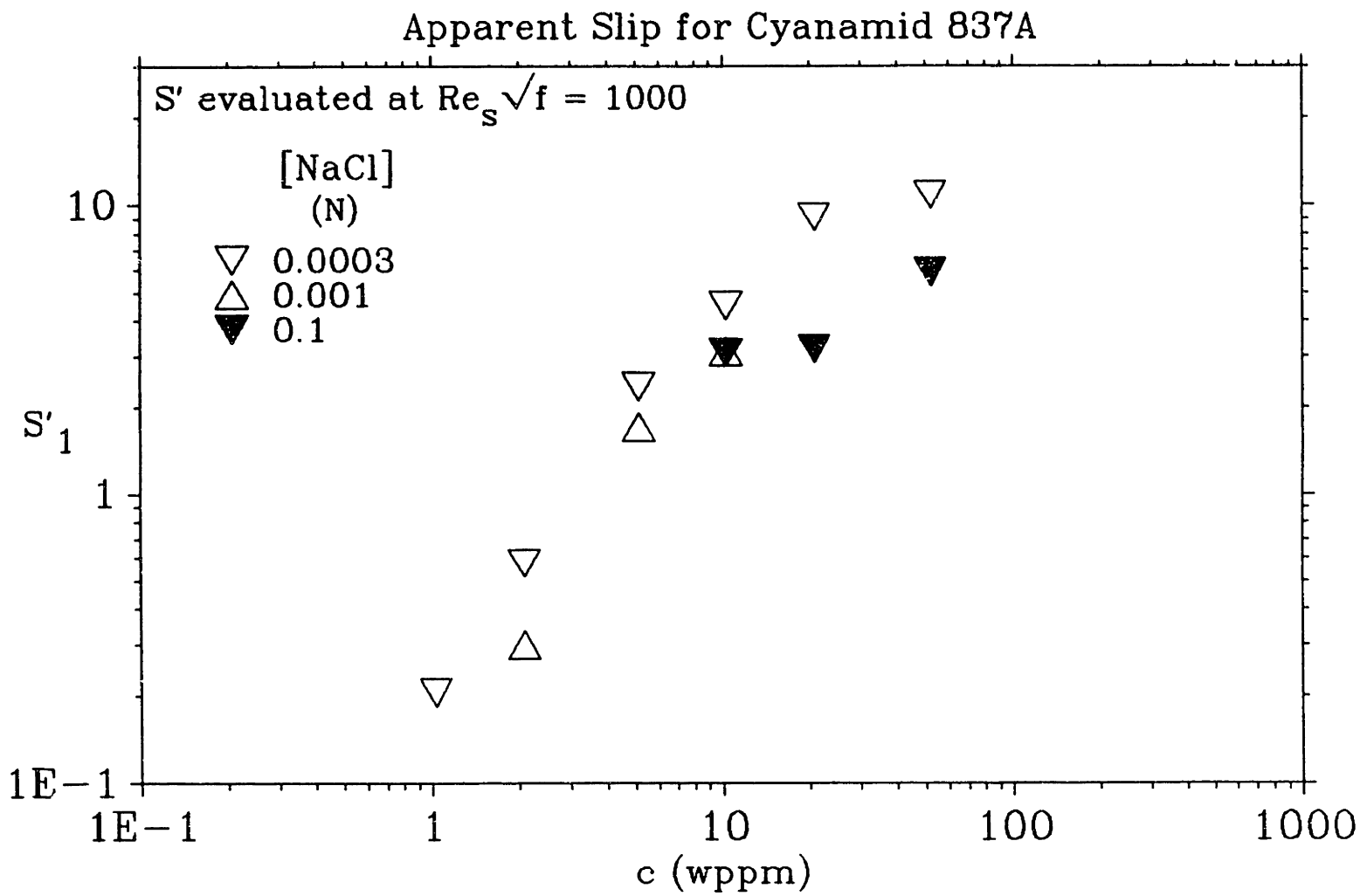


Figure 5.3.8: Apparent Slip S'_1 for Cyanamid 837A

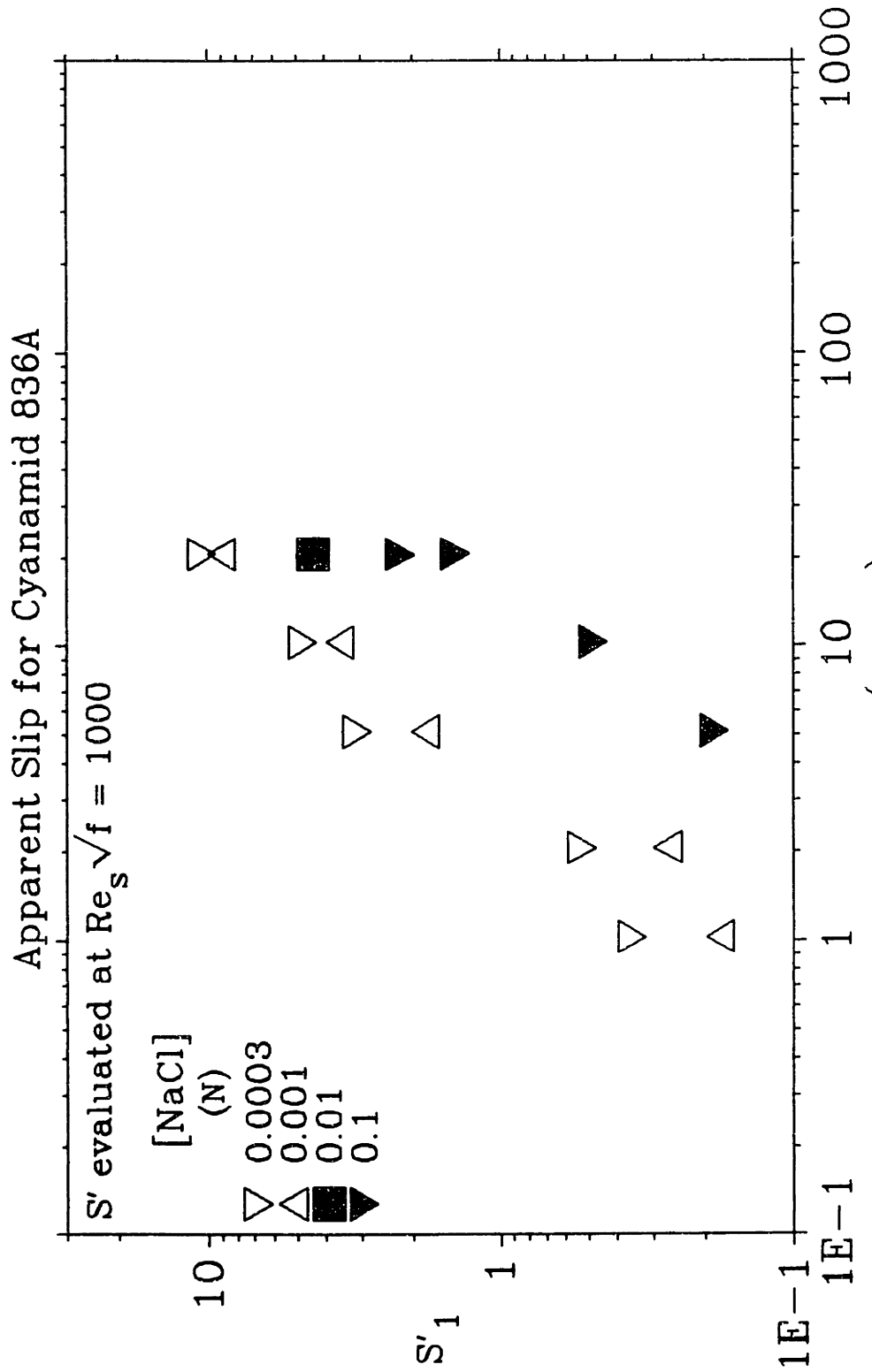


Figure 5.3.9: Apparent Slip S'_1 for Cyanamid 836A

5.3.2 The Slope Increment δ

Figures 5.3.10 - 5.3.16 are double-logarithmic plots of the slope increment δ versus concentration c for additives C832A, B1120, P500, A507 & D1438, C837A, and C836A, respectively, from all runs. Whereas in Type-B drag-reduction the rungs of the ladder have slopes that are only slightly larger than the slope of the turbulent baseline N, in Type-A drag-reduction the spokes of the Type-A fan generally have slopes appreciably steeper than N. Thus the slope increment δ in Type-A behavior, at high salinity, generally exceeds that in Type-B behavior, at low salinity.

In Figure 5.3.10 for additive C832A, values of δ at high salinity are clearly greater than those at low salinity. The slope increments δ observed from the gravity-driven system(○ ▽ △ ▼) and the pump-driven system(◇ ◆) are nearly equal. At high concentration, the data reach nearly a constant value because of the limiting effect of the MDR asymptote.

To discern the effect of pipe diameter, Figure 5.3.11 juxtaposes data in the 1.458-cm(○ ▽) and 1.021-cm(● ▼) pipes, from the pump-driven system, at both 0.3 and 0.0001 N NaCl. For c > 1 wppm, data at high salinity(▽ ▼) and at low salinity(○ ●) are either adjacent or overlapping, the former exceeding the latter, indicating that pipe diameter has only a weak effect on the shape of the Type-A fan and the Type-B ladder, respectively.

In Figures 5.3.12 and 5.3.13, the slope increments δ for additives B1120 and P500, respectively, show the same trends as in Figure 5.3.10. High-salinity data exceed low-salinity data and reach a limiting MDR value at high concentrations. In Figure

5.3.13 as in Figure 5.3.11, data from the 1.458-cm(○ ▽) and 1.021-cm(● ▼) pipes, from the pump-driven system, are compared directly at both high(▽ ▼) and low(○ ●)salinity. At each concentration, data from each pipe either overlap or lie adjacently, again suggesting that Type-A behavior, as well as Type-B behavior, is influenced little by pipe diameter.

Figure 5.3.14 shows data for additives A507 and D1438. Because each additive exhibits Type-A fans at both high and low salinities, the latter having both lower $Re_s\sqrt{f}$ and steeper slopes, the slope increments at low salinity are greater than those at high salinity for both additives. All the slope increments for D1438 slightly exceed all those for A507.

Figures 5.3.15 and 5.3.16, for respective additives C837A and C836A, show nearly-equal slope increments δ at all salinities for $c \geq 2$ wppm, strongly reflecting Type-A drag-reduction behavior.

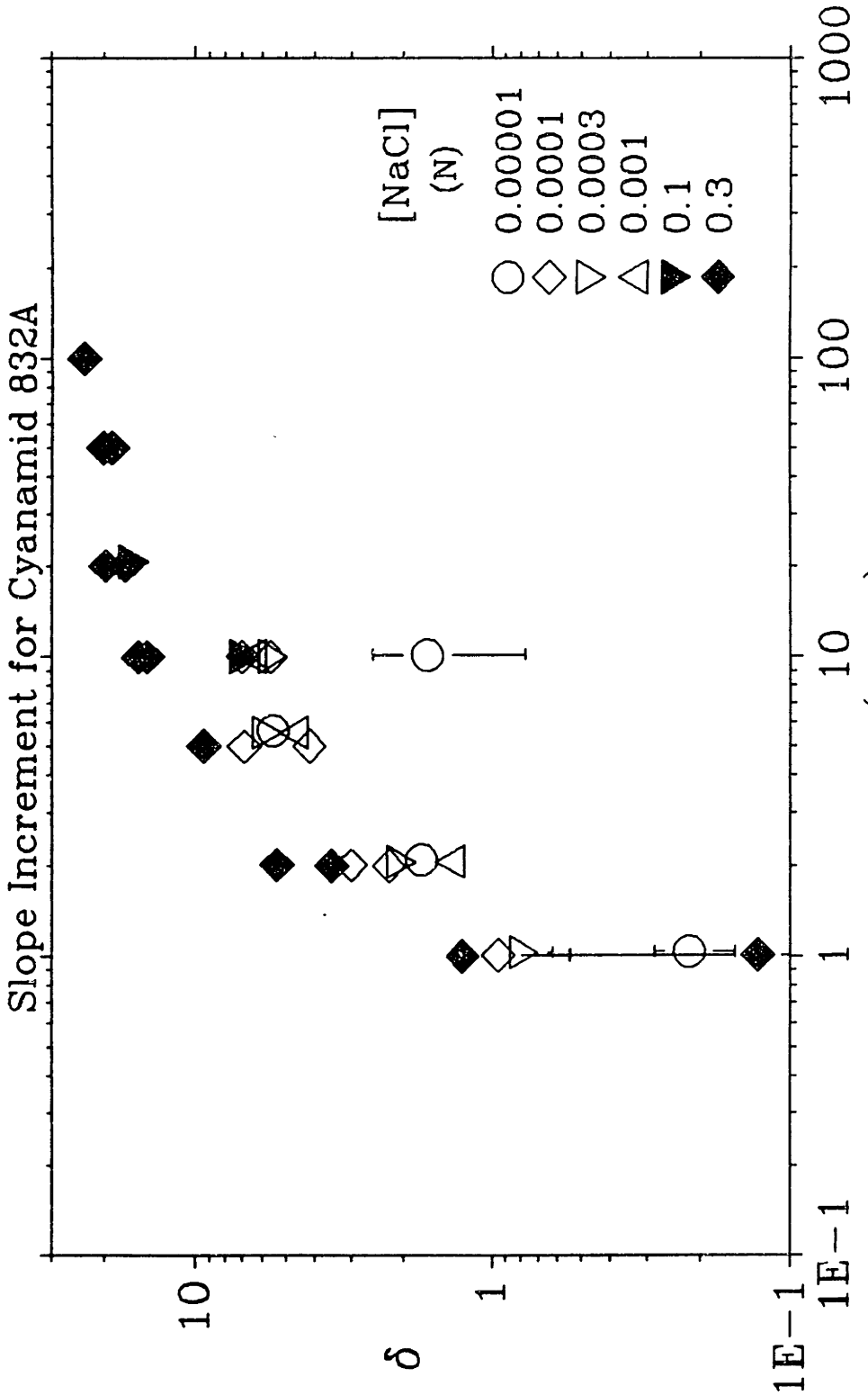


Figure 5.3.10: Slope Increment δ for Cyanamid 832A

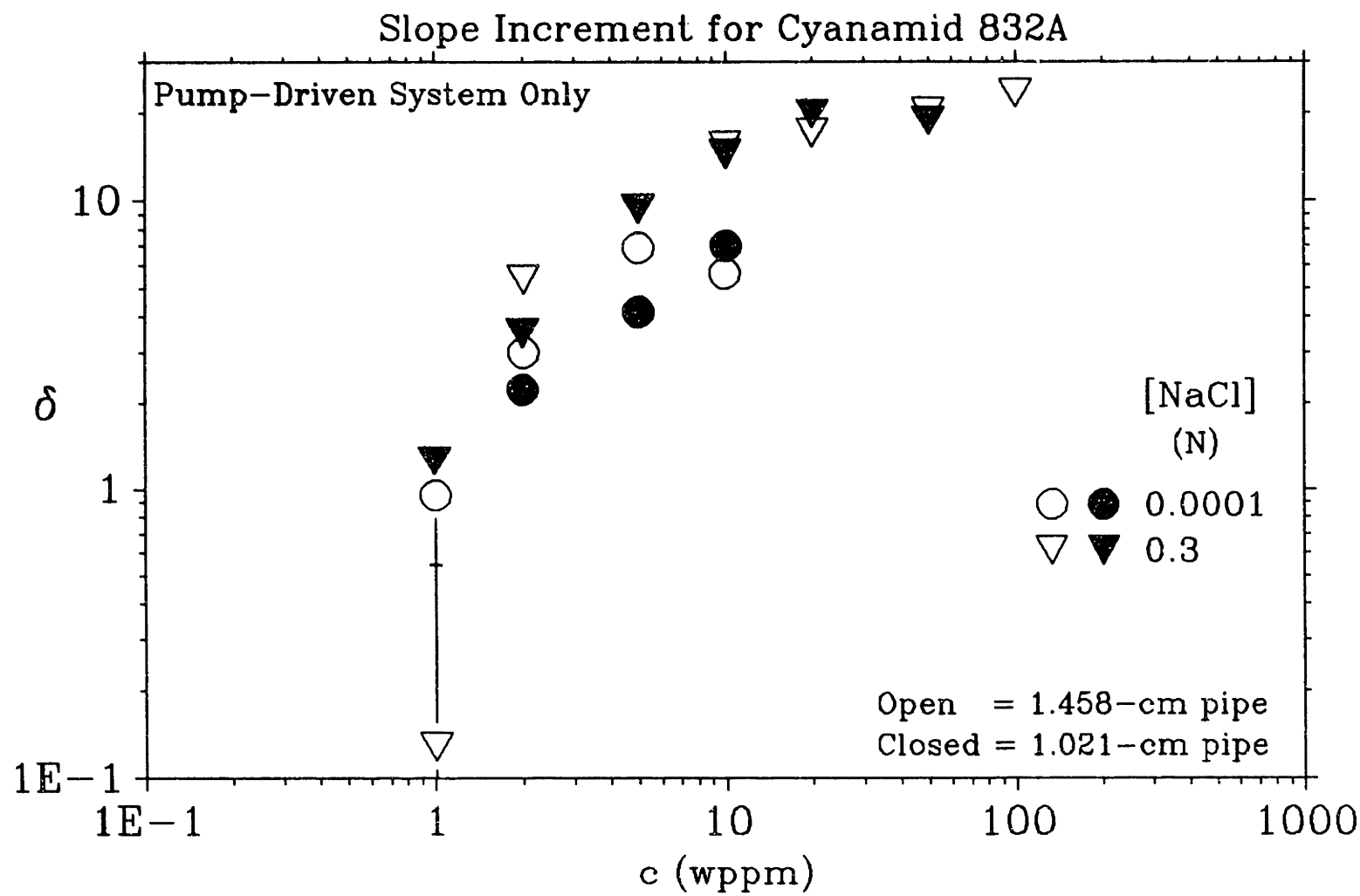


Figure 5.3.11: Slope Increment δ for Cyanamid 832A from the Pump-Driven System in Both Pipes

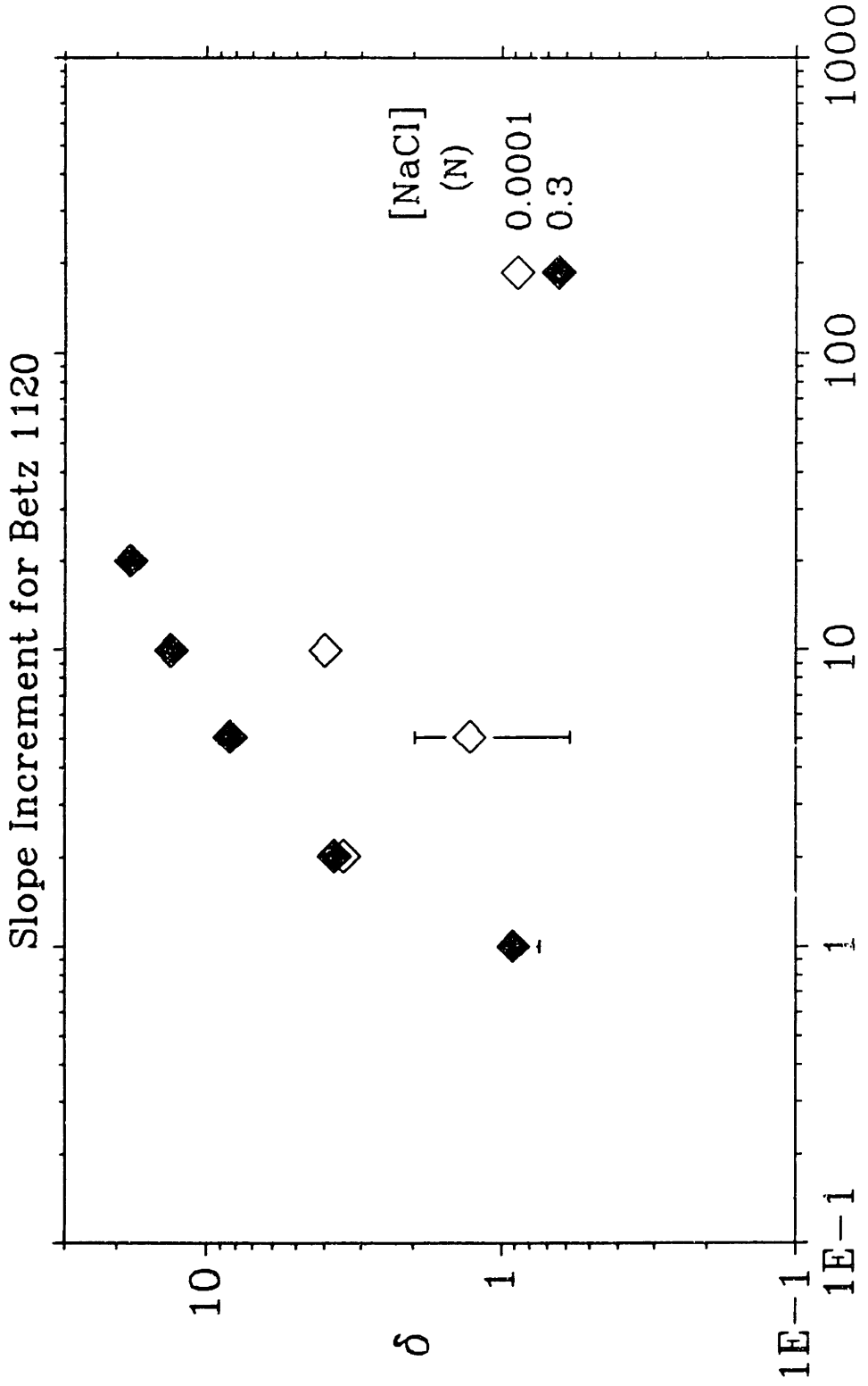


Figure 5.3.12: Slope Increment δ for Betz 1120

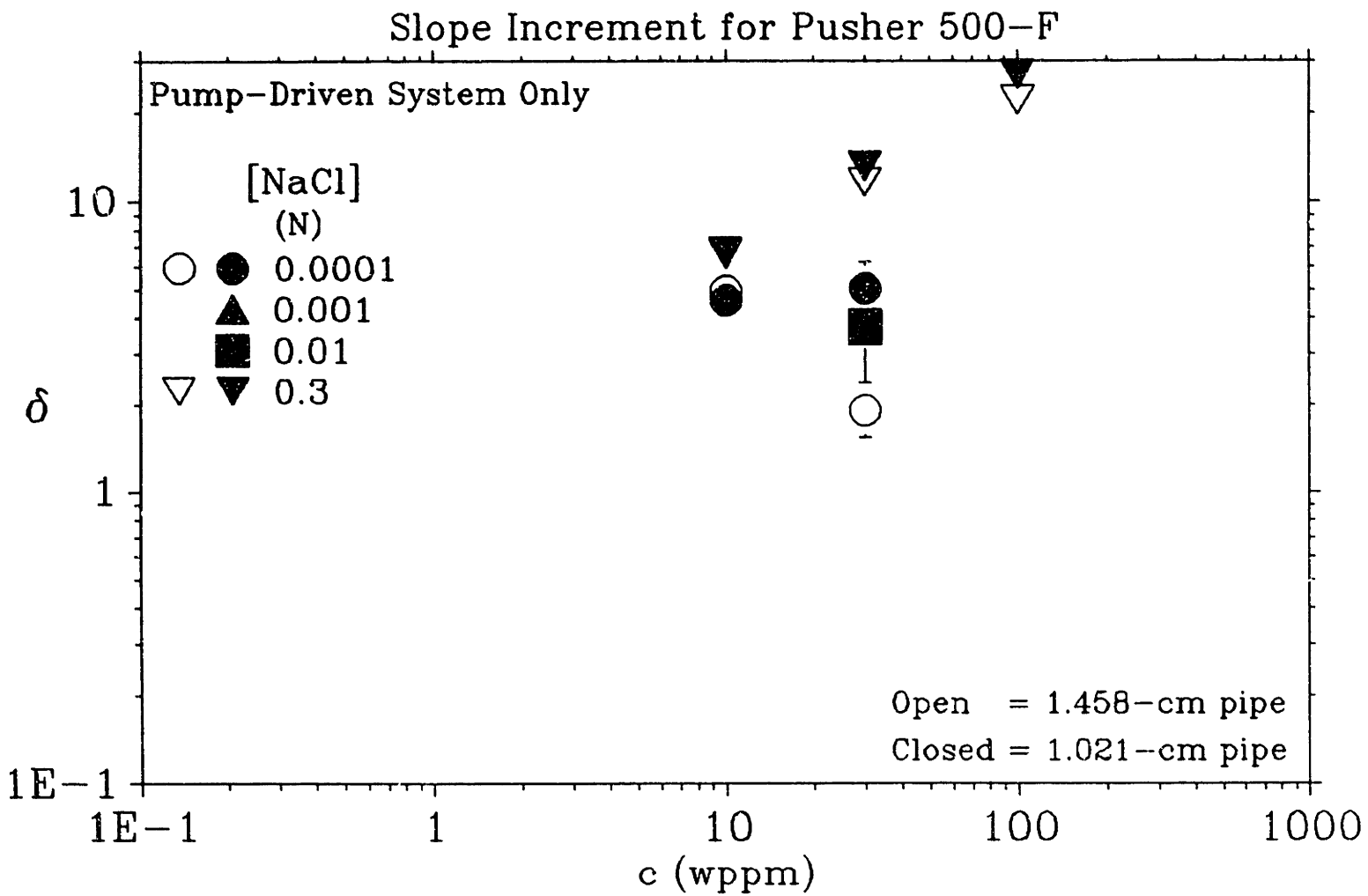


Figure 5.3.13: Slope Increment δ for Pusher 500-F

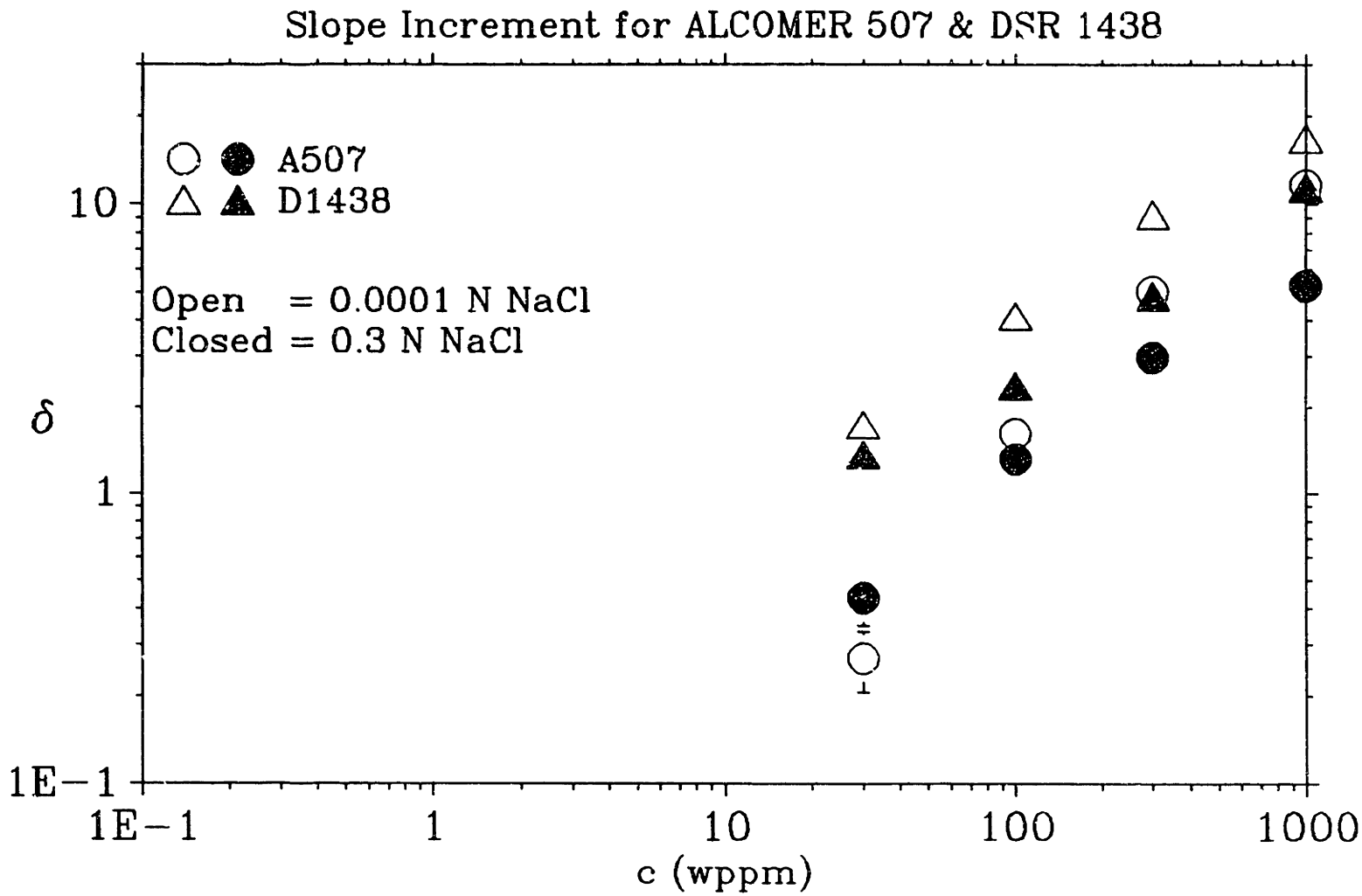


Figure 5.3.14: Slope Increment δ for Alcomer 507 and DSR 1438

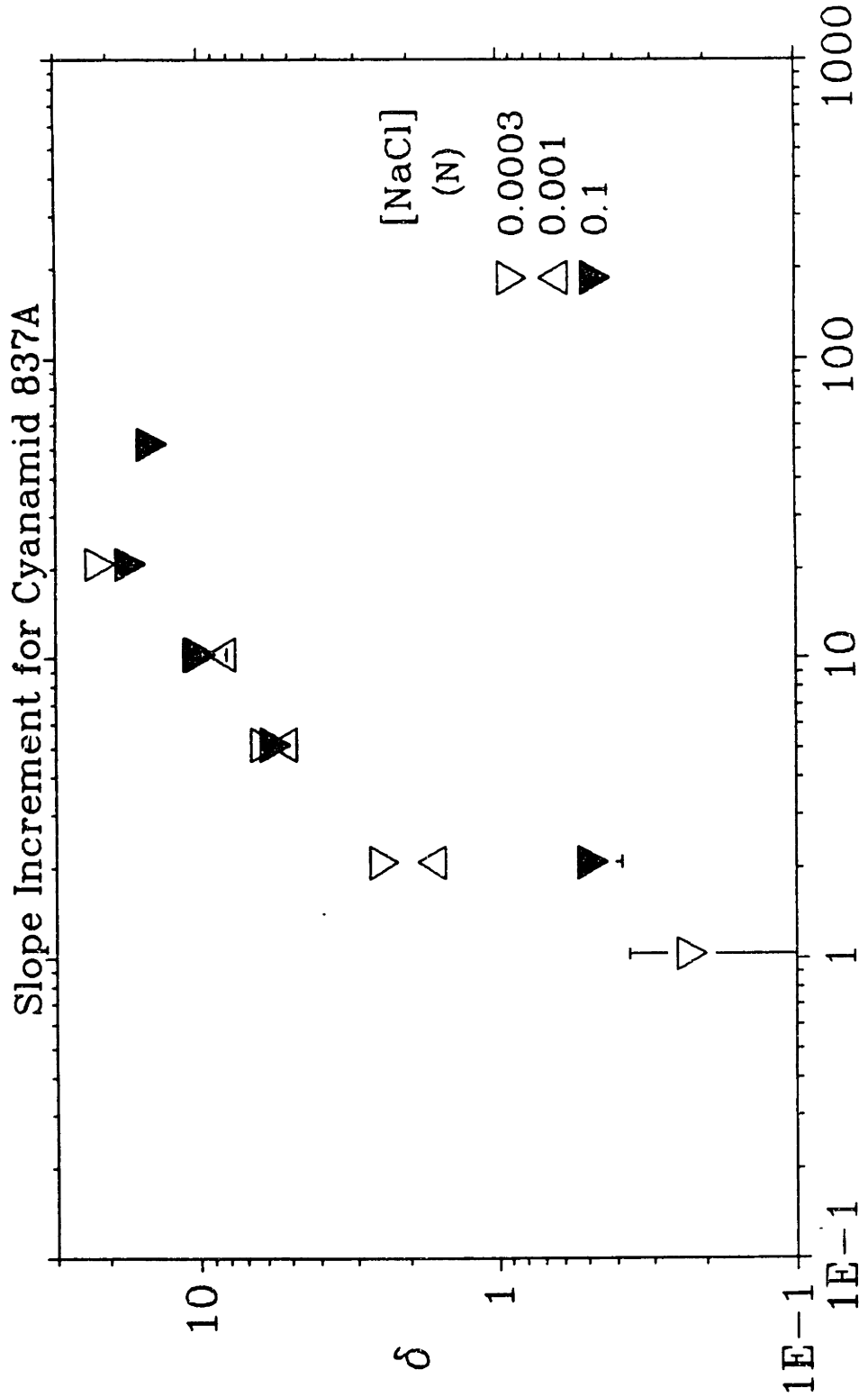


Figure 5.3.15: Slope Increment δ for Cyanamid 837A

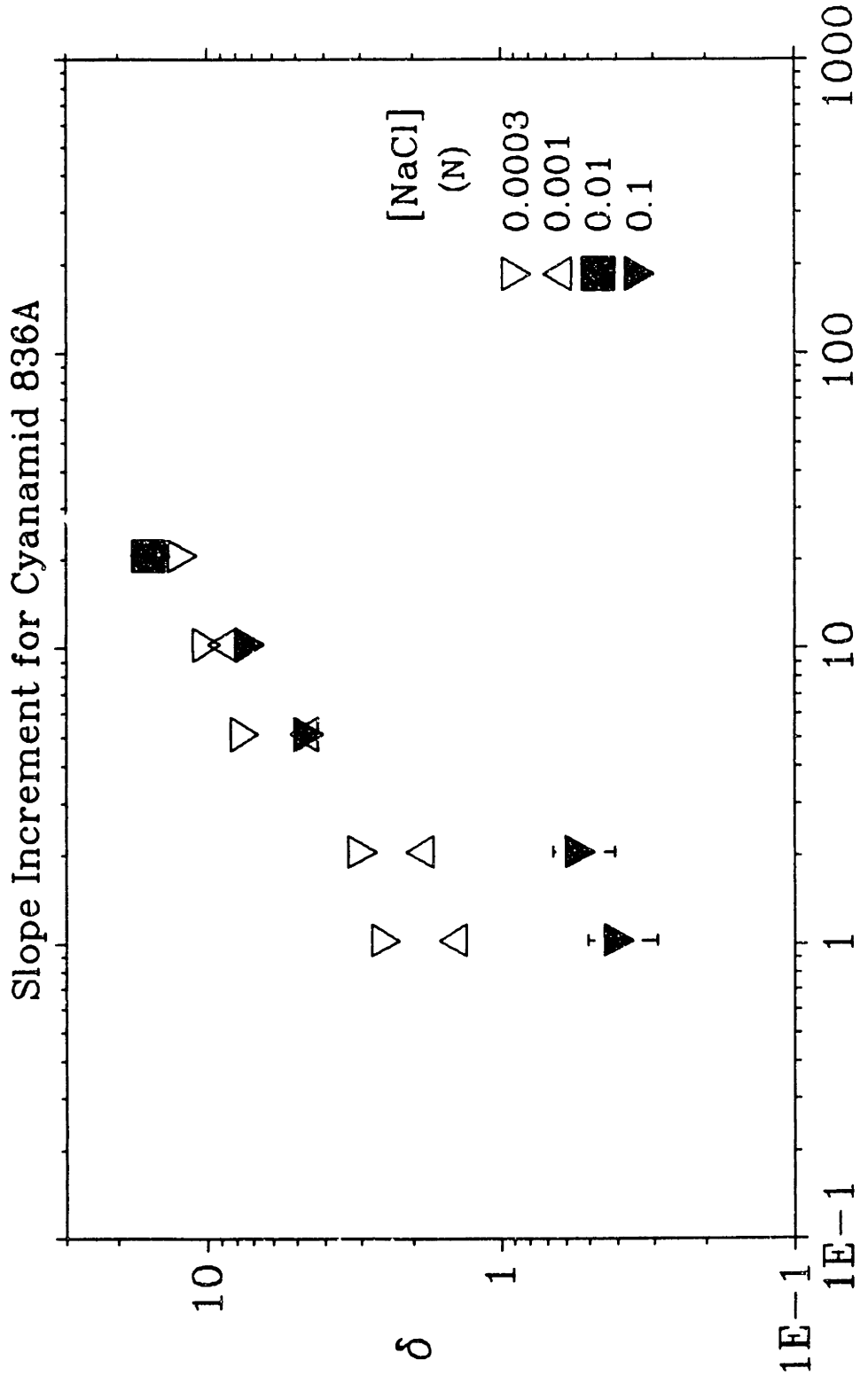


Figure 5.3.16: Slope Increment δ for Cyanamid 836A

5.3.3 The Onset Wall Shear Stress T_w^*

Figures 5.3.17 - 5.3.22 show the concentration dependence of the onset wall shear stress T_w^* for all additives, and average values are summarized in Table 5.3.3.

To provide both consistency and significance to the preceding slope-increment data, the regressed T_w^* are plotted against concentration with the error bars reflecting the uncertainty in the slopes and intercepts (A_p, B_p), from which the slope increments are derived. It should be noted that even the regressed T_w^* derived from (A_p, B_p), for which the standard-error coefficients are small and the square of the regression coefficient $r^2 > 0.999$, has an uncertainty of ± 50 percent. The uncertainty in T_w^* is determined from the minimum and maximum regressed T_w^*, using all combinations of (A_p, B_p) and their standard-error coefficients. (See discussion preceding Table 5.2.2.) Both large standard-error coefficients and small slopes A_p, which occur mostly at low concentrations, increase the difference between minimum and maximum T_w^* values and, thus, the uncertainty in T_w^*. Because the ideal Type-A fan, characterized by T_w^* and (A_p, B_p), radiates from a single point on the turbulent baseline N, the onset wall shear stress T_w^* has one concentration-independent value; however, under the best conditions, the many T_w^* in a given fan lie within a narrow range and have small uncertainties.

In each of Figures 5.3.17 - 5.3.22, the T_w^* data-scatter about an average T_w^* value. Table 5.3.3 summarizes the best overall average T_w^* calculated from the best T_w^* values for each additive; the standard deviation accompanying each value reflects the scatter in the best T_w^* values and not the uncertainty in the overall average, which is at least 100 percent.

Table 5.3.3
Overall Average T_w^* for Each Polymer Additive

Polymer	Ensemble Average Onset Wall Shear Stress	Number of Values
	T_w^*†	
	(dyne/cm^2)	
C832A	7.7±2.2	5
B1120	6.4±1.2	3
P500	9.5±4.6	4
A507	50.4±20.1	6
D1438	41.0±19.2	8
C837A	13.7±7.0	6
C836A	15.2±4.6	10

† ±[ ] are the standard deviations of the averages, not the uncertainties in them.

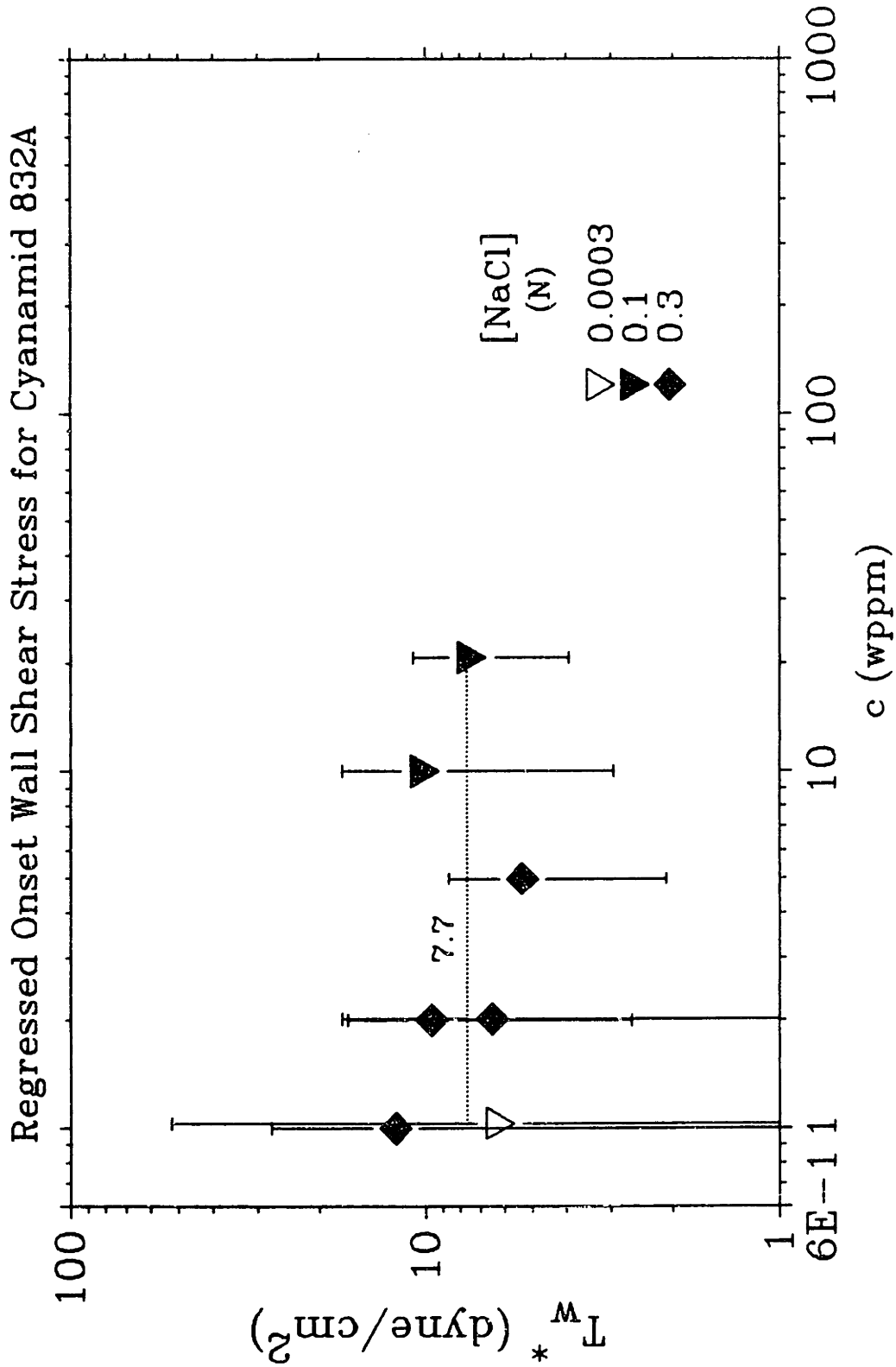


Figure 5.3.17: Regressed Onset Wall Shear Stress T_w^* for Cyanamid 832A

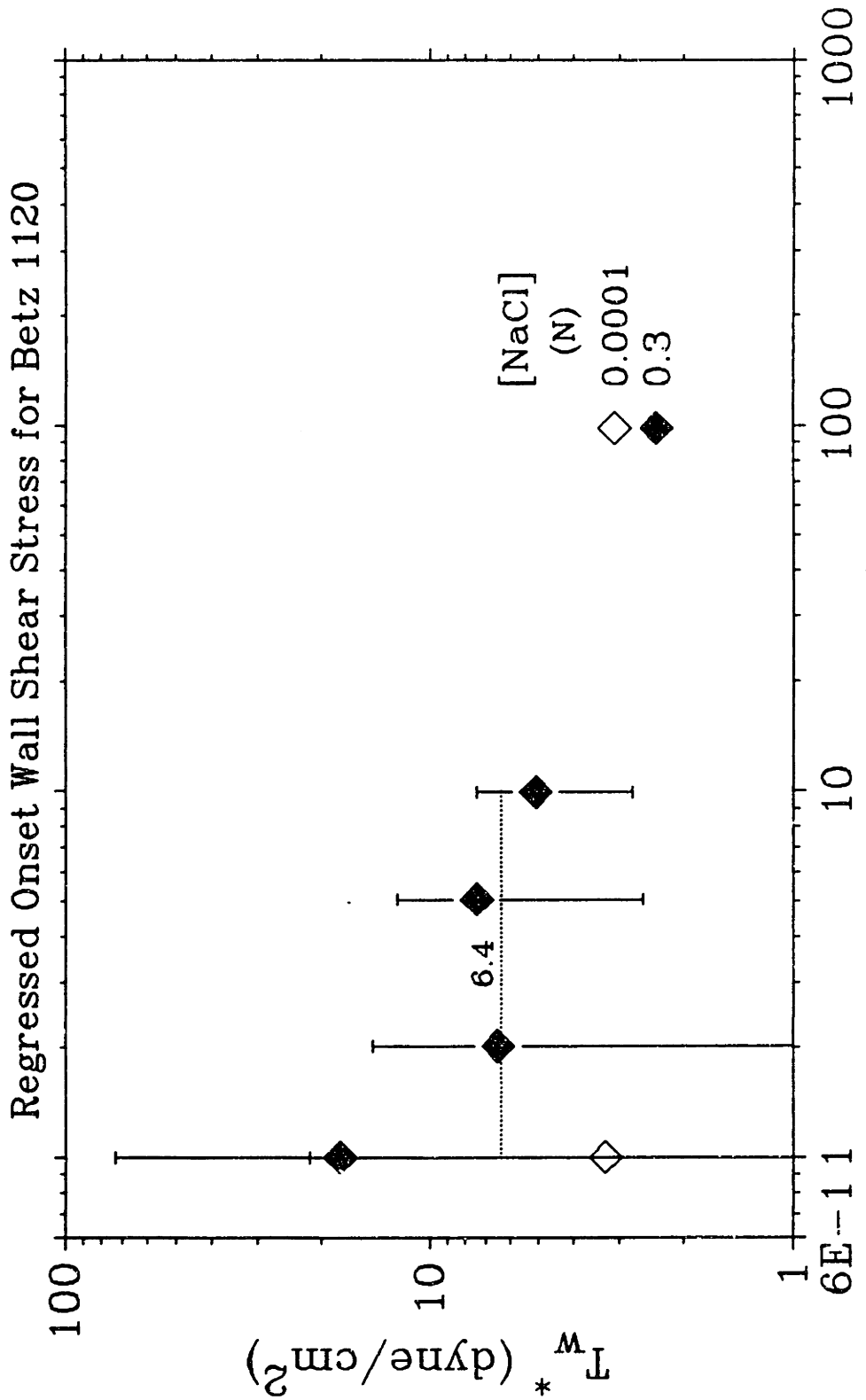


Figure 5.3.18: Regressed Onset Wall Shear Stress T_w^* for Betz 1120

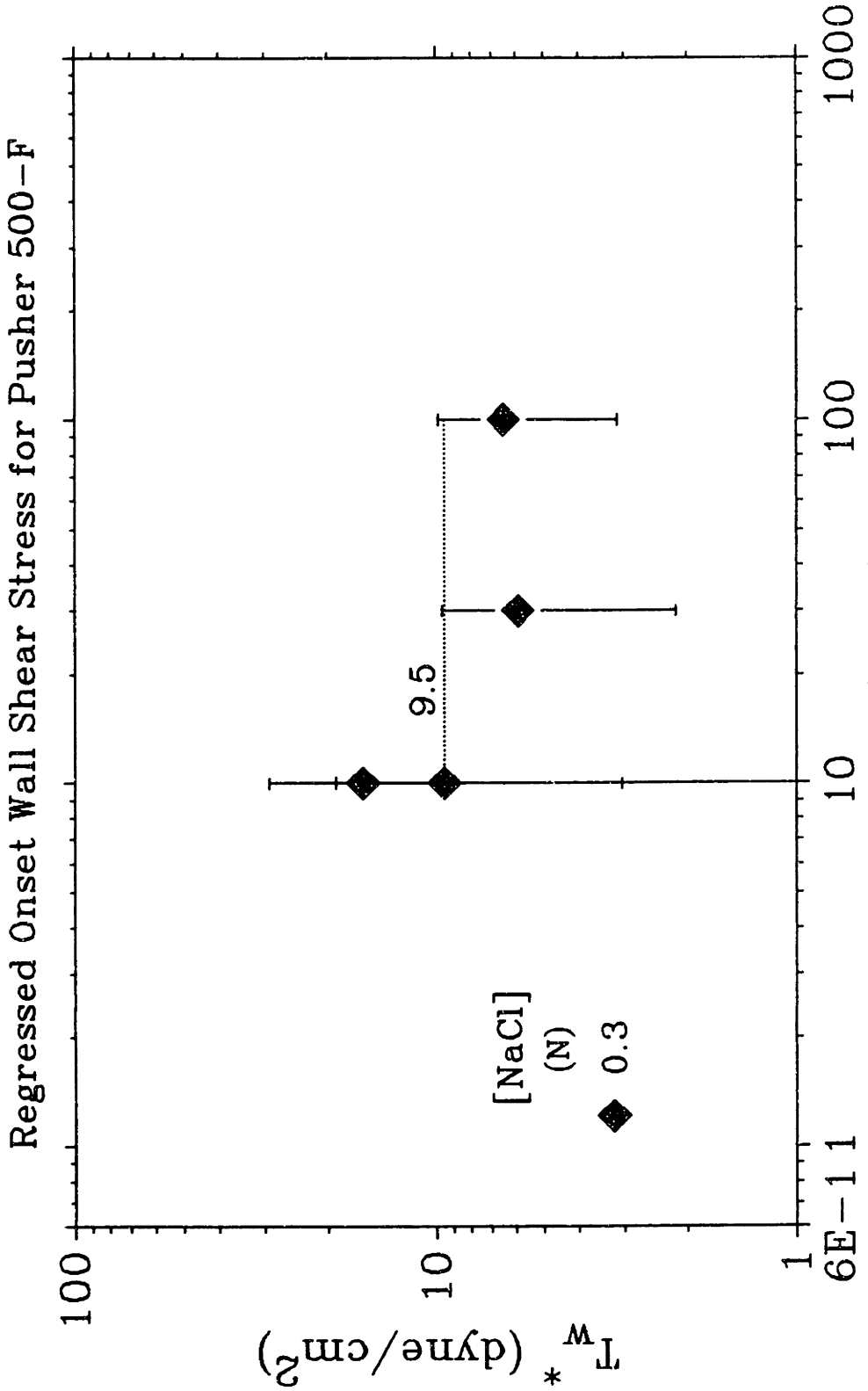


Figure 5.3.19: Regressed Onset Wall Shear Stress T_w^* for Pusher 500-F

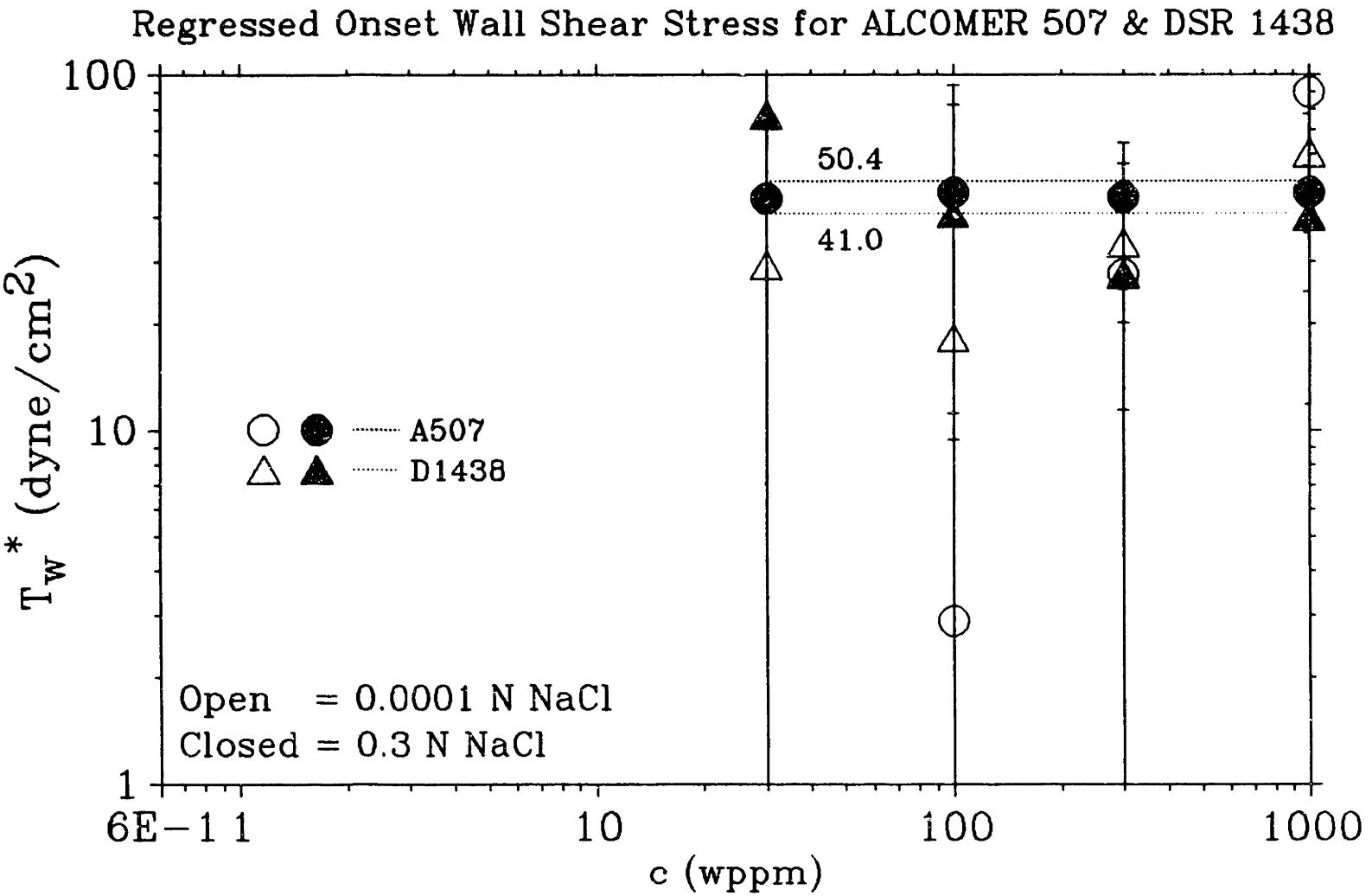


Figure 5.3.20: Regressed Onset Wall Shear Stress T_w^* for Alcomer 507 and DSR 1438

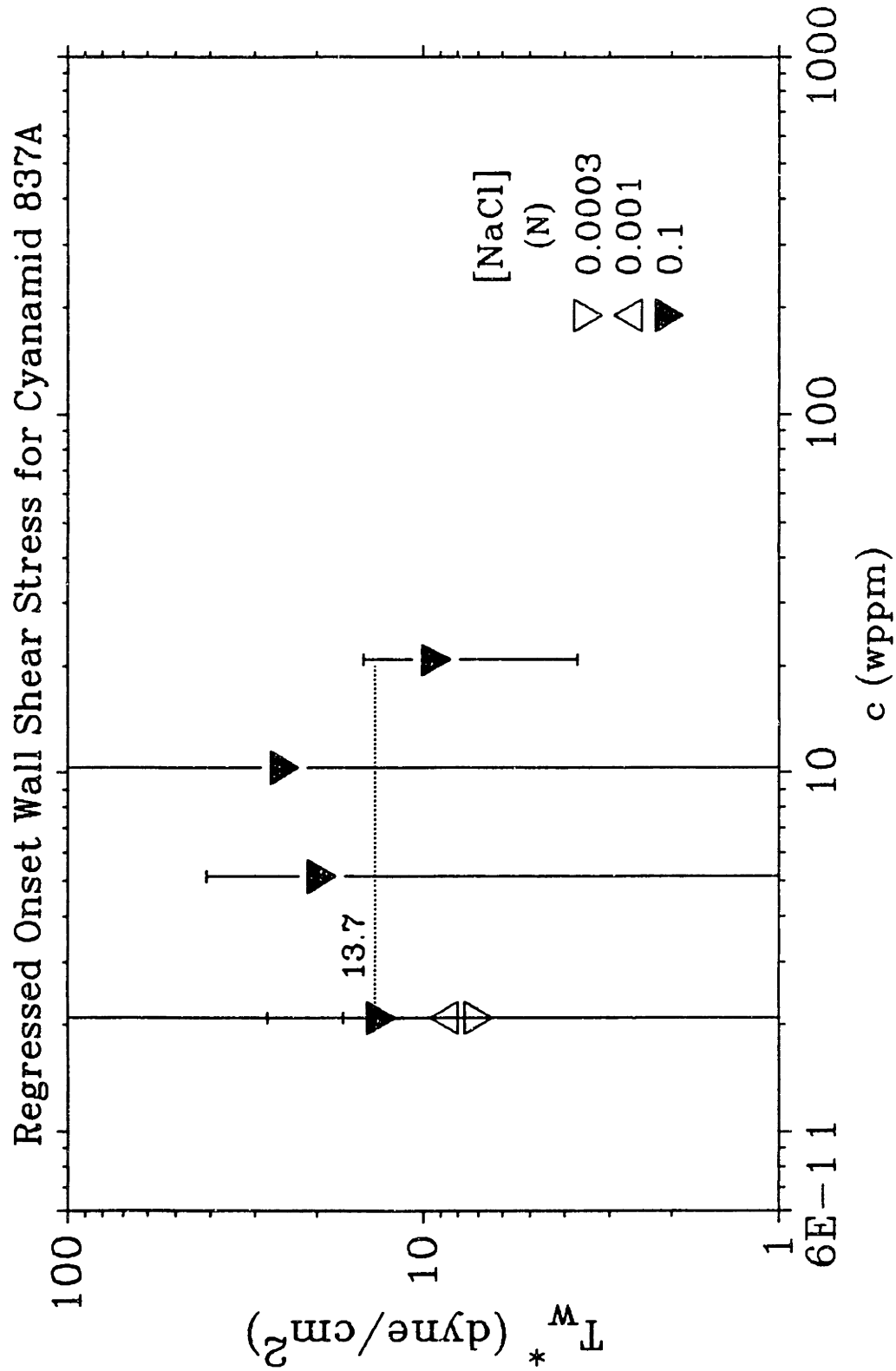


Figure 5.3.21: Regressed Onset Wall Shear Stress T_w^* for Cyanamid 837A

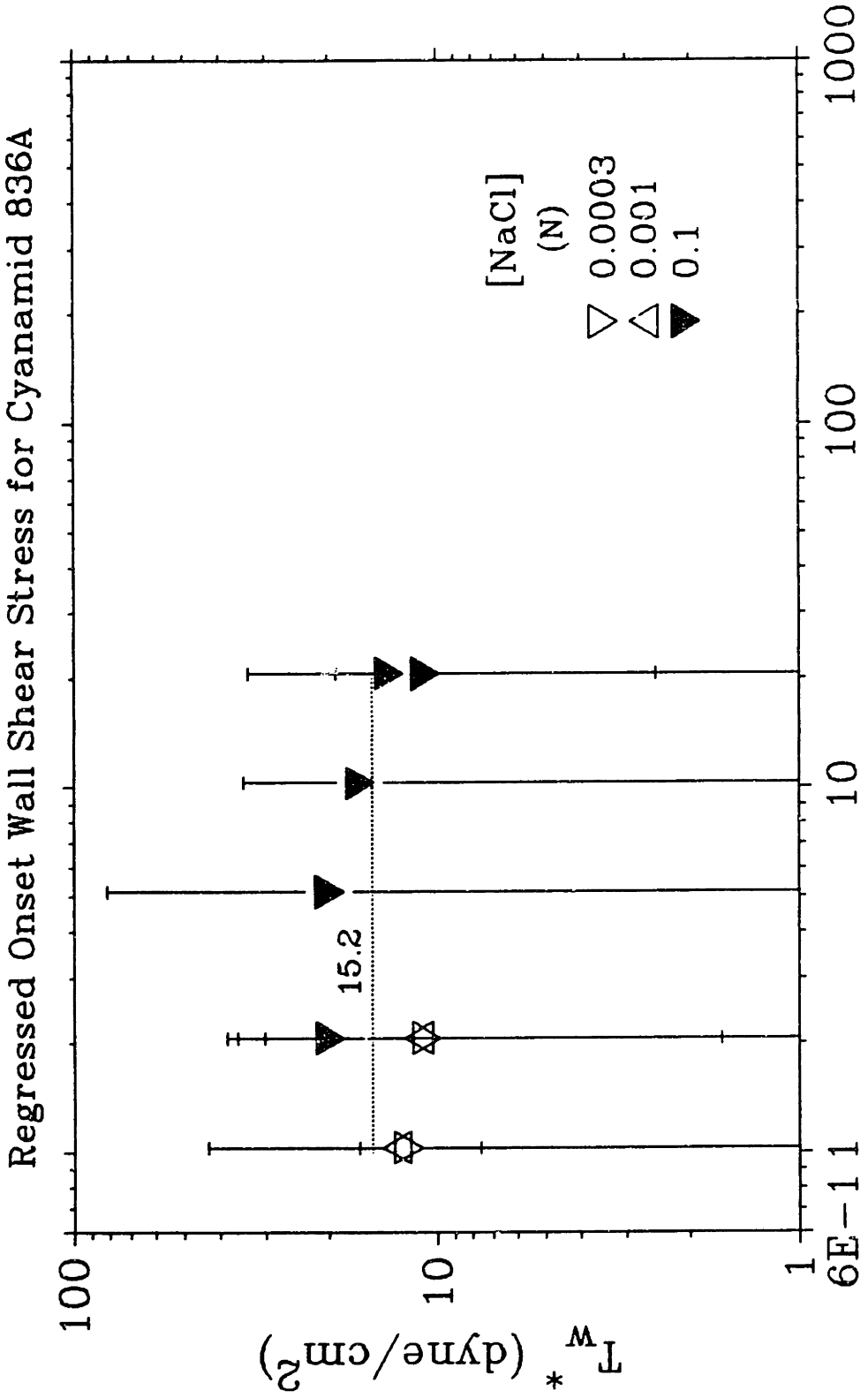


Figure 5.3.22: Regressed Onset Wall Shear Stress T_w^* for Cyanamid 836A

5.3.4 The Retro-Onset Wall Shear Stress $T_w^\#$

Figure 5.3.23 illustrates the concentration dependence of the regressed retro-onset wall shear stress $T_w^\#$ in semi-logarithmic coordinates. Because the retro-onset phenomenon in Type-B drag-reduction behavior occurs less frequently than the onset phenomenon does in Type-A drag-reduction behavior, all but two of the observed retro-onset points pertain to solutions of C832A with salinities up to 0.0003 N NaCl; solutions of B1120 and P500 with 0.0001 N NaCl account for the rest. Data from the 1.458-cm pipe are represented by open symbols; data from the 1.021-cm pipe, closed symbols.

As for the onset wall shear stress T_w^*, the retro-onset wall shear $T_w^\#$ is determined from the slopes and intercepts (A_p, B_p) of the segments P within a Type-B ladder and the slope and intercept of the MDR asymptote, (19.0, 32.4).(See discussion preceding Table 5.2.2.) The uncertainty in $T_w^\#$, shown by error bars in the figures, is determined from the lowest and highest regressed $T_w^\#$ that can be calculated from combinations of (A_p, B_p) and their standard errors. Because the MDR asymptote is much steeper than the turbulent baseline N, the uncertainty in $T_w^\#$ is generally much smaller than that for T_w^*.

In Figure 5.3.23, the log-$T_w^\#$ data for additives C832A and B1120 in the 1.458-cm pipe depends linearly on concentration. The resulting best-fit line through these data is:

$$\log T_w^\# = -0.436 + 0.134c \qquad (5.3\text{-}1)$$

The ordinate intercept corresponds to $T_w^\# = 0.37$ dyne/cm^2, which is very close to the "ideal" value $T_w^\# = 0.346$ dyne/cm^2, at the intersection of N($c = 0$) with M.

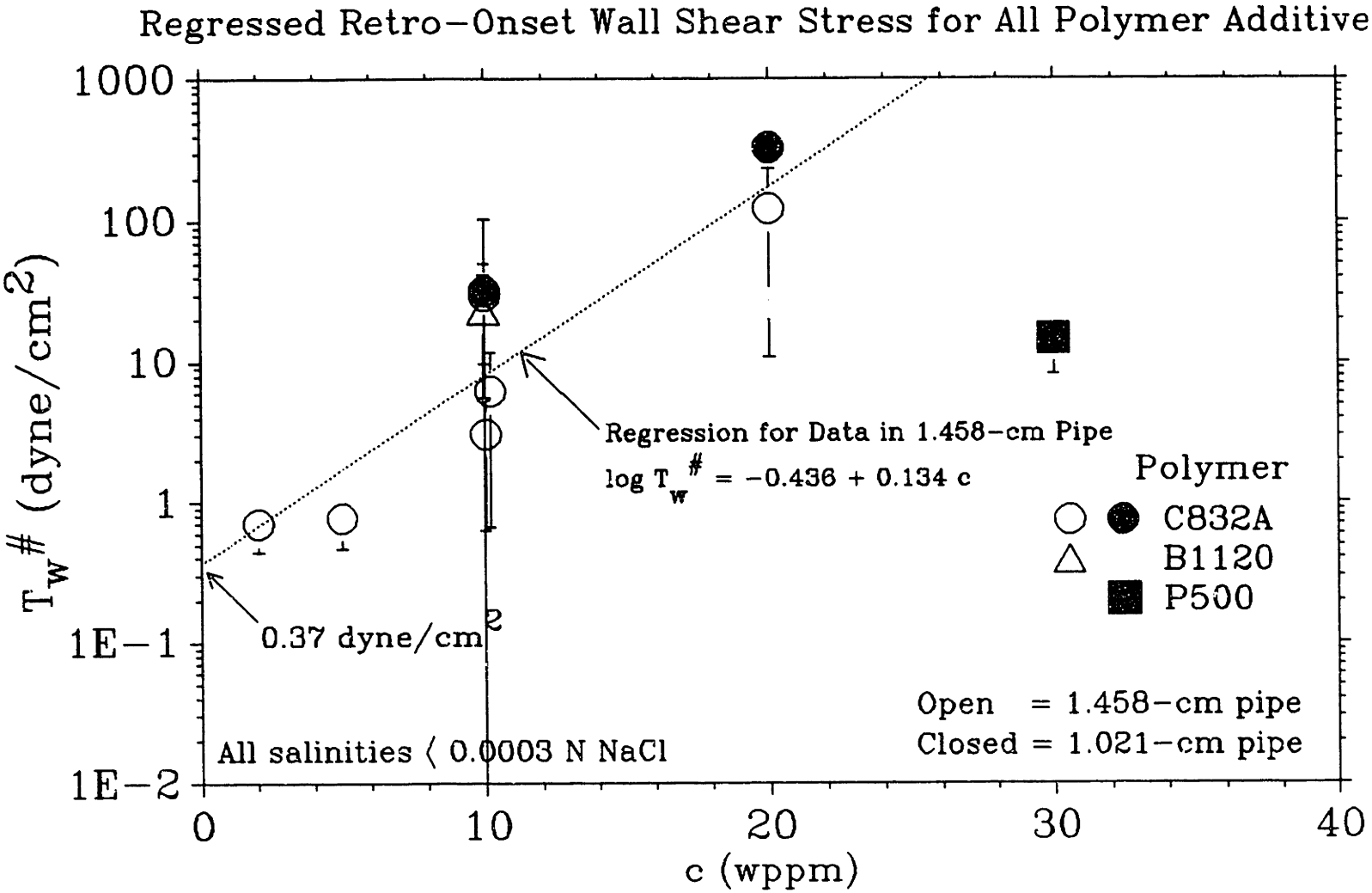


Figure 5.3.23: Regressed Retro-Onset Wall Shear Stress $T_w^{\#}$ for All Polymer Additives

5.4.1 Laminar-Flow Parameters

Figures 5.4.1 - 5.4.7 are double-logarithmic plots of the estimated intrinsic viscosity η_{sp}/c versus concentration c for additives C832A, B1120, P500, A507, D1438, C836A, and C837A, respectively, from all experiments. In each figure, the estimated intrinsic viscosities η_{sp}/c are grouped according to solution salinity. Data at low salinities, [NaCl] $\leq$ 0.001 N, are represented by open symbols; data at high salinity, [NaCl] $\geq$ 0.01 N, by closed symbols. For all data, it is assumed that the absolute error in pressure-drop measurement $\epsilon = \pm 2\%$, even though laminar-flow data for solvent adhered to Poiseuille's Law to within one percent. Using $\epsilon = \pm 1\%$ approximately halves the reported standard error in η_{sp}/c. The standard error in η_{sp}/c, denoted by bars above and below each data point, is calculated from the equation,

$$s.e. = \epsilon(\pm 2 + \epsilon)\left[\frac{\frac{\eta_{sp}}{c} + \frac{1}{c}}{\frac{\eta_{sp}}{c}}\right] \qquad (5.4\text{-}1)$$

As seen from equation 5.4-1, data at low concentrations have much greater uncertainty than data at higher concentrations. Thus, to get the best average η_{sp}/c for both the extended and collapsed conformations at low and high salinity, respectively, η_{sp}/c data with low uncertainties and at high concentrations are used to calculate the average η_{sp}/c. From equations 2.4-10 and 2.4-11, the macromolecular parameters for each additive can be inferred from the best average η_{sp}/c at high salinity, under the assumption that the collapsed conformation obtains. These parameters are summarized in Table 5.4.1.

Moreover, the ratio of the average η_{sp}/c at low salinity to that at high salinity approximates the intrinsic-viscosity ratio $[\eta]/[\eta]o$; from equations 2.4-2 and 2.4-5, it can be shown that $[\eta]/[\eta]o = \alpha^3$, the cube of the linear expansion factor α. From these data, the magnitude of macromolecular expansion can be determined.

Table 5.4.1
Inferred Polymer Characteristics

Polymer	Estimated Intrinsic Viscosity at High Salinity	Parameters Inferred Via Equations 2.4-10 and 2.4-11			
		Molecular Weight	Number of Backbone Chain Links	Radius of Gyration	Contour Length
	$\eta_{sp}/c^{\ddagger}$	$M_w \times 10^{-6}$	$N_{bb} \times 10^{-5}$	R_G	L_c
	(cm^3/g)	(g/mole)		(nm)	(μm)
C832A	3000±600	18.0±5.0	5.0±1.4	280±50	64±18
B1120	3300±800	20.1±6.4	5.6±1.8	300±60	71±23
P500	1850±500	9.5±3.5	2.7±1.0	190±40	34±12
A507	340±80	1.0±0.3	0.3±0.1	50±10	3.6±1.1
D1438	440±150	1.4±0.6	0.4±0.2	60±20	5.0±2.2
C837A*	2700±900	15.7±6.7	4.4±1.9	260±70	56±24
C836A	2700±1450	15.5±11.0	4.4±3.1	260±110	55±39

‡ ±[ ] are average standard errors of ±0.02ΔP in pressure measurement.
* Only one datum with a small average standard error and of uncertain accuracy.

Table 5.4.2
Macromolecular Expansion

Polymer	Estimated Intrinsic Viscosity η_{sp}/c		Coil Expansion Ratio	Linear Expansion Factor
	Low Salinity	High Salinity	α^3	α
	(cm^3/g)			
C832A	97000±2000	3000±600	32.4	3.2
B1120	97000±3000	3300±800	29.6	3.1
P500	72000±2000	1850±500	38.7	3.4
A507	7000±500	340±80	20.3	2.7
D1438	5800±400	440±150	13.0	2.4
C837A	31000±2000	2700±900	11.4	2.2
C836A	48000±4000	2700±1450	17.9	2.6

± values are average standard errors.

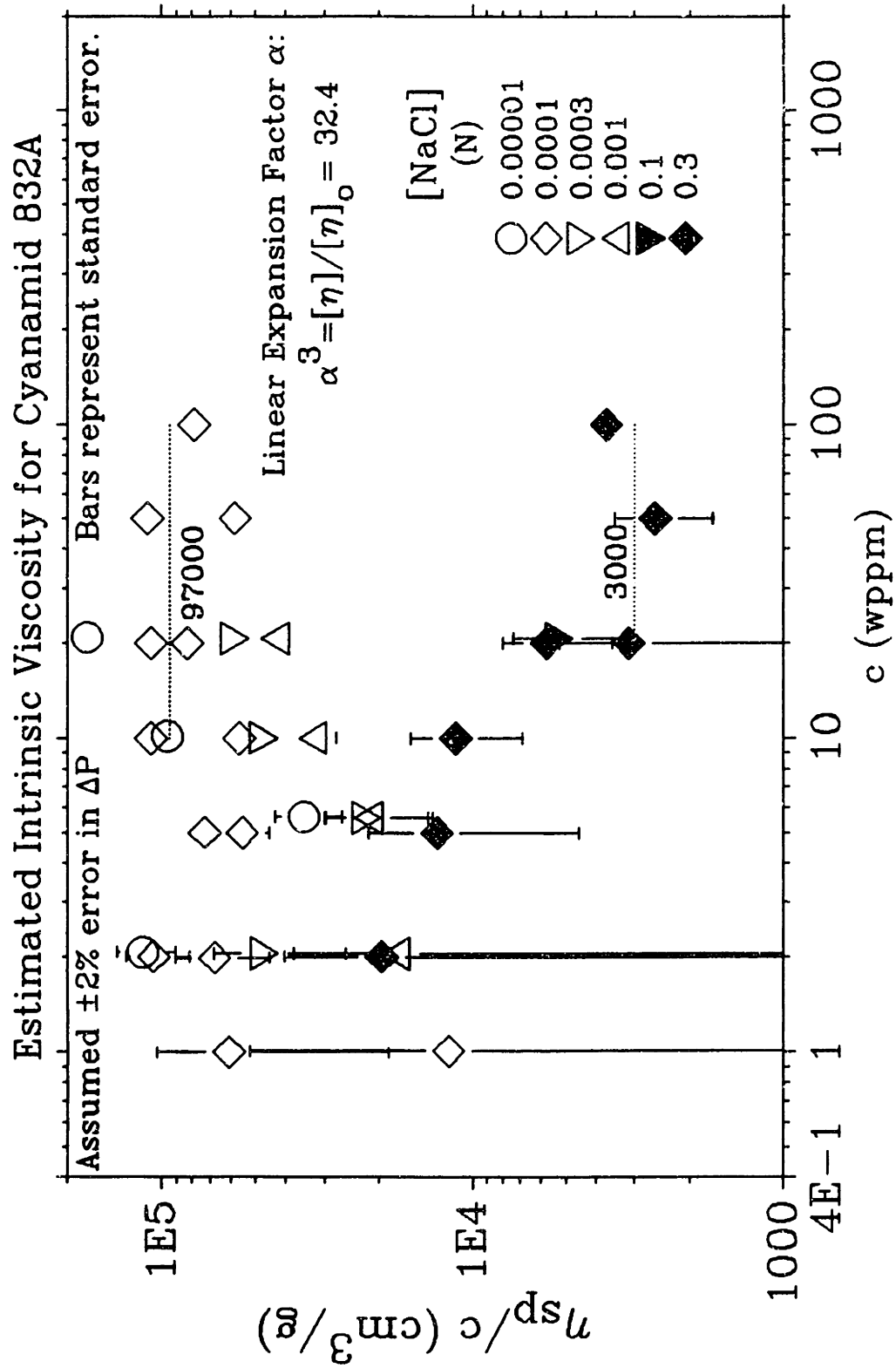


Figure 5.4.1: Estimated Intrinsic Viscosity η_{sp}/c for Cyanamid 832A

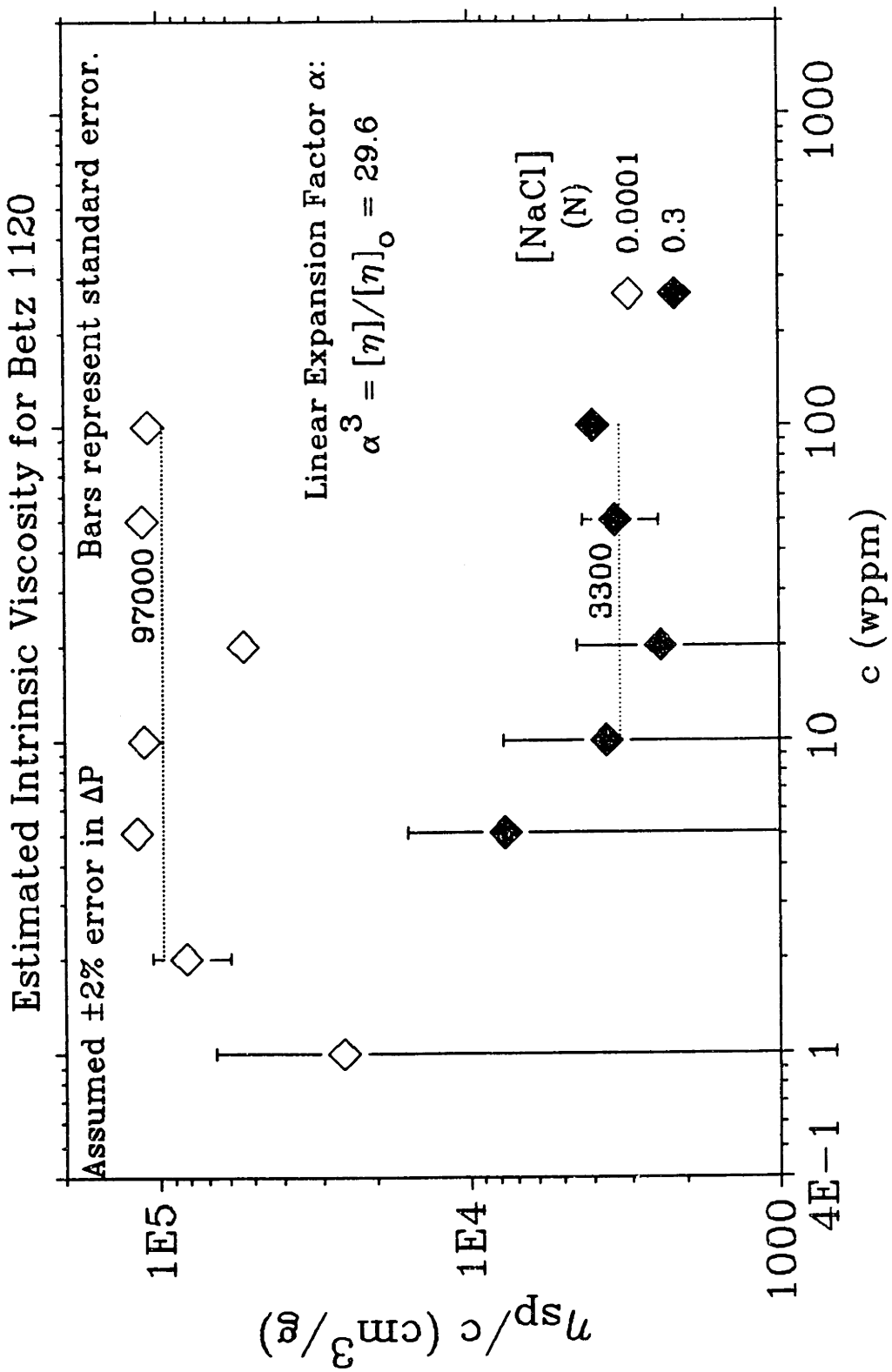


Figure 5.4.2: Estimated Intrinsic Viscosity η_{sp}/c for Betz 1120

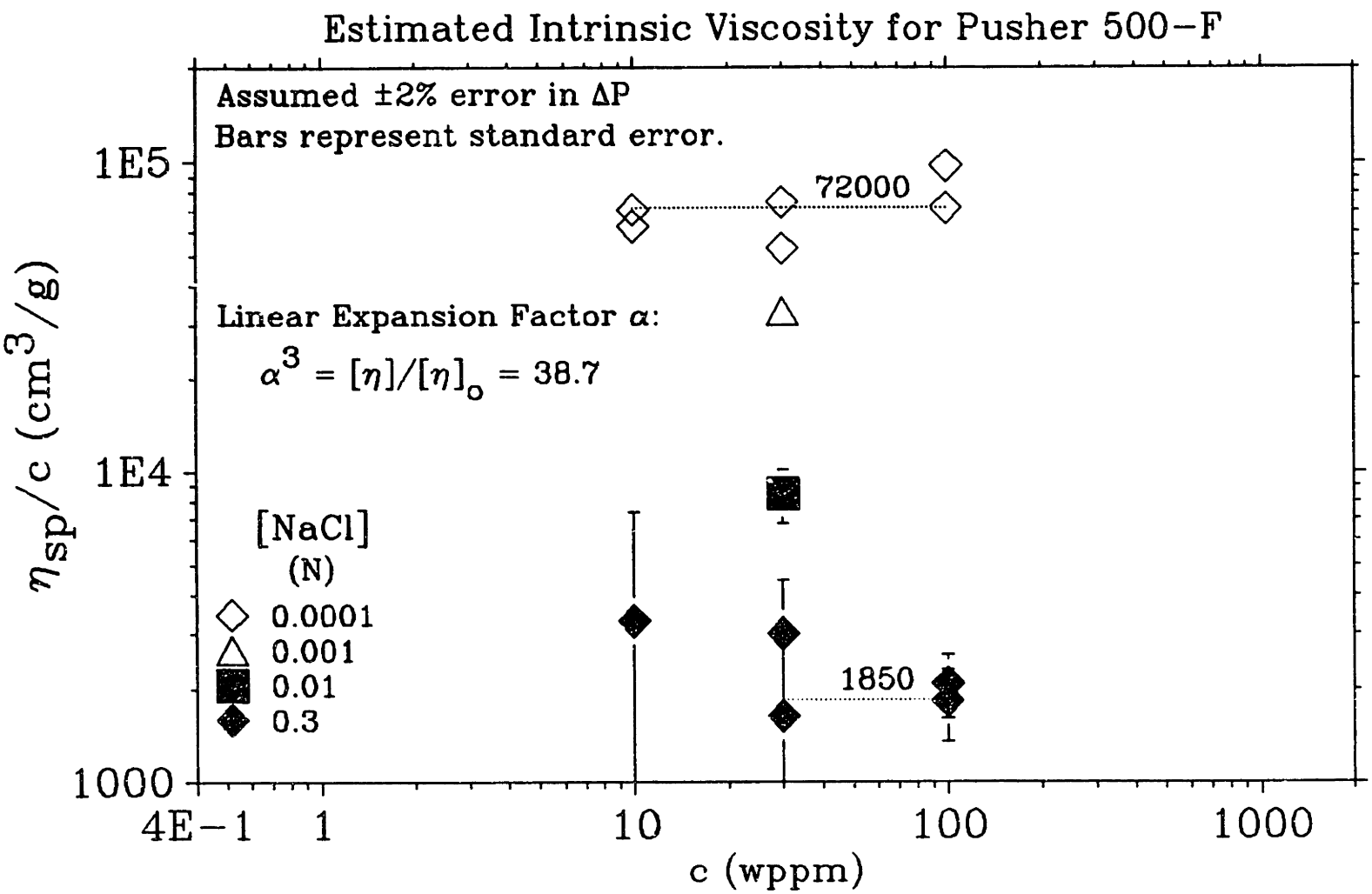


Figure 5.4.3: Estimated Intrinsic Viscosity η_{sp}/c for Pusher 500-F

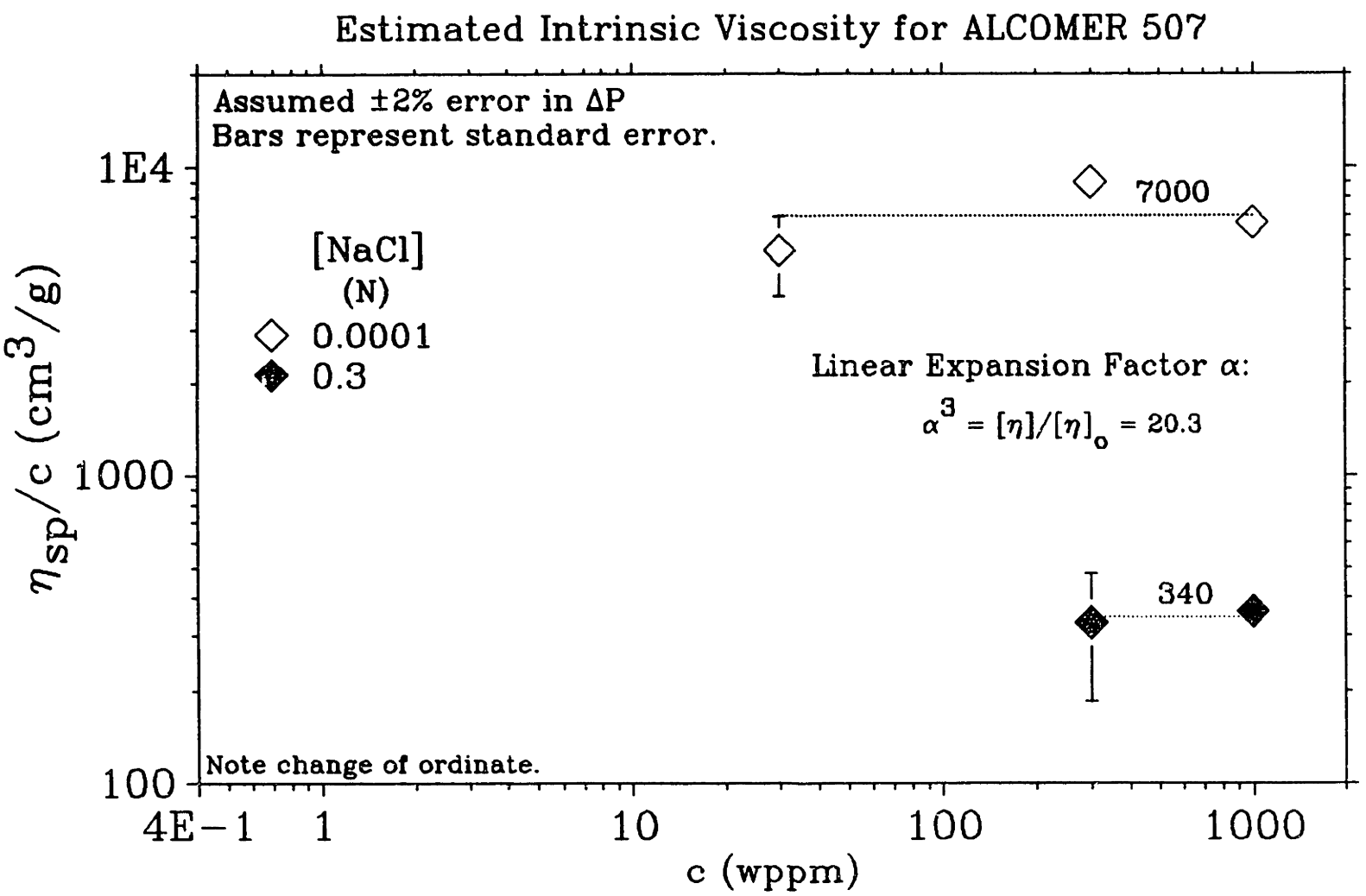


Figure 5.4.4: Estimated Intrinsic Viscosity η_{sp}/c for Alcomer 507

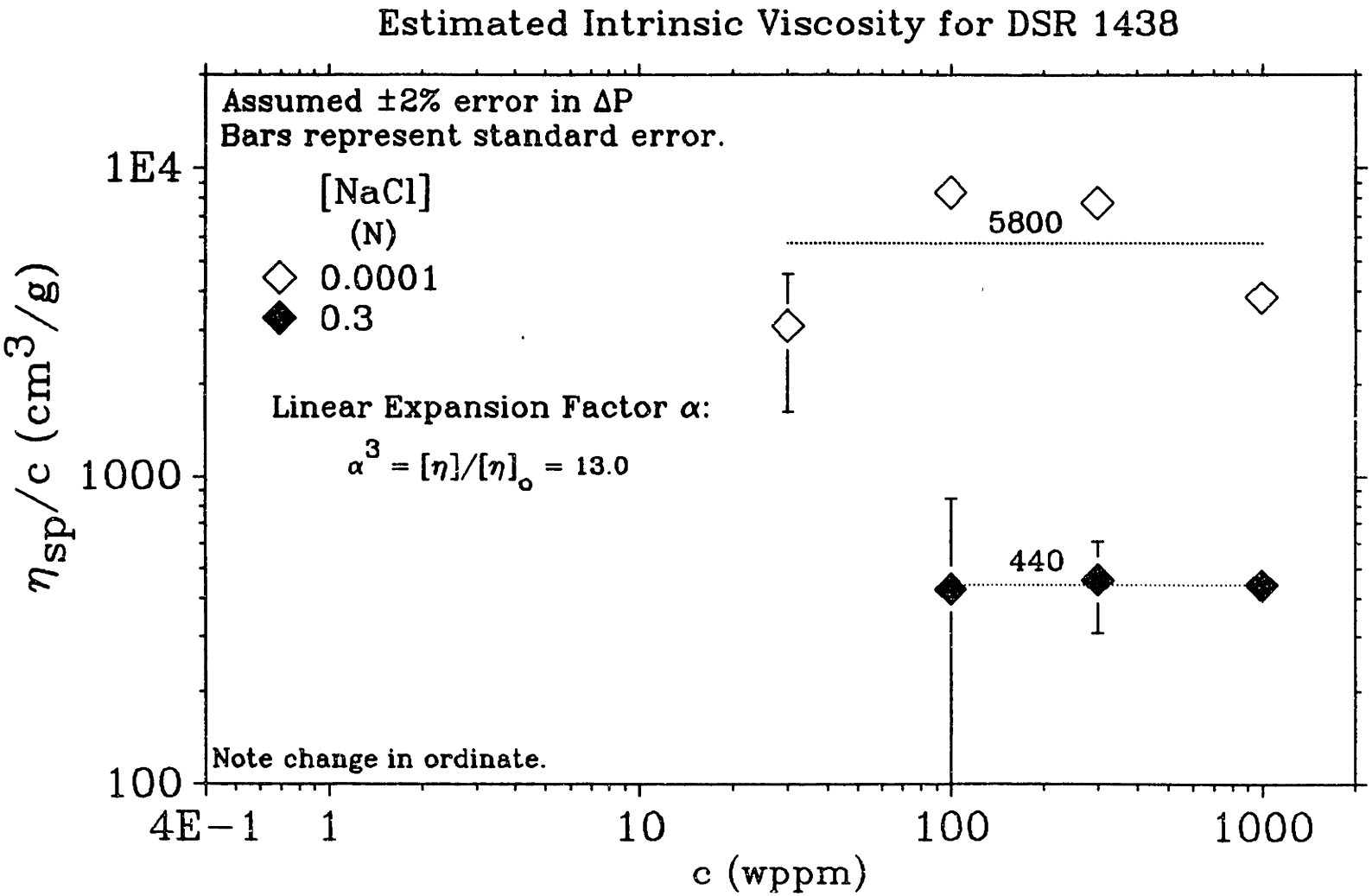


Figure 5.4.5: Estimated Intrinsic Viscosity η_{sp}/c for DSR 1438

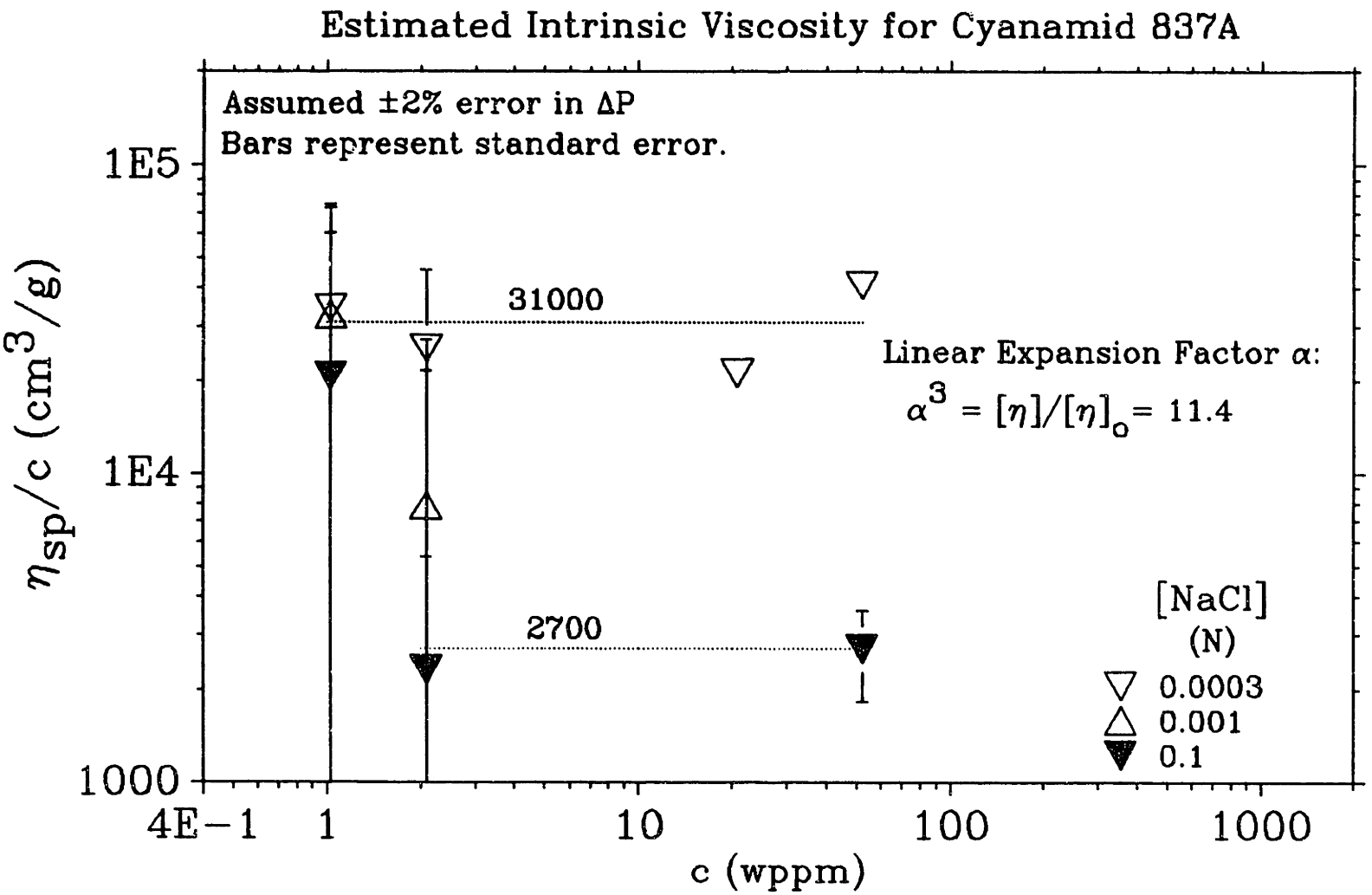


Figure 5.4.6: Estimated Intrinsic Viscosity η_{sp}/c for Cyanamid 837A

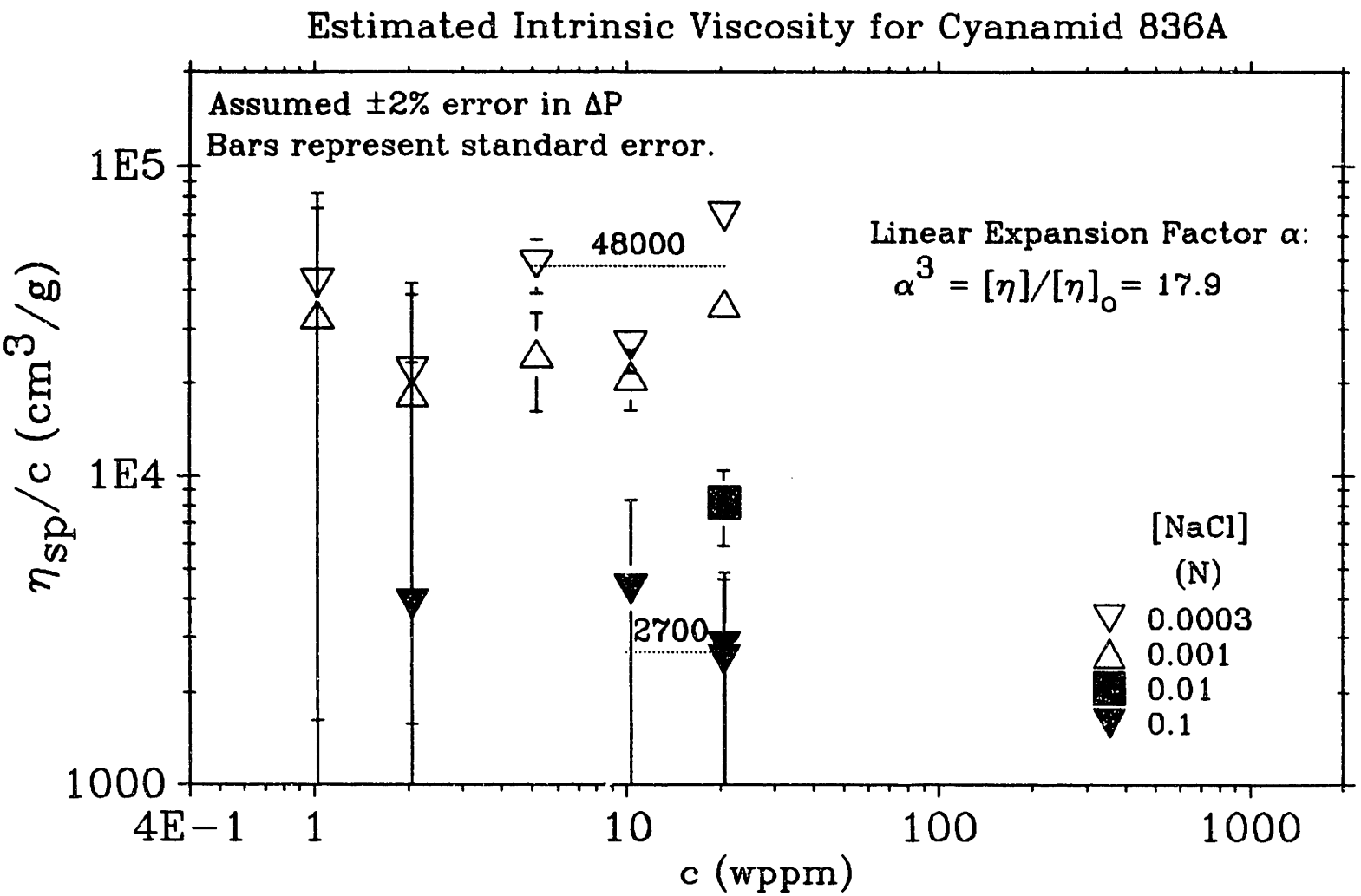


Figure 5.4.7: Estimated Intrinsic Viscosity η_{sp}/c for Cyanamid 836A

CHAPTER VI

DISCUSSION

In this chapter the results presented in Chapter V are analyzed, correlated, and compared with the literature. Wherever possible, the results are physically interpreted in terms of the mechanisms underlying turbulent drag reduction. The discussion comprises seven parts: §6.1, the influence of pipe diameter; §6.2, an overview of the effect of additive initial-conformation on the phenomenon; §6.3, Type-A drag reduction by solutions of collapsed additives; §6.4, Type-B drag reduction by solutions of extended additives; §6.5, comparisons between Type-A and Type-B drag reduction; §6.6, analysis of Type-B flow enhancement and comparison with literature; and §6.7, modelling of both Types A and B of drag reduction.

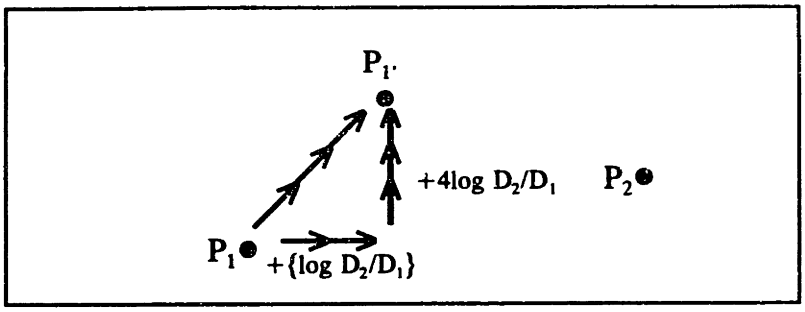
6.1 Influence of Pipe Diameter

In §5.2.3, the pipe diameter was observed to influence gross flow enhancement structure systematically. Data for P500 in 0.3 N NaCl from the 1.458- and 1.021-cm pipes in Figures 5.2.12 and 5.2.13, respectively, virtually superposed on the same PK plot when their abscissae and ordinates were appropriately corrected by the ratio of pipe diameters. Likewise, the P500 data in 0.0001 N NaCl from the 1.458- and 1.021-cm pipes in Figures 5.2.12 and 5.2.13, respectively, also superposed when these data were corrected by the pipe-diameter ratio. This superposition was further supported by the

results for additive C832A in the 1.458- and 1.021-cm pipes, as shown in Figures 5.2.6 and 5.2.8 at 0.3 N NaCl and in Figures 5.2.7 and 5.2.9 at 0.0001 N NaCl.

The transformations that superpose drag reduction data from different pipes are quantitatively effected as follows: On a given set of PK axes, let data point P_1, from a pipe of diameter D_1 have coordinates $(\log Re_s\sqrt{f},\ 1/\sqrt{f})_1$ and data point P_2, from a pipe of diameter D_2 have coordinates $(\log Re_s\sqrt{f},\ 1/\sqrt{f})_2$. In order to put P_1 on the same basis as P_2 for our comparison, P_2 is left unchanged, while the coordinates of P_1 are changed in a two-step process to arrive at a new point $P_{1'}$, coordinates $(\log Re_s\sqrt{f},\ 1/\sqrt{f})_{1'}$, as shown in Equation 6.1-1 and the accompanying sketch. The net effect is to slide P_1 linearly, parallel to the PK baseline N, by an amount proportional to the pipe-diameter ratio. After transformation, both abscissae become solely dependent upon wall shear stress, sharing the common diameter D_2 in their PK form; also, the ordinate of the transformed point $P_{1'}$ preserves its original vertical displacement, that is, flow enhancement, relative to solvent.

$$
\begin{aligned}
P_1\left[\log\frac{\sqrt{2}\,D_1u_{\tau_1}}{\nu_s},\frac{1}{\sqrt{f_1}}\right] &\Rightarrow P_{1'}\left[\log\frac{\sqrt{2}\,D_1u_{\tau_1}}{\nu_s}+\log\frac{D_2}{D_1},\frac{1}{\sqrt{f_1}}+4\log\frac{D_2}{D_1}\right] \\
P_2\left[\log\frac{\sqrt{2}\,D_2u_{\tau_2}}{\nu_s},\frac{1}{\sqrt{f_2}}\right] &\Rightarrow P_2\left[\log\frac{\sqrt{2}\,D_2u_{\tau_2}}{\nu_s},\frac{1}{\sqrt{f_2}}\right]
\end{aligned}
\qquad (6.1\text{-}1)
$$



Coordinate Transformation According to Equation 6.1-1.

Figure 6.1.1 shows original data for additive P500 in 0.3-N NaCl at c = 10, 30, and 100 wppm from the 1.458-cm(open symbols) and 1.021-cm(closed symbols) pipes. In the polymeric-regime, at every concentration, the data in the 1.021-cm pipe lie systematically somewhat higher than the corresponding data in the 1.458-cm pipe. Figure 6.1.2 displays the superposition of these data by the transformation of equation 6.1-1. The 1.021-cm data have been shifted horizontally by a multiplicative factor of $\log(1.458/1.021) \approx 0.155$ and vertically by an additive factor of $4\log(1.428) \approx 0.619$, effectively sliding the 1.021-cm data forward along the baseline N. The two Type-A fans precisely overlap, with coinciding onset points, linear P segments, and regions of polymer degradation. Thus the flow enhancement in both pipes scales with the wall shear stress.

Figure 6.1.3 shows original data for additive P500 in 0.0001-N NaCl at c = 10, 30, and 100 wppm from the 1.458-cm(open symbols) and 1.021-cm(closed symbols) pipes. Figure 6.1.4 shows these same data after the 1.021-cm data are transformed by Equation 6.1-1. The two Type-B ladders are seen to superpose neatly, with their corresponding ladder rungs and regions of polymer degradation coinciding. Again, the flow enhancement in both pipes depends only upon the wall shear stress.

Theoretically, the foregoing results imply that both Type-A and Type-B drag

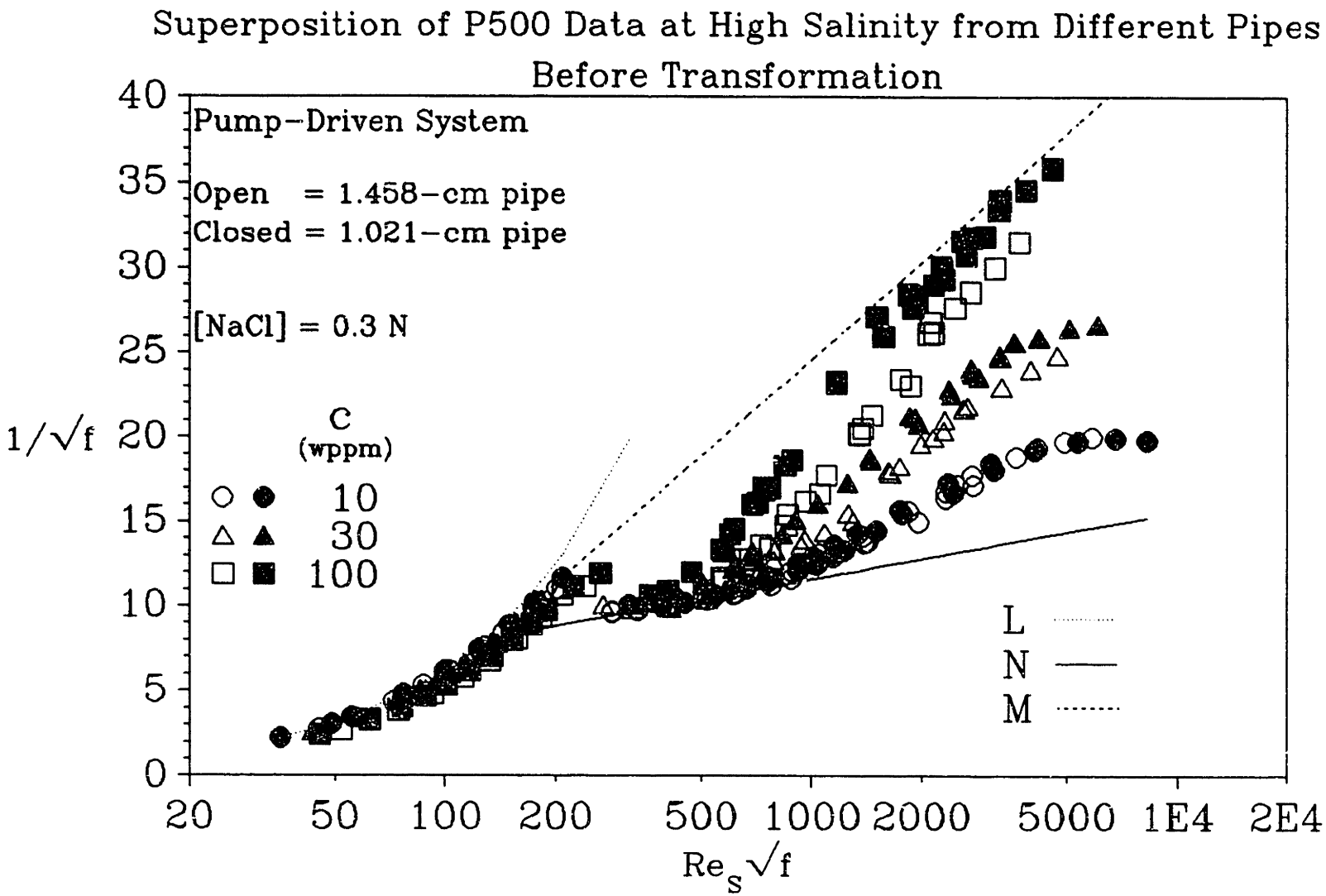


Figure 6.1.1: Superposition of P500 Data at High Salinity from Different Pipes, Before Transformation

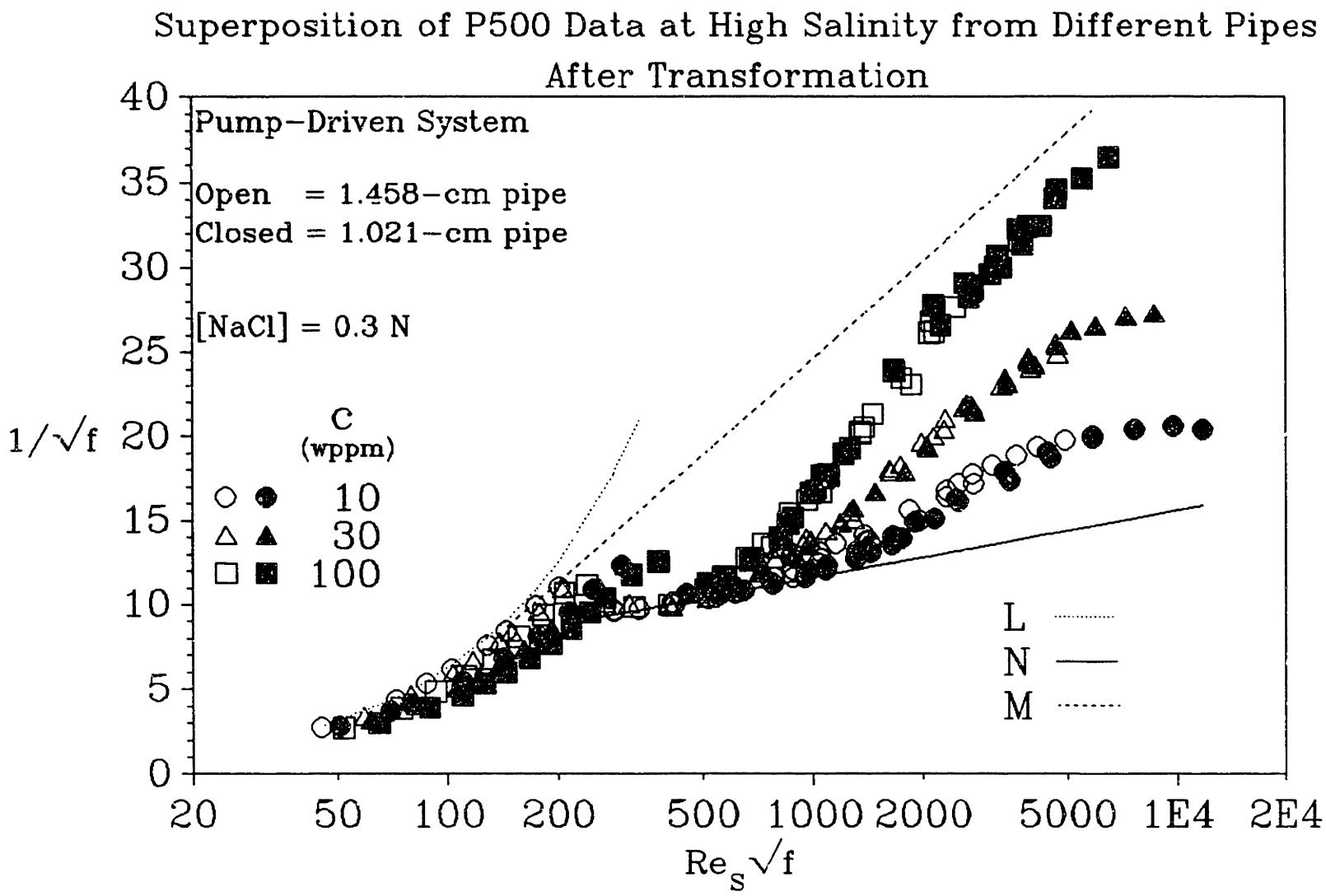


Figure 6.1.2: Superposition of P500 Data at High Salinity from Different Pipes, After Transformation

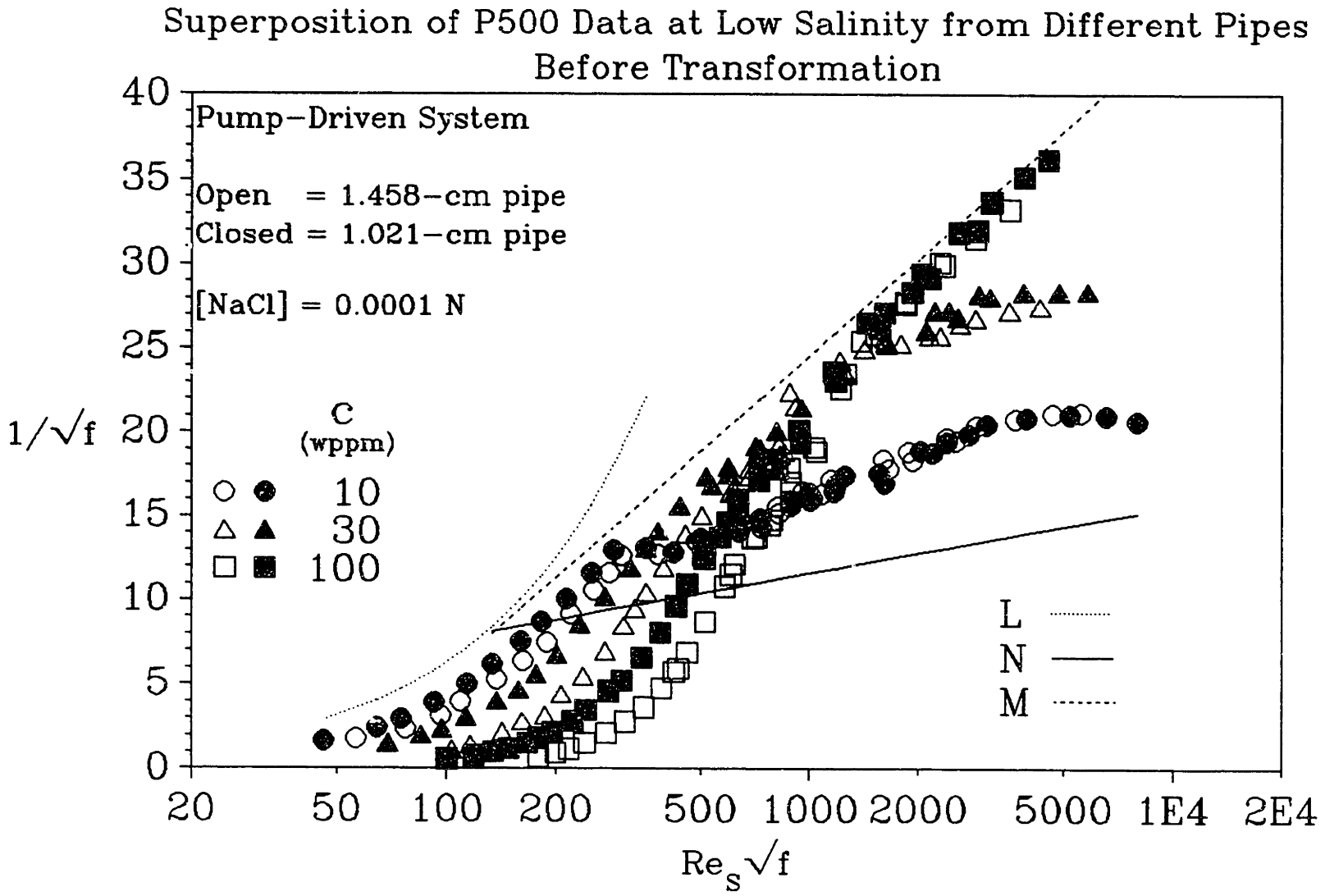


Figure 6.1.3: Superposition of P500 Data at Low Salinity from Different Pipes, Before Transformation

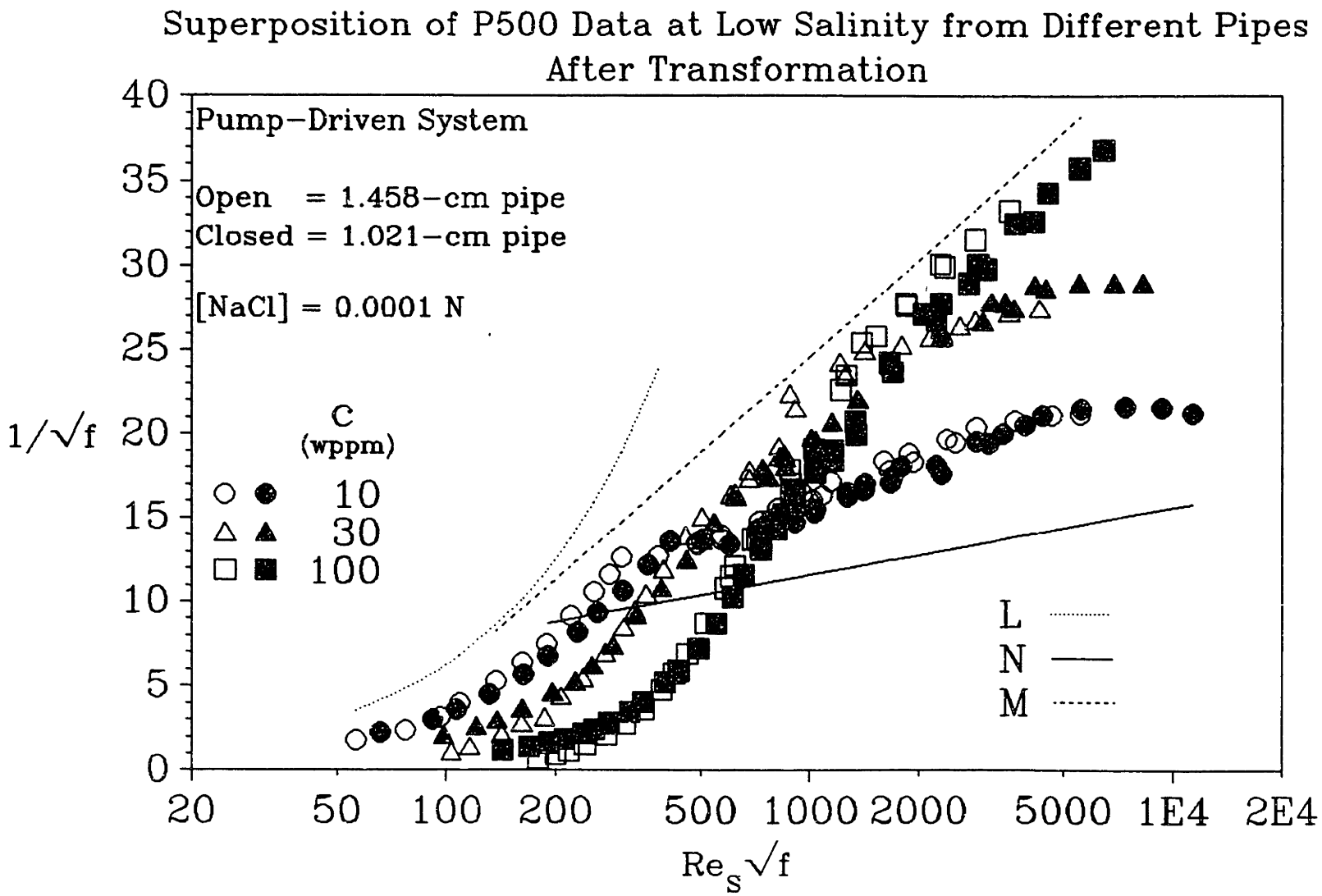


Figure 6.1.4: Superposition of P500 Data at Low Salinity from Different Pipes, After Transformation

reduction in the polymeric regime are controlled by the finer wall-turbulence scales related to the wall shear stress and not by the large scales of turbulence imposed by pipe diameter.

Figures 6.1.5 and 6.1.6 respectively show data for C832A in 0.3 N NaCl at $2 \leq c \leq 50$ wppm in the 1.458-cm(open symbols) and 1.021-cm(closed symbols) pipes, before and after transformation of the 1.021-cm data via equation 6.1-1. In Figure 6.1.6, despite a small mismatch between the 2-wppm data, the two Type-A fans overlap, with their onset points occuring at the nearly same $Re_s\sqrt{f}^*$; also, the corresponding linear P segments superpose, as do the regions of polymer degradation, which follow the linear P segments at higher $Re_s\sqrt{f}$.

Figures 6.1.7 and 6.1.8 respectively show data for C832A in 0.0001N NaCl at $2 \leq c \leq 50$ wppm in the 1.458-cm(open symbols) and 1.021-cm(closed symbols) pipes, before and after transformation of the 1.021-cm data via equation 6.1-1.

In Figure 6.1.8, after transformation, the two Type-B ladders somewhat overlap. While the corresponding ladder rungs at $c = 1$, 10, and 20 wppm coincide, the 1.458-cm rungs at $c = 2$ and 5 wppm lie above, and nearly parallel to, the corresponding 1.021-cm rungs with an approximately constant upshift. Similarly, while the corresponding regions of polymer degradation at $c = 1$ and 10 wppm occur over the same range of $Re_s\sqrt{f}$, polymer degradation in the 1.458-cm pipe at $c = 2$ and 5 wppm occurs at slightly smaller $Re_s\sqrt{f}$ than it does in the 1.021-cm pipe at the same concentrations. The systematic differences between the corresponding 2- and 5-wppm rungs may arise from experimental factors. Despite these discrepancies, the coinciding P segments(ladder rungs) and polymer-degradation regions at $c = 1$, 10, and 20 wppm in Figure 6.1.8

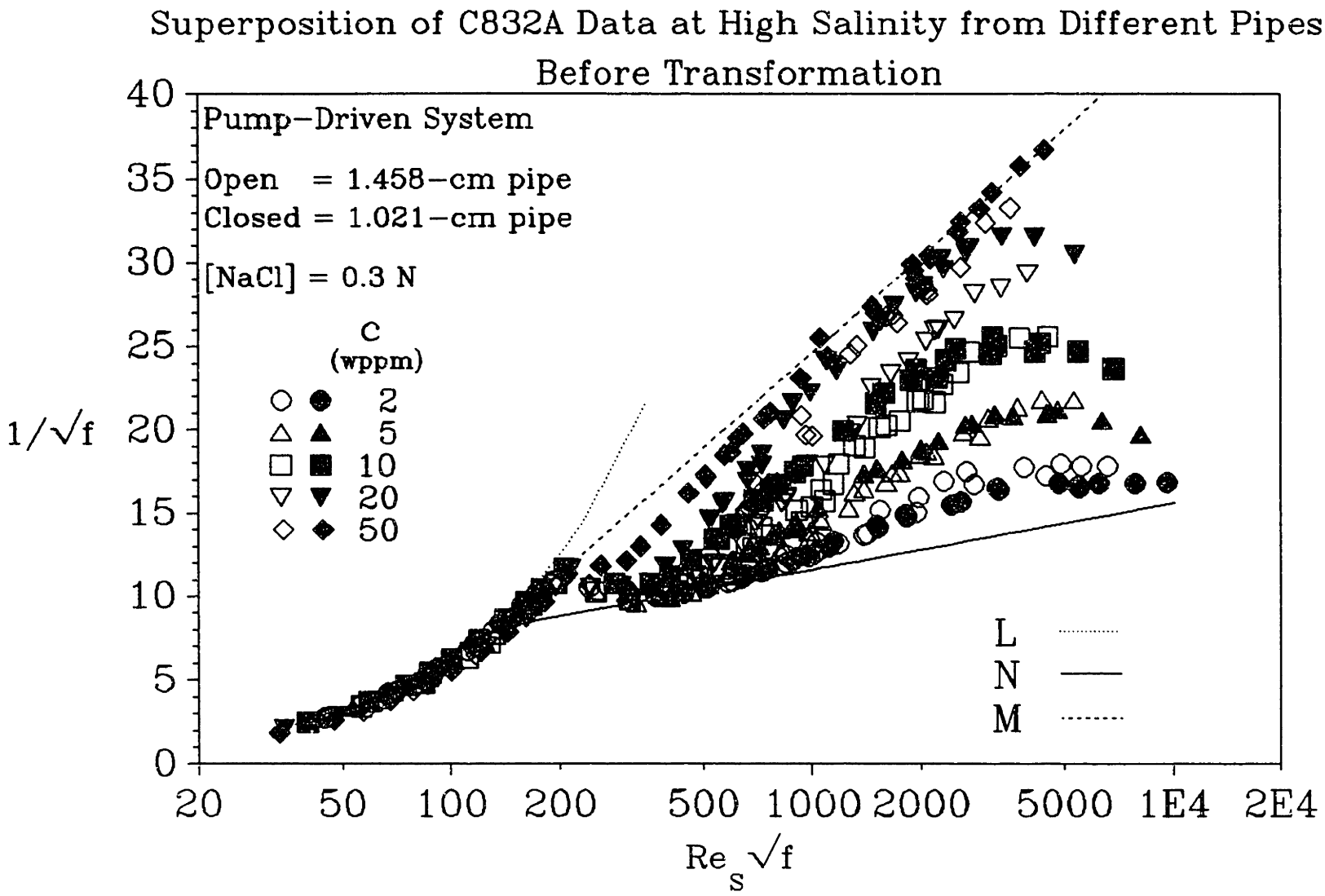


Figure 6.1.5: Superposition of C832A Data at High Salinity from Different Pipes, Before Transformation

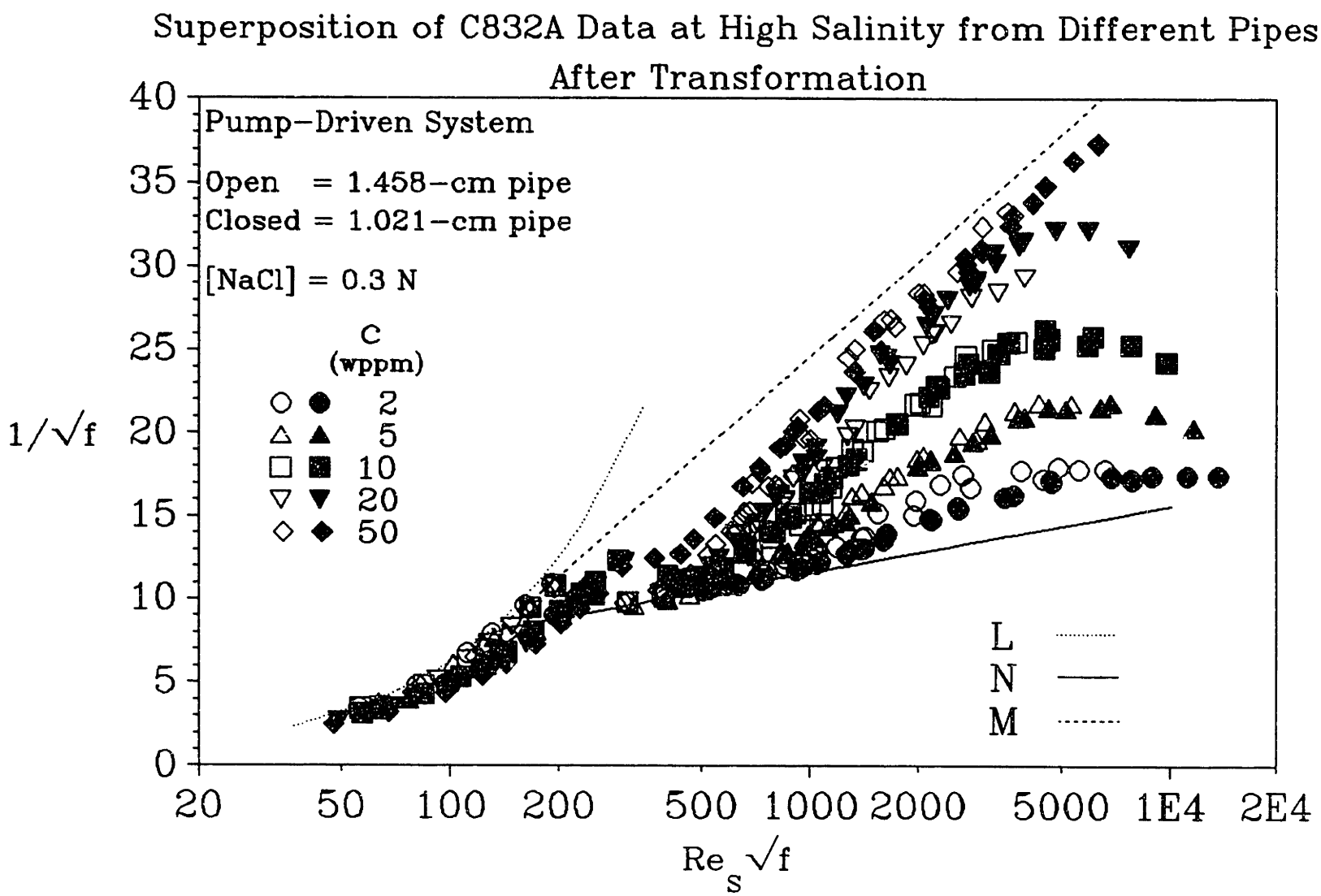


Figure 6.1.6: Superposition of C832A Data at High Salinity from Different Pipes, After Transformation

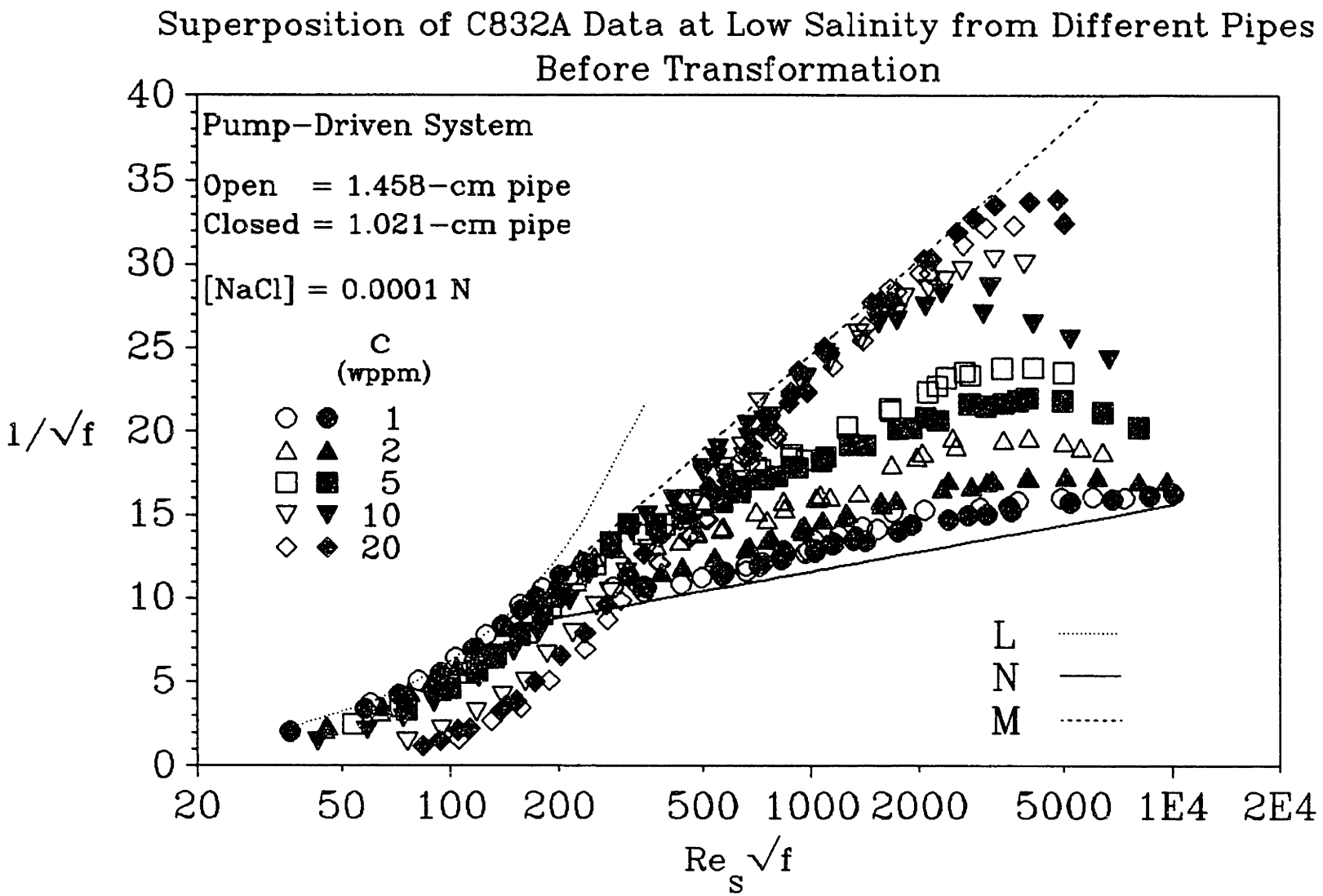


Figure 6.1.7: Superposition of C832A Data at Low Salinity from Different Pipes, Before Transformation

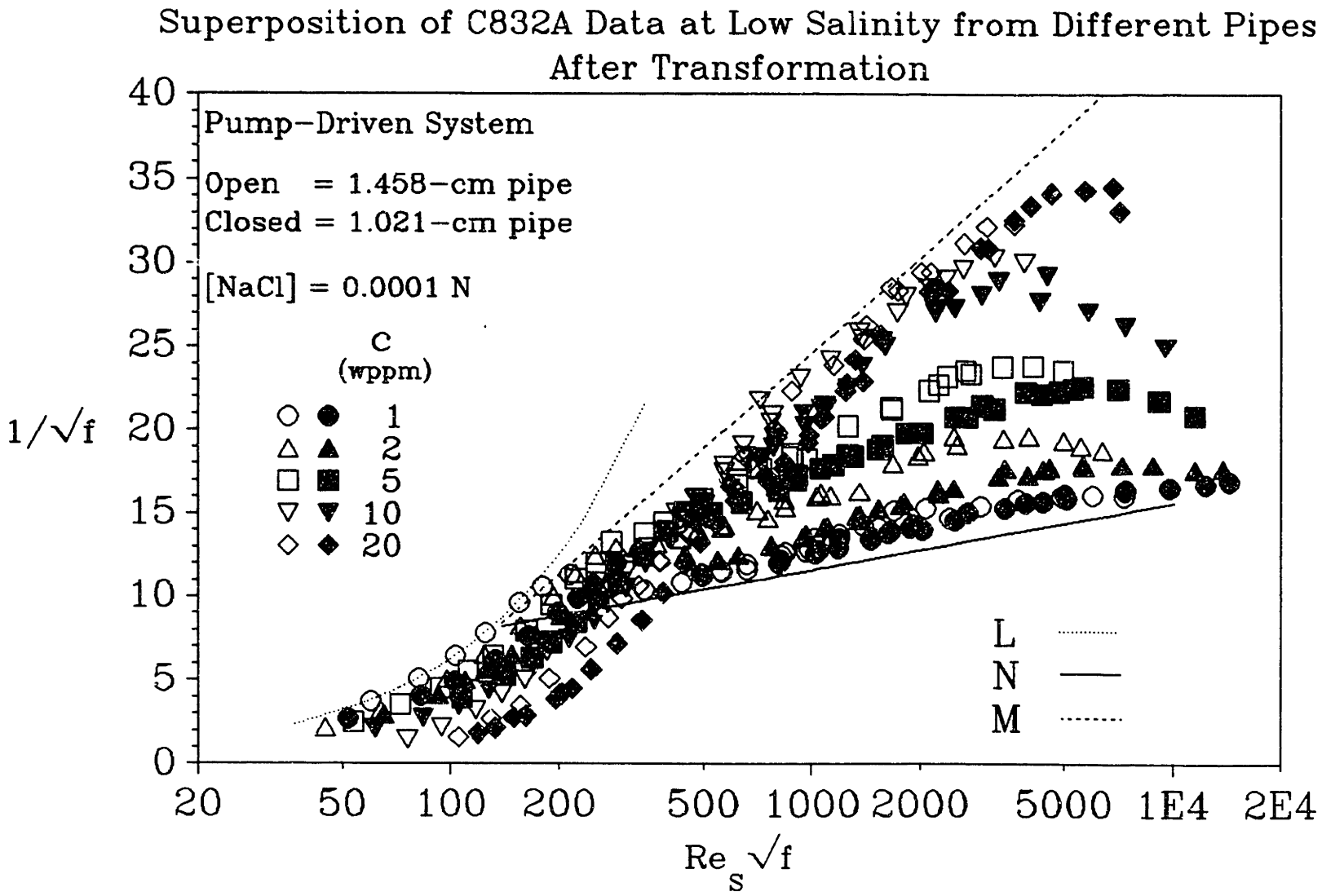


Figure 6.1.8: Superposition of C832A Data at Low Salinity from Different Pipes, After Transformation

suggest that wall shear stress scales flow enhancement in the polymeric regime and that S'/c is independent of pipe diameter.

In summary, the influence of pipe diameter upon both Types A and B of turbulent drag reduction was sought from the experiments with additives P500 and C832A in each of the 1.458- and 1.021-cm pipes. For P500, at all concentrations from 10 to 100 wppm, the respective Type-A fans and Type-B ladders obtained in the polymeric regime at high and low salinities in both pipes scaled with wall shear stress and were independent of pipe diameter. For C832A, polymeric-regime data for $2 \leq c \leq 50$ wppm at both high and low salinities in both pipes were also found to scale with wall shear stress rather than pipe diameter, reinforcing the results obtained with P500. Theoretically, these results imply that drag reduction in the polymeric regime is relatively unaffected by the large scales of turbulence, imposed by the pipe diameter, and is instead controlled by the finer wall-turbulence scales related to the wall shear stress.

6.1.1 Additive Degradation

The aforementioned superposition of polymeric regimes further succeeds in superposing the degradation-induced maxima and downward departures from P segments observed in both pipes at the highest $Re_*\sqrt{f}$. Thus the wall shear stress also appears to scale polymer degradation during drag reduction. Perusal of Figures 6.1.2 and 6.1.4 shows that for additive P500 at both high and low salinities, degradation becomes significant beyond a characteristic "falloff" wall shear stress, $T_w\hat{} \approx 690$ dynes/cm^2, corresponding to $Re_*\sqrt{f}\hat{} \approx 6000$ in the 1.458-cm pipe. Note also that the Type-A fans

in Figure 6.1.2 exhibit onset at $Re_s\sqrt{f}^* \approx 700$, where $T_w^* \approx 9.5$ dynes/cm^2. For P500, a 70-fold range of wall shear stress thus separates onset from the degradation falloff; this is the region within which its initially-collapsed conformation can effectively reduce turbulent drag. The C832A data exhibited degradation falloffs at $T_w\hat{} \approx 170$ dynes/cm^2, corresponding to $Re_s\sqrt{f}\hat{} \approx 3000$ in the 1.458-cm pipe, and Type-A onsets at $Re_s\sqrt{f}^* \approx 550$, where $T_w^* \approx 5.7$ dynes/cm^2; in this case only a 30 fold range of wall shear stress separated onset from the degradation falloff. Lastly, the molecular weights of additives P500 and C832A are in the ratio $9.5/18 \approx 0.5$ while their falloff shear stresses are in the ratio $690/170 \approx 4$; this provides the following dimensional inverse-square relation for degradation of HPAM additives in the present pipes:

$$T_w\hat{} \approx 5.9\times10^{16} M_w^{-2} \qquad (6.1\text{-}2)$$

where $T_w\hat{}$ and M_w are in dyne/cm^2 and g/mole, respectively.

Since degradation likely occurs by scission near the midpoints of the extended polymer chains(Merrill & Horn, 1984), the observed dependence of $T_w\hat{}$ on M_w likely reflects an underlying connection to some length scale of the extended additive, such as its contour length L_c, over which the disruptive turbulent flow field acts.

6.2 Effect of Macromolecular Conformation

The effects of macromolecular additive conformation on gross flow physics are summarized in the central kernel of Figure 6.2.1. Observations with any additive and salinity fall into one of three sets, namely, (i) laminar flow that is Newtonian with

Observed Effects of Macromolecular Additive Conformation on Gross-Flow Behavior

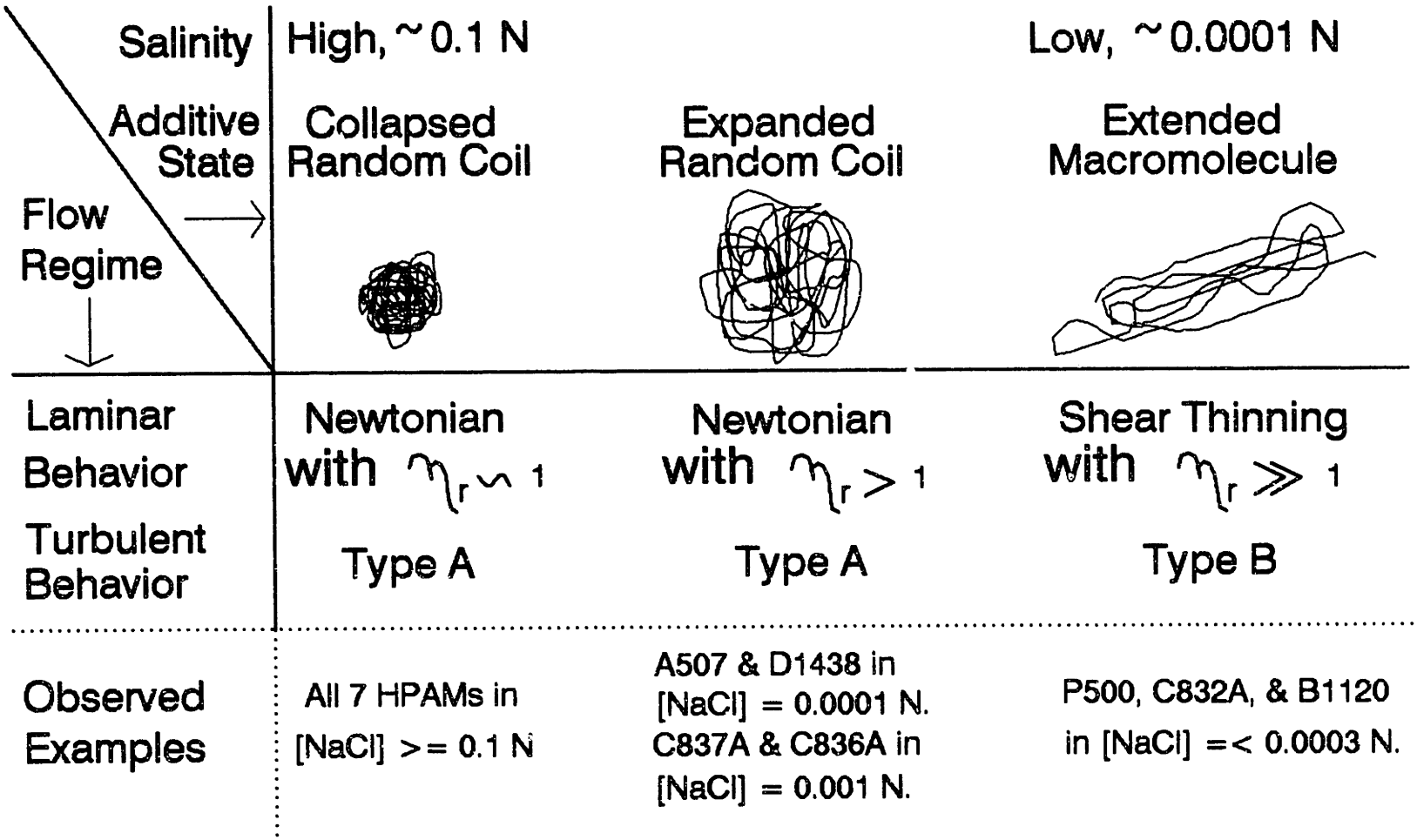


Figure 6.2.1: Observed Effects of Macromolecular Additive Conformation on Gross-Flow Behavior

relative viscosities near unity, and turbulent flow with Type-A drag reduction, (ii) laminar flow that is Newtonian but with relative viscosities appreciably greater than unity, and turbulent flow with Type-A drag reduction, and (iii) laminar flow with shear-thinning and relative viscosities greatly in excess of unity, and turbulent flow with Type-B drag reduction. The preceding are associated with each of three initial conformations of the additive: (i) collapsed random-coil, (ii) expanded random-coil, and (iii) the extended macromolecule. The observed examples actually used to derive the above classification are given in the bottom row of Figure 6.2.1: (i), all seven HPAM additives at high salinities; (ii), A507 & D1438 in 0.0001 N NaCl and C837A & C836A in 0.001 N NaCl; and (iii), P500, C832A & B1120 in <0.0003 N NaCl. Comparisons between these and the HPAM characterization data in Table 6.2 show that, while Type-A drag reduction behavior is achieved by the initially-collapsed conformations of all additives, Type-B drag reduction behavior, associated with the initially-extended macromolecular conformation, is only accessible to additives of the highest molecular weight and backbone charge. The lowest molecular weight additives, D1438 and A507, each with $M_w \approx 1\times10^6$ g/mole, do not exhibit Type-B behavior, despite the latter possessing a highly charged backbone, with nominal degree of hydrolysis $\approx$ 60%. The highest molecular weight additives, B1120 and C832A, with $M_w \approx 20\times10^6$ g/mole, and high backbone charge $\approx$ 50%, both exhibit Type-B drag reduction. However, P500, with $M_w \approx 10\times10^6$ g/mole, and backbone charge $\approx$ 30% achieves Type-B behavior, whereas C837A and C836A, with $M_w \approx 16\times10^6$ g/mole, and backbone charges $\approx$ 8 and 15%, do not. These data suggest that, at any given molecular weight, a threshold backbone charge must be exceeded to induce Type-B behavior; for these $M_w\times10^{-6} \approx$ 1, 10, 16,

Table 6.2
Inferred Polymer Characteristics†

Polymer	Manufacturer's Data‡		Estimated Intrinsic Viscosity at High Salinity	Parameters Inferred from Equations 2.4-10 and 2.4-11	
	Molecular Weight	Degree of Hydrolysis		Molecular Weight	Radius of Gyration
	$M_w \times 10^{-6}$		η_{sp}/c	$M_w \times 10^{-6}$	R_G
	(g/mole)	(%)	(cm^3/g)	(g/mole)	(nm)
C832A	14 - 17	50(?)	3000±600	18.0±5.0	280±50
B1120	8 - 10	High(?)	3300±800	20.1±6.4	300±60
P500	2 - 3	30	1850±500	9.5±3.5	190±40
A507	1 - 2	60	340±80	1.0±0.3	50±10
D1438	2 - 4	10	440±150	1.4±0.6	60±20
C837A	14 - 17	8(?)	2700±900	15.7±6.7	260±70
C836A	14 - 17	15(?)	2700±1450	15.5±11.0	260±110

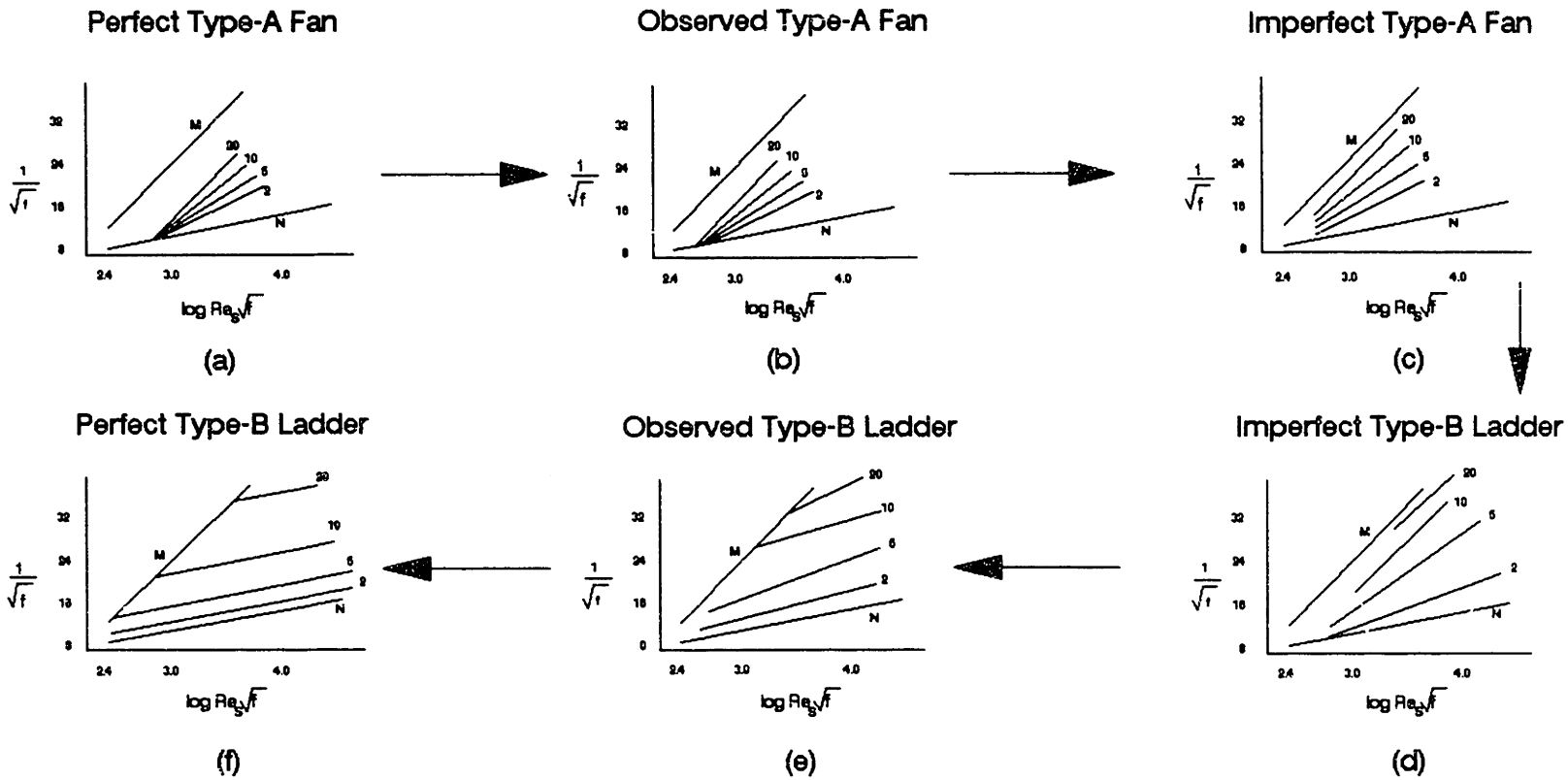
Polymer	Number of Backbone Chain Links	Contour Length	Estimated Intrinsic Viscosity at Low Salinity	Coil Expansion Ratio	Linear Expansion Factor
	$N_{bb} \times 10^{-5}$	L_c	η_{sp}/c	α^3	α
		(μm)	(cm^3/g)		
C832A	5.0±1.4	64±18	97000±2000	32.4	3.2
B1120	5.6±1.8	71±23	97000±3000	29.6	3.1
P500	2.7±1.0	34±12	72000±2000	38.7	3.4
A507	0.3±0.1	3.6±1.1	7000±500	20.3	2.7
D1438	0.4±0.2	5.0±2.2	5800±400	13.0	2.4
C837A	4.4±1.9	56±24	31000±2000	11.4	2.2
C836A	4.4±3.1	55±39	48000±4000	17.9	2.6

† ± values are average standard errors.
‡ The accuracy of manufacturers' data is unknown.

and 20 g/mole, the threshhold charges are, respectively, $>60\%$, $<30\%$, $>15\%$, and $<50\%$.

The ranges of turbulent-flow behaviour actually observed are more precisely elaborated in Figure 6.2.2. This shows six composite Prandtl-Karman(PK) plots labelled (a) through (f) that depict the continuous transformation of the Perfect Type-A Fan, (a), to the Perfect Type-B Ladder, (f). In each PK plot, the units on the log-$Re\sqrt{f}$ abscissa and the $1/\sqrt{f}$ ordinate correctly locate the Newtonian turbulent baseline N and the MDR Asymptote M. To begin, (a) displays a Perfect Type-A Fan, the spokes of which have concentrations c = 2, 5, 10, and 20 wppm. From the fan's single onset point, its four spokes radiate with slope increments δ that increase as the square-root of the concentration, $\sqrt{c}$, as depicted to scale in (a). In a slight departure from ideality, (b) shows the Observed Type-A Fan having the "same" four spokes. While the spokes of the observed fan in (b) continue to obey the $\sqrt{c}$ law, here they radiate from adjacent points along, rather than one point on, the turbulent baseline N, constituting a diffuse onset point. In a further systematic departure from (b), the Imperfect Type-A Fan in (c) now has no discernable onset point, and its spokes, now assuming shallower slopes, no longer obey the $\sqrt{c}$ rule. From (c) to (d), the spokes of the Imperfect Type-A Fan become less steep, attaining slopes near that of N; any remnant of an onset point has completely disappeared. In (d), the Imperfect Type-B Ladder obtains. Its ladder rungs are neither mutually parallel nor parallel to N; moreover, they have neither retro-onset points along M nor apparent slips S' in proportion to their respective concentrations c. In (e), the Observed Type-B Ladder has ladder rungs that are nearly parallel to N and have apparent slips S' nearly in proportion to their concentrations c. While the ladder

The Progression of Turbulent Drag-Reduction Behavior from Type A to Type B, As Seen With HPAM Additives in Solutions of Decreasing Salinity



Note: Concentrations are hypothetical, corresponding to an HPAM Mw ~ 15E6.

Figure 6.2.2: The Progression of Turbulent Drag-Reduction Behavior from Type A to Type B as Seen with HPAM Additives in Solutions of Decreasing Salinity

rungs at high concentrations exhibit sharp retro-onset points, the rungs at low concentrations do not, their retro-onset points obscured by laminar-to-turbulent transitions. Finally in (f), the Perfect Type-B Ladder is reached. In this PK plot, the rungs exhibit distinct retro-onset points from M and have slopes identical to that of N. Their upshifts relative to N, S', are constant, independent of $Re_s\sqrt{f}$, and proportional to their respective concentrations such that $S'_{20}/20 = S'_{10}/10 = S'_5/5 = S'_2/2$. Each PK plot in this sequence of six drag-reduction structures depends intimately on the state of the additive, as shown conceptually in Figure 6.2.1.

Figure 6.2.3 details the dependence of turbulent drag reduction behavior on salinity observed with the present HPAM additives. In the columns of this figure, using the scheme evolved in Figure 6.2.2, each of the two broad categories, the Type-A fan and the Type-B ladder, are amplified into their perfect, observed, and imperfect counterparts, respectively representing their idealized, typical, and distorted (but still recognizable) forms. The rows in the figure represent the HPAM additives studied, arranged by increasing molecular weights. The cells of the matrix contain the salinity at which solutions of the additive represented by that row gives rise to the flow behavior represented by that column. All the kinds of turbulent flow behavior listed, except the perfect Type-A fan, were observed. A prominent feature of Figure 6.2.3 is its general lower-diagonal nature, with high-salinity entries down the left and low-salinity entries along the diagonal to the right. These trends have physical significance, reflecting the influence of additive molecular weight, M_w, and degree of backbone hydrolysis (loosely, "charge"), upon the salinity-induced conformational changes. Thus, at the lowest molecular weights, additives A507 and D1438 with $M_w \approx 1.0\times10^6$ g/mole show only

Dependence of Turbulent Drag-Reduction Behavior on Salinity

HPAM ADDITIVE \ DRAG-REDUCTION BEHAVIOR	Perfect Type-A Fan	Observed Type-A Fan	Imperfect Type-A Fan	Imperfect Type-B Ladder	Observed Type-B Ladder	Perfect Type-B Ladder
A507		0.3 0.0001				
D1438		0.3 0.0001				
P500		0.3			0.0001	
C836A		0.1	0.01 0.001 0.0003			
C837A		0.1 0.001	0.0003			
C832A		0.1 0.3		0.001	0.0001 0.0003	0.00001
B1120		0.3			0.0001	

Figure 6.2.3: Dependence of Turbulent Drag-Reduction Behavior on Salinity

Type-A drag reduction at both high and low salinity, apparently unable to extend sufficiently, even in solutions of low salinity, to induce Type-B drag reduction. Additives C832A and B1120, with the highest $M_w \approx 20.1 \times 10^6$ g/mole, and high backbone charges, display Type-A behavior at high salinities and Type-B at low salinities. Additive C832A exhibits the widest range of behaviour, from Observed Type-A in 0.1 and 0.3 N NaCl to Imperfect, Observed and Perfect Type-B Ladders in 0.001, 0.0001 and 0.00001-N aqueous NaCl. Also, additives C832A, C836A and C837A, respectively high-, moderate- and low-charge homologues, exhibit a noteworthy spectrum of behavior. All three exhibit Observed Type-A Fans in 0.1-N aqueous NaCl, but in 0.001 N NaCl they respectively exhibit the Observed Type-A Fan, the Imperfect Type-A Fan, and the Imperfect Type-B Ladder, three adjacent columns in Figure 6.2.3, and in 0.0003 N NaCl, only C832A attains Type-B behaviour. This demonstrates the strong influence of backbone charge in enabling the initial conformational extension required for Type-B behaviour.

6.3 Type-A Drag Reduction

Type-A drag reduction has been known for long, and here the focus is exclusively on the present, new, results for HPAM additives in their variously random-coiling conformations. A Type-A fan is defined by the wall shear stress at its onset point T_w^*, and by the slope increments δ of the P segments emanating therefrom. Both of these parameters have previously been related to the macromolecular properties of the additive(Virk, 1975b), as considered below.

6.3.1 Onset

For a given polymer-solvent pair, the onset wall shear stress T_w^* is not greatly influenced by either polymer concentration or pipe diameter, but is strongly, and inversely, dependent upon the polymer coil-size in solution, as measured by its rms radius of gyration, R_G. determines the two being inversely related. The inverse relationship between T_w^* and R_G was generalized by Virk(1975b):

$$T_w^* \propto R_G^{-g}. \tag{6.3-1}$$

When g = 2, $T_w^* \propto R_G^{-2}$, so it follows that $Re_s\sqrt{f^*} \propto R_G^{-1}$ and the length-based onset constant Ω_L, equation 2.3-4, obtains. Because $R_G \propto \eta^{1/3}$ for a polymer of fixed molecular weight, it can be expected that $Re_s\sqrt{f^*} \propto \eta^{-1/3}$ to a good approximation. Figure 6.3.1 shows the observed dependence of $Re_s\sqrt{f^*}$ on η_{sp}/c in doubly-logarithmic coordinates among 20.6-wppm solutions of additive C836A with salinities ranging from 0.0003 to 0.1 N NaCl in the 1.458-cm pipe. The $Re_s\sqrt{f^*}$ data are derived from the slopes and intercepts, (A_p, B_p), of the observed P segments of these solutions. The η_{sp}/c data are directly determined from the corresponding laminar-flow data. The data shown in Figure 6.3.1 are listed in Table 6.3.1. The best-fit power-law line through these data is:

$$Re_s\sqrt{f^*} = (1.88\pm0.13)\times10^4 \left[\frac{\eta_{sp}}{c}\right]^{-(0.41\pm0.02)} \tag{6.3-2}$$

where η_{sp}/c is in cm^3/g. From the exponent of -0.41 in equation 6.3-2, g $\approx$ 2.5, which is within the range of commonly observed literature values, 2 $\leq$ g $\leq$ 3.

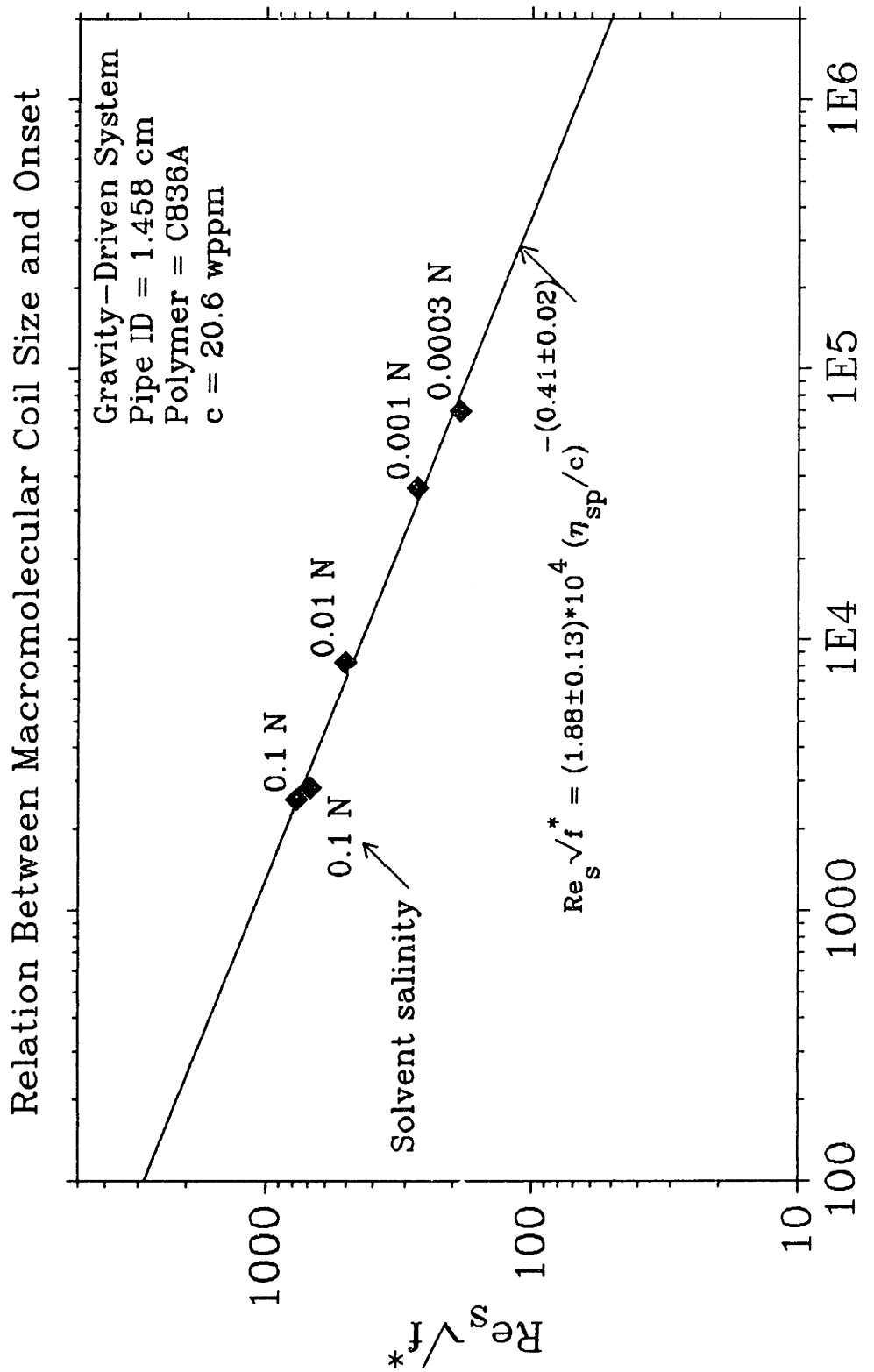


Figure 6.3.1: Relation Between Macromolecular Coil Size and Onset

For the class of HPAM polymers of various molecular weights, Figure 6.3.2 presents average T_w^* values versus R_G in log-log coordinates for all seven HPAMs in saline solutions of at least 0.1 N NaCl and includes individual T_w^* values versus R_G for solutions of additives C836A, P500, A507, and D1438 having salinities less than 0.1 N. These data are listed in Table 6.3.1. The best-fit line through all the data, shown dotted in Figure 6.3.2, has the following power-law form:

$$T_w^* = (0.38 \pm 0.02) \times 10^5 R_G^{-(1.52 \pm 0.20)} \qquad (6.3\text{-}3)$$

where T_w^* and R_G are in dyne/cm^2 and nm, respectively. The exponent -1.52 in equation 6.3-3 is somewhat higher than previously quoted in the literature. Another fitted line, obtained by excluding the data for additives A507 and D1438 in 0.3 N NaCl, is shown dashed in Figure 6.3.2:

$$T_w^* = (23.5 \pm 9.4) \times 10^5 R_G^{-(2.24 \pm 0.25)} \qquad (6.3\text{-}4)$$

This fit has an exponent -2.24, that lies in the range of literature values. To obtain an average value of the "onset constant" Ω_L from among the data represented by equation 6.3-4, equation 6.3-1 with g = 2 is assumed to be satisfied by the geometric-mean values of T_w^* and R_G. This "forced" line, shown solid in Figure 6.3.2 has the form:

$$T_w^* = 5.97 \times 10^5 R_G^{-2} \qquad (6.3\text{-}5)$$

By rearranging equation 6.3-5, $T_w^* R_G^2 = \rho u_\tau^2 R_G^2 = \rho \nu_s^2 (u_\tau R_G/\nu_s)^2 = \rho \nu_s^2 (\Omega_L)^2 = 5.79 \times 10^5$ dyne/cm$^2 \cdot$nm^2. With $\rho \approx 1.009$ g/cm^3 and $\nu_s \approx 9.801 \times 10^{-3}$ cm^2/s for 0.3-N aqueous NaCl at 25 °C, equation 6.3-5 corresponds to $\Omega_L \approx 8.3 \times 10^{-3}$ which is similar to a previous value of $\Omega_L = (8.2 \pm 0.3) \times 10^{-3}$ for HPAM additives in 1.0-m NaCl(Virk,

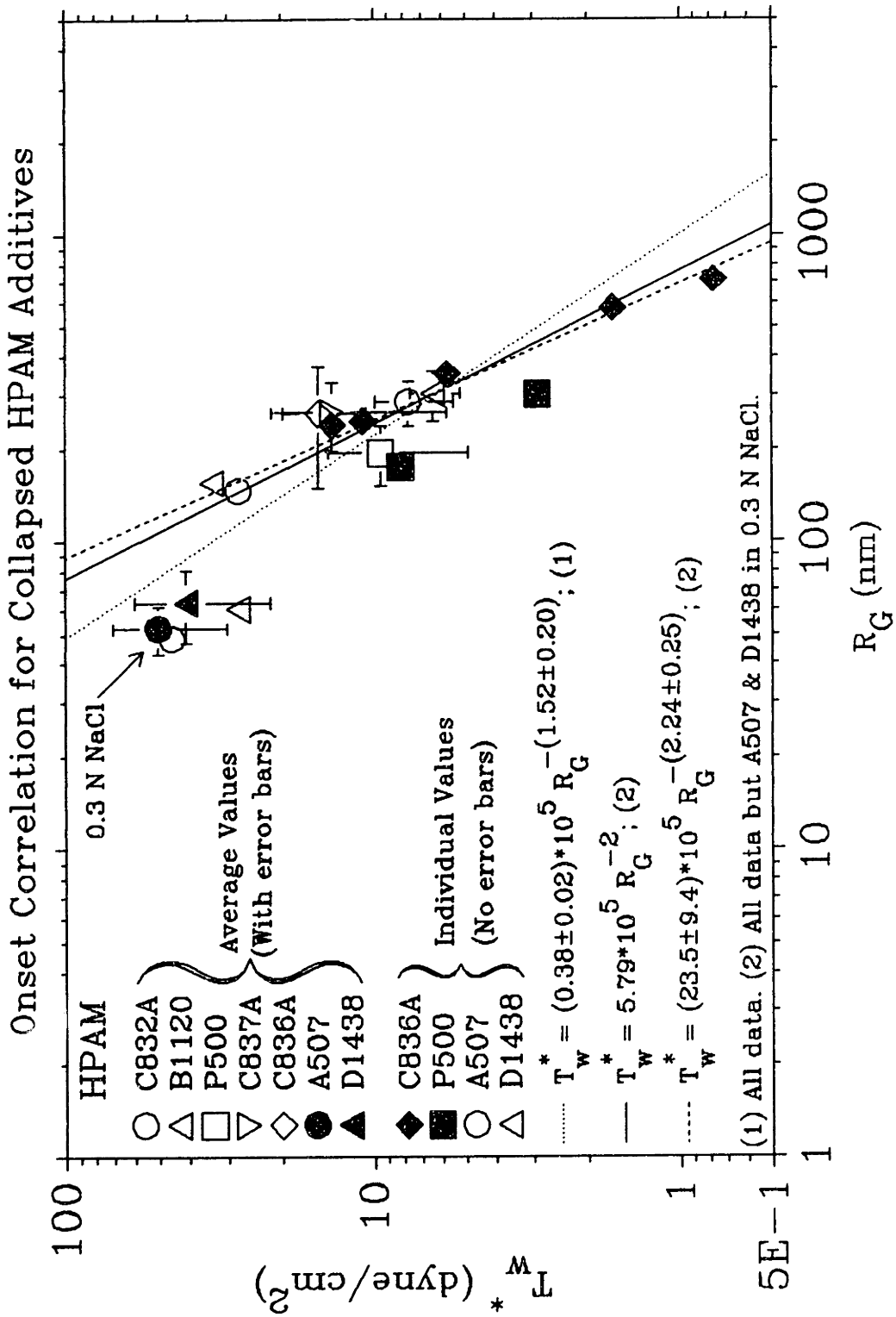


Figure 6.3.2: Onset Correlation for Collapsed HPAM Polymers

1975b). Values of Ω_L for the data points in Figure 6.3.2 are provided in Table 6.3.1; among these data, the average $\Omega_L \approx (8.6\pm1.7)\times10^{-3}$ over a 20-fold range of molecular weights.

6.3.2 Slope Increment

While the macromolecular coil size influences the observed onset of a solution of initially coiled macromolecules, it appears to have little influence on the slope increment, a measure of macromolecular resistance to expansion by the turbulent flow field. Figure 6.3.3 shows the dependence of the slope increment on macromolecular coil size for the same 20.6-wppm solutions of C836A used in Figure 6.3.1. Figure 6.3.3, a log-log plot of δ versus η_{sp}/c shows that the slope increment does not significantly depend on the initial coil size, with $\delta \approx 15.3\pm0.7$, roughly constant, for $2500 < \eta_{sp}/c < 70000$. Thus, for initially randomly-coiled macromolecular additives, the turbulent-flow strength, T_w^*, required to excite the macromolecular interaction leading to drag reduction decreases with increasing coil-size, but the molecular deformation processes thereafter associated with δ seem essentially independent of the initial coil size.

For a polymer-solvent pair, the slope increment δ also does not greatly depend on pipe diameter; however, it does depend approximately on the square root of the polymer concentration. Figure 6.3.4 shows the concentration dependence of δ on doubly-logarithmic coordinates for solutions of the seven HPAM additives at high salinity. Except for the concentrations that are very low, with uncertain δ, and those that give rise to nearly maximally drag-reducing turbulent flows, which are independent of

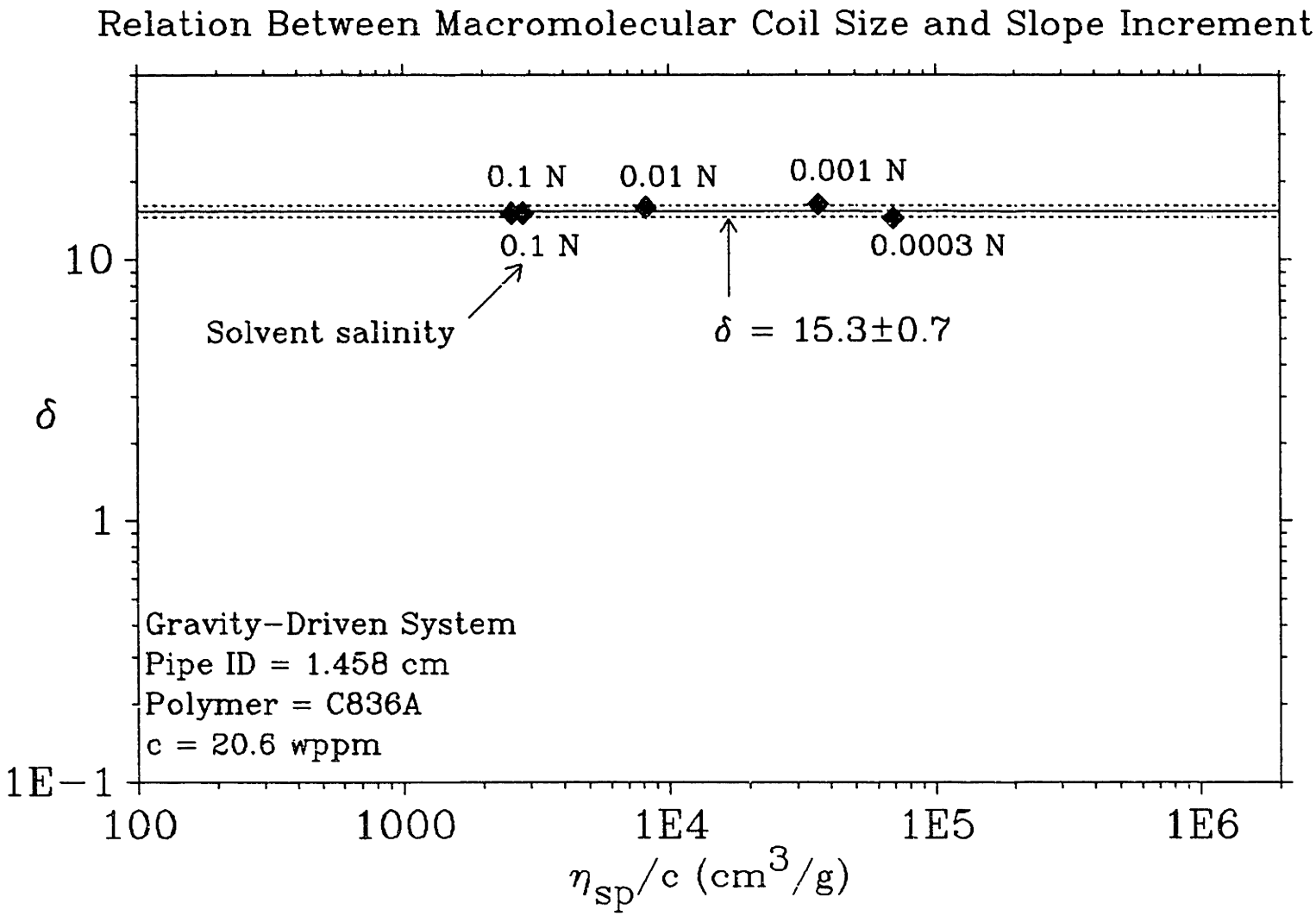


Figure 6.3.3: Relation Between Macromolecular Coil Size and Slope Increment

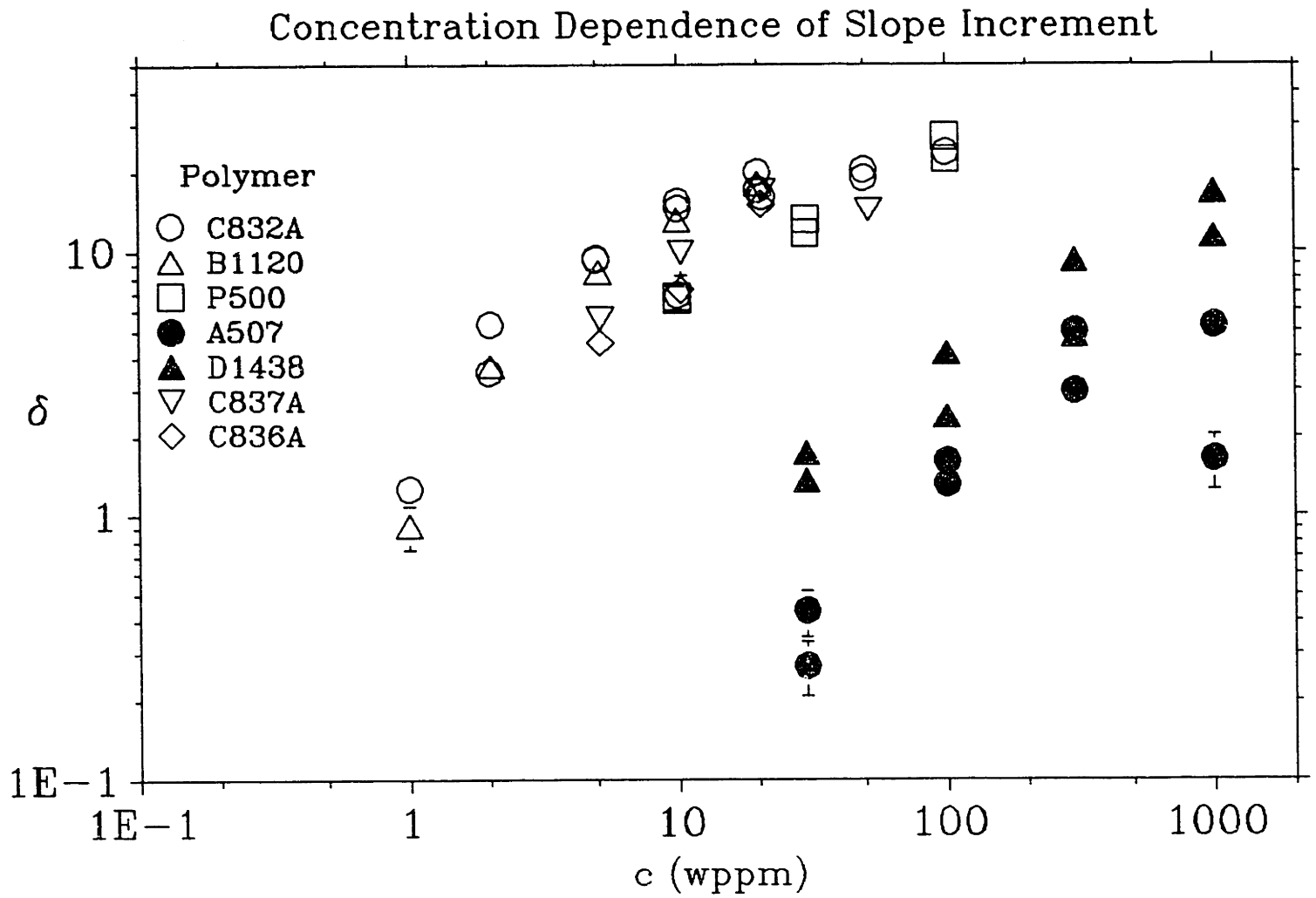


Figure 6.3.4: Concentration Dependence of Slope Increment

Table 6.3.1
Onset Data for Type-A Drag Reduction by HPAM Additives†

HPAM	Concen-tration Range	Salinity	Esti-mated Intrin-sic Visco-sity	Radius of Gyration	Onset Wall Shear Stress[1]	Length-Based Onset Constant
	c	[NaCl]	η_{sp}/c	R_G	T_w^*	$\Omega_L \times 10^3$
	(wppm)	(N)	(cm^3/g)	(nm)	($dyne/cm^2$)	
Part A: Average Values						
C832A[2]	20-100	0.3	3000	280±50	7.7±2.2	8.5±2.7
B1120	10-100	0.3	3300	300±60	6.4±1.2	8.3±2.4
P500[2]	30-100	0.3	1850	190±40	9.5±4.6	6.5±3.1
A507	300-1000	0.3	340	50±10	50.4±20.1	4.0±1.5
D1438	100-1000	0.3	440	60±20	41.0±19.2	4.4±2.2
C837A	50	0.1	2700	260±70	13.7±7.9	10.8±5.9
C836A	20	0.1	2700	260±110	15.2±4.6	11.2±6.5
Part B: Other Individual Values						
C836A[3]	20.6	0.0003	69170	715	0.77(190)	7.1
C836A[3]	20.6	0.001	36330	580	1.6(270)	8.3
C836A	20.6	0.01	8190	350	5.8(510)	9.4
C836A[4]	20.6	0.1	2820	250	10.8(690)	9.0
C836A[4]	20.6	0.1	2560	240	13.7(770)	9.8
P500	30	0.01	8480	300	2.9	5.8
P500[4]	30	0.3	1630	170	8.4	5.4
A507	30-300	0.0001	7000	135	23.7[5]	8.6
A507[4]	30-300	0.3	330	49	45.6	4.0

HPAM	Concen-tration Range	Salinity	Esti-mated Intrin-sic Visco-sity	Radius of Gyration	Onset Wall Shear Stress[1]	Length-Based Onset Constant
	c	[NaCl]	η_{sp}/c	R_G	T_w^*	$\Omega_L \times 10^3$
	(wppm)	(N)	(cm^3/g)	(nm)	($dyne/cm^2$)	
D1438	30-300	0.0001	5800	140	30	10.1
D1438[4]	30-300	0.3	440	60	46.5	4.4

† All solvent physical properties are evaluated at 25°C.
1 Values in parentheses are the corresponding $Re_*\sqrt{f^*}$.
2 Data are included from both pipes.
3 T_w^* and $Re_*\sqrt{f^*}$ are virtual values regressed via (A_p, B_p) data.
4 Data are incorporated into Part-A averages.
5 T_w^* data are visual values.

polymer parameters, the data show a slope of one-half, corresponding to a square-root concentration dependence. Data from the 1.458- and 1.021-cm pipes, which are not distinguished for additives C832A(○) and P500(□), either lie adjacently or overlap, showing δ to be essentially independent of pipe-diameter, as previously-established.

To illustrate explicitly the empirical square-root-concentration dependence of δ, the specific slope increment $\delta/\sqrt{c}$ is plotted against concentration in Figure 6.3.5 in log-log coordinates. Values of $\delta/\sqrt{c}$ for each polymer are approximately constant over concentrations for which turbulent drag reduction in the polymeric regime is not too close to the MDR asymptote. Also, $\delta/\sqrt{c}$ does not depend on pipe diameter, or flow length scale, the data for each of additives C832A and P500 in two different pipes showing no obvious differences. Note, however, that the levels of constant $\delta/\sqrt{c}$ vary appreciably with additive molecular weight, suggesting a further rescaling of $\delta/\sqrt{c}$ on a

macromolecular basis.

To generate a macromolecular-based parameter, Virk(1975b) inserted the molecular weight M_w into the specific slope increment $\delta/\sqrt{c}$ to produce an intrinsic slope increment $\Pi = \delta/\sqrt{(c/M_w)}$, equation 2.3-5, which characterizes Type-A drag-reduction efficacy per macromolecule in solution. The intrinsic slope increment Π is found to depend on the number of backbone chain links N_{bb} raised to the 3/2 power for many polymer-solvent systems, with the associated slope modulus κ defined by $\Pi = \kappa N_{bb}^{3/2}$.

Figures 6.3.6 presents the averaged Π versus N_{bb} in doubly-logarithmic coordinates for all HPAM additives. The best-fit line through the data, shown solid in Figure 6.3.6, is:

$$\Pi = (102 \pm 22) \times 10^{-6} N_{bb}^{(1.43 \pm 0.05)} \qquad (6.3\text{-}6)$$

The exponent of 1.43 and coefficient of $(102 \pm 22) \times 10^{-6}$ in equation 6.3-6 agree well with the literature values of 3/2 and $(80 \pm 20) \times 10^{-6}$(Virk, 1975b). By assuming an exponent of 3/2 and using the average Π from the Π values of all seven HPAM additives, another line through the data is obtained, shown dotted in Figure 6.3.6:

$$\Pi = 43.5 \times 10^{-6} N_{bb}^{3/2} \qquad (6.3\text{-}7)$$

While equation 6.3-7 has a coefficient, $\kappa \approx 43.5 \times 10^{-6}$, about half that of equation 6.3-6, $\kappa \approx (102 \pm 22) \times 10^{-6}$, the two lines do not differ greatly in this narrow range of N_{bb} between $\sim 3 \times 10^4$ and $\sim 6 \times 10^5$ backbone links. Table 6.3.2 summarizes the data for Figures 6.3.5 and 6.3.6.

Table 6.3.2
Specific and Intrinsic Slope Increment Data

Polymer	Molecular Weight	Number of Backbone Chain Links	Average Specific Slope Increment	Average Intrinsic Slope Increment	Slope Modulus†
	$M_w \times 10^{-6}$	$N_{bb} \times 10^{-5}$	$\delta/\sqrt{c}$	$\Pi \times 10^{-3}$	$\kappa \times 10^{6}$
	(g/mole)				
C832A	18.0±5.0	5.0±1.4	4.1±0.7	17.2±5.3	47.9
B1120	20.1±6.4	5.7±1.8	3.6±0.6	16.2±5.4	38.3
P500	9.5±3.5	2.7±1.0	2.3±0.2	7.0±2.0	51.1
A507	1.0±0.3	0.3±0.1	0.16±0.02	0.16±0.04	42.8
D1438	1.4±0.6	0.4±0.2	0.29±0.05	0.35±0.14	56.4
C837A	15.7±6.7	4.4±1.9	2.8±0.6	1.1±0.5	38.1
C836A	15.5±11.0	4.4±3.1	2.5±0.6	9.9±5.9	34.4

† Slope moduli are averages; uncertainties in N_{bb} cause very large uncertainties in the slope moduli.

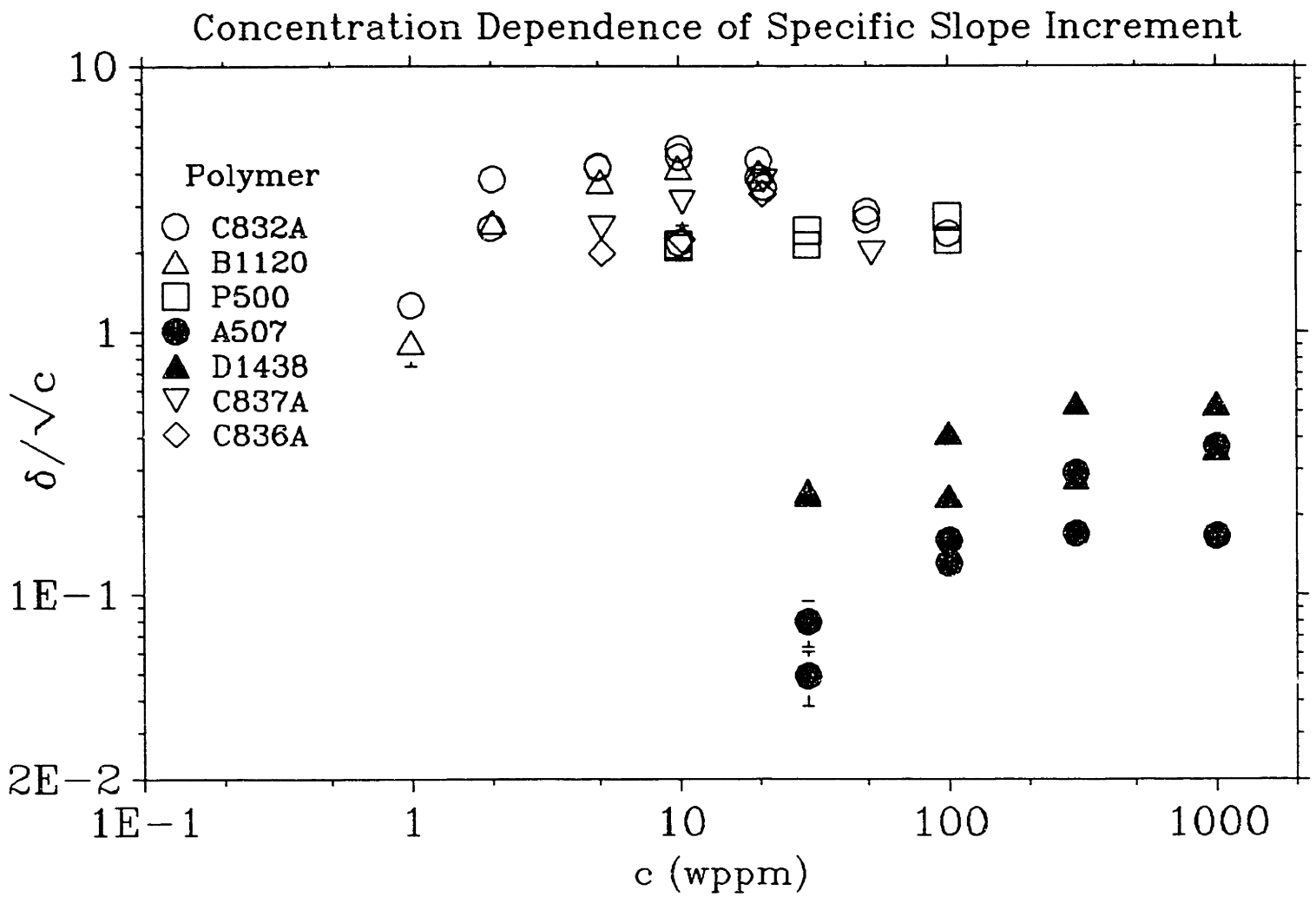


Figure 6.3.5: Concentration Dependence of Specific Slope Increment

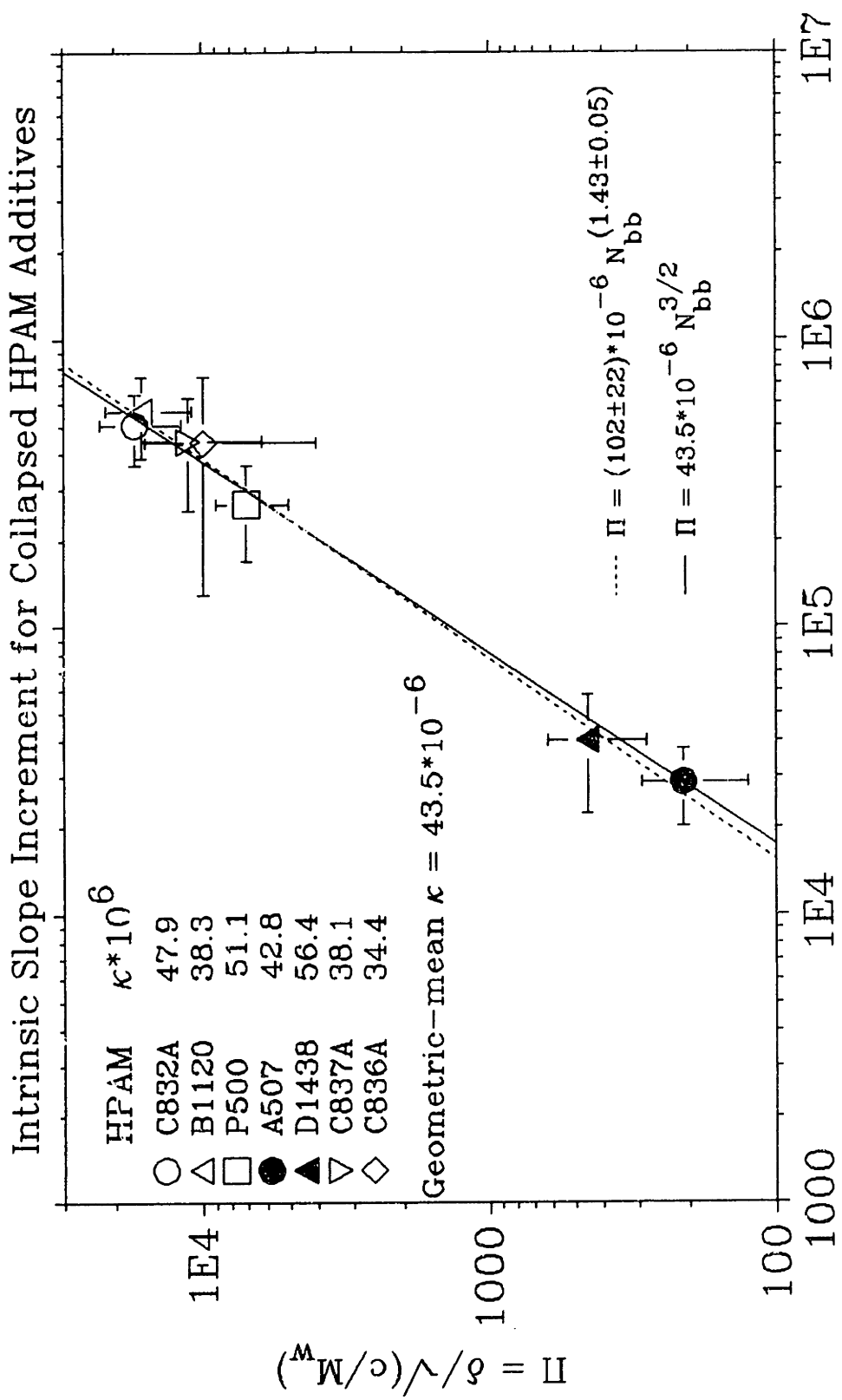


Figure 6.3.6: Intrinsic Slope Increment for Collapsed HPAM Additives

6.4 Type-B Drag Reduction

Type-B drag reduction has hitherto been little studied. Here the new results for HPAM additives in their extended conformations are discussed. A Type-B ladder is primarily defined by the flow enhancements induced by its P segment rungs at a known, high, $Re_s\sqrt{f}$; and secondarily by the wall shear stresses at its retro-onset points, where the rungs intersect the MDR asymptote. The dependence of both these parameters on the molecular properties of the additive are considered.

6.4.1 Flow Enhancement

The observed apparent-slip data for Type-B flow enhancement are analyzed in a manner analogous to the analysis performed on the observed slope-increment data in Type-A flow enhancement.

In Figure 6.4.1, S' at $Re_s\sqrt{f} = 3000$ is plotted against concentration in log-log coordinates for additives C832A, B1120, and P500 in 0.0001 N NaCl solutions from the pump-driven system. For low concentrations of additives C832A and B1120, S' is approximately linear in concentration, having a slope near unity on these coordinates; for $c \geq 20$ wppm, S' becomes constant because of the limiting effect of the MDR asymptote, as shown in Figure 6.4.1. The data for additive P500 show a concentration power dependence less than unity, perhaps because the highest concentrations used are too close to MDR. At $c = 100$ wppm, solutions of all three additives are maximally drag reducing and, thus, reach the asymptotic $S' \approx 20$. Figure 6.4.2 similarly shows the

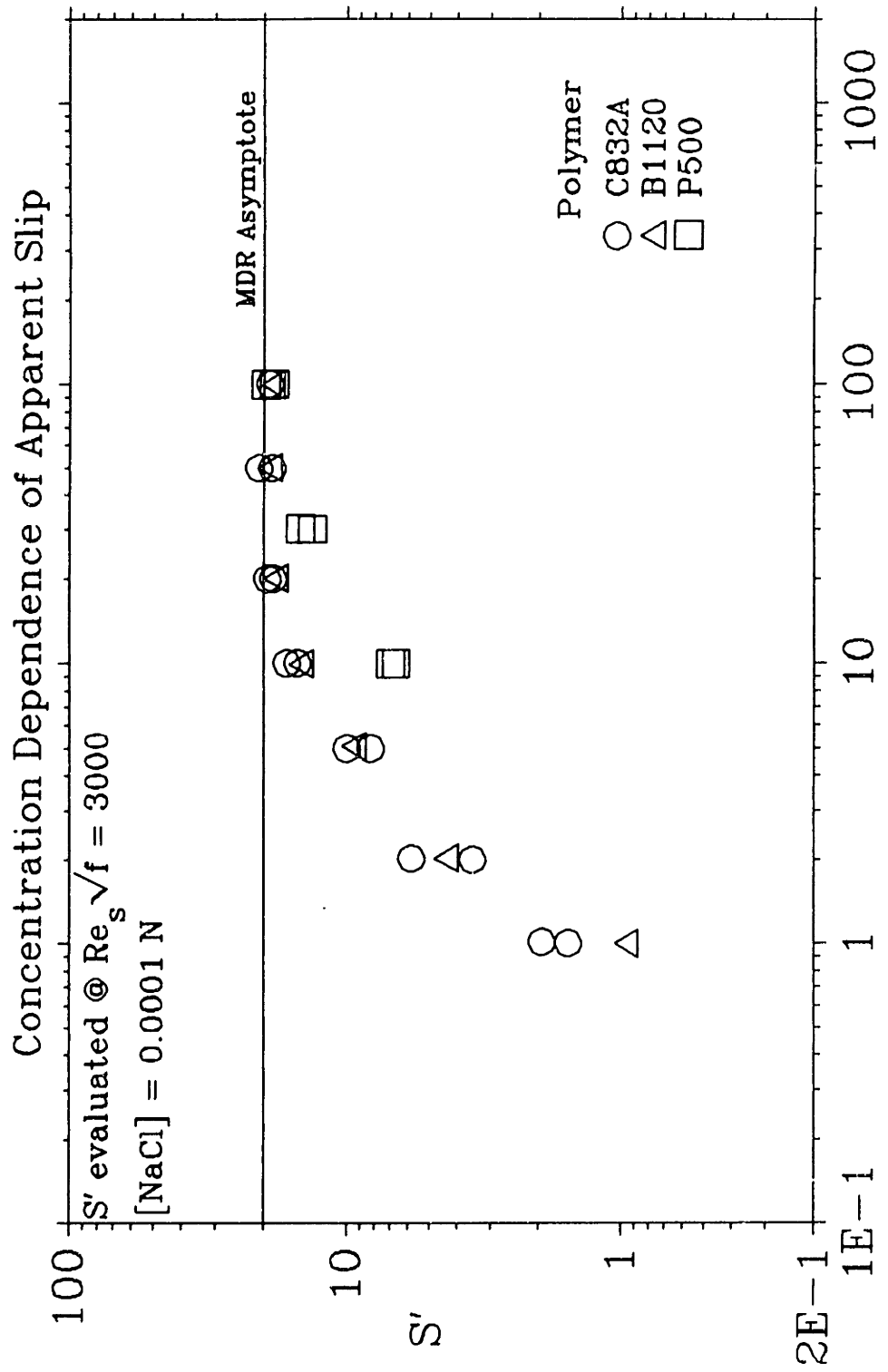


Figure 6.4.1: Concentration Dependence of Apparent Slip at $Re_s\sqrt{f}$ = 3000

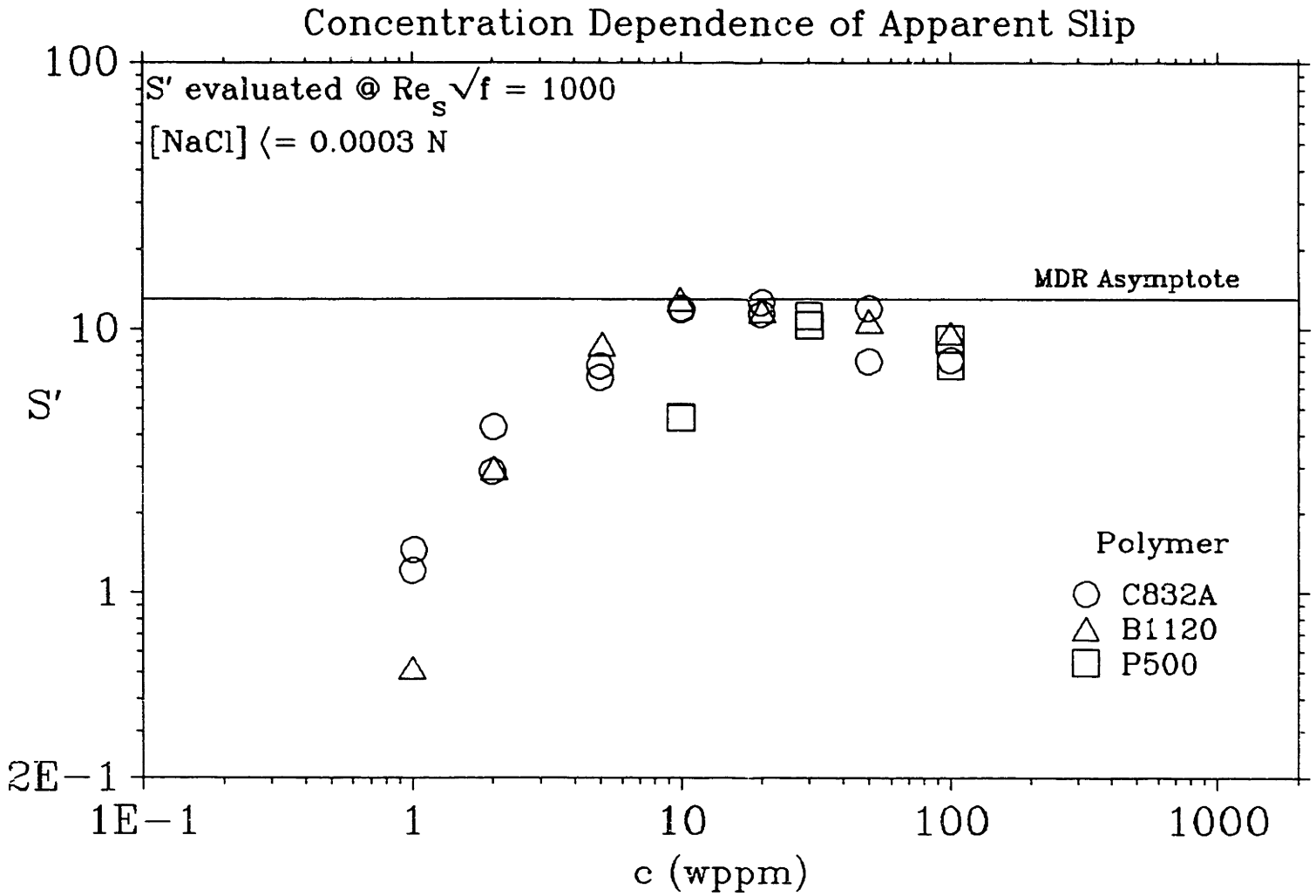


Figure 6.4.2: Concentration Dependence of Apparent Slip at $Re_s\sqrt{f} = 1000$

concentration dependence of S' at $Re_s\sqrt{f} = 1000$ on doubly-logarithmic coordinates for additives C832A, B1120, and P500. For these additives, S' is roughly linear in concentration up to c = 10 wppm. At high concentrations, a plateau due to the MDR asymptote is reached at S' ≈ 10. The data decline from the MDR plateau at the highest concentrations because the associated high laminar viscosities shift the laminar regime to higher $Re_s\sqrt{f}$; thus, these data may not represent fully-turbulent flow.

In Figures 6.4.1 and 6.4.2, data from the 1.458- and 1.021-cm pipes for additives C832A and P500 are not distinguished. To better display the effect of pipe diameter, Figure 6.4.3 displays S' at $Re_s\sqrt{f} \approx 3000$ and 1000 plotted against concentration in log-log coordinates for solutions of additives C832A and P500 with 0.0001 N NaCl from both pipes. With the exception of data at c = 2 wppm, S' at respective $Re_s\sqrt{f} = 3000$ and 1000 for additive C832A in the large pipe(○, △) and small pipe(●, ▲) are nearly the same, the difference being less than the ratio of pipe diameters. At high concentrations, S' at $Re_s\sqrt{f} = 3000$ and 1000 reach their respective MDR-asymptote values, S' ≈ 20 and 13. The wide separation of S' at $Re_s\sqrt{f} = 1000$ from the two pipes for additive C832A at c = 50 wppm is likely an artifact, caused by these flows not being fully turbulent, on account of the high laminar viscosity. For additive P500, the same trends for S' are observed at respective $Re_s\sqrt{f} = 3000$ and 1000 in both the large pipe(□, ▽) and the small pipe(■, ▼). In the two pipes, S' at $Re_s\sqrt{f} = 3000$ are virtually identical and reach the MDR plateau, S' ≈ 20, at c = 100 wppm; similarly, S' at $Re_s\sqrt{f} = 1000$ are nearly the same. Data at c = 100 wppm are both more separated and well below the MDR plateau because of the differing, but similar, effects of enhanced laminar viscosity in the two pipes.

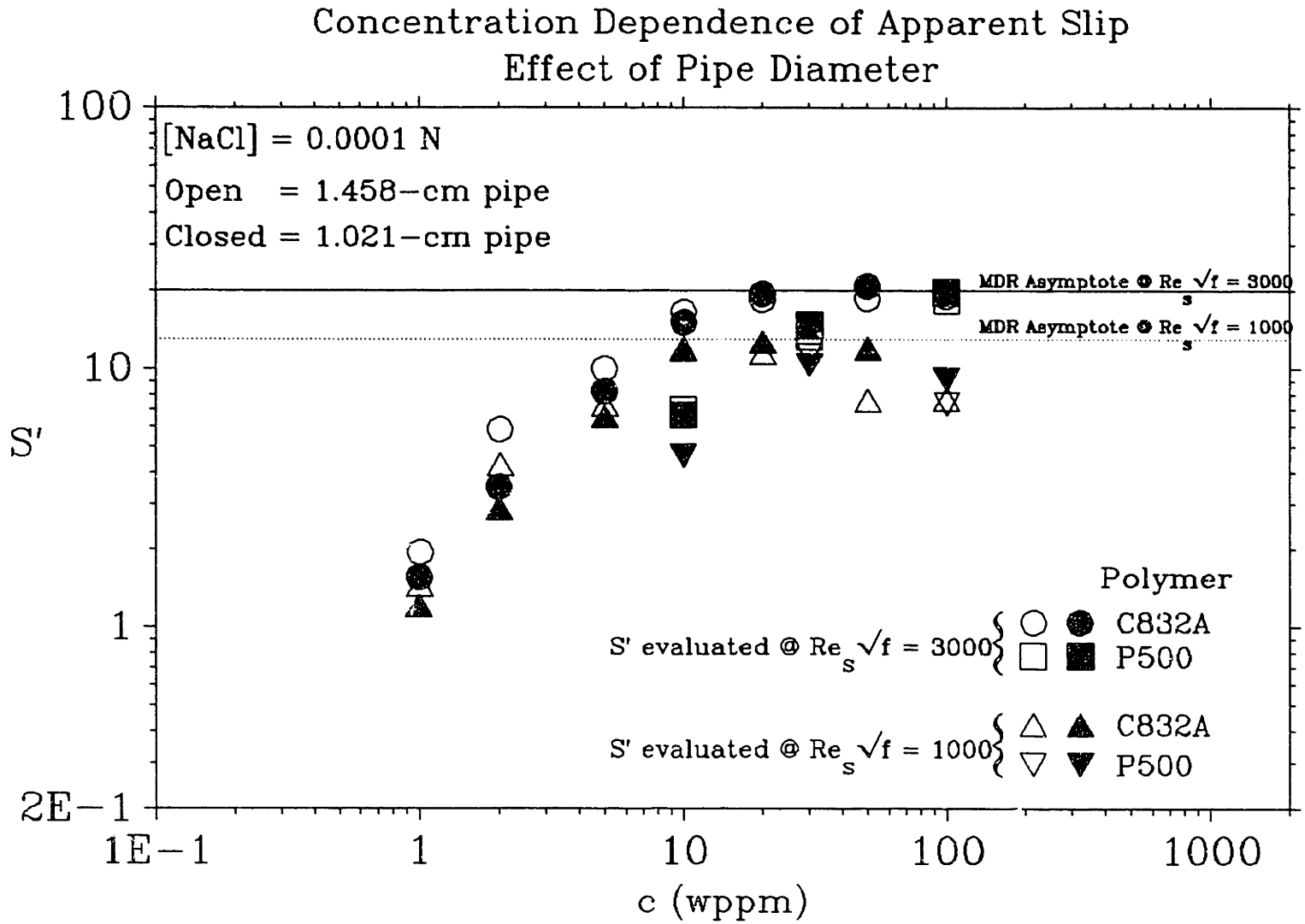


Figure 6.4.3: Concentration Dependence of Apparent Slip, Effect of Pipe Diameter

In summary Figure 6.4.3 suggests that in Type-B drag reduction, the flow enhancement, as measured by the apparent slip S', is independent of pipe diameter; it can also be seen that S' is only a weak function of $Re_s\sqrt{f}$, increasing slowly therewith.

To better demonstrate the linearity of S' with concentration at low concentrations, Figure 6.4.4 presents the specific slip S'/c at $Re_s\sqrt{f} = 3000$ plotted against concentration on log-log coordinates for the three HPAM additives at low salinity. For $c \leq 10$ wppm, additives C832A and B1120 have respective $S'/c \approx 1.9$ and 1.6; the data for $c \geq 10$ wppm rapidly decline along the line corresponding to the MDR asymptote. For additive P500, the initial $S'/c \approx 0.6$ and then declines with increasing concentration, merging into the line determined by the MDR asymptote. Because additives C832A and B1120 are about twice the molecular weight of P500 — respectively 18×10^6 and 20.1×10^6 versus 9.5×10^6 g/mole — the specific slip appears to vary with the molecular weight to a power between one and two, $S'/c \propto M_w^{1\cdot2}$. Also, S'/c is independent of pipe diameter for the data for each of additives C832A and P500 in different pipes. Figure 6.4.5 presents a doubly-logarithmic plot of S'/c at $Re_s\sqrt{f} = 1000$ versus concentration for these three HPAM additives at low salinity. Additives C832A and B1120 with respective $M_w \approx 18\times10^6$ and 20.1×10^6 g/mole display similar initial specifc slips $S'/c \approx 1.6$; additive P500 with a $M_w \approx 9.5\times10^6$ g/mole shows an initial $S'/c \approx 0.4$. In Figure 6.4.5, the specific slip appears to vary more closely with the square of the molecular weight: $S'/c \propto M_w^2$. For $c \geq 20$ wppm, S'/c for these HPAM additives lie adjacent to the line representing the MDR asymptote. The slight divergence at the highest concentrations reflects the large laminar viscosities, which shift the laminar-flow regimes to higher $Re_s\sqrt{f}$.

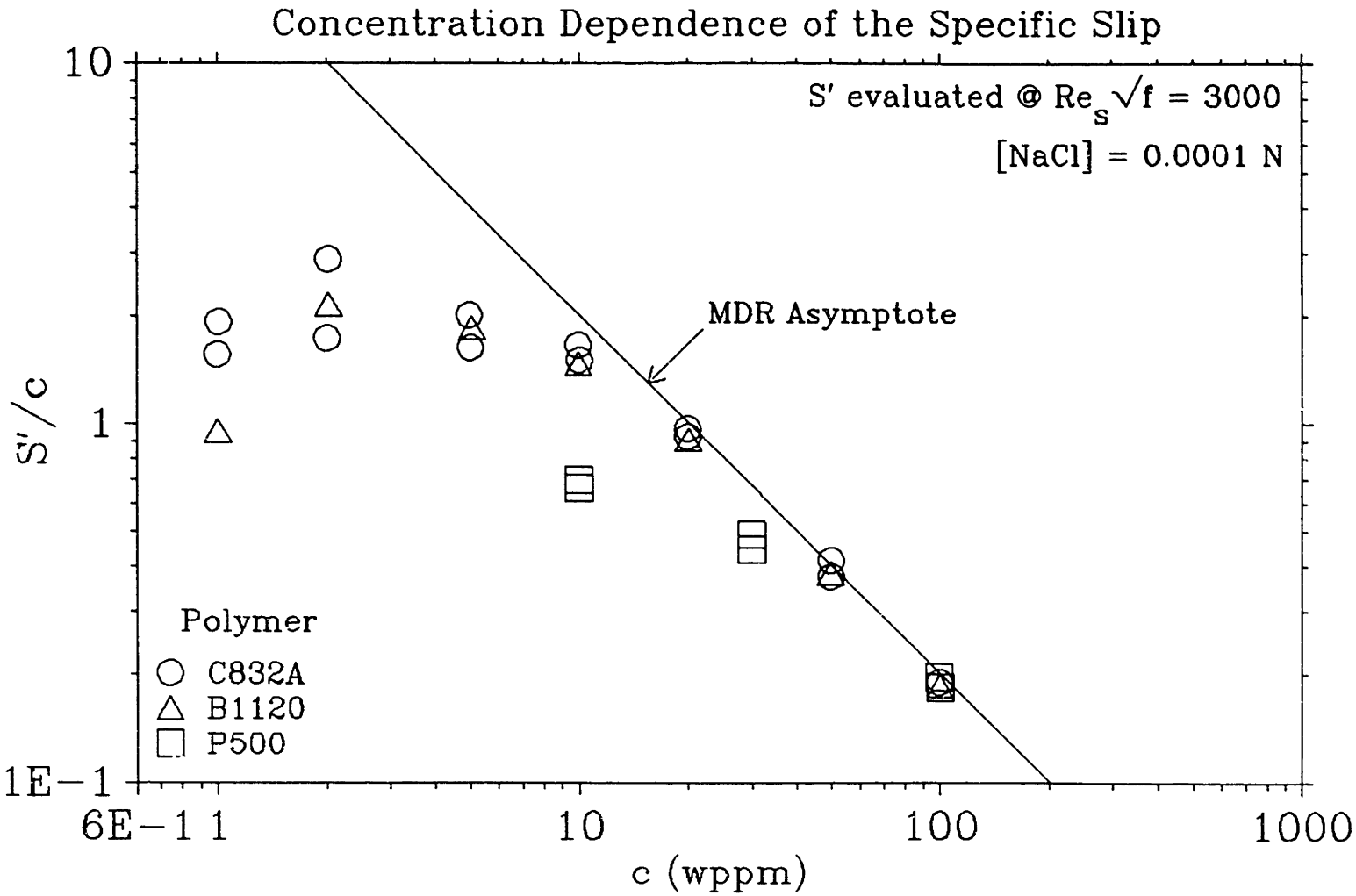


Figure 6.4.4: Concentration Dependence of the Specific Slip at $Re_s\sqrt{f} = 3000$

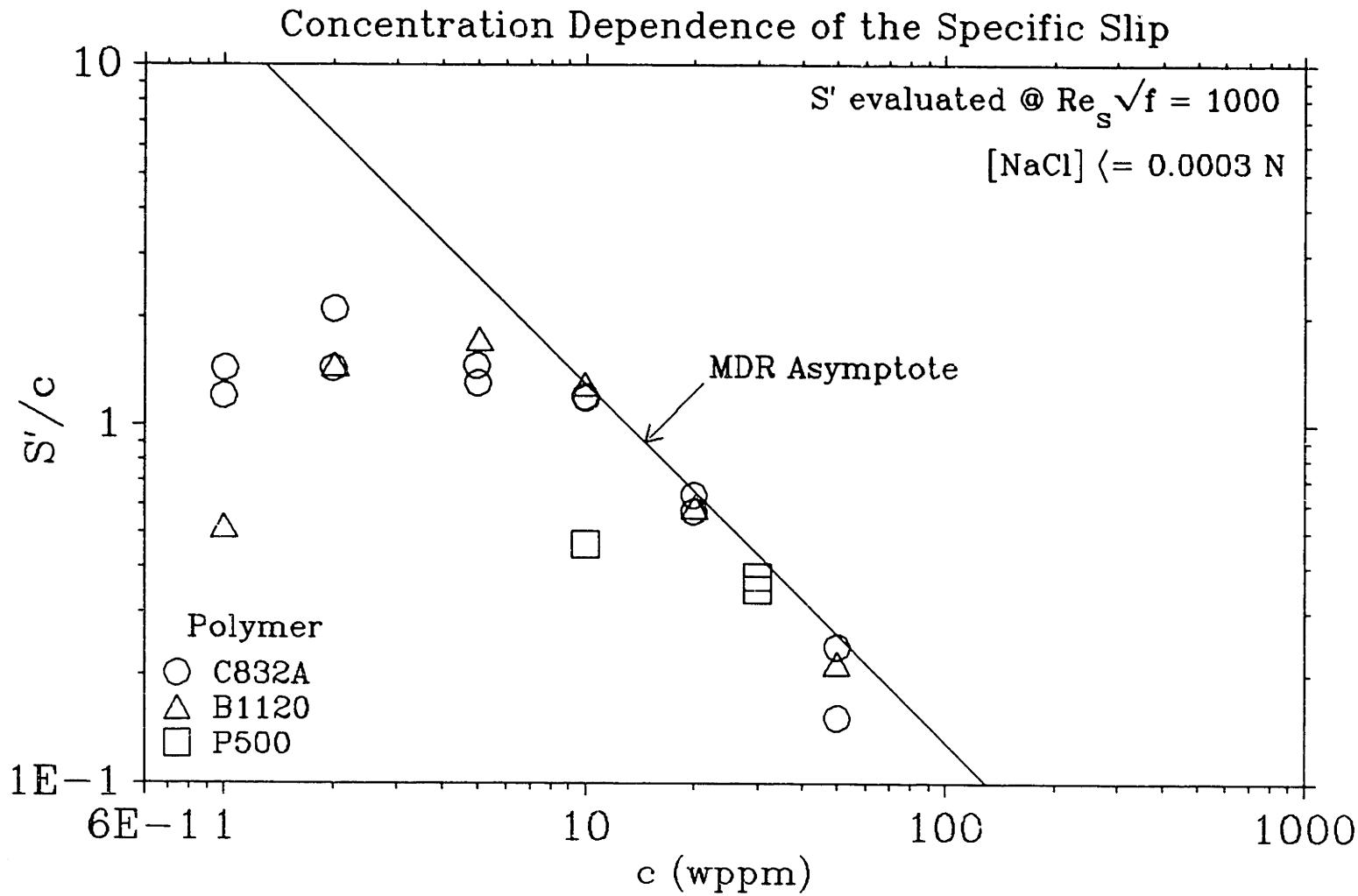


Figure 6.4.5: Concentration Dependence of the Specific Slip at $Re_s\sqrt{f} = 1000$

To further analyze the effect of molecular weight on Type-B drag-reduction, we define an intrinsic slip, a measure of flow enhancement per molecule:

$$\Sigma \equiv \frac{S'}{\left[\frac{c}{M_w}\right]} = \left[\frac{S'}{c}\right] M_w. \qquad (6.4\text{-}1)$$

Since the intrinsic slip Σ is a molecular quantity, we might expect it to depend upon a molecular attribute of the additive, of which the number of backbone chain links, N_{bb}, is the most fundamental. For any macromolecule, the number of backbone chain links, N_{bb}, and the related contour length, L_c, are derived from molecular weight by $M_w = mN_{bb}$ and $L_c = aN_{bb}$, respectively, where m and a are respectively the molecular weight and length per backbone chain link. For HPAM, specifically, m = 35.54 g/mole and $a = 1.26\times10^{-8}$ cm. Figure 6.4.6 presents Σ plotted against N_{bb} in log-log coordinates for additives C832A, B1120, and P500 in 0.0001 N NaCl solutions. The best-fit line through the three data points, shown dashed in Figure 6.4.6, is:

$$\Sigma = (1.00\pm0.23)\times10^{-7} N_{bb}^{(2.53\pm0.40)} \qquad (6.4\text{-}2)$$

The N_{bb} exponent of 2.53 in equation 6.4-2 is identically also the molecular-weight dependence of the intrinsic slip, that is, $\Sigma \propto M_w^{2.53}$. Note that because $\Sigma = S'/(c/M_w) = M_w(S'/c)$, the specific slip variation is $S'/c \propto M_w^{1.53}$, as previously observed in Figures 6.4.4 and 6.4.5.

If we assume for the moment (this is justified in §6.6) that the intrinsic slip Σ varies approximately as N_{bb}^3, then we can define a "slip modulus" λ as the proportionality constant in the relation $\Sigma = \lambda N_{bb}^3$. This is shown by the solid line in

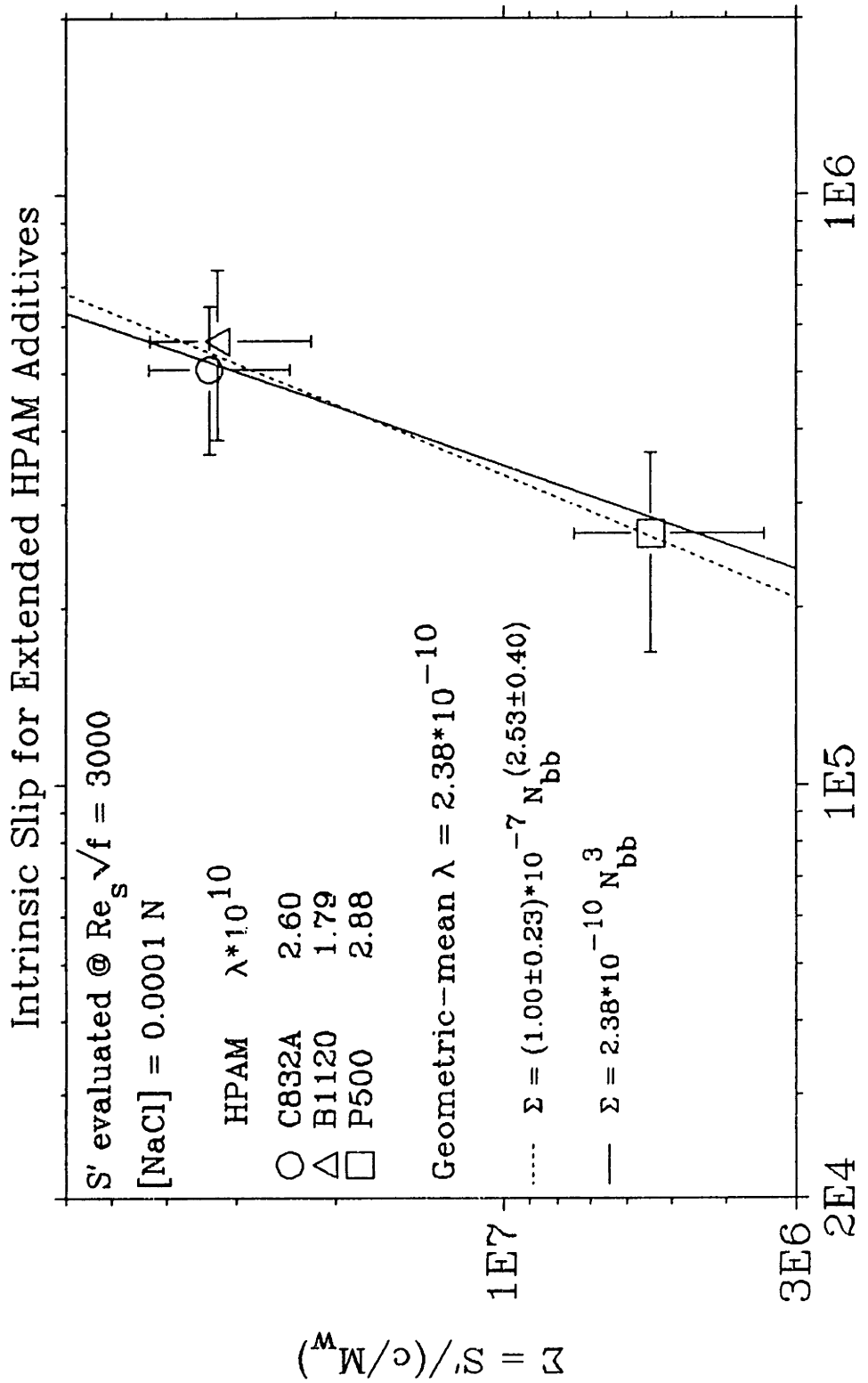


Figure 6.4.6: Intrinsic Slip for Extended HPAM Additives

Figure 6.4.6, corresponding to the equation:

$$\Sigma = 2.38\times10^{-10}N_{bb}^{\ 3} \tag{6.4-3}$$

where the geometric-mean slip modulus $\lambda = 2.38\times10^{-10}$ g/mole/wppm. From equation 6.4-3, the specific slip S'/c is seen to vary as macromolecular contour length to the third power, by the expression

$$\frac{S'}{c} = \left[\frac{\lambda}{a^3}\right]\left[\frac{L_c^{\ 3}}{M_w}\right] \tag{6.4-4}$$

with λ in g/mole/wppm, backbone-link length a and contour length L_c in cm, and M_w in g/mole. If every macromolecule in solution occupied a sphere of diameter equal to its contour length, then this "pervaded" volume fraction per wppm of additive, X_v/c, must also vary as L_c^3, given by the expression

$$\frac{X_v}{c} = \left[\frac{\pi L_c^{\ 3}}{6}\right]\left[\frac{\rho N_A}{10^6 M_w}\right] \tag{6.4-5}$$

with L_c in cm, fluid density ρ in g/cm^3, M_w in g/mole, and Avogadro's number N_A = 6.022×10^{23} mole^{-1}. Equations 6.4-4 and 6.4-5 both have factors of L_c^3/M_w on their respective right sides, so the maximum pervaded volume fraction per unit of slip, X_v/S', depends solely on the physical properties of the additive and solvent, and should thus be constant for a given polymer-solvent system. From equations 6.4-4 and 6.4-5, X_v/S' can be written

$$\frac{X_v}{S'} = \left[\frac{\pi L_c^{\ 3}}{6}\right]\left[\frac{\rho N_A}{10^6 M_w}\right]\left[\frac{c}{S'}\right] = \left[\frac{\pi}{6\times10^6}\right]\left[\frac{\rho N_A a^3}{\lambda}\right] \tag{6.4-6}$$

With $\rho \approx 1$ g/cm^3, a $\approx 1.26\times10^{-8}$ cm, and $\lambda = 2.38\times10^{-10}$ g/mole/wppm, $X_v/S' \approx$ 2630 for the present HPAM additives — C832A, B1120, and P500. Thus, to induce unit flow enhancement, the HPAM additive macromolecules would have to pervade a volume 2630 times greater than that of the solvent surrounding them. Since that is impossible, the additive macromolecules must align themselves to a considerable extent, even in the turbulent flow field. All slip data are summarized in Table 6.4.

Table 6.4
Specific and Intrinsic Slip Data

HPAM	Molecular Weight	Number of Backbone Chain Links	Contour Length
	$M_w\times10^{-6}$	$N_{bb}\times10^{-5}$	$L_c\times10^{-3}$
	(g/mole)		(cm)
C832A	18.0±5.0	5.0±1.4	6.4
B1120	20.1±6.4	5.7±1.8	7.1
P500	9.5±3.5	2.7±1.0	3.4

Average Specific Slip†	Average Intrinsic Slip†	Volume Fraction per wppm	Volume Fraction per unit slip
S'/c	$\Sigma\times10^{-6}$	X_v/c	X_v/S'
(wppm^{-1})	(g/mole/wppm)	(wppm^{-1})	
1.87	33.6±9.4	4520	2420
1.62	32.5±10.4	5640	3480
0.58	5.45±2.02	1260	2170

† These parameters are evaluated at $Re_s\sqrt{f} = 3000$.

6.4.2 Retro-Onset

Here retro-onset data in Type-B drag reduction are analyzed for the first time according to a model of an ideal Type-B ladder.

As mentioned briefly in §5.3, the retro-onset wall shear stress $T_w^{\#}$ in the idealized Type-B ladder depends on concentration, pipe diameter, and flow-enhancement efficiency of the additive, characterized by the specific slip S'/c.

In an ideal Type-B ladder, each rung, or P segment, is parallel to N and has a constant specific slip, S'/c, that provides a corresponding $1/\sqrt{f_p}$ within the polymeric regime; each rung spans a range of $Re_s\sqrt{f}$, with lower bound at the retro-onset point, $Re_s\sqrt{f}^{\#}$, where it intersects the MDR asymptote, and an upper bound of $Re_s\sqrt{f}\hat{}$, which denotes the degradation falloff, where the rung begins to deviate downward from its parallel path. Since a rung's parallel displacement above N is proportional to c, the retro-onset $Re_s\sqrt{f}^{\#}$ increases with increasing c, rungs farther above N intersecting the MDR asymptote M at higher $1/\sqrt{f_p}$ and, therefore, higher $Re_s\sqrt{f}^{\#}$. In PK coordinates, each rung is described by the equation

$$\frac{1}{\sqrt{f_p}} = 4.0\log Re_s\sqrt{f} - 0.4 + c\left[\frac{S'}{c}\right] \qquad (6.4\text{-}7)$$

The intersection of P with M, that is, with equation 2.3-7, provides the retro-onset point:

$$Re_s\sqrt{f}^{\#} = 10^{\left[\frac{c\frac{S'}{c}+32}{15}\right]} \doteq 136 + 10^{\frac{S'}{15}} \qquad (6.4\text{-}8)$$

where the constant 136 = $Re_s\sqrt{f}^{\#}_o$ is physically the intersection of the zero concentration

rung, that is, the PK line N, with M. The nondimensional equation 6.4-8 is independent of pipe diameter; however, converting $Re_s\sqrt{f^{\#}}$ to $T_w^{\#}$ by the relation $T_w^{\#} = (\rho v_s^2)(Re_s\sqrt{f^{\#}})^2/(2D^2)$ yields a dimensional, general equation in which $T_w^{\#}$ depends on pipe diameter:

$$\log T_w^{\#} = \log T_{w\,o}^{\#} + \frac{2c}{15}\left[\frac{S'}{c}\right] \tag{6.4-9}$$

where $T_{w\,o}^{\#}$ represents the stress at the intersection of the Newtonian turbulent baseline N and the MDR asymptote M. Whereas in equation 6.4-8, the pipe-diameter independent $Re_s\sqrt{f^{\#}}_o = 10^{32/15} \approx 136$, the pipe-diameter dependent $T_{w\,o}^{\#} = (\rho v_s^2)(Re_s\sqrt{f^{\#}}_o)^2/(2D^2) \approx 0.346$ and 0.705 dyne/cm^2 for the 1.458- and 1.021-cm pipes, respectively. Recall that the experimentally obtained retro-onset relation 5.3-1 in §5.3 obeyed the form of equation 6.4-9. While equation 5.3-1

$$\log T_w^{\#} = -0.436 + 0.134c \tag{5.3-1}$$

has approximately the theoretical ordinal intercept, $\log T_{w\,o}^{\#} = -0.436$ or $T_{w\,o}^{\#} = 0.37$ dyne/cm^2, the coefficient (2/15)(S'/c) yields an $S'/c \approx 1.00$ which is lower than the observed average specific slip of additives C832A and B1120 in the 1.458-cm pipe, $S'/c \approx 1.75$; the differences between these two specific slips are caused by the observed Type-B ladders being less than perfect, with rungs not entirely parallel to N. To account for ladder imperfections, the factor β is incorporated into equation 6.4-9 to give the following expression for the observed Type-B ladders

$$\log T_w^{\#} = \log T_{w\,o}^{\#} + \left[\frac{2}{15}\right]\beta\left[\frac{S'}{c}\right]c \tag{6.4-10}$$

For the HPAM data shown in Figure 6.4.6, the ladder-imperfection factor $\beta \approx 0.58$.

6.5 Comparisons Between Type-A and Type-B Flow Enhancement

After separate analyses of Type-A and Type-B flow enhancement in §6.3 and §6.4, the two types are directly compared to establish quantitatively the relative effectiveness of initially collapsed and extended macromolecules on flow enhancement. In §6.5.1, the slip ratio at constant concentration, a measure of relative flow enhancement by equally concentrated solutions of initially collapsed and extended additives, is introduced. In §6.5.2, additive equivalence and isoslip are defined to quantify the concentration equivalence at constant flow enhancement between solutions of initially collapsed macromolecules and solutions of initially extended macromolecules.

6.5.1 Slip Ratio at Constant Concentration

In the polymeric regime, Type-A drag reduction is observed never to exceed Type-B drag reduction, that is, $S'_A < S'_B$, with the former approaching the latter as $Re_s\sqrt{f}$ increases. Hence, initially random-coiling macromolecules in Type-A drag reduction are stretched toward the extended conformations present in Type-B drag reduction. Because the extended conformation induces flow enhancement, the slip ratio S'_A/S'_B at fixed concentration, defined as R_{sc}, directly reflects relative macromolecular extension; thus, the dependence of R_{sc} on $Re_s\sqrt{f}$ should provide insight into the dynamics of coil extension by the turbulent flow.

Figure 6.5.1 illustrates in semilogarithmic coordinates the dependence of the slip ratio at constant concentration on $Re_s\sqrt{f}$ and salinity for three 30-wppm P500 solutions

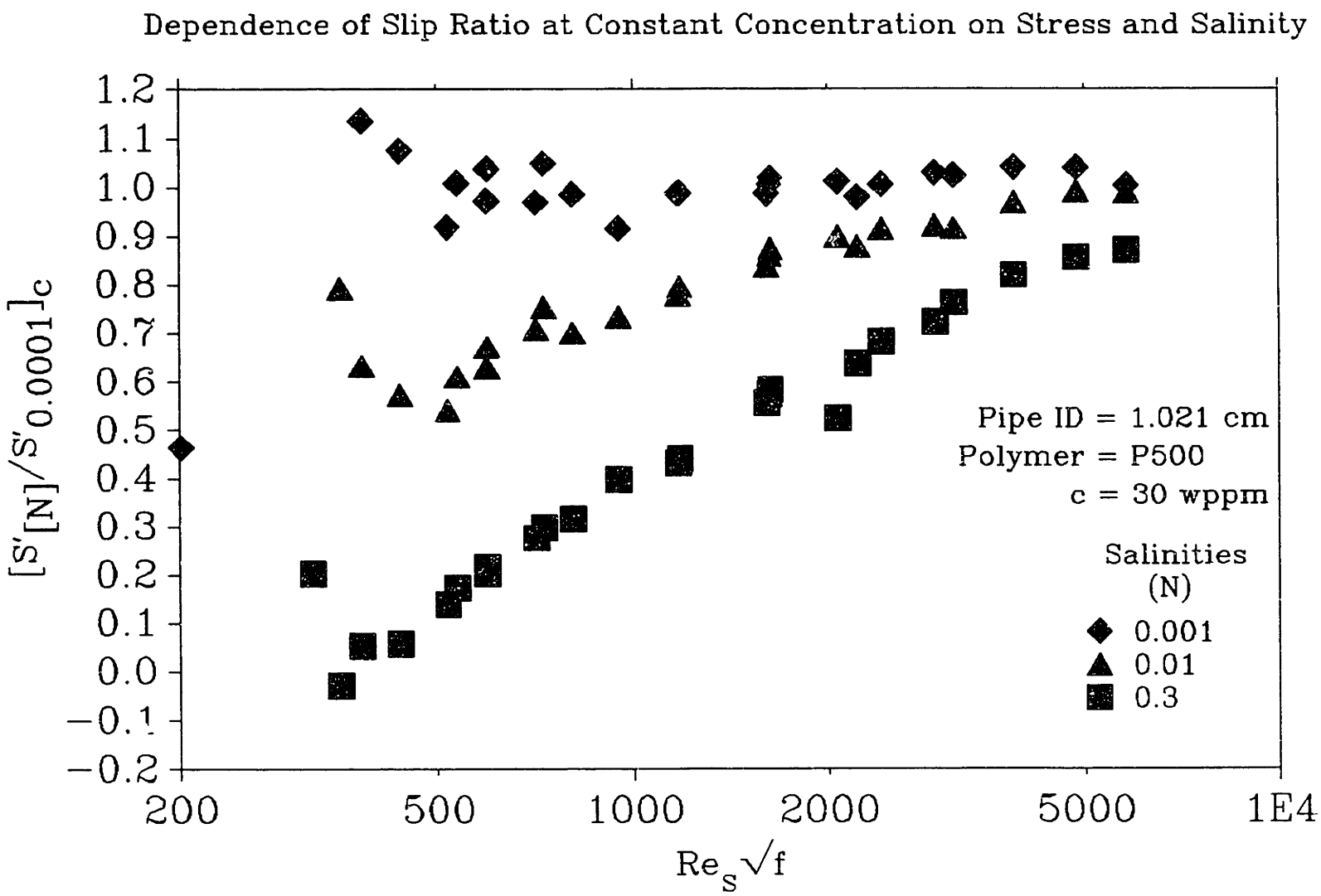


Figure 6.5.1: Dependence of Slip Ratio at Constant Concentration on Stress and Salinity

in the 1.021-cm pipe with 0.3, 0.01, and 0.001 N NaCl, each of which is referenced to a fourth 30-wppm P500 solution also in the 1.021-cm pipe with 0.0001 N NaCl. Because only the 0.3-N P500 solution exhibits Type-A behavior, whereas the 0.01- and 0.001-N P500 solutions exhibit behaviors somewhere between Types A and B, the slip ratio in Figure 6.5.1 is written as $[S'_{[N]}/S'_{0.0001}]_c$. For the 30-wppm P500 solution in 0.3 N NaCl(■), $[S'_{[N]}/S'_{0.0001}]_c \approx 0$ at $Re_s\sqrt{f^*} \approx 450$ and then increases monotonically, but with decreasing slope, to $[S'_{[N]}/S'_{0.0001}]_c \approx 0.85$ at $Re_s\sqrt{f} \approx 5000$. The observed increase in the slip ratio for $Re_s\sqrt{f} > Re_s\sqrt{f^*}$ reflects the progressive extension of the initially-collapsed macromolecular conformation with increasing turbulent flow strength. For the 0.01-N P500 solution(▲), $[S'_{[N]}/S'_{0.0001}]_c \approx 0.55$ at $Re_s\sqrt{f} \approx 450$ and increases with shallow slope up to $Re_s\sqrt{f} \approx 5000$ at which $[S'_{[N]}/S'_{0.0001}]_c \approx 0.95$. For the 0.001-N P500 solution(◆), $[S'_{[N]}/S'_{0.0001}]_c \approx 1.0$, approximately constant, for $500 \leq Re_s\sqrt{f} \leq 5000$. These results suggest that the extended conformations of the additive induce drag reduction, and thence the more closely an initial conformation resembles the active extended form, the more effective it is in drag reduction.

Figure 6.5.2 shows the slip ratio for the extreme conformations, $R_{sc} = S'_A/S'_B$ versus $Re_s\sqrt{f}$ in semilogarithmic coordinates for solution pairs, in 0.3 N and 0.0001 N NaCl, of additives C832A at c = 2 and 5 wppm in the 1.458-cm and 1.021-cm pipes, B1120 at c = 2 and 5 wppm in the 1.458-cm pipe, and P500 at c = 10 and 30 wppm in the two pipes. Data for these additives at c = 2, (5,10), and 30 wppm characterize the relative macromolecular extensions at flow enhancements near the turbulent baseline N, in the polymeric regime P, and near the MDR asymptote M, respectively. In the region $200 < Re_s\sqrt{f} < 500$, R_{sc} declines precipitously from 0.8 ± 0.1 to 0.0 ± 0.1 with

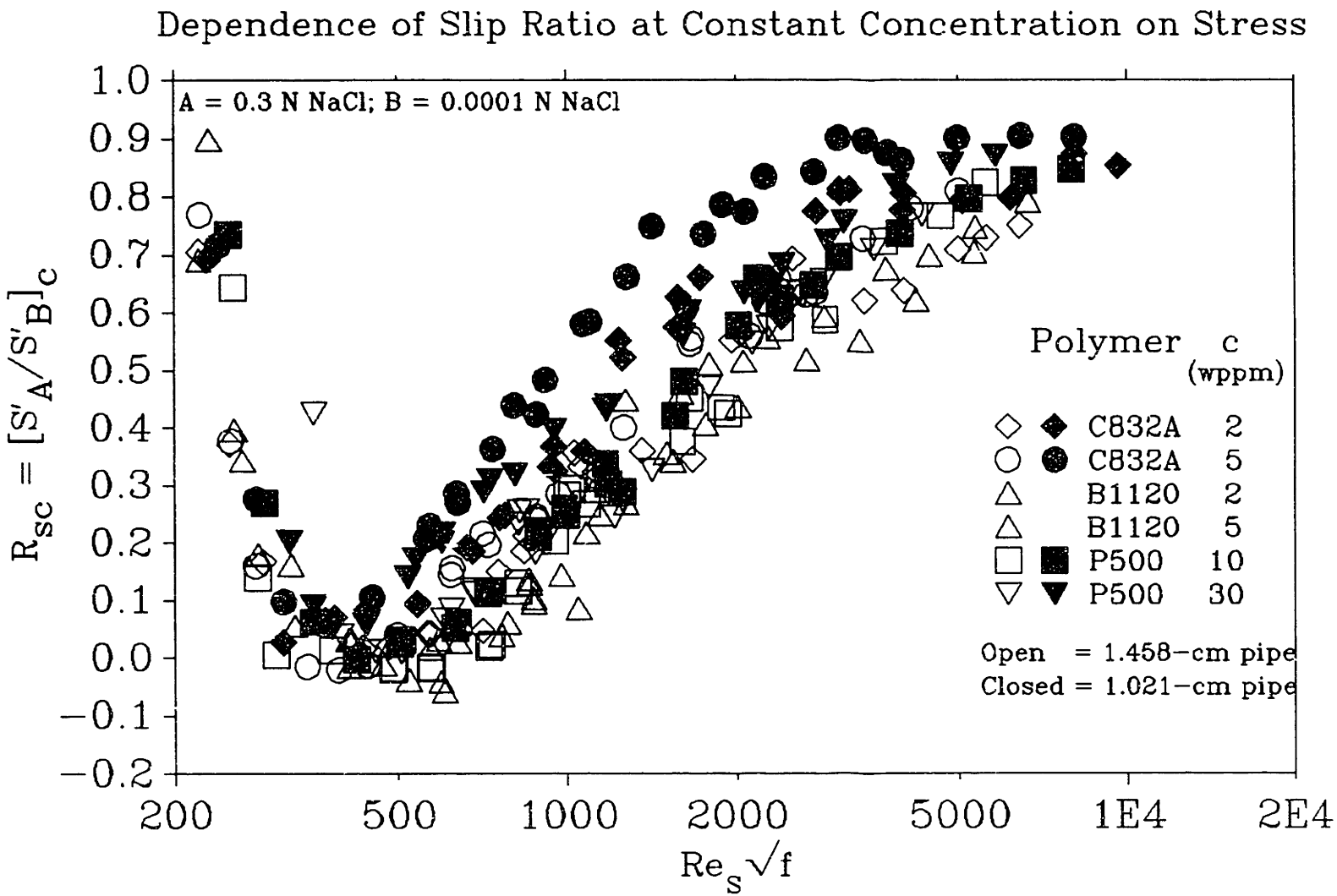


Figure 6.5.2: Dependence of Slip Ratio at Constant Concentration on Stress

increasing $Re_s\sqrt{f}$, for all additives. The behavior in this region arises from the relative positions of laminar-to-turbulent transitions common to Type-A flow trajectories and rightward-shifted, drag-enhancing laminar segments common to Type-B flow trajectories, given that $Re_s\sqrt{f}^* \approx 530\pm40$, 610 ± 40, and 630 ± 70 for additives C832A, B1120, and P500, respectively, at these concentrations. From being approximately zero at $Re_s\sqrt{f} \approx 550\pm100$, in the vicinity of the onset points, R_{sc} increases with increasing $Re_s\sqrt{f}$ up to $R_{sc} \approx 0.8$ at $Re_s\sqrt{f} \approx 3000$ for all additives at all concentrations. The near universality of the broad band of R_{sc}-versus-$Re_s\sqrt{f}$ data, combined with the observations that $S'_A \geq 0$ only for $Re_s\sqrt{f} \geq Re_s\sqrt{f}^*$, suggest a more refined plot of R_{sc} versus the normalized flow-strength parameter $Re_s\sqrt{f}/Re_s\sqrt{f}^*$.

Figure 6.5.3, a semilogarithmic plot of R_{sc} vs. $Re_s\sqrt{f}/Re_s\sqrt{f}^*$, presents the data shown in Figure 6.5.2 with an abscissa normalized by $Re_s\sqrt{f}^*$, to remove the influence of differing onset points among the additives. For $0.8 < Re_s\sqrt{f}/Re_s\sqrt{f}^* < 1$, $R_{sc} \approx 0$. At $Re_s\sqrt{f}/Re_s\sqrt{f}^* \approx 1$, all 10 curves are essentially fixed at $R_{sc} \approx 0$. For $Re_s\sqrt{f}/Re_s\sqrt{f}^* > 1$, R_{sc} increases monotonically with increasing $Re_s\sqrt{f}/Re_s\sqrt{f}^*$ up to $R_{sc} \approx 0.6$ at $Re_s\sqrt{f}/Re_s\sqrt{f}^* \approx 5$, with the data in a narrower band than that in Figure 6.5.2. For $Re_s\sqrt{f}/Re_s\sqrt{f}^* > 5$, the rate of increase of R_{sc} declines, and at $Re_s\sqrt{f}/Re_s\sqrt{f}^* \approx 15\pm5$, all data attain the final asymptotic $R_{sc} \approx 0.8\pm0.1$.

The shape of the data in Figure 6.5.3 suggests a relation that satisfies the boundary conditions $R_{sc} = 0$ at $Re_s\sqrt{f}/Re_s\sqrt{f}^* = 1$ and $R_{sc} \to 1$ as $Re_s\sqrt{f}/Re_s\sqrt{f}^* \to \infty$, having the general form: $R_{sc} = 1 - (Re_s\sqrt{f}/Re_s\sqrt{f}^*)^x$. After some trial and error, the following equation, shown in Figure 6.5.3 by the solid curve, is found to well approximate the data:

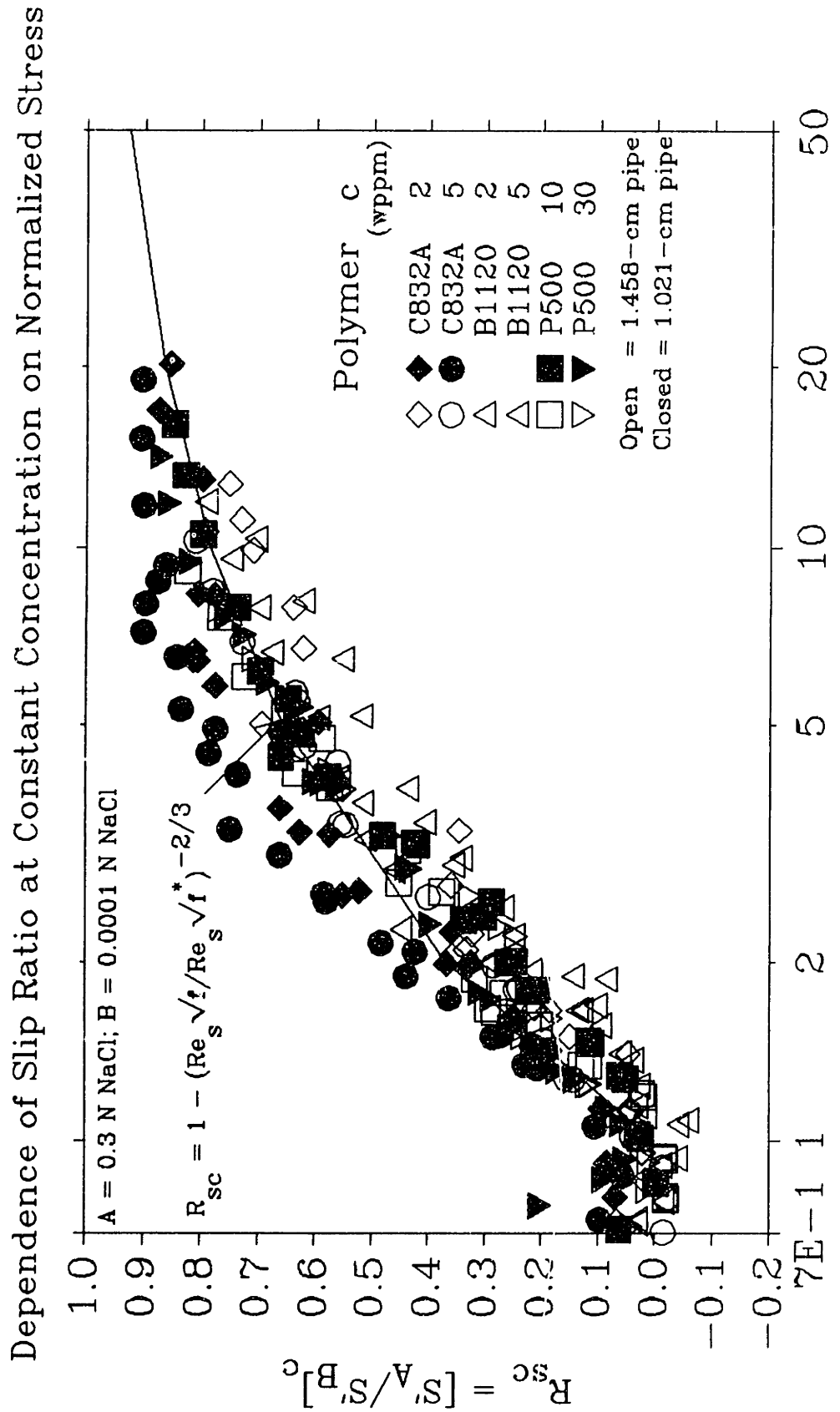


Figure 6.5.3: Dependence of Slip Ratio on Normalized Stress

$$R_{sc} = 1 - \left[\frac{Re_s\sqrt{f}}{Re_s\sqrt{f}^{\bullet}} \right]^{-2/3} \qquad (6.5\text{-}1)$$

Equation 6.5-1 physically represents the extension of initially collapsed, random-coiling HPAM macromolecule towards their fully extended conformations by the turbulent flow field. This process seems relatively independent of additive parameters and absolute wall shear stress levels. Relation 6.5-1 provides an indication of the normalized flow strengths required to achieve significant extensions of initially collapsed, random-coiling macromolecules; for $R_{sc} = 0.5$, $T_w/T_w^{\bullet} = 10$, while for $R_{sc} = 0.8$, $T_w/T_w^{\bullet} = 125$. These also indicate that macromolecular extension is most facile at low flow strengths, near onset, and then becomes increasingly more difficult at higher flow strength.

6.5.2 Additive Equivalence Between Types A and B Drag Reduction

Figure 6.5.4, a semilogarithmic PK plot with abscissa $Re_s\sqrt{f}$ and ordinate $1/\sqrt{f}$, provides an example of an isoslip point and additive equivalence for additive C832A among a 5.6-wppm solution in 0.00001 N NaCl(□, abbr 5.6B), a 20.9-wppm solution in 0.00001 N NaCl(◇, abbr 20.9B), and a 20.7-wppm solution in 0.1 N NaCl(◆, abbr 20.7A). The former two trajectories are part of a Type-B ladder, while the third belongs to a Type-A fan. The lines L, N, and M respectively represent the Newtonian laminar and turbulent baselines and the MDR asymptote. Laminar regimes are omitted to provide the most-expansive view. It is seen that the trajectory 20.7A intersects 5.6B at ($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (950, 15.1). This is termed an "isoslip point", since both solutions here exhibit

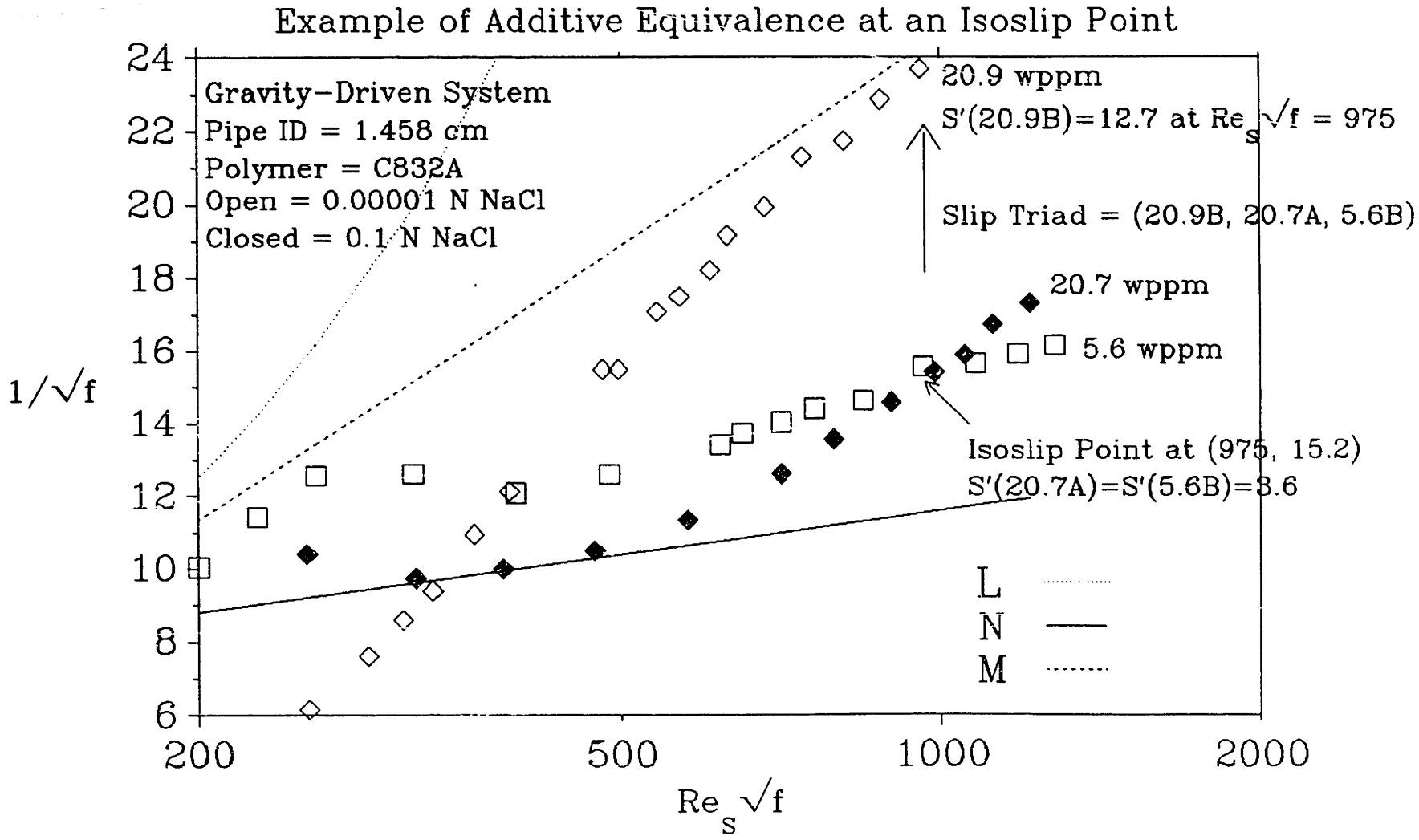


Figure 6.5.4: Example of Additive Equivalence at an Isoslip Point

the identical flow enhancement, S'(20.7A) = S'(5.6B) ≈ 3.6. At this isoslip point, 20.7 wppm of the initially collapsed conformation and 5.6 wppm of the initially extended conformation are evidently equivalent in their abilities to reduce drag. The term "additive equivalence" is used to describe such a case, where two different additive solutions cause the same drag reduction. Continuing, at the isoslip $Re_s\sqrt{f} \approx 950$, the trajectory 20.9B exhibits S' = 12.7, generating a "slip triad" (20.9B, 20.7A, 5.6B) with associated S'(12.7, 3.6, 3.6). Within this triad, the collapsed to extended slip ratio at constant concentration, R_{sc} = S'(A)/S'(B) = 3.6/12.7 ≈ 0.28, while the extended to collapsed concentration ratio at constant slip $R_{cs} = c_B/c_A = 5.6/20.7 \approx 0.27$. The essential equality between R_{sc} and R_{cs} is striking. Physically, $R_{sc} = R_{cs}$ implies that, for fixed total additive concentration, the collapsed to extended slip ratio R_{sc} at any $Re_s\sqrt{f}$ simply represents the fraction of originally collapsed macromolecules that have become extended in the flow, and thence effective in drag reduction.

6.5.2.1 Analysis of Isoslip Points and Additive Equivalences

The detailed flow trajectories presented in §5.2 for additive solutions at high and low salinity are intercalated to establish isoslip points and additive equivalences. Two PK plots, with the laminar regimes omitted, demonstrate isoslip points for each additive. In each pair of plots, alternate spokes of a Type-A fan are superposed upon an entire Type-B ladder, identifying all isoslip points between the two drag-reduction structures.

Figures 6.5.5 and 6.5.6 illustrate isoslip points among solutions of additive C832A, comprising data at 0.3 N and 0.0001 N NaCl, from the pump-driven system

using the 1.458-cm pipe. In the former, Type-A fan spokes at c = 5 and 20 wppm(5A and 20A) are shown with Type-B ladder rungs at c = 1, 2, 5, 10, and 20 wppm(1B, 2B, 5B, 10B, and 20B); in the latter, the 2A and 10A spokes of the Type-A fan are superposed upon the 1B, 2B, 5B, and 10B rungs of the Type-B ladder. The lines L, N, and M, shown for reference in both figures, respectively represent the Newtonian laminar and turbulent baselines and the MDR asymptote.

In Figure 6.5.5, the 5A data onset at $Re_s\sqrt{f}^* \approx 500$ and, rising linearly into the polymeric regime, intersect the 1B and 2B data, forming isoslip points, at ($Re_s\sqrt{f}$, $1/\sqrt{f}$) $\approx$ (750, 12.5) and (2000, 18.2), respectively; the 5B data attain $1/\sqrt{f} \approx 17.5$ and 22.1 at $Re_s\sqrt{f} \approx 750$ and 2000, respectively. Notice that polymer degradation causes both the 5A and 5B data to decline from their P segments at almost the same $Re_s\sqrt{f} \approx 3000$, preventing the intersection of these P segments; therefore, the extended conformation, the only conformation in solutions exhibiting Type-B drag-reduction behavior, not only also obtains for Type-A drag-reduction at high $Re_s\sqrt{f} > Re_s\sqrt{f}^*$, it is responsible for flow enhancement regardless of the type.

At $Re_s\sqrt{f} \approx 750$, the slip triad S'(5B, 5A, 1B) $\approx$ (6.4, 1.4, 1.4) produces $R_{cs} = c_B/c_B = 1/5 = 0.20$ at S' $\approx$ 1.4 and $R_{sc} = S'_A/S'_B \approx 1.4/6.4 \approx 0.22$ at c = 5 wppm. At $Re_s\sqrt{f} \approx 2000$, the triad S'(5B, 5A, 2B) $\approx$ (9.3, 5.4, 5.4) yields $R_{cs} = 2/5 = 0.40$, and $R_{sc} \approx 5.4/9.3 \approx 0.58$. At the first isoslip point, the ratios R_{cs} and R_{zc} agree well, whereas at the second isoslip point, they differ somewhat because the 2B data exhibit too-large an apparent slip.

The 20A data show an apparent onset at $Re_s\sqrt{f}^* \approx 400$ and, ascending linearly into the polymeric regime, form isoslip points with the 1B, 2B, and 5B data at respective

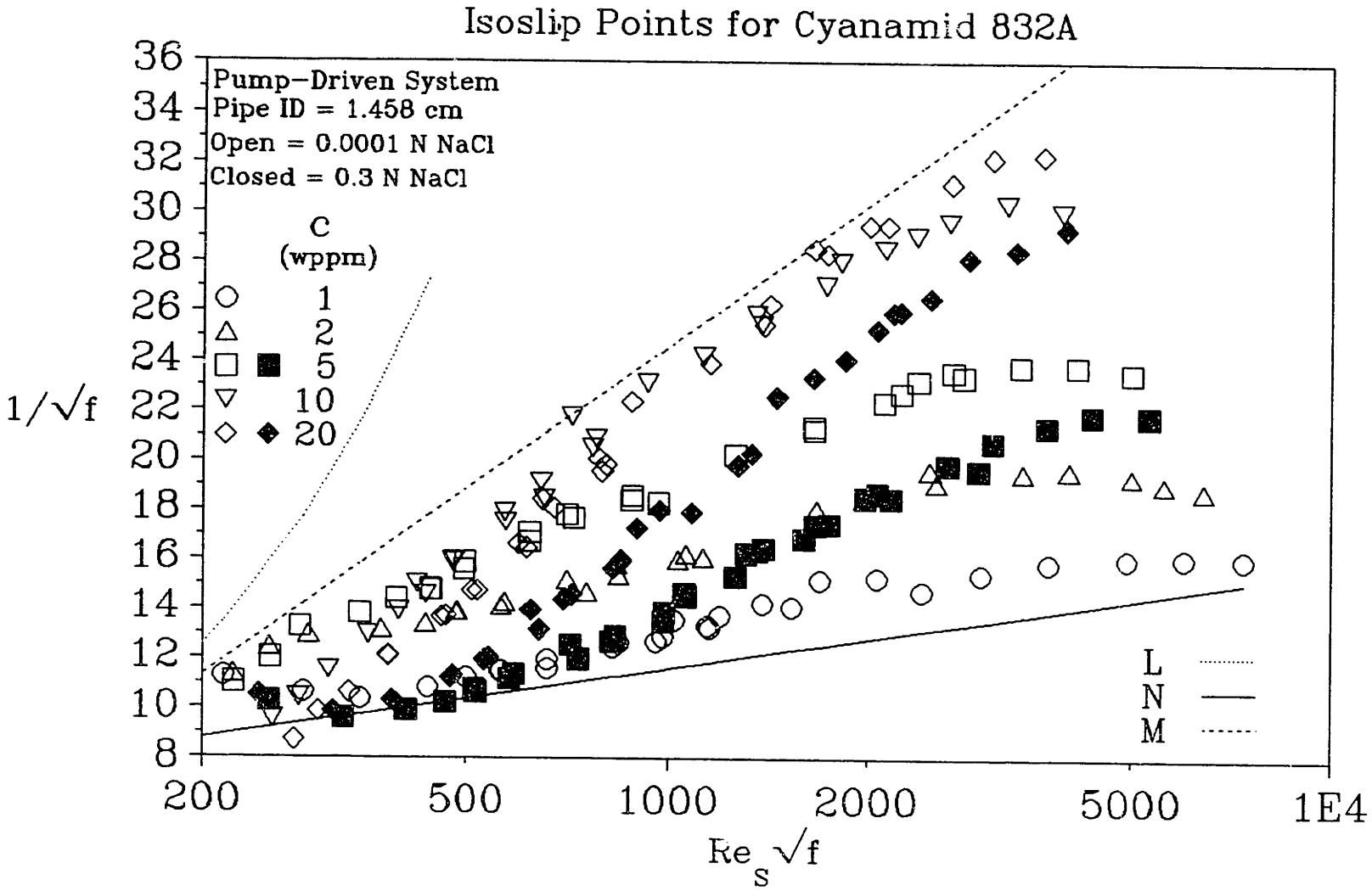


Figure 6.5.5: Isoslip Points for Cyanamid 832A at c = 5 and 20 wppm in the 1.458-cm Pipe

($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (500, 11.6), (750, 15.2) and (1200, 19.9). At $Re_s\sqrt{f}$ ≈ 500, 750, and 1200, the 20B data attain respective $1/\sqrt{f}$ ≈ 14.4, 19.6, and 24.7. As seen in Figure 6.5.5, the first two $1/\sqrt{f}$ data appear somewhat transitional, not yet fully turbulent, and the third is clearly limited by the MDR asymptote. Interestingly, at $Re_s\sqrt{f}$ ≈ 3000, where the 20A data decline from their P segment, the 20B data depart from M into the polymeric regime, exhibiting retro-onset; this suggests that the 20B retro-onset is induced by polymer degradation, which is reinforced by the 10B rung lying closely beneath. Moreover, degradation of additive C832A in the 1.458-cm pipe occurs at $Re_s\sqrt{f} \geq 3000$, irrespective of the concentration, implying that additive length is central to polymer degradation.

At $Re_s\sqrt{f}$ ≈ 500, the observed slip triad S'(20B, 20A, 1B) ≈ (4.0, 1.3, 1.3) yields R_{cs} = 1/20 = 0.05 and R_{sc} ≈ 1.3/4.0 ≈ 0.31. At $Re_s\sqrt{f}$ ≈ 750, the slip triad S'(20B, 20A, 2B) ≈ (8.5, 4.1, 4.1) gives R_{cs} = 2/20 = 0.10 and R_{sc} ≈ 4.1/8.5 ≈ 0.48. At $Re_s\sqrt{f}$ ≈ 1200, S'(20B, 20A, 5B) ≈ (12.7, 8.0, 8.0) yields R_{cs} = 5/20 = 0.25 and R_{sc} ≈ 8.0/12.7 ≈ 0.62. Because the 20B data do represent turbulent-flow enhancement, $R_{sc} >> R_{cs}$ for these three isoslip points; however, by reversing the analysis under the assumption that S'/c ≈ constant, virtual 20B data can be inferred at these $Re_s\sqrt{f}$ that would lie the "forbidden" region above the MDR asymptote.

The 1B, 2B, 5B and 10B data at $Re_s\sqrt{f}$ = 1000, which better account for rung slopes A_p greater than the turbulent baseline slope A_n, yield an average S'/c ≈ 1.6 and an inferred S'(20B) ≈ 31.3. The corrected triads at $Re_s\sqrt{f}$ ≈ 500, 750, and 1200 are respectively: S'(20B, 20A, 1B) ≈ (31.3, 1.3, 1.3); S'(20B, 20A, 2B) ≈ (31.3, 4.1, 4.1); and S'(20B, 20A, 5B) ≈ (31.3, 8.0, 8.0). Thus, the respective inferred R_{sc} ≈

0.04, 0.13, and 0.25 are all much nearer their unchanged complimentary R_{cs} = 0.05, 0.10, and 0.25.

In Figure 6.5.6, the 2A data onset at $Re_s\sqrt{f}^* \approx 600$ and, ascending into the polymeric regime, intersect the 1B data, creating an isoslip point at $(Re_s\sqrt{f}, 1/\sqrt{f}) \approx (1150, 13.5)$. The 2B data at $Re_s\sqrt{f} \approx 1150$ attain $1/\sqrt{f} \approx 16.6$. The resulting triad $S'(2B, 2A, 1B) \approx (4.7, 1.6, 1.6)$ yields $R_{cs} = 0.50$ and $R_{sc} \approx 0.34$, the disagreement between which arises from overly flow-enhancing 2A and 2B data. Unsurprisingly, the 2A and 2B data display the effect of polymer degradation at $Re_s\sqrt{f} \approx 3000$, just as do the data pairs 5AB and 20AB in Figure 6.5.5.

The 10A data, which possess an apparent onset at $Re_s\sqrt{f}^* \approx 550$, rise linearly into the polymeric regime and intersect the 1B, 2B, and 5B data at $(Re_s\sqrt{f}, 1/\sqrt{f}) \approx (650, 12.3)$, (1100, 16.4), and (2400, 23.0), respectively, forming three isoslip points. (Because the isoslip coordinates $(Re_s\sqrt{f}, 1/\sqrt{f})$ are derived from (A_p, B_p) of the intersecting P segments, regressed isoslip points may differ somewhat from visual isoslip points. The 10A/1B isoslip point illustrates nicely a poor match between regressed and visual isoslip points, wherein the latter occurs at $(Re_s\sqrt{f}, 1/\sqrt{f}) \approx (500, 10.0)$.) Given that the 10B data at $Re_s\sqrt{f} \approx 650$, 1100, and 2400 achieve respective $1/\sqrt{f} \approx 19.3$, 24.2, and 29.3, the corresponding slip triads, concentration ratios, and slip ratios are observed: $S'(10B, 10A, 1B) \approx (8.4, 1.4, 1.4)$, $R_{cs} = 0.10$, and $R_{sc} \approx 0.16$; $S'(10B, 10A, 2B) \approx (12.5, 4.6, 4.6)$, $R_{cs} = 0.20$, and $R_{sc} \approx 0.37$; and $S'(10B, 10A, 5B) \approx (16.2, 9.9, 9.9)$, $R_{cs} = 0.50$, and $R_{sc} \approx 0.61$. At the 10A/1B and 10A/2B isoslip points, R_{cs} and R_{sc} differ because the 10B data at these $Re_s\sqrt{f}$ are either transitional or limited by the MDR asymptote. With an inferred $S'(10B) \approx 15.6$, obtained from the average

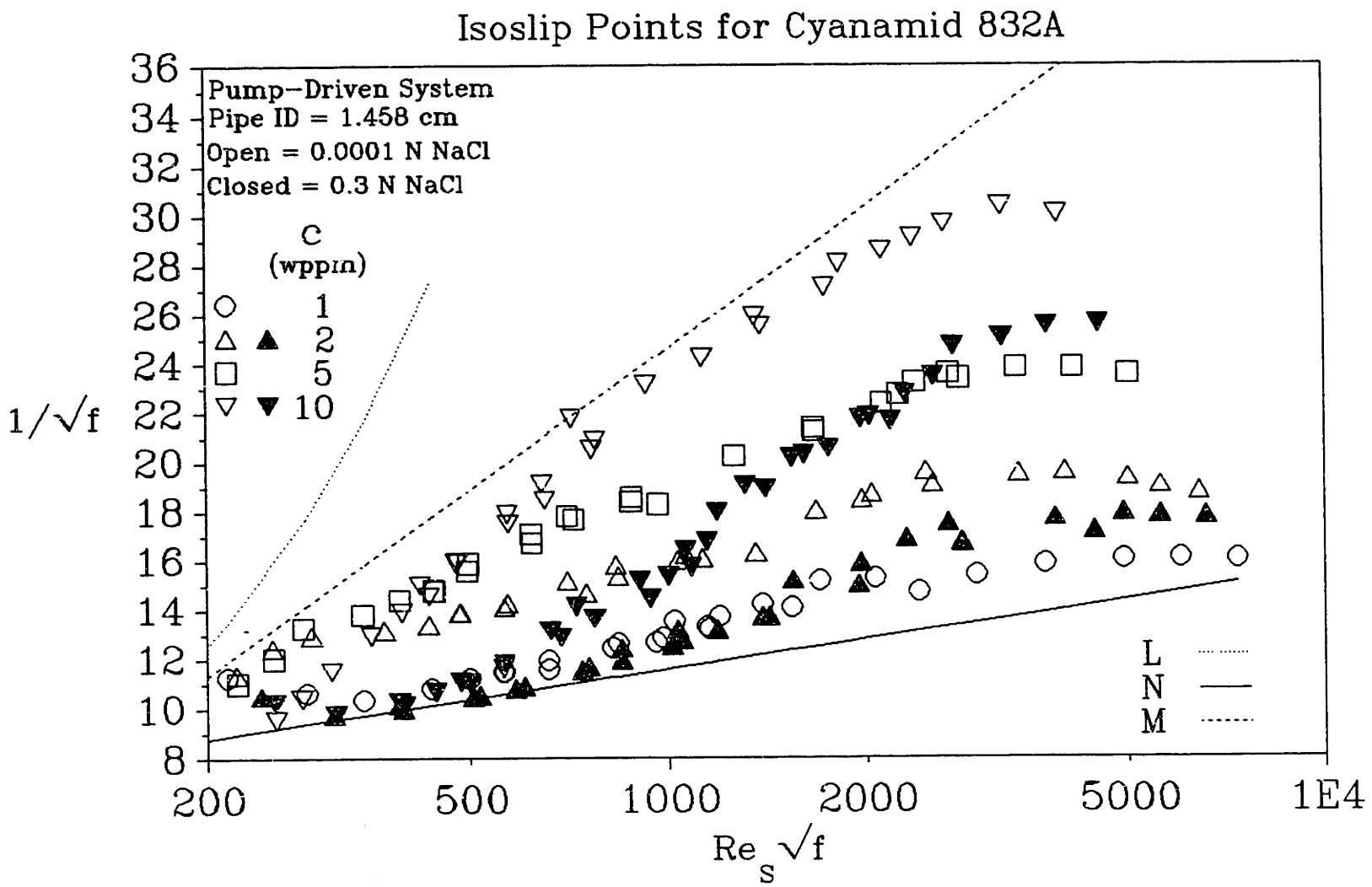


Figure 6.5.6: Isoslip Points for Cyanamid 832A at c = 2 and 10 wppm in the 1.458-cm Pipe

S'/c ≈ 1.6 at $Re_s\sqrt{f}$ = 1000, the corrected slip triads at $Re_s\sqrt{f}$ ≈ 650 and 1100 are respectively: S'(10B, 10A, 1B) ≈ (15.6, 1.4, 1.4); and S'(10B, 10A, 2B) ≈ (15.6, 4.6, 4.6). The inferred slip ratios and their complimentary concentration ratios, which are unchanged, agree better: R_{cs} = 0.10 and R_{sc} ≈ 0.09; and R_{cs} = 0.20 and R_{sc} ≈ 0.30. Like the P segments of the data pairs 2AB, 5AB, and 20AB, the 10A and 10B P segments, which do not come close to intersecting, show the effect of polymer degradation at $Re_s\sqrt{f}$ ≈ 3000, which is evidently characteristic for additive C832A in this 1.458-cm pipe.

Figures 6.5.7 and 6.5.8 show the isoslip points among solutions of additive C832A from the pump-driven system with the 1.021-cm pipe. The former superposes 5A and 20A data upon 1B, 2B, 5B, 10B, and 20B data; the latter, 2A and 10A data upon 1B, 2B, 5B, and 10B data. The lines L, N, and M, shown for reference in both figures, respectively represent the Newtonian laminar and turbulent baselines and the MDR asymptote.

In Figure 6.5.7, the 5A data, having an apparent onset at $Re_s\sqrt{f}^* \approx 400$, rise linearly into the polymeric regime and intersect the 1B and 2B data at ($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (600, 12.2) and (750, 13.5), respectively. As the 5B data attain respective $1/\sqrt{f}$ ≈ 16.3 and 17.1 at $Re_s\sqrt{f}$ ≈ 600 and 750, the respective slip triads, concentration ratios, and slip ratios are: S'(5B, 5A, 1B) ≈ (5.6, 1.5, 1.5), R_{cs} = 0.20, and R_{sc} ≈ 0.26; and S'(5B, 5A, 2B) ≈ (6.0, 2.4, 2.4), R_{cs} = 0.40, and R_{sc} ≈ 0.40. That $R_{cs} \approx R_{sc}$ for these isoslip points nicely illustrates additive equivalence. Notice that the 5A and 5B data nearly form an isoslip point at $Re_s\sqrt{f}$ ≈ 3000; however, both solutions suffer polymer degradation at this point, causing the two to decline along adjacent downward paths as

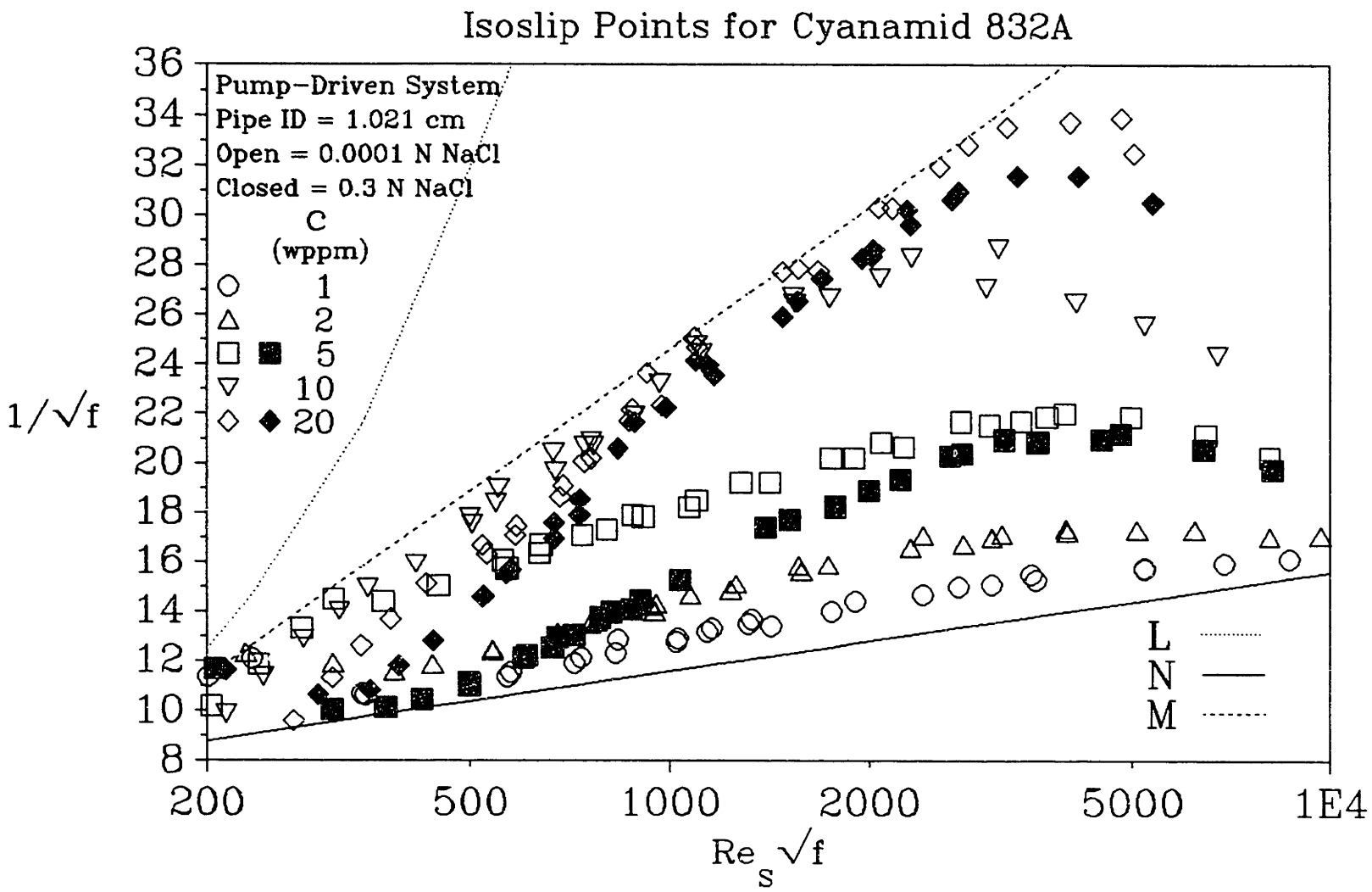


Figure 6.5.7: Isoslip Points for Cyanamid 832A at c = 5 and 20 wppm in the 1.021-cm Pipe

seen in Figure 6.5.7. Their virtual isoslip point, at which $R_{cs} = R_{sc} = 1$, occurs at $(Re_s\sqrt{f}, 1/\sqrt{f}) \approx (3700, 22.7)$, which corresponds to the slip triad S'(5B, 5A, 5B) ≈ (8.8, 8.8, 8.8).

The 20A data rise steeply toward the MDR asymptote from an apparent onset point at $Re_s\sqrt{f}^* \approx 300$ and intersect the 1B, 2B, 5B, and 10B data at $(Re_s\sqrt{f}, 1/\sqrt{f}) \approx$ (360, 11.3), (370, 11.6), (600, 16.2), and (1500, 26.9), respectively. The 20B data attain respective $1/\sqrt{f} \approx 13.5$, 13.8, 17.8, and 28.0, of which the first two are transitional and the last two are MDR-limited. The four sets of slip triads, concentration ratios, and slip ratios are respectively: S'(20B, 20A, 1B) ≈ (3.7, 1.5, 1.5), $R_{cs} = 0.05$, and $R_{sc} \approx$ 0.40; S'(20B, 20A, 2B) ≈ (3.9, 1.7, 1.7), $R_{cs} = 0.10$, and $R_{sc} \approx 0.44$; S'(20B, 20A, 5B) ≈ (7.1, 5.5, 5.5), $R_{cs} = 0.25$, and $R_{sc} \approx 0.78$; and S'(20B, 20A, 10B) ≈ (15.7, 14.0, 14.0), $R_{cs} = 0.50$, and $R_{sc} \approx 0.89$. Poor agreement between R_{cs} and R_{sc} at all isoslip points reflects the unsuitability of the 20B data, which do not characterize turbulent-flow enhancement as seen in Figure 6.5.7. Corrected slip triads can be constructed from inferred 20B data, under the assumption of constant S'/c.

From the 1B, 2B, 5B, and 10B data, the average S'/c ≈ 1.3 and 1.6, yielding S'(20B)/c ≈ 25.8 and 32.3, at $Re_s\sqrt{f} = 1000$ and 3000, respectively. The corrected slip triads and inferred slip ratios at $Re_s\sqrt{f} \approx 360$, 370, 600, and 1500 are respectively: S'(20B, 20A, 1B) ≈ (25.8, 1.5, 1.5) and $R_{sc} \approx 0.06$; S'(20B, 20A, 2B) ≈ (25.8, 1.7, 1.7) and $R_{sc} \approx 0.07$; S'(20B, 20A, 5B) ≈ (25.8, 5.5, 5.5) and $R_{sc} \approx 0.21$; and S'(20B, 20A, 10B) ≈ (32.3, 14.0, 14.0) and $R_{sc} \approx 0.43$. The inferred $R_{sc} \approx 0.06$, 0.07, 0.21, and 0.43 agree favorably with their complimentary $R_{cs} = 0.05$, 0.10, 0.25, and 0.50.

Notice that the 20A and 20B data depart from their respective P and M segments

at $Re_s\sqrt{f} \approx 3000$ because of polymer degradation, in a similar manner as the 5A and 5B data. As noted for the 20B data in Figure 6.5.5, the departure of the 20B data from M into the polymeric regime likely results from polymer degradation, lowering the effective concentration; thus, the observed 20B retro-onset, when compared with the 10B retro-onset, must correspond to that for a solution with $10 < c < 20$ wppm.

In Figure 6.5.8, the 2A data, onsetting at $Re_s\sqrt{f}^* \approx 500$, rise linearly into the polymeric regime, and intersect the 1B data at $(Re_s\sqrt{f}, 1/\sqrt{f}) \approx (1300, 13.5)$. As the 2B data attain $1/\sqrt{f} \approx 14.9$, above this isoslip point, at $Re_s\sqrt{f} \approx 1300$, the slip triad S'(2B, 2A, 1B) $\approx$ (2.9, 1.5, 1.5) yields $R_{cs} = 0.50$ and $R_{sc} \approx 0.51$.

As previously observed for the data pairs 5AB and 20AB in Figure 6.5.7, the 2A data approach the 2B data until polymer degradation first appears at $Re_s\sqrt{f} \approx 3000$, after which point they converge up to $Re_s\sqrt{f} \approx 10000$. The 2A and 2B data make a virtual isoslip point at $(Re_s\sqrt{f}, 1/\sqrt{f}) \approx (17000, 22.0)$ with slip triad S'(2B, 2A, 2B) $\approx$ (5.4, 5.4, 5.4) and $R_{cs} = R_{sc} = 1$.

The 10A data, which rise into the polymeric regime from an apparent onset point at $Re_s\sqrt{f}^* \approx 350$, intersect the 1B, 2B, and 5B data at isoslip points with respective $(Re_s\sqrt{f}, 1/\sqrt{f}) \approx (430, 11.6)$, (460, 12.1), and (950, 17.9). As the 10B data achieve $1/\sqrt{f} \approx 16.6$, 17.2, and 25.7 above the respective isoslip points, the slip triads, concentration ratios, and slip ratios are: S'(10B, 10A, 1B) $\approx$ (6.5, 1.5, 1.5), $R_{cs} = 0.1$, and $R_{sc} \approx 0.23$; S'(10B, 10A, 2B) $\approx$ (7.0, 1.9, 1.9), $R_{cs} = 0.2$, and $R_{sc} \approx 0.27$; and S'(10B, 10A, 5B) $\approx$ (14.2, 6.4, 6.4), $R_{cs} = 0.5$, and $R_{sc} \approx 0.45$. For the first two slip triads, R_{cs} and R_{sc} do not agree because the 10B data are MDR-limited; however, they do agree for the third because the 10B data occur near the beginning of the 10B ladder rung.

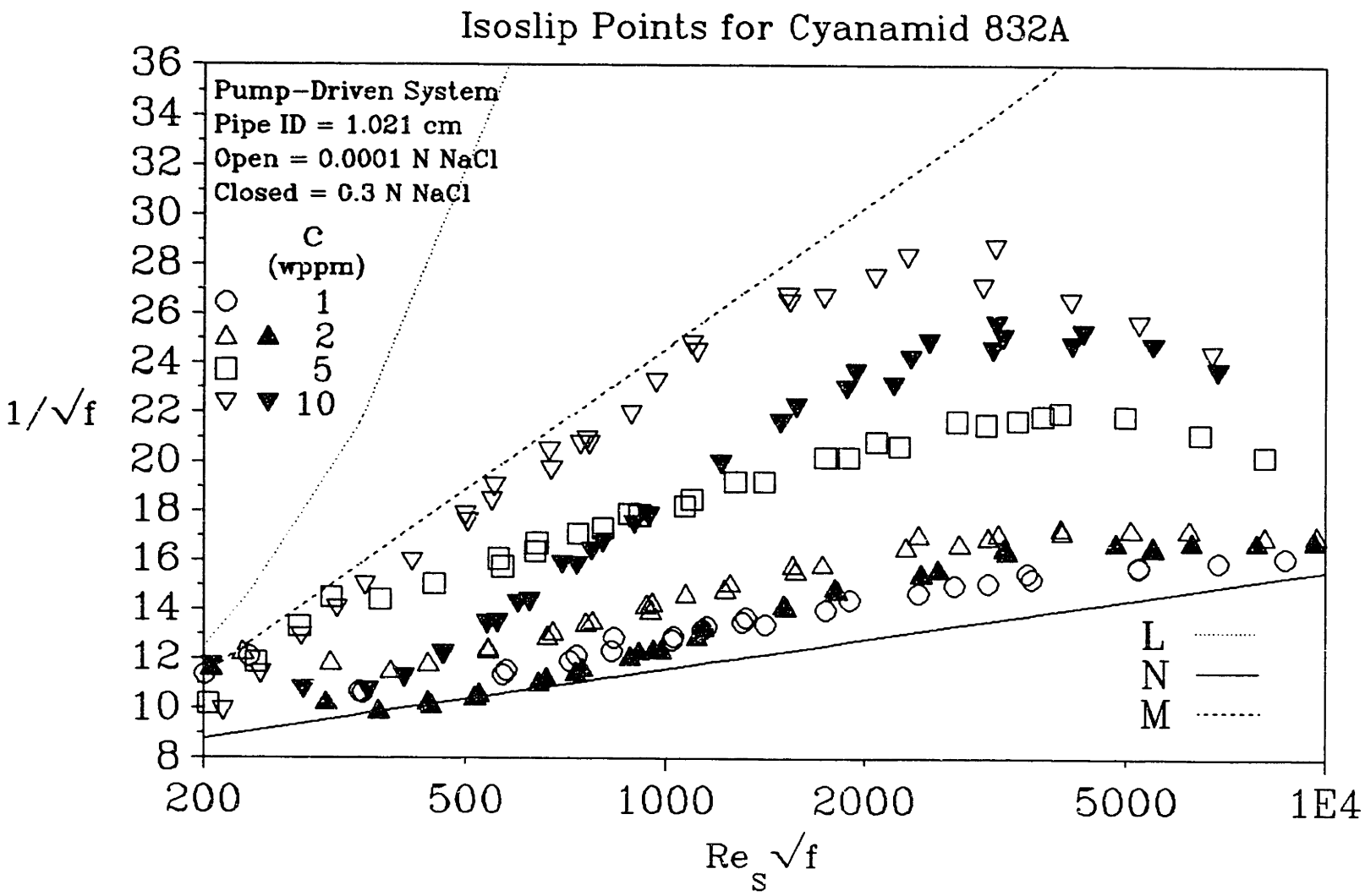


Figure 6.5.8: Isoslip Points for Cyanamid 832A at c = 2 and 10 wppm in the 1.021-cm Pipe

Given an average S'/c ≈ 1.3 at $Re_s\sqrt{f}$ = 1000, the corrected slip triads at $Re_s\sqrt{f}$ ≈ 430 and 460 are S'(10B, 10A, 1B) ≈ (12.9, 1.5, 1.5) and S'(10B, 10A, 2B) ≈ (12.9, 1.9, 1.9), respectively; the respective inferred R_{sc} ≈ 0.11 and 0.15 better match their complimentary R_{cs} = 0.1 and 0.2.

Note that as the 10A fan spoke approaches the 10B ladder rung near $Re_s\sqrt{f}$ ≈ 2500, polymer degradation causes the 10A and 10B data to decline from their P segments beginning at $Re_s\sqrt{f}$ ≈ 2700, which is slightly lower than that for 2AB, 5AB, and 20AB solutions in this 1.021-cm pipe. The virtual 10A/10B isoslip point, at which the P segments of the 10A and 10B data would intersect in the absence of polymer degradation, occurs at ($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (6000, 32.8) and possess the slip triad S'(10B, 10A, 10B) = (18.1, 18.1, 18.1), at which $R_{cs} = R_{sc} = 1$.

Figure 6.5.9 shows the isoslip points among the C832 data at 0.1 N and 0.0003 N NaCl from the gravity-driven system using the 1.458-cm pipe. In the figure, 10A and 20.7A data are superposed over 2.1B, 5.6B, 10B, and 20.7B data; the lines N and M represent respectively the Newtonian turbulent baseline and the MDR asymptote, providing reference.

The 10A data onset at $Re_s\sqrt{f}^*$ ≈ 650 and, ascending into the polymeric regime, form an isoslip point with the 2.1B data at ($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (1100, 13.5). With the 10B data attaining $1/\sqrt{f}$ ≈ 20.9 above the isoslip point, the resulting slip triad S'(10B, 10A, 2.1B) ≈ (9.1, 1.7, 1.7) yields R_{cs} ≈ 0.21 and R_{sc} ≈ 0.19, which show good agreement.

The 20.7A data onset at $Re_s\sqrt{f}^*$ ≈ 550 and, rising into the polymeric regime, intersect the 2.1B and 5.6B data at isoslip points with respective ($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (700, 12.2) and (950, 15.1). The 20.7B data attain $1/\sqrt{f}$ ≈ 19.9 and 22.7 above the respective

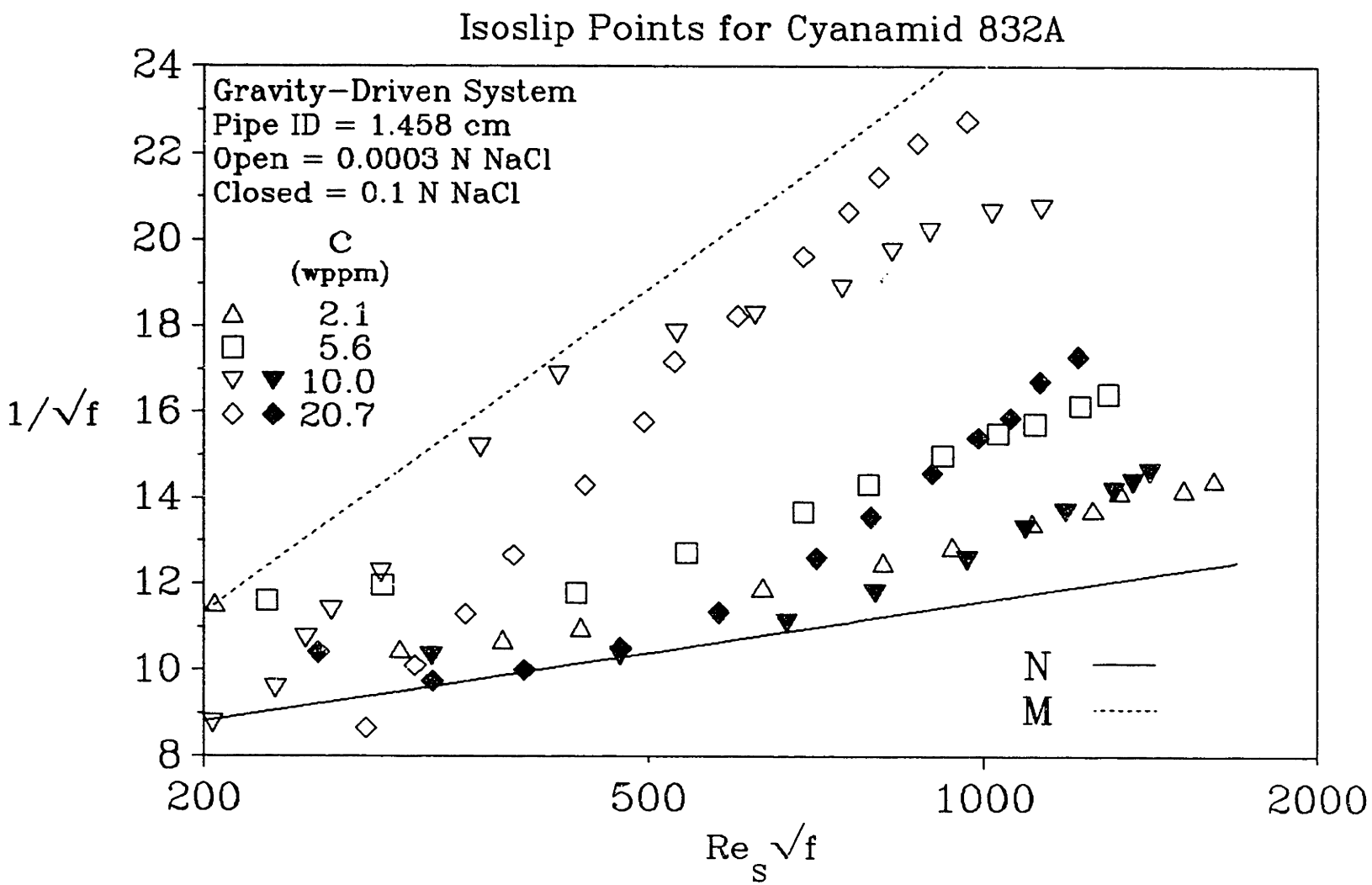


Figure 6.5.9: Isoslip Points for yanamid 832A at c = 10 and 20.7 wppm in the 1.458-cm Pipe

isoslip points, and the slip triads S'(20.7B, 20.7A, 2.1B) ≈ (9.0, 1.2, 1.2) and S'(20.7B, 20.7A, 5.6B) ≈ (11.2, 3.6, 3.6) yield R_{cs} ≈ 0.10 and 0.27 and R_{sc} ≈ 0.14 and 0.32, respectively. The complimentary R_{cs} and R_{sc} show favorable agreement.

Figures 6.5.10 and 6.5.11 show the isoslip points among solutions of additive B1120 from the pump-driven system using the 1.458-cm pipe. The former superposes 5A and 20A data upon 1B, 2B, 5B, 10B, and 20B data; the latter, 2A and 10A data upon 1B, 2B, 5B, and 10B data. The lines L, N, and M respectively represent the Newtonian laminar and turbulent baselines and the MDR asymptote, which provide reference.

In Figure 6.5.10, the 5A data, which onset at $Re_s\sqrt{f^*}$ ≈ 650, rise into the polymeric regime and form isoslip points with the 1B and 2B data at respective ($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (850, 14.2) and (1900, 16.7). Above these isoslip points, the 5B data attain $1/\sqrt{f}$ ≈ 20.2 and 22.1, respectively. At $Re_s\sqrt{f}$ ≈ 850, the slip triad S'(5B, 5A, 1B) ≈ (8.9, 2.9, 2.9) gives R_{cs} = 0.20 and R_{sc} ≈ 0.32; at $Re_s\sqrt{f}$ ≈ 1900, the triad S'(5B, 5A, 2B) ≈ (9.4, 4.0, 4.0) yields R_{cs} = 0.4 and R_{sc} ≈ 0.43.

Note that the 5A and 5B data, the P segments of which are well separated for 1000 < $Re_s\sqrt{f}$ < 2500, both exhibit polymer degradation at $Re_s\sqrt{f}$ ≈ 3000.

Interestingly, additives B1120 and C832A, which both show polymer degradation at $Re_s\sqrt{f}$ ≈ 3000, have approximately equal molecular weights and, thus, contour lengths; this reinforces the notion that polymer degradation and drag reduction both involve the presence of extended additives in turbulent flow.

The 20A data, which have an apparent onset point at $Re_s\sqrt{f^*}$ ≈ 500, ascend linearly into the polymeric regime and form isoslip points with the 1B, 2B, 5B, and 10B data at respective ($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (550, 11.5), (650, 13.2), (1600, 21.6), and (3600,

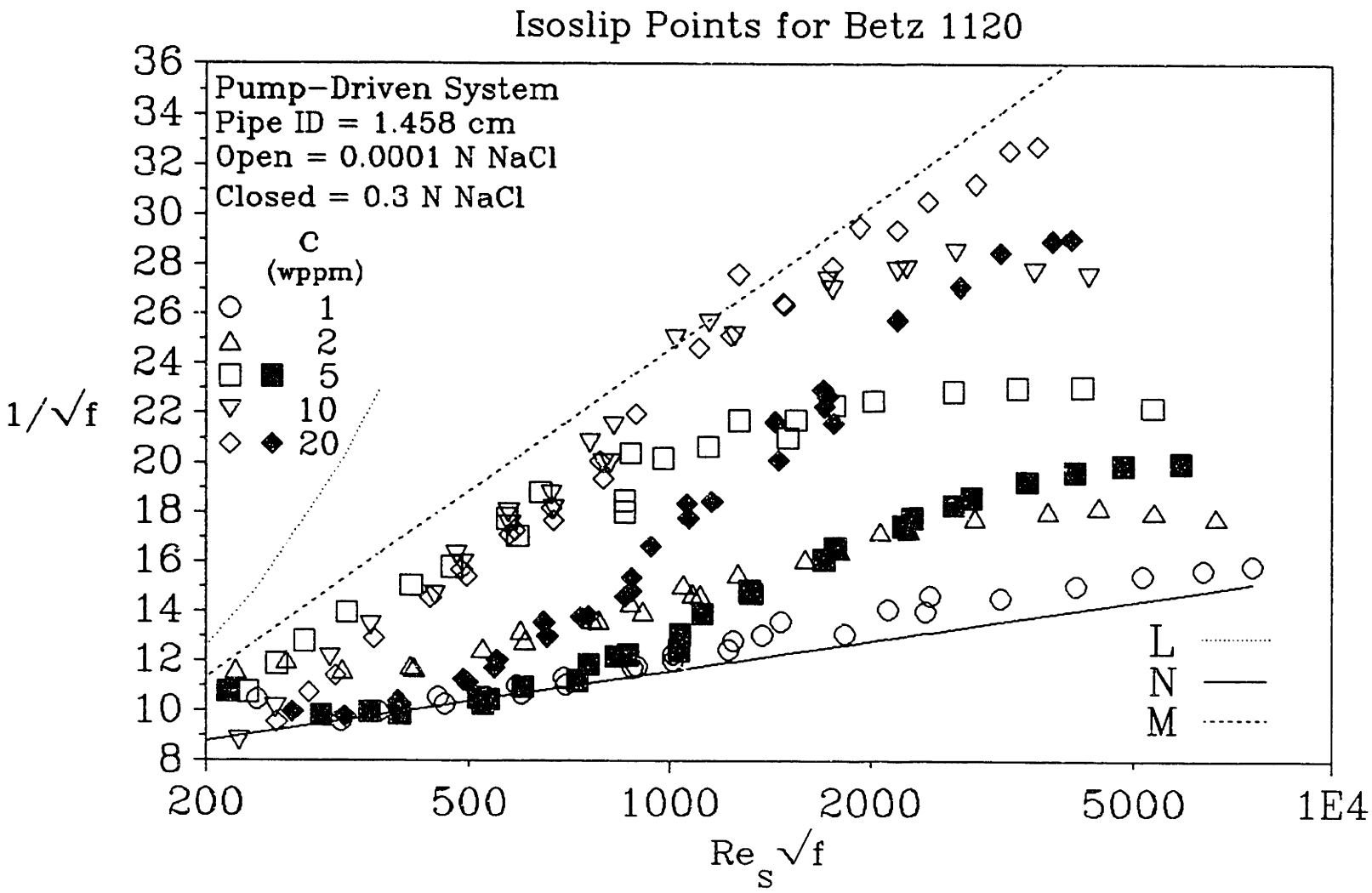


Figure 6.5.10: Isoslip Points for Betz 1120 at c = 5 and 20 wppm

29.5). The 20B data have $1/\sqrt{f} \approx$ 16.7, 18.0, 27.0, and 32.7 at $Re_s\sqrt{f} \approx$ 550, 650, 1600, and 3600, respectively. For these four isoslip points, the respective sets of slip triads, concentration ratios, and slip ratios are: S'(20B, 20A, 1B) $\approx$ (6.2, 1.0, 1.0), R_{cs} = 0.05, and $R_{sc} \approx$ 0.16; S'(20B, 20A, 2B) $\approx$ (7.2, 2.4, 2.4), R_{cs} = 0.10, and $R_{sc} \approx$ 0.33; S'(20B, 20A, 5B) $\approx$ (14.6, 9.3, 9.3), R_{cs} = 0.25, and $R_{sc} \approx$ 0.63; and S'(20B, 20A, 10B) $\approx$ (18.8, 15.7, 15.7), R_{cs} = 0.50, and $R_{sc} \approx$ 0.83. As seen in Figure 6.5.10, the mismatches between R_{cs} and R_{sc} arise from the MDR-limited 20B data. With average S'/c $\approx$ 1.3 and 1.6 at $Re_s\sqrt{f}$ = 1000 and 3000, respectively, calculated from the 1B, 2B, 5B, and 10B data, the corrected slip triads at $Re_s\sqrt{f} \approx$ 550, 650, 1600, and 3600 are respectively: S'(20B, 20A, 1B) $\approx$ (25.4, 1.0, 1.0); S'(20B, 20A, 2B) $\approx$ (25.4, 2.4, 2.4); S'(20B, 20A, 5B) $\approx$ (32.5, 9.3, 9.3); and S'(20B, 20A, 10B) $\approx$ (32.5, 15.7, 15.7). The respective inferred $R_{sc} \approx$ 0.04, 0.09, 0.29, and 0.48 agree more favorably with their corresponding R_{cs} = 0.05, 0.10, 0.25, and 0.50.

The 20A and 20B data, which remain well separated up to the highest $Re_s\sqrt{f} \approx$ 3800, appear to be affected similarly by polymer degradation, as seen in Figure 6.5.10. The 20A data decline from their P segment at $Re_s\sqrt{f} \approx$ 3300; the last 20B data point departs into the polymeric regime from their M segment at $Re_s\sqrt{f} \approx$ 3300.

In Figure 6.5.11, the 2A data onset at $Re_s\sqrt{f}^* \approx$ 600 and then, rising into the polymeric regime, intersect the 1B data at an isoslip point with ($Re_s\sqrt{f}$, $1/\sqrt{f}$) $\approx$ (1100, 13.6). With $1/\sqrt{f} \approx$ 14.8 for the 1B data above the isoslip point, the slip triad S'(2B, 2A, 1B) $\approx$ (3.1, 1.9, 1.9) yields R_{cs} = 0.50 and $R_{sc} \approx$ 0.60.

The 10A data, onsetting at $Re_s\sqrt{f}^* \approx$ 500, rise into the polymeric regime and form isoslip points with the 1B, 2B, and 5B data at respective ($Re_s\sqrt{f}$, $1/\sqrt{f}$) $\approx$ (600,

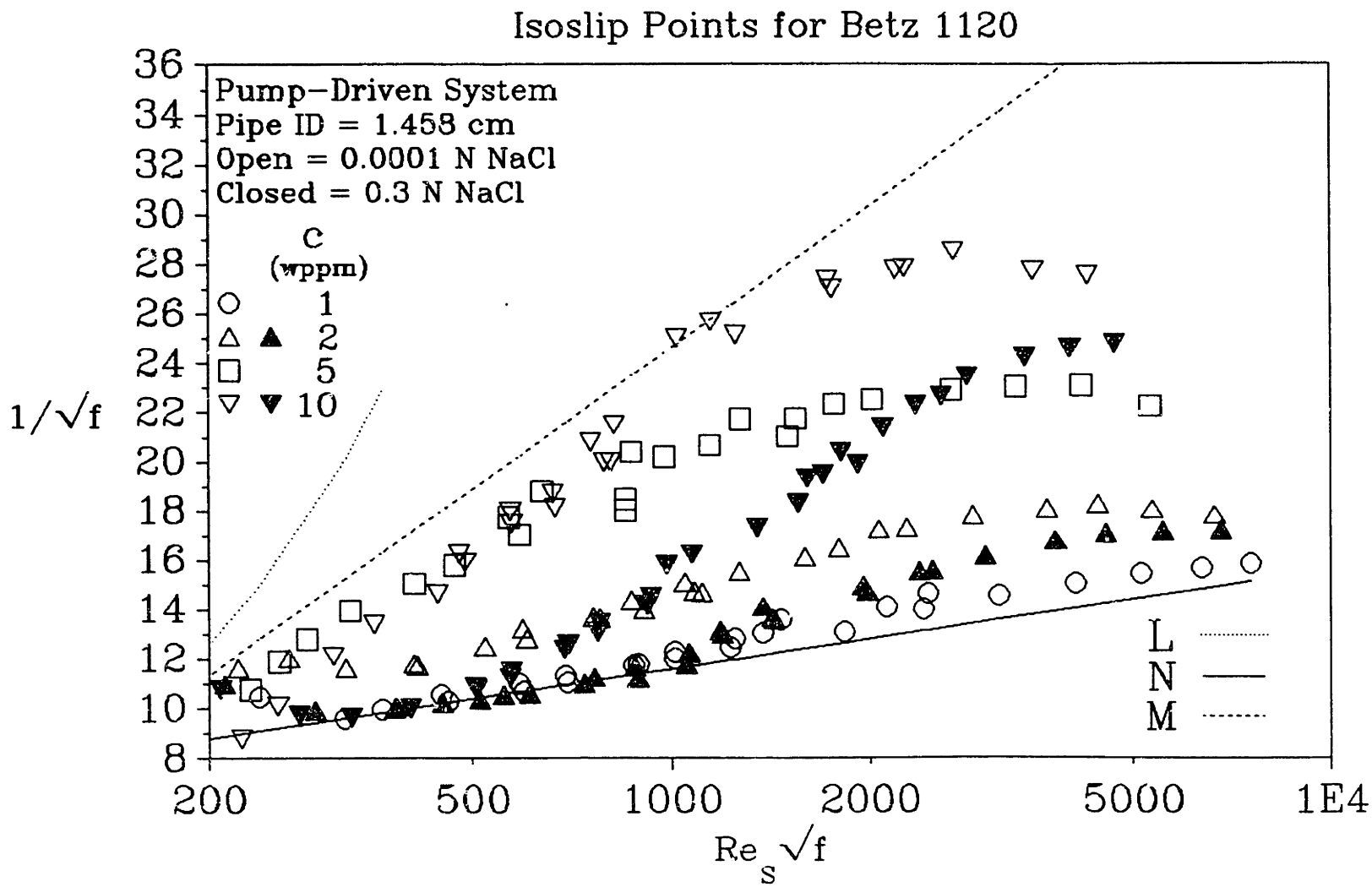


Figure 6.5.11: Isoslip Points for Betz 1120 at c = 2 and 10 wppm

11.7), (800, 14.0), and (2700, 22.9). Above these isoslip points, the 10B data achieve respective $1/\sqrt{f} \approx 18.3$, 21.9, and 28.6. Thus, the slip triads, concentration ratios, and slips ratios at $Re_s\sqrt{f} \approx 600$, 800, and 2700 are respectively: S'(10B, 10A, 1B) $\approx$ (7.5, 1.0, 1.0), $R_{cs} = 0.10$, and $R_{sc} \approx 0.13$; S'(10B, 10A, 2B) $\approx$ (10.6, 2.7, 2.7), $R_{cs} = 0.20$, and $R_{sc} \approx 0.26$; and S'(10B, 10A, 5B) $\approx$ (15.2, 9.6, 9.6), $R_{cs} = 0.50$, and $R_{sc} \approx 0.63$. Despite the MDR-limited 10B data at the first two isoslip points, all three isoslip points have about the same ratios $R_{cs}/R_{sc} \approx 0.76$, 0.78, and 0.79, respectively, perhaps indicating that the 10B rung is too low with respect to the 5B data. Corrected slip triads for the 10A/1B and 10A/2B isoslip points are S'(10B, 10A, 1B) $\approx$ (12.7, 1.0, 1.0) and S'(10B, 10A, 2B) $\approx$ (12.7, 2.7, 2.7), and the respective inferred $R_{sc} \approx 0.08$ and 0.21 more closely match their complimentary $R_{cs} = 0.10$ and 0.20.

Figures 6.5.12 and 6.5.13 show the isoslip points among the P500 data in the 1.458- and 1.021-cm pipes, respectively. In each figure, a partial Type-A fan comprising 30A and and 100A data is superposed upon a Type-B ladder comprising 10B, 30B, and 100B data; the accompanying lines L, N, and M respectively represent the Newtonian laminar and turbulent baselines and the MDR asymptote.

In Figure 6.5.12, the 30A data onset at $Re_s\sqrt{f}^* \approx 550$ and, rising into the polymeric regime, make an isoslip point with the 10B data at $(Re_s\sqrt{f}, 1/\sqrt{f}) \approx (1700, 18.2)$. Given that the 30B data attain $1/\sqrt{f} \approx 25.3$ above the isoslip point, the resulting slip triad S'(30B, 30A, 10B) $\approx$ (12.8, 5.7, 5.7) yields $R_{cs} = 0.33$ and $R_{sc} \approx 0.45$. Either the 10B rung is too low or the 10B rung is too high.

The 100A data onset at $Re_s\sqrt{f}^* \approx 600$ and, rising into the polymeric regime, intersect the 10B and 30E data at isoslip points with respective $(Re_s\sqrt{f}, 1/\sqrt{f}) \approx (900,$

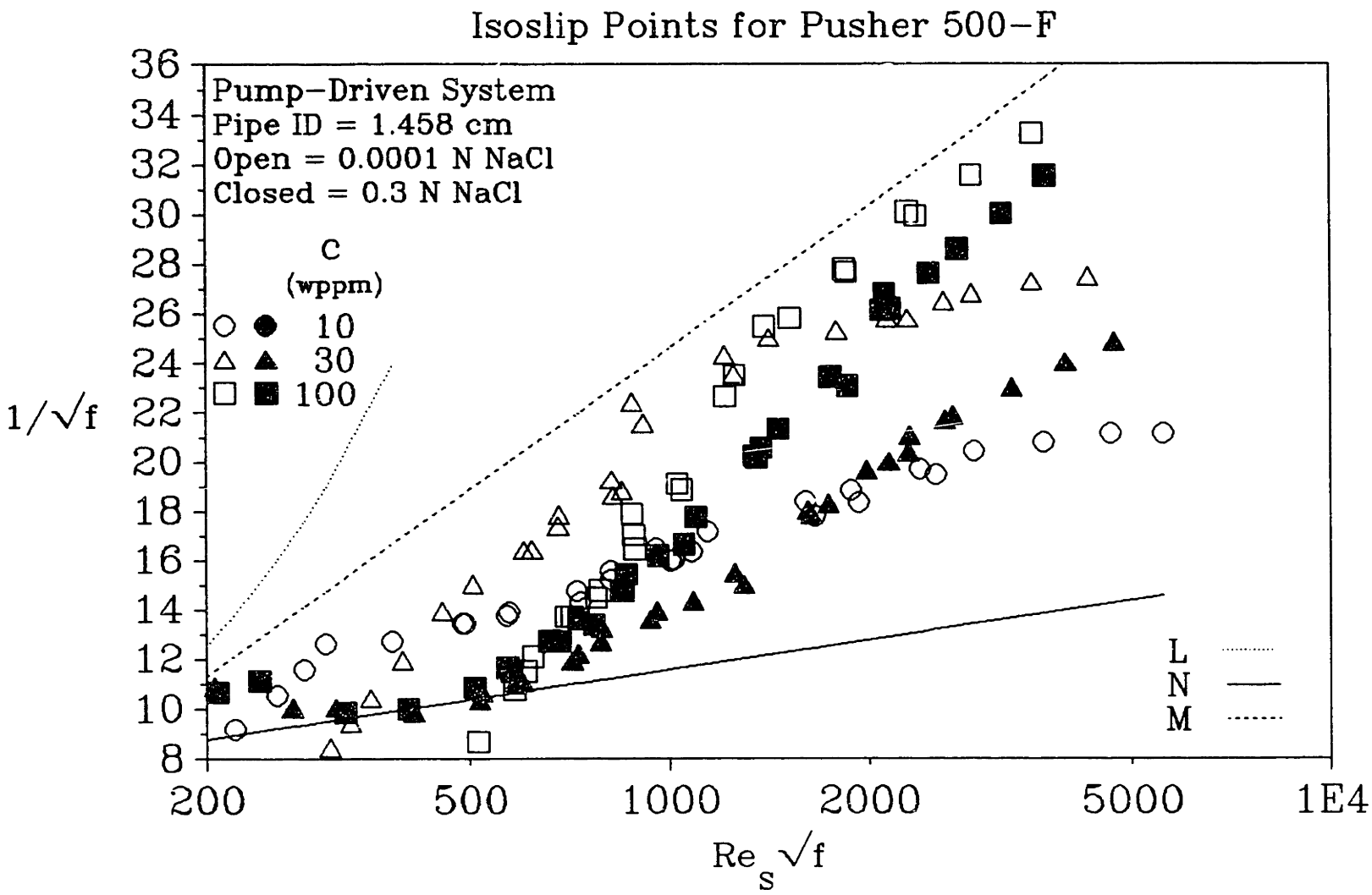


Figure 6.5.12: Isoslip Points for Pusher 500-F in the 1.458-cm Pipe

15.8) and (2200, 26.0). (Even though the 100A data do cross the 100B data at ($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (600, 12), the 100B data show either laminar or transitional behavior; thus, the intersection does not constitute a legitimate isoslip point.) The 100B data attain $1/\sqrt{f} \approx$ 17.2 and 30.1 at $Re_s\sqrt{f} \approx$ 900 and 2200. The respective slip triads S'(100B, 100A, 10B) ≈ (5.8, 4.3, 4.3) and S'(100B, 100A, 30B) ≈ (17.1, 13.0, 13.0) give R_{cs} = 0.10 and 0.30 and $R_{sc} \approx$ 0.75 and 0.76. The large discrepancies between complimetary R_{cs} and R_{sc} arise because the 100B data are either transitional or MDR-limited, as seen in Figure 6.5.12. With average S'/c ≈ 0.4 and 0.6 at $Re_s\sqrt{f} \approx$ 1000 and 3000, respectively, the corrected triads S'(100B, 100A, 10B) ≈ (41.8, 4.3, 4.3) and S'(100B, 100A, 30B) ≈ (57.2, 13.0, 13.0) give inferred $R_{sc} \approx$ 0.10 and 0.22 that are much closer to their complimentary R_{cs} = 0.1 and 0.3.

In Figure 6.5.13, the 30A data, rising into the polymeric regime from an apparent onset point at $Re_s\sqrt{f}^* \approx$ 450, form an isoslip point with the 10B data at ($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (1000, 16.2). The 30B data achieve $1/\sqrt{f} \approx$ 22.1 above the isoslip point. The resulting slip triad S'(30B, 30A, 10B) ≈ (10.5, 4.6, 4.6) yields R_{cs} = 0.33 and $R_{sc} \approx$ 0.43. That R_{cs} and R_{sc} do not agree results from MDR-limited 30B data, as seen in Figure 6.5.13. Given an average S'/c ≈ 0.4 at $Re_s\sqrt{f}$ = 1000, the corrected slip triad S'(30B, 30A, 10B) ≈ (12.2, 4.6, 4.6) yields an inferred $R_{sc} \approx$ 0.37 that agrees better with R_{cs} = 0.33.

The 100A data, which have an apparent onset point at $Re_s\sqrt{f}^* \approx$ 450, rise steeply into the polymeric regime virtually atop the 100B data and intersect the 10B and 30B data at isoslip points with respective ($Re_s\sqrt{f}$, $1/\sqrt{f}$) ≈ (600, 14.3) and (1300, 24.8). The 100B data achieve $1/\sqrt{f} \approx$ 15.7 and 25.7 above the respective isoslip points. The resulting slip

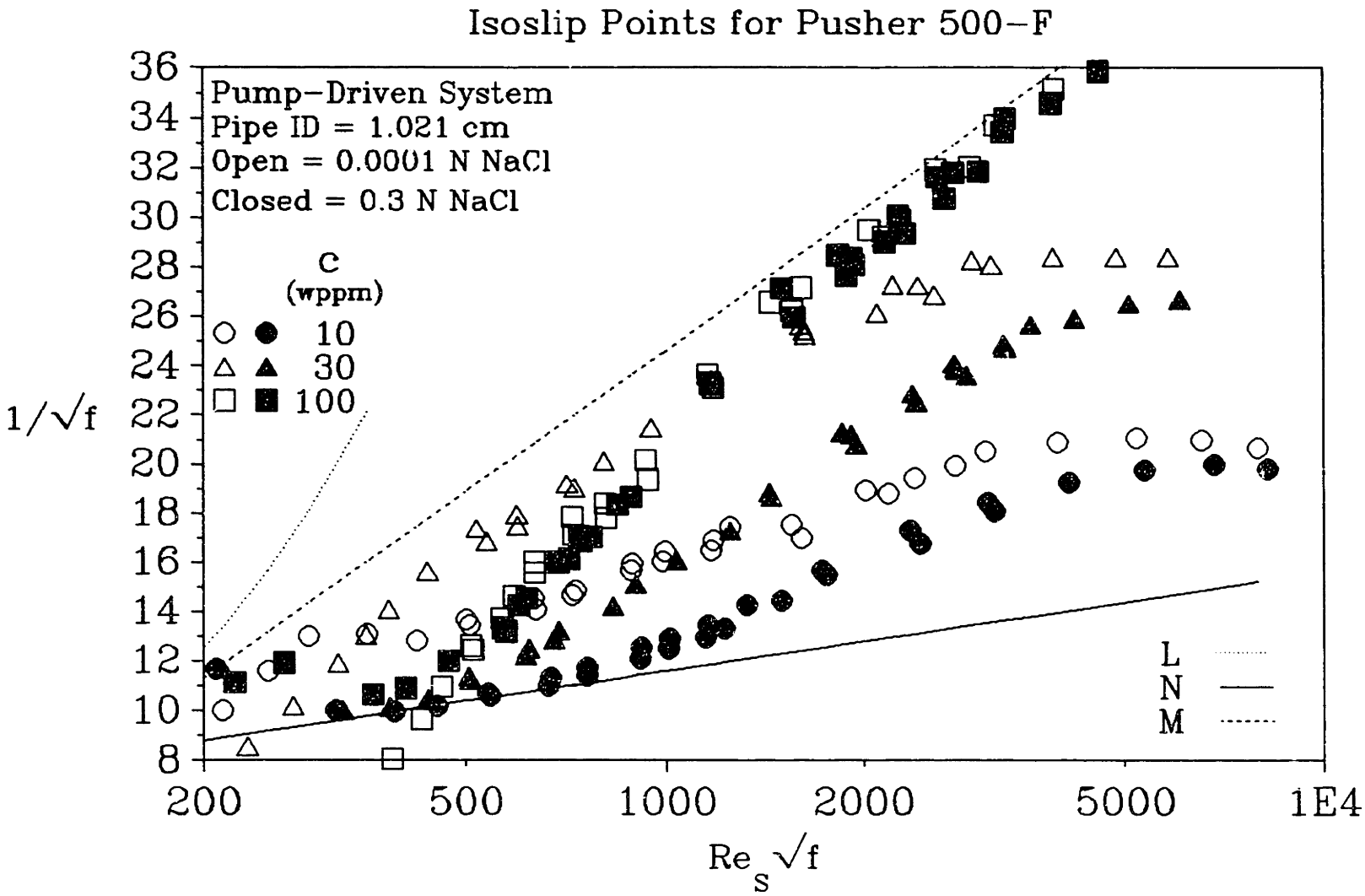


Figure 6.5.13: Isoslip Points for Pusher 500-F in the 1.021-cm Pipe

triads S'(100B, 100A, 10B) ≈ (4.9, 3.6, 3.6) and S'(100B, 100A, 30B) ≈ (13.6, 12.7, 12.7) have R_{cs} = 0.10 and 0.30 and R_{sc} ≈ 0.72 and 0.93. The complimentary R_{cs} and R_{sc} greatly differ because the 100B data are either transitional or MDR-limited, as seen in Figure 6.5.13. Given an average S'/c ≈ 0.4 at $Re_s\sqrt{f}$ = 1000, the corrected slip triads S'(100B, 100A, 10B) ≈ (41.8, 3.6, 3.6) and S'(100B, 100A, 30B) ≈ (41.8, 12.7, 12.7) yield inferred R_{sc} ≈ 0.08 and 0.30 that almost exactly match their complimentary R_{cs} = 0.10 and 0.30.

6.5.2.2 Summary of Additive Equivalence and Isoslip Points

The 42 isoslip-point coordinates ($Re_s\sqrt{f}$, $1/\sqrt{f}$), slip triads (C_B, C_A, c_B), and R_{sc} and R_{cs} values derived from the flow trajectories shown in Figures 6.5.4 - 6.5.13 are listed in Table 6.5, documenting all additive equivalences observed in the present work. Figure 6.5.14 is a plot of the slip ratio R_{sc} versus the concentration ratio R_{cs} among all slip triads. Evidently, the data collectively adhere to the line $R_{sc} = R_{cs}$, reinforcing the earlier conclusion, from the introductory example in Figure 6.5.4, that for fixed total additive concentration, the collapsed to extended slip ratio R_{sc} is simply the fraction of originally collapsed macromolecules that have become extended in the flow, and thence effective in drag reduction. Thus the extended additive states appear to be the active species responsible for drag reduction, with Type-B drag reduction the inherently fundamental form of the phenomenon. Type-A drag reduction appears to be a special case wherein the initially randomly-coiled and ineffective additives are extended, and hence activated, by the turbulent flow field.

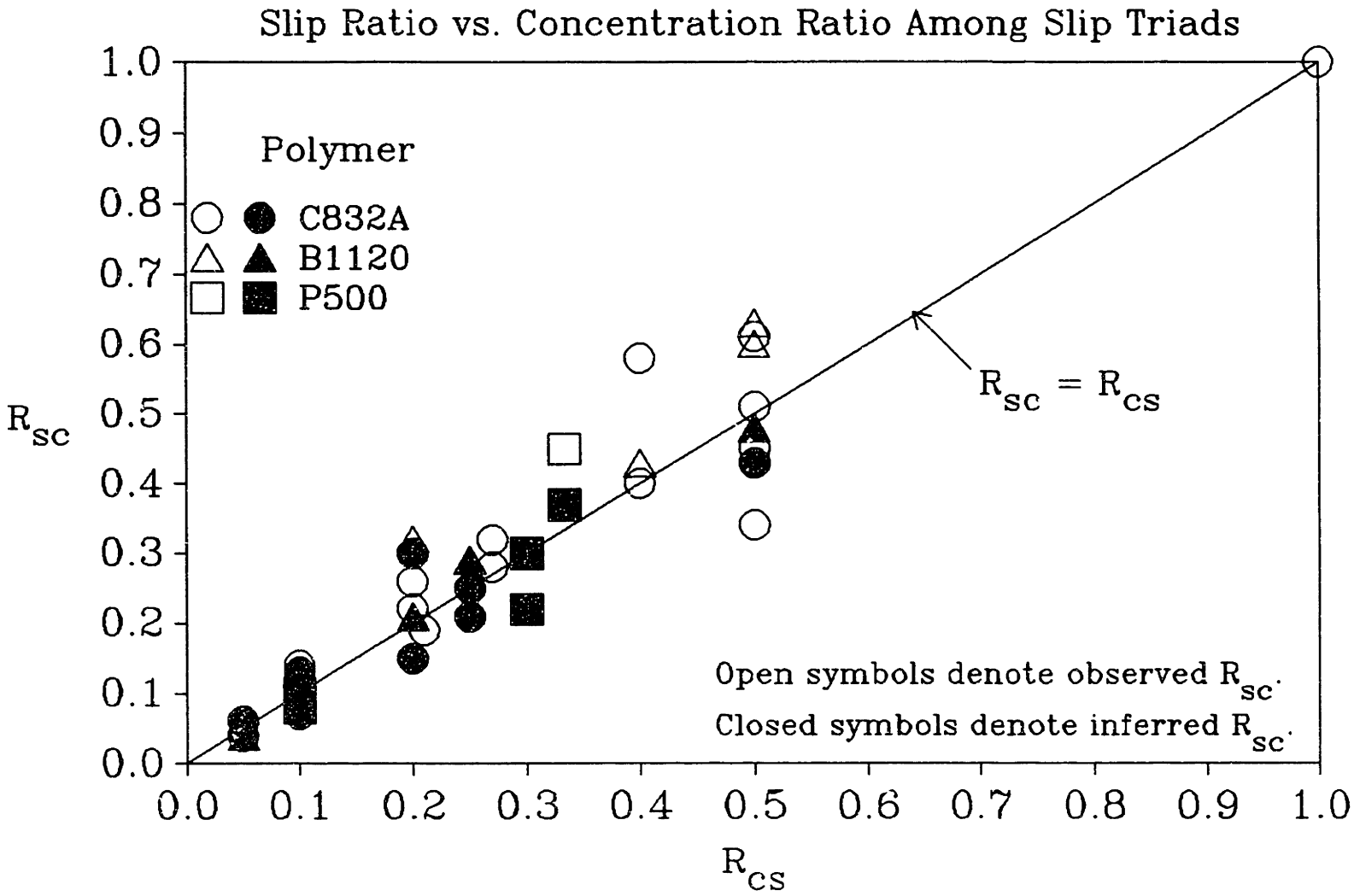


Figure 6.5.14: Slip Ratio versus Concentration Ratio Among Slip Triads

Table 6.5
Summary of Isoslip Points

Polymer	Isoslip Point Coordinates	Slip Triad			Concen-tration Ratio	Slip Ratio
		$S'(C_B, C_A, c_B) = (Y, X, X)$			R_{cs}	R_{sc}
	$(Re\sqrt{f}, 1/\sqrt{f})$	(C_B, C_A, c_B)	Y	X	c_B/C_A	X/Y
Figure 6.5.4: Gravity-Driven System with 1.458-cm Pipe						
C832A	(950, 15.1)	(20.9B, 20.7A, 5.6B)	12.7	3.6	0.27	0.28
Figure 6.5.5: Pump-Driven System with 1.458-cm Pipe						
C832A	(750, 12.5)	(5B, 5A, 1B)	6.4	1.6	0.20	0.22
C832A	(2000, 18.2)	(5B, 5A, 2B)	9.3	5.4	0.40	0.58
C832A†	(500, 11.6)	(20B, 20A, 1B)	31.3	1.3	0.05	0.04
C832A†	(750, 15.2)	(20B, 20A, 2B)	31.3	4.1	0.10	0.13
C832A†	(1200, 19.9)	(20B, 20A, 5B)	31.3	8.0	0.25	0.25
Figure 6.5.6: Pump-Driven System with 1.458-cm Pipe						
C832A	(1150, 13.5)	(2B, 2A, 1B)	4.7	1.6	0.50	0.34
C832A†	(650, 12.3)	(10B, 10A, 1B)	15.6	1.4	0.10	0.09
C832A†	(1100, 16.4)	(10B, 10A, 2B)	15.6	4.6	0.20	0.30
C832A	(2400, 23.0)	(10B, 10A, 5B)	16.2	9.9	0.50	0.61
Figure 6.5.7: Pump-Driven System with 1.021-cm Pipe						
C832A	(600, 12.2)	(5B, 5A, 1B)	5.6	1.5	0.20	0.26
C832A	(750, 13.5)	(5B, 5A, 2B)	6.0	2.4	0.40	0.40
C832A‡	(3700, 13.5)	(5B, 5A, 5B)	8.8	8.8	1.0	1.0
C832A†	(360, 11.3)	(20B, 20A, 1B)	25.8	1.5	0.05	0.06
C832A†	(370, 11.6)	(20B, 20A, 2B)	25.8	1.7	0.10	0.07

Polymer	Isoslip Point Coordinates	Slip Triad			Concen-tration Ratio	Slip Ratio
		$S'(C_B, C_A, c_B) = (Y, X, X)$			R_{cs}	R_{sc}
	$(Re\sqrt{f}, 1/\sqrt{f})$	(C_B, C_A, c_B)	Y	X	c_B/C_A	X/Y
C832A†	(600, 16.2)	(20B, 20A, 5B)	32.3	5.5	0.25	0.21
C832A†	(1500, 26.9)	(20B,20A,10B)	32.3	14.0	0.50	0.43
Figure 6.5.8: Pump-Driven System with 1.021-cm Pipe						
C832A	(1300, 13.5)	(2B, 2A, 1B)	2.9	1.5	0.50	0.51
C832A‡	(17000, 22.0)	(2B, 2A, 2B)	5.4	5.4	1.0	1.0
C832A†	(430, 11.6)	(10B, 10A, 1B)	12.9	1.5	0.10	0.11
C832A†	(460, 12.1)	(10B, 10A, 2B)	12.9	1.9	0.20	0.15
C832A	(950, 17.9)	(10B, 10A, 5B)	14.2	6.4	0.50	0.45
C832A‡	(6000, 32.8)	(10B,10A,10B)	18.1	18.1	1.0	1.0
Figure 6.5.9: Gravity-Driven System with 1.458-cm Pipe						
C832A	(1100, 13.5)	(10B, 10A, 2.1B)	9.1	1.7	0.21	0.19
C832A	(700, 12.2)	(20.7B, 20.7A, 2.1B)	9.0	1.2	0.10	0.14
C832A	(950, 15.1)	(20.7B, 20.7A, 5.6B)	11.2	3.6	0.27	0.32
Figure 6.5.10: Pump-Driven System with 1.458-cm Pipe						
B1120	(850, 14.2)	(5B, 5A, 1B)	8.9	2.9	0.20	0.32
B1120	(1900, 16.7)	(5B, 5A, 2B)	9.4	4.0	0.40	0.43
B1120†	(550, 11.5)	(20B, 20A, 1B)	25.4	1.0	0.05	0.04
B1120†	(650, 13.2)	(20B, 20A, 2B)	25.4	2.4	0.10	0.09
B1120†	(1600, 21.6)	(20B, 20A, 5B)	32.3	9.3	0.25	0.29
B1120†	(3600, 29.5)	(20B,20A,10B)	32.3	15.7	0.50	0.48

Polymer	Isoslip Point Coordinates	Slip Triad			Concen-tration Ratio	Slip Ratio
		$S'(C_B, C_A, c_B) = (Y, X, X)$			R_{cs}	R_{sc}
	$(Re_s\sqrt{f}, 1/\sqrt{f})$	(C_B, C_A, c_B)	Y	X	c_B/C_A	X/Y
Figure 6.5.11: Pump-Driven System with 1.458-cm Pipe						
B1120	(1100, 13.6)	(2B, 2A, 1B)	3.1	1.9	0.50	0.60
B1120†	(600, 11.7)	(10B, 10A, 1B)	12.7	1.0	0.10	0.08
B1120†	(800, 14.0)	(10B, 10A, 2B)	12.7	2.7	0.20	0.21
B1120	(2700, 22.9)	(10B, 10A, 5B)	15.2	9.6	0.50	0.63
Figure 6.5.12: Pump-Driven System with 1.458-cm Pipe						
P500	(1700, 18.2)	(30B,30A,10A)	12.8	5.7	0.33	0.45
P500†	(900, 15.8)	(100B, 100A, 10B)	41.8	4.3	0.10	0.10
P500†	(2200, 26.0)	(100B, 100A, 30B)	57.2	13.0	0.30	0.22
Figure 6.5.13: Pump-Driven System with 1.021-cm Pipe						
P500†	(1000, 16.2)	(30B, 30A, 10B)	12.2	4.6	0.33	0.37
P500†	(600, 14.3)	(100B, 100A, 10B)	41.8	3.6	0.10	0.08
P500†	(1300, 24.8)	(100B, 100A, 30B)	41.8	12.7	0.30	0.30

† Y and R_{sc} are the inferred values belonging to the corrected slip triad.
‡ The slip triad is a virtual isoslip point with $C_B = C_A = c_B$ and Y = X.

6.6 Comparison of Type-B Drag Reduction with Literature

The results in §6.4 indicate that in Type-B drag reduction — the nondimensional flow enhancement or apparent slip, S' — only depends weakly on flow parameters, such as $Re_*\sqrt{f}$ and pipe diameter, but strongly depends on additive parameters, such as concentration and molecular weight.

In this section, data for HPAM additives from this work and from the available literature are compared quantitatively. The comparison is then broadened to include other types of additives, including fibers. Also, retro-onset data from this work and the few that could be extracted from the literature are compared and correlated.

6.6.1 Present and Literature Flow-Enhancement Data

Figure 6.6.1 depicts the dependence of flow enhancement on concentration by six HPAM additives, including both the present data for additives C832A, B1120, and P500, and literature data for additives AP30(Clarke, 1970), Magnifloc® E-10(MagE10)(Oliver & Bakhtiyarov, 1983), and Hydropur® SB125 (HSB125)(Interthal & Wilski, 1985) with respective $M_w \times 10^{-6} \approx 9.2$, 16.5, and 23 g/mole. The experimental conditions for these data, shown in Figure 6.6.1 and summarized in Table 6.6, are similar, with pipe diameters $0.5 < D < 1.5$ cm and nondimensional stress levels therein corresponding to $Re_*\sqrt{f} \approx 3000$. For all HPAMs at $c < 20$ wppm, S' is observed to be approximately linear in c; at the highest concentrations $c \geq 20$ wppm, S' attains the MDR asymptote where $S' = S_M$, independent of c. For additives MagE10, C832A, B1120, HSB125,

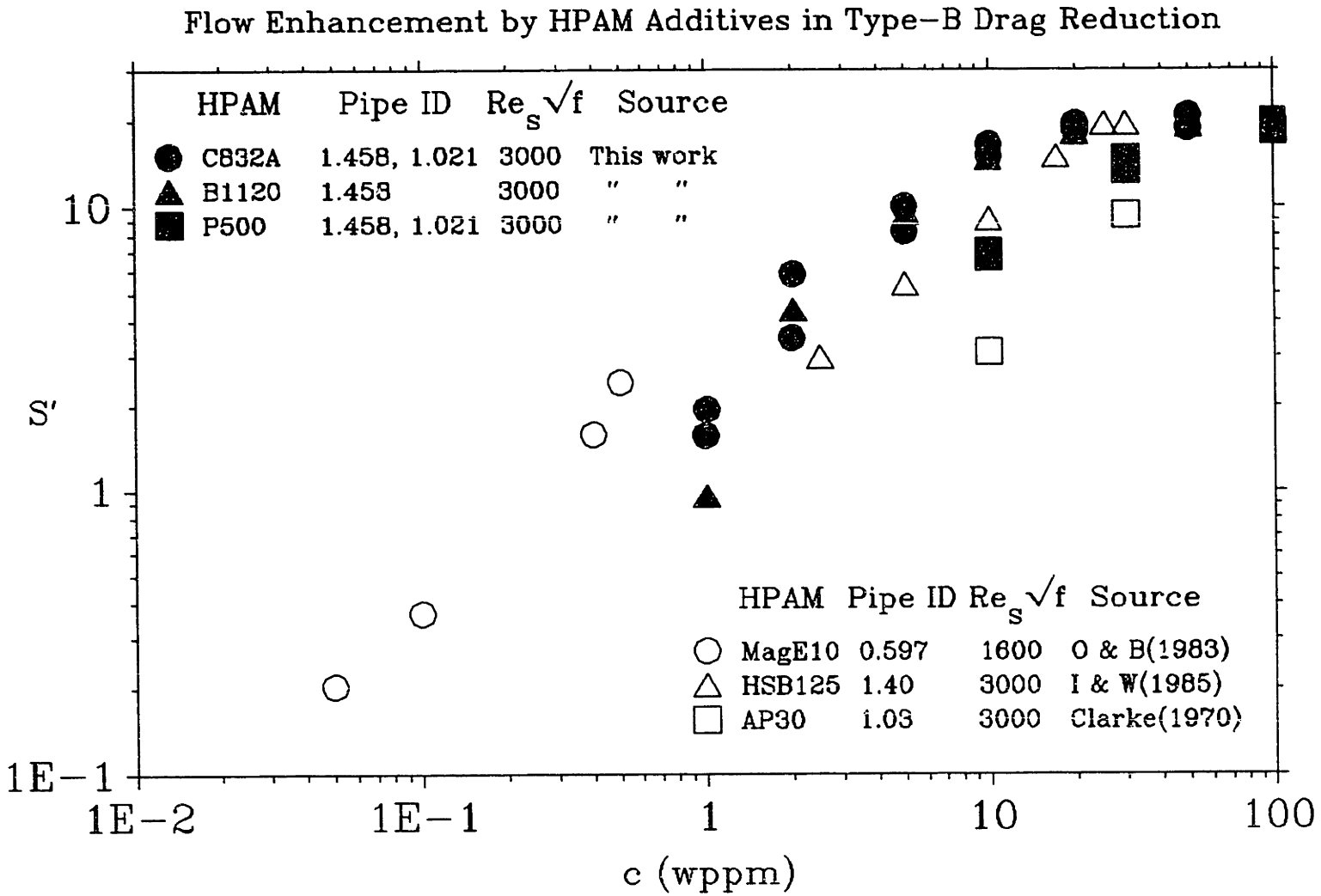


Figure 6.6.1: Flow Enhancement by HPAM Additives in Type-B Drag Reduction

P500, and AP30 with $M_w \times 10^{-6}$ = 23, 18.0, 20.1, 16.5, 9.5, and 9.2 g/mole, the respective specific slips S'/c ≈ 4.1, 1.87, 1.62, 0.91, 0.58, and 0.31. These data reinforce our earlier finding that HPAM additive efficacy increases with increasing molecular weight. Next, the intrinsic slip $\Sigma = S'/(c/M_w)$, a measure of flow enhancement per molecule developed in §6.4.1, is plotted against N_{bb}, the number of backbone chain links, in Figure 6.6.2, using doubly logarithmic coordinates. The six HPAM data points straddle a line with an approximate slope of three. Figure 6.6.2 contains three correlating lines that lie within the data scatter. Equation 6.4-2, the best-fit line of the present data(closed symbols), is shown dotted:

$$\Sigma = (1.00 \pm 0.23) \times 10^{-7} N_{bb}^{(2.53 \pm 0.40)} \qquad (6.4\text{-}2)$$

Inclusion of the three HPAM data from the literature leads to the best-fit line for all HPAM additives(open and closed symbols), shown dashed:

$$\Sigma = (1.73 \pm 0.66) \times 10^{-11} N_{bb}^{(3.19 \pm 0.43)} \qquad (6.6\text{-}1)$$

Finally, the best-fit line of slope 3, having the form of the earlier correlation of equation 6.4-3, is indicated by the solid line in Figure 6.6.2:

$$\Sigma = 2.21 \times 10^{-10} N_{bb}^{3} \qquad (6.6\text{-}2)$$

where the slip modulus $\lambda = 2.21 \times 10^{-10}$ g/mole/wppm, the geometric-mean value of the six individual slip moduli listed in Figure 6.6.2. This mean slip modulus is slightly lower than the value $\lambda = 2.38 \times 10^{-10}$ g/mole/wppm determined in §6.4.1 from only the present data.

The Type-B flow-enhancement comparison is now expanded to encompass

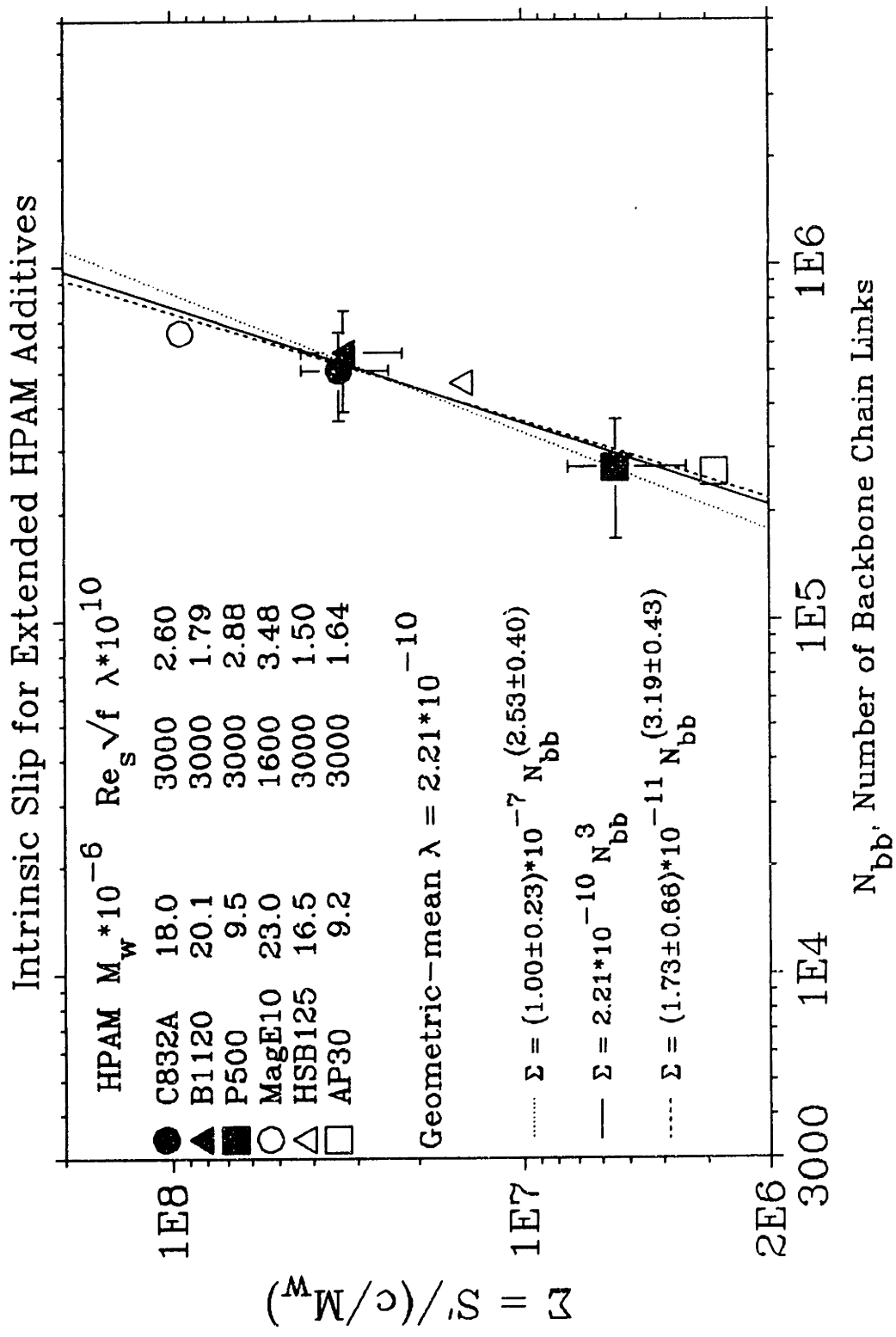


Figure 6.6.2: Intrinsic Slip for Extended HPAM Additives

various other additives, including xanthan gum(Rochefort & Middleman, 1984) with $M_w \approx 2.0\times10^6$ g/mole; asbestos fibers with (d_f, l_f) = (35 nm, 1.4 mm)(Sharma et al., 1979); asbestos fibers with (d_f, l_f) = (50 nm, 1.4 mm)(McComb & Chan, 1985); paper fibers with (d_f, l_f) = (30 μm, 2.7 mm)(Lee & Duffy, 1976); and nylon fibers with (d_f, l_f) = (20 μm, 1.0mm) (Bobkowicz & Gauvin, 1965). Table 6.6 summarizes the physical dimensions of these fiber additives, the prevailing experimental conditions, and the flow-enhancements achieved. Figure 6.6.3 illustrates the observed flow enhancements S' over a seven-decade concentration domain. Data for HPAMs in Figure 6.6.1 occupy the upper left, where the low c and high S' give rise to high specific slips $S'/c \approx O(1)$ as seen in the figure. To the right at higher c and slightly downward at lower S' from the HPAM data, data for xanthan(▽) and asbestos fibers(◇ ◆) lie roughly along the same trajectory with $0.03 < S'/c < 0.07$. These additives are clearly less effective per unit mass than HPAM. Farther to the right of the asbestos data, are the data for paper(▲) and nylon(▼) fibers, showing the lowest $S'/c \approx 0.0016$ and 0.00021, respectively. The observed specific slips span nearly five orders of magnitude, from $S'/c \approx 0.00021$ for nylon fibers to $S'/c \approx 4.1$ for the highest molecular-weight HPAM.

Because the most-important physical properties of fibers are their lengths l_f and aspect ratios l_f/d_f, additive efficacies exhibited by fibers and linear-polymer can be compared on an equal basis through their l_f and L_c, respectively.

To help interpret the broad variation in additive efficacy observed above, the additive-pervaded volume fraction per wppm, X_v/c, derived from either the macromolecular contour length L_c or the fiber length l_f and aspect ratio l_f/d_f, and then the additive-pervaded volume fraction required to induce unit slip can be calculated for each

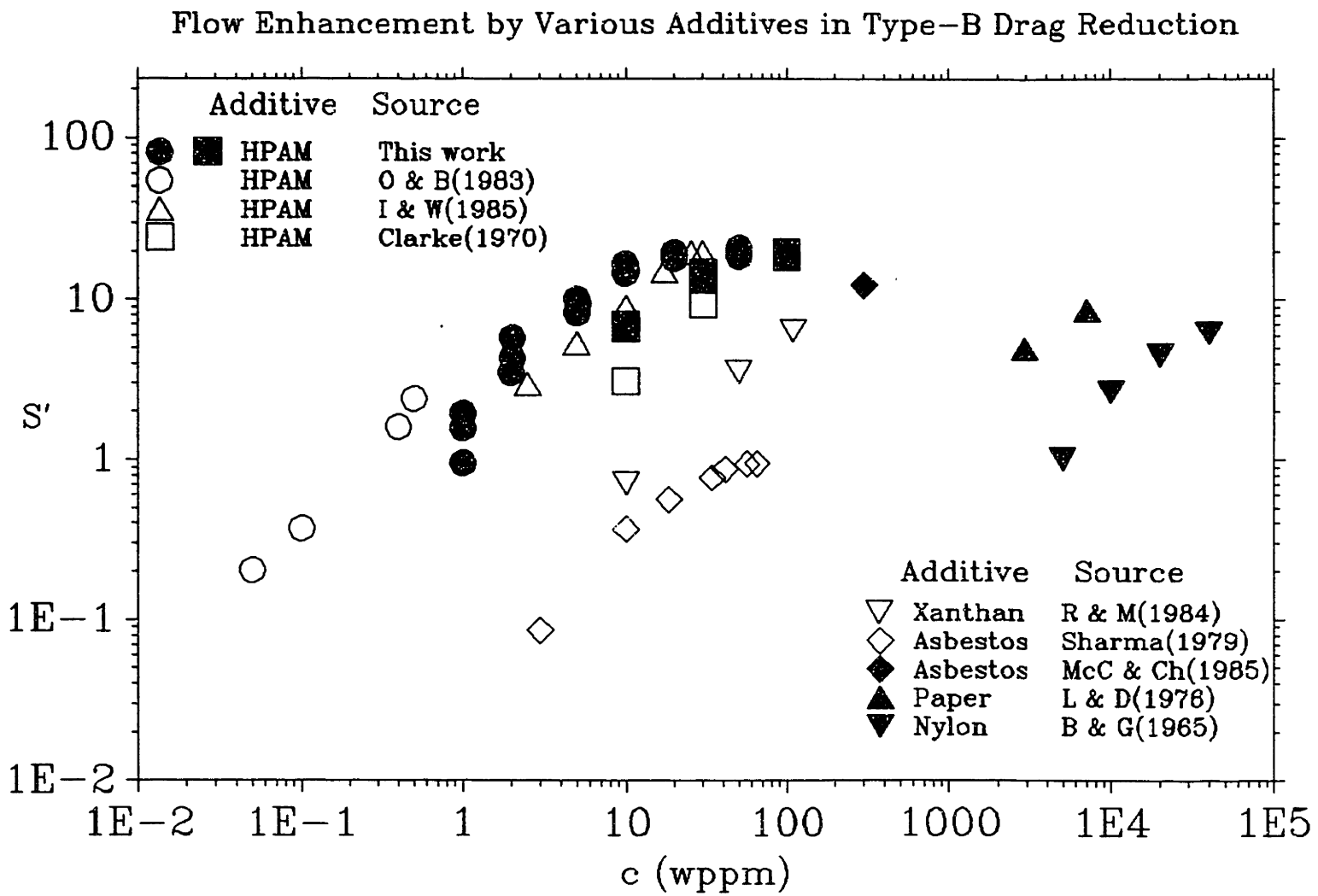


Figure 6.6.3: Flow Enhancement by Various Additives in Type-B Drag Reduction

additive. In §6.4.1, general expressions for X_v/c and X_v/S' are given for polymer additives by equations 6.4-5 and 6.4-6

$$\frac{X_v}{c} = \left[\frac{\pi L_c^3}{6}\right]\left[\frac{\rho N_A}{10^6 M_w}\right] \tag{6.4-5}$$

$$\frac{X_v}{S'} = \left[\frac{\pi L_c^3}{6}\right]\left[\frac{\rho N_A}{10^6 M_w}\right]\left[\frac{c}{S'}\right] = \left[\frac{\pi}{6\times 10^6}\right]\left[\frac{\rho N_A a^3}{\lambda}\right] \tag{6.4-6}$$

with Avogadro's number $N_A = 6.022\times 10^{23}$ mole^{-1}, and with densities, concentrations, lengths, and molecular weights in g/cm^3, wppm, cm, and g/mole, respectively. Analogous expressions for X_v/c and X_v/S' can be derived for fiber additves using d_f, l_f, and ρ_f in lieu of L_c and M_w. The respective equations for polymer and fiber X_v/S' are:

$$\frac{X_v}{c} = \left[\frac{\pi l_f^3}{6}\right]\left[\frac{4\rho}{10^6 \rho_f \pi d_f^2 l_f}\right] \tag{6.6-3}$$

$$\frac{X_v}{S'} = \left[\frac{\pi l_f^3}{6}\right]\left[\frac{4\rho}{10^6 \rho_f \pi d_f^2 l_f}\right]\left[\frac{c}{S'}\right] \tag{6.6-4}$$

again with Avogadro's number $N_A = 6.022\times 10^{23}$ mole^{-1} and with densities, concentrations, and lengths, in g/cm^3, wppm, and cm, respectively. The last two columns of Table 6.6 respectively list X_v/c and X_v/S' for each additive. For all HPAM additives, $X_v/S' = 3000\pm 100$, implying, since X_v cannot physically exceed unity, that these additives must be significantly aligned during drag reduction. Note also that equation 6.6-2, with the slip modulus $\lambda = 2.21\times 10^{10}$ g/mole/wppm for the six HPAM polymers, yields $X_v/S' \approx 2840$, which agrees with the average value cited above. For the xanthan

data, with uncertain molecular characterization, $X_v/S' \approx 40$, still much greater than unity, but two orders of magnitude lower than that for HPAM. Thus for polymeric additives, the additive-pervaded volume per unit slip seems to increase with increasing number of backbone chain links.

Within the fiber data cited, X_v/S' again assumes larger values for greater additive efficacies. For asbestos(Sharma et al., 1979), asbestos (McComb & Chan, 1985), paper, and nylon fibers with repsective aspect ratios $l_f/d_f = 40000$, 28000, 90, and 51, their respective $(S'/c, X_v/S') \approx (0.03, 14000)$, (0.04, 5000), (0.0016, 4), and (0.00021, 7). For fibers, both S'/c and X_v/S' increase with increasing aspect ratio, a suitably normalized measure of the fiber length.

In summary, in Type-B turbulent flow-enhancment by polymer additives, HPAM and xanthan, and fiber additives, asbestos, nylon, and paper, the additive efficacies S'/c and additive-pervaded volume fractions per unit slip X_v/S' seem to respectively depend on the number polymer backbone chain links and the fiber aspect ratio.

Additive†	Fiber Diameter	Aspect Ratio	Fiber Length	Pipe Diameter
	$d_f \times 10^3$	l_f/d_f	l_f	D
	(cm)		(cm)	(cm)
Fiber Additives				
Asbestos[5]	0.0035	40000	0.14	1.9
Asbestos[6]	0.005	28000	0.14	1.95
Paper[7]	3.0	90	0.27	10.0
Nylon[8]	2.0	51	0.10	4.98

Stress Level of Data	Specific Slip	Intrinsic Slip	Volume Fraction Per wppm	Volume Fraction Per Unit Slip
$Re_s\sqrt{f}$	S'/c	$\Sigma \times 10^{-6}$	X_v/c	X_v/S'
	($wppm^{-1}$)	(g/mole/wppm)	($wppm^{-1}$)	
1600	0.03	n/a	420	13900
1300	0.041	n/a	205	4980
3000	0.0015	n/a	0.006	4.1
5800	0.00021	n/a	0.0015	7.1

† Note the wrap-around nature of this table in both the HPAM- and Fiber-Additive sections.
1 — Clarke(1970); 2 — Oliver & Bakhtiyarov(1983); 3 — Interthal & Wilski (1985); 4 — Rochefort & Middleman(1984); 5 — Sharma et al.(1979); 6 — McComb & Chan(1985); 7 — Bobkowicz & Gauvin(1965); 8 — Lee & Duffy (1976).
n/a = not applicable

6.6.2 Present and Literature Retro-Onset Data

In §6.4.2, retro-onset data from the present work were analyzed and correlated

In Figure 6.6.4, the $T_w^{\#}$ data from this work, previously shown in Figure 5.3.23, and the few available $T_w^{\#}$ data for HPAMs in the literature — AP30(Clarke, 1970) and HSB125(Interthal & Wilski, 1985) — are plotted semilogarithmically against concentration to adhere to the form of equation 6.4-10. The legend in Figure 6.6.4 provides the additive molecular weight and experimental conditions for these data. The dotted line represents equation 5.3-1 for the best-fit line through C832A(● ◆) and B1120(▲) data from the 1.458-cm pipe:

$$\log T_w^{\#} = -0.436 + 0.134c \qquad (5.3\text{-}1)$$

While the ordinal intercept, $T_{w_o}^{\#} = 0.37$ dyne/cm^2, closely matches the ideal intercept value for a 1.458-cm pipe, $T_{w_o}^{\#} = 0.346$ dyne/cm^2, the coefficient yields an inferred S'/c = 1.00, which differs from the observed average for the two additives, S'/c ≈ 1.75. The ratio 1.00/1.75 produces a ladder imperfection factor $\beta = 0.58$. Literature data from a 1.40-cm pipe for additive HSB125(▽), of $M_w = 16.5 \times 10^6$ g/mole, lie close to the dotted line in Figure 6.6.4.

Well to the right of the dotted line at c = 30 wppm, two data points for additives P500(■) and AP30(□) lie close together. Both data points refer to similar polymer molecular weights — $M_w \times 10^{-6} = 9.5$ and 9.2 g/mole, respectively — and nearly identical pipe diameters — D = 1.021 and 1.02 cm, respectively. Equation 6.4-10 can be used to predict the concentration dependence of $T_w^{\#}$ data for additives with respective

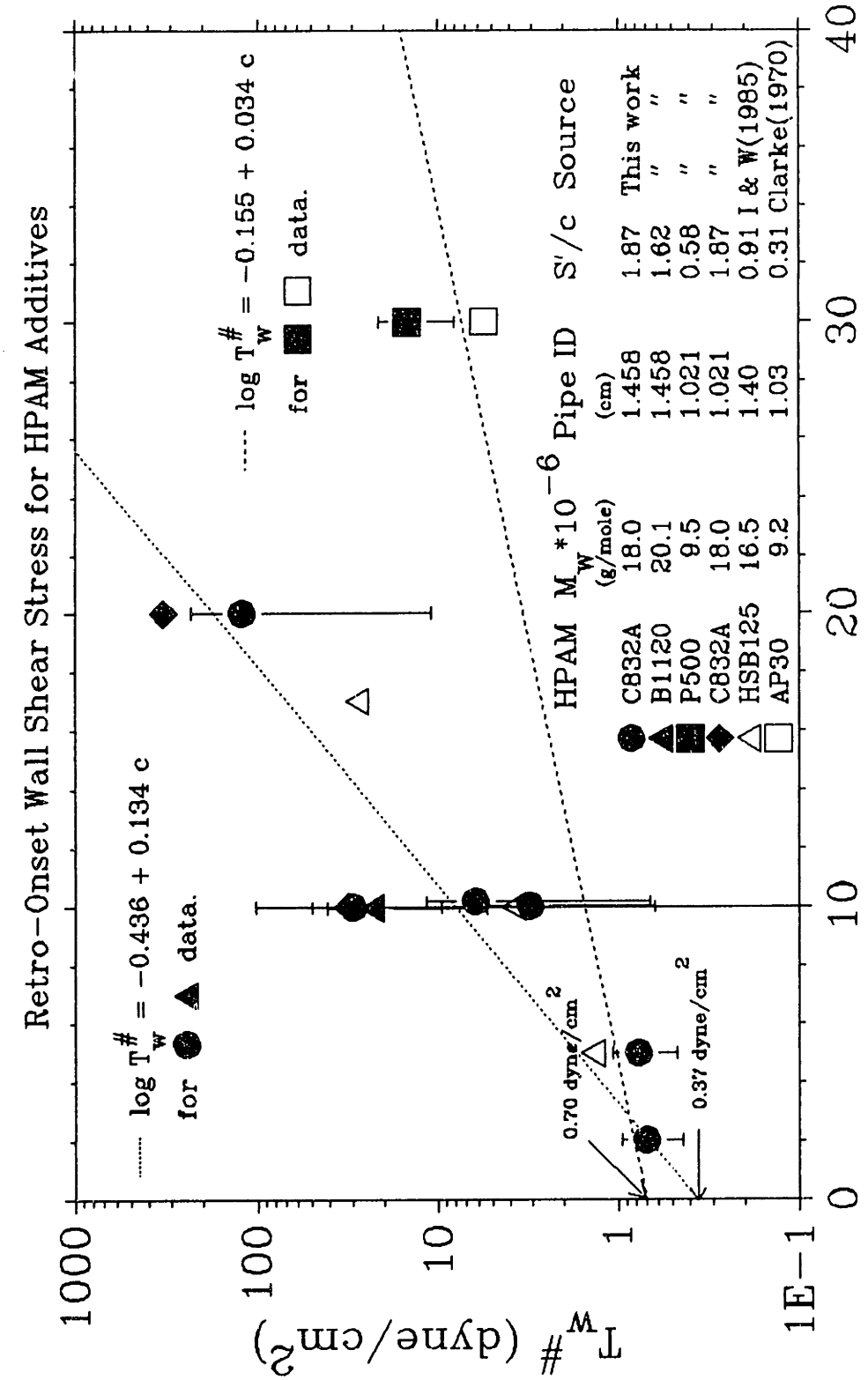


Figure 6.6.4: Retro-Onset Wall Shear Stress for HPAM Additives

$M_w \times 10^{-6}$ = 9.5 and 9.2 g/mole in pipes of respective inner diameters of 1.02 and 1.03 cm. With $T_w^{\#}{}_o = (\rho \nu_s^2)(Re_s\sqrt{f^{\#}})^2/(2D^2)$, the theoretical ordinate intercept for a 1.026-cm pipe and water solvent at 25°C should be $T_w^{\#}{}_o \approx 0.70$ dyne/cm^2, or log $T_w^{\#}{}_o \approx -0.155$. The slope of this second line can be predicted from concentration coefficient in equation 6.4-10 for imperfect Type-B ladders, $(2/15)\beta(S'/c)$. With an average $S'/c \approx 0.44$ for additives P500 and AP30 and $\beta = 0.58$, the slope of the line should be ~ 0.034. In Figure 6.6.4, the dashed line represents retro-onset predictions for HPAM additives of $M_w \approx 9 \times 10^6$ g/mole in a 1.026-cm pipe, corresponding to the relation:

$$\log T_w^{\#} = -0.155 + 0.034c \qquad (6.6\text{-}5)$$

As seen in Figure 6.6.4, this line runs close to the data points for additives P500 and AP30.

In conclusion, the retro-onset correlations developed from the present data also accommodate the few retro-onset data available in the literature.

6.7 Modelling Types A and B of Drag Reduction

Prior to this work, only Type-A drag reduction by random-coiling additives was amenable to modelling from knowledge of the additive's macromolecular properties. As a result of this work, prelimary modelling of Type-B drag reduction based on macromolecular parameters can also be undertaken. These approaches are illustrated for HPAM polymers.

6.7.1 Modelling a Perfect Types-A Fan

Type-A drag reduction for collapsed HPAM additives can be predicted from their molecular weights as follows. For known M_w, the rms radius of gyration R_G is obtained from equation 2.4-11, $R_G = 1.5\times10^{-2}M_w^{0.59}$; and this yields the onset wall shear stress T_w^* via equation 6.3-5, $T_w^* = 5.79\times10^5 R_G^{-2}$; this finally leads to the onset point on N, at $Re_s\sqrt{f}^*$, using the known pipe diameter, D, and solvent physical properties. Next, using $N_{bb} = M_w/m$, the intrinsic slope increment is obtained from equation 6.3-7, $\Pi = 43.5\times10^{-6}N_{bb}^{3/2}$, and hence the specific slope increment $\delta/\sqrt{c}$, and for known c, the slope increment δ. A polymeric regime segment P can now be calculated by the following equation:

$$\frac{1}{\sqrt{f_p}} = 4.0\log(Re_s\sqrt{f}) - 0.4 + \sqrt{c}\left[\frac{\delta}{\sqrt{c}}\right]\log\left[\frac{Re_s\sqrt{f}}{Re_s\sqrt{f}^*}\right] \qquad (6.7\text{-}1)$$

Equation 6.7-1 allows the construction of a perfect fan comprising any set of additive concentrations. However, it does not account for two important observed physical phenomena: the MDR asymptote which limits the extent of flow enhancement, $1/\sqrt{f_p} \leq 1/\sqrt{f_m}$, at any $Re_s\sqrt{f} > 400$; and polymer degradation which causes fan radii to deviate downward from their linear slopes, as observed in §5.2. The valid domain of $Re_s\sqrt{f}$ and range of $1/\sqrt{f_p}$ for equation 6.7-1 are therefore constrained. The lower bound on $Re_s\sqrt{f}$ is the onset $Re_s\sqrt{f}^*$, described above. The upper bound on $Re_s\sqrt{f}$ is the smaller of two values: either the point where the P segment intersects the line M or the point at which degradation begins. The former is the simultaneous solution of equation 2.4-7 for the

MDR asymptote and equation 6.7-1 for an ideal fan radius:

$$Re_s\sqrt{f} = 10^{\left(\frac{32-\delta\log Re_s\sqrt{f^*}}{15-\delta}\right)} \qquad (6.7\text{-}2)$$

The latter is determined via equation 6.1-2 for $T_w\hat{}$:

$$Re_s\sqrt{f}\,\hat{} \approx 3.4\times10^8\left[\frac{D\sqrt{\rho}}{\eta_s M_w}\right] \qquad (6.7\text{-}3)$$

This completes the information required to construct, and constrain, a perfect Type-A fan.

Figure 6.7.1 compares the experimentally-observed Type-A fan for additive B1120 and the perfect Type-A fan predicted by the preceding model. For B1120, $M_w \approx 20.1\times10^6$ g/mole and R_G = 300 nm in 0.3 N NaCl, hence, using the length-based onset constant for HPAM, $\Omega_L = R_G u_\tau^*/\nu_s = 8.3\times10\text{-}3$, the onset point $Re_s\sqrt{f^*} \approx 570$ in a 1.458 cm pipe. From equation 6.3-7, the intrinsic slope increment, $\Pi = 43.5\times10^{-6}$ $N_{bb}^{3/2}$, and using $N_{bb} \approx 5.7\times10^5$, the estimated a specific slope increment $\delta/\sqrt{c} \approx 4.1$. From $Re_s\sqrt{f^*}$ and $\delta/\sqrt{c}$, P segment trajectories can be predicted by equation 6.7-1, for any concentration c. In Figure 6.7.1, the predicted P segments for $1 \le c \le 100$ wppm are shown by various kinds of lines, as indicated by the legend, emanating from the predicted onset point on N, labelled $Re_s\sqrt{f^*} = 570$. While the predicted onset point closely matches the observed onset points, as seen by inspection, the predicted fan segments only match the observed radii for c = 5, 10, and 20 wppm. At low concentrations, the model overestimates the slope increments for c = 1 and 2 wppm. At high concentration, it misses entirely the fan radii for c = 50 and 100 wppm, possibly

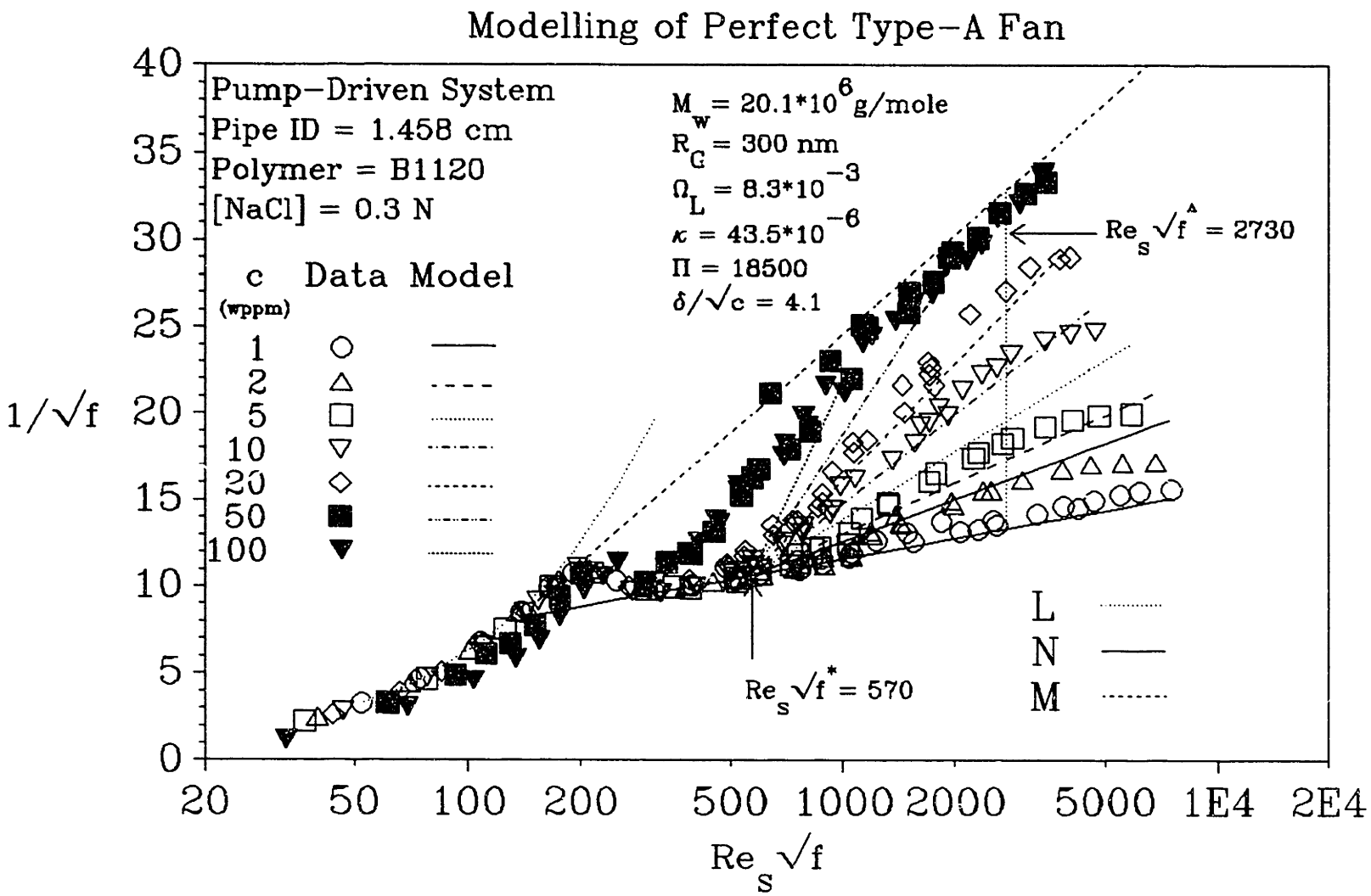


Figure 6.7.1: Modelling of Perfect Type-A Fan

due to the ill-defined onsets observed for these higher concentrations. Also in Figure 6.7.1, the vertical dotted line marks the "degradation falloff", estimated to occur at $Re_s\sqrt{f}^{\wedge} = 2730$; at higher $Re_s\sqrt{f}$, the flow data are seen to deviate downwards from their linear paths.

6.7.2 Modelling a Perfect Type-B Ladder

In a perfect Type-B ladder, the P segments, or ladder rungs, run parallel to the Newtonian baseline N and have constant flow enhancements S' above N that depend only on concentration, since the specific slip S'/c is essentially constant. Thus, only knowledge of the specifc slip S'/c is required to construct a perfect ladder in a PK coordinates. From the present work, equation 6.6-2 correlates S'/c and M_w by an expression for the intrinsic slip: $\Sigma = S'/(c/M_w) = \lambda N_{bb}^3$, where $\lambda = 2.21\times10^{-10}$ g/mole/wppm. For HPAM additives,

$$\frac{S'}{c} = \left[\frac{\lambda}{m^3}\right] M_w^2 \qquad (6.7\text{-}4)$$

with M_w in g/mole and $\lambda/m^3 \approx 4.9\times10^{-15}$ $[(g/mole)^2 \cdot wppm]^{-1}$. Equation 6.4-7 then describes each rung in PK coordinates:

$$\frac{1}{\sqrt{f_p}} = 4.0\log Re_s\sqrt{f} - 0.4 + c\left[\frac{S'}{c}\right] \qquad (6.4\text{-}7)$$

The retro-onset point for any rung, its intersection with the line M, is given by equation 6.4-8:

$$Re_s\sqrt{f}^{\#} = 10^{\left[\frac{c\left(\frac{S'}{c}\right)+32}{15}\right]} \doteq 136 + 10^{\frac{S'}{15}} \qquad (6.4\text{-}8)$$

The domain of valid $Re_s\sqrt{f}$ for each Type-B P segment is limited as follows: The lower bound for $Re_s\sqrt{f}$ is given by equation 6.4-8 for the retro-onset point $Re_s\sqrt{f}^{\#}$; the upper bound is set by degradation, using equation 6.7-3. This completes the information to construct a perfect Type-B ladder.

Figure 6.7.2 compares the observed Type-B ladder for additive B1120 at c = 1, 2, 5, and 10 wppm and the perfect Type-B ladder predicted by the preceding model. For B1120, using equation 6.6-2 for the intrinsic slip, $\Sigma = 2.21\times10^{-10}N_{bb}^{3}$, the model estimates a specific slip S'/c = 2.0. From this, using equations 6.4-7 and 6.4-8, all P segments can be calculated. The predicted ladder rungs are depicted by various types of line segments in Figure 6.7.2, as noted in the legend. The model accurately predicts ladder rungs at intermediate concentrations of 5 and 10 wppm but overpredicts the rungs at both low and high concentrations, c = 1 and 10 wppm. The degradation falloff is predicted to occur at $Re_s\sqrt{f}^{\wedge}$ = 2800, beyond which the data begin to fall below from their linear P segments.

In summary, simple models are presented for a perfect Type-A fan and a perfect Type-B ladder during drag reduction by collapsed and extended HPAM additives. These accord reasonably with the observed flow-enhancement behavior of high molecular-weight HPAM additives and may serve to provide preliminary estimates in engineering applications of drag reduction.

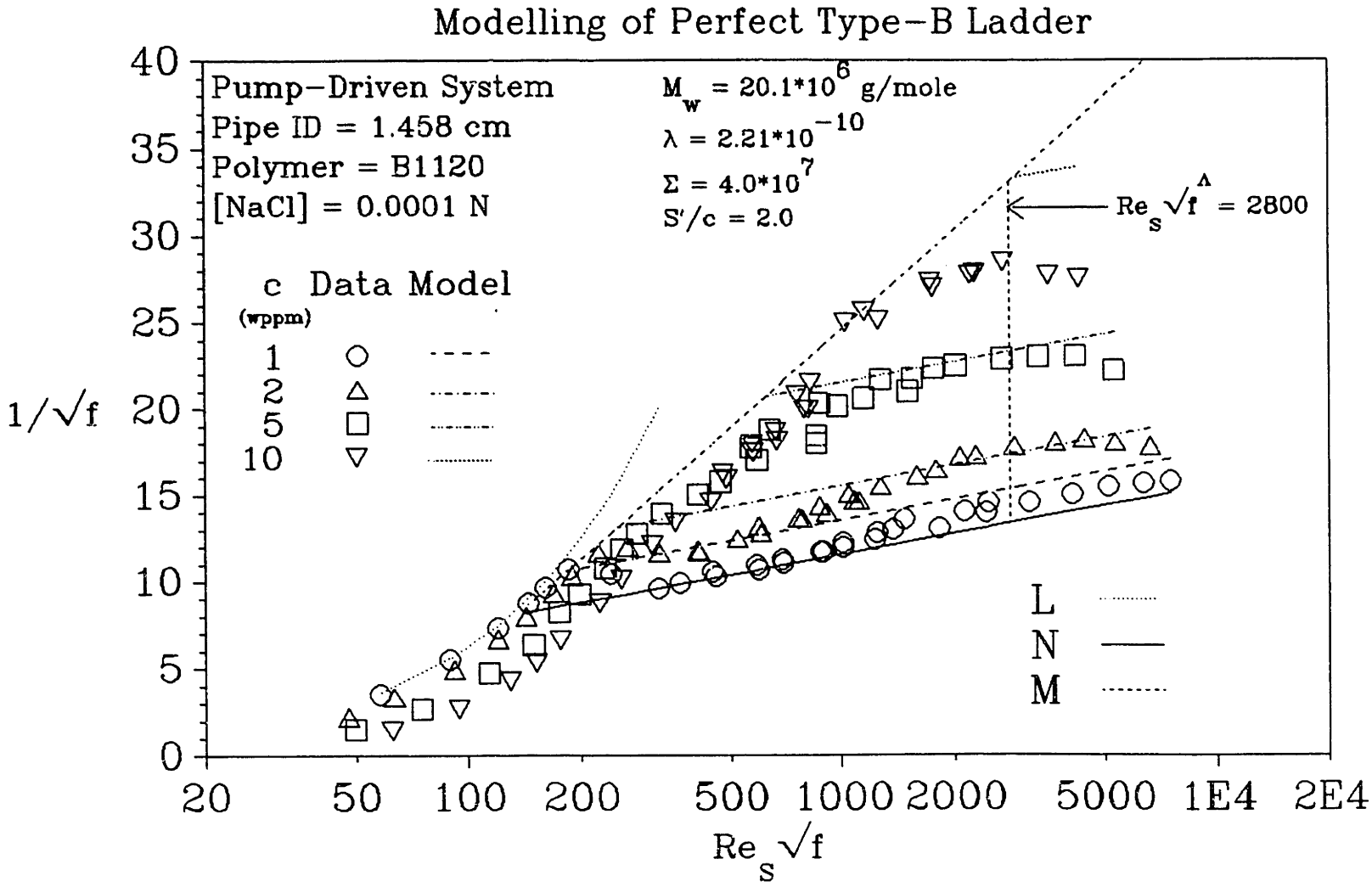


Figure 6.7.2: Modelling of Perfect Type-B Ladder

CHAPTER VII

CONCLUSIONS

1. The drag reduction phenomenon was experimentally studied in two pipes, of diameters 1.46 and 1.02 cm, using seven polyelectrolytic HPAM additives, with molecular weights from 1 to 20×10^6 g/mole and degree of backbone hydrolysis from 8 to 60%, at concentrations from 1 to 1000 wppm, in saline solutions containing from 0.3 to 0.00001 N NaCl.

2. Both laminar and turbulent flow behavior were greatly influenced by salinity-induced changes in the initial conformation of the HPAM additives. Initially collapsed, random-coiling conformations exhibited Newtonian laminar flow and Type-A turbulent drag reduction, while initially extended conformations exhibited shear-thinning in laminar flow and Type-B turbulent drag reduction.

3. The gross-flow physics of Type-B drag reduction were delineated. A characteristic "ladder" structure prevailed, with polymeric-regime segments that were roughly parallel to, but shifted upward from, the Prandtl-Karman line and intersected the maximum drag reduction asymptote at retro-onset points.

4. In the polymeric regime, both Type-A fan and Type-B ladder structures were essentially independent of pipe diameter, and were scaled by the wall shear stress. Thus

both types of drag reduction are insensitive to the large turbulence scales imposed by pipe diameter, and are controlled instead by the finer wall-turbulence scales associated with the wall shear stress. The wall shear stress also scaled incipient degradation during drag reduction.

5. New correlations were presented for Type-A drag reduction by HPAM additives, as follows:

(*Onset Correlation*) $$T_w^* = 5.79\times10^5 R_G^{-2} \qquad (6.3\text{-}5)$$

(*Slope-Increment Correlation*) $$\Pi = 43.5\times10^{-6} N_{bb}^{3/2} \qquad (6.3\text{-}7)$$

6. In Type-B drag reduction it was found that the flow enhancement S' was proportional to additive concentration, and that the intrinsic slip, $\Sigma = S'/(c/M_w)$, varied roughly as the third power of backbone chain links N_{bb}. New correlations were presented for Type-B drag reduction by HPAM additives:

(*Intrinsic-Slip Correlation*) $$\Sigma = 2.21\times10^{-10} N_{bb}^{3} \qquad (6.6\text{-}2)$$

(*Retro-Onset Correlation*) $$\log T_w^{\#} = -0.436 + 0.134c \qquad (5.3\text{-}1)$$

7. Analysis of available literature for Type-B drag reduction by polyelectrolytic and fiber additives revealed a wide range of additive efficacies, with specific slips S'/c from 0.0001 to 4. For the most effective additives, HPAM and asbestos fibers, the additive-pervaded volume fraction per unit flow enhancement, $X_v/S' \approx 3000$, implied that these additives align during drag reduction.

8. The slip ratio R_{sc}, which is the relative flow enhancement induced in Type-A and Type-B drag reduction at constant additive concentration, was found to be a universal function of the normalized turbulent flow strength ($Re_s\sqrt{f}/Re_s\sqrt{f}^*$), as follows:

$$R_{sc} = 1 - \left[\frac{Re_s\sqrt{f}}{Re_s\sqrt{f}^*} \right]^{-2/3} \qquad (6.5\text{-}2)$$

The extension of initially collapsed, random-coiling, HPAM macromolecules by the turbulent flow field thus seems independent of additive parameters and absolute wall shear stress levels.

9. Gross flow additive equivalence was detected at iso-slip points, where different polymer solutions induced equal flow enhancements. At numerous such points, the collapsed to extended slip ratio at constant concentration, R_{sc}, was essentially equal to the extended to collapsed concentration ratio at constant slip, R_{cs}. Thus, for fixed total additive concentration, the collapsed to extended slip ratio R_{sc} observed at any $Re_s\sqrt{f}$ simply represents the fraction of originally collapsed macromolecules that have become extended in the flow, and thence effective in drag reduction.

10. If extended additive states are the active species responsible for drag reduction, as appears likely, then Type-B behavior should underlie the basic mechanism of additive-turbulence interaction.

CHAPTER VIII

RECOMMENDATIONS

1. Flow-structure measurements under conditions of gross-flow additive equivalence might discover whether gross-flow additive equivalence reflects additive equivalence in the corresponding mean and turbulent flow structures.

2. Experiments conducted in the pump-driven system using additives C837A and C836A, of low and moderate backbone charges respectively, might permit the effect of backbone charge on turbulent drag-reduction behavior to be better identified.

3. Additional polymer-characterization techniques, such as light-scattering and viscometry, might be used on solutions of collapsed HPAM additives, at least, to directly determine additive properties, such as radius of gyration and intrinsic viscosity. This would augment the present in-situ, laminar-flow data from which such properties were inferred.

CHAPTER IX

APPENDICES

APPENDIX A

A2.4 Linear Polymers: Theory and Experiment

The following sections present some theory, experimental results, and theoretical calculations for dilute solutions of both nonionic and ionic linear polymers. These provide the bases for inferring physical properties of polymers from experimental data.

A2.4.1 Nonionic Linear Polymers

The static and dynamic properties of nonionic linear polymers have been widely discussed(Flory, 1953; Morawetz, 1975). The relevant macromolecular properties discussed briefly are molecular weight, chain configuration, and intrinsic viscosity. Only vinyl polymers such as PAM are treated.

Free radical polymerization of vinyl monomer($CH_2=CXY$) in solution produces contaminant-free polymer of high molecular weight. Common methods include thermal initiation, redox systems, and electromagnetic and ultrasonic irradiation. Osmometry, light-scattering, ultracentrifugation, and sedimentation provide various average molecular weights for a given polymer sample.

Theoretically, some average chain configuration can be calculated via statistical methods. Such methods require that the chain have a large degree of polymerization to average over the fine details which would otherwise make the calculation virtually impossible. Some assumptions for idealized chains include: infinitely thin, non-

intersecting bonds; equal bond lengths; freely rotating bonds; only short-range intramolecular forces; perfect chain solvation; homogeneity; and isotropy. For a three-dimensional chain of this type, the end-to-end displacement has been calculated,

$$\langle h^2 \rangle^{1/2} = \ell N^{1/2} \qquad \text{(A2.4-1)}$$

in which ℓ and N are the bond length and number of bonds, respectively. The radius of gyration, R_G, relates simply to the end-to-end displacement:

$$R_G = \langle R^2 \rangle^{1/2} = \left(\frac{\langle h^2 \rangle}{6}\right)^{1/2} = \ell\left(\frac{N}{6}\right)^{1/2} \qquad \text{(A2.4-2)}$$

While these assumptions greatly simplify the calculations, they apply only random-coiling chains. Fortunately, real chains behave qualitatively the same as these idealized, random-flight chains.

Having restricted bonds and long-range forces, real chains may be expanded and extended enough to invalidate the above statistical calculations. For a restricted angle θ,

$$\langle h^2 \rangle = N\ell^2 \frac{(1-\cos\theta)}{(1+\cos\theta)} \qquad \text{(A2.4-3)}$$

thus, for tetrahedrally linked vinyl polymers in which $\theta = 109.47°$ and $\cos\theta = -1/3$, $\langle h^2 \rangle^{1/2}$ is $\sqrt{2}$ times that for random-flight chains.

Without the random-flight assumptions, $\langle h^2 \rangle^{1/2}$ and R_G become larger as the spectrum of statistically acceptable configurations shifts to larger values. This expansion is characterized by a linear-expansion factor:

$$\alpha = \frac{\langle h^2 \rangle^{1/2}}{\langle h_o^2 \rangle^{1/2}} = \frac{R_G}{R_{Go}} \qquad \text{(A2.4-4)}$$

in which the o subscript indicates the unperturbed state.

In thermodynamic calculations of dilute solutions of linear polymers, solvent-polymer interactions and excluded volume effects are very important; these reflect roughly enthalpic and entropic phenomena, respectively. Most importantly, solvent-polymer interactions influence volume exclusion. For example, good solvent-polymer interactions can increase the population of otherwise less-probable chain configurations, leading to chain expansion. Both chemical properties and temperature determine the exact nature of this interaction. Calculating how these affect the statistical configuration of a single polymer chain gives rise to an expression for α:

$$\alpha^5 - \alpha^3 = 2C_M\psi_1(1-\frac{\Theta}{T})M^{1/2} \qquad \text{(A2.4-5)}$$

in which C_M is a constant for a given solvent-polymer pair, ψ_1 reflects the entropy of mixing, Θ is the temperature at which enthalpic and entropic effects cancel, and M is the molecular weight of the polymer chain. Clearly, increasing M and T above the Θ temperature leads to macromolecular expansion.

Adopting the random-flight model, an equivalent-chain model accounts for the excluded-volume effect of real chains. Rather than consisting of N C-C bonds of bond-length ℓ, this chain consists of N' Kuhn statistical segments of length ℓ' in which $\ell' = 1/\lambda \equiv \langle h^2\rangle/Lc$ and $N' \equiv L_c^2/\langle h^2\rangle$ as $L_c \to \infty$. While the contour length remains the same($L_c = N'\ell' = N\ell$), $\ell' > \ell$, and N' < N so that $\langle h'^2\rangle^{1/2}/\langle h^2\rangle^{1/2} = R'_G/R_G = (\ell'/\ell)^{1/2} > 1$. While these larger average sizes are consistent with the excluded-volume effect, N' and ℓ' have no physical meaning, rather they must be determined empirically. To account for excluded-volume effects under the assumption(Peterlin, 1955) that

$<h^2>^{1/2} \propto N^{1+\epsilon}$, a new relation between $<h^2>^{1/2}$ and R_G obtains:

$$R_G = <R^2>^{1/2} = \frac{<h^2>^{1/2}}{[(2+\epsilon)(3+\epsilon)]^{1/2}} \qquad \text{(A2.4-6)}$$

When $\epsilon = 0$(i.e. no excluded-volume effects), this reduces to the ideal random-coiling relationship previously derived.

So far, the polymer has been considered an ensemble of unconnected segments, the radial distribution of which is identical to the radial density distribution of a macromolecule composed of the same linear sequence of segments. In addition, it has been at rest with respect to the solvent. The macromolecule is modelled now as a string of beads in a laminar flow field. Strictly speaking, there are N beads and N-1 bonds; however, as $N \to \infty$, $N \approx N-1$, and the distinction loses importance.

In this laminar flow field, the solvent exerts a force at every point of contact along the polymer chain. While in the idealized case the solvent exerts a force at every bead, that is, a free-draining polymer, for real chains the solvent does not penetrate into the inner, more-bead-dense core. The solvent exerts a force on the macromolecule that depends on several parameters: R_G or $<h^2>^{1/2}$; $N = M/m$, the number of beads; the bead distribution; and ς/η_o, the ratio of bead friction coefficient to solvent viscosity. While ς must be inferred experimentally, it can be reasoned that the overall macromolecular frictional coefficient f_o becomes independent of ς when ς/η_o becomes sufficiently large. Furthermore, it can be shown that $f_o/\eta_o \sim <h^2>^{1/2}$(or R_G), independent of both the polymer and solvent!

To describe the contribution of polymer molecules to dilute-solution viscosity, Kraemer(1938) defined the intrinsic viscosity:

$$[\eta] = \lim_{c\to 0}\frac{\eta_{sp}}{c} = \lim_{c\to 0}\frac{(\eta_r - 1)}{c} = \lim_{c\to 0}\frac{\eta - \eta_s}{c\eta_s} \qquad \text{(A2.4-7)}$$

in which the subscript indicates solvent. Since the intrinsic viscosity $[\eta]$ can depend on the shear rate $\dot{\gamma}$, a stricter definition includes the restriction $\dot{\gamma} \to 0$. Huggins(1942) included in his definition the observation that the slope of the η_{sp}/c curve varied as $[\eta]^2$:

$$\frac{\eta_{sp}}{c} = [\eta] + k'[\eta]^2 c \qquad \text{(A2.4-8)}$$

in which the Huggins (slope) coefficient k' varies with M_w and is typically between 0.35 and 0.40. The physical significance of k' has not been elucidated, and experimental k' values vary widely(Fanood & George, 1987). Intrinsic viscosity has also been defined as,

$$[\eta] = \lim_{c\to 0}\frac{\ln \eta_r}{c} = \lim_{c\to 0}\frac{\ln(\frac{\eta}{\eta_o})}{c} \qquad \text{(A2.4-9)}$$

Both definitions can be used to extrapolate dilute solution viscosities down to infinite dilution; the latter is preferred because as $c \to 0$ the extrapolation has greater linearity. Better methods for extrapolating viscosity data down to infinite dilution have been devised and discussed extensively elsewhere(Bohandecký & Kovář, 1982).

Kirkwood & Riseman(1948) and Debye & Bueche(1948) independently developed theories for intrinsic viscosity. In both treatments, the intrinsic viscosity had the same dependence: $[\eta] \sim \langle h^2 \rangle^{3/2}/M$. The Flory-Fox equation followed from this dependence:

$$[\eta] = \Phi\frac{\langle h^2\rangle^{3/2}}{M} \qquad \text{(A2.4-10)}$$

in which the KR constant Φ is 3.62×10^{23} mole^{-1} for all polymer-solvent systems. The equation obtains if the polymer behaves somewhat like a random coil.

In a solution of random-coiling polymers of diameter $<h^2>^{1/2}$ with concentration c, the volume fraction of coils is:

$$\phi = \frac{\pi}{6}<h^2>^{3/2}\frac{\rho c N_A}{M} \qquad \text{(A2.4-11)}$$

in which ρ and N_A are the solvent density and Avogadro's number, respectively. Substituting for $<h^2>^{1/2}$ via the Flory-Fox equation yields the following equation:

$$\phi = \frac{\pi\rho N_A}{6\Phi}c[\eta] \approx 1.26c[\eta] \qquad \text{(A2.4-12)}$$

Rearranging and setting $\phi = 1$ gives one definition of diluteness: $c[\eta] = 0.79$. Einstein's limiting law for dilute solutions of hard spheres, $c[\eta] = 2.5$, constitutes a laxer dilute-solution criterion. Other such criteria have been developed elsewhere(Wolff, 1977).

The above value of the KR constant is theoretical; experiments have inferred smaller Φ values. Flory(1953) tabulated Φ values from 10 polymer-solvent systems; Φ ranged between 1.75×10^{23} and 2.6×10^{23} mole^{-1} with a best value of $(2.1\pm0.2)\times10^{23}$ mole^{-1}. Flory speculated that polymer heterogeneity reduced the experimental value from the probable true value of 2.5×10^{23} mole^{-1}. Fujita(1988) recently discussed both experimental values and theoretical calculations for the KR constant. He tabulated values from several experiments using polystyrene near the Θ condition and showed Φ to range from 1.7 to 2.9×10^{23} mole^{-1}, citing a "most reliable" experimental value of 2.55×10^{23}

mole^{-1}(Miyaki et al., 1980; Fujita, 1988).

On the theoretical side, improved KR techniques(Miyaki et al., 1980), renormalization group methods(Oono & Kohomoto, 1983), and Monte Carlo methods(Zimm, 1980; Garcia de la Toree et al., 1982) have been used to calculate Φ. The respective Φ values are 2.85×10^{23}, 2.36×10^{23}, and 2.51×10^{23} mole^{-1}. The last value has been declared the upper bound by Fixman(1981). To account for good solvents, the Flory-Fox equation has been corrected by introducing a 0.8 factor(Yamakawa, 1971). The Flory-Fox equation in terms of R_G is:

$$[\eta] = (0.8)(6^{3/2})\frac{\Phi R_G^{3/2}}{M} \qquad \text{(A2.4-13)}$$

It should be noted no single value for Φ has been accepted, from either experiment or theory. For example, Banijamali et al.(1974) used $\Phi = 2.66\times10^{23}$ mole^{-1} (Pyun & Fixman, 1966) and neglected the 0.8 solvent factor in the Flory-Fox equation. While Virk(1975b) used the same Φ, he did include the 0.8 solvent factor. More recently, Merrill & Horn(1984) and Tam & Tiu(1990) used $\Phi = 2.5\times10^{23}$ mole^{-1} and 2.85×10^{23} mole^{-1}, respectively, without any solvent correction. Coincidentally, using the 0.8 solvent factor with $\Phi = 2.5\times10^{23}$ mole^{-1} yields an effective $\Phi' = 2.0\times10^{23}$ mole^{-1}, identical within experimental error to Flory's best Φ value of $(2.1\pm0.2)\times10^{23}$ mole^{-1}.

To relate $[\eta]$ and the linear-expansion factor α, the Flory-Fox equation can be modified:

$$[\eta] = (0.8)(6^{3/2})\Phi\left(\frac{\langle R_o^2\rangle}{M}\right)^{3/2} M^{1/2}\alpha^3 = KM^{1/2}\alpha^3 \qquad \text{(A2.4-14)}$$

Under Θ conditions, in which $\alpha \equiv 1$, $[\eta]_\Theta = KM^{1/2}$. Experiments indicate that log α^3

varies with log M; thus, intrinsic viscosity may be expressed as $[\eta] = K'M^a$. That $[\eta] = KM^{1/2}\alpha^3$ agrees qualitatively with the empirical Mark-Houwink-Kuhn-Sakurada(MHKS) relation, $[\eta] = K'M_w^a$, is not surprising.

To this point, the theoretical treatment has considered only monodisperse polymers of molecular weight M. For heterogeneous polymer solutions, the relation can be transformed:

$$[\eta] = K'M_v^a \qquad \text{(A2.4-15)}$$

in which M_v is the viscosity average molecular weight. Because M_v and M_w are not too different, using M_w in the MHKS relation,

$$[\eta] = K'M_w^a \qquad \text{(A2.4-16)}$$

does not introduce too-unacceptable an error in $[\eta]$.

A2.4.2 Linear Polyelectrolytic Polymers

Linear polyelectrolytic polymers(called henceforth polyions, but also known as ionic polymers and macroions) differ from nonionic linear polymers in that some of the side-chain residues are either acids or salts of the monomer. Making polyions can be achieved either by polymerizing monomers that are either acids or salts or by reacting nonionic polymers with acid or base to alter the residues. For example, HPAM has been made by hydrolyzing PAM in NaOH(Farinato, 1988) and by copolymerizing PAM and sodium acrylate(NaA)(Morgan et al., 1990).

The presence of ionizable residues along the chain drastically alters the static and

dynamic properties of the otherwise nonionic polymer. The physical and transport properties of polyions based on idealized models have been calculated elsewhere(Tanford, 1961; Rice & Nagasawa, 1961; Oosawa, 1970; Bohandecký & Kovář, 1982).

In any model, interactions among polyion charges and between polyion charges and solvent counterions must be considered. Counterion mobility both inside and outside the polyion domain further complicates the problem. Accounting for solvent dielectric effects all but makes this an intractable problem. How the solvent arranges itself near polyion charges and how mobile counterions "bind" themselves to the polyion are not known. Treated as a continuous medium, the solvent is characterized by its bulk dielectric constant(i.e., its relative permittivity, ϵ_r). Counterions in the solvent are modelled to screen polyion charges, reducing the strength of their electrostatic interactions.

Three basic models have been used to describe polyion behavior. The random-flight and cylindrical models represent the extremes of polyion configuration. The former applies only to very weakly ionized polyions and polyions in a solution of high ionic strength(i.e., a large salt concentration) and uses much of the statistics that apply to nonionic linear polymers. The latter model obtains for highly ionized polyions in a solution of low ionic strength; the chain is almost fully extened to which cylindrical symmetry applies. The third model, the worm-like chain model, bridges those two extremes. It best describes real polyion chains by allowing for local rigid-rod behavior amid global flexibility. For a spherical(i.e., random-coiling) polyion, the random-flight model can be modified by including an electrostatic contribution to the radial distribution function of chain segments. The characteristic length across which charges interact in a

dielectric medium is the Debye screening length κ^{-1}:

$$\kappa^2 = \frac{8\pi e^2 I}{(4\pi\epsilon_o\epsilon_r)k_bT} \qquad \text{(A2.4-17)}$$

in which the ionic strength $I \equiv \frac{1}{2}\Sigma z_i^2 c_i$, the unit charge $e = 1.602\times10^{-19}$ C, the inverse Coloumbic proportionality constant $4\pi\epsilon_o = 1.113\times10^{-10}$ $C^2/(J\cdot m)$, ϵ_r is the relative permittivity of the solvent, z_i is the charge on species i, and c_i is the concentration of species i in m^{-3}.(The $4\pi\epsilon_o\epsilon_r$ group is the solvent bulk-dielectric constant D.) For 1.0×10^{-4} N aqueous NaCl at 25°C, $\epsilon_r = 78.54$, and $I = 1.2\times10^{23}$ m^{-3}; thus, $\kappa^{-1} \approx 300$ Å. For 0.3 N aqueous NaCl at 25°C, $\kappa^{-1} \approx 6$ Å. For a single PAM polymer of $M_w = 15.5\times10^6$ g/mole, $\langle h^2\rangle^{1/2} \approx 1.26$ Å $\times\sqrt{(2\cdot15.5\times10^6/35.54)} = 1170$ Å, and $R_G \approx 480$ Å. Since κ^{-1} for a dilute aqueous salt solution and $\langle h^2\rangle^{1/2}$ of a neutral PAM are of the same order, a HPAM chain of equal Mw should not be random-coiling at all. Rather, the charges everywhere along the backbone should repel and should coordinate polarizable water molecules around themselves, expanding and swelling the chain. Conversely, since κ^{-1} in concentrated brine and the distance between neighboring charges in a **fully ionized HPAM** are about the same, a HPAM of equal Mw should be nearly random-coiling. Clearly, spherical polyions can exist only when there are very few ionizable backbone groups or when the counterion concentration is so high that κ^{-1} becomes smaller than the distance between ionizable backbone groups.

Highly ionizable polyions in a solvent of low ionic strength will most certainly be expanded. For dilute polyion solutions, each chain can be modelled as having locally cylindrical symmetry. For calculating properties which do not depend upon M_w (via R_G, $\langle h^2\rangle^{1/2}$, and L_c), the chain may be treated as an infinitely long cylinder(Manning, 1969).

In the limit of zero radius, it may be treated as a line charge. Thus, the electrostatic potential depends only upon radial position from the line charge. The characteristic length scale here is that for a simple electrolyte solution, the Bjerrum length Q. The Bjerrum length and Debye screening length are related by

$$Q = \frac{e^2}{(4\pi\epsilon_o\epsilon_r)k_bT} = \frac{\kappa^2}{8\pi I} \qquad \text{(A2.4-18)}$$

In this model, the Poisson-Boltzmann equation describes the potential field radially about the line charge, and a Boltzmann distribution function accounts for charge-screening by the solvent and counterions: $\nabla^2\Phi(r) = \kappa^2\sinh\Phi(r)$. Although no general analytical solution exists, it was shown that for high linear charge densities, counterions "condense" onto the chain. The criterion for condensation is

$$\xi = \frac{Q}{A} \geq 1 \qquad \text{(A2.4-19)}$$

in which A is the distance between neighboring polyion charges. Here, condensation means that enough counterions will associate with the polyion charges to lower ξ to unity. Condensation does not neutralize the line charge; rather, counterions in the bulk solution are still influenced by the significant electrostatic potential of the "condensed" line charge. For a HPAM polyion of $M_w = 15.5\times10^6$ g/mole in 1.0×10^{-4} N aqueous NaCl at 25°C, Q ≈ 7 Å; thus, for condensation to occur the polyion must have about ⅓ of its residues ionizable. Infinite dilution of the polyion solution does not reduce counterion condensation. As [NaCl] → 0, the polyion expands so that $\langle h^2\rangle^{1/2} \rightarrow L_c$. The line charge, albeit condensed, still exerts forces so long in range that other polyions in this "dilute" solution may be influenced. In 1.0×10^{-5} N and 1.0×10^{-6} N aqueous NaCl

at 25°C, κ^{-1} is 962 Å and 3043 Å, respectively. In a 1-ppm solution of PAM of M_w = 15.5×10^6 g/mole, the number density is $\sim3.9\times10^{10}$ cm^{-3}; with $L_c \approx 55$ μm, each cylindrical polyion has an effective radius b $\approx$ 0.4 μm = 4000 Å in a densely packed arrangement of parallel polyions. That b and κ^{-1} are approximately equal implies that in "dilute" solutions, interactions between polyions can occur. Experiments have confirmed the interesting behavior of "dilute" polyion solutions(Kratky & Porod, 1949).

Worm-like chain models have been used to describe stiff nonionic polymers in solution(Kratky & Porod, 1949). This linear chain consists of N bonds of length ℓ connected at bond angle θ. In the limit $N \to \infty$, two lengths characterize the chain: the persistence length $\mathcal{L} \equiv (2\lambda)^{-1} = \ell/(1+\cos\theta)$ and contour length $L_c = N\ell$. The worm-like chain obtains in the limit $\ell \to 0$ and $\theta \to \pi$. As $\mathcal{L}/L_c \to 0$, the chain exhibits greater flexibility, and $R_G = (\mathcal{L}L_c/3)^{1/2} = (N\ell/6\lambda)^{1/2}$; the random-flight result is recovered if λ^{-1} were equal to ℓ. As $L_c/\mathcal{L} \to 0$, the chain becomes rigid, and $R_G = L_c/\sqrt{12}$, the exact result for a rigid rod. To apply the worm-like-chain model to polyion chains, $\mathcal{L}$ must be related to the electrostatic potential and charge screening due to the polyion charges and solvent and counterions, respectively. Odijk & Houwaart(1978) calculated excluded-volume effects in a dilute solution of polyions and a 1:1 salt, combining excluded-volume theory, counterion condensation, and cylindrical polyion models. The highly ionizable model polyion($\xi = Q/A \geq 1$) had an effective persistence length of $\mathcal{L}_T \sim O(L_c)$ and a surrounding impenetrable cylindrical shell of radius $b = 2\kappa^{-1}$, twice the Debye screening length. These dimensions characterized short-range and excluded-volume(long-range) effects, respectively. The effective persistence length can be separated into bare(nonelectrostatic) and electrostatic persistence lengths provided that the latter makes

a small contribution: $\mathscr{L}_T = \mathscr{L}_p + \mathscr{L}_{p,e}$, in which $\mathscr{L}_{p,e} = 1/(4Q\kappa^2)$. With Q ≈ 7 Å and $\kappa^{-1} = b/2 \approx 304$ Å from previous calculations, $\mathscr{L}_{p,e} \approx 3300$ Å; $\mathscr{L}_{p,e}/\mathscr{L}_T \sim \mathscr{L}_{p,e}/L_c \approx$ 3300 Å/550000 Å = 0.006, indeed a small perturbation. It follows that the otherwise rigid chain only "collapses" when the salt concentration increases(i.e., κ^{-1} decreases); the smaller radius b enhances chain flexibility. Yet, when the polyion solution is diluted, the chain expands, reaches a maximum when $\kappa^{-1}_{max} = (2Q\mathscr{L}_p)^{1/2}$, and then drops off upon further dilution. Intrinsic viscosity measurements have exhibited such maxima at low ionic strengths(Takahashi & Nagasawa, 1964; Cohen et al., 1988; Tam & Tiu, 1990).

Recently, Monte Carlo methods have been used to simulate the conformation of polyions in solvents of varying ionic strengths. Carnie et al.(1988) studied fully ionized polyions, characterized by PAA, in solutions of varying ionic strength. The chains contained between 20 and 320 beads of diameter 2.52 Å and were either freely rotating or hindered. Simple 1:1 salt concentrations ranged between 1.0×10^{-4} and 0.1 N. At 0.1 N, both $<h^2>$ and $<R^2>$ varied as N^ν with ν between 1.3 and 1.6, implying extension even at small screening lengths. At lower salt concentrations, $<h^2>$ went as N^2(or M_w^2), implying high extension at large screening lengths. Over all salt concentrations and chain lengths, the $<R^2>/<h^2>$ ratio ranged between about 1/7 and 1/12, close to the ideal ratios for random-flight(1/6) and rigid rods(1/12), respectively. If $<h^2>^{1/2} \propto N^\nu = N^{1+\epsilon}$, the $<R^2>/<h^2>$ ratios for $\nu = 0.3$ and 0.6 are 1/7.59 and 1/9.36, respectively; thus, these results are consistent with excluded-volume effects treated in §A2.4.1. Brender(1990) calculated thermal effects on coil-to-rod transition in small polyions. The Bjerrum length Q was varied between 1×10^{-4} and 18 Å, corresponding to temperatures between 2.1×10^7 and -155 °C. For water at 25°C, Q ≈ 7.14 Å. Added

1:1 salt concentrations ranged between 0 to 1.0 N. Without added salt, the polyion proceeds through a coil-to-rod transition as Q increases; transition is indicated by the $<R^2>/<h^2>$ ratio changing from about 1/6 to about 1/11. Only at 0.1 N does the transition disappear with the ratio ranging between about 1/6 and 1/8. At 1.0 N, only random-coiling behavior occurs with the ratio being $\sim 1/6$. At Q = 8 Å, the ratio varies from 1/10 at 0 N to $\sim$ 1/7 at 1.0 N; thus, a coil-to-rod transition can occur in a solution of short polyions at room temperature. Between 0.01 N and 0.1 N, the polyion collapses with $<h^2>^{1/2}/L_c$ decreasing from 0.8 to 0.2. Qian & Kholodenko(1988) studied polyion rigidity due to electrostatic effects. In the limit $N \rightarrow \infty$, the static properties of polyions are not universal, unlike those of neutral polymers. Einvoll and Hemmer(1988) investigated counterion distributions around polyions; only supercritical polyions(i.e., polyions for which $\xi = Q/A \geq 1$) have universal counterion distributions.

Given that the static properties of polyions differ from those of random-flight polymers, the dynamic properties of polyions also can be expected to differ. While the universal KR constant Φ characterizes very large random-flight polymers under Θ conditions irrespective of polymer and solvent, no such universality has been found for polyelectrolytic polymers, except perhaps in the limit $\lambda^{-1} \rightarrow 0$.

Under certain conditions, two general equations do fit $[\eta]$ data for polyions, the coefficients of which depend on both polyion-solvent pair and temperature. Fuoss & Strauss(1948) proposed the following equation to fit viscosity data of dilute polyion solutions:

$$\frac{\eta_{sp}}{c} = \frac{A}{1+Bc^{1/2}} \qquad \text{(A2.4-20)}$$

in which A and B are system specific. Recently Ait-Kadi et al.(1987) found that equation A2.4-20 did not obtain for their HPAM samples, claiming that the equation applied only to highly ionized polyions. Noda et al.(1970) empirically determined an expression for the dependence of solution viscosity on solvent ionic strength at moderate 1:1-salt concentrations:

$$[\eta] = [\eta]_{s\infty} + k_{s\infty}[salt]^{-1/2} \qquad \text{(A2.4-21)}$$

in which $[\eta]_{s\infty} \equiv [\eta]$ as [salt] $\rightarrow \infty$. While this equation has been "confirmed" theoretically(Fixman, 1964), it is not universal. Isoionic dilution of polyion solutions(i.e. using a diluent of the same ionic strength as the original polyion solution) shows η_{sp}/c to vary linearly with c as do nonionic polymers according to the Huggins equation. Despite this fact, Φ seems to depend on polyion charge. Clarke(1970) observed that while high-molecular-weight PAM solutions obeyed the linear Huggins equation, high-molecular-weight HPAM solutions did not, displaying great nonlinearity. To date, each polyion-solvent pair must be investigated separately.

APPENDIX B

B3.0 Experimental Equipment

Table B3.0
Equipment and Vendors

Equipment	Vendor
Moyno 3L4-SSQ-AAA pump; Reliance 2 Hp TEFC-XE motor, model #P14G9245; and T. B. Woods 2 Hp E-trAc AC Inverter, Model AFC2002-0B2	Robbins & Myers, Inc. Fluids Handling Group P.O. Box 743 7 - 11 Elm St. Southbridge, MA 01550 1-(508)-765-0628
Unistrut channels and assorted pieces	Unistrut Northeast 55 Shawmut, P.O. Box 157 Canton, MA 02021 (617)-821-1720
316-SS seamless 0.574"-ID and microsmooth 0.402"-ID tubing	Stainless Pipe & Fittings 37 Rogers Street Cambridge, MA 02142 (617)-491-1320
Assorted tools	Kaufman. Co. 110 Second Street Cambridge, MA 02141 (617)-491-5500
Swagelok fittings	Cambridge Valve & Fittings, Inc. 50 Manning Road Billerica, MA 01821 (617)-272-8270
PVC pipe, valves, and fittings	Metro Pipe 303 Binney St. Cambridge, MA 02142 (617)-492-6400
Jamesbury ball valves	Boston Pipe & Fittings Co. 161 - 171 Sidney Street Cambridge, MA 02139 (617)-876-7800

Equipment	Vendor
Stainless-steel pipe stubs, flanges, reducers, and valves	Tek Supply, Inc. 9 Walkup Drive Westboro, MA 01581 1-(800)-343-813
Flexible stainless-steel hose with flanged ends	Northeast Rubber 110 Alexander Street P.O. Box 937 Framingham, MA 01701 1-(508)-626-9300
CJ3D pressure transducers, carrier demodulator, and accessories	C.J. Enterprises, Inc. 9048 Independence Ave. Canoga Park, CA 91304 (818)-996-4131
Micro Motion mass flow meter	Pond Technical 174 North Plain Industrial Rd. Wellingford, CT 06492 (203)-284-1500
Lightning bench mixer	M.A. Olson Co.,Inc. Industrial Sales Equipment 414 Old Boston Road Topsfield, MA 01983 (508)-887-2384
55-gallon drum heater	Cole-Parmer Instrument Co. 7425 North Oak Park Ave. Chicago, IL 60648 1-(800)-323-4340
55-gallon flexible drum heater	N.E. Industrial Heat 460 Totten Pond Road Waltham, MA (617)-890-5885
5000Ω thermistors	Omega Eng., Inc. 1 Omega Drive, Box 4047 Stamford, CT 06907-0047 (203)-359-1660

Equipment	Vendor
Electronic parts	E.M.F. 110 - 120 Brookline Avenue Cambridge, MA 02139 (617)-547-1991
Computer supplies	Unitech 24 Thorndike Street Cambridge, MA 02142 (617)-UNI-TECH
Thermal paper	University Stationary Co. 311 Massachusetts Avenue Cambridge, MA 02139 (617)-547-6650
Clear plastic pipe	A.I.N Plastics 1400 Providence Highway Norwood, MA (617)-769-9050
Tricomb Spiral Wrap Honeycomb	ELDIM, Inc. 8 Southside Road Danvers, MA 01923 (617)-774-1777
Large vincon tubing and gaskets	Greene Rubber Co. Inc. 160 Second Street Cambridge, MA 02142 (617)-547-7655
Glass U-tube manometer	Lab Glass, Inc. 1172 N. W. Blvd. P.O. Box 610 Vineland, NJ 08360-0610 1-(609)-691-3200
Cyanamid HPAM samples	American Cyanamid Co. Specialty Polymers Dept. Paper Chemicals Dept. Wayne, NJ 07470 1-(800)-438-5615

Equipment	Vendor
Betz HPAM samples	Betz Laboratories, Inc. 4636 Somerton Road Trevose, PA 19047 (215)-355-3300
Allied Colloid HPAM samples	Allied Colloids Inc. P.O. Box 820 2301 Wilroy Road Suffolk, VA 23434 (804)-934-3700

C3.4 Experimental Equipment

(3) The Water and Mercury Manometers

Figure C3.4.3a shows a schematic of the water manometer. Two glass tubes were taped along the outer edges of the meter stick, next to the millimeter markings. The lower end of each tube extended a little below the bottom of the meter stick. The meter stick mounted on a ring stand by two screws. One end of a short length of ¼" flexible tubing slid over the lower end of each glass tube.

Into the other end of the left flexible tube inserted one run of a small plastic tee. The branch run of this tee connected to the left side of the stopcock via a short length of ¼" flexible tubing. The other run inserted into one end of a short length of ¼" flexible tubing. The other end of this short length slid over and was clamped to the stub of a ¼"-stub-to-⅛"-port reducer. One end of a long length of ⅛" flexible vincon tubing inserted into the port of the reducer; on its other end were a ⅛" stainless-steel nut with nylon ferrules.

Into the other end of the right flexible tube inserted the branch run of a small plastic tee. The left run of this tee connected to the right side of the stopcock. Its right run connected to the left run of another small plastic tee via a short length of ¼" flexible tubing. The branch run of the second tee inserted into one end of a short length of ¼" flexible tubing. The other end of this short length slid over and was clamped to the stub of a ¼"-stub-to-⅛"-port reducer. One end of a long length of ⅛" flexible vincon

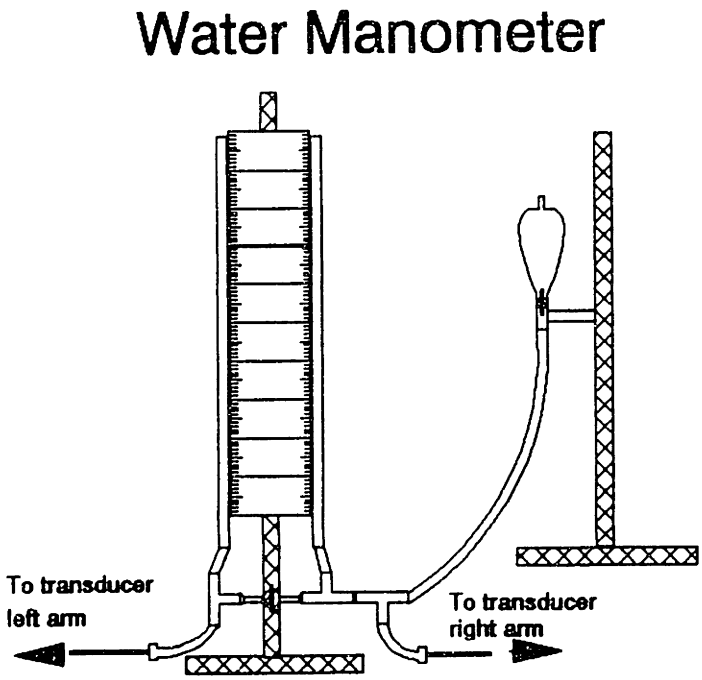


Figure C3.4.3a

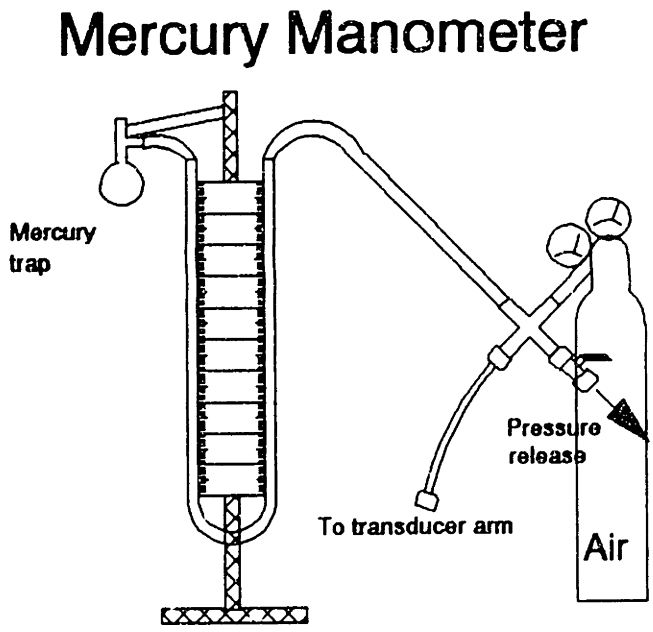


Figure C3.4.3b

tubing inserted into the port of the reducer; on its other end were a ⅛" stainless-steel nut and nylon ferrules. The right run of the second tee inserted into one end of a long length of ¼" flexible tubing; its other end slid over the tip of the small separation funnel supported by the other ring stand.

The stopcock was held just below the meter stick by a three-prong grip. This grip was held by a regular holder that also clamped onto the ring stand. On the other ring stand, a regular holder clamped onto a three-prong grip. The water reservoir, the small separation funnel, was supported by this three-prong grip.

Figure C3.4.3b is a schematic of the mercury manometer. The U-tube with meter stick, configured much like the two glass tubes on the meter stick in the water manometer, mounted onto a ring stand by two screws. The manometer was filled with enough mercury so that the maximum height difference produced a pressure differential of 10 psid, corresponding to $(760/14.69)\times 10$ psid $\approx$ 517 mm Hg. To the top of the left arm connected a mercury trap. Over the top of the right arm fitted one end of the compressed-air supply tube.

On the end of the regulating valve attached a ¼" brass union cross. Onto one arm attached a ¼" brass toggle valve via a ¼" brass port connector. This served as a quick release valve in case of overpressure. The arm opposite the toggle-valve connected to one end of a long length of ¼" flexible vincon tubing via a ¼" brass port connector. The other end fitted over the top of the right arm of the U-tube. The arm opposite the compressed-air arm held the tube of a ¼"-stub-to-⅛"-port reducer. One end of a long length of ⅛" flexible vincon tubing inserted into the port of the reducer; on its other end were a ⅛" stainless-steel nut with nylon ferrules.

APPENDIX E

SOLVENT DATA SETS 1 - 5

Page 1 Solvent Set 1: Runs S0000234 - S0000339

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000234	3.038215	11.78286	68.24586	11.79687
Taps 14	2.966118	11.46444	57.80837	11.46749
	2.910348	11.24147	50.84505	11.16585
	2.802582	10.81852	39.66998	10.82951
	2.732203	10.52913	33.74142	10.55190
	2.626263	10.10585	26.43280	10.05378
Taps 12	3.031306	11.72522	67.17172	11.83259
	2.958489	11.43340	56.79117	11.53547
	2.904197	11.21679	50.12769	11.16595
	2.790962	10.76385	38.62270	10.78149
	2.788244	10.75297	38.38174	10.85745
	2.714753	10.45901	32.40440	10.62589
	2.599687	9.998751	24.86382	10.23872
	2.497443	9.589853	19.64913	9.810283
	2.402701	9.210804	15.79724	10.44229
	2.285805	8.743220	12.06938	11.10361
Taps 23	3.034262	11.73705	67.63051	11.75232
	2.961102	11.44440	57.14552	11.42846
	2.902216	11.20884	49.89953	11.28602
	2.790435	10.76174	38.57584	10.80702
	2.791784	10.76715	38.69590	10.74859
	2.717777	10.47110	32.63300	10.54544
	2.601143	10.00465	24.94843	10.20631
	2.492916	9.571666	19.44449	9.913529
	2.418633	9.274532	16.38751	10.05003
	2.282197	8.728791	11.96954	11.19623
Taps 34	3.033108	11.73243	67.45106	11.79938
	2.956537	11.42614	56.54798	11.53177
	2.901546	11.20618	49.82258	11.23773
	2.790209	10.76083	38.55579	10.80020
	2.787698	10.74839	38.28062	10.83583
	2.717442	10.46976	32.60787	10.53529
	2.602381	10.00952	25.01851	10.14321
	2.490511	9.562047	19.33712	9.992695
	2.422687	9.290748	16.54120	9.900550
	2.275179	8.700717	11.77767	11.37863
Taps 14	3.853248	15.01299	445.7883	15.05011
	3.793046	14.77218	388.0844	14.69472
	3.707958	14.43183	319.0354	14.37018
	3.635020	14.14008	269.7124	14.09598
	3.545850	13.78340	219.6496	13.74518
	3.407862	13.23144	159.8609	13.29011
	3.320978	12.89391	130.8754	12.81594
	3.172693	12.29077	93.91946	12.02108

Page 2 Solvent Set 1: Runs S0000234 - S0000339

	3.879419	15.11767	473.4781	15.16218
	3.820446	14.88178	413.3577	14.76231
	3.733435	14.53374	338.3103	14.85403
	3.640207	14.16082	272.9527	14.46561
	3.539273	13.75709	216.3481	13.82602
	3.402309	13.20973	157.8300	12.88753
	3.188728	12.35491	96.51812	12.39657
	3.890204	15.16081	485.3829	15.12776
	3.825939	14.90373	418.6195	14.90935
	3.752232	14.60892	353.2746	14.54939
	3.690941	14.35376	306.7757	14.36116
	3.595588	13.9[illegible]	246.3025	13.91224
	3.461721	13.4[illegible]	180.9678	13.52498
	3.321424	12.8356[illegible]	131.0098	13.07772
	3.212135	12.44854	101.8626	12.01415
	3.890664	15.16265	485.8967	15.24875
	3.828651	14.91460	421.2415	14.95086
	3.770888	14.68355	368.7813	14.73367
	3.692822	14.37128	308.1075	14.42870
	3.599651	13.99860	248.6175	13.90764
	3.487792	13.55116	192.1662	13.49503
	3.323849	12.89539	131.7437	13.12276
	3.212418	12.44967	101.9290	12.11515

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000236	3.859631	15.03852	452.3879	15.10065
	3.742761	14.57104	345.6557	14.49329
	3.626185	14.10474	264.2809	14.21685
	3.430978	13.32391	168.6002	13.55652
	3.429817	13.31926	168.1501	13.54217
	3.320295	12.88118	130.6698	13.06987
	3.180714	12.32285	94.75336	12.01602
	3.024946	11.69978	66.19525	11.81808
	2.948935	11.39574	55.56678	11.48668
	2.909874	11.23949	50.78725	11.24139
	2.866479	11.06591	45.95781	11.18724
	2.810627	10.84251	40.41177	10.91602
	2.718945	10.47578	32.72093	10.57486
	2.609690	10.03876	25.44314	10.29535
	2.413060	9.252240	16.17857	10.37846
	2.309442	8.837771	12.74449	10.99695
	2.131359	8.125439	8.457459	8.320143
	2.057115	7.828462	7.128459	7.146469
	2.003300	7.613200	6.297672	6.494558
	1.764053	6.656213	3.630223	3.529578

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000243	3.849040	14.99616	441.4397	14.95855
	3.813977	14.86391	409.1267	14.79664
	3.787146	14.74858	382.8480	14.66232
	3.765569	14.58203	347.8490	14.55550
	3.682253	14.32901	309.7000	14.27546
	3.604480	14.02392	282.5575	13.94596
	3.527650	13.71040	210.6350	13.58632
	3.467277	13.22911	159.6458	13.09750
	3.294200	12.77680	123.0497	12.52294
	3.125550	12.10220	83.45085	11.87054
	3.023164	11.69265	65.92413	11.68725
	3.377480	13.10992	149.0599	13.26144
	3.271282	12.68513	116.7246	13.17178
	3.193996	12.37598	97.69593	12.36503
	3.122606	12.09042	82.88692	11.92437
	3.037921	11.75168	68.20273	11.27133
	3.025607	11.70242	66.29602	11.74576
	2.946190	11.38476	55.21675	11.30026
	2.882879	11.13151	47.72669	11.16048
	2.771594	10.68637	36.93812	10.65554
	2.697726	10.39090	31.16041	10.44308
	2.645557	10.18223	27.63361	10.19450
	2.582254	9.929019	25.88552	10.05510
	2.474593	9.498372	18.64116	9.697407
	2.283133	8.732533	11.99536	10.34221
	2.927925	11.31170	52.94259	11.42071
	2.883452	11.13381	47.78951	11.27471
	2.839963	10.95985	43.23577	11.05321
	2.798690	10.79476	39.31608	10.84736
	2.731746	10.52698	33.69775	10.61890
	2.476589	9.506356	18.72704	9.874056
	2.254181	8.624726	11.27357	10.76504
	2.191363	8.365454	9.710543	9.621582
	2.094442	7.978569	7.771812	7.750865
	1.991336	7.565336	6.126523	6.198186
	1.791665	6.764663	3.848528	3.909549

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000243'	3.875679	15.10271	469.4177	14.91848
	3.801660	14.80644	395.8593	14.74219
	3.715985	14.46394	324.9865	14.36572
	3.602394	14.00937	250.1926	13.99522
	3.448165	13.39264	175.4063	13.30815

	3.334583	12 .933	135.0401	12.96466
	3.176723	.0689	93.88661	12.43166
	3.095712	78284	77.90985	11.98479
	3.396816	13.18726	155.8464	13.38965
	3.327248	12.90899	132.7788	13.09652
	3.272738	12.69095	117.1165	12.86825
	3.173982	12.29592	93.29579	12.42600
	3.091574	11.96629	77.17098	12.01793
	3.030738	11.72295	67.08395	12.00398
	2.948638	11.39459	55.53015	11.40635
	2.882951	11.13180	47.73440	11.46939
	2.778398	10.71359	37.52137	10.84093
	2.780033	10.72013	37.66289	10.73877
	2.708320	10.43328	31.93010	10.50190
	2.652314	10.20925	28.06693	10.34856
	2.584640	9.938561	24.01708	10.29282
	2.481975	9.527903	18.96076	10.07846
	2.345139	9.060556	14.48835	10.78108
	2.266114	8.664458	11.53439	11.16897
	2.199324	8.397299	9.890195	9.868805

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000243''	2.920772	11.28308	52.07773	11.37276
	2.887209	11.14883	48.20466	11.29514
	2.845458	10.98183	43.78633	11.06748
	2.795236	10.78094	39.00465	10.84818
	2.748410	10.59364	35.01790	10.67543
	2.679383	10.31753	29.87193	10.42630
	2.565046	9.860185	22.95759	10.07266
	2.458238	9.432954	17.95224	9.782378
	2.263793	8.655172	11.47289	10.46160
	2.190567	8.362269	9.692757	9.203031
	1.996144	7.584577	6.194757	5.866763
	1.796149	6.784598	3.908675	3.897965

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000243'''	2.992687	11.57075	61.45645	11.89957
	2.911222	11.24489	50.94511	11.44182
	2.857838	11.03135	45.05245	11.06055
	2.738804	10.55521	34.25191	10.67506
	2.668908	10.27563	29.16006	10.42829
	2.550337	9.801350	22.19307	10.08261
	2.447132	9.388529	17.49896	9.909985
	2.317836	8.871336	12.99314	11.15809
	2.249583	8.598333	11.10358	10.62227

	2.187340	8.349440	9.621439	9.250355
	2.053210	7.820841	7.097253	7.020039
	1.745710	6.882840	5.480088	5.448110
	1.932094	7.328379	8.345334	5.334249
	Data Log(Ro/f)	PK 1//f	L 1//f	Data 1//f
S0000245	3.844841	15.08936	457.8483	14.98803
	3.813415	14.86166	408.5974	14.83526
	3.760256	14.64102	359.8626	14.61962
	3.714830	14.48932	324.1231	14.46734
	3.653582	14.21432	281.4894	14.22070
	3.552398	13.80959	222.9865	13.86842
	3.455164	13.42065	178.2560	13.47380
	3.375820	13.10328	148.4912	13.09372
	3.266205	12.66482	115.3681	12.88761
	3.130352	12.12140	84.37863	12.19902
	3.037661	11.75064	68.16185	11.74550
	3.393460	13.17384	154.6466	13.28211
	3.376272	13.10508	148.6456	13.17273
	3.350444	13.00177	140.0634	13.03558
	3.297628	12.79051	124.0248	12.82751
	3.268047	12.67219	115.8585	12.80415
	3.156763	12.22705	89.66919	12.28308
	3.062880	11.85152	72.23709	11.85894
	3.074559	11.89823	74.20610	11.86882
	2.987363	11.56945	60.70770	11.62506
	2.927313	11.30925	52.86805	11.37032
	2.822331	10.88932	41.51565	10.74247
	2.753818	10.61527	35.45670	10.41762
	2.695929	10.38371	31.03200	10.28973
	2.638993	10.15598	27.21921	9.963989
	2.538897	9.755590	21.61612	9.503857
	2.956532	11.42613	56.54741	11.51321
	2.934564	11.33825	53.75812	11.36944
	2.901512	11.20604	49.81869	11.24644
	2.871997	11.08799	46.54552	11.06616
	2.832012	10.92804	42.45142	10.88514
	2.774337	10.69735	37.17215	10.69753
	2.752440	10.52976	33.75361	10.44708
	2.682676	10.33070	30.09928	10.33592
	2.611423	10.04569	25.54487	10.13025
	2.570894	9.883578	23.26883	9.966052
	2.502006	9.608027	19.85577	9.831373
	2.415848	9.263395	16.28279	9.959077
	2.286978	8.747914	12.10203	11.21828
	2.200777	8.403111	9.923338	9.842418
	2.039242	7.756970	6.841049	6.799137

	1.879558	7.118235	4.736296	4.816192
	1.685246	6.340987	3.027797	2.991622
	Data Log(Ro/f)	PK 1//f	L 1//f	Data 1//f
S0000248	3.904482	15.21792	501.6054	14.97251
	3.839363	14.95745	431.7613	14.78537
	3.762996	14.65198	362.1399	14.51706
	3.756013	14.62405	356.3657	14.50070
	3.679000	14.31600	298.4558	14.28422
	3.602761	14.01104	250.4040	13.92980
	3.467310	13.44924	183.3117	13.39016
	3.345459	12.98183	138.4648	13.06204
	3.180399	12.32159	94.68458	12.27964
	3.080714	11.92285	75.26519	12.01507
	3.448740	13.39496	175.6386	13.38979
	3.382512	13.13005	150.7970	13.11411
	3.225436	12.50174	105.0307	12.55231
	3.137758	12.15103	85.82997	12.28829
	3.102061	12.00824	79.05724	12.50835
	3.033093	11.73237	67.44869	11.68591
	2.975395	11.50158	59.05757	11.47580
	2.864110	11.05644	45.70784	11.02006
	2.790981	10.76392	38.62433	10.72418
	2.737079	10.54831	34.11612	10.48759
	2.967519	11.47007	57.99614	11.52784
	2.732250	10.52900	33.73886	10.52722
	2.667187	10.26875	29.04477	10.31255
	2.565197	9.860791	22.96560	10.06778
	2.494442	9.577850	19.51383	9.798643
	2.362817	9.051269	14.41111	10.75756
	2.244183	8.576735	10.96639	10.43042
	2.174173	8.296694	9.333697	9.114597
	2.046598	7.786394	6.937907	6.847004
	1.944472	7.377890	5.499872	5.510991
	1.752103	6.608415	3.531701	3.543791
	Data Log(Ro/f)	PK 1//f	L 1//f	Data 1//f
S0000251	3.901414	15.20565	498.0743	14.80896
	3.827658	14.91063	420.2799	14.62510
	3.737621	14.55048	341.5869	14.39549
	3.646282	14.18513	276.7979	14.21198
	3.535779	13.74311	214.6144	13.74737
	3.389845	13.15938	153.3649	12.82512
	3.161735	12.24694	90.70161	12.19818
	3.898820	15.19528	495.1088	14.89766

	3.824984	14.89993	417.7006	14.71543
	3.737373	14.55029	341.5496	14.39707
	3.646990	14.18796	277.2495	14.18883
	3.534411	13.75764	213.9398	13.79073
	3.342392	13.08936	144.0363	13.65574
	3.167679	12.27071	91.95139	12.03234
	3.106137	12.02685	79.80270	12.08902
	3.024842	11.69937	66.17942	11.89499
	2.968148	11.47259	58.68021	11.57495
	2.861284	11.04513	45.41134	11.11226
	2.784652	10.75860	38.06557	10.93238
	3.425638	13.30255	166.5399	13.28684
	3.299294	12.79717	124.5015	12.83619
	3.117309	12.06923	81.88211	12.01070
	3.198977	12.39591	98.82295	12.43969
	3.350025	13.00010	139.9281	13.14843
	3.197067	12.38827	98.38926	12.44637
	3.464574	13.45829	182.1604	13.49719
	3.583316	13.94126	240.5469	13.79860
	3.672655	14.29062	294.1274	14.21055
	2.792820	10.77128	38.78824	10.67078
	2.686991	10.34796	30.39986	10.21758
	2.571670	9.904683	23.31046	9.890253
	2.399208	9.196832	15.67069	10.26016
	2.862174	11.04869	45.50450	10.98114
	2.974216	11.49686	58.89747	11.37345
	3.022712	11.69085	65.85558	12.03333
	3.107936	12.03174	80.13585	11.98297

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000252'	3.894275	15.17710	489.9545	15.19085
	3.812921	14.85168	406.2572	14.96172
	3.754074	14.61630	354.7776	14.68519
	3.651149	14.20459	279.9173	14.18100
	3.568783	13.87513	231.5600	13.92824
	3.468953	13.47561	183.9641	13.48601
	3.373504	13.09401	147.7015	12.59775
	3.206076	12.42430	100.4515	12.34895
	3.115229	12.06091	81.49089	12.17776
	2.986873	11.54749	60.63924	12.27394
	3.423113	13.29245	165.5745	13.42475
	3.299242	12.79696	124.4865	12.89579
	3.354116	13.01646	141.2527	13.11359
	3.202675	12.41070	99.66797	12.39000
	3.114907	12.05963	81.43064	12.13191

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000255	3.863222	15.05289	456.1447	15.11204
	3.807632	14.83053	401.3405	14.88555
	3.752498	14.60999	353.4912	14.62542
	3.687122	14.34848	304.0900	14.35674
	3.608088	14.03235	253.4947	14.04971
	3.521228	13.68491	207.5430	13.83905
	3.422200	13.28880	165.2268	13.21136
	3.264596	12.65838	114.9413	12.99396
	3.134553	12.14621	85.59211	12.08045
	2.915400	11.26160	51.43763	11.16769
	3.391836	13.16733	154.0685	13.39224
	3.264545	12.65818	114.9278	12.96620
	3.326127	12.90450	132.4363	12.98312
	3.175080	12.30032	93.53209	12.25559
	3.082806	11.93122	75.62873	12.12545
	2.999954	11.59981	62.49347	11.68305
	2.927298	11.30919	52.86625	11.27254
	2.863728	11.05491	45.66758	11.02099
	2.754206	10.61682	35.48841	10.56589
	2.679079	10.31631	29.85105	10.29314
	2.609985	10.03994	25.46042	10.25008
	2.538381	9.753525	21.59043	10.11382
	3.013212	11.65285	64.43070	11.84863
	2.936332	11.34532	53.97745	11.51029
	2.869596	11.07838	46.28882	11.37445
	2.765531	10.66212	36.42600	10.73728
	2.688073	10.35229	30.47571	10.41644
	2.538459	9.753837	21.59431	9.939724
	2.472182	9.488728	18.53796	9.723701
	2.317595	8.870382	12.98600	10.80299
	2.246787	8.587149	11.03233	10.18938
	2.184637	8.338551	9.561320	9.180304
	2.036884	7.747536	6.803996	6.645777
	1.888136	7.152547	4.830774	4.734096
	1.670451	6.281805	2.926384	3.113977

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000255	2.971981	11.48792	58.59510	11.48367
	2.911149	11.24459	50.93651	11.32788
	2.807958	10.83183	40.16415	10.77921
	2.743561	10.57424	34.62910	10.46602
	2.628886	10.11554	26.59297	10.12852
	2.529630	9.718523	21.15976	9.782427
	2.448892	9.395568	17.57001	9.832460
	2.333099	8.932398	13.45797	10.67395

	2.237487	8.549951	10.79861	9.924609
	2.047491	7.790766	6.975439	6.351272
	2.139171	8.156487	8.610947	8.280677
	1.935230	7.341033	5.384414	5.465851
	1.775539	6.702187	5.727515	5.778943
	1.572572	5.890288	2.333888	2.334280

Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000258	3.867492	15.06996	460.6513	15.06582
	3.803425	14.81450	397.6541	14.83469
	3.725789	14.50515	332.4065	14.61462
	3.657283	14.22913	283.8988	14.23996
	3.555999	13.82399	224.0430	13.88987
	3.458394	13.43357	179.5869	13.52564
	3.337851	12.95140	134.0601	12.75187
	3.215675	12.46270	102.6964	12.38942
	3.138950	12.15580	84.06584	12.09554
	3.398734	13.19493	156.5361	13.27064
	3.305027	12.82010	126.1557	12.80722
	3.144757	12.17902	87.22420	13.23113
	3.042274	11.76909	68.88980	11.72674
	3.051142	11.80456	70.31084	11.76618
	2.965432	11.46173	57.71817	11.60185
	2.914437	11.25775	51.32367	11.14822
	2.801994	10.80797	39.61631	10.76351
	2.730466	10.52186	33.60059	10.46844
	3.033475	11.73390	67.50810	12.02306
	2.961468	11.44659	57.21742	11.51432
	2.906652	11.22661	50.41185	11.15284
	2.792716	10.77086	38.77899	10.78661
	2.729828	10.51931	33.55124	10.47628
	2.616072	10.06428	25.81975	10.11030
	2.504082	9.616329	19.95089	9.812277
	2.422524	9.290098	16.53501	9.881748
	2.296924	8.787696	12.38237	10.82632
	2.223800	8.495200	10.46357	10.40261
	2.140616	8.162464	8.639651	8.089704
	2.066056	7.866225	7.276731	6.946643
	1.966783	7.387134	5.529217	5.554279
	1.730418	6.521673	3.359683	3.660735

Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000261	3.869759	15.07903	463.0621	15.07215
	3.799041	14.79614	393.4787	14.78128
	3.711780	14.44712	321.8551	14.45649

	3.614205	14.05682	257.0903	14.02617
	3.482370	13.52948	189.7798	13.48453
	3.357899	13.03159	142.4883	13.06183
	3.218199	12.47279	103.2951	12.38728
	3.048723	11.79489	69.92037	11.64548
	3.413855	13.25542	162.0821	13.40808
	3.291511	12.76604	122.2901	12.83456
	3.039521	11.75808	68.45442	11.71612
	2.965234	11.46093	57.69184	11.23195
	2.903595	11.21438	50.05825	11.09382
	2.790232	10.76092	38.55781	10.72887
	2.718975	10.47590	32.72315	10.37486
	3.015048	11.66019	64.70365	11.77444
	2.938049	11.35219	56.19129	11.47840
	2.886880	11.14752	48.16819	10.99849
	2.776012	10.70404	37.31574	10.57479
	2.705814	10.42325	31.74641	10.28035
	2.593528	9.974114	24.51368	9.980183
	2.492193	9.568773	19.41214	9.728459
	2.403401	9.213606	15.82274	9.988366
	2.276364	8.705457	11.80985	10.71360
	2.206013	8.424053	10.04369	9.369517
	2.127446	8.109787	8.381598	7.900905
	2.024667	7.698670	6.615269	6.327208
	1.843775	6.975100	4.361694	4.366117
	1.699051	6.396204	3.125584	3.086220

Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000264	3.871015	15.08406	464.4036	15.04557
	3.836219	14.94487	428.6470	14.94225
	3.800152	14.80060	394.4866	14.76015
	3.757476	14.62990	357.5658	14.65580
	3.713402	14.45360	323.0593	14.41885
	3.662424	14.24969	287.2796	14.18784
	3.602245	14.00898	250.1070	13.96846
	3.531598	13.72639	212.5585	13.69665
	3.447552	13.39020	175.1589	13.29691
	3.447252	13.38901	175.0381	13.30609
	3.332163	12.92865	134.2899	13.00771
	3.305466	12.82186	126.2835	12.91024
	3.182558	12.33023	95.15649	12.23812
	3.139599	12.15839	86.19450	12.15951
	3.400431	13.20172	157.1490	13.33871
	3.289876	12.75950	121.8305	12.42626
	3.173928	12.29571	93.28439	12.48372
	3.030027	11.72011	66.97426	11.71655
	2.950539	11.40215	55.77242	11.41894

	2.897556	11.16622	48.68965	11.05104
	2.778401	10.71360	37.52164	10.77439
	2.769949	10.43979	32.05014	10.39835
	3.020003	11.68801	65.44410	11.68903
	2.943848	11.38547	55.17381	11.30600
	2.887795	11.15110	48.26985	11.06370
	2.776207	10.70482	37.33252	10.65101
	2.707610	10.43044	31.87798	10.42155
	2.597029	9.988118	24.71209	9.980269
	2.492479	9.569918	19.42493	9.741676
	2.385840	9.143341	15.19548	10.37668
	2.273372	8.693489	11.72876	10.86272
	2.203563	8.414252	9.987188	9.570627
	2.104826	8.019384	7.956207	7.891348
	2.029752	7.719010	6.693181	6.720747
	1.912100	7.248401	5.104819	5.124193
	1.687676	6.350705	3.044782	3.150076

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000267	3.857383	15.02953	450.0532	15.07660
	3.815086	14.86034	408.2881	14.95695
	3.763533	14.65413	362.5881	14.65887
	3.707684	14.43073	318.8338	14.54238
	3.638139	14.15255	271.6564	14.15387
	3.542862	13.85144	228.4241	13.86220
	3.560615	13.84246	227.2454	13.93410
	3.431551	13.32620	168.8230	13.39721
	3.345440	12.98256	138.5226	13.06217
	3.236669	12.54667	107.7828	12.59064
	3.165591	12.26256	91.51064	12.35789
	3.078102	11.91240	74.81391	12.09271
	3.387318	13.14927	152.4750	13.35026
	3.321446	12.88579	131.0173	12.94728
	3.234710	12.53884	107.2978	12.64755
	3.162934	12.25173	90.95246	12.43374
	3.091687	11.96475	77.19115	11.72030
	3.010396	11.64158	64.01426	11.71297
	2.933247	11.35298	53.59538	11.31578
	2.874028	11.09611	46.76341	11.06713
	2.872621	11.09048	46.61262	11.03806
	2.766172	10.66468	36.47979	10.57508
	2.690770	10.36308	30.66551	10.34049
	2.585636	9.942546	24.07224	9.892964
	2.487640	9.550562	19.20970	9.738615
	2.384795	9.139181	15.15917	10.44907
	2.274991	8.699964	11.77256	10.84614
	2.195269	8.393079	9.866196	9.632115

	2.155547	8.222190	8.941854	8.872952
	2.073454	7.894625	7.405192	7.378641
	1.982820	7.531280	6.007588	5.948860
	1.787038	6.748154	3.827529	3.826207

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000270	3.880137	15.12055	474.2612	15.17133
	3.830708	14.92283	423.2417	15.01680
	3.774809	14.69923	372.1252	14.82377
	3.712137	14.44855	322.1198	14.51902
	3.646681	14.18472	277.0521	14.28376
	3.557542	13.83017	225.6433	13.81786
	3.460237	13.44095	180.3506	13.29849
	3.347984	12.99194	139.2728	12.91561
	3.233149	12.53259	106.9128	12.55823
	3.109529	12.03811	80.42048	11.92807
	3.407004	13.22801	159.5453	13.52940
	3.341308	12.96523	137.1475	13.11575
	3.257571	12.63028	113.0970	12.72390
	3.152757	12.21103	88.84602	12.14772
	3.070198	11.88079	73.46459	11.88905
	2.992882	11.57153	61.48408	11.46887
	2.928214	11.31285	52.97781	11.43449
	2.821119	10.88447	41.39994	10.89390
	2.821822	10.89729	41.46700	10.82071
	2.751820	10.60728	35.29395	10.50670
	2.643838	10.17535	27.52442	10.10224
	2.543356	9.775425	21.83918	9.870354
	2.473228	9.492915	18.58270	9.716861
	2.331757	8.927030	13.41644	11.03822
	2.250226	8.600907	11.12005	10.55460
	2.190530	8.362120	9.691928	9.406834
	2.124582	8.098328	8.326492	8.225170
	2.061183	7.844733	7.195538	7.107829
	1.950901	7.403604	5.581889	5.569239
	1.804316	6.817266	3.982875	3.976200

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000272	3.886644	15.14657	481.4206	15.08120
	3.820731	14.88292	413.6294	14.91997
	3.744261	14.65704	363.1964	14.65954
	3.706542	14.42616	317.9963	14.46008
	3.600251	14.00100	248.9609	14.09515
	3.493240	13.57296	194.5899	13.68080
	3.371887	13.08754	147.1523	13.15715
	3.233089	12.53235	106.8981	12.45179

	3.151950	12.20780	88.[illegible]8088	12.28064
	3.416185	13.26474	162.9540	13.33634
	3.348991	12.99436	139.4670	12.98521
	3.343126	12.97280	137.7231	13.14964
	3.259451	12.63780	113.5876	12.73497
	3.149824	12.19729	88.24802	12.31309
	3.040383	11.76153	68.39037	11.85914
	2.956325	11.42630	56.52037	11.53037
	2.912500	11.23690	51.09528	10.96219
	2.783837	10.75535	37.99422	11.02069
	3.030554	11.72221	67.05557	11.64142
	2.952921	11.41168	54.07913	11.28467
	2.894137	11.17455	48.97984	11.12582
	2.787068	10.75155	38.35027	10.81281
	2.728492	10.51477	33.46359	10.27114
	2.662359	10.24943	28.72361	10.36902
	2.614157	10.05643	25.79618	9.889297
	2.518135	9.672542	20.60703	9.711575
	2.422774	9.291096	16.54451	10.02223
	2.294830	8.779522	12.32283	11.13263
	2.216197	8.464789	10.28199	9.916892
	2.163634	8.254539	9.109925	8.908205
	2.103198	8.012792	7.926440	7.861558
	1.989586	7.558323	6.191842	6.128424
	1.824497	6.897989	6.172318	6.177335

Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000276			
3.900127	15.20051	496.6014	16.95375
3.834358	14.93743	426.8141	14.78898
3.767537	14.67015	365.9466	14.56312
3.686672	14.34669	303.7755	14.26009
3.600924	14.00369	249.3473	13.89825
3.490299	13.56119	193.2769	13.44764
3.360509	13.04203	145.3472	12.95116
3.204627	12.41851	100.1169	12.36229
3.119953	12.07981	82.38214	12.01887
3.423381	13.29352	165.6769	13.41645
3.323836	12.89534	131.7397	13.12315
3.294498	12.41799	100.0871	12.33812
3.119584	12.07833	82.31226	12.00197
3.057590	11.83036	71.36257	11.77988
2.975518	11.50207	59.07425	11.49705
2.921071	11.28428	52.11364	11.25747
2.810780	10.84312	40.42593	10.76459
2.639127	10.12051	26.66905	10.12357
3.059295	11.80118	70.17381	11.72053

	2.972659	11.49063	58.68661	11.38576
	2.915519	11.26127	51.42793	11.12111
	2.804443	10.81777	39.84042	10.72377
	2.628840	10.11536	26.59014	10.09174
	2.524141	9.696565	20.89398	9.771773
	2.339481	8.957925	13.65719	10.79996
	2.235127	8.540510	10.74008	10.16891
	2.163684	8.254736	9.110962	8.830356
	2.090475	7.961900	7.697595	7.508274
	1.884883	7.139533	4.794721	4.751990
	1.784390	6.737561	3.804261	3.789528

Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000279			
3.880471	15.12188	474.6254	15.22825
3.824782	14.89915	417.5062	15.00341
3.749935	14.59974	351.4114	14.74016
3.672033	14.28813	293.7065	14.35503
3.569471	13.87788	231.9270	14.02368
3.454120	13.41648	177.8281	13.54812
3.370539	13.08215	146.6963	13.13864
3.241295	12.56518	108.9369	13.26953
3.196507	12.38602	98.26242	12.25920
3.407229	13.22891	159.6282	13.46150
3.341747	12.96699	137.2865	13.04349
3.263483	12.65393	114.6473	12.49532
3.132630	12.13052	84.82241	12.66667
3.029137	11.71654	66.83704	11.72866
2.954705	11.41882	56.31001	11.23528
2.882651	11.13060	47.70143	11.30644
2.780552	10.72221	37.70794	10.70931
2.709908	10.43963	32.04708	10.48768
3.022880	11.69152	65.88109	11.62716
2.947134	11.38853	55.33680	11.19589
2.783863	10.73545	37.99651	10.50340
2.604573	10.02549	25.24951	9.992138
2.514983	9.659933	20.45800	9.756553
2.421072	9.284290	16.47982	10.10544
2.304740	8.818963	12.60726	10.88983
2.219582	8.478330	10.36245	9.751364
2.143229	8.172918	8.691799	8.148378
2.075086	7.900347	7.429624	7.121120
1.928098	7.312395	5.296375	5.246925
1.667564	6.270257	2.906996	2.881476

Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000282			
3.857736	15.03094	450.4187	15.13249

	3.816520	14.86408	409.6382	14.97507
	3.780090	14.72036	376.6778	14.77752
	3.739632	14.58863	343.1724	14.56517
	3.692206	14.34682	307.6708	14 39972
	3.638968	14.18887	272.1749	14.19078
	3.578911	13.91544	237.0234	13.89896
	3.488879	13.55381	192.6459	13.56262
	3.417830	13.27182	163.5725	13.19529
	3.326955	12.90782	132.6891	12.84197
	3.209467	12.43784	101.2388	12.34301
	3.109578	12.03831	80.43740	11.29814
	3.391240	13.16496	153.8581	13.29008
	3.291295	12.76817	122.2287	13.01159
	3.172818	12.29127	95.04699	12.20893
	3.032993	11.73197	67.43311	11.43109
	2.950787	11.40314	55.80424	11.42765
	2.897175	11.18870	49.32370	11.02400
	2.784349	10.73739	38.03901	10.76455
	2.716912	10.46765	32.56810	10.50015
	2.664113	10.25445	28.83987	10.26379
	3.016992	11.66796	64.99386	11.77095
	2.944765	11.37906	55.03581	11.31363
	2.888749	11.15507	48.37819	11.07349
	2.784182	10.75472	38.02440	10.56069
	2.663418	10.26247	28.96001	10.19741
	2.604589	10.01835	25.14602	9.949427
	2.502197	9.668788	19.86498	9.692444
	2.436902	9.339211	17.00915	9.8.5826
	2.290616	8.762445	12.20583	11.11161
	2.216428	8.465712	10.28746	9.781186
	2.155155	8.220612	8.933736	8.698814
	2.001963	7.607855	6.278327	6.181479
	1.773843	6.695374	3.712989	3.644538

Data	PK	L	Data
Log(Re/f)	1//f	1//f	1//f
S0000285	3.860921	15.04368	453.7347	14.95428
	3.797796	14.79118	592.3527	14.69974
	3.721154	14.48461	328.8776	14.44213
	3.649727	14.19891	279.0022	14.18654
	3.562367	13.84947	228.1644	13.87798
	3.431859	13.32743	168.9425	13.38773
	3.322741	12.89176	131.4683	12.90286
	3.167301	12.26920	91.87171	12.30933
	3.027750	11.71100	66.62391	11.88185
	3.386776	13.14710	152.2847	13.36695
	3.321815	12.88726	131.1279	12.93637
	3.263219	12.41287	99.79284	12.46549

	2.992388	11.56955	61.41419	11.67501
	2.916966	11.26786	51.62343	11.32726
	2.855669	11.02243	44.82178	11.12088
	2.751267	10.60507	35.24908	10.58541
	2.679173	10.31669	29.85753	10.37890
	2.972230	11.48892	58.62871	11.48161
	2.901395	11.20558	49.80532	11.47590
	2.789713	10.75885	38.51181	10.76635
	2.678737	10.31495	29.82755	10.31822
	2.563278	9.853115	22.86435	9.987877
	2.457495	9.429902	17.92155	9.875868
	2.322860	8.891443	13.14440	11.12368
	2.432 73	9.331093	16.92985	9.846596
	2.291541	8.766165	12.22985	11.20011
	2.214873	8.459693	10.25069	9.828635
	2.142431	8.169725	8.675838	8.591703
	2.050139	7.800557	7.014867	6.964791
	1.925160	7.301442	5.263087	5.279104
	1.75 .27	6.603309	3.521335	3.543490

Data	PK	L	Data
Log(Re/f)	1//f	1//f	1//f
S0000288	3.862135	15.04854	455.0043	15.14992
	3.814717	14.85687	407.9413	14.92632
	3.758967	14.63587	358.7961	14.72939
	3.685641	14.34256	303.0547	14.40579
	3.722277	14.48911	329.7293	14.49076
	3.651161	14.20464	279.9246	14.37388
	3.557249	13.82899	225.4911	13.94042
	3.428000	13.31200	167.4681	13.51629
	3.361182	13.04473	143.5697	13.13692
	3.203618	12.41447	99.88452	12.58830
	3.122636	12.09054	82.89270	12.13498
	3.426768	13.30707	166.9738	13.52414
	3.357781	13.03112	142.4496	13.21038
	3.275062	12.70024	117.7449	12.78570
	3.202503	12.41001	99.62839	12.59222
	3.037514	11.75005	68.13883	11.86921
	2.952398	11.40959	56.01163	11.71499
	2.910726	11.24290	50.68692	11.01895
	3.020001	11.68000	65.44580	11.86675
	2.950037	11.40014	55.70798	11.37620
	2.891412	11.16564	48.67344	11.09871
	2.785284	10.74113	38.12098	10.60462
	2.598847	9.995388	24.81373	10.05652
	2.515281	9.661127	20.47267	9.780288
	2.433197	9.332789	16.94639	9.876030
	2.317626	8.870504	12.98691	10.94166

	2.228790	8.515162	10.58450	10.14526
	2.163484	8.174738	8.700908	8.619564
	2.059052	7.834211	7.160328	7.010824
	1.884680	7.138601	4.792149	4.766697
	1.696507	6.386050	3.107332	3.194515
	3.420475	13.31390	167.6314	13.41044
	3.333797	12.93819	134.7962	12.97108
	3.202337	12.40935	99.59049	12.54030
	3.113799	12.05483	81.20633	12.30342
	3.081193	11.93677	76.74914	12.01151
	3.000046	11.63218	63.66874	11.71155
	2.950420	11.40249	55.78337	11.47353
	2.844811	10.97924	43.72115	10.95672
	2.779026	10.71619	37.57561	10.68996
	2.657548	10.23019	28.40721	10.31872

Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000293	3.874255	15.09702	467.8813	15.20572
	3.810144	14.84064	403.6890	14.98009
	3.753069	14.61227	353.9560	14.73990
	3.686252	14.34493	303.4678	14.45707
	3.576944	13.90777	235.9527	14.07098
	3.502504	13.61001	198.7854	13.71938
	3.390350	13.16140	153.5431	13.12834
	3.290489	12.76195	122.0027	12.63470
	3.180274	12.35309	96.41728	12.29805
	3.496108	13.22443	159.2166	13.40526
	3.503615	12.81446	125.7462	13.20152
	3.187977	12.35191	96.35129	12.30648
	3.012081	11.64832	64.26305	11.75564
	2.924044	11.29625	52.47398	11.43464
	2.853667	11.01464	44.62180	11.24945
	2.750043	10.60017	35.16985	10.64398
	3.056122	11.82449	71.12177	11.76297
	2.977257	11.50902	59.31130	11.38504
	2.923671	11.29388	52.40245	11.43460
	2.788868	10.75547	38.43694	10.74911
	2.741228	10.56491	34.44362	10.68215
	2.724420	10.49768	33.13602	10.38589
	2.675689	10.30275	29.61893	10.19116
	2.615472	10.06188	25.78411	10.04200
	2.520439	9.681756	20.71642	9.841888
	2.449711	9.398844	17.60317	9.860419
	2.317443	8.869775	12.98147	10.94971
	2.231427	8.525709	10.64896	10.13134
	2.195885	8.383543	9.812187	9.444378

	2.148325	8.193303	8.794394	8.513749
	2.084458	7.945834	7.626732	7.464950
	1.984568	7.558275	6.031825	5.975641
	1.816070	6.864283	4.092143	4.077883

Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000298	3.882505	15.13002	476.8544	15.12291
	3.809232	14.83693	402.8216	14.91857
	3.722242	14.48897	329.7029	14.58166
	3.609882	14.03953	254.5440	14.16538
	3.455480	13.42192	178.3857	13.47534
	3.344371	12.97748	138.1184	13.05297
	3.879461	15.11784	473.5250	15.22930
	3.812470	14.84988	405.8360	14.80776
	3.722498	14.48999	329.8968	14.57309
	3.610181	14.04072	254.7190	14.15565
	3.457541	13.43016	179.2344	13.41153
	3.342304	12.96921	137.4624	13.11526
	3.918544	15.27417	518.1129	15.19874
	3.846101	14.98440	438.5119	14.96475
	3.760189	14.64075	359.8072	14.59053
	3.647544	14.19017	277.6031	14.18331
	3.492284	13.56913	196.1620	13.51906
	3.378866	13.11546	149.5361	13.16515
	3.913879	15.25551	512.5778	15.36287
	3.843225	14.97290	435.6176	15.06418
	3.759174	14.63669	358.9668	14.62469
	3.647157	14.18862	277.3558	14.19596
	3.490643	13.56257	195.4300	13.57022
	3.376755	13.10702	148.8110	13.22930

Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000300	3.874568	15.09827	468.2186	15.29795
	3.875312	15.10124	469.0212	15.20302
	3.819287	14.87714	412.2561	15.05798
	3.756616	14.62646	356.0589	14.71928
	3.667440	14.24976	290.6149	14.37731
	3.553156	13.81262	223.3759	13.89529
	3.470789	13.48315	184.7860	13.56690
	3.878439	15.11375	472.4105	15.16220
	3.798298	14.79319	392.8064	14.89187
	3.739119	14.55647	342.7671	14.62786
	3.650507	14.20203	279.5038	14.09473
	3.558708	13.83483	226.2498	13.71879

	3.455393	15.42157	178.3500	15.38713
	3.876906	15.10762	470.7442	15.21581
	3.814435	14.88774	407.6759	14.93433
	3.739435	14.63774	339.1831	14.62404
	3.691123	14.36449	306.9049	14.39224
	3.594973	13.97989	265.9538	14.07586
	3.488682	13.58472	192.5582	13.63927
	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
B0000302	3.871632	15.08652	465.0434	15.16041
	3.828673	14.91469	421.2634	15.06302
	3.782001	14.73120	379.0372	14.89098
	3.731916	14.52764	337.1290	14.63947
	3.660057	14.24022	285.7174	14.39472
	3.588288	13.95315	242.1944	14.07026
	3.482264	13.52905	189.7335	13.62545
	3.361127	13.04451	143.5514	13.09738
	3.280343	12.72137	119.1854	12.81717
	3.185982	12.34393	95.90980	12.25206
	3.401141	13.20456	157.4060	13.43764
	3.331086	12.92434	133.9571	13.15823
	3.182667	12.33067	95.18042	12.34595
	3.249823	12.59929	111.0971	12.69259
	3.092016	11.96804	77.24963	12.16930
	3.041942	11.76776	68.83703	11.88010
	2.966514	11.46605	57.86210	11.46260
	2.901964	11.20784	49.87086	11.36441
	2.794178	10.77671	38.90978	10.86273
	2.723386	10.49354	33.05727	10.60600
	2.996895	11.58758	62.05477	11.38484
	2.936884	11.34753	54.04611	11.13654
	2.819545	10.87818	41.25019	10.75936
	2.736174	10.54470	34.04524	10.43627
	2.679449	10.31859	29.89019	10.25624
	2.617851	10.07140	25.92575	10.15266
	2.523270	9.693082	20.85214	9.853512
	2.453928	9.415713	17.77495	9.949136
	2.317485	8.869940	12.98270	11.22109
	2.248194	8.592776	11.06812	10.06543
	2.174634	8.298544	9.343640	8.619886
	2.111668	8.046673	8.082549	7.571628
	1.987906	7.551625	6.078360	5.901861
	1.806763	6.826974	4.005195	3.911635
	1.625624	6.102496	2.639393	2.630566
	2.960857	11.49343	57.11335	11.42569
	2.903978	11.21591	50.10239	11.32549

	2.804171	10.81448	39.81548	10.70702
	2.735447	10.54267	34.00537	10.48881
	2.684121	10.33448	30.19742	10.28494
	2.624122	10.09448	26.30282	10.12581
	2.526556	9.706225	21.01050	9.879132
	2.459170	9.456680	17.99078	9.788134
	2.329746	8.958984	13.35445	10.84655
	2.260196	8.560784	10.86615	10.30361
	2.165638	8.262555	9.152061	9.053807
	2.084645	7.938582	7.594962	7.546790
	2.003367	7.613471	6.298657	6.228196
	1.899078	7.192312	4.942630	4.932255
	1.745717	6.582869	3.480145	3.511805
	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
B0000305	3.869922	15.07969	463.2365	15.18591
	3.819938	14.87975	412.8750	15.05046
	3.766529	14.66611	365.0983	14.77204
	3.711981	14.44792	322.0042	14.56434
	3.647343	14.18937	277.4745	14.36641
	3.574409	13.89763	234.5791	13.99662
	3.481477	13.52591	189.3902	13.61939
	3.360857	13.04343	143.4625	13.07599
	3.181731	12.32692	94.97543	12.34472
	3.402664	13.21065	157.9588	13.33034
	3.307652	12.83040	126.9206	12.90352
	3.174295	12.29718	93.36911	12.52960
	3.096843	11.98737	78.11296	11.98065
	3.029382	11.71752	66.87473	11.77190
	2.950472	11.40189	55.76386	11.48174
	2.884273	11.13709	47.87982	11.31733
	2.777451	10.70980	37.43959	10.81201
	2.707566	10.43026	31.87469	10.53039
	3.016902	11.66760	64.98034	11.78071
	2.937630	11.35052	54.13903	11.52222
	2.888763	11.15505	48.37754	10.98372
	2.776275	10.70510	37.33838	10.60823
	2.709061	10.43624	31.98463	10.48577
	2.596203	9.984814	24.66514	10.12679
	2.498854	9.595416	19.71215	9.811742
	2.407941	9.231766	15.98901	10.29888
	2.283790	8.735160	12.01351	11.05858
	2.208450	8.433800	10.10020	9.646241
	2.138486	8.153946	8.597389	8.551855
	2.020342	7.681371	6.549722	6.612358
	1.924436	7.297744	5.251895	5.254399
	1.685190	6.340763	3.027406	3.082498

Page 21 Solvent Set 1: Runs 80000234 - 80000339

	Data Log(Re/f)	PK 1/f	L 1/f	Data 1/f
80000308	3.868483	15.07473	461.9163	15.19500
	3.813294	14.88317	406.6070	14.96033
	3.748237	14.89294	350.0395	14.70445
	3.690751	14.56380	306.6418	14.49656
	3.611848	14.04747	255.7106	14.18161
	3.492923	13.57169	194.4481	13.83683
	3.381971	13.12788	150.6692	13.20413
	3.183483	12.33393	98.35942	12.26730
	3.400898	13.20359	157.3181	13.35446
	3.332715	12.93084	134.4607	13.02053
	3.238682	12.60273	111.3172	12.58205
	3.182710	12.33084	95.10798	12.26146
	3.041018	11.76407	68.69074	11.87413
	3.042949	11.77179	68.99689	11.98190
	2.969406	11.47762	58.24874	11.48628
	2.910914	11.24345	50.90895	11.17097
	2.800047	10.80018	39.43912	10.82213
	2.730513	10.52205	33.60421	10.54546
	2.620337	10.08135	26.07462	10.17532
	2.965252	11.46100	57.69422	11.40613
	2.900298	11.20119	49.67962	11.30034
	2.800078	10.80029	39.44161	10.71177
	2.728014	10.51205	33.41141	10.52091
	2.621316	10.08526	26.13340	10.11712
	2.527029	9.708117	21.03339	9.821632
	2.454471	9.417885	17.79718	9.794526
	2.319140	8.876562	13.03229	10.97587
	2.228362	8.513451	10.57409	10.12873
	2.150925	8.203703	8.847200	8.701123
	2.063902	7.855611	7.240738	7.169281
	1.968404	7.474417	5.814123	5.848440
	1.728544	6.514259	3.345375	3.335036

	Data Log(Re/f)	PK 1/f	L 1/f	Data 1/f
80000311	3.872814	15.09125	466.3316	15.01721
	3.808769	14.83507	402.3917	14.79292
	3.741520	14.56408	344.6677	14.56132
	3.674057	14.29622	295.0783	14.23961
	3.575570	13.90228	235.2068	13.89444
	3.465775	13.46310	182.6451	13.41827
	3.359724	13.03889	143.0885	13.05113
	3.175942	12.30377	93.71793	12.45404
	3.399929	13.19971	156.9673	13.38431
	3.304816	12.81926	126.0946	12.95878

Page 22 Solvent Set 1: Runs 80000234 - 80000339

	3.181822	12.32728	94.99533	12.28657
	3.065422	11.78168	69.39083	11.77413
	3.038689	11.75475	68.32343	11.84355
	2.961278	11.44519	57.17130	11.50641
	2.904213	11.21685	50.12955	11.19362
	2.789720	10.75888	38.51237	10.98321
	2.720727	10.48291	32.85546	10.70315
	3.024170	11.69668	66.07703	11.91050
	2.958276	11.43310	56.77492	11.36733
	2.899287	11.19715	49.56418	11.27067
	2.784255	10.74502	38.20634	10.79607
	2.726709	10.50683	33.31111	10.51452
	2.614807	10.05923	25.74469	10.22650
	2.519854	9.679419	20.68878	9.959451
	2.437726	9.350907	17.12406	10.00889
	2.307525	8.850100	12.68834	11.22265
	2.218557	8.474228	10.33801	10.34909
	2.139546	8.158187	8.618404	8.765612
	2.012131	7.648525	6.427045	6.560478
	1.829436	6.917744	4.220035	4.294127
	1.657041	6.228167	2.837408	2.823847

	Data Log(Re/f)	PK 1/f	L 1/f	Data 1/f
80000314	3.851583	15.00633	444.0828	15.14204
	3.780163	14.72073	376.7584	14.87319
	3.693415	14.37366	308.5285	14.52987
	3.582810	13.93124	239.1610	14.05814
	3.428400	13.31360	167.6025	13.37354
	3.319832	12.87932	130.5306	12.87882
	3.166267	12.26506	91.65713	12.22784
	3.094807	11.97922	77.74761	11.53188
	3.383789	13.13515	151.2408	13.30824
	3.277748	12.71099	118.4755	13.21346
	3.165489	12.26195	91.48911	12.22216
	3.085159	11.94063	76.03946	11.76436
	2.991572	11.56628	61.29883	11.61688
	2.933432	11.33373	53.61824	11.45936
	2.883150	11.13260	47.75632	11.31973
	2.786660	10.74664	38.24199	11.07881
	2.661404	10.24561	28.66052	10.14690
	2.686757	10.34703	30.38348	10.85431
	2.997371	11.58948	62.12285	11.54445
	2.954161	11.41664	56.23951	11.24007
	2.845268	10.98107	43.76715	10.84928
	2.774228	10.69691	37.16283	10.56965
	2.665997	10.26399	28.96528	10.21067
	2.573048	9.892194	23.38452	9.801933

	2.507923	9.631695	20.12814	9.752011
	2.388990	9.153962	15.30631	10.42761
	2.265469	8.661877	11.81726	10.65475
	2.201800	8.407283	9.966746	9.421666
	2.134990	8.139963	8.528467	8.296954
	2.051189	7.804787	7.031846	6.851037
	1.956782	7.427129	5.697993	5.540003
	1.843424	6.973707	4.338196	4.325584
	1.629885	6.119543	2.663421	2.654374

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000317	3.873945	15.09586	467.5684	15.04522
	3.800705	14.80282	394.9890	14.84149
	3.715279	14.46111	324.4586	14.45417
	3.603617	14.01447	250.8994	14.01896
	3.502002	13.60801	198.5559	13.58118
	3.403924	13.21569	158.4180	13.32172
	3.335107	12.94042	135.2032	13.00758
	3.180758	12.32303	94.76284	12.37241
	3.087632	11.95053	76.47385	12.26505
	3.402069	13.20827	157.7426	13.37876
	3.338477	12.95390	136.2564	12.90704
	3.183971	12.33588	95.46654	12.28121
	3.028143	11.71257	66.68433	11.86301
	2.954569	11.41747	56.26639	11.44904
	2.905260	11.22104	50.25054	11.09124
	2.789263	10.75705	38.47187	10.80701
	2.721800	10.48720	32.93672	10.50395
	2.952582	11.41033	56.03542	11.35295
	2.894058	11.17623	48.97090	11.15482
	2.791759	10.76703	38.69366	10.73526
	2.726959	10.50783	33.33032	10.36224
	2.607803	10.03121	25.33280	10.21567
	2.505907	9.623631	20.03493	9.959472
	2.425053	9.300214	16.63158	10.18703
	2.310326	8.841304	12.77044	10.96121
	2.225689	8.502757	10.50919	10.11613
	2.140525	8.161302	8.633872	8.528995
	2.048174	7.792697	6.983197	6.979213
	1.975406	7.493626	5.878771	5.893607
	1.834029	6.934119	4.264909	4.235076
	1.654025	6.216103	2.817772	2.830000

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000320	3.885177	15.14070	479.7969	15.03016
	3.828371	14.91548	420.9708	14.84640

	3.752563	14.61025	353.5438	14.61824
	3.673517	14.29406	294.7115	14.27384
	3.613283	14.05313	256.5449	14.05490
	3.527907	13.71162	210.7595	13.68655
	3.412722	13.25089	161.6600	13.38257
	3.346662	12.98644	138.8489	12.98430
	3.191181	12.36472	97.06468	12.38251
	3.414668	13.25867	162.3859	13.32275
	3.315017	12.86007	129.0915	13.03467
	3.192308	12.36923	97.31687	12.35042
	3.111650	12.04660	80.82219	11.89677
	3.036748	11.74707	68.02189	11.78430
	2.955766	11.42306	56.44775	11.52318
	2.898273	11.19309	49.44853	11.21165
	2.789476	10.75790	38.49076	10.82922
	3.028122	11.71249	66.68110	11.73114
	2.954117	11.41647	56.25385	11.35711
	2.895843	11.18337	49.17266	11.20618
	2.788993	10.75597	38.44802	10.76509
	2.725370	10.50148	33.20862	10.43380
	2.612845	10.05138	25.62862	10.07958
	2.523210	9.692841	20.84924	9.856482
	2.439690	9.358761	17.20166	9.945390
	2.304718	8.818874	12.60662	11.20046
	2.224903	8.499613	10.49018	10.19448
	2.150729	8.202918	8.843203	8.696066
	2.077195	7.908782	7.465786	7.487815
	1.952730	7.410923	5.605455	5.651552
	1.803935	6.815741	3.979379	4.047597
	1.654569	6.218276	2.821298	2.807111

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
S0000323	3.858942	15.03576	451.6708	15.05654
	3.780796	14.72318	377.2914	14.72025
	3.701539	14.40615	314.3543	14.42276
	3.576649	13.90659	235.7923	13.94005
	3.430479	13.32191	168.4067	13.46066
	3.327837	12.91135	132.9589	12.78707
	3.170649	12.28259	92.58271	12.24258
	3.081345	11.92538	75.37466	12.02986
	3.391783	13.16715	154.0505	13.24758
	3.294118	12.77647	123.0265	12.89809
	3.171644	12.28657	92.79489	12.21439
	3.086479	11.94591	2.27096	11.88849
	3.395193	13.18077	155.2648	13.05137
	3.289079	12.75621	121.6071	12.96061
	3.168192	12.27277	92.06036	12.22880

	3.076308	11.90523	74.50560	12.08809
	3.022665	11.69044	68.84846	11.80802
	2.944079	11.37631	54.94894	11.46296
	2.889296	11.18718	48.43694	11.15327
	2.751914	10.66768	38.30163	10.61989
	2.661308	10.29683	28.66743	10.31830
	2.585222	9.620880	20.06332	9.760795
	3.013030	11.65212	64.40370	11.70516
	2.942596	11.36980	54.73643	11.31407
	2.888870	11.15229	48.30038	11.06111
	2.781537	10.72614	37.79352	10.69464
	2.713429	10.45371	32.30798	10.38768
	2.608329	10.03331	25.36352	9.966452
	2.517952	9.671810	20.59835	9.714535
	2.304167	8.816669	12.59062	10.90810
	2.232865	8.531462	10.68428	9.967624
	2.151680	8.206722	8.862591	8.641097
	2.088213	7.952852	7.657606	7.626190
	2.015909	7.663639	6.483205	6.426877
	1.926228	7.304913	5.273614	5.233787
	1.800406	6.801627	3.947180	3.936705
	1.672786	6.291146	2.942162	2.951649

Data Log(Re/f)	PK 1/f		L 1/f		Data 1/f
S0000326	3.844274	14.97709	436.6712	15.02160	
	3.780859	14.72343	377.3458	14.77577	
	3.705339	14.42135	317.1148	14.47937	
	3.634084	14.13633	269.1316	14.21749	
	3.550075	13.80030	221.7970	13.80136	
	3.423648	13.29667	165.7861	13.18868	
	3.310998	12.84399	127.9024	12.82130	
	3.159733	12.23893	90.28454	12.10894	
	3.378184	13.11274	149.3021	13.18032	
	3.276961	12.70784	118.2611	12.94213	
	3.152599	12.21039	88.81362	12.30949	
	3.006652	11.62660	63.46468	12.05828	
	2.951909	11.40763	55.94866	11.44061	
	2.872472	11.08989	46.59644	11.16638	
	2.940530	11.36212	54.50178	11.36465	
	2.876708	11.10683	47.05314	11.30140	
	2.774377	10.69750	37.17552	10.85281	
	3.026071	11.70428	66.36684	11.75683	
	2.970178	11.48071	58.35241	11.33793	
	2.905890	11.22356	50.32345	11.16229	
	2.789659	10.75855	38.50517	10.65443	
	2.726692	10.50676	33.30983	10.44923	
	2.620990	10.08396	26.11380	10.02656	

	2.519279	9.677118	20.66139	9.750896
	2.457300	9.429200	17.91349	9.706331
	2.330202	8.920810	13.36850	10.77349
	2.236549	8.546196	10.77529	10.20940
	2.154943	8.219773	8.929424	8.605937
	2.040795	7.763181	6.865550	6.798728
	1.933965	7.335843	5.368411	5.531997
	1.780011	6.720047	3.766099	3.704207
	1.656035	6.224141	2.830840	2.846041

Data Log(Re/f)	PK 1/f		L 1/f		Data 1/f
S0000329	3.444039	13.37615	173.7480	13.42903	
	3.333927	12.93570	134.8365	13.45900	
	3.222879	12.49151	104.4141	12.41460	
	3.095985	11.98394	77.95885	11.63924	
	2.995431	11.58172	61.84599	11.61103	
	2.935500	11.34200	53.87419	11.41007	
	2.833589	10.93435	42.60586	10.80383	
	2.759117	10.63646	35.89195	10.68756	
	2.647462	10.18984	27.75506	10.28299	
	3.056794	11.82717	71.23196	11.65854	
	2.982167	11.52867	59.98567	11.50259	
	2.918911	11.27564	51.85512	11.35646	
	2.818550	10.87420	41.15576	10.80405	
	2.651746	10.20698	28.03023	10.08946	
	2.561011	9.864046	22.74530	9.823396	
	2.489687	9.358750	19.30046	9.700457	
	2.374212	9.104849	14.86251	10.39946	
	2.256558	8.626235	11.28536	10.43616	
	2.170890	8.283561	9.263400	8.842129	
	2.071946	7.887786	7.376097	7.166780	
	1.951498	7.405995	5.589576	5.571848	
	1.745762	6.583048	3.480504	3.500396	
	3.913115	15.25246	511.6767	15.04661	
	3.833429	14.93371	425.9016	14.76284	
	3.762220	14.64888	361.4937	14.55346	
	3.676904	14.30761	297.0188	14.25651	
	3.582201	13.92880	238.8258	13.96933	
	3.441935	13.36774	172.9082	13.35796	
	3.347307	12.98922	139.0551	12.91886	
	3.214283	12.45713	102.3677	12.53487	
	3.126812	12.10725	83.69372	12.26536	

Data Log(Re/f)	PK 1/f		L 1/f		Data 1/f
S0000333	3.853769	15.01507	466.3232	14.99821	
	3.781626	14.72650	378.0131	14.75709	

	3.818765	14.87506	411.7616	14.90234
	3.742774	14.57110	365.6657	14.52425
	3.695622	14.38068	309.6723	14.41103
	3.642582	14.17020	274.4304	14.22896
	3.582991	13.93196	239.2610	13.98900
	3.513085	13.65234	203.6879	13.69343
	3.425243	13.39097	166.3886	13.41046
	3.315046	12.86018	129.1000	12.96291
	3.162193	12.24877	90.79741	12.28751
	3.386925	13.14770	152.3370	13.24232
	3.292732	12.77092	122.6364	12.79419
	3.166758	12.26703	91.75693	12.21401
	3.092861	11.93144	75.63823	11.85347
	Data Log(Ro/f)	PK 1//f	L 1//f	Data 1//f
S0000336	3.893624	15.17449	489.2199	15.00912
	3.811278	14.84511	404.7239	14.81648
	3.741742	14.56697	344.8439	14.55021
	3.679463	14.31785	298.7742	14.33616
	3.591360	13.96544	243.9164	14.04834
	3.478610	13.51444	188.1439	13.65957
	3.352814	13.01125	140.8299	13.03480
	3.198632	12.39452	98.74430	12.39356
	3.419038	13.27615	164.0281	13.39931
	3.321861	12.88744	131.1417	13.03512
	3.196380	12.38552	98.23576	12.42989
	3.111397	12.04558	80.77506	12.09319
	Data Log(Ro/f)	PK 1//f	L 1//f	Data 1//f
S0000339	3.838167	15.15266	483.1111	15.02842
	3.807409	14.82963	401.1336	14.78142
	3.716629	14.46651	325.4686	14.49989
	3.613271	14.05308	256.5377	14.15074
	3.456414	13.42565	178.7698	13.53770
	3.349932	12.99973	139.8983	12.97441
	3.190886	12.36354	96.99882	12.47506
	3.112562	12.05025	80.99214	11.95243
	3.415313	13.26125	162.6274	13.39331
	3.309744	12.83897	127.5334	13.28352
	3.191412	12.36566	97.11630	12.45997
	3.112647	12.05059	81.00795	11.95010
	3.035355	11.74142	67.80090	11.73623
	2.962740	11.45096	57.36153	11.39678
	2.899685	11.19874	49.60952	11.19816
	2.793982	10.77592	38.89219	10.73421

3.028051	11.71220	66.47019	11.68556
2.951944	11.40785	55.95573	11.41912
2.893598	11.17439	48.91908	11.16014
2.796156	10.78462	39.08738	10.67937
2.725193	10.50078	33.19518	10.46628
2.611246	10.04498	25.53444	10.08367
2.523293	9.693175	20.65325	9.715576
2.449546	9.398107	17.59652	9.643636
2.322434	8.889738	13.13150	10.81802
2.231845	8.527460	10.65970	9.970923
2.157746	8.231066	8.987659	8.613246
2.091043	7.964173	7.707676	7.436[illegible]
2.018302	7.674008	6.522019	6.3[illegible]
1.941109	7.364437	5.457445	5.4[illegible]
1.855202	7.020810	4.477985	4.4[illegible]
1.738372	6.553489	3.421782	[illegible]2607

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
T0000341	4.018862	15.67545	652.7441	15.93942
	3.942135	15.36884	547.0355	15.53262
	3.864215	15.06486	457.1890	15.17150
	3.733927	14.61571	356.6544	14.66823
	3.617070	14.04828	258.7917	14.07127
	3.483989	13.56395	191.3679	13.59209
	3.339447	12.95778	136.5612	12.69805
	3.251117	12.60444	111.4298	12.44964
	4.019654	15.67861	653.9343	15.91041
	3.930389	15.40155	537.5321	15.55122
	3.856054	15.02622	448.6803	15.07273
	3.756297	14.62519	356.5968	14.58841
	3.601167	14.00467	249.4869	13.90101
	3.489268	13.55707	192.8182	13.48986
	3.333433	12.93373	134.6833	12.87509
	3.195330	12.38132	97.99652	12.38659
	4.043730	15.77692	691.2111	15.90777
	3.973613	15.49445	588.1573	15.57920
	3.896642	15.18656	492.6313	15.25213
	3.762893	14.65157	362.0542	14.67888
	3.597332	13.98933	267.2935	14.00022
	3.511047	13.64419	202.7346	13.55913
	3.351754	13.00701	140.4864	13.04471
	3.219403	12.47741	105.5818	12.38463
	3.518312	13.67324	206.1542	13.59238
	3.321964	12.88785	131.1730	12.81725
	3.605275	14.02110	251.8576	14.09273
	3.711588	14.44635	321.7131	14.51670
	3.830104	14.92041	422.6534	15.02765
	3.895278	15.17311	488.8306	15.28616
	3.929087	15.31954	531.8231	15.45547
	3.946827	15.38731	552.9777	15.53985
	3.948025	15.39210	554.5049	15.46213
	3.874006	15.09602	467.6131	15.14655
	3.783037	14.73214	379.2425	14.74420
	3.658576	14.23430	284.7455	14.40067
	3.517561	13.67024	205.7981	13.58522
	3.359332	13.03733	162.9593	13.03780
	3.215412	12.46165	102.6343	12.71225

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
T0000341	3.458109	13.43243	179.4690	13.77928
	3.351985	13.00794	140.5613	13.19506

3.283882	12.73552	120.1605	12.86276
3.196023	12.38409	98.15293	12.59746
3.484259	13.53703	190.6074	13.78495
3.441125	13.36450	172.5860	13.43527
3.390662	13.16265	153.6535	13.07666
3.288972	12.75589	121.5774	12.71286
3.151733	12.20693	88.63672	12.20620
3.483426	13.53370	190.2421	13.81142
3.412549	13.25019	161.5955	13.39044
3.321686	12.88674	131.0890	12.96948
3.243743	12.57497	109.5527	12.69742
3.154869	12.21947	89.27912	12.11837
3.284792	12.73917	120.4128	12.83581
3.321591	12.88636	131.0604	12.97231
3.248412	12.59365	110.7369	12.56163
3.319167	12.87666	130.3309	13.04492
3.246501	12.58600	110.2508	12.61702
3.046065	11.78426	69.49367	11.92322
2.984631	11.53772	60.29918	11.42008
2.944052	11.37621	54.94559	11.46248
2.855440	11.02176	44.80437	11.07113
2.797170	10.78868	39.17878	10.81542
2.693863	10.37545	30.88471	10.45385
2.613829	10.05531	25.68675	10.15413
2.546021	9.784085	21.97361	10.01420
2.399936	9.199745	15.69699	11.32320
2.416027	9.264111	16.28950	10.91888
2.288273	8.753092	12.13816	11.13778
2.230337	8.522148	10.62715	10.01232
2.176858	8.307433	9.391572	9.060778
2.132289	8.129156	8.475572	8.234969
2.081947	7.927790	7.547925	7.369711
2.017786	7.671144	6.511275	6.396376
1.945029	7.380119	5.506934	5.436711
1.905968	7.223872	5.033245	4.738176
1.900690	7.202760	4.972447	4.780385
2.004371	7.617487	6.313234	6.116954
2.117793	8.071172	8.197343	7.853479
2.202231	8.408924	9.956602	9.423877
2.293594	8.774378	12.28781	11.38586
2.418997	9.275990	16.40127	10.81395
2.553292	9.813169	22.34458	9.800869
2.595806	9.983224	24.64257	10.00969
2.695159	10.38063	30.97703	10.31090
2.795405	10.78162	39.01987	10.67134

	2.853496	11.01478	44.62464	10.91849
	2.915438	11.26178	51.44213	11.20289
	2.938948	11.38579	54.30354	11.27299
	2.939935	11.38974	54.42708	11.26815
	2.984115	11.53466	60.25538	11.40262
	3.037900	11.75163	68.20061	11.64219

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
T0000342	3.983876	15.53530	602.2216	15.71480
	3.914260	15.25734	513.0273	15.37247
	3.827886	14.91154	420.5002	15.00403
	3.721107	14.48443	328.8422	14.59878
	3.588839	13.96735	241.3901	13.92139
	3.459855	13.43942	180.1919	13.32106
	3.304027	12.81611	125.8457	12.71380
	3.170786	12.28314	92.61192	12.09523
	3.116596	12.06638	81.74797	12.18001
	3.060503	11.84201	71.84286	11.90342
	3.013986	11.65594	64.54565	11.73408
	2.925327	11.30130	52.62681	11.40580
	2.843786	11.05514	45.67376	11.10147
	2.765651	10.66260	36.43606	10.63844
	2.681086	10.32434	29.98934	10.33599
	2.615735	10.06294	25.79977	10.12729
	2.557679	9.750717	21.55556	9.915001
	3.034680	11.81872	70.88599	11.80383
	3.016418	11.66567	64.90811	11.62425
	2.924706	11.29892	52.55172	11.20590
	2.859187	11.03674	45.19256	10.97535
	2.762902	10.65161	36.20619	10.55473
	2.676651	10.30660	29.68460	10.26099
	2.537595	9.750380	21.55138	9.939007
	2.368272	9.073091	14.59328	11.54410
	2.272147	8.688589	11.69573	11.11844
	2.219335	8.477341	10.35655	9.919042
	2.143388	8.173552	8.694972	8.524580
	2.091873	7.967494	7.722423	7.706562
	2.032436	7.729745	6.734670	6.702890
	1.990516	7.562044	6.114994	6.120783
	1.954446	7.417785	5.627641	5.626102
	1.912926	7.251706	5.114539	5.140487
	1.882082	7.128331	4.763902	4.794096
	1.809442	6.837769	4.030159	4.053246
	1.740628	6.562512	3.439602	3.437728
	1.648809	6.195238	2.784130	2.843856

	Data	PK	L	Data

	Log(Re/f)	1//f	1//f	1//f
T0000345	3.995704	15.58281	618.8486	15.86320
	3.927267	15.30907	528.6249	15.47556
	3.842164	14.96865	434.5551	15.06049
	3.732262	14.52905	337.3983	14.54797
	3.998160	15.59264	622.3589	15.80935
	3.929209	15.31683	530.9936	15.44132
	3.843755	14.97502	436.1497	15.02236
	3.735498	14.54199	339.9211	14.50529
	4.000992	15.60396	626.4295	15.74209
	3.931851	15.32740	534.2340	15.38232
	3.847112	14.98844	439.5340	14.99101
	3.736304	14.54521	340.5530	14.51108
	3.846856	14.98742	439.2755	14.99983
	3.999293	15.59717	623.9835	15.80748
	3.930799	15.32319	532.9414	15.42322
	3.845920	14.98368	438.3294	15.00182
	3.746369	14.58547	348.5378	14.62165
	3.580081	13.92032	237.6628	13.83418
	3.469035	13.47614	184.0414	13.39863
	3.312742	12.85097	128.4171	12.80153
	4.012305	15.64922	642.9630	15.76185
	3.935433	15.34173	538.6581	15.36472
	3.838718	14.95487	431.1203	14.88768
	3.735229	14.54091	339.7107	14.41885
	3.629415	14.11766	266.2538	13.95625
	3.478815	13.51526	188.2327	13.45978
	3.324643	12.89857	131.9846	12.79730
	4.015991	15.66396	648.4429	15.69932
	3.947180	15.38872	553.4271	15.32890
	3.860879	15.04351	453.6898	14.95899
	3.736871	14.54748	340.9981	14.42937
	3.612984	14.05193	256.3685	13.89812
	3.480320	13.52128	188.8863	13.47386
	3.325300	12.90120	132.1845	12.85575

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
T0000348	4.006769	15.62707	634.8188	15.82065
	3.938782	15.35512	542.8281	15.41809
	3.850197	15.00078	442.6672	15.12535
	3.731078	14.52431	336.4795	14.42654
	3.606298	14.02519	252.4519	13.92398
	3.476163	13.50465	187.0870	13.42055
	3.313404	12.85361	128.6129	13.01482

3.532689	13.73075	213.0932	13.68924
3.460624	13.44329	180.3943	13.30222
3.334603	12.93841	135.0464	12.70624
3.247904	12.59161	110.6074	12.41097
4.007941	15.63176	636.5336	15.77803
3.960122	15.34048	544.5053	15.37040
3.845727	14.98290	438.1343	14.89979
3.757742	14.63097	357.7854	14.50513
3.668307	14.03522	253.6221	13.85974
3.478566	13.51426	188.1251	13.34650
3.324897	12.89759	132.0619	12.67492
3.533510	13.73404	213.4965	13.63260
3.533937	13.73574	213.7063	13.64997
3.462149	13.44859	181.1461	13.26170
3.336269	12.93707	134.9427	12.71601
3.202753	12.41101	99.68577	12.04939
4.011541	15.64416	641.8327	15.64776
3.934104	15.33441	537.0122	15.27336
3.836374	14.94549	428.7996	14.85378
3.744765	14.57906	347.2526	14.46101
3.608066	14.03226	253.4814	13.86743
3.476325	13.50529	187.1560	13.41561
3.320451	12.88180	130.7167	12.80535
3.533493	13.73397	213.4877	13.66395
3.460653	13.44261	180.5235	13.30744
3.332863	12.93145	134.5044	12.75725
3.194794	12.37917	97.87555	12.27225
3.868227	15.07291	461.4321	15.04358
3.817264	14.86905	410.3406	14.80208
3.769068	14.67627	367.2391	14.64913
3.687895	14.35158	304.6322	14.24174
3.581451	13.92580	238.4138	13.82997
3.490790	13.56316	193.4952	13.45303
3.295034	12.78013	123.2862	12.66855
3.865178	15.06071	458.2032	15.01350
3.813709	14.85483	406.9954	14.78967
3.755166	14.62066	355.6693	14.50624
3.682833	14.33133	301.1017	14.27929
3.597748	13.99099	247.5301	13.89575
3.486223	13.54489	191.4710	13.47312
3.333090	12.93236	134.5767	12.77939
3.812968	14.85187	406.3014	14.83165
3.820320	14.88128	413.2384	14.83151
3.760091	14.64036	359.7259	14.60386
3.690250	14.36100	306.2884	14.29314
3.604423	14.01769	251.3643	13.93300
3.494072	13.57629	194.9633	13.47276

3.338264	12.95305	136.1897	12.85801
3.104658	12.01863	79.53138	12.08846
3.049486	11.79794	70.04325	11.87156
3.003010	11.61204	62.93468	11.71209
2.913435	11.25374	51.20532	11.28055
2.852235	11.00894	44.67490	10.94404
2.854862	11.01944	44.74475	11.03307
2.812040	10.86816	40.54342	10.75051
2.753098	10.61239	35.39796	10.60330
2.754621	10.61848	35.52235	10.54210
2.664879	10.25951	28.89078	10.23305
2.606608	10.02643	25.26320	10.05338
2.539257	9.757030	21.63404	9.896379
2.336659	8.938638	13.50640	11.62850
2.251939	8.607759	11.16400	10.56786
2.179234	8.316939	9.443106	9.151637
2.136963	8.147854	8.567294	8.463412
2.059662	7.838650	7.170389	7.158748
1.973711	7.494844	5.882695	5.856990
1.867766	7.071065	4.609420	4.575264
1.752134	6.608536	3.531946	3.538103
1.543231	5.772924	2.183288	2.185732

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
T0000351	3.981698	15.52679	599.2093	15.69936
	3.912608	15.25043	511.0793	15.33879
	3.838222	14.95289	430.6284	14.92762
	3.741659	14.56663	344.7776	14.55192
	3.648526	14.19410	278.2314	14.08780
	3.560205	13.84082	227.0311	13.81192
	3.420422	13.28168	164.5517	13.33936
	3.291054	12.76421	122.1616	12.83457
	3.982559	15.53023	600.3978	15.66829
	3.906269	15.22507	503.6734	15.25304
	3.829216	14.91686	421.7902	14.86870
	3.743209	14.57283	346.0104	14.50007
	3.634637	14.13854	269.4742	13.96379
	3.478720	13.51488	188.1919	13.32995
	3.296321	12.77728	123.0840	12.73819
	3.777639	14.71055	374.5584	14.68377
	3.692761	14.37104	308.0645	14.28254
	3.582653	13.93061	239.0743	13.80306
	3.454734	13.41893	178.0796	13.23629
	3.301100	12.80440	125.0202	12.56924
	3.212854	12.45141	102.0315	12.32097
	3.490481	13.56192	193.3578	13.76913
	3.421069	13.28427	164.7972	13.30447

	3.294983	12.77993	123.2716	12.70447
	3.213090	12.65236	102.0871	12.27265
	3.040916	11.76566	68.67463	11.90006
	2.985221	11.54698	60.40897	11.61708
	2.939061	11.38624	54.31771	11.39781
	2.945765	11.38282	55.15505	11.31957
	2.855569	11.02203	44.81150	10.95687
	2.794921	10.77968	38.97642	10.68627
	2.696433	10.38573	31.06798	10.29684
	2.609037	10.03614	25.40487	10.04162
	2.540256	9.761024	21.68383	9.966490
	2.419785	9.279140	16.45104	11.00619
	2.293668	8.774473	12.28989	11.20360
	2.207204	8.428824	10.07131	9.730617
	2.099452	7.997008	7.858341	7.914981
	2.012625	7.650563	6.434368	6.469790
	1.843419	7.053676	4.343510	4.598575
	1.743157	6.672634	3.459705	3.459903
	1.569286	5.877146	2.318283	2.391108

Data	PK	L	Data
Log(Re/f)	1//f	1//f	1//f
T0000354	4.002613	15.61045	628.7718	15.86305
	3.974384	15.49753	589.2017	15.51965
	3.922528	15.29011	522.8979	15.26216
	3.869908	15.07963	463.2209	15.07455
	3.799171	14.79668	395.5971	14.78426
	3.728930	14.51572	334.8192	14.40028
	3.671310	14.28524	293.2176	14.17333
	3.581053	13.92421	238.1955	13.95982
	3.474860	13.49944	186.5245	13.37008
	3.318714	12.87485	130.1951	12.76993
	3.509524	13.63809	202.9248	13.77112
	3.445463	13.38185	174.3185	13.14345
	3.313788	12.85515	128.7265	12.71325
	3.230952	12.52380	106.3732	12.30787
	4.001870	15.60748	627.6981	15.89219
	3.982913	15.53165	600.8875	15.49452
	3.930816	15.32326	532.9621	15.28562
	3.854089	15.01635	446.6526	14.88927
	3.801954	14.80781	396.1266	14.68985
	3.730220	14.52088	335.8152	14.35757
	3.641690	14.16676	273.8866	13.96177
	3.568147	13.79258	220.8144	13.55278
	3.455952	13.42380	178.5798	13.03404
	3.289733	12.75893	121.7906	12.28604
	3.519280	13.67712	206.6142	13.77246
	3.449904	13.39961	176.1101	13.30658
	3.322936	12.89174	131.4669	12.73228

	3.187452	12.34981	96.23494	12.17353
	4.002801	15.61120	629.0443	15.89400
	3.959167	15.43658	568.8883	15.23139
	3.894081	15.17632	489.7358	14.97111
	3.816324	14.86529	409.4536	14.65079
	3.745370	14.58148	347.7367	14.37586
	3.660255	14.24102	285.8483	13.99068
	3.569046	13.87618	231.7000	13.66440
	3.477747	13.51107	187.7792	13.31088
	3.321659	12.88663	131.0808	12.71230
	3.235587	12.54235	107.5147	12.39896
	3.523176	13.69270	208.4764	13.77316
	3.451716	13.40686	176.8466	13.37128
	3.324540	12.89816	131.9534	12.80033
	3.512516	13.65006	203.4211	13.80056
	3.463559	13.45423	181.7354	13.63000
	3.392820	13.17128	154.4190	12.83289
	3.316315	12.86526	129.4779	12.75406
	3.228323	12.51329	105.7312	12.49484
	3.510726	13.64290	202.5847	13.85754
	3.467775	13.39110	175.2489	13.19218
	3.385447	13.14178	151.8193	13.05263
	3.270019	12.68007	116.3857	12.76988

Data	PK	L	Data
Log(Re/f)	1//f	1//f	1//f
T0000358	3.990472	15.56188	611.4578	15.77197
	3.921416	15.28566	521.5507	15.40850
	3.834907	14.93962	427.3335	15.04287
	3.726652	14.50661	333.0678	14.47690
	3.567815	13.87126	231.0445	13.91301
	3.455778	13.42311	178.5084	13.50577
	3.304728	12.81891	126.0689	12.74907
	3.990996	15.56398	612.1764	15.71744
	3.920420	15.28168	520.3554	15.40909
	3.833615	14.93446	426.0847	15.05467
	3.724709	14.49883	331.5808	14.50905
	3.565494	13.86197	229.8131	13.95604
	3.452513	13.41005	177.1712	13.57704
	3.309192	12.83677	127.3715	12.59026
	4.005890	15.62356	633.5355	15.71028
	3.935151	15.34060	538.3082	15.40787
	3.849767	14.99907	442.2296	15.00430
	3.740111	14.56044	343.5514	14.48549
	3.580300	13.92120	237.7827	13.95254

3.471172	13.48468	194.9492	13.45372
3.313405	12.85362	128.6132	12.89787
4.012044	15.44825	642.6042	15.48852
3.939291	15.35716	543.4643	15.24169
3.851311	15.03824	443.8040	14.95107
3.738674	14.58469	342.4161	14.53351
3.578854	13.91841	236.9925	13.99906
3.468796	13.47518	183.9403	13.52751
3.307540	12.85024	126.8939	13.07265
3.512065	13.64826	203.2103	13.87735
3.468031	13.47220	183.4248	13.55075
3.395403	13.18161	153.3400	12.81649
3.315009	12.86003	129.0892	12.85031
3.231025	12.52410	104.3912	12.47349
3.510685	13.64274	202.5457	13.92152
3.442879	13.37151	175.2842	13.40209
3.317458	12.86983	129.8190	12.77806
3.235902	12.54361	107.5926	12.33620
3.511676	13.64670	203.0281	13.88981
3.442588	13.37035	175.1681	13.41107
3.315515	12.86206	129.2395	12.83537
3.231748	12.52707	104.5733	12.45217
3.084286	11.94514	76.23708	12.10372
3.032605	11.73042	67.37300	11.74759
2.984487	11.53795	60.30698	11.62441
2.894265	11.17706	48.99433	11.28258
2.837166	10.94842	42.95227	11.04458
2.840149	10.96059	43.25435	10.93954
2.735708	10.54283	34.00856	10.48348
2.645296	10.18118	27.61700	10.16529
2.588562	9.954248	24.23494	9.989557
2.519415	9.677663	20.66788	9.876952
2.327522	8.910089	13.28624	11.82299
2.226909	8.507636	10.53874	10.23466
2.124961	8.099245	8.333768	8.271409
2.026801	7.707207	6.447861	6.642729
1.914268	7.257074	5.130369	5.163173
1.830549	6.922277	4.231062	4.241913
1.677477	6.309909	2.974112	3.003392
1.552047	5.808271	2.228168	2.220375

Data	PK	L	Data
Log(Re/f)	1//f	1//f	1//f
T0000361			
3.992814	15.57125	614.7437	15.65180
3.920059	15.28023	519.9237	15.42189

3.823822	14.89528	416.5837	15.01307
3.734246	14.53698	338.9426	14.66704
3.651775	14.20710	280.3209	14.30183
3.544680	13.77872	219.0586	13.90914
3.453748	13.41499	177.6759	13.53847
3.303570	12.81428	125.7333	12.75429
3.217071	12.46828	103.0271	12.45218
3.978840	15.51536	595.2790	15.59055
3.908032	15.23213	505.7228	15.29284
3.811055	14.84422	404.5153	14.91284
3.712684	14.45073	322.5260	14.58757
3.555442	13.82177	224.5549	13.77648
3.444628	13.37851	173.9835	13.33564
3.284738	12.73895	120.3978	12.84730
3.982804	15.53121	600.7367	15.65945
3.912307	15.24922	510.7251	15.34947
3.826882	14.90753	419.5295	14.94882
3.713926	14.45570	323.4491	14.54202
3.561190	13.84476	227.5466	13.78062
3.442435	13.36974	173.1072	13.58580
3.294275	12.77710	123.0709	12.73955
3.990610	15.56244	611.6315	15.51993
3.917236	15.26894	516.5540	15.31377
3.828673	14.91469	421.2633	15.02224
3.713579	14.45431	323.1909	14.68556
3.557369	13.82947	225.5534	14.02843
3.449106	13.39642	175.7868	13.49999
3.291551	12.76620	122.3013	12.93592
3.500964	13.60385	198.0817	13.88771
3.433809	13.33523	169.7030	13.34949
3.306867	12.82746	126.6914	12.77258
3.222966	12.49186	104.4352	12.39565
3.498784	13.59515	197.0899	13.86345
3.431482	13.32592	168.7959	13.33070
3.307546	12.83018	126.8897	12.66661
3.175492	12.30197	93.62090	12.01744
3.498494	13.59397	196.9584	13.87271
3.432052	13.32821	169.0179	13.31319
3.307734	12.83093	126.9446	12.66112
3.076466	11.90586	74.53267	12.11109
3.019719	11.67887	65.40334	11.83398
2.974610	11.49844	58.95090	11.61257
2.885350	11.14140	47.99883	11.25658

	2.827334	10.90934	41.99686	10.97904
	2.833247	10.93298	42.57229	10.78719
	2.735905	10.33542	33.86768	10.40402
	2.667326	10.10210	27.73920	10.13347
	2.583499	9.988837	25.95186	9.969816
	2.582713	9.611683	19.89726	9.968210
	2.317325	8.869301	12.97793	11.99210
	2.234701	8.538897	10.72956	10.22489
	2.129269	8.117079	8.416853	8.347148
	2.049389	7.793556	6.906650	6.923068
	1.948492	7.393971	5.551621	5.513150
	1.863699	7.084798	4.566459	4.537077
	1.769369	6.678278	3.676627	3.654495
	1.629347	6.117389	2.662118	2.715974

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
T0000364	3.972075	15.48830	586.0779	15.62241
	3.891648	15.16659	486.9995	15.33394
	3.813124	14.85249	406.4479	15.01783
	3.717332	14.46932	325.9959	14.51115
	3.564361	13.85744	229.2143	13.98073
	3.444627	13.37851	173.9833	13.15636
	3.285469	12.74187	120.6004	12.65328
	3.971265	15.48506	584.9865	15.65156
	3.914926	15.25970	513.8143	15.44363
	3.853817	14.99527	426.2828	15.03501
	3.712078	14.44831	322.0763	14.68774
	3.563257	13.85302	228.6322	14.01632
	3.423488	13.29475	165.7937	13.80623
	3.279263	12.71705	118.8895	12.83537
	3.985342	15.54136	604.2374	15.53313
	3.914231	15.25692	512.9929	15.24714
	3.826465	14.90586	419.1267	14.92947
	3.714536	14.45814	323.9038	14.48838
	3.575538	13.90215	235.1899	13.96787
	3.436965	13.34784	170.9406	13.72700
	3.288241	12.75296	121.3727	12.80868
	3.471720	13.48488	185.1827	13.51603
	3.396532	13.18613	135.7445	13.05750
	3.296108	12.78443	123.5915	12.65729
	3.211739	12.44703	101.7745	12.29644
	3.470996	13.48398	184.8744	13.52331
	3.363741	13.05496	144.4181	12.98372
	3.250254	12.63301	113.2750	12.41503
	3.160406	12.24242	90.46620	12.09070

	3.473778	13.49511	186.0623	13.57407
	3.394673	13.17869	155.0790	13.23241
	3.299352	12.79740	124.5179	12.67701
	3.214352	12.45741	102.3841	12.33406
	3.055881	11.82352	71.08235	11.96940
	3.000248	11.60099	62.53578	11.71217
	2.951632	11.40653	55.91302	11.55551
	2.896422	11.06569	45.95184	11.19144
	2.906268	10.82507	40.00815	10.93824
	2.809257	10.83703	40.28447	10.87320
	2.707031	10.42812	31.83546	10.41914
	2.627931	10.11172	26.53451	10.22509
	2.556710	9.826843	22.52116	9.957055
	2.442111	9.368445	17.29781	10.70614
	2.301126	8.804504	12.50276	11.69162
	2.227923	8.511694	10.56340	10.46540
	2.152455	8.209820	8.678410	8.817226
	2.054938	7.819353	7.091178	7.110727
	1.958603	7.434412	5.681764	5.712933
	1.852389	7.009555	4.449067	4.484229
	1.683872	6.343488	3.032159	3.026526

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
T0000367	3.983638	15.53455	601.8921	15.59417
	3.911781	15.24712	510.1074	15.33538
	3.823373	14.89349	416.1533	15.07614
	3.724154	14.49661	331.1576	14.64389
	3.573012	13.89204	233.8258	14.04976
	3.430244	13.32097	168.3156	13.94108
	3.290949	12.76379	122.1320	12.80855
	3.988953	15.55581	609.3035	15.64968
	3.919265	15.27706	518.9740	15.31131
	3.985495	15.54198	604.4707	15.70379
	3.914736	15.26694	515.9602	15.33142
	3.838410	14.95364	430.8151	15.05641
	3.729415	14.51766	335.1937	14.63168
	3.562755	13.85102	228.3681	13.85553
	3.449309	13.39723	175.8685	13.49772
	3.297116	12.78846	123.8785	12.77122
	3.997727	15.59090	621.7380	15.51068
	3.919742	15.27897	519.5448	15.15863
	3.828787	14.91514	421.3733	15.25738
	3.722878	14.49151	330.1858	14.60326
	3.566664	13.86665	230.4329	13.94994
	3.457099	13.42839	179.0522	13.46475

	3.298215	12.79286	124.1925	12.94170
	3.481700	13.52499	189.4875	13.66341
	3.468376	13.23838	160.8501	13.14357
	3.308688	12.83478	127.2239	12.71913
	3.218779	12.47811	103.4331	12.51574
	3.484560	13.53024	190.7394	13.57393
	3.377921	13.11168	149.2113	13.01384
	3.310243	12.84097	127.6800	12.67369
	3.221483	12.48578	104.0790	12.43804
	3.484967	13.53986	190.9180	13.56123
	3.409985	13.23994	160.6446	13.09495
	3.308968	12.85387	127.3058	12.71095
	3.207804	12.43122	100.8524	12.85601

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
T0000370	3.997465	15.58986	621.3426	15.64073
	3.923396	15.29358	523.9338	15.16790
	3.847104	14.98842	439.5294	15.12874
	3.757516	14.53005	341.5030	14.72221
	3.548223	13.87289	231.2615	14.02596
	3.451979	13.40791	176.9335	13.74795
	3.303339	12.82135	126.2465	12.84654
	3.223037	12.49215	104.4523	12.42161
	3.483592	13.53437	190.3148	13.60421
	3.397965	13.19186	156.2592	13.46244
	3.308612	12.85445	127.2016	12.72135
	3.215038	12.46015	102.5460	12.62400
	3.101674	12.00649	78.98490	11.91404
	3.104857	12.01942	79.56782	11.84084
	3.048440	11.79304	69.87797	11.70656
	3.000869	11.60347	62.62527	11.51113
	2.910169	11.24047	50.82175	11.30045
	2.850056	11.00022	44.25239	11.05462
	2.843843	10.98337	43.82512	11.18704
	2.752217	10.60887	35.32628	10.66002
	2.671397	10.28559	29.32769	10.27280
	2.609199	10.03679	25.41439	10.01079
	2.537175	9.748703	21.53058	9.803210
	2.361499	8.965999	13.72081	11.81067
	2.259271	8.657086	11.35407	10.71657
	2.193950	8.375803	9.768568	9.477785
	2.118769	8.075075	8.215781	8.068992
	2.040497	7.761990	6.860847	6.812781
	1.953437	7.413751	5.614588	5.574557
	1.845285	6.981140	4.374884	4.368270

	1.640548	6.162193	2.731671	2.752026

File/Run	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000011	1.611320	6.045260	2.553078	2.462361
	1.716478	6.466714	3.235058	3.317172
	1.847602	6.991211	4.402333	4.413000
	1.952243	7.409054	5.599429	5.644227
	2.008912	7.635650	6.379584	6.365922
	2.048819	7.795276	6.993572	7.028098
	2.667751	7.951004	7.649464	7.679320
	2.114784	8.058824	8.139280	8.205801
	2.152285	8.209140	8.874935	8.893575
	2.224389	8.497522	10.47757	10.35029
	2.253156	8.612626	11.19532	10.98339
	2.284643	8.738652	12.03768	11.23361
	2.314552	8.858211	12.89534	11.15747
	2.339040	9.156160	15.30806	10.31968
	2.447774	9.391105	17.52693	9.740202
	2.461936	9.447745	18.10574	9.774658
	2.486008	9.544033	19.13744	9.847404
	2.516426	9.665707	20.52612	9.830592
	2.535057	9.740230	21.42582	9.910809
	2.557396	9.830387	22.56715	10.00136
	2.591143	9.964573	24.37941	10.03350
	2.620603	10.08241	26.09035	10.09169
	2.640701	10.16360	27.33890	10.22195
	2.660810	10.24324	28.62134	10.25950
	2.685696	10.34274	30.30866	10.34125
	2.702911	10.41164	31.53490	10.43084
	2.719239	10.47695	32.74309	10.52684
	2.737712	10.55084	34.16585	10.52844
	2.755303	10.62121	35.57814	10.64066
	2.768728	10.67491	36.69512	10.77859
	2.780943	10.72377	37.74189	10.79015
	2.799884	10.79593	39.34275	10.79791
	2.817706	10.87082	41.07584	10.91293
	2.831119	10.92447	42.36426	10.99598
80000012	3.248781	12.59512	110.8311	12.32020
	3.246867	12.58747	110.3442	12.52294
	3.240104	12.56041	108.6384	12.50622
	3.231437	12.52575	106.4921	12.48627
	3.223687	12.49474	104.6095	12.43418
	3.217716	12.47086	103.1803	12.38167
	3.207941	12.43176	100.8837	12.37639
	3.200761	12.40304	99.22962	12.33522
	3.187375	12.34950	96.21775	12.30051

	3.180386	12.32154	94.68185	12.25534
	3.175050	12.30020	93.52564	12.15451
	3.175050	12.30020	93.52564	12.15451
	3.175050	12.30020	93.52564	12.15451
	3.137627	12.15051	85.80404	12.13520
	3.137627	12.15051	85.80404	12.13520
	3.117319	12.06927	81.88402	12.06050
	3.117319	12.06927	81.88402	12.06050
	3.089419	11.95767	76.78912	11.90396
	3.089419	11.95767	76.78912	11.90396
	3.044352	11.77740	69.22013	11.72422
	3.044352	11.77740	69.22013	11.72422
	3.177943	12.31177	94.15070	12.31597
	3.177943	12.31177	94.15070	12.31597
	3.168546	12.27418	92.13547	12.19759
	3.146607	12.18642	87.59662	12.08879
	3.146607	12.18642	87.59662	12.08879
	3.118998	12.07599	82.20125	12.09281
	3.097177	11.98870	78.17310	12.02318
	3.097177	11.98870	78.17310	12.02318
	3.068062	11.87225	73.10428	11.79562
	3.068062	11.87225	73.10428	11.79562
	3.028502	11.71400	66.73962	11.64173
	3.005802	11.62321	63.34068	11.47652
	2.971413	11.48565	58.51858	11.41637
	2.930257	11.32103	53.22771	11.22417
	2.887677	11.15071	48.25670	11.03868
	2.851603	11.00641	44.41029	10.93444
	2.813241	10.85296	40.65567	10.78115
	2.770496	10.68198	36.84479	10.57577
	2.738758	10.55503	34.24826	10.56970
	2.693030	10.37212	30.82554	10.43017
	2.658763	10.23505	28.48679	10.25103
	2.609408	10.03763	25.42663	10.09267
	2.564802	9.859208	22.94469	9.898846
	2.500946	9.603787	19.80736	9.657903
	2.452478	9.409915	17.71572	9.806958
	2.341198	8.964792	13.71128	10.94683
	2.237398	0.549595	10.79639	10.63119
	2.172668	8.290754	9.301837	9.175411

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000013	3.172404	12.28961	92.95747	12.17827
	3.097585	11.99034	78.24667	11.91684
	2.986601	11.54640	60.60119	11.43417
	2.915512	11.26204	51.45080	11.13995
	2.776316	10.70526	37.34190	10.61445
	2.697185	10.38874	31.12185	10.35362
	2.599950	9.999801	24.87885	9.971679

	2.500114	9.600459	19.76946	10.02352
	2.316019	8.864077	12.93894	11.48705
	2.216465	8.487845	10.24109	10.48678
	2.160273	8.241093	9.039698	9.272960
	2.115332	8.061331	8.151036	8.444721
	2.063027	7.852110	7.226159	7.481157
	1.962234	7.448937	5.729468	5.918285
	1.837471	6.949886	4.298843	4.491918
	1.631368	6.128552	2.674657	2.734640

Data	PK	L	Data
Log(Re/f)	1//f	1//f	1//f
80000016			
2.912981	11.25192	51.15191	11.04677
2.864989	11.05995	45.80042	10.92384
2.797654	10.79061	39.22242	10.72995
2.682949	10.32827	30.05725	10.28102
2.601937	10.00775	24.99297	10.00915
2.513115	9.652461	20.37020	9.480006
2.389879	9.159518	15.33767	10.42014
2.310429	8.862518	12.77937	10.95832
2.244731	8.578926	10.98022	10.65117
2.170609	8.282438	9.257415	9.035737
2.066795	7.867182	7.289128	7.336046
2.013741	7.654965	6.450914	6.360514
1.884076	7.134307	4.785825	4.710647
1.690091	6.360364	3.061760	2.950434

Data	PK	L	Data
Log(Re/f)	1//f	1//f	1//f
80000022			
1.844495	6.977983	4.368937	4.336346
2.004301	7.617205	6.312208	6.454480
2.125446	8.101785	8.343077	8.606921
2.233507	8.534028	10.70008	10.72332
2.340878	8.963515	13.70120	11.04608
2.462[illegible]	9.451525	18.16518	9.633523
2.581739	9.926956	23.85718	10.16674
2.725434	10.50173	33.21367	10.69244
2.828418	10.91367	42.10162	10.92614
2.895332	11.18215	49.13749	11.25399
2.897714	11.19085	49.38495	11.12124
2.967026	11.46810	57.93033	11.30950
3.016552	11.67421	65.22783	11.49744
3.081693	11.92677	75.43509	11.78960
3.128543	12.11337	83.98916	12.04939
3.151911	12.20744	88.67293	12.10462
3.203545	12.41426	99.87231	12.31049

Data	PK	L	Data
Log(Re/f)	1//f	1//f	1//f

80000025				
	1.799389	6.797558	3.937944	3.976037
	1.993003	7.572015	6.150122	6.260660
	2.142532	8.170129	8.677855	8.707590
	2.213970	8.455883	10.22941	10.11398
	2.284086	8.736346	12.02171	11.05304
	2.414600	9.258400	16.23604	10.03269
	2.491524	9.566098	19.38227	10.03662
	2.668821	10.27528	29.15419	10.25779
	2.783991	10.73596	38.00766	10.79556
	2.853012	11.01204	44.55456	10.97272
	2.903673	11.21469	50.06720	11.21763
	2.919129	11.27651	51.88108	11.09337
	2.996502	11.58601	61.99872	11.43969
	3.057378	11.82951	71.32767	11.64194
	3.101639	12.00655	78.98041	11.87410
	3.144233	12.17693	87.11919	11.96460
	3.160494	12.24197	90.44295	11.97434
	3.197613	12.39045	98.51302	12.20181
	3.216399	12.46559	102.8677	12.33444
	3.223870	12.49548	104.6527	12.34602

Data	PK	L	Data
Log(Re/f)	1//f	1//f	1//f
80000034			
3.201667	12.40667	99.43696	12.21632
3.149860	12.19944	88.25528	11.94282
3.123438	12.09375	83.04593	11.93045
3.103855	12.01542	79.38440	11.81686
3.070646	11.88258	73.54050	11.71679
3.031399	11.72559	67.18616	11.45224
2.971694	11.48677	58.55640	11.29501
2.857529	11.03011	45.02037	10.82805
2.834690	10.93876	42.71400	10.67243
2.777245	10.70898	37.42190	10.49175
2.686434	10.34573	30.36089	10.15451
2.626770	10.10708	26.46366	10.08665
2.557939	9.831756	22.58495	9.917160
2.440270	9.361081	17.22464	9.856488
2.266768	8.667074	11.55177	11.08290
2.107650	8.030627	8.008235	7.971127
1.969413	7.477653	5.824974	5.740973
1.864658	7.058634	4.576555	4.430496
1.738193	6.552772	3.420369	3.299742

Data	PK	L	Data
Log(Re/f)	1//f	1//f	1//f
80000038			
1.803928	6.815714	3.979316	3.912053
1.946352	7.385408	5.523725	5.455952
2.060796	7.843187	7.189140	6.906283
2.150027	8.200109	8.828918	8.704182

	2.193292	8.373170	9.753772	9.332882
	2.280093	8.722375	11.92542	11.30610
	2.457288	9.429034	17.91177	9.762799
	2.587772	9.931090	24.19093	9.885934
	2.637629	10.91051	42.02520	10.53312
	2.883542	11.13417	47.77942	10.90704
	2.783982	10.53375	34.26199	10.29098
	2.738833	10.53533	34.25415	10.35154
	2.893266	11.17306	48.88177	10.97379
	2.972100	11.48840	58.61122	11.23485
	3.029325	11.71730	66.86609	11.46669
	3.068342	11.87337	73.15142	11.63235
	3.123021	12.09328	83.11920	11.84819
	3.146039	12.18415	87.48210	11.98175
	3.168830	12.27332	92.19560	11.98814
	3.209701	12.40280	99.21600	12.21314
	3.243942	12.57577	109.6030	12.35856
	3.206536	12.42622	100.5625	12.16920

Data Log(Ra/S)	PH 1/T	L 1/T	Data 1/T
S0000042	3.254697	12.61879	112.3511	12.87341
	3.208022	12.43208	100.9025	12.61578
	3.170107	12.28043	92.46720	12.32533
	3.151013	12.20405	88.48987	12.18403
	3.123689	12.09475	83.07587	11.84676
	3.072192	11.88876	73.80269	11.76375
	3.013247	11.65299	64.43587	11.51647
	2.897640	11.19044	49.37882	11.00138
	2.848854	11.07541	46.20980	10.91535
	2.767823	10.67129	36.61874	10.54032
	2.581467	9.925869	23.84226	10.00976
	2.689047	10.35619	30.54412	10.30985
	2.517926	9.671704	20.59709	9.938009
	2.449118	9.396474	17.57917	9.896904
	2.246065	8.584262	11.01401	10.99682
	2.164425	8.257700	9.126516	8.903499
	1.994079	7.576517	6.165372	6.215096
	1.802269	6.809078	3.964147	3.940869

Page 1 Solvent Set 4: Runs 80000065 - 80000085

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000065	3.091814	11.96468	77.16033	11.04873
	3.050246	11.80098	70.16402	11.01985
	3.013214	11.65288	64.43689	11.12158
	2.970487	11.49198	58.39395	10.81624
	2.882099	11.12859	47.64088	10.32265
	2.781417	10.72846	37.78305	10.26904
	2.689116	10.35446	30.34898	9.931553
	2.560192	9.840771	22.70245	9.617185

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000066	3.132414	12.12965	84.78018	11.35588
	3.122234	12.08894	82.81456	11.28622
	3.064878	11.94731	76.34108	11.15309
	3.055874	11.82349	71.08108	11.14023
	3.017643	11.67057	65.09135	10.96532
	2.980992	11.52396	59.82393	10.85053
	2.929335	11.31814	53.13931	10.73473
	2.887591	11.15056	48.26713	10.54187
	2.838462	11.03325	45.11726	10.27644
	2.836859	11.02743	44.95103	10.45147
	2.793454	10.78181	39.02428	10.19893
	2.794647	10.77846	38.93358	10.33902
	2.739942	10.55977	34.34178	10.07588
	2.701905	10.40762	31.46190	9.958834
	2.667869	10.27167	29.09041	9.897392

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000067	3.158135	12.23254	89.93299	11.44382
	3.103318	12.01327	79.28637	11.32899
	3.044864	11.83945	72.56786	11.12043
	2.976487	11.50394	59.20424	10.93296
	2.861562	11.04425	45.44044	10.73082
	2.894025	11.17610	48.96723	10.35396
	2.730097	10.52038	33.57200	9.982692
	2.595200	9.990601	24.60823	9.428523
	2.489865	9.559460	19.36834	9.346189
	2.218359	8.473436	10.33330	9.702147

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000068	2.656841	10.22736	28.36102	9.991616
	2.566727	9.842908	22.73039	9.780193
	2.471440	9.485762	18.50634	9.540397
	2.338494	8.933978	13.62619	10.40929

Page 2 Solvent Set 4: Runs 80000065 - 80000085

	2.212304	8.449216	10.19023	9.459614
	2.140277	8.161109	8.632911	8.327407
	2.085295	7.941181	7.606333	7.410057
	2.005018	7.620074	6.322643	6.148794
	1.901594	7.206377	4.982811	4.893889
	1.755188	6.620753	3.554874	3.410754

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000069	3.106148	12.02459	79.80478	11.23451
	3.105073	12.02029	79.60732	11.29968
	3.060855	11.85942	72.56641	11.13596
	3.022685	11.69074	65.85143	11.27479
	2.956277	11.41710	56.25450	10.90689
	2.849596	10.99838	44.20553	10.66324
	2.756024	10.61609	35.47354	10.26775
	2.647211	10.18884	27.73904	9.959317

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000072	3.146386	12.18554	87.55210	11.29784
	3.091539	11.96615	77.16481	11.26815
	3.049417	11.79846	70.06441	11.22440
	2.972871	11.49148	58.71529	10.84723
	2.866010	11.06404	45.90819	10.59060
	2.840877	10.96350	43.32687	10.54002
	2.758325	10.63330	35.82658	10.25718
	2.740105	10.56042	34.35462	10.09827
	2.636009	10.14603	27.03267	9.856086
	2.631658	10.12663	26.76322	9.849011
	2.544416	9.785666	21.99361	9.631831
	2.474025	9.496101	18.61681	9.530845
	2.321736	8.896944	13.11040	10.63683
	2.220361	8.481447	10.38106	9.728959
	2.150911	8.205246	8.844872	8.302606
	2.011370	7.645483	6.415801	6.254382
	1.897934	7.191739	4.940999	4.767862
	1.779161	6.716647	3.758735	3.574753

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000077	3.172080	12.28832	92.88815	11.38121
	3.144796	12.17918	87.23206	11.23900
	3.123606	12.09442	83.07805	11.24492
	3.093793	11.97517	77.56644	11.12922
	3.036274	11.74509	67.94447	10.96483
	2.938231	11.35292	54.21402	10.78498
	2.908748	11.23499	50.45576	10.68755
	2.834645	10.93858	42.709a0	10.5301e

	2.831272	10.92838	62.37918	10.46392
	2.788577	10.42258	51.72988	10.09332
	2.644638	10.17888	27.67458	9.925118
	2.566746	9.847968	25.04869	9.793234
	2.494387	9.577848	19.81044	9.557581
	2.319981	8.899727	15.66785	10.62784
	2.169145	8.276878	9.226213	9.197190
	2.096186	7.984744	7.799487	7.569662
	1.991958	7.567835	6.135343	5.883888
	1.879289	7.117157	4.733357	4.714956
	1.707389	6.429287	3.188387	3.062859

	Data Log(Rw/f)	PK 1/f	L 1/f	Data 1/f
80000081	3.172089	12.28832	92.88815	11.38121
	3.144796	12.17918	87.23206	11.23900
	3.123606	12.09642	83.07805	11.24492
	3.093793	11.97517	77.56644	11.12922
	3.038276	11.74509	67.94447	10.94493
	2.938231	11.35272	54.21402	10.78498

	Data Log(Rw/f)	PK 1/f	L 1/f	Data 1/f
80000085	3.146173	12.18469	87.50908	11.31425
	3.113779	12.05511	81.21939	11.18433
	3.093153	11.97261	77.45208	11.28853
	3.068607	11.87442	73.19401	11.01414
	3.011173	11.64470	64.12921	10.88928
	2.947103	11.38841	55.33290	10.67687
	2.858662	11.03464	45.13798	10.56542
	2.745447	10.58259	34.79588	10.27927
	2.635478	10.15391	27.18684	9.837140
	2.527554	9.710217	21.05885	9.727424
	2.454027	9.416199	17.77899	9.601603
	2.334533	8.938135	13.50249	10.53551
	2.242721	8.570884	10.92952	10.93321
	2.166154	8.264618	9.142936	8.694049

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000089	3.112021	12.04808	80.89120	11.89807
	3.086489	11.96475	76.38795	11.81074
	3.068927	11.87576	73.24994	11.69421
	3.039193	11.75477	68.60272	11.54907
	3.025267	11.70167	66.24615	11.50548
	2.976427	11.50570	59.19804	11.27732
	2.890367	11.16139	48.55428	10.99957
	2.789621	10.75848	38.80362	10.54759
	2.684979	10.33991	30.29936	10.29580
	2.604098	10.01639	25.11744	9.967027
	2.529267	9.717069	21.14206	9.756130
	2.423184	9.300738	16.63459	10.03202
	2.238407	8.554430	10.82648	10.79105
	2.196342	8.385370	9.822514	9.628492
	2.092796	7.971185	7.738849	9.345424

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000093	3.100553	12.00221	78.78325	11.81843
	3.069111	11.84044	71.77801	11.54812
	3.022472	11.68989	65.81924	11.38599
	2.945253	11.38101	55.09775	11.23142
	2.919948	11.27979	51.97901	11.11081
	2.829697	10.91878	42.22374	10.68501
	2.685743	10.34297	30.31262	10.02327
	2.553319	9.813276	22.34596	9.849707
	2.395225	9.180894	15.52757	10.06604

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000100	3.100655	12.00262	78.80173	11.77736
	3.087735	11.95094	76.49191	11.77180
	3.074910	11.89964	74.26603	11.72525
	3.060330	11.84132	71.81420	11.48738
	3.023025	11.69210	65.90298	11.38767
	2.946988	11.38795	55.31827	11.08115
	2.905014	11.22005	50.22208	10.95079
	2.681752	11.12701	47.60281	10.96495
	2.844072	10.97628	43.64679	10.76293
	2.815616	10.87446	41.16200	10.83999
	2.728216	10.51286	33.42694	10.39350
	2.640496	10.16198	27.31343	10.15920
	2.537654	9.750619	21.55434	9.841297
	2.449844	9.399384	17.60865	9.774193
	2.358625	8.634500	11.33718	11.23686
	2.178893	8.315375	9.435692	9.600309
	2.091269	7.965079	7.711695	7.796231

	1.990134	7.560539	6.109628	6.127747
	1.861087	7.044350	4.539078	4.584147
	1.763919	6.655679	3.629107	3.751327

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000116	3.184288	12.33715	95.53631	12.11000
	3.181670	12.32668	94.96205	12.15578
	3.150062	12.20024	88.29625	11.97227
	3.120202	12.08081	82.42952	11.96941
	3.077048	11.90819	74.63255	11.80346
	2.994308	11.57723	61.48629	11.32934
	2.933425	11.33370	53.61736	11.17226
	2.905986	11.22394	50.33458	11.31125
	2.881737	11.12694	47.60113	10.98042
	2.800729	10.80291	39.50110	10.81204
	2.711414	10.44565	32.15843	10.39474
	2.609831	10.03932	25.45136	10.06358
	2.493856	9.575424	19.48660	9.753502
	2.303801	8.815207	12.58003	11.71973
	2.224471	8.497885	10.47976	9.938083
	2.141614	8.166456	8.659528	8.458289
	2.099434	7.997739	7.858051	7.823745
	2.029003	7.716014	6.681649	6.700814
	1.898019	7.192077	4.941961	5.022760
	1.781359	6.725436	3.777800	3.775318

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f
80000117	3.170018	12.28007	92.44814	12.05153
	3.137180	12.14872	85.71582	11.97729
	3.117519	12.07007	81.92181	11.67754
	3.068500	11.87400	73.17802	11.63802
	3.017531	11.67012	65.07460	11.38411
	2.922548	11.29019	52.29119	11.04368
	2.893374	11.17349	48.89382	10.95337
	2.787118	10.74847	38.28233	10.54891
	2.700339	10.40135	31.34867	10.28648
	2.482482	9.529930	18.98289	9.649900
	2.563055	9.852220	22.85257	9.902820
	2.299989	8.799958	12.67008	11.06418
	2.235419	8.541678	10.74730	10.00803
	2.157684	8.230738	8.985961	8.686156
	2.087226	7.948905	7.640230	7.516080
	1.930911	7.355646	5.429896	5.506653
	1.787411	6.749645	3.830816	3.816162

	Data Log(Re/f)	PK 1//f	L 1//f	Data 1//f

80000125

3.158725	12.15490	86.02127	11.96073
3.108171	12.03266	80.17737	11.87593
3.071684	11.88473	73.71647	11.54916
3.017280	11.66960	65.03252	11.45492
2.977190	11.50376	59.30215	11.42842
2.916139	11.26453	51.52521	11.09796
2.872190	11.08876	46.56612	11.14741
2.773954	10.69582	37.13954	10.67885
2.685176	10.34070	30.27310	10.35610
2.563939	9.783756	21.76944	10.01034
2.436636	9.426545	17.08413	9.692793
2.285074	8.660299	11.50460	11.32564
2.192106	8.369126	9.727173	9.761575
2.130510	8.122043	8.440960	8.544174
2.057766	7.831667	7.139156	7.360951
1.967523	7.470094	5.799674	5.917074
1.857832	7.031329	4.505183	4.557007

Data Log(Ra/4)	PK 1/f4	L 1/f4	Data 1/f4

80000131

3.165715	12.26286	91.53485	12.09050
3.126816	12.11526	84.09067	11.94044
3.078118	11.91247	74.81466	11.97900
3.033328	11.74131	67.79473	11.58917
2.999419	11.59767	62.41653	11.37594
2.936126	11.34490	53.95188	11.11112
2.896005	11.18402	49.19093	11.01246
2.796743	10.78497	39.14023	10.62125
2.709422	10.43369	31.93762	10.23618
2.569645	9.878643	23.20303	9.815135
2.475765	9.503061	18.69155	9.712102
2.331466	8.925866	13.40746	10.04191
2.225304	8.501225	10.49995	10.13594
2.154585	8.218343	8.922074	8.892539
2.085354	7.941416	7.607565	7.582556
2.044510	7.784941	6.936492	6.906904
1.930234	7.320936	5.322491	5.339715
1.830790	6.923160	4.233212	4.201268

APPENDIX F

POLYMER-SOLUTION RUN DATA

Page 1 Cyanamid 832A

Q1P01465 5/19/90 12:58

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14 <C> (ppm)=
S = 2.7 S = 7.25 S = 9.9 [NaCl]=
Z = 2.7 Z = 8.25 Z = 7.5

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25	8.006333	0.0175	0.0915	7.914833
49	0.991564	25	5.340333	0.0175	0.0915	5.248833
40	0.80944	25	3.6085	0.0175	0.0915	3.517
30	0.60708	25	2.116333	0.0175	0.0915	2.024833
23	0.465428	25	1.34825	0.0175	0.0915	1.25675
16	0.323776	25	0.710333	0.0175	0.0915	0.618833
11	0.222596	25	0.435	0.0175	0.0915	0.3435
7	0.141652	25	0.242833	0.0175	0.0915	0.151333
18	0.364248	24.9	9.495333	0.0135	0.0315	9.481833
15	0.30354	25.15	5.046	0.0275	0.0415	5.0185
13	0.263068	25.15	4.67425	0.0275	0.0415	4.64675
10	0.20236	25.15	3.146166	0.0275	0.0415	3.118666
8	0.161888	25.15	2.173375	0.0275	0.0415	2.145875
		24.85	2.3584	0.0325	0.0205	2.3379
		24.8	1.598	0.0175	0.0155	1.5805
		24.8	1.1798	0.0145	0.0135	1.1653
		24.8	0.730166	0.0125	0.0115	0.717666
		24.7	0.530666	0.0105	0.0095	0.520166
		24.7	3.2116	-0.0145	-0.0355	3.2471
		24.65	2.5096	-0.0445	-0.0465	2.5561
		24.6	1.905857	-0.0535	-0.0545	1.960357
		24.6	1.167	-0.058	-0.0595	1.2265
		24.6	0.7622	-0.062	-0.0635	0.8257
		24.5	0.411166	-0.066	-0.0675	0.478666
		24.5	0.2655	-0.0685	-0.0695	0.335
		24.4	0.1822	-0.0695	-0.07	0.2522
		24.4	0.093733	-0.07	-0.071	0.164733
		24.3	0.041190	-0.071	-0.071	0.112190
		24.25	-0.00109	-0.072	-0.071	0.069909
		24.2	-0.03386	-0.071	-0.0715	0.037633
		24.3	4.4536	-0.07	-0.0835	4.5371
		24.4	7.019	-0.082	-0.0815	7.1005
		24.5	9.4675	-0.081	-0.078	9.5455
		24.6	13.4862	-0.0775	-0.069	13.5552

Page 2 Cyanamid 832A

		density	viscosity			
	co[NaCl]	1.000088	1.001574	ID(cm) =	1.45796	
1.008150	X coeff	-0.00025	-0.02281	K(V/psi)=	1.088055	12.19257
0.000100	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		7.274295	727.2685	118373.2	1026.242	0.003891	3.868294
		4.824051	593.9360	96671.50	680.5669	0.003869	3.779104
		3.252373	484.8457	78915.51	456.0163	0.003890	3.692159
		1.860965	363.6342	59186.63	262.5411	0.003981	3.572268
		1.155042	278.7862	45376.42	162.9509	0.004204	3.468697
		0.568751	193.9382	31566.20	80.23830	0.004278	3.314860
		0.315700	133.3325	21701.76	44.53842	0.005024	3.187036
		0.139086	84.84800	13810.21	19.62197	0.005466	3.009040
		0.777673	218.1805	35431.95	109.7124	0.004622	3.381812
		0.411603	181.8171	29693.63	58.06809	0.005522	3.246116
		0.381113	157.5748	25734.48	53.76664	0.004342	3.229403
		0.255784	121.2114	19795.75	36.08549	0.004925	3.142813
		0.175998	96.96914	15836.60	24.82950	0.005295	3.061631
2424	14.9	0.191747	97.44627	15807.18	27.05139	0.005712	3.077286
1939	14.9	0.129628	77.94898	12630.18	18.28766	0.006035	2.991778
1645	15	0.095574	65.68913	10643.70	13.48346	0.006266	2.925599
1620	19.9	0.058860	48.76192	7900.965	8.303982	0.007003	2.820342
1330	19.9	0.042662	40.03293	6471.977	6.018748	0.007531	2.749466
1329	19.9	0.042837	40.00283	6467.111	6.043478	0.007573	2.750357
1155	19.9	0.033721	34.76544	5614.065	4.757394	0.007893	2.697905
1224	25	0.025862	29.32650	4730.424	3.648602	0.008507	2.634791
1114	30	0.016180	22.24246	3587.753	2.282757	0.009252	2.557958
1090	35	0.010893	18.65423	3008.964	1.536786	0.008855	2.452035
1005	39.9	0.006314	15.08731	2428.130	0.890890	0.007848	2.332655
1186	59.9	0.004419	11.85978	1908.696	0.623499	0.008888	2.255161
933	59.9	0.003327	9.329829	1498.145	0.469392	0.010812	2.192526
613	60	0.002173	6.119671	982.6715	0.306600	0.016416	2.100044
623	89.9	0.001480	4.150947	665.0399	0.208808	0.024299	2.015646
391	90.1	0.000922	2.599386	415.9886	0.130114	0.038612	1.912442
280	120	0.000496	1.397641	223.4170	0.070042	0.071896	1.777469
1593	20	0.059856	47.70947	7642.726	8.444416	0.007438	2.819057
1609	15	0.093674	64.25156	10317.24	13.21539	0.006419	2.917298
1885	14.9	0.125970	75.77814	12195.62	17.76601	0.006203	2.982528
2360	14.9	0.178829	94.87343	15303.27	25.22883	0.005620	3.059677

Tap DL= 122.2234
75.79972 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.07317	461.5028	41.09759	16.03095	1.063541	0.034736
14.71641	375.8243	39.40299	16.07657	1.092424	0.042776
14.36863	307.6378	37.75103	16.03255	1.115801	0.052115
13.88907	233.4254	35.47309	15.84730	1.140991	0.067890
13.47479	185.8984	33.50526	15.42170	1.144485	0.083859
12.85944	129.0447	30.58234	15.28839	1.188885	0.118473
12.34814	96.14283	28.15370	14.10776	1.142500	0.146737
11.63616	63.81471	24.77177	13.52569	1.162384	0.211952
13.12724	150.5539	31.85443	14.70899	1.120493	0.097699
12.58446	110.1529	29.27620	16.84795	1.338790	0.152950
12.51761	105.9946	28.95867	15.17440	1.212244	0.143162
12.17125	86.83475	27.31345	14.24815	1.170639	0.164083
11.84652	72.02965	25.77099	13.74139	1.159951	0.190774
11.90914	74.67349	26.06844	13.23024	1.110931	0.177174
11.56711	61.32791	24.44378	12.87157	1.112773	0.209881
11.30239	52.65987	23.18639	12.63260	1.117692	0.239890
10.88136	41.32590	21.18650	11.94917	1.098131	0.289144
10.59786	35.10322	19.83987	11.52311	1.087305	0.328263
10.60142	35.17526	19.85679	11.49087	1.083898	0.326674
10.39162	31.17352	18.86021	11.25567	1.083148	0.361065
10.15916	27.26917	17.75604	10.84196	1.067210	0.397590
9.751832	21.56940	15.82120	10.39595	1.066051	0.481977
9.408141	17.69764	14.18867	10.62628	1.129477	0.600435
8.930622	13.44422	11.92045	11.28798	1.263963	0.839615
8.620646	11.24712	10.44806	10.60657	1.230369	0.943047
8.370105	9.736581	9.258003	9.616730	1.148937	0.987690
8.000178	7.869093	7.500849	7.804833	0.975582	0.991833
7.662587	6.479280	5.897288	6.415063	0.837192	0.990088
7.249771	5.108848	3.936416	5.089070	0.701962	0.996128
6.709879	3.744121	1.371928	3.729464	0.555816	0.996085
10.87623	41.20386	21.16210	11.59437	1.066028	0.281390
11.26919	51.66285	23.02867	12.48146	1.107573	0.241594
11.53015	60.03693	24.26823	12.69595	1.101109	0.211469
11.83870	71.70630	25.73386	13.33850	1.126685	0.186015

01P01465

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.890890	82.78591	-0.05017	1.917956
0.623499	65.07604	-0.20516	1.813421
0.469392	51.19388	-0.32846	1.709218
0.306600	33.57936	-0.51342	1.526072
0.208808	22.77674	-0.68025	1.357491
0.130114	14.26314	-0.88567	1.154215
0.070042	7.669023	-1.15463	0.884740

Regression Output:

Constant	-2.04025
Std Err of Y Est	0.001118
R Squared	0.999989
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	1.000916
Std Err of Coef.	0.002338

Tw vs. K'*(8<U>/D)^n

K' = 0.009114
n = 1.000916

Tw* = 0.010550
Res/f* = 23.67577

Regression Output:

Constant	-1.71307
Std Err of Y Est	0.414623
R Squared	0.918856
No. of Observations	15
Degrees of Freedom	13
X Coefficient(s)	4.955447
Std Err of Coef.	0.408425

t = 24.73382 deg C
s.d.)t = 0.286387 deg C

Q2P01462 5/16/90 13:17

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=	
Z =	2.7	Z =	8.2	Z =	7.5	[NaCl]=	

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
24	0.485664	25.9	0.914	0.0285	0.0345	0.8855
33	0.667788	25.9	1.631333	0.0285	0.0345	1.602833
39	0.789204	25.9	2.241333	0.0285	0.0345	2.212833
48	0.971328	25.9	3.472333	0.0285	0.0345	3.443833
60	1.21416	25.9	5.733	0.0285	0.0345	5.7045
53	1.072508	25.9	4.366	0.0285	0.0345	4.3375
19	0.384484	25.9	0.612333	0.0285	0.0345	0.577833
11	0.222596	25.9	0.2898	0.0285	0.0345	0.2553
15	0.30354	25.9	0.4226	0.0285	0.0345	0.3881
9	0.182124	25.9	0.210428	0.0285	0.0345	0.175928
18	0.364248	26.1	5.9974	0.0475	0.0465	5.9499
24	0.485664	26.1	9.4268	0.0475	0.0465	9.3793
		25.9	1.7878	0.044	0.042	1.7458
		25.75	1.135	0.0435	0.0415	1.0915
		25.8	0.9278	0.0425	0.0415	0.8853
		25.7	0.5515	0.0425	0.0415	0.509
		25.7	0.406	0.0415	0.0405	0.3645
		25.6	2.318333	0.0525	0.0375	2.280833
		25.5	1.8665	0.017	0.0175	1.849
		25.5	1.370666	0.0145	0.0125	1.358166
		25.5	0.827	0.008	0.0065	0.8205
		25.4	0.62975	0.0025	0.0015	0.62825
		25.4	0.489545	-0.001	-0.0005	0.490045
		25.35	0.367312	-0.0015	-0.0025	0.369812
		25.3	0.244380	-0.0025	-0.0015	0.245880
		25.2	0.154652	-0.0015	-0.0005	0.155152
	0.098538	25.05	0.098	0	0.0015	0.0965
		24.9	0.042875	0.0015	0.0015	0.041375
		24.8	0.022	0.0015	0.0005	0.0205
		25.1	3.1892	-0.0005	-0.0105	3.1997
		25.3	4.96825	-0.0095	-0.0095	4.97775
		25.5	7.0312	-0.0095	-0.0065	7.0377
		25.5	10.5858	-0.0055	-0.0045	10.5903

		density	viscosity			
	co[NaCl]	1.000088	1.001574	ID(cm) =	1.45796	
2.015260	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08	12.09067
0.000100	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		0.819907	290.9074	48320.51	115.6707	0.002741	3.403148
		1.484104	399.9977	66440.71	209.3743	0.002624	3.531998
		2.048919	472.7245	78520.84	289.0572	0.002594	3.602028
		3.188734	581.8148	96641.03	449.8599	0.002665	3.698074
		5.281944	727.2685	120801.2	745.1655	0.002826	3.807662
		4.016203	642.4205	106707.8	566.5974	0.002753	3.748173
		0.535030	230.3017	38253.74	75.48101	0.002854	3.310455
		0.236388	133.3325	22146.90	33.34924	0.003762	3.133079
		0.359351	181.8171	30200.32	50.69659	0.003076	3.224025
		0.162896	109.0902	18120.19	22.98113	0.003873	3.052222
		0.492106	218.1805	36404.27	69.42537	0.002925	3.294265
		0.775746	290.9074	48539.03	109.4407	0.002594	3.393096
2594	15	0.144392	103.5851	17205.78	20.37056	0.003808	3.026037
2000	15	0.090276	79.86520	13221.01	12.73597	0.004005	2.922574
1685	15.1	0.073221	66.84083	11077.42	10.32996	0.004637	2.877600
1646	20	0.042098	49.29680	8151.470	5.939177	0.004902	2.756429
1358	20	0.030147	40.67135	6725.210	4.253104	0.005157	2.683918
1692	25	0.030090	40.53958	6688.314	4.245070	0.005180	2.682523
1469	25	0.024393	35.19659	5793.731	3.441345	0.005571	2.635959
1482	29.9	0.017917	29.68902	4887.126	2.527809	0.005752	2.568967
1320	34.9	0.010824	22.65517	3729.280	1.527108	0.005967	2.459530
1278	40.1	0.008288	19.08997	3135.330	1.169294	0.006435	2.400572
1537	59.9	0.006465	15.36971	2524.316	0.912068	0.007743	2.346624
1175	59.9	0.004878	11.74978	1927.604	0.688292	0.009999	2.285004
1183	90	0.003243	7.873378	1290.206	0.457631	0.014806	2.195883
740	89.9	0.002046	4.930499	806.1378	0.288768	0.023823	2.094914
910	180.1	0.001273	3.026541	493.1684	0.179605	0.039323	1.990321
420	200	0.000545	1.257877	204.2759	0.077006	0.097603	1.804948
238	240	0.000270	0.593997	96.24627	0.038154	0.216858	1.651471
1629	20	0.042212	48.78766	7958.818	5.955257	0.005017	2.751104
1629	14.9	0.065669	65.48679	10731.28	9.264551	0.004332	2.849037
1960	14.9	0.092845	78.79319	12970.19	13.09851	0.004231	2.926206
2502	14.9	0.139714	100.5819	16556.84	19.71058	0.003907	3.014945

Tap DL= 122.2234
75.79972 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.21259	158.1350	32.25981	19.09780	1.445424	0.120768
13.72799	212.7541	34.70796	19.51804	1.421769	0.091739
14.00811	249.9816	36.03853	19.63164	1.401448	0.078532
14.39229	311.8565	37.86342	19.36808	1.345725	0.062105
14.83065	401.3679	39.94558	18.81087	1.268378	0.046866
14.59269	349.9883	38.81529	19.05559	1.305831	0.054446
12.84182	127.7424	30.49864	18.71624	1.457445	0.146515
12.13231	84.91008	27.12850	16.30173	1.343661	0.191988
12.49610	104.6901	28.85648	18.02959	1.442817	0.172218
11.80888	70.48586	25.59221	16.06722	1.360604	0.227949
12.77706	123.0681	30.19104	18.48785	1.446956	0.150224
13.17238	154.5169	32.06882	19.63337	1.490495	0.127062
11.70415	66.36174	25.09471	16.20453	1.384511	0.244184
11.29029	52.29432	23.12891	15.80120	1.399538	0.302158
11.11040	47.14987	22.27441	14.68379	1.321625	0.311428
10.62571	35.67048	19.97215	14.28258	1.344153	0.400403
10.33567	30.18553	18.59445	13.92473	1.347247	0.461304
10.33009	30.08867	18.56793	13.89292	1.344898	0.461732
10.14383	27.02959	17.68323	13.39672	1.320676	0.495631
9.875870	23.16581	16.41038	13.18517	1.335090	0.569165
9.438121	18.00571	14.33107	12.94478	1.371541	0.718926
9.202288	15.71998	13.21087	12.46554	1.354613	0.792973
8.986496	13.88366	12.18585	11.36369	1.264530	0.818494
8.740016	12.04714	11.01507	10.00031	1.144199	0.830098
8.383532	9.812127	9.321780	8.218188	0.980277	0.837554
7.979657	7.776684	7.403374	6.478804	0.811915	0.833106
7.561285	6.112254	5.416106	5.042825	0.666926	0.825035
6.819795	3.988677	1.894029	3.200872	0.469350	0.802489
6.205886	2.801248	-1.02203	2.147396	0.346025	0.766585
10.60441	35.23586	19.87099	14.11703	1.331241	0.400644
10.99614	44.14863	21.73170	15.19198	1.381573	0.344110
11.30482	52.73349	23.19792	15.37233	1.359803	0.291509
11.65978	64.68823	24.88395	15.99677	1.371961	0.247290

Q2P01462

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.912068	84.33548	-0.03997	1.926010
0.688292	64.47247	-0.16222	1.809374
0.457631	43.20216	-0.33948	1.635505
0.288768	27.05423	-0.53945	1.432235
0.179605	16.60699	-0.74568	1.220290
0.077006	6.902121	-1.11347	0.838982
0.038154	3.259334	-1.41845	0.513128

Regression Output:

Constant	-1.92195
Std Err of Y Est	0.006467
R Squared	0.999852
No. of Observations	6
Degrees of Freedom	4

X Coefficient(s) 0.968245
Std Err of Coef. 0.005886

Tw vs. K'*(8<U>/D)^n

K' = 0.011968
n = 0.968245

Tw)Retro=0.699017
Res/f)R= 196.6891

Regression Output:

Constant	-4.88763
Std Err of Y Est	0.388709
R Squared	0.974677
No. of Observations	23
Degrees of Freedom	21

X Coefficient(s) 7.005665
Std Err of Coef. 0.246414

t = 25.60454 deg C
s.d.)t = 0.338750 deg C

Page 1 Cyanamid 832A

05P01459 5/13/90 13:52

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 7.5 Z = 8.15 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.8	3.67125	0.0285	0.0305	3.64075
50	1.0118	24.8	2.4975	0.0285	0.0305	2.467
41	0.829676	24.8	1.692666	0.0285	0.0305	1.662166
33	0.667788	24.8	1.146	0.0285	0.0305	1.1155
26	0.526136	24.8	0.76325	0.0285	0.0305	0.73275
18	0.364248	24.8	0.432666	0.0285	0.0305	0.402166
13	0.263068	24.8	0.261666	0.0285	0.0305	0.231166
9	0.182124	24.8	0.1665	0.0285	0.0305	0.136
18	0.364248	25	4.4485	0.0195	0.0345	4.429
24	0.485664	25	7.207333	0.0195	0.0345	7.187833
28	0.566608	25	9.096666	0.0195	0.0345	9.077166
32	0.647552	25	11.513	0.0195	0.0345	11.4935
		24.8	1.278	0.0225	0.0165	1.2615
		24.8	0.861	0.0165	-0.1	0.8445
		24.7	0.689	0.0615	0.0565	0.6275
		24.7	0.458	0.0565	0.0515	0.4015
		24.7	0.367	0.0515	0.0475	0.3155
		24.6	1.984857	-0.0285	-0.0355	2.020357
		24.6	1.558285	-0.0315	-0.0315	1.589785
		24.6	1.191857	-0.0335	-0.0345	1.226357
		24.6	0.7723	-0.0365	-0.0385	0.8108
		24.6	0.621545	-0.0395	-0.0415	0.663045
		24.6	0.471833	-0.0425	-0.0435	0.515333
		24.5	0.333722	-0.0445	-0.0445	0.378222
		24.5	0.233625	-0.0445	-0.0435	0.277125
		24.5	0.140352	-0.0435	-0.0415	0.181852
		24.4	0.094272	-0.0405	-0.0375	0.131772
		24.3	0.058526	-0.0375	-0.0335	0.092026
		24.3	0.024136	-0.0335	-0.031	0.055136
		24.3	0	-0.0305	-0.0305	0.0305
		24.35	2.535333	-0.031	-0.043	2.578333
		24.4	4.020166	-0.0415	-0.0395	4.059666
		24.6	5.116833	-0.0385	-0.037	5.153833
		24.6	8.023333	-0.0355	-0.0295	8.052833

Page 2 Cyanamid 832A

		density	viscosity			
	co[NaCl]	1.000088	1.001574	ID(cm) =	1.45796	
4.991468	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08	12.03909
0.000100	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		3.371064	727.2685	117840.3	475.5826	0.001803	3.699312
		2.284259	606.0571	98200.31	322.2584	0.001759	3.614801
		1.539043	496.9668	80524.25	217.1249	0.001763	3.529053
		1.032870	399.9977	64812.20	145.7151	0.001826	3.442451
		0.678472	315.1497	51064.16	95.71742	0.001932	3.351194
		0.372376	218.1805	35352.11	52.53409	0.002213	3.220919
		0.214043	157.5748	25532.08	30.19676	0.002438	3.100679
		0.125925	109.0902	17676.05	17.76536	0.002993	2.985486
		0.367884	218.1805	35511.98	51.90042	0.002186	3.220254
		0.597041	290.9074	47349.31	84.22931	0.001996	3.325401
		0.753974	339.3920	55240.86	106.3691	0.001851	3.376077
		0.954681	387.8765	63132.41	134.6844	0.001795	3.427328
2515	14.9	0.104783	101.1045	16382.11	14.78265	0.002900	2.945575
1973	15	0.070146	78.78702	12765.97	9.896119	0.003197	2.858431
1642	15	0.052121	65.56933	10600.35	7.353244	0.003429	2.792953
1629	20	0.033349	48.78766	7887.321	4.704904	0.003963	2.695989
1345	20	0.026206	40.28201	6512.244	3.697129	0.004569	2.643646
1680	24.9	0.026466	40.41372	6518.814	3.733893	0.004584	2.644809
1467	25.1	0.020826	35.00864	5646.964	2.938138	0.004807	2.592764
1230	25	0.016065	29.47026	4753.612	2.266473	0.005233	2.536404
1344	35	0.010621	23.00118	3710.136	1.498467	0.005679	2.446552
1259	40	0.008685	18.85318	3041.055	1.225397	0.006913	2.402867
1143	44.9	0.006750	15.24820	2459.566	0.952405	0.008214	2.348139
1122	60	0.006954	11.20109	1802.687	0.699005	0.011171	2.279983
807	60	0.003630	8.056403	1296.585	0.512164	0.015823	2.212448
530	60	0.002382	5.291070	851.5370	0.336088	0.024073	2.120970
580	90	0.001726	3.860151	619.8471	0.243533	0.032772	2.050037
397	90.1	0.001205	2.639274	422.8487	0.170077	0.048957	1.971095
240	90	0.000722	1.597304	255.9104	0.101899	0.080083	1.859859
250	180.1	0.000399	0.831467	133.2127	0.056368	0.163488	1.771289
1602	19.9	0.033776	48.22012	7734.258	4.765108	0.004109	2.695302
1634	15.1	0.053182	64.81775	10408.16	7.502812	0.003580	2.794370
1948	15	0.067515	77.78871	12547.47	9.524980	0.003156	2.848160
2516	15	0.105492	100.4704	16206.08	14.88272	0.002956	2.945069

Tap DL= 122.2234
76.33526 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.39724	312.7462	37.88692	23.54951	1.635695	0.075299
14.05920	257.4431	36.28122	23.84029	1.695707	0.092604
13.71621	211.3167	34.65202	23.81621	1.736354	0.112703
13.36980	173.1137	33.00657	23.39943	1.750170	0.135168
13.00477	140.3054	31.27269	22.74687	1.749116	0.162123
12.48367	103.9440	28.79747	21.25669	1.702758	0.204501
12.00271	78.80600	26.51290	20.24915	1.687047	0.256949
11.54194	60.44580	24.32423	18.27676	1.583508	0.302366
12.48101	103.7850	28.78484	21.38552	1.713443	0.206055
12.90160	132.2151	30.78262	22.38270	1.734877	0.169290
13.10430	148.5789	31.74546	23.23716	1.773246	0.156396
13.30931	167.1892	32.71923	23.60065	1.773243	0.141161
11.38230	55.13855	23.56593	18.56925	1.631415	0.336774
11.03372	45.11402	21.91019	17.68570	1.602877	0.392022
10.77181	38.80014	20.66611	17.07524	1.585178	0.440081
10.38395	31.03625	18.82379	15.88328	1.529598	0.511765
10.17458	27.51225	17.82927	14.79396	1.454011	0.537722
10.17923	27.58605	17.85138	14.76926	1.450920	0.535388
9.971059	24.47061	16.86253	14.42282	1.446468	0.589393
9.745616	21.49235	15.79167	13.82355	1.418438	0.643184
9.386209	17.47561	14.08449	13.26897	1.413667	0.759285
9.211468	15.80327	13.25447	12.02699	1.305654	0.761044
8.992558	13.93219	12.21465	11.03364	1.226974	0.791952
8.719935	11.90868	10.91969	9.460991	1.084984	0.794461
8.449792	10.19361	9.636516	7.949740	0.940820	0.779874
8.083882	8.257537	7.898439	6.445149	0.797283	0.780517
7.800151	7.013227	6.550720	5.523911	0.708179	0.787641
7.484383	5.847577	5.050823	4.519486	0.603855	0.772881
7.039436	4.526255	2.937321	3.533695	0.501985	0.780710
6.525159	3.366432	0.494507	2.473180	0.379022	0.734659
10.38120	30.98718	18.81073	15.59971	1.502687	0.503424
10.77748	38.92694	20.69303	16.71105	1.550552	0.429292
10.99264	44.05962	21.71505	17.79900	1.619173	0.403975
11.38027	55.07441	23.55632	18.39111	1.616051	0.333932

05P01459

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.952405	83.66872	-0.02117	1.922563
0.699005	61.46174	-0.15551	1.788604
0.512164	44.20644	-0.29059	1.645485
0.336088	29.03273	-0.47354	1.462887
0.243533	21.18111	-0.61344	1.325948
0.170077	14.48201	-0.76935	1.160828
0.101899	8.764598	-0.99182	0.942732
0.056368	4.562360	-1.24896	0.659189

Regression Output:

Constant	-1.92127
Std Err of Y Est	0.003412
R Squared	0.999918
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	0.988725
Std Err of Coef.	0.003990

Tw vs. K'*(8<U>/D)^n

K' = 0.011987
n = 0.988725

Tw)Retro=0.775105
Res/f)R= 202.0130

Regression Output:

Constant	-13.6573
Std Err of Y Est	0.273221
R Squared	0.994377
No. of Observations	23
Degrees of Freedom	21
X Coefficient(s)	10.87003
Std Err of Coef.	0.178573

t = 24.66029 deg C
s.d.)t = 0.202113 deg C

01P11453 5/7/90 12:38

10 PSID Taps 14	1.0 PSID Taps 14	0.1 PSID Taps 14	
S = 2.7	S = 7.25	S = 9.9	<C>(pps)=
Z = 2.7	Z = 7.65	Z = 8.1	[NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	24.6	2.26	0.0245	0.0235	2.2365
50	1.0118	24.6	1.545	0.0245	0.0235	1.5215
40	0.80944	24.6	1.04425	0.0245	0.0235	1.02075
31	0.627316	24.6	0.684	0.0245	0.0235	0.6605
24	0.485664	24.6	0.463666	0.0245	0.0235	0.440166
18	0.364248	24.6	0.29375	0.0245	0.0235	0.27025
14	0.283304	24.6	0.21075	0.0245	0.0235	0.18725
11	0.222596	24.6	0.1502	0.0245	0.0235	0.1267
8	0.161888	24.6	0.099	0.0245	0.0235	0.0755
18	0.364248	24.6	3.123	0.0145	0.0185	3.1085
26	0.526136	24.8	5.39025	0.0145	0.0185	5.37575
35	0.70826	24.8	9.063666	0.0145	0.0185	9.049166
		24.5	1.021166	0.0275	0.0265	0.994666
		24.4	0.715714	0.0275	0.0265	0.688214
		24.3	0.568428	0.0275	0.0235	0.540928
		24.3	0.403333	0.0235	0.0235	0.379833
		24.25	0.336	0.0235	0.0235	0.3125
		24.2	1.837428	0.014	-0.066	1.863428
		24.2	1.570714	-0.0665	-0.0665	1.637214
		24.2	1.263	-0.0665	-0.066	1.32925
		24.2	0.94	-0.0645	-0.0645	1.0045
		24.2	0.7567	-0.062	-0.0595	0.81745
		24.1	0.632545	-0.055	-0.054	0.687045
		24	0.46125	-0.0495	-0.0465	0.50925
		23.9	0.239833	-0.0445	-0.0345	0.279333
		23.9	0.334181	-0.0325	-0.0375	0.366681
		23.9	0.18	-0.0355	-0.0195	0.2075
		23.8	0.134090	-0.0185	-0.0135	0.150090
		23.8	0.084666	-0.0125	-0.0095	0.095666
		23.8	0.053428	-0.0095	-0.0075	0.061928
		23.9	2.396166	-0.0075	-0.0395	2.419666
		24	3.445666	-0.0365	-0.0425	3.485166
		24.2	4.45025	-0.0415	-0.0445	4.49325
		24.2	6.203	-0.042	-0.0465	6.24725

		density	viscosity				11.93037
	co[NaCl]	1.000088	1.001574		ID(cm) =	1.45796	12.03909
9.974748	X coeff	-0.00025	-0.02281		K(V/psi)=	1.08	12.03909
0.000099	constant	0.003419	-4.14933		XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		2.070833	727.2685	117309.8	292.1487	0.001107	3.591530
		1.408796	606.0571	97758.23	198.7499	0.001085	3.507882
		0.945138	484.8457	78206.58	133.3381	0.001137	3.421205
		0.611574	375.7554	60610.10	86.27957	0.001225	3.326682
		0.407561	290.9074	46923.95	57.49794	0.001362	3.238554
		0.250231	218.1805	35192.96	35.30212	0.001487	3.132629
		0.173379	169.6960	27372.30	24.46003	0.001703	3.052957
		0.117314	133.3325	21506.81	16.55052	0.001866	2.968134
		0.069907	96.96914	15641.31	9.862388	0.002103	2.855719
		0.258200	218.1805	35352.11	36.42638	0.001534	3.141407
		0.446524	315.1497	51064.16	62.99474	0.001271	3.260351
		0.751648	424.2400	68740.22	106.0410	0.001181	3.373436
2515	14.9	0.082619	101.1045	16271.61	11.65581	0.002286	2.891014
2570	20	0.057164	76.97009	12359.55	8.064713	0.002729	2.810052
2130	20	0.044931	63.79233	10220.42	6.338772	0.003123	2.756775
1592	20	0.031550	47.67953	7638.928	4.451007	0.003925	2.680002
1648	25	0.025957	39.48535	6318.975	3.661974	0.004709	2.637138
1641	24.9	0.024411	39.47554	6310.282	3.443867	0.004431	2.623311
1431	25	0.021447	34.28613	5480.740	3.025793	0.005161	2.595207
1200	25	0.017413	28.75147	4596.008	2.456633	0.005958	2.549958
1111	29.9	0.013159	22.25675	3557.807	1.856451	0.007514	2.489129
1060	35	0.010708	18.14081	2899.862	1.510758	0.009204	2.444385
1018	40	0.009000	15.24427	2431.350	1.269752	0.010955	2.405662
731	40.1	0.006671	10.91922	1737.613	0.941162	0.015826	2.339649
381	44.9	0.003659	5.082735	807.0100	0.516245	0.040064	2.208260
583	45	0.004803	7.760236	1232.129	0.677677	0.022561	2.267343
275	45	0.002718	3.660488	581.1931	0.383488	0.057381	2.143708
179	44.9	0.001966	2.387951	378.2920	0.277388	0.097527	2.072391
130	60.2	0.001253	1.293498	204.9119	0.176804	0.211862	1.974594
69	59.9	0.000811	0.689987	109.3056	0.114452	0.481984	1.880159
1193	15	0.031697	47.63959	7563.964	4.471871	0.003950	2.677076
1566	14.9	0.045656	62.95415	10018.10	6.441059	0.003258	2.757296
1887	15	0.058862	75.35282	12045.37	8.304133	0.002932	2.814435
2455	14.9	0.081839	98.69249	15776.28	11.54576	0.002376	2.885999

Page 3 Cyanamid 832A

74.66555
76.33526 Tap DL= 122.2234
76.33526 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.96612	244.0117	35.83908	30.04719	2.151433	0.123138
13.63152	201.2622	34.24976	30.35785	2.227032	0.150837
13.28482	164.8488	32.60291	29.65086	2.231935	0.179866
12.90673	132.6058	30.80697	28.56684	2.213329	0.215426
12.55421	108.2517	29.13254	27.09191	2.157992	0.250267
12.13051	84.82212	27.11995	25.93144	2.137703	0.305715
11.81182	70.60528	25.60618	24.23004	2.051337	0.343176
11.47253	58.07839	23.99455	23.14416	2.017353	0.398498
11.02287	44.83320	21.85867	21.80487	1.978146	0.486355
12.16562	86.55400	27.28673	25.52749	2.098329	0.294931
12.64140	113.8233	29.54667	28.03915	2.218041	0.246339
13.09374	147.6780	31.69528	29.09208	2.221831	0.196996
11.16405	48.62895	22.52928	20.91297	1.873240	0.430051
10.84021	40.35829	20.99100	19.14033	1.765679	0.474260
10.62710	35.69897	19.97873	17.89341	1.683753	0.501230
10.32000	29.91453	18.52004	15.95990	1.546500	0.533516
10.14855	27.10304	17.70562	14.57164	1.435834	0.537638
10.09324	26.25373	17.44291	15.02234	1.488356	0.572198
9.980830	24.60863	16.90894	13.91975	1.394649	0.565645
9.799832	22.17369	16.04920	12.95456	1.321916	0.584231
9.556518	19.27568	14.89346	11.53593	1.207127	0.598470
9.377541	17.38863	14.04332	10.42298	1.111483	0.599413
9.222649	15.90531	13.30758	9.554001	1.035928	0.600679
8.958599	13.66249	12.05334	7.948829	0.887284	0.581799
8.433042	10.09579	9.556950	4.995953	0.592425	0.494854
8.669375	11.56708	10.67953	6.657519	0.767935	0.575557
8.174832	8.701382	8.330456	4.174574	0.510661	0.479759
7.889564	7.383651	6.975432	3.202108	0.405866	0.433675
7.498377	5.894871	5.117291	2.172566	0.289738	0.368551
7.120638	4.742851	3.323030	1.440400	0.202285	0.303699
10.30830	29.71371	18.46446	15.91008	1.543423	0.535445
10.62918	35.74177	19.98862	17.51819	1.648122	0.490132
10.85774	40.76759	21.07426	18.46652	1.700770	0.452970
11.14399	48.07056	22.43398	20.51188	1.840622	0.426703

Page 4 Cyanamid 832A

01P11453

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.269752	83.64713	0.103719	1.922451
0.941162	59.91509	-0.02633	1.777536
0.516245	27.88957	-0.28714	1.445441
0.677677	42.58133	-0.16897	1.629219
0.383488	20.08553	-0.41624	1.302883
0.277388	13.10297	-0.55691	1.117369
0.176804	7.097577	-0.75250	0.851110
0.114452	3.786043	-0.94137	0.578185

Regression Output:

Constant	-1.37424
Std Err of Y Est	0.006784
R Squared	0.999611
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.736518
Std Err of Coef.	0.008379

Tw vs. K'*(8<U>/D)^n

K' = 0.042242
n = 0.736518

Tw)Retro=29.84650
Res/f)R =1247.887

Regression Output:

Constant	-3.39885
Std Err of Y Est	0.075995
R Squared	0.994728
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	9.633234
Std Err of Coef.	0.404877

t = 24.29558 deg C
s.d.)t = 0.311157 deg C

Cyanamid 832A

02P11456

5/10/90 9:20(H20)12:45

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14	
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=
Z =	2.7	Z =	8.15	Z =	7.5	[NaCl]=

	Freq. (Hz)	Q)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
^	60	1.21416	23.3	8.85175	0.0285	0.0395	8.81225
.	50	1.0118	23.3	6.39325	0.0285	0.0395	6.35375
.	40	0.80944	23.3	4.3352	0.0285	0.0395	4.2957
.	30	0.60708	23.3	2.5988	0.0285	0.0395	2.5593
.	21	0.424956	23.3	1.3874	0.0285	0.0395	1.3479
.	14	0.283304	23.3	0.691	0.0285	0.0395	0.6515
.	9	0.182124	23.3	0.364333	0.0285	0.0395	0.324833
.	7	0.141652	23.3	0.238166	0.0285	0.0395	0.198666
H20							
.	18	0.364248	23.3	11.4115	-0.0265	-0.0265	11.438
.	13	0.263068	23.3	6.551222	-0.0265	-0.0265	6.577722
.	15	0.30354	23.3	8.390111	-0.0265	-0.0265	8.416611
.	11	0.222596	23.3	4.7916	-0.0265	-0.0265	4.8181
v	8	0.161888	23.3	2.8075	-0.0265	-0.0265	2.834
	60	1.21416	25	1.969333	0.0345	0.0365	1.932833
	50	1.0118	25	1.39	0.0345	0.0365	1.3535
	42	0.849912	25	1.053333	0.0345	0.0365	1.016833
	32	0.647552	25	0.697	0.0345	0.0365	0.6605
	25	0.5059	25	0.472333	0.0345	0.0365	0.435833
	19	0.384484	25	0.32875	0.0345	0.0365	0.29225
	14	0.283304	25	0.22875	0.0345	0.0365	0.19225
	10	0.20236	25	0.1485	0.0345	0.0365	0.112
	8	0.161888	25	0.125625	0.0345	0.0365	0.089125
	18	0.364248	25.1	3.1305	0.0125	0.0095	3.118
	24	0.485664	25.1	4.4316	0.0125	0.0095	4.4191
	30	0.60708	25.1	6.5284	0.0625	0.0095	6.4659
			24.8	1.0706	0.0255	0.0195	1.0511
			24.8	0.7585	0.0205	0.0175	0.738
			24.7	0.634	0.0175	0.0155	0.6165
			24.6	0.455571	0.0155	0.0125	0.440071
			24.6	0.366666	0.0125	0.0095	0.354166
			24.6	0.246444	0.0105	0.0095	0.235944
			24.5	1.514111	0.0175	0.0085	1.505611
			24.5	1.162	0.0135	0.0135	1.1485
			24.5	0.9399	0.0125	0.0125	0.9274
			24.4	0.798909	0.0075	0.0125	0.786409
			24.35	0.602333	0.0025	0.0125	0.589833
			24.3	0.269809	-0.0005	0.0125	0.257309
			24.2	0.3875	0.0025	0.0125	0.375
			24.2	0.190857	-0.0055	0.0125	0.178357

Cyanamid 832A

24.1	0.1159	-0.0015	-0.0015	0.1174
24.2	2.1935	-0.0015	-0.0225	2.216
24.3	2.703833	-0.023	-0.024	2.727833
24.4	3.728166	-0.0235	-0.0225	3.750666
24.5	4.383166	-0.0215	-0.0215	4.404666
24.6	6.5538	-0.0215	-0.015	6.5688

Page 3 Cyanamid 832A

		density	viscosity			
	co[NaCl]	1.000088	1.001574	ID(cm) =	1.45796	
20.00475	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08	12.03909
0.000100	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		8.159490	727.2685	113919.3	1151.123	0.004362	3.876482
		5.883101	606.0571	94932.81	829.9755	0.004529	3.805453
		3.9775	484.8457	75946.25	561.1372	0.004785	3.720455
		2.369722	363.6342	56959.68	334.3153	0.005068	3.607999
		1.248055	254.5440	39871.78	176.0730	0.005447	3.468767
		0.603240	169.6960	26581.18	85.10392	0.005924	3.310895
		0.300771	109.0902	17087.90	42.43221	0.007147	3.159769
		0.183950	84.84800	13290.59	25.95136	0.007226	3.053001
		0.950071	218.1805	34175.81	134.0341	0.005644	3.409528
		0.546363	157.5748	24682.53	77.07983	0.006223	3.289391
		0.699106	181.8171	28479.84	98.62852	0.005980	3.342922
		0.400206	133.3325	20885.21	56.46002	0.006366	3.221791
		0.235399	96.96914	15189.25	33.20971	0.007080	3.106553
		1.789660	727.2685	118373.2	252.4815	0.000957	3.563784
		1.253240	606.0571	98644.39	176.8045	0.000965	3.486416
		0.941512	509.0880	82861.29	132.8265	0.001027	3.424311
		0.611574	387.8765	63132.41	86.27957	0.001150	3.330623
		0.403549	303.0285	49322.19	56.93189	0.001243	3.240347
		0.270601	230.3017	37484.87	38.17593	0.001443	3.153564
		0.178009	169.6960	27620.43	25.11316	0.001748	3.062620
		0.103703	121.2114	19728.87	14.63029	0.001997	2.945296
		0.082523	96.96914	15783.10	11.64219	0.002483	2.895686
		0.258989	218.1805	35592.18	36.53771	0.001539	3.145025
		0.367062	290.9074	47456.25	51.78441	0.001227	3.220754
		0.537075	363.6342	59320.31	75.76946	0.001149	3.303401
2451	14.9	0.087307	98.53169	15965.23	12.31712	0.002544	2.905953
1886	15	0.061300	75.31289	12203.05	8.648118	0.003057	2.829159
1559	14.9	0.051208	62.67274	10132.07	7.224342	0.003688	2.789113
1589	20.1	0.036553	47.35291	7638.120	5.156896	0.004611	2.714922
1315	19.9	0.029418	39.58143	6384.565	4.150237	0.005312	2.667765
1427	29.9	0.019598	28.58720	4611.173	2.764871	0.006784	2.579566
1420	29.8	0.019723	28.54243	4593.576	2.782572	0.006849	2.579966
1095	29.9	0.015045	21.93622	3530.383	2.122583	0.008845	2.521175
1224	40	0.012149	18.32906	2949.852	1.713960	0.010230	2.474743
995	40	0.010302	14.89985	2392.556	1.453390	0.013127	2.437949
1030	60	0.007726	10.28264	1649.283	1.090091	0.020673	2.374997
425	75	0.003370	3.394271	543.8098	0.475542	0.082764	2.194367
600	59.9	0.004912	5.999890	959.1003	0.693050	0.038602	2.275170
330	90	0.002336	2.196293	351.0839	0.329628	0.137013	2.113800

Page 4 Cyanamid 832A

175	100	0.001537	1.048230	167.1852	0.216971	0.395923	2.022003
1323	20.2	0.029029	39.23081	6271.162	4.095467	0.005335	2.660939
1563	20	0.035734	46.81099	7499.777	5.041404	0.004613	2.707048
1532	14.8	0.049134	62.00346	9956.259	6.931738	0.003615	2.777179
1864	15	0.057701	74.43437	11979.35	8.140419	0.002946	2.813066
2416	15	0.086051	96.47717	15561.96	12.14003	0.002615	2.900838

Tap DL= 122.2234
40.77743

76.33526
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.10592	470.2860	41.25316	15.13963	1.002231	0.032192
14.82181	399.3317	39.90362	14.85807	1.002446	0.037207
14.48182	328.3490	38.28865	14.45608	0.998222	0.044026
14.03199	253.4424	36.15198	14.04650	1.001033	0.055422
13.47507	183.9278	33.50658	13.54871	1.005465	0.073663
12.84358	127.8721	30.50702	12.99207	1.011561	0.101602
12.23907	90.29194	27.63561	11.82823	0.966431	0.130999
11.81200	70.61244	25.60702	11.76367	0.995908	0.166594
13.23811	160.4755	32.38104	13.31036	1.005457	0.082943
12.75756	121.6946	30.09843	12.67646	0.993642	0.104166
12.97168	137.6583	31.11552	12.93049	0.996824	0.093931
12.48716	104.1529	28.81404	12.53277	1.003652	0.120330
12.02621	79.87919	26.62451	11.88454	0.988220	0.148781
13.85513	228.9097	35.31190	32.31985	2.332698	0.141190
13.54566	191.5561	33.84190	32.18520	2.376051	0.168019
13.29724	166.0320	32.66192	31.19175	2.345729	0.187865
12.92249	133.8145	30.88184	29.48688	2.281826	0.220356
12.56138	108.6994	29.16659	28.35927	2.257654	0.260896
12.21425	89.01113	27.51772	26.32035	2.154887	0.295697
11.85048	72.19385	25.78978	23.91168	2.017781	0.331214
11.38118	55.10310	23.56062	22.37723	1.966160	0.406097
11.18274	49.15490	22.61804	20.06806	1.794556	0.408261
12.18010	87.27811	27.35548	25.48762	2.092562	0.292027
12.48301	103.9044	28.79433	28.54560	2.286755	0.274729
12.81360	125.6845	30.36463	29.49861	2.302132	0.234703
11.22381	50.33079	22.81312	19.82537	1.766367	0.393901
10.91663	42.17352	21.35403	18.08459	1.656608	0.428813
10.75645	38.45856	20.59314	16.46589	1.530791	0.428146
10.45969	32.41924	19.18353	14.72528	1.407812	0.454214
10.27106	29.08340	18.28753	13.72038	1.335829	0.471759
9.918264	23.73811	16.61175	12.14074	1.224079	0.511445
9.919867	23.76001	16.61936	12.08326	1.218087	0.508554
9.684703	20.75180	15.50234	10.63275	1.097892	0.512377
9.498975	18.64764	14.62013	9.886815	1.040829	0.530191
9.351797	17.13284	13.92103	8.727961	0.933292	0.509428
9.099988	14.82099	12.72494	6.955013	0.764288	0.469267
8.377471	9.777952	9.292990	3.475994	0.414921	0.355493
8.700681	11.77742	10.82823	5.089716	0.584979	0.432158
8.055200	8.122318	7.762200	2.701537	0.335378	0.332606

7.688014	6.574816	6.018068	1.589257	0.206718	0.241718
10.24375	28.62988	18.15785	13.69015	1.336438	0.478177
10.42819	31.83676	19.03392	14.72310	1.411855	0.462456
10.70871	37.41617	20.36640	16.63093	1.553028	0.444485
10.83226	40.63936	21.04827	18.42326	1.697642	0.453335
11.20335	49.74146	22.71593	19.55355	1.745330	0.393103

Cyanamid 832A

Q2P11456

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
2.122583	120.3666	0.326864	2.080506
1.713960	100.5737	0.234000	2.002484
1.453390	81.75726	0.162382	1.912526
1.090091	56.42210	0.037463	1.751449
0.475542	18.62477	-0.32281	1.270090
0.693050	32.92211	-0.15923	1.517487
0.329628	12.05132	-0.48197	1.081034
0.216971	5.751767	-0.66359	0.759801

Regression Output:

Constant	-1.22318
Std Err of Y Est	0.022885
R Squared	0.994726
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s)	0.709385
Std Err of Coef.	0.029822

Tw vs. K'*(8<U>/D)^n

K'	=	0.059815
n	=	0.709385

Tw)Retro=122.7480
Res/f)R =2457.132

Regression Output:

Constant	26.11734
Std Err of Y Est	0.237809
R Squared	0.992102
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s)	1.740428
Std Err of Coef.	0.883294

t = 24.67031 deg C
s.d.)t = 0.316933 deg C

Cyanamid 832A

05P11449 4/30/90 9:12(H2O)12:45

10 PSID Taps 14	1.0 PSID Taps 14	0.1 PSID Taps 14	
S = 2.7	S = 7.25	S = 9.9	C>(ppm)=
Z = 2.7	Z = 7.65	Z = 8.1	[NaCl]=

	Freq. (Hz)	D)est (1/s)	Temp (deg C)	<V> (volts)	<V'>o (volts)	<V>f (volts)	<V>corr (volts)
^	60	1.21416	23.8	9.22425	0.0395	0.0725	9.15175
.	50	1.0118	23.8	6.647	0.0395	0.0725	6.5745
.	38	0.768968	23.8	4.064	0.0395	0.0725	3.9915
.	31	0.627316	23.8	2.8622	0.0395	0.0725	2.7897
.	25	0.5059	23.8	1.96975	0.0395	0.0725	1.89725
.	18	0.364248	23.8	1.1178	0.0395	0.0725	1.0453
.	11	0.222596	23.8	0.52175	0.0395	0.0725	0.44925
.	8	0.161888	23.8	0.328	0.0395	0.0725	0.2555
.	6	0.121416	23.8	0.2444	0.0395	0.0725	0.1719
H2O							
.	18	0.364248	24.7	11.3555	0.0675	0.0675	11.288
.	14	0.283304	24.7	7.2694	0.0675	0.0675	7.2019
.	10	0.20236	24.7	3.892833	0.0675	0.0675	3.825333
.	8	0.161888	24.7	2.85975	0.0675	0.0675	2.79225
v	6	0.121416	24.7	1.680666	0.0675	0.0675	1.613166
	60	1.21416	24.9	1.816	0.0445	0.0445	1.7715
	50	1.0118	24.9	1.4085	0.0445	0.0445	1.364
	40	0.80944	24.9	0.97075	0.0445	0.0445	0.92625
	31	0.627316	24.9	0.6945	0.0445	0.0445	0.65
	25	0.5059	24.9	0.50325	0.0445	0.0445	0.45875
	18	0.364248	24.9	0.3265	0.0445	0.0445	0.282
	13	0.263068	24.9	0.252666	0.0445	0.0445	0.208166
	9	0.182124	24.9	0.178285	0.0445	0.0445	0.133785
	7	0.141652	24.9	0.137428	0.0445	0.0445	0.092928
	18	0.364248	25.1	3.1535	0.0625	0.0795	3.091
	26	0.526136	25.1	5.2532	0.0625	0.0795	5.1907
	35	0.70826	25.1	8.17025	0.0625	0.0795	8.10775
	42	0.849912	25.1	10.99866	0.0625	0.0795	10.93616
			24.7	1.223	-0.0055	-0.0075	1.2305
			24.5	0.8724	-0.0075	-0.0075	0.8799
			24.5	0.6812	-0.0085	-0.011	0.6897
			24.45	0.501333	-0.011	-0.011	0.512333
			24.4	0.414857	-0.0115	-0.0115	0.426357
			24.4	0.293	-0.0105	-0.0115	0.3035
			24.4	1.919444	0.0015	-0.0015	1.917944
			24.3	1.443625	-0.0215	-0.0215	1.465125
			24.3	1.1082	-0.0295	-0.0295	1.1377
			24.2	0.813235	-0.0355	-0.0355	0.848735
			24.2	0.632812	-0.0415	-0.0375	0.670312
			24.1	0.615882	-0.0445	-0.0445	0.660382

Cyanamid 832A

24	0.454066	-0.0495	-0.0445	0.498566
24	0.3064	-0.0445	-0.0435	0.3499
23.8	0.183705	-0.0435	-0.0435	0.227205
24	2.1912	-0.047	-0.0565	2.2477
24.05	2.232666	-0.0595	-0.0585	2.291166
24.1	3.093625	-0.0595	-0.0605	3.154125
24.1	3.980428	-0.0625	-0.0625	4.042928
24.1	4.7718	-0.0635	-0.0605	4.8323
24.2	5.41	-0.061	-0.061	5.471
24.3	7.3338	-0.061	-0.0575	7.3913

		density	viscosity			
	coINaCl]	1.000088	1.001574	ID(cm) =	1.45796	
50.01393	X coeff	-0.00025	-0.02281	K(V/psi)=	1.097177	11.93037
0.000100	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch	Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
			8.341179	727.2685	115211.6	1176.755	0.004460	3.836190
			5.992196	606.0571	96009.71	845.3663	0.004614	3.814369
			3.637772	460.6034	72967.38	513.2374	0.004950	3.766006
			2.542616	375.7554	59526.02	358.7068	0.005093	3.628216
			1.729210	303.0285	48004.85	243.9533	0.005326	3.544500
			0.952717	218.1805	34563.49	134.4073	0.005660	3.415058
			0.409459	133.3325	21122.13	57.76573	0.006514	3.231682
			0.232870	96.96914	15361.55	32.85285	0.007004	3.109133
			0.156674	72.72685	11521.16	22.10335	0.008378	3.023076
			0.946156	218.1805	35272.44	133.4817	0.005623	3.422424
			0.603661	169.6960	27434.12	85.16322	0.005930	3.324039
			0.320638	121.2114	19595.80	45.23496	0.006174	3.187451
			0.234045	96.96914	15676.64	33.01864	0.007041	3.119093
			0.135215	72.72685	11757.48	19.07586	0.007202	2.999956
			1.614598	727.2685	118106.5	227.7840	0.000863	3.540445
			1.243190	606.0571	98422.10	175.3866	0.000957	3.483682
			0.844212	484.8457	78737.68	119.0996	0.001016	3.399639
			0.592429	375.7554	61021.70	83.57869	0.001187	3.322752
			0.418118	303.0285	49211.05	58.98727	0.001288	3.247063
			0.257023	218.1805	35431.95	36.26029	0.001527	3.141399
			0.189729	157.5748	25589.74	26.76661	0.002161	3.075430
			0.121936	109.0902	17715.97	17.20251	0.002898	2.979480
			0.084697	84.84800	13779.09	11.94899	0.003328	2.900350
			0.259086	218.1805	35592.18	36.55139	0.001539	3.145106
			0.435082	315.1497	51410.93	61.38057	0.001239	3.257670
			0.679589	424.2400	69207.03	95.87499	0.001068	3.354507
			0.916666	509.0880	83048.43	129.3213	0.001000	3.419489
2215		15	0.103140	92.44398	14945.07	14.55079	0.003414	2.941157
1790		14.9	0.077752	71.95909	11580.98	10.40490	0.004029	2.866362
1509		15	0.057810	60.25830	9697.881	8.155774	0.004504	2.813476
1545		20	0.042943	46.27190	7438.536	6.058095	0.005673	2.748429
1249		20.1	0.035737	37.22076	5976.755	5.041717	0.007297	2.708047
1288		30	0.025439	25.71659	4129.464	3.588919	0.010881	2.634240
1281		29.9	0.025318	25.66237	4120.757	3.571909	0.010875	2.633208
933		30	0.019341	18.62856	2984.556	2.728595	0.015766	2.573742
595		29.9	0.015018	11.91968	1909.699	2.118811	0.029902	2.518819
782		60.1	0.011204	7.793834	1245.867	1.580657	0.052175	2.454206
578		60	0.008848	5.370935	858.5599	1.248365	0.086771	2.402958
449		60	0.008717	4.482434	714.9158	1.229872	0.122731	2.398732

285		60	0.006581	2.845198	452.7653	0.728512	0.229972	2.136711
159		60	0.004619	1.587321	252.5956	0.551641	0.518551	2.257921
139		120	0.002999	0.693829	109.9142	0.423139	1.762260	2.164089
1571		30	0.029671	31.36706	4991.545	4.186034	0.008530	2.887718
1584		30	0.030245	31.62662	5038.530	4.266985	0.008553	2.868170
1916		24.9	0.041637	46.09038	7351.161	5.874127	0.005544	2.728274
1860		20	0.053370	55.70598	8884.700	7.529402	0.004864	2.772182
1593		14.9	0.062791	64.03957	10213.84	8.999499	0.004399	2.830911
1775		15	0.072222	70.88037	11330.43	10.13899	0.004056	2.858853
2269		15	0.097572	90.60708	14516.52	13.76528	0.003362	2.925165

Tap DL= 122.2234
40.77743

75.75206
4
0.4

Solvent 1//f	L 1//f	MDK 1//f	1//f	1//f/Slv	1//f/L
15.14476	480.9172	41.43761	14.97290	0.988652	0.031134
14.85747	407.6144	40.07302	14.72128	0.990833	0.036115
14.42402	317.6042	38.01411	14.35894	0.995487	0.045210
14.11286	265.5198	36.53612	14.01167	0.992829	0.052770
13.77800	218.9679	34.94550	13.70202	0.994485	0.062575
13.26023	162.5319	32.48611	13.29104	1.002323	0.081774
12.52672	106.5521	29.00196	12.38955	0.989049	0.116276
12.03653	80.35514	26.67353	11.94817	0.992658	0.148692
11.69230	65.91073	25.03844	10.92497	0.934372	0.165754
13.28969	165.3122	32.62607	13.33554	1.003449	0.080668
12.89935	132.0443	30.77195	12.98527	1.006660	0.098340
12.34980	96.23455	28.16156	12.72659	1.030509	0.132245
12.07637	82.21925	26.86277	11.91679	0.986786	0.144939
11.59982	62.49366	24.59916	11.75867	1.013694	0.188157
13.76178	216.9331	34.86847	34.02733	2.472596	0.156856
13.53473	190.3542	33.78996	32.31543	2.387593	0.169764
13.19855	156.8626	32.19315	31.37206	2.376931	0.199997
12.89092	131.4050	30.77190	29.02366	2.251479	0.220871
12.58825	110.3934	29.29420	27.86116	2.213266	0.252380
12.16559	86.55256	27.28659	25.58557	2.103108	0.295607
11.90192	74.36370	26.03413	21.50725	1.807040	0.289217
11.51792	59.61584	24.21012	18.57312	1.612541	0.311547
11.20140	49.68554	22.70665	17.33237	1.547384	0.348851
12.18042	87.29446	27.35702	25.48285	2.092114	0.291918
12.63068	113.1228	29.49573	28.40438	2.248840	0.251093
13.01802	141.3798	31.33563	30.59446	2.350161	0.216399
13.27795	164.1987	32.57030	31.61125	2.380731	0.192518
11.36462	54.58046	23.48198	17.11058	1.505863	0.313547
11.06545	45.94546	22.06089	15.75371	1.423684	0.342878
10.85390	40.67767	21.05604	14.90049	1.372823	0.366306
10.59371	35.01948	19.82016	13.27571	1.253168	0.379095
10.43219	31.91005	19.05290	11.70625	1.122128	0.366851
10.13696	26.92279	17.65056	9.586356	0.945683	0.356068
10.13285	26.85892	17.63096	9.583894	0.946319	0.357009
9.894970	23.42193	16.50111	7.964106	0.804864	0.340027
9.675276	20.63950	15.45756	5.782903	0.597698	0.280186
9.416825	17.78632	14.22991	4.377897	0.464901	0.246138
9.211835	15.80661	13.25621	3.294781	0.368523	0.214769
9.194930	15.65354	13.17592	2.854448	0.310437	0.182351

8.946845	13.57026	11.99751	2.085270	0.233073	0.153683
8.699286	11.76846	10.97681	1.788686	0.160740	0.122152
8.256356	9.119460	8.717693	0.753294	0.091238	0.082602
10.25487	28.81369	18.21065	10.32719	1.055809	0.375765
10.27548	29.12397	18.29904	10.81267	1.052483	0.371263
10.55309	34.21010	19.62721	13.43017	1.272628	0.392579
10.76873	38.73138	20.65147	14.33705	1.331359	0.370166
10.92364	42.34400	21.38732	15.07569	1.380097	0.356029
11.03541	45.15797	21.91821	15.68170	1.421034	0.347263
11.30066	52.60727	23.17814	17.24633	1.526134	0.327851

05P11447

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
2.728595	102.2171	0.435939	2.009523
2.118811	65.40471	0.326092	1.815609
1.580653	42.76569	0.198836	1.631095
1.248365	29.47096	0.096341	1.469394
1.229872	24.59565	0.089859	1.390858
0.928512	15.61194	-0.03221	1.193456
0.651641	8.709819	-0.18599	0.940009
0.423139	3.807122	-0.37351	0.580596

Regression Output:

Constant	-0.71112
Std Err of Y Est	0.014584
R Squared	0.997394
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	0.566093
Std Err of Coef.	0.011811

Tw vs. K'*(8<U>/D)^n

K' =	0.194481	415309.1
n =	0.566093	

Regression Output:

Constant	-39.6827
Std Err of Y Est	0.339163
R Squared	0.990507
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	20.77389
Std Err of Coef.	1.016835

t = 24.50285 deg C
s.d.)t = 0.393690 deg C

Q1P21446 4/26/90 12:11

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14
S = 2.7 S = 7.25 S = 9.9 <C (ppa)=
Z = 2.7 Z = 8 Z = 7.65 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.1	1.931333	0.0235	0.1315	1.799833
50	1.0118	25.1	1.4595	0.0235	0.1315	1.329
39	0.789204	25.1	1.016333	0.0235	0.1315	0.884833
29	0.586844	25.1	0.670666	0.0235	0.1315	0.539166
21	0.424956	25.1	0.482	0.0235	0.1315	0.3505
15	0.30354	25.1	0.37725	0.0235	0.1315	0.24575
9	0.182124	25.1	0.2742	0.0235	0.1315	0.1427
7	0.141652	25.1	0.23325	0.0235	0.1315	0.10175
10	0.20236	25.1	0.285	0.1295	0.1325	0.1525
6	0.121416	25.1	0.213333	0.1295	0.1325	0.080833
18	0.364248	25	3.356	0.0525	0.0715	3.2845
25	0.5059	25	5.3175	0.0525	0.0715	5.246
34	0.688024	25	8.25125	0.0525	0.0715	8.17975
		24.5	1.1738	0.0795	0.0255	1.1213
		24.45	0.9382	0.0295	0.0335	0.9067
		24.45	0.79825	0.0595	0.0245	0.75625
		24.4	0.583666	0.0295	0.0285	0.554666
		24.4	0.451857	0.0285	-0.0175	0.446357
		24.3	2.8242	0.0565	0.0575	2.7667
		24.3	2.337571	0.0575	0.0515	2.286071
		24.3	1.882416	0.0645	0.0915	1.790916
		24.3	1.581769	0.078	0.0805	1.501269
		24.2	1.121916	-0.0495	-0.1595	1.281416
		24.2	0.957928	-0.0355	-0.0055	0.963428
		24.1	0.498117	-0.0105	0.0045	0.493617
		23.9	0.309923	0.0005	0.0145	0.295423
		24.2	3.625333	0.0145	-0.1435	3.768833
		24.2	4.75725	0.0065	0.1835	4.75075
		24.3	5.147666	-0.0075	-0.0385	5.186166
		24.3	6.916333	0.0005	0.009	6.907333

		density	viscosity			
	co)NaCl	1.000098	1.001574	ID(cm) =	1.45796	
99.99499	X coeff	-0.00025	-0.02281	K(V/psi)=	1.091653	11.97073
0.000100	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	U (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.648722	727.2685	118640.6	232.5983	0.000681	3.545957
		1.216503	606.0571	98867.18	171.6217	0.000937	3.480940
		0.810544	472.7245	77116.40	114.3498	0.001026	3.392772
		0.493899	351.5131	57342.97	69.67826	0.001170	3.285203
		0.321072	254.5440	41524.21	45.29625	0.001402	3.171685
		0.225117	181.8171	29660.15	31.75607	0.001926	3.114588
		0.130719	109.0902	17796.09	18.44158	0.003107	2.996553
		0.093207	84.84800	13841.40	13.14948	0.003663	2.923109
		0.139696	121.2114	19773.43	19.70607	0.003590	3.013976
		0.074046	72.72685	11864.06	10.44635	0.007961	2.877137
		0.275297	218.1805	35511.98	38.83838	0.001636	3.137300
		0.439704	303.0285	49422.19	62.03262	0.001354	3.258979
		0.685603	412.1188	67078.18	96.72348	0.001142	3.375435
2226	15	0.093984	88.88997	14505.82	13.25909	0.003364	2.914000
1716	15	0.075997	68.52435	11015.77	10.72149	0.004578	2.872778
1420	15	0.063386	56.70429	9115.617	8.942465	0.005576	2.832979
1345	20.1	0.046490	40.08160	6436.138	6.558793	0.008186	2.765170
1267	25	0.037412	30.35676	4874.563	5.278060	0.011484	2.717995
1258	24.9	0.036523	30.26217	4848.424	5.152601	0.011231	2.711786
831	25	0.030178	19.91039	3189.924	4.257496	0.021514	2.670350
956	40	0.023641	14.31583	2293.597	3.335377	0.033612	2.617743
888	45	0.019818	11.82005	1893.737	2.795909	0.040126	2.579034
669	45.1	0.016915	8.885225	1420.229	2.386463	0.060611	2.547665
458	50.1	0.012718	5.475788	875.3210	1.794254	0.119984	2.481729
197	59.9	0.006516	1.869965	298.2459	0.919295	0.527122	2.375670
142	120	0.003899	0.708803	112.5401	0.550185	2.195627	2.222086
1082	14.9	0.049752	43.49705	6953.133	7.018937	0.007436	2.777923
1349	14.9	0.062714	54.23062	8668.925	8.847623	0.006032	2.328201
1564	15	0.068462	62.45459	10006.10	9.658527	0.004965	2.848228
2194	14.9	0.091183	88.20013	14130.89	12.86396	0.003315	2.910460

Page 3 Cyanamid 832A

Tap DL= 122.2234
75.75206 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.78783	220.2104	34.99220	33.67250	2.442190	0.152910
13.52376	189.1563	33.73787	32.66715	2.415537	0.172699
13.17109	154.4018	32.06267	31.21578	2.370022	0.202172
12.74081	120.5267	30.01886	29.73560	2.333886	0.246713
12.36674	97.17753	28.24203	26.70641	2.159535	0.274820
12.05835	81.37080	26.77718	22.78163	1.889282	0.279973
11.58621	62.00601	24.53452	17.93787	1.548207	0.289292
11.29243	52.35872	23.13907	16.52232	1.463132	0.315560
11.64390	64.09981	24.80855	19.27992	1.655795	0.300779
11.09254	46.66777	22.18960	15.88899	1.432402	0.340470
12.22920	89.78009	27.58870	24.72150	2.021514	0.275356
12.63591	113.4643	29.52061	27.16832	2.150087	0.239443
13.02174	141.6822	31.35327	29.59006	2.272358	0.208848
11.27600	51.86571	23.06100	17.23901	1.528823	0.332377
11.08951	46.58634	22.17519	14.77870	1.332673	0.317232
10.93191	42.56608	21.42661	13.39080	1.224926	0.314736
10.66068	36.39571	20.13823	11.05236	1.036740	0.303672
10.47198	32.64942	19.24191	9.331259	0.891069	0.285801
10.44714	32.18595	19.12394	9.414869	0.901190	0.292514
10.28140	29.25703	18.33665	6.814439	0.662792	0.232916
10.06937	25.89542	17.32951	5.535721	0.549758	0.213772
9.916138	23.70907	16.60165	4.992122	0.503434	0.210557
9.774661	21.85472	15.92966	4.061849	0.415548	0.185856
9.526919	18.95003	14.75286	2.886937	0.303029	0.152344
8.942121	13.53350	11.97507	1.577350	0.154029	0.101773
8.488347	10.42237	9.819648	0.874870	0.079505	0.064752
10.71169	37.48034	20.38054	11.59463	1.082427	0.309352
10.91280	42.08053	21.33582	12.87549	1.179852	0.305972
10.99291	44.06650	21.71634	14.19176	1.290991	0.322053
11.24184	50.85580	22.89875	17.36637	1.544797	0.341482

Page 4 Cyanamid 832A

Q1P21446

Tw dyne/cm2	8 U /D (1/sec)	Log Tw	Log 8 U /D
5.152601	166.0521	0.712026	2.220244
4.257496	109.2507	0.629154	2.038424
3.335337	78.55271	0.523139	1.895161
2.795909	64.85802	0.446523	1.811963
2.386463	48.75429	0.377754	1.688012
1.794254	30.04630	0.253383	1.477791
0.919295	10.26072	-0.03654	1.011178
0.550185	3.889290	-0.25949	0.589870

Regression Output:

Constant	-0.62294
Std Err of Y Est	0.014747
R Squared	0.998228
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.595105
Std Err of Coef.	0.012533

Tw vs. K'*(8 U /D)^n

K' = 0.238264
n = 0.595105

Regression Output:

Constant	-20.0648
Std Err of Y Est	0.080859
R Squared	0.998523
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	15.14316
Std Err of Coef.	0.411689

t = 24.62668 deg C
s.d.)t = 0.408805 deg C

01P03166 5/19/90 15:38

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 C (ppm)=

Z = 2.7 Z = 8.25 Z = 7.5 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	25.1	8.433666	0.0225	0.0945	8.339166
48	0.971328	25.1	5.748666	0.0225	0.0945	5.654166
53	1.072508	25.1	7.014	0.0225	0.0945	6.9195
40	0.80944	25.1	4.370666	0.0225	0.0945	4.276166
30	0.60708	25.1	2.869666	0.0225	0.0945	2.775166
23	0.465428	25.1	1.733	0.0225	0.0945	1.6385
17	0.344012	25.1	1.05375	0.0225	0.0945	0.95925
11	0.222596	25.1	0.547375	0.0225	0.0945	0.452875
9	0.182124	25.1	0.418	0.0225	0.0945	0.3235
20	0.40472	24.2	1.4525	0.0375	0.0295	1.415
15	0.30354	24.2	0.7855	0.0375	0.0295	0.748
10	0.20236	24.2	0.4095	0.0375	0.0295	0.372
20	0.40472	25.3	13.511	0.0665	0.099	13.4445
16	0.323776	25.3	9.671666	0.0665	0.099	9.605166
13	0.263068	25.3	6.5244	0.0665	0.099	6.4254
10	0.20236	25.3	4.593	0.0665	0.099	4.494
7	0.141652	25.3	2.4026	0.0665	0.099	2.3036
		25.1	2.216	0.0775	0.0805	2.1355
		25.1	1.5082	0.0795	0.0745	1.4337
		25.05	1.1692	0.0715	0.0685	1.1007
		25	0.7135	0.0665	0.0645	0.649
		25	0.5215	0.0635	0.0615	0.46
		24.9	2.767833	-0.0645	-0.063	2.830833
		24.9	2.077142	-0.0665	-0.0695	2.146642
		24.9	1.440285	-0.072	-0.0745	1.512285
		24.8	0.769363	-0.0765	-0.078	0.845863
		24.8	0.332571	-0.0815	-0.0835	0.414071
		24.7	0.1858	-0.0845	-0.0855	0.2703
		24.6	0.070826	-0.0865	-0.0865	0.157326
		24.5	-0.00765	-0.0865	-0.0845	0.07885
		24.5	-0.05432	-0.0855	-0.0845	0.031178
		24.5	3.592	-0.085	-0.0875	3.6795
		24.6	6.276	-0.0875	-0.0855	6.3615
		24.7	8.7712	-0.0845	-0.081	8.8522
		24.7	12.4562	-0.0825	-0.0795	12.5357

		density	viscosity			
	co[NaCl]	1.01234	1.029478	ID(cm) =	1.45796	
1.008150	X coeff	-0.00025	-0.02281	K(V/psi)=	1.088055	12.090a7
0.300023	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		7.664287	727.2685	116838.9	1081.261	0.004050	5.871330
		5.196581	581.8148	93471.14	733.1227	0.004290	5.786957
		6.359513	642.4205	103207.7	897.1866	0.004307	5.830806
		3.930101	484.8457	77892.62	554.4503	0.004673	5.726296
		2.366761	363.6342	58419.46	333.8976	0.005002	5.616171
		1.505898	278.7862	44788.25	212.4489	0.005415	5.517991
		0.881619	206.0594	33104.36	124.3769	0.005803	5.401734
		0.416224	133.3325	21420.47	58.72005	0.006544	5.238757
		0.297319	109.0902	17525.84	41.94520	0.006983	5.165705
		1.300485	242.4228	38163.51	183.4697	0.006183	5.477280
		0.687465	181.8171	28622.63	96.98613	0.005811	5.338852
		0.341894	121.2114	19081.75	48.23374	0.006502	5.187173
		1.111973	242.4228	39122.43	156.8748	0.005288	5.454111
		0.794427	193.9382	31297.94	112.0762	0.005904	5.381091
		0.531434	157.5748	25429.58	74.97366	0.005982	5.293789
		0.371691	121.2114	19561.21	52.43745	0.007071	5.216155
		0.190527	86.84800	13692.85	26.87915	0.007397	5.071042
1976	14.9	0.176623	79.43640	12761.81	24.91771	0.007823	5.052618
1599	14.9	0.118579	64.28077	10326.99	16.72887	0.008021	4.966098
1369	15.2	0.091037	53.94842	8657.283	12.84332	0.008742	4.908210
1355	20	0.053677	40.58150	6504.908	7.572743	0.009110	4.795006
1375	24.9	0.038045	33.07670	5301.945	5.367429	0.009719	4.718262
1370	24.9	0.037346	32.95642	5270.761	5.268726	0.009610	4.713247
1177	25	0.028319	28.20040	4510.125	3.995215	0.009955	4.652169
1167	30.1	0.019951	23.22326	3714.124	2.814654	0.010339	4.577106
1291	45.1	0.011159	17.14622	2736.037	1.574315	0.010608	4.449954
1124	49.9	0.005462	13.49225	2152.970	0.770666	0.008387	4.294842
988	59.9	0.003565	9.879819	1572.978	0.503080	0.010210	4.201242
867	89.9	0.002075	5.776679	917.6397	0.292814	0.017383	4.082774
482	100	0.001040	2.887127	457.5937	0.146755	0.014877	4.491750
228	120	0.000411	1.138079	180.3792	0.058029	0.088752	3.710277
1265	20	0.048542	37.88605	6004.731	6.848258	0.009451	4.766243
1295	14.9	0.083925	52.05978	8269.825	11.81997	0.008654	4.886114
1550	14.9	0.116784	62.31094	9920.601	16.47564	0.008406	4.959845
1900	14.9	0.165379	76.38115	12160.73	23.33135	0.007922	5.034393

Tap DL= 122.2234
75.79972 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.08532	464.7400	41.15527	15.71294	1.041604	0.033810
14.74781	382.6776	39.55210	15.26597	1.035134	0.039892
14.92322	423.3369	40.38531	15.23723	1.021041	0.035993
14.50518	332.7944	38.39962	14.62851	1.008502	0.043956
14.06468	258.2566	36.30725	14.13794	1.005208	0.054743
13.67196	206.0022	34.44184	13.58852	0.993896	0.065962
13.20693	157.6212	32.23295	13.12654	0.993913	0.083279
12.55503	108.3023	29.13640	12.36149	0.984585	0.114138
12.26282	91.53473	27.74841	11.96665	0.975848	0.130733
13.50912	187.5686	33.66832	12.71651	0.941328	0.067796
12.95541	136.3743	31.03820	13.11767	1.012524	0.096188
12.34869	96.17307	28.15629	12.40066	1.004208	0.128941
13.41644	177.8245	33.22812	13.75036	1.024888	0.077325
13.12436	150.3044	31.84074	13.01439	0.991620	0.086586
12.77515	122.9332	30.18200	12.92854	1.012006	0.105167
12.46462	102.8101	28.70696	11.89159	0.954027	0.115665
11.88417	73.60765	25.94981	11.62655	0.978322	0.157953
11.81047	70.55029	25.59975	11.30559	0.957251	0.160248
11.46439	57.80669	23.95586	11.16543	0.973923	0.193151
11.23284	50.59305	22.85600	10.69475	0.952096	0.211387
10.77202	38.80486	20.66711	10.47695	0.972607	0.269990
10.47305	32.66951	19.24699	10.14314	0.968499	0.310477
10.45298	32.29439	19.15169	10.20061	0.975855	0.315863
10.21267	28.12224	18.01022	10.02348	0.981474	0.356425
9.908427	23.60407	16.56503	9.834438	0.992532	0.416641
9.399819	17.61306	14.14914	9.708834	1.032874	0.551229
8.779369	12.32317	11.20200	10.91932	1.243747	0.886080
8.404970	9.933965	9.423610	9.896464	1.177453	0.996224
7.930939	7.561619	7.171960	7.584683	0.956341	1.003050
7.327000	5.341092	4.302251	5.354636	0.730808	1.002535
6.521109	3.358592	0.475269	3.356675	0.514739	0.999429
10.66497	36.48578	20.15862	10.28608	0.964473	0.281920
11.14445	48.08329	22.43616	10.74934	0.964546	0.223556
11.43538	56.84931	23.81805	10.90668	0.953766	0.191852
11.73757	67.65095	25.25348	11.23481	0.957166	0.166070

01P03166

Tw dyne/cm2	8 U>/D (1/sec)	Log Tw	Log 8<U>/D
0.770666	74.03363	-0.11313	1.869429
0.503080	54.21174	-0.29836	1.734093
0.292814	31.69733	-0.53340	1.501022
0.146755	15.84201	-0.83340	1.199810
0.058029	6.244776	-1.23635	0.795516

Regression Output:

Constant	-2.03140
Std Err of Y Est	0.001211
R Squared	0.999994
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	0.998782
Std Err of Coef.	0.001725

Tw vs. K'*(8<U>/D)^n

K' = 0.009302
n = 0.998782

Tw* = 53.37396
Res/f* = 1652.073

Regression Output:

Constant	-0.81535
Std Err of Y Est	0.130490
R Squared	0.970511
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	4.129070
Std Err of Coef.	0.415542

t = 24.89571 deg C
s.d.)t = 0.318561 deg C

Cyanamid 832A

02P03163 5/16/90 16:04

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 8.2 Z = 7.5 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
24	0.485664	25.3	1.203666	0.0315	0.0385	1.172166
35	0.70826	25.3	2.242333	0.0315	0.0385	2.210833
45	0.91062	25.3	3.604333	0.0315	0.0385	3.572833
51	1.032036	25.3	4.663666	0.0315	0.0385	4.632166
60	1.21416	25.3	6.467666	0.0315	0.0385	6.436166
24	0.485664	25.3	1.196333	0.0315	0.0385	1.164833
16	0.323776	25.3	0.61175	0.0315	0.0385	0.57325
12	0.242832	25.3	0.392	0.0315	0.0385	0.3535
8	0.161888	25.3	0.2478	0.0315	0.0385	0.2093
40	0.80944	24.2	3.103666	0.0315	0.0385	3.065166
10	0.20236	24.15	0.340375	0.0315	0.0385	0.301875
24	0.485664	25.2	11.97766	0.0655	0.1035	11.91216
15	0.30354	25.2	6.44325	0.0655	0.1035	6.33975
20	0.40472	25.2	8.998333	0.0655	0.1035	8.894833
10	0.20236	25.2	3.4675	0.0655	0.1035	3.364
7	0.141652	25.2	1.8878	0.0655	0.1035	1.7843
		25	1.931333	0.0775	0.0745	1.856833
		25	1.292666	0.074	0.0715	1.221166
		24.9	1.045	0.0705	0.0685	0.9765
		24.8	0.686166	0.0685	0.0655	0.620666
		24.7	0.521	0.0655	0.0645	0.4565
		24.7	0.331166	0.0655	0.0645	0.266666
		24.6	1.644333	0.018	0.018	1.626333
		24.6	1.055222	0.017	0.014	1.041222
		24.5	0.637	0.01	0.006	0.631
		24.5	0.403666	0.004	0.0015	0.399666
		24.5	0.278642	-0.0005	-0.0025	0.279142
		24.4	0.1806	-0.0055	-0.0065	0.1861
		24.1	0.129333	-0.0075	-0.0075	0.136833
		24.1	0.0622	-0.0085	-0.0065	0.0717
		24	0.028	-0.0065	-0.0065	0.0345
		24.3	2.7624	-0.0075	-0.0125	2.7759
		24.3	3.736333	-0.0125	-0.0105	3.746833
		24.3	6.001714	-0.0115	-0.0085	6.010214
		24.3	7.89525	-0.012	-0.0105	7.90575
		24.2	11.2145	-0.0115	-0.011	11.2255

Cyanamid 832A

		density	viscosity			
	co[NaCl]	1.01224	1.029478	ID(cm) =	1.45796	
2.015260	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08	12.09067
0.300061	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.085339	290.9074	46946.92	153.1173	0.003584	3.448847
		2.047067	424.2400	68464.26	288.7959	0.003179	3.586630
		3.308179	545.4514	88025.47	466.7108	0.003108	3.690859
		4.289043	618.1782	99762.20	605.0891	0.003137	3.747244
		5.959413	727.2685	117367.3	840.7414	0.003149	3.818866
		1.078549	290.9074	46946.92	152.1594	0.003562	3.447484
		0.530787	193.9382	31297.94	74.88230	0.003944	3.293524
		0.327214	145.4537	23473.46	46.17687	0.004324	3.188547
		0.193796	96.96914	15648.97	27.34037	0.005761	3.074737
		2.838117	484.8457	76327.03	400.3955	0.003273	3.646742
		0.279513	121.2114	19060.24	39.43322	0.005316	3.142936
		0.985236	290.9074	46841.12	138.9950	0.003254	3.426849
		0.524350	181.8171	29275.70	73.97426	0.004433	3.289890
		0.735677	242.4228	39034.27	103.7878	0.003499	3.583423
		0.278231	121.2114	19517.13	39.25224	0.005293	3.152282
		0.147576	84.84800	13661.99	20.81979	0.005729	3.014588
2080	14.9	0.153575	83.61726	13403.21	21.66613	0.006139	3.021270
1655	15	0.101000	66.08846	10593.47	14.24897	0.006463	2.930271
1855	20	0.080764	55.55623	8885.176	11.39412	0.007313	2.880734
1374	19.9	0.051334	41.35733	6599.423	7.242140	0.008388	2.781342
1426	24.9	0.037756	34.30355	5461.510	5.326590	0.008967	2.717648
1039	25	0.022055	24.89398	3963.402	3.111553	0.009946	2.596912
1040	25	0.021455	24.91794	3958.276	3.026919	0.007657	2.589979
965	30.1	0.013736	19.20547	3050.518	1.937915	0.010410	2.493106
1070	39.9	0.008324	16.06311	2545.915	1.174412	0.009016	2.383363
991	44.9	0.005272	13.22044	2095.368	0.743856	0.008430	2.284198
975	59.9	0.003682	9.749822	1545.293	0.519538	0.010826	2.206262
656	59.9	0.002455	6.539880	1036.199	0.346367	0.016042	2.117237
720	90.1	0.001805	4.786594	751.8335	0.254673	0.022017	2.047504
499	120	0.000945	2.490796	391.2310	0.133447	0.042605	1.907168
410	199.9	0.000455	1.228541	192.5330	0.064211	0.084266	1.747332
1396	24.9	0.036621	33.58187	5298.581	5.166484	0.009074	2.707080
1689	25.1	0.049430	40.30647	6359.594	6.973578	0.008502	2.768211
1824	20.1	0.079290	54.35602	8576.346	11.18616	0.007499	2.870822
1609	14.9	0.104297	64.68277	10205.71	14.71412	0.006966	2.970750
2006	14.9	0.148094	80.64242	12695.16	20.89281	0.006363	3.005496

74.66555 Tap DL= 122.2234
75.79972 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.39538	175.6820	33.12810	16.70166	1.246821	0.095067
13.94652	241.2741	35.74598	17.73508	1.271649	0.073505
14.36343	306.7178	37.72632	17.93697	1.248794	0.058480
14.58897	349.2406	38.79765	17.85341	1.223760	0.051120
14.87466	411.6673	40.15466	17.81889	1.197935	0.043284
13.38993	175.1316	33.10220	16.75415	1.251249	0.095666
12.77409	122.8583	30.17697	15.92176	1.246409	0.129594
12.35418	96.47781	28.18240	15.20651	1.230879	0.157616
11.89894	74.23647	26.02000	13.17493	1.107235	0.177472
14.18697	277.0911	36.88810	17.21614	1.213517	0.062131
12.17174	86.85934	27.31579	13.71488	1.126780	0.157897
13.30739	167.0050	32.71014	17.52983	1.317299	0.104965
12.75956	121.8345	30.10791	15.01817	1.177013	0.123266
13.05369	144.3122	31.50503	16.90530	1.295059	0.117143
12.20912	88.74874	27.49336	13.74465	1.125768	0.154871
11.65835	64.63506	24.87717	13.21070	1.133153	0.204389
11.68508	65.63723	25.00413	12.76258	1.092212	0.194441
11.32108	53.22936	23.27515	12.43848	1.098700	0.233677
11.12293	47.49137	22.33396	11.69314	1.051263	0.246216
10.72537	37.77658	20.44551	10.91851	1.018007	0.289028
10.45459	32.32426	19.15932	10.56000	1.010082	0.326689
9.987650	24.70544	16.94133	10.02664	1.003904	0.405847
9.959756	24.31191	16.80884	10.17576	1.021687	0.418550
9.572424	19.45298	14.96901	9.800935	1.023871	0.503826
9.133455	15.10928	12.88391	10.53125	1.153041	0.697005
8.736792	12.02480	10.99976	10.89086	1.246551	0.905699
8.425049	10.04945	9.518987	9.610552	1.140711	0.956325
8.068948	8.186857	7.827506	7.895270	0.978475	0.964383
7.790017	6.972433	6.502583	6.739339	0.865125	0.966569
7.228672	5.047171	3.836192	4.844682	0.670203	0.959880
6.589331	3.493114	0.799322	3.444867	0.522794	0.986187
10.41232	31.54719	18.95853	10.49733	1.008164	0.332750
10.67284	36.65143	20.19600	10.86472	1.016104	0.295888
11.08329	46.41985	22.14565	11.54724	1.041860	0.248756
11.32140	53.23905	23.27665	11.98099	1.058260	0.225041
11.62198	63.29603	24.70443	12.53550	1.078602	0.198045

02P03163

Tw dyne/cm2	8U/D (1/sec)	Log Tw	Log 8U/D
1.174412	88.14022	0.069820	1.945174
0.743856	72.54217	-0.12851	1.860590
0.519538	52.49843	-0.28438	1.720341
0.346367	35.88510	-0.46046	1.554914
0.254673	26.26461	-0.59401	1.419370
0.133447	13.66729	-0.87468	1.135682
0.064211	6.741155	-1.19238	0.828734

Regression Output:

Constant	-2.00529
Std Err of Y Est	0.001947
R Squared	0.999959
No. of Observations	4
Degrees of Freedom	2

X Coefficient(s) 0.994741
Std Err of Coef. 0.004492

Tw vs. K'*(8U/D)^n

K' = 0.009878
n = 0.994741

Tw* = 6.516127
Res/f* = 579.8690

Regression Output:

Constant	-15.1892
Std Err of Y Est	0.410444
R Squared	0.964582
No. of Observations	18
Degrees of Freedom	16

X Coefficient(s) 9.351965
Std Err of Coef. 0.448004

t = 24.77361 deg C
s.d.)t = 0.453609 deg C

Page 1 Cyanamid 832A

05P03160 5/13/90 16:36

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 7.5 Z = 8.15 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.7	4.329	0.0295	0.0315	4.2975
49	0.991564	24.7	2.891	0.0295	0.0315	2.8595
41	0.829676	24.7	2.117	0.0295	0.0315	2.0855
33	0.667788	24.7	1.466	0.0295	0.0315	1.4345
27	0.546372	24.7	1.080666	0.0295	0.0315	1.049166
19	0.384484	24.7	0.629666	0.0295	0.0315	0.598166
14	0.283304	24.7	0.4216	0.0295	0.0315	0.3921
10	0.20236	24.7	0.2738	0.0295	0.0315	0.2423
8	0.161888	24.7	0.203714	0.0295	0.0315	0.172214
30	0.60708	24.2	1.35525	0.0265	0.0295	1.32575
21	0.424956	24.2	0.763	0.0265	0.0295	0.7335
16	0.323776	24.2	0.507166	0.0265	0.0295	0.477666
12	0.242832	24.2	0.3314	0.0265	0.0295	0.3019
20	0.40472	24.8	7.3475	0.0595	0.17	7.1775
15	0.30354	24.8	4.828	0.0595	0.17	4.658
11	0.222596	24.8	3.046625	0.0595	0.17	2.876625
8	0.161888	24.8	2.0405	0.0595	0.17	1.8705
		24.6	1.6588	0.0365	0.0095	1.6493
		24.6	1.1776	0.0135	0.0025	1.1751
		24.6	0.8622	0.0015	-0.0025	0.8647
		24.5	0.5845	-0.0035	-0.0055	0.59
		24.5	0.439	-0.0065	-0.0075	0.4465
		24.5	2.809166	-0.0125	-0.0265	2.835666
		24.5	2.258285	-0.0275	-0.0285	2.286785
		24.45	1.707285	-0.0315	-0.0345	1.741785
		24.4	1.089444	-0.0385	-0.0415	1.127944
		24.4	0.632642	-0.0445	-0.0455	0.677142
		24.4	0.3614	-0.0475	-0.0495	0.4089
		24.3	0.249	-0.0505	-0.051	0.2995
		24.3	0.135722	-0.0525	-0.054	0.188222
		24.2	0.111461	-0.0545	-0.0555	0.165961
		24.2	0.057375	-0.056	-0.055	0.112375
		24.1	0.019	-0.0555	-0.0555	0.0745
		24.1	-0.012	-0.0555	-0.0555	0.0435
		24.2	3.565333	-0.0555	-0.064	3.629333
		24.3	5.7166	-0.0665	-0.062	5.7786
		24.3	7.156166	-0.0645	-0.0635	7.219666
		24.3	10.2755	-0.0665	-0.0645	10.34

Page 2 Cyanamid 832A

		density	viscosity		
	co[NaCl]	1.01234	1.029478	ID(cm) =	1.45796
4.991468	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08 11.93037
0.300067	constant	0.003419	-4.14933	XS(cm2)=	1.669479

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		3.979166	727.2685	115789.3	561.3723	0.002102	3.725049
		2.647685	593.9360	94561.28	373.5298	0.002097	3.636586
		1.931018	496.9668	79122.70	272.4239	0.002185	3.568046
		1.328240	399.9977	63684.12	187.3853	0.002320	3.486791
		0.971450	327.2708	52105.19	137.0501	0.002534	3.418863
		0.553858	230.3017	36666.61	78.13711	0.002918	3.296852
		0.363055	169.6960	27017.50	51.21910	0.003523	3.205139
		0.224351	121.2114	19298.22	31.65108	0.004267	3.100618
		0.159457	96.96914	15438.57	22.49595	0.004739	3.026476
		1.227546	363.6342	57245.27	173.1796	0.002594	3.464746
		0.679166	254.5440	40071.69	95.81539	0.002929	3.336215
		0.442283	193.9382	30530.81	62.39648	0.003286	3.243078
		0.279537	145.4537	22898.11	39.43649	0.003692	3.143447
		0.601615	242.4228	38683.61	84.87469	0.002861	3.215798
		0.390432	181.8171	29012.70	55.08133	0.003301	3.221911
		0.241117	133.3325	21275.98	34.01639	0.003790	3.117253
		0.156784	96.96914	15473.44	22.11885	0.004660	3.023790
2160	15	0.138243	86.25442	13701.72	19.50314	0.005193	2.994491
1695	15	0.098496	67.68576	10752.04	13.89568	0.006008	2.920878
1415	15	0.072478	56.50463	8975.900	10.22516	0.006344	2.854273
1411	20	0.049453	42.25867	6697.767	6.976811	0.007739	2.770282
1459	25.1	0.037425	34.81773	5518.418	5.279909	0.008627	2.709766
1452	25	0.037978	34.78928	5513.909	5.357890	0.008769	2.712950
1255	25.1	0.030627	29.94945	4746.823	4.320799	0.009542	2.666253
1269	30	0.023327	25.33723	4011.285	3.291041	0.010155	2.606627
1160	35.2	0.015106	19.73941	3121.537	2.131210	0.010834	2.511781
1367	50	0.009069	16.37636	2589.713	1.279437	0.009450	2.400977
1124	50.1	0.005476	13.43839	2125.112	0.772601	0.008474	2.291446
1010	59.9	0.004011	10.09981	1593.558	0.565894	0.010989	2.222850
805	75	0.002520	6.429149	1014.397	0.355639	0.017043	2.121987
575	59.9	0.002222	5.749895	905.1796	0.313578	0.018787	2.093671
599	89.9	0.001505	3.991039	628.2910	0.212328	0.026404	2.009002
659	150.1	0.000997	2.629805	413.0652	0.140765	0.040316	1.918760
309	120	0.000582	1.542396	242.2653	0.082191	0.068433	1.801926
1384	20.1	0.048607	41.24382	6492.826	6.857495	0.007985	2.763580
1396	15	0.077393	55.74591	8795.644	10.91845	0.006959	2.865563
1653	15	0.096693	66.00859	10414.90	13.64130	0.006201	2.913911
2090	14.9	0.138484	84.01927	13256.64	19.53705	0.005482	2.991912

74.66555 Tap DL= 122.2234
74.66555 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.50019	331.8405	38.37594	21.80816	1.503990	0.065718
14.14634	270.6865	36.69514	21.83367	1.543414	0.080660
13.87218	231.1674	35.39288	21.39215	1.542089	0.092539
13.54716	191.7219	33.84904	20.76057	1.532466	0.108284
13.27545	163.9622	32.55841	19.86173	1.496124	0.121136
12.78741	123.8034	30.24020	18.51050	1.447556	0.149515
12.42055	100.2351	28.49765	16.84633	1.356326	0.168068
12.00247	78.79492	26.51174	15.30731	1.275346	0.194267
11.70590	66.42875	25.10304	14.52550	1.240869	0.218662
13.45898	182.2327	33.43018	19.63330	1.458750	0.107737
12.94486	135.5487	30.98809	18.47660	1.427330	0.136309
12.57231	109.3850	29.21848	17.44457	1.387539	0.159478
12.17378	86.96151	27.32549	16.45707	1.351844	0.189245
12.86319	129.3237	30.60016	18.69514	1.453382	0.144560
12.48764	104.1816	28.81631	17.40511	1.393786	0.167065
12.06901	81.87160	26.82781	16.24188	1.345750	0.198382
11.69516	66.01924	25.05201	14.64861	1.252536	0.221884
11.57796	61.71221	24.49533	13.87663	1.198538	0.224860
11.28351	52.09051	23.09669	12.90067	1.143321	0.247658
11.01709	44.68420	21.83120	12.55463	1.139559	0.280963
10.68112	36.82663	20.23535	11.36705	1.064218	0.308663
10.43906	32.03662	19.08556	10.76583	1.031302	0.336047
10.45180	32.27234	19.14605	10.67847	1.021687	0.330886
10.26494	28.98115	18.25847	10.23687	0.997265	0.353225
10.02651	25.26432	17.12592	9.923294	0.989705	0.392778
9.647126	20.30773	15.32384	9.606984	0.995838	0.473070
9.203911	15.73467	13.21857	10.28665	1.117638	0.653756
8.765784	12.22717	11.13747	10.86264	1.239209	0.888401
8.491403	10.44073	9.834167	9.539314	1.123408	0.913663
8.087951	8.276904	7.917770	7.659848	0.947069	0.925448
7.974684	7.754450	7.379749	7.295646	0.914850	0.940833
7.636008	6.380903	5.771040	6.154017	0.805920	0.964443
7.275040	5.183704	4.056444	4.980334	0.684578	0.960767
6.807706	3.961017	1.836607	3.822649	0.561517	0.965067
10.65432	36.26275	20.10803	11.19059	1.050333	0.308597
11.06225	45.86103	22.04571	11.98681	1.083578	0.261372
11.25564	51.26147	22.96431	12.69825	1.128167	0.247715
11.56765	61.34692	24.44634	13.50581	1.167550	0.220154

05P03160

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.772601	73.73808	-0.11204	1.867691
0.565894	55.41889	-0.24726	1.743657
0.355639	35.27750	-0.44899	1.547497
0.313578	31.55035	-0.50365	1.499004
0.212328	21.89930	-0.67299	1.340430
0.140765	14.43005	-0.85150	1.159268
0.082191	8.463315	-1.08517	0.927540

Regression Output:

Constant	-2.01086
Std Err of Y Est	0.001903
R Squared	0.999957
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	0.998741
Std Err of Coef.	0.006505

Tw vs. K'*(8<U>/D)^n

K' = 0.009752
n = 0.998741

Tw* = 5.352524
Res/f* = 518.4457

Regression Output:

Constant	-25.8988
Std Err of Y Est	0.251146
R Squared	0.990353
No. of Observations	16
Degrees of Freedom	14
X Coefficient(s)	13.39286
Std Err of Coef.	0.353267

t = 1.960167 deg C
s.d.)t = 0.224121 deg C

Q1P13154 5/7/90 15:42

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 7.65 Z = 8.1 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.5	3.141	0.0195	0.0235	3.1175
50	1.0118	24.5	2.200666	0.0195	0.0235	2.177166
42	0.849912	24.5	1.619333	0.0195	0.0235	1.595833
31	0.627316	24.5	1.013333	0.0195	0.0235	0.989833
23	0.465428	24.5	0.653666	0.0195	0.0235	0.630166
17	0.344012	24.5	0.42175	0.0195	0.0235	0.39825
13	0.263068	24.5	0.28375	0.0195	0.0235	0.26425
10	0.20236	24.5	0.2258	0.0195	0.0235	0.2023
8	0.161888	24.5	0.1776	0.0195	0.0235	0.1541
6	0.121416	24.5	0.087	0.0195	0.0235	0.0635
25	0.5059	23.9	0.776	0.0255	0.0205	0.7555
19	0.384484	23.9	0.595833	0.0255	0.0205	0.485333
14	0.283304	23.9	0.331666	0.0255	0.0205	0.311166
9	0.182124	23.9	0.206285	0.0205	0.0205	0.185785
35	0.70826	24.4	12.77733	0.0405	0.0465	12.73083
27	0.546372	24.9	8.977333	0.045	0.0785	8.898833
22	0.445192	24.9	6.562	0.045	0.0785	6.4835
16	0.323776	24.9	4.065	0.045	0.0785	3.9865
11	0.222596	24.9	2.452333	0.045	0.0785	2.373833
9	0.182124	24.9	1.980833	0.045	0.0785	1.902333
7	0.141652	24.9	1.565333	0.045	0.0785	1.486833
		24.7	1.4534	0.074	0.053	1.4004
		24.7	1.0754	0.0535	0.0495	1.0259
		24.6	0.860714	0.0495	0.0475	0.813214
		24.6	0.586833	0.0475	0.0445	0.542333
		24.6	0.4696	0.0445	0.0435	0.4261
		24.6	0.379857	0.0445	0.0435	0.336357
		24.5	0.314285	0.0445	0.0435	0.270785
		24.4	1.646166	0.0005	-0.0175	1.663666
		24.4	1.042	-0.0235	-0.0295	1.0715
		24.4	0.663714	-0.033	-0.0385	0.702214
		24.4	0.384833	-0.0425	-0.0495	0.427333
		24.3	0.257230	-0.0535	-0.0565	0.310730
		24.3	0.124769	-0.0595	-0.0595	0.184269
		24.2	0.0796	-0.0605	-0.0605	0.1401
		24.2	0.020777	-0.0605	-0.0805	0.081277
		24.1	-0.02233	-0.0575	-0.0595	0.037166
		24.1	2.506428	-0.0615	-0.0785	2.584928
		24.3	3.379333	-0.0795	-0.079	3.458333
		24.3	4.7564	-0.0805	-0.0805	4.8369
		24.3	5.725666	-0.0805	-0.0785	5.804166

24.2	8.6105	-0.0775	-0.0775	8.688		

		density	viscosity			
						12.03909
	co[NaCl]	1.01234	1.029478	ID(cm) =	1.45796	11.93037
9.974748	X coeff	-0.00025	-9.02281	K(V/psi)=	1.08	12.03909
0.299977	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		2.886574	727.2685	115268.0	407.2317	0.001525	3.653374
		2.015895	606.0571	96056.71	284.3981	0.001533	3.575416
		1.477623	509.0880	80687.64	208.4599	0.001593	3.507964
		0.916512	375.7554	59555.16	129.2996	0.001814	3.404252
		0.583487	278.7862	44186.08	82.31720	0.002098	3.306198
		0.36875	206.0594	32659.28	52.02246	0.002427	3.206549
		0.244675	157.5748	24974.74	34.51836	0.002753	3.117478
		0.187314	121.2114	19211.34	26.42597	0.003563	3.059469
		0.142685	96.96914	15369.07	20.12972	0.004240	3.000372
		0.058796	72.72685	11526.80	8.294856	0.003106	2.807858
		0.699537	303.0285	47382.62	98.68920	0.002128	3.339677
		0.449382	230.3017	36010.79	63.39796	0.002367	3.243580
		0.288117	169.6960	26534.27	40.64697	0.002795	3.147056
		0.172023	109.0902	17057.74	24.26875	0.004039	3.035066
		1.057458	424.2400	67088.17	149.1839	0.001641	3.434329
		0.739161	327.2708	52340.82	104.2793	0.001928	3.361493
		0.538537	266.6651	42648.07	75.97571	0.002116	3.292731
		0.331129	193.9382	31016.78	46.71507	0.002460	3.187122
		0.197177	133.3325	21324.03	27.81733	0.003100	3.074552
		0.158013	109.0902	17446.94	22.29214	0.003711	3.026470
		0.123500	84.84800	13569.84	17.42318	0.004794	2.972958
2155	14.9	0.116321	86.63231	13792.83	16.41033	0.004331	2.957982
1670	15	0.085214	66.68745	10617.39	12.02182	0.005355	2.890409
1870	20	0.067547	56.00547	8896.607	9.529503	0.006018	2.838973
1409	20.1	0.045047	41.98883	6670.029	6.355234	0.00[illegible]140	2.751004
1167	20.1	0.035393	34.77712	5524.431	4.993175	0.009178	2.698627
1242	24.9	0.027938	29.87728	4746.080	3.941539	0.008747	2.647271
1275	30	0.022492	25.45703	4034.799	3.173152	0.009699	2.599199
1270	29.9	0.021794	25.44201	4023.331	3.074680	0.009409	2.591368
1140	35.2	0.014036	19.39907	3067.718	1.980276	0.010423	2.495831
1101	40.1	0.009199	16.44605	2600.735	1.297786	0.009504	2.404070
1013	44.9	0.005598	13.51394	2137.058	0.789769	0.008566	2.296218
1010	59.9	0.004070	10.09981	1593.558	0.574272	0.011151	2.226042
596	59.9	0.002413	5.959891	940.3574	0.340554	0.018991	2.112576
453	59.9	0.001835	4.529917	713.1241	0.258923	0.024994	2.052083
264	60.1	0.001064	2.631166	414.2125	0.150212	0.042978	1.933850
379	179.8	0.000486	1.262607	198.3186	0.068689	0.085346	1.762956
1427	25	0.033862	34.19029	5370.292	4.777297	0.008094	2.684103
1376	19.9	0.045304	41.41753	6534.898	6.391467	0.007360	2.749283
1378	14.9	0.063363	55.39643	8740.503	8.939244	0.005770	2.822133
1633	15	0.076035	65.20994	10288.88	10.72688	0.004996	2.861719

2115	15	0.113813	84.45745	13295.75	16.05659	0.004458	2.948324

76.33526
74.66555 Tap DL= 122.2234
76.33526 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.21349	281.3548	37.01411	25.60557	1.801497	0.091008
13.90166	235.1240	35.53292	25.53352	1.836723	0.108595
13.63185	201.3005	34.25133	25.05198	1.837752	0.124450
13.21700	158.5375	32.28079	23.47833	1.776372	0.148093
12.82479	126.4966	30.41777	21.83165	1.702300	0.172586
12.42619	100.5608	28.52443	20.29820	1.633501	0.201849
12.06991	81.91409	26.83209	19.05559	1.578767	0.232628
11.83787	71.67192	25.72991	16.75284	1.415190	0.233743
11.60148	62.55362	24.60707	15.35589	1.323614	0.245485
10.83143	40.15485	20.94930	17.94117	1.656399	0.446799
12.95870	136.6335	31.05386	21.67414	1.672554	0.158629
12.57432	109.5115	29.22802	20.55193	1.634437	0.187669
12.18822	87.68726	27.39407	18.91257	1.551708	0.215682
11.74026	67.75574	25.26625	15.73459	1.340224	0.232225
13.33731	169.9062	32.85225	24.67837	1.850325	0.145247
13.04597	143.6724	31.46837	22.76916	1.745301	0.158479
12.77092	122.6342	30.16190	21.73540	1.701944	0.177237
12.34849	96.16186	28.15533	20.15922	1.632525	0.209638
11.89820	74.20481	26.01648	17.96045	1.509509	0.242038
11.70588	66.42786	25.10293	16.41530	1.402312	0.247114
11.49183	58.72704	24.08620	14.44164	1.256687	0.245911
11.43193	56.73651	23.80166	15.19395	1.329080	0.267798
11.16163	48.56116	22.51777	13.66497	1.224280	0.281397
10.95589	43.13739	21.54050	12.88992	1.176529	0.298811
10.60401	35.22772	19.86908	11.83377	1.115970	0.335922
10.39450	31.22533	18.87391	11.05758	1.063791	0.354122
10.18908	27.74289	17.89816	10.69210	1.049368	0.385399
9.996796	24.83585	16.98478	10.15366	1.015692	0.408831
9.965473	24.39205	16.83599	10.30902	1.034473	0.422638
9.583325	19.57543	15.02079	9.794542	1.022040	0.500348
9.216280	15.84711	13.27733	10.25713	1.112936	0.647256
8.784874	12.36228	11.22815	10.80432	1.229878	0.873975
8.504168	10.51773	9.894801	9.469475	1.113509	0.900334
8.050305	8.099467	7.738952	7.256321	0.901372	0.895901
7.808335	7.046345	6.589594	6.325301	0.810070	0.897671
7.335402	5.366989	4.343164	4.823613	0.657579	0.898755
6.651825	3.621066	1.096172	3.423001	0.514595	0.945392
10.33641	30.19839	18.59797	11.11460	1.075286	0.368052
10.59713	35.08839	19.83638	11.64006	1.098416	0.331735
10.88853	41.49670	21.22053	13.16445	1.209019	0.317240
11.04687	45.45691	21.97267	14.14648	1.280586	0.311206

11.39329 55.48872 23.61817 14.97573 1.314433 0.269887

Cyanamid 832A

01P13154

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.789769	74.15259	-0.10249	1.870126
0.574272	55.41889	-0.24088	1.743657
0.340554	32.70263	-0.46781	1.514582
0.258923	24.85619	-0.58682	1.395434
0.150212	14.43752	-0.82329	1.159492
0.068689	6.928078	-1.16311	0.840612

Regression Output:

Constant	-1.97878
Std Err of Y Est	0.000956
R Squared	0.999989
No. of Observations	4
Degrees of Freedom	2

X Coefficient(s) 0.997100
Std Err of Coef. 0.002269

Tw vs. K'*(8<U>/D)^n

K' = 0.010500 14399.84
n = 0.997100

Tw* = 5.898375
Res/f* = 541.7759

Regression Output:

Constant	-42.8489
Std Err of Y Est	0.568876
R Squared	0.961354
No. of Observations	10
Degrees of Freedom	8

X Coefficient(s) 19.52735
Std Err of Coef. 1.384227

t = 24.44285 deg C
s.d.)t = 0.277010 deg C

Page 1 Cyanamid 832A

02P13157 5/10/90 15:54

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14
S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=
Z = 2.7 Z = 8.15 Z = 7.5 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.9	2.405666	0.0365	0.0375	2.368166
49	0.991564	24.9	1.717	0.0365	0.0375	1.6795
41	0.829676	24.9	1.238	0.0365	0.0375	1.2005
34	0.688024	24.9	0.96525	0.0365	0.0375	0.92775
27	0.546372	24.9	0.683166	0.0365	0.0375	0.645666
20	0.40472	24.9	0.4524	0.0365	0.0375	0.4149
14	0.283304	24.9	0.3075	0.0365	0.0375	0.27
10	0.20236	24.9	0.215	0.0365	0.0375	0.1775
8	0.161888	24.9	0.15825	0.0365	0.0375	0.12175
30	0.60708	23.9	0.790333	0.0345	0.0315	0.755833
30	0.60708	24.9	8.399	-0.0225	-0.0015	8.4005
23	0.465428	24.9	5.757666	-0.0225	-0.0015	5.759166
17	0.344012	24.9	3.582	-0.0225	-0.0015	3.5835
13	0.263068	24.9	2.721833	-0.0225	-0.0015	2.723333
9	0.182124	24.9	1.585166	-0.0225	-0.0015	1.586666
7	0.141652	24.9	1.210666	-0.0225	-0.0015	1.212166
		24.7	1.2174	0.0055	-0.011	1.2284
		24.7	0.8574	-0.0135	-0.0165	0.8709
		24.7	0.6435	-0.0175	-0.0195	0.661
		24.6	0.477714	-0.0205	-0.0235	0.498214
		24.6	0.363	-0.0235	-0.0255	0.3865
		24.5	0.237125	-0.0255	-0.0255	0.262625
		24.4	1.610571	-0.0125	0.0005	1.623071
		24.4	1.080428	0.0045	0.0065	1.073928
		24.3	0.650666	0.005	0.0025	0.648166
		24.3	0.416615	0.0005	-0.0025	0.419115
		24.2	0.307764	-0.005	-0.0065	0.312764
		24.2	0.233470	-0.0075	-0.0075	0.240970
		24.1	0.085583	-0.0085	-0.0075	0.093083
		24.1	0.1625	-0.0075	-0.0115	0.174
		24	0.035708	-0.0125	-0.0075	0.045708
		24	2.477285	-0.0095	-0.0135	2.490785
		24.1	3.116571	-0.0145	-0.0135	3.130071
		24.1	4.548285	-0.0135	-0.0135	4.561785
		24	5.407833	-0.0145	-0.0085	5.416333
		23.9	7.608	-0.009	-0.009	7.617

Page 2 Cyanamid 832A

		density	viscosity		
	co[NaCl]	1.01234	1.029478	ID(cm) =	1.45796
20.00475	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08 12.03909
0.300206	constant	0.003419	-4.14933	XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		2.192746	727.2685	116312.9	309.3480	0.001158	3.597618
		1.555092	593.9360	94988.90	219.3891	0.001232	3.523001
		1.111574	496.9669	79480.51	156.8185	0.001257	3.450093
		0.859027	412.1188	65910.66	121.1898	0.001413	3.394127
		0.597839	327.2708	52340.82	84.34192	0.001560	3.315416
		0.384166	242.4228	38770.98	54.19741	0.001827	3.219383
		0.25	169.6960	27139.68	35.26946	0.002426	3.126093
		0.164351	121.2114	19385.49	23.18641	0.003126	3.035011
		0.112731	96.96914	15508.39	15.90391	0.003350	2.953146
		0.699845	363.6342	56859.15	98.73274	0.001478	3.339772
		0.697768	363.6342	58156.47	98.43972	0.001474	3.348979
		0.478372	278.7862	44586.62	67.48774	0.001720	3.267006
		0.297655	206.0594	32955.33	41.99259	0.001959	3.163980
		0.226207	157.5748	25201.13	31.91288	0.002546	3.104377
		0.131792	109.0902	17446.94	18.59306	0.003095	2.987069
		0.100685	84.84800	13569.84	14.20455	0.003909	2.928608
2125	15	0.102034	84.85678	13510.15	14.39478	0.003960	2.929224
1641	15	0.072339	65.52940	10433.01	10.20568	0.004708	2.854840
1826	20	0.054904	54.68770	8706.896	7.745807	0.005130	2.794957
1708	25	0.041383	40.92293	6500.708	5.838233	0.006906	2.732579
1417	25	0.032103	33.95070	5393.152	4.529129	0.007784	2.677446
1265	30.1	0.021814	25.17346	3989.854	3.077523	0.009620	2.592556
1256	29.9	0.021262	25.16154	3978.979	2.999655	0.009385	2.586004
980	30	0.014068	19.56697	3094.269	1.984765	0.010269	2.496322
1089	40.2	0.008491	16.22634	2560.208	1.197899	0.009012	2.385693
892	39.9	0.005490	13.39093	2112.834	0.774581	0.008556	2.291016
1001	60	0.004097	9.993134	1573.173	0.578031	0.011465	2.226473
784	59.9	0.003156	7.839856	1234.192	0.445346	0.014352	2.169846
453	90	0.001219	3.014911	473.5541	0.172030	0.037487	1.962315
562	59.9	0.002279	5.619897	882.7210	0.321575	0.020167	2.098154
247	100	0.000598	1.479503	231.8628	0.084475	0.076440	1.806892
1416	25	0.032629	33.92674	5316.887	4.603308	0.007921	2.675062
1687	25	0.041004	40.41978	6348.762	5.784795	0.007013	2.725656
1788	19.9	0.059759	53.81871	8453.341	8.430796	0.005765	2.807447
1593	14.9	0.070954	64.03957	10036.07	10.01011	0.004834	2.843747
2065	15	0.099783	82.46082	12893.86	14.07724	0.004100	2.916801

Page 3 Cyanamid 832A

Tap DL= 122.2234
40.77743

76.33526
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.99047	247.4560	35.95474	29.37717	2.099798	0.118716
13.69200	208.3924	34.53703	28.48858	2.080672	0.136706
13.40037	176.1866	33.15176	28.19471	2.104024	0.160027
13.17650	154.8843	32.08842	26.59673	2.018496	0.171720
12.36166	129.2100	30.59290	25.31771	1.968463	0.195942
12.47753	103.5770	28.76828	23.39500	1.874970	0.225870
12.10437	83.55526	26.99578	20.30070	1.677137	0.242961
11.74004	67.74716	25.26521	17.88404	1.523336	0.263982
11.41258	56.10821	23.70978	17.27509	1.513687	0.307888
12.95909	136.6636	31.05568	26.00323	2.006563	0.190271
12.99591	139.5916	31.23061	26.03865	2.003602	0.186534
12.66802	115.5810	29.67312	24.11003	1.903219	0.208598
12.25592	91.17183	27.71563	22.59149	1.843312	0.247790
12.01750	79.47991	26.58317	19.81722	1.649029	0.249336
11.54827	60.66662	24.35432	17.97419	1.556439	0.296278
11.31443	53.02591	23.24355	15.99435	1.413624	0.301632
11.31810	53.13815	23.26100	15.89036	1.403977	0.299038
11.01936	44.74255	21.84197	14.57367	1.322551	0.325723
10.77982	38.97959	20.70418	13.96066	1.295072	0.358153
10.53031	33.76443	19.51900	12.03320	1.142719	0.356386
10.30978	29.73898	18.47147	11.33434	1.099377	0.381127
9.970216	24.45874	16.85853	10.19536	1.022582	0.416839
9.944016	24.09262	16.73407	10.32209	1.038020	0.428433
9.585291	19.59760	15.03013	9.868137	1.029508	0.503537
9.142773	15.19054	12.92817	10.53372	1.152136	0.693439
8.764067	12.21509	11.12931	10.81057	1.233510	0.885017
8.505894	10.52819	9.903000	9.339053	1.097950	0.887052
8.279387	9.241168	8.827090	8.347110	1.008179	0.903252
7.449262	5.730540	6.883996	5.164806	0.693331	0.901277
7.992617	7.834914	7.464930	7.041565	0.881008	0.898741
6.827568	4.006564	1.930950	3.616921	0.529752	0.902748
10.30025	29.57621	18.42618	11.23556	1.090804	0.379885
10.50262	33.23049	19.38747	11.94076	1.136931	0.359331
10.82978	40.11687	20.94149	13.16986	1.216077	0.328287
10.97498	43.61412	21.63119	14.38191	1.310426	0.329753
11.26720	51.60374	23.01922	15.61643	1.386008	0.302622

Page 4 Cyanamid 832A

02P13157

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.774581	73.47764	-0.11093	1.866155
0.578031	54.83351	-0.23804	1.739046
0.445346	43.01822	-0.35130	1.633652
0.172030	16.54317	-0.76439	1.218618
0.321575	30.83704	-0.49271	1.489072
0.084475	8.118209	-1.07327	0.909460

Regression Output:

Constant	-1.97833
Std Err of Y Est	0.001474
R Squared	0.999985
No. of Observations	4
Degrees of Freedom	2

X Coefficient(s) 0.995396
Std Err of Coef. 0.002667

Tw vs. K'*(8<U>/D)^n

K' = 0.010511
n = 0.995396

Tw* = 3.494575
Res/f* = 420.8153

Regression Output:

Constant	-45.3737
Std Err of Y Est	0.651620
R Squared	0.989413
No. of Observations	28
Degrees of Freedom	26

X Coefficient(s) 21.13878
Std Err of Coef. 0.428818

t = 24.53611 deg C
s.d.)t = 0.368293 deg C

05P13150 4/30/90 15:54

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 C (ppm)=

Z = 2.7 Z = 7.65 Z = 8.1 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.5	1.9205	0.0405	0.0445	1.876
50	1.0118	25.5	1.416	0.0405	0.0445	1.3715
39	0.789204	25.5	1.036666	0.0405	0.0445	0.992166
30	0.60708	25.5	0.688	0.0405	0.0445	0.6435
23	0.465428	25.5	0.4666	0.0405	0.0445	0.4221
17	0.344012	25.5	0.309666	0.0405	0.0445	0.265166
10	0.20236	25.5	0.194333	0.0405	0.0445	0.149833
7	0.141652	25.5	0.145333	0.0405	0.0445	0.100833
30	0.60708	24	0.6834	0.0405	0.0345	0.6429
24	0.485664	24	0.51	0.0345	0.0335	0.4755
10	0.20236	24	0.1832	0.0345	0.0335	0.1487
30	0.60708	25.35	7.23575	0.0635	0.1045	7.13125
22	0.445192	25.35	4.3212	0.0635	0.1045	4.2167
16	0.323776	25.35	2.76428	0.0635	0.1045	2.662928
10	0.20236	25.35	1.542	0.0635	0.1045	1.4375
8	0.161888	25.35	1.42075	0.0635	0.1045	1.31625
6	0.121416	25.35	0.885	0.0635	0.1045	0.7805
		25	1.1038	0.0365	0.0365	1.0673
		24.9	0.796	0.0295	0.0295	0.7665
		24.8	0.677	0.0245	0.0245	0.6525
		24.8	0.479333	0.0205	0.0205	0.458833
		24.7	0.412142	0.0175	0.0155	0.394642
		24.7	0.27025	0.0135	0.0115	0.25675
		24.5	1.6005	0.0455	0.0515	1.555
		24.4	1.063666	0.049	0.0485	1.015166
		24.4	0.677333	0.0465	0.0465	0.630833
		24.4	0.45325	0.0435	0.041	0.41225
		24.4	0.333230	0.0395	0.039	0.294230
		24.3	0.264928	0.0395	0.04	0.224928
		24.2	0.193125	0.0405	0.042	0.151125
		24	0.113066	0.047	0.0445	0.063566
		24	0.081909	0.0455	0.0455	0.036409
		24.2	2.423166	0.0465	0.051	2.372166
		24.2	3.346333	0.0545	0.054	3.292333
		24.2	4.027	0.0535	0.0505	3.9765
		24.2	4.6708	0.052	0.052	4.6188
		24.2	4.7856	0.0515	0.051	4.7346
		24.1	6.4702	0.051	0.0505	6.4197

		density	viscosity		
	co[NaCl]	1.01234	1.029478	ID(cm) =	1.45796
50.01393	X coeff	-0.00025	-0.02281	K(V/psi)=	1.097177
0.300085	constant	0.003419	-4.14933	XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f
		1.709842	727.2685	117398.0	241.2209	0.000903	5.549517
		1.250026	606.0571	98048.38	176.3510	0.000951	5.481194
		0.904299	472.7245	76637.73	127.5753	0.001131	5.41[illegible]
		0.586505	363.6342	58949.03	82.74290	0.001239	5.317170
		0.384714	278.7862	45194.25	54.27471	0.001303	5.225604
		0.241680	206.0594	33404.45	34.09582	0.001591	5.124656
		0.136562	121.2114	19649.67	19.26596	0.002393	5.000700
		0.091962	84.84800	13754.77	12.96541	0.003568	2.914678
		0.585958	363.6342	56987.57	82.66575	0.001238	5.302190
		0.433384	290.9074	45590.05	61.14102	0.001431	5.225691
		0.135529	121.2114	18995.85	19.12023	0.002577	2.984274
		0.597739	363.6342	58749.88	84.32778	0.001263	5.319811
		0.353442	266.6651	43083.24	49.86292	0.001389	5.205716
		0.223205	193.9382	31333.27	31.48941	0.001658	5.105909
		0.120490	121.2114	19583.29	16.99858	0.002292	2.972034
		0.110327	96.96914	15666.63	15.56479	0.002279	2.952899
		0.065421	72.72685	11749.97	9.229494	0.003457	2.339416
2093	14.9	0.089460	84.13987	13486.98	12.62093	0.003512	2.907925
1620	15	0.064247	64.69081	10346.08	9.063943	0.004290	2.831052
1363	14.9	0.054692	54.79343	8743.432	7.715881	0.005091	2.795101
1392	20.1	0.038459	41.48222	6619.352	5.425752	0.006246	2.718639
1425	25	0.033078	34.14237	5435.849	4.666693	0.007930	2.684928
1264	30	0.021520	25.23740	4018.078	3.036095	0.009443	2.591531
1258	29.9	0.020527	25.20161	3994.316	2.895975	0.009032	2.549750
946	30	0.013401	18.88812	2986.917	1.890609	0.010497	2.485769
1091	40	0.008527	16.33742	2581.557	1.174841	0.008719	2.382457
1313	60	0.005442	13.10787	2072.844	0.767759	0.008851	2.290010
976	60	0.003884	9.743555	1540.819	0.547964	0.011433	2.216344
717	59.9	0.002969	7.169869	1131.263	0.418898	0.016141	2.157517
484	59.9	0.001994	4.809911	761.9251	0.281449	0.023799	2.070176
330	90	0.000905	2.196295	344.1959	0.127696	0.052435	1.896.16
231	119.8	0.000480	1.154978	181.0045	0.067806	0.100581	1.759164
1413	24.9	0.031314	33.79082	5351.019	4.417876	0.007574	2.668102
1554	20.1	0.043461	46.30990	7290.355	6.131521	0.005681	2.777[illegible]
1342	14.9	0.052493	57.94921	9492.978	7.405668	0.005040	2.780[illegible]
1514	15	0.060972	61.25661	9643.348	8.601884	0.004540	2.812794
1580	14.9	0.062501	63.51696	9999.184	8.817546	0.004529	2.818171
2044	15	0.084746	81.62224	12820.46	11.95581	0.003554	2.857 [illegible]

Tap DL= 122.2234
75.75206 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.79805	221.5098	35.04074	33.26546	2.410881	0.150175
13.52597	189.3976	33.74839	32.42133	2.396967	0.171181
13.24475	161.0901	32.41259	29.73247	2.244848	0.184570
12.96868	129.7331	30.62624	28.39917	2.206843	0.218904
12.50241	105.0713	28.88648	26.88307	2.150230	0.255855
12.09862	83.27911	26.96846	25.06964	2.072107	0.301031
11.60280	62.60094	24.61331	19.61799	1.690797	0.313381
11.25879	51.35452	22.97927	16.73997	1.486835	0.325968
12.80876	125.3344	30.34161	28.41775	2.218618	0.226735
12.54677	107.7888	29.09718	26.43480	2.106900	0.245246
11.53709	60.27735	24.30120	19.69630	1.707214	0.326761
12.87925	130.5248	30.67644	28.13156	2.184254	0.215526
12.42286	100.3683	28.50861	26.82821	2.159583	0.267297
12.02363	79.76089	26.61228	24.55250	2.042019	0.307826
11.48813	58.60223	24.06864	20.88582	1.818034	0.356399
11.41159	56.07631	23.70508	17.46128	1.530135	0.311784
10.95766	43.18139	21.54891	17.00671	1.552057	0.393843
11.21570	50.09626	22.77458	16.82633	1.500248	0.335880
10.92421	42.35775	21.39000	15.26591	1.397438	0.360404
10.78040	38.99257	20.70693	14.01457	1.300004	0.359416
10.47455	32.69784	19.25414	12.65250	1.207927	0.386952
10.33971	30.25579	18.61364	11.22894	1.086001	0.371133
9.966326	24.40403	16.84005	10.29050	1.032527	0.421672
9.917403	23.72635	16.60766	10.52183	1.060946	0.443466
9.543077	19.12710	14.82961	9.760091	1.022740	0.510275
9.129831	15.07779	12.86670	10.70927	1.172998	0.710267
8.760323	12.18879	11.11153	10.62883	1.213292	0.872016
8.467378	10.29733	9.720048	9.352058	1.104480	0.908202
8.230150	8.982924	8.593216	7.870967	0.956357	0.876214
7.880793	7.346464	6.933768	6.482073	0.822515	0.882339
7.186465	4.926021	3.625710	4.367061	0.607678	0.886529
6.636658	3.589589	1.024129	3.151553	0.474870	0.877970
10.27241	29.10601	18.29395	11.49076	1.118565	0.394776
10.55712	34.23957	19.64635	13.28821	1.258695	0.387529
10.72112	37.68432	20.42533	14.08572	1.313829	0.373782
10.85117	40.61090	21.04310	14.83997	1.367590	0.365391
10.87268	41.11988	21.14526	15.19821	1.397834	0.369607
11.10320	47.77298	22.38274	16.77263	1.506540	0.351090

05P13150

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.767759	71.92448	-0.11477	1.856876
0.547964	53.46404	-0.26124	1.728061
0.418898	39.34192	-0.37789	1.594855
0.281449	26.55717	-0.55059	1.424181
0.127696	12.05132	-0.89382	1.081034
0.067806	6.337506	-1.16872	0.801918

Regression Output:

Constant	-1.95939
Std Err of Y Est	0.006384
R Squared	0.999783
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.987127
Std Err of Coef.	0.008396

Tw vs. K'*(8<U>/D)^n

K' = 0.010979
n = 0.987127

Tw* = 3.320129
Res/f* = 406.4724

Regression Output:

Constant	-53.3586
Std Err of Y Est	0.115907
R Squared	0.996677
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	24.29819
Std Err of Coef.	0.701470

t = 24.75526 deg C
s.d.)t = 0.574890 deg C

Q1P23147 4/26/90 15:09

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14
S = 2.7 S = 7.25 S = 9.9 [Cl (ppm)=
Z = 2.7 Z = 8 Z = 7.65 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	24.9	1.896	0.118	0.1065	1.7895
50	1.0118	24.9	1.4205	0.118	0.1065	1.314
40	0.80944	24.9	1.0405	0.118	0.1065	0.934
31	0.627316	24.9	0.706	0.118	0.1065	0.5995
25	0.5059	24.9	0.538333	0.118	0.1065	0.431833
18	0.364248	24.9	0.37325	0.118	0.1065	0.26675
11	0.222596	24.9	0.2528	0.118	0.1065	0.1463
8	0.161888	24.9	0.193	0.118	0.1065	0.0865
60	1.21416	24.15	1.916	0.0375	0.0945	1.8215
47	0.951092	24.15	1.3	0.0375	0.0945	1.2055
37	0.748732	24.15	0.96325	0.0375	0.0945	0.86875
26	0.526136	24.15	0.5745	0.0375	0.0945	0.48
17	0.344012	24.15	0.3504	0.0375	0.0945	0.2559
10	0.20236	24.15	0.231333	0.0375	0.0945	0.136833
25	0.5059	24.8	5.479666	-0.0005	0.1215	5.358166
18	0.364248	24.8	3.242666	-0.0005	0.1215	3.121166
12	0.242832	24.8	2.17975	-0.0005	0.1215	2.05825
8	0.161888	24.8	1.064333	-0.0005	0.1215	0.942833
		24.7	0.980333	0.0775	0.0765	0.903833
		24.6	0.6735	0.0665	0.0645	0.609
		24.6	0.562833	0.0605	0.0565	0.506333
		24.6	0.428	0.0565	0.0565	0.3715
		24.5	0.363166	0.0535	0.0515	0.311666
		24.5	0.30975	0.0505	0.049	0.25925
		24.3	1.5468	0.0085	0.0125	1.5343
		24.3	1.162111	0.0115	0.0145	1.147611
		24.3	0.7141	0.0135	0.0075	0.7066
		24.3	0.58825	0.0075	0.0045	0.58375
		24.3	0.5	0.0045	0.0045	0.4955
		24.2	0.354166	0.0055	0.009	0.345166
		24.2	0.0888	0.0085	0.014	0.0803
		24.15	0.165692	0.0125	0.0115	0.154192
		24.1	0.2132	0.0115	0.0125	0.2007
		24	0.0578	0.0115	0.0125	0.0453
		24.2	2.566333	0.0085	0.0105	2.555833
		24.2	3.126	0.0095	0.0115	3.1145
		24.2	3.559	0.0105	0.0215	3.5375
		24.2	3.86025	0.0135	0.0225	3.83775
		24.2	5.4232	0.019	0.029	5.3942

		density	viscosity			
	co)NaCl	1.01234	1.029478	ID(cm) =	1.45796	
99.99499	X coeff	-0.00025	-0.02281	K(V/psi)=	1.09165	11.76
0.299995	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.639257	727.2685	116312.9	231.2629	0.000866	3.534447
		1.203679	606.0571	96927.45	169.8125	0.000915	3.467379
		0.855583	484.8457	77541.96	120.7038	0.001017	3.392254
		0.549167	375.7554	60095.02	77.47534	0.001087	3.296976
		0.395577	303.0285	48463.72	55.80723	0.001204	3.225739
		0.244354	218.1805	34893.88	34.47297	0.001434	3.121133
		0.134016	133.3325	21324.03	18.90682	0.002107	2.990703
		0.079237	96.96914	15508.39	11.17867	0.002355	2.876589
		1.668570	727.2685	114361.4	235.3987	0.000881	3.530907
		1.104288	569.6937	89583.16	155.7906	0.000950	3.441276
		0.795811	448.4822	70522.91	112.2713	0.001105	3.370139
		0.439700	315.1497	49556.64	62.03196	0.001237	3.241313
		0.234415	206.0594	32402.42	33.07079	0.001542	3.104727
		0.125345	121.2114	19060.24	17.68341	0.002384	2.968788
		0.449106	303.0285	48354.51	63.35897	0.001366	3.252313
		0.261607	218.1805	34815.25	36.90700	0.001535	3.134963
		0.172516	145.4537	23210.16	24.33828	0.002279	3.044554
		0.079025	96.96914	15473.44	11.14876	0.002348	2.875022
2074	15	0.075756	82.82022	13185.90	10.68760	0.003086	2.864864
1610	15	0.051044	64.29149	10212.86	7.201271	0.003451	2.778143
1375	15	0.042439	54.90733	8722.164	5.987264	0.003934	2.738052
1037	15	0.031138	41.41011	6578.097	4.392893	0.005074	2.670814
1115	20.1	0.026123	33.22750	5266.376	3.685379	0.006612	2.631694
938	19.9	0.021729	28.23375	4474.894	3.065565	0.007618	2.591708
945	20.1	0.020254	28.16142	4443.337	2.857424	0.007137	2.574470
1160	29.9	0.015149	23.23837	3666.572	2.137269	0.007839	2.511412
1180	40	0.009327	17.67017	2788.017	1.315946	0.008348	2.406102
1020	40	0.007706	15.27422	2409.981	1.087154	0.009230	2.364628
814	40	0.006541	12.18942	1923.259	0.922801	0.012302	2.329037
845	59.9	0.004556	8.449845	1330.220	0.642825	0.017833	2.249544
220	59.9	0.001060	2.199959	346.3296	0.149547	0.061206	1.932887
423	60	0.002035	4.222872	664.0380	0.287162	0.031897	2.074068
576	60.2	0.002649	5.731191	900.2020	0.373776	0.022540	2.130818
366	179.8	0.000598	1.219299	191.0845	0.084365	0.112400	1.806608
1475	20.1	0.033739	43.95566	6919.739	4.759890	0.004879	2.684296
1732	19.9	0.041114	52.13311	8207.078	5.800331	0.004227	2.727224
1975	20.1	0.046698	58.85589	9265.413	6.588111	0.007767	2.754878
2086	19.9	0.050661	62.78850	9884.506	7.147285	0.003591	2.772568
2680	20	0.071208	80.26453	12635.67	10.04596	0.003088	2.846493

Tap DL= 122.2234
40.77743

75.757
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.73778	213.9574	34.75449	33.97666	2.473226	0.158801
13.46951	183.3408	33.48020	33.04209	2.453102	0.180222
13.17301	154.5734	32.07184	31.35319	2.380107	0.202836
12.78790	123.8386	30.24254	30.32930	2.371717	0.244909
12.50295	105.1040	28.88905	28.81888	2.304965	0.274193
12.08453	82.60640	26.90154	26.40070	2.184669	0.319596
11.56281	61.17636	24.42336	21.78541	1.884092	0.356108
11.10635	47.04024	22.25520	20.60521	1.855263	0.438033
13.72362	212.2203	34.68723	33.68004	2.454164	0.158703
13.36510	172.6458	32.98424	32.43024	2.426486	0.187842
13.08055	146.5615	31.63265	30.07394	2.299132	0.205196
12.56525	108.9414	29.18494	28.43077	2.262650	0.260973
12.01891	79.54404	26.58982	25.45949	2.118286	0.320067
11.47515	58.16590	24.00698	20.48047	1.784767	0.352104
12.60925	111.7360	29.39395	27.04729	2.145035	0.262064
12.13985	85.27929	27.16430	25.51561	2.101805	0.299200
11.77821	69.25229	25.44652	20.94711	1.778461	0.302475
11.10009	46.87082	22.22542	20.63309	1.858822	0.440211
11.05945	45.78720	22.03241	17.99890	1.627467	0.393098
10.71257	37.49931	20.38472	17.02174	1.588950	0.453921
10.55221	34.19266	19.62300	15.94304	1.510872	0.466270
10.28325	29.28829	18.34546	14.03738	1.365071	0.479283
10.12677	26.76545	17.60219	12.29750	1.214355	0.459454
9.966835	24.41118	16.84246	11.45707	1.149520	0.469337
9.897882	23.46121	16.51494	11.83692	1.195904	0.504531
9.645651	20.29050	15.31684	11.29399	1.170889	0.556614
9.224408	15.92143	13.31594	10.94443	1.186464	0.687402
9.058515	14.47134	12.52794	10.46842	1.149020	0.719243
8.916148	13.33267	11.85170	9.015726	1.011168	0.676212
8.598178	11.10259	10.34134	7.488227	0.870908	0.674457
7.331551	5.355105	4.324871	4.042049	0.551322	0.754803
7.896275	7.412231	7.007310	5.599174	0.709090	0.755396
8.123274	8.446926	8.085555	6.660721	0.819955	0.788537
6.826435	4.003952	1.925569	2.982748	0.436940	0.744951
10.33718	30.21179	18.60163	14.31506	1.384812	0.473823
10.50889	33.35065	19.41726	15.38027	1.463548	0.461168
10.61951	35.54335	19.94269	16.29244	1.534199	0.458382
10.69027	37.02103	20.27880	16.68731	1.560980	0.450752
10.98597	43.89082	21.68338	17.99305	1.637820	0.409950

01P23147

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.087154	83.81147	0.036291	1.923303
0.922801	66.88483	-0.03489	1.825327
0.642825	46.36530	-0.19190	1.666193
0.373776	31.44772	-0.42738	1.497589
0.287162	23.17140	-0.54187	1.364952
0.149547	12.07144	-0.82521	1.081759
0.084365	6.690439	-1.07383	0.825454

Regression Output:

Constant	-1.93132
Std Err of Y Est	0.027037
R Squared	0.995375
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 1.024926
Std Err of Coef. 0.040334

Tw vs. K'*(8<U>/D)^n

K' = 0.011713
n = 1.024926

Tw* = 2.159753
Res/f* = 326.3512

Regression Output:

Constant	-59.4947
Std Err of Y Est	0.106517
R Squared	0.992827
No. of Observations	7
Degrees of Freedom	5

X Coefficient(s) 27.50921
Std Err of Coef. 1.045661

t = 24.46025 deg C
s.d.)t = 0.309917 deg C

Page 1 Cyanamid 832A

Y1P01443 10/31/90 12:37

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=	
Z =	2.85	Z =	9.15	Z =	6.9	[NaCl]=	
FlowCo=	0.019693						

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
23	60	1.181580	24.9	9.736	0.0505	0.0535	9.6855
23	51	1.004343	24.9	7.199	0.0505	0.0535	7.1485
23	40	0.787720	24.9	4.5405	0.0505	0.0535	4.49
23	30	0.590790	24.9	2.64225	0.0505	0.0535	2.59175
23	20	0.393860	24.9	1.277	0.0505	0.0535	1.2265
14	15	0.295395	24.9	2.1954	0.0505	0.0535	2.1449
14	10	0.196930	24.9	1.08325	0.0505	0.0535	1.03275
14	20	0.393860	24.9	3.613	0.0505	0.0535	3.5625
14	30	0.590790	24.9	7.803333	0.0505	0.0535	7.752833
23	17	0.334781	24.7	10.9405	0.0305	0.019	10.91
23	13	0.256009	24.7	6.7486	0.0305	0.019	6.7181
23	9	0.177237	24.7	3.574	0.0305	0.019	3.5435
23	7	0.137851	24.7	2.37125	0.0305	0.019	2.34075
14			24.5	6.246333	0.0425	0.0245	6.203833
14			24.4	4.7312	0.0115	0.0045	4.7197
14			24.3	3.753	-0.0035	-0.0095	3.7565
14			24.4	2.441142	-0.0105	-0.0145	2.451642
14			24.3	1.88175	-0.0155	-0.0215	1.89725
14			24.15	1.147714	-0.0245	-0.0265	1.172214
14			24.2	0.4085	-0.0245	-0.0245	0.433
14			24.1	2.627846	-0.0025	-0.0075	2.635346
14			24.1	1.215529	-0.0055	-0.004	1.219529
14			24	0.898333	-0.005	-0.001	0.899333
14			24.05	0.673347	0.0005	0.0045	0.668847
14			24	0.55832	0.0045	0.0065	0.55182
14			24	0.444625	0.0075	0.0105	0.434125
14			23.9	0.312304	0.0095	0.0145	0.297804
14			23.8	0.210708	0.0135	0.0145	0.196208
14			23.7	0.131807	0.0145	0.0155	0.116307
14			23.65	0.091909	0.0155	0.0155	0.076409
14			23.6	0.044347	0.0155	0.0145	0.029847
14			23.7	7.307285	0.015	0.0015	7.292285
14			23.8	11.58566	0.0135	0.004	11.58166
24			23.9	10.231	0.0015	0.0055	10.2255
23			24	7.80725	0.002	0.0065	7.80075
23			24.1	9.645	0.0015	0.0075	9.6375
23			24.2	12.7415	0.0025	0.0105	12.731

Page 2 Cyanamid 832A

		density	viscosity			
	co[NaCl]	1.000088	1.001574	ID(cm) =	1.02108	
0.999734	X coeff	-0.00025	-0.02281	K(V/psi)=	1.098348	13.19632
0.000100	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

	0							
Batch	Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
			8.818243	1442.958	164114.5	3914.435	0.003770	4.003332
			6.508410	1226.514	139497.3	2889.096	0.003851	3.957379
			4.087957	961.9723	109409.6	1814.652	0.003932	3.836395
			2.359680	721.4792	82057.27	1047.466	0.004035	3.717068
			1.116677	480.9861	54704.84	495.6950	0.004296	3.554605
			1.952841	360.7396	41028.63	288.8935	0.004452	3.437367
			0.940275	240.4930	27352.42	139.0996	0.004823	3.278661
			3.243507	480.9861	54704.84	479.8280	0.004159	3.547541
			7.058631	721.4792	82057.27	1044.218	0.004023	3.716394
			0.826745	408.8382	46289.78	366.8618	0.004401	3.487279
			0.509088	312.6409	35398.07	225.9041	0.004634	3.381990
			0.268521	216.4437	24506.35	119.1544	0.005100	3.243083
			0.177378	168.3451	19060.50	78.71052	0.005569	3.155044
1987	15	0.470118	161.7697	18233.55	69.54696	0.005329	3.124196
1686	15	0.357652	137.2640	15436.58	52.90933	0.005630	3.063838
1458	15	0.284662	118.7016	13318.99	42.11155	0.005992	3.013287
1556	19.9	0.185782	95.48762	10738.44	27.48369	0.006044	2.921610
1625	25	0.143771	79.37869	8906.735	21.26877	0.006768	2.864958
1210	24.9	0.088828	59.34397	6636.232	13.14089	0.007481	2.758921
1220	44.9	0.032812	33.18211	3714.829	4.854067	0.008839	2.542154
1216	44.9	0.032114	33.07332	3694.306	4.750896	0.008708	2.537504
1248	59.9	0.014861	25.44358	2842.061	2.198518	0.006809	2.370181
1006	60	0.010959	20.47563	2281.984	1.621282	0.007753	2.303060
1155	90	0.008150	15.67220	1748.619	1.205771	0.009842	2.239256
1070	99.9	0.006724	13.08003	1457.753	0.994798	0.011658	2.196999
854	99	0.005290	10.53448	1174.055	0.782623	0.014139	2.144908
591	99.9	0.003629	7.224579	803.3561	0.536869	0.020622	2.062080
383	100	0.002391	4.677236	518.9256	0.353716	0.032416	1.970488
236	104.9	0.001417	2.747432	304.1326	0.209674	0.055689	1.855949
146	100	0.000931	1.782967	197.1467	0.137747	0.086870	1.764224
111	199.9	0.000363	0.678110	74.89572	0.053808	0.234594	1.559616
1195	25	0.088865	58.37386	6461.814	13.14623	0.007734	2.754576
1265	20	0.141136	77.24157	8569.725	20.87896	0.007016	2.856615
1126	15	0.124609	91.67221	10193.73	27.65313	0.006597	2.918018
1456	15.1	0.095061	117.7538	13123.51	42.19786	0.006101	3.010776
1658	15	0.117444	134.9844	15077.83	52.13369	0.005736	3.057676
1948	15	0.155142	158.5945	17755.10	68.86787	0.005490	3.119110

82.06026
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	DATA 1//f	1//f/Slv	1//f/L
15.61333	629.8150	43.66332	16.28598	1.043082	0.025858
15.34951	541.0774	42.41020	16.11337	1.049764	0.029780
14.94558	428.8201	40.49150	15.94632	1.066959	0.037186
14.46827	325.7780	38.22430	15.74158	1.088007	0.048317
13.81842	224.1226	35.13750	15.25527	1.103980	0.068066
13.34946	171.0989	32.90997	14.98717	1.122679	0.087593
12.71464	118.7248	29.89456	14.39906	1.132478	0.121281
13.79016	220.5064	35.00328	15.50545	1.124385	0.070317
14.46557	325.2925	38.21148	15.76605	1.089901	0.048467
13.54911	191.9372	33.85830	15.07321	1.112486	0.078531
13.12796	150.6156	31.85781	14.68890	1.118902	0.097525
12.57233	109.3863	29.21857	14.00217	1.113729	0.128006
12.21217	88.90464	27.50784	13.39953	1.097227	0.150718
12.09678	83.19106	26.95973	13.69855	1.132412	0.164663
11.85535	72.39667	25.81293	13.32639	1.124082	0.184074
11.65315	64.44186	24.85247	12.91765	1.108511	0.200454
11.28644	52.17831	23.11059	12.86268	1.139657	0.246513
11.05983	45.79715	22.03421	12.15514	1.099034	0.265412
10.63568	35.87582	20.01951	11.56111	1.087011	0.322253
9.772619	21.82905	15.91994	10.63613	1.088360	0.487246
9.750018	21.54689	15.81258	10.71589	1.099063	0.497328
9.080727	14.65756	12.63345	12.11857	1.334537	0.826779
8.812243	12.55859	11.35815	11.35668	1.288739	0.904296
8.557027	10.84268	10.14588	10.07948	1.177919	0.929611
8.387997	9.837377	9.342987	9.261575	1.104146	0.941467
8.179632	8.725453	8.353252	8.409701	1.028127	0.963812
7.848323	7.210426	6.779537	6.963493	0.887258	0.965753
7.481955	5.839409	5.039289	5.554132	0.742336	0.951146
7.023796	4.485689	2.863035	4.237540	0.603311	0.944679
6.656899	3.631658	1.120273	3.392849	0.509674	0.934242
5.838464	2.267233	-2.76729	2.064623	0.353624	0.910635
10.61830	35.51868	19.93696	11.37044	1.070834	0.320125
11.02406	44.86376	21.86429	11.93853	1.082952	0.266106
11.27207	51.74860	23.04235	12.31160	1.092221	0.237911
11.64310	64.07032	24.80476	12.80186	1.099523	0.199809
11.83070	71.37664	25.69584	13.20270	1.115969	0.184972
12.07644	82.22244	26.86309	13.49623	1.117567	0.164142

Y1P01443

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.782623	82.53601	-0.10644	1.916643
0.536869	56.60343	-0.27013	1.752842
0.353716	36.64540	-0.45134	1.564019
0.209674	21.52570	-0.67845	1.332957
0.137747	13.96926	-0.86091	1.145173
0.053808	5.312891	-1.26914	0.725330

Regression Output:

Constant	-1.97516
Std Err of Y Est	0.001150
R Squared	0.999993
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.973236
Std Err of Coef.	0.001449

Tw vs. K'*(8<U>/D)^n

K' = 0.010508
n' = 0.973236

Regression Output:

Constant	1.039455
Std Err of Y Est	0.164353
R Squared	0.976134
No. of Observations	16
Degrees of Freedom	14
X Coefficient(s)	4.008034
Std Err of Coef.	0.167492

t = 24.31756 deg C
s.d.)t = 0.433903 deg C

Page 1 Cyanamid 832A

Y2P01446 11/4/90 12:55

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.85 Z = 9.15 Z = 6.9 [NaCl]=

FlowCo= 0.019693

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
23	60	1.181580	25.1	8.847	0.0345	0.0295	8.8125
23	50	0.984650	25.1	6.191333	0.0345	0.0295	6.156833
23	39	0.768027	25.1	3.6565	0.0345	0.0295	3.622
23	32	0.630176	25.1	2.473333	0.0345	0.0295	2.438833
23	25	0.492325	25.1	1.538333	0.0345	0.0295	1.503833
23	19	0.374167	25.1	0.9285	0.0345	0.0295	0.894
23	15	0.295395	25.1	0.585	0.0345	0.0295	0.5505
23	10	0.196930	25.1	0.317166	0.0345	0.0295	0.282666
14	25	0.492325	25.2	4.481	0.0285	0.0275	4.4525
14	19	0.374167	25.2	2.701333	0.0285	0.0275	2.672833
14	9	0.177237	25.2	0.719166	0.0285	0.0275	0.690666
23	17	0.334781	24.9	8.917333	0.0415	0.0635	8.875833
23	20	0.393860	24.9	11.724	0.0415	0.0635	11.6825
23	14	0.275702	24.9	6.142	0.0415	0.0635	6.1005
23	9	0.177237	24.9	2.894666	0.0415	0.0635	2.853166
14			24.5	5.5992	0.0655	-0.0205	5.5337
14			24.2	4.0902	-0.0145	-0.0635	4.1047
14			24.2	3.3108	0.0785	0.0645	3.2323
14			24.2	2.190666	0.0625	0.0645	2.128166
14			24.2	1.687333	0.0645	0.0605	1.622833
14			24.1	1.099875	0.0605	0.0585	1.039375
14			24	6.554142	-0.0455	-0.0405	6.594642
14			24	4.30275	-0.0425	-0.0425	4.34525
14			24	3.2986	-0.0485	-0.0475	3.3461
14			24	2.1373	-0.0555	-0.0565	2.1938
14			24	1.127235	-0.0585	-0.0595	1.186735
14			23.9	0.808904	-0.0605	-0.0605	0.869404
14			23.9	0.562772	-0.061	-0.0585	0.621272
14			23.8	0.401090	-0.06	-0.0595	0.460590
14			23.7	0.274458	-0.0615	-0.0615	0.335958
14			23.5	0.18364	-0.0645	-0.0655	0.24914
14			23.4	0.110041	-0.0675	-0.0705	0.180541
14			23.3	0.066291	-0.0715	-0.074	0.137791
14			23.2	0.018666	-0.0765	-0.0795	0.098166
14			23.1	-0.03555	-0.0805	-0.0845	0.048947
14			23.3	10.1014	-0.086	-0.103	10.2044
14			23.5	13.2545	0	-0.0045	13.259
24			23.6	13.37025	-0.0375	-0.0375	13.40775
23			23.8	6.838	-0.0115	-0.0135	6.8515
23			23.9	11.5388	-0.0235	-0.0115	11.5503

Page 2 Cyanamid 832A

		density	viscosity			
	co[NaCl]	1.000088	1.001574	ID(cm) = 1.02108		
1.999589	X coeff	-0.00025	-0.02281	K(V/psi)=	1.098348	13.19632
0.000100	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		8.023413	1442.958	164856.7	3561.608	0.003430	3.984791
		5.605539	1202.465	137380.5	2488.309	0.003451	3.906921
		3.297679	937.9229	107156.8	1463.846	0.003337	3.791716
		2.220455	769.5778	87923.57	985.6646	0.003337	3.705833
		1.369177	601.2326	68690.29	607.7805	0.003372	3.600842
		0.813949	456.9368	52204.62	361.3138	0.003470	3.487911
		0.501207	360.7396	41214.17	222.4868	0.003428	3.382621
		0.257356	240.4930	27476.11	114.2409	0.003961	3.237879
		4.053815	601.2326	68845.43	599.7009	0.003327	3.598921
		2.433503	456.9368	52322.52	360.0001	0.003458	3.488105
		0.628823	216.4437	24784.35	93.02491	0.003982	3.194253
		0.672599	408.8382	46499.12	298.4605	0.003580	3.444441
		0.885284	480.9861	54704.84	392.8380	0.003405	3.504105
		0.462287	336.6903	38293.39	205.1366	0.003629	3.363020
		0.216209	216.4437	24617.18	95.94114	0.004107	3.198000
2166	15.7	0.419336	168.4803	18989.93	62.03453	0.004382	3.099374
1722	14.9	0.311048	141.1358	15800.55	46.01499	0.004631	3.031551
1499	15	0.244939	122.0396	13662.67	36.23511	0.004878	2.979666
1538	20	0.161269	93.91109	10513.60	23.85742	0.005424	2.888913
1298	20	0.122976	79.25657	8872.992	18.19247	0.005807	2.830047
1235	25	0.078762	60.32780	6738.645	11.65172	0.006419	2.732311
1234	25	0.079319	60.27895	6718.016	11.73416	0.006474	2.732857
1144	29.9	0.052264	46.72458	5207.397	7.731712	0.007100	2.642269
1313	40.1	0.040246	39.98627	4456.421	5.953877	0.007466	2.585531
1091	40	0.026386	33.30852	3712.193	3.903534	0.007054	2.493860
1245	60	0.014273	25.34012	2824.125	2.111615	0.006593	2.360439
1168	75	0.010457	19.01832	2114.792	1.546973	0.008575	2.291887
1048	90.1	0.007472	14.20453	1579.510	1.105460	0.010984	2.218918
778	90	0.005539	10.55668	1171.233	0.819551	0.014743	2.152949
630	100	0.004040	7.693627	851.6617	0.597786	0.020247	2.083449
456	100.1	0.002996	5.563157	613.0527	0.443306	0.028715	2.016557
325	100	0.002171	3.968934	436.3858	0.321246	0.040882	1.945639
250	100	0.001657	3.053026	334.9249	0.245179	0.052730	1.885977
170	100	0.001180	2.076058	227.2357	0.174672	0.081240	1.811362
120	150.1	0.000588	0.976317	106.6224	0.087094	0.183156	1.659260
1280	20	0.122737	78.15748	8574.079	18.15718	0.005958	2.820759
1520	20	0.159478	92.81200	10227.76	23.59237	0.005490	2.879591
1499	15.2	0.161267	120.4338	13301.63	35.78811	0.004946	2.971060
1952	19.9	0.082409	119.7891	13290.24	36.58161	0.005111	2.977792
2016	14.9	0.138925	165.2322	18373.43	61.66950	0.004528	3.092181

83.13996
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	DATA 1//f	1//f/Slv	1//f/L
15.53916	603.4926	43.31104	17.07318	1.098719	0.028290
15.22768	504.4302	41.83150	17.02175	1.117816	0.033744
14.76686	386.8981	39.64261	17.31025	1.172235	0.044741
14.42333	317.4778	38.01085	17.30899	1.200069	0.054520
14.00336	249.2999	36.01600	17.22079	1.229760	0.069076
13.55164	192.2167	33.87031	16.97453	1.252581	0.088309
13.13048	150.8346	31.86979	17.07755	1.300603	0.113220
12.55151	108.0835	29.11971	15.88823	1.265841	0.146999
13.99568	248.1997	35.97950	17.33619	1.238681	0.069847
13.55242	192.3027	33.87400	17.00526	1.254776	0.088429
12.37701	97.75381	28.29081	15.84615	1.280289	0.162102
13.37776	173.9089	33.04439	16.71101	1.249163	0.096090
13.61642	199.5194	34.17799	17.13643	1.258512	0.085888
13.05208	144.1783	31.49738	16.59983	1.271815	0.115134
12.39200	98.60090	28.36201	15.60405	1.259203	0.158254
11.99749	78.56958	26.48811	15.10598	1.259094	0.192262
11.72620	67.20966	25.19948	14.69334	1.253034	0.218619
11.51866	59.64126	24.21367	14.31755	1.242987	0.240061
11.15565	48.39426	22.48936	13.57806	1.217146	0.280571
10.92019	42.25985	21.37091	13.12266	1.201688	0.310523
10.52924	33.74364	19.51392	12.48132	1.185395	0.369886
10.53143	33.78607	19.52429	12.42748	1.180037	0.367828
10.16907	27.42518	17.80312	11.86728	1.166996	0.432714
9.942126	24.06642	16.72510	11.57323	1.164060	0.480886
9.575442	19.48680	14.98335	11.90611	1.243400	0.610983
9.041756	14.33240	12.44834	12.31529	1.362047	0.859262
8.767551	12.23962	11.14587	10.79890	1.231690	0.882290
8.475672	10.34661	9.759443	9.541233	1.125719	0.922160
8.211797	8.888519	8.506039	8.235576	1.002895	0.926540
7.933797	7.574069	7.185535	7.027775	0.885802	0.927873
7.666231	6.492887	5.914599	5.901194	0.769764	0.908870
7.382558	5.514672	4.567154	4.945736	0.669921	0.896832
7.143908	4.806813	3.433567	4.354820	0.609585	0.905968
6.845450	4.048019	2.015889	3.508440	0.512521	0.866705
6.237040	2.851937	-0.87405	2.336622	0.374636	0.819310
10.88303	41.36561	21.19443	12.95471	1.190358	0.313176
11.11836	47.36652	22.31223	13.49550	1.213802	0.284916
11.48424	58.47097	24.05014	14.21819	1.238061	0.243166
11.51117	59.38444	24.17806	13.98750	1.215124	0.235541
11.96872	77.27904	26.35145	14.85965	1.241540	0.192285

Y2P01446

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.546973	149.0055	0.189482	2.173202
1.105460	111.2902	0.043543	2.046457
0.819551	82.70997	-0.08642	1.917557
0.597786	60.27834	-0.22345	1.780161
0.443306	43.58645	-0.35329	1.639351
0.321246	31.09597	-0.49316	1.492704
0.245179	23.91997	-0.61051	1.378760
0.174672	16.26558	-0.75777	1.211269
0.087094	7.649293	-1.06000	0.883621

Regression Output:

Constant	-1.89022
Std Err of Y Est	0.005671
R Squared	0.999713
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.935276
Std Err of Coef.	0.007917

Tw vs. K'*(8<U>/D)^n

K' = 0.012875
n = 0.935276

Tw)Retro=0.912706
Res/f)R =154.5732

Regression Output:

Constant	-4.45987
Std Err of Y Est	0.221595
R Squared	0.985366
No. of Observations	23
Degrees of Freedom	21
X Coefficient(s)	6.236909
Std Err of Coef.	0.165859

t = 24.2825 deg C
s.d.)t = 0.673010 deg C

Y5P01449 11/8/90 12:40

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=	
Z =	2.7	Z =	9.15	Z =	6.9	[NaCl]=	
FlowCo=	0.019693						

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
12	60	1.181580	24.7	6.285666	-0.0145	0.0265	6.259166
12	50	0.984650	24.7	4.013	-0.0145	0.0265	3.9865
12	40	0.787720	24.7	2.412666	-0.0145	0.0265	2.386166
12	32	0.630176	24.7	1.534	-0.0145	0.0265	1.5075
14	30	0.590790	24.6	4.05275	0.0255	0.0255	4.02725
14	22	0.433246	24.6	2.2305	0.0255	0.0255	2.205
14	16	0.315088	24.6	1.286	0.0255	0.0255	1.2605
14	10	0.196930	24.6	0.606333	0.0255	0.0255	0.580833
14	13	0.256009	24.6	0.9128	0.0255	0.0255	0.8873
23	17	0.334781	25	5.890666	0.0665	0.0905	5.800166
23	24	0.472632	25	10.732	0.0665	0.0905	10.6415
23	27	0.531711	25	13.347	0.0665	0.0905	13.2565
23	14	0.275702	24.9	4.20125	0.0795	0.0835	4.11775
23	9	0.177237	24.9	1.96575	0.0795	0.0835	1.88225
23			24.7	1.455	0.0575	0.0575	1.3975
14			24.5	2.9826	0.0575	0.0455	2.9251
14			24.1	2.352666	0.0445	0.0405	2.308166
14			24.1	1.495166	0.0435	0.0315	1.451666
14			24.1	1.152	0.0345	0.0415	1.1175
14			24	7.173	-0.0145	-0.0415	7.2145
14			24	4.4434	-0.046	-0.0475	4.4909
14			24	3.030111	-0.0515	-0.0535	3.083611
14			24	2.136888	-0.0555	-0.0555	2.192388
14			23.9	1.699181	-0.0585	-0.0585	1.757681
14			23.85	1.236666	-0.0595	-0.0595	1.296166
14			23.8	0.877875	-0.0605	-0.0605	0.938375
14			23.7	0.676357	-0.0615	-0.0605	0.736857
14			23.6	0.495909	-0.0615	-0.0595	0.555409
14			23.5	0.349	-0.06	-0.0595	0.4085
14			23.3	0.2635	-0.06	-0.06	0.3235
14			23.2	0.169695	-0.06	-0.0595	0.229695
14			23.1	0.072695	-0.0595	-0.0605	0.133195
14			23	0.004125	-0.0605	-0.0605	0.064625
14			23.3	9.235166	-0.0605	-0.0695	9.304666
14			23.6	12.30475	-0.0695	-0.0695	12.37425
24			23.8	11.63125	-0.0695	-0.0685	11.69975
23			24.1	8.47325	-0.0695	-0.0575	8.53075

		density	viscosity		
	co[NaCl]	1.000088	1.001574	ID(cm) =	1.02108
5.000475	X coeff	-0.00025	-0.02281	K(V/psi)=	1.098348 13.19632
0.000100	constant	0.003419	-4.14933	XS(cm2)=	0.818859

Batch Vol (ml)	0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		5.698709	1442.958	163375.7	2528.757	0.002435	3.906481
		3.629541	1202.465	136146.4	1610.580	0.002233	3.808519
		2.172505	961.9723	108917.1	964.0319	0.002089	3.697075
		1.372515	769.5778	87133.72	609.0430	0.002062	3.597352
		3.666642	721.4792	81703.78	542.4246	0.002089	3.571212
		2.007560	529.0847	59769.44	296.9883	0.002127	3.440412
		1.147632	384.7889	43468.68	169.7749	0.002299	3.318979
		0.528824	240.4930	27167.92	78.23162	0.002712	3.150734
		0.807849	312.6409	35318.30	119.5091	0.002451	3.242743
		0.439529	408.8382	46604.14	195.0375	0.002340	3.353042
		0.806399	577.1833	65794.08	357.8331	0.002154	3.484823
		1.004560	649.3313	74018.34	445.7657	0.002120	3.532536
		0.312037	336.6903	38293.39	138.4642	0.002449	3.277667
		0.142634	216.4437	24617.18	63.29291	0.002709	3.107675
2203	15	0.105900	179.3551	20307.08	46.99261	0.002929	3.041042
1776	15	0.221660	144.5913	16297.32	32.79130	0.003145	2.960936
1532	15	0.174909	124.7263	13931.99	25.87528	0.003334	2.905559
1562	20	0.110005	95.37655	10653.60	16.27364	0.003586	2.804859
1312	19.9	0.084682	80.51398	8993.452	12.52753	0.003874	2.748049
1319	20.1	0.087381	80.13815	8931.299	12.92681	0.004035	2.753877
1237	25	0.054393	60.42550	6734.348	8.046716	0.004418	2.650941
1178	30	0.037348	47.95287	5344.289	5.525160	0.004817	2.569304
1165	35	0.026554	40.64886	4530.266	3.928284	0.004766	2.495233
1097	40	0.021288	33.49170	3724.198	3.149383	0.005629	2.446259
1048	50	0.015699	25.59657	2843.069	2.322448	0.007106	2.379626
919	60	0.011365	18.70487	2075.250	1.681363	0.009634	2.308992
846	70.1	0.008924	14.73814	1631.469	1.320287	0.012186	2.255510
816	90.1	0.006727	11.06002	1221.552	0.995172	0.016310	2.193140
593	90.1	0.004947	8.037490	885.7210	0.731943	0.022714	2.125444
451	90	0.003918	6.119622	671.3385	0.579641	0.031027	2.072815
345	99.9	0.002782	4.217394	461.6165	0.411564	0.046384	1.997469
188	100	0.001613	2.295876	250.7297	0.238657	0.090759	1.878152
84	99.9	0.000782	1.026843	111.8876	0.115793	0.220131	1.720122
1541	19.9	0.112697	94.56711	10374.25	16.67193	0.003737	2.802228
1400	15	0.149876	113.9796	12588.77	22.17196	0.003421	2.867092
1746	15	0.141706	142.1489	15771.00	31.44733	0.003120	2.944953
2147	15	0.103324	174.7959	19524.79	45.86577	0.003009	3.029861

82.563
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	DATA 1//f	1//f/Slv	1//f/L
15.22592	503.9200	41.82315	20.26310	1.330828	0.040210
14.83407	402.1603	39.96186	21.15860	1.426351	0.052612
14.38829	311.1385	37.84440	21.87875	1.520593	0.070318
13.98940	247.3045	35.94968	22.02085	1.574109	0.089043
13.88485	232.8587	35.45303	21.87586	1.575520	0.093944
13.36165	172.3028	32.96783	21.68036	1.622581	0.125827
12.87591	130.2745	30.66061	20.85435	1.619640	0.160080
12.20293	88.43293	27.46394	19.20094	1.573468	0.217124
12.57097	109.3008	29.21212	20.19558	1.606524	0.184770
13.01217	140.9038	31.30781	20.67196	1.588663	0.146709
13.53929	190.8551	33.81165	21.54581	1.591353	0.112890
13.73014	213.0183	34.71820	21.71712	1.581711	0.101949
12.71066	118.4533	29.87567	20.20489	1.589600	0.170572
12.03070	80.08588	26.64584	19.21154	1.596876	0.239886
11.76417	68.69464	25.37981	18.47586	1.570519	0.268956
11.44374	57.12378	23.85780	17.83115	1.558156	0.312149
11.22223	50.28511	22.80562	17.31624	1.543029	0.344361
10.81943	39.87854	20.89232	16.69696	1.543237	0.418695
10.59219	34.98884	19.81294	16.06485	1.516668	0.459142
10.61550	35.46152	19.92367	15.74117	1.482847	0.443894
10.20376	27.97828	17.96787	15.04369	1.474328	0.537691
9.877216	23.18377	16.41677	14.40740	1.458650	0.621443
9.580932	19.54848	15.00942	14.48407	1.511760	0.740930
9.385037	17.46382	14.07892	13.32826	1.420160	0.763192
9.118507	14.97983	12.81291	11.86207	1.300878	0.791869
8.835968	12.73128	11.47085	10.18775	1.152986	0.800214
8.622041	11.25616	10.45469	9.058756	1.050650	0.804781
8.372560	9.750346	9.269660	7.830187	0.935220	0.803067
8.101777	8.343041	7.983442	6.635178	0.818978	0.795294
7.891260	7.390862	6.983486	5.677099	0.719416	0.768124
7.589876	6.213683	5.551913	4.643144	0.611754	0.747245
7.112610	4.720984	3.284898	3.319351	0.466685	0.703105
6.480690	3.280972	0.282329	2.131373	0.328890	0.649616
10.80891	39.63769	20.84233	16.35794	1.513375	0.412686
11.06837	46.02279	22.07476	17.09584	1.544567	0.371464
11.37981	55.05962	23.55411	17.90218	1.573153	0.325141
11.71944	66.94856	25.16736	18.22741	1.555314	0.272260

Y5P01449

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
2.322448	200.5451	0.365946	2.302212
1.681363	146.5497	0.225661	2.165985
1.320287	115.4710	0.120668	2.062473
0.995172	86.65351	-0.00210	1.937786
0.731943	62.97246	-0.13552	1.799150
0.579641	47.94627	-0.23684	1.680754
0.411564	33.04261	-0.38556	1.519074
0.238657	17.98782	-0.62222	1.254978
0.115793	8.045158	-0.93631	0.905534

Regression Output:

Constant	-1.74953
Std Err of Y Est	0.002109
R Squared	0.999967
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 0.898279
Std Err of Coef. 0.002946

Tw vs. K'*(8<U>/D)^n

K' = 0.017801
n = 0.898279

Tw)Retro=2.451489
Res/f)R =251.0400

Regression Output:

Constant	-6.36946
Std Err of Y Est	0.221248
R Squared	0.990509
No. of Observations	20
Degrees of Freedom	18

X Coefficient(s) 8.152781
Std Err of Coef. 0.188096

t = 24.15810 deg C
s.d.)t = 0.579784 deg C

Y1P11452 11/11/90 12:48

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.85 Z = 9.15 Z = 6.9 [NaCl]=

FlowCo= 0.019693

Tap Pair	Freq. (Hz)		Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
14	60	1.181580		24.7	13.082	0.0875	0.0985	12.9835
14	49	0.964957		24.7	7.9355	0.0875	0.0985	7.837
14	40	0.787720		24.7	4.9805	0.0875	0.0985	4.882
14	30	0.590790		24.7	2.725	0.0875	0.0985	2.6265
14	21	0.413553		24.7	1.345666	0.0875	0.0985	1.247166
14	15	0.295395		24.7	0.7854	0.0875	0.0985	0.6869
14	10	0.196930		24.7	0.4468	0.0875	0.0985	0.3483
12	17	0.334781		24.9	3.5855	0.0395	0.0425	3.546
12	24	0.472632		24.9	6.316	0.0395	0.0425	6.2765
12	33	0.649869		24.9	11.61966	0.0395	0.0425	11.58016
12	15	0.295395		24.9	2.7994	0.0425	0.0435	2.7569
12	10	0.196930		24.9	1.5025	0.0425	0.0435	1.46
12				24.6	1.1465	0.0395	0.0345	1.112
12				24.3	0.7308	0.0345	0.0345	0.6963
14				24.2	2.15625	0.0315	0.0245	2.12475
14				24.1	1.6408	0.027	0.0235	1.6138
14				24.1	1.1304	0.0275	0.0235	1.1069
14				24	0.931666	0.0265	0.0245	0.907166
14				23.8	5.767	0.0605	0.0595	5.7075
14				23.8	3.9505	0.055	0.055	3.8955
14				23.8	2.860125	0.0515	0.063	2.797125
14				23.8	2.3707	0.063	0.069	2.3017
14				23.7	1.857727	0.0675	0.0695	1.788227
14				23.6	1.420266	0.069	0.068	1.352266
14				23.6	1.117	0.067	0.0685	1.0485
14				23.5	0.772318	0.0675	0.0695	0.702818
14				23.3	0.531954	0.0205	0.015	0.516954
14				23.1	0.359681	0.02	0.0265	0.333181
14				22.9	0.22292	0.0285	0.0325	0.19042
14				22.8	0.163478	0.0335	0.036	0.129978
14				22.7	0.117391	0.0365	0.0355	0.081891
14				22.5	0.081147	0.0355	0.0365	0.044647
14				23	7.048714	0.0365	0.0375	7.011214
14				23.3	10.469	0.0215	0.0375	10.4315
14				23.6	12.6024	0.0265	0.0335	12.5689
13				23.7	12.009	0.0535	0.103	11.906

		density	viscosity			
	co[NaCl]	1.000088	1.001574	ID(cm) =	1.02108	
9.999572	X coeff	-0.00025	-0.02281	K(V/psi)=	1.098348	13.45545
0.000100	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		11.82093	1442.958	163375.7	1748.729	0.001684	3.826389
		7.135261	1178.416	133423.5	1055.554	0.001524	3.716768
		4.444857	961.9723	108917.1	657.5496	0.001424	3.613992
		2.391318	721.4792	81687.86	353.7595	0.001362	3.479382
		1.135493	505.0354	57181.50	167.9791	0.001320	3.317655
		0.625393	360.7396	40843.93	92.51759	0.001425	3.188140
		0.317112	240.4930	27229.28	46.91203	0.001626	3.040670
		0.263536	408.8382	46499.12	116.9421	0.001403	3.240984
		0.466465	577.1833	65645.81	206.9902	0.001246	3.364973
		0.860630	793.6271	90262.99	381.8978	0.001215	3.497972
		0.204890	360.7396	41028.63	90.91873	0.001401	3.186325
		0.108506	240.4930	27352.42	48.14877	0.001669	3.048291
2433	14.9	0.682643	199.4097	22526.84	36.67221	0.001849	2.986211
1743	15	0.051748	141.9046	15922.50	22.96300	0.002286	2.881601
1740	15	0.157909	141.6604	15859.27	23.36040	0.002334	2.884342
1496	15	0.119936	121.7954	13604.60	17.74280	0.002398	2.823627
1543	20.1	0.082264	93.74766	10471.66	12.16972	0.002776	2.741757
1305	20	0.067420	79.68399	8880.684	9.973776	0.003149	2.697561
1300	20	0.069129	79.37869	8806.832	10.22659	0.003253	2.701026
1220	25	0.047182	59.59507	6611.898	6.979888	0.003940	2.618085
1165	30	0.033878	47.42367	5261.517	5.011839	0.004467	2.546159
1156	35	0.027878	40.33484	4475.032	4.124145	0.005082	2.503828
1070	40	0.021658	32.66738	3616.182	3.204114	0.006019	2.468030
1130	55	0.016378	25.09032	2771.166	2.422967	0.007716	2.386364
945	60.1	0.012699	19.20206	2120.821	1.878683	0.010214	2.331117
930	90	0.008512	12.61917	1390.616	1.259297	0.015853	2.243269
686	90	0.006261	9.308338	1021.149	0.926270	0.021430	2.174604
424	90.1	0.004035	5.746873	627.6088	0.596989	0.036234	2.077248
256	99.9	0.002306	3.129428	340.2224	0.341191	0.069833	1.953793
159	99.9	0.001574	1.943668	210.8338	0.232892	0.123564	1.869887
95	100	0.000991	1.160150	125.5603	0.146731	0.218507	1.768585
72	150	0.000540	0.586181	63.15541	0.079997	0.466621	1.634892
1890	25	0.084919	92.32352	10059.81	12.56257	0.002954	2.737818
1478	15	0.126345	120.3299	13200.50	18.69097	0.002587	2.827051
1708	15	0.152234	139.0551	15358.31	22.52073	0.002334	2.870482
2144	14.9	0.144205	175.7231	19452.03	32.00068	0.002077	2.947755

82.563
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	DATA 1//f	1//f/Slv	1//f/L
14.90555	419.0533	40.30139	24.36678	1.634744	0.058147
14.46707	325.5730	38.21859	25.61320	1.770448	0.078671
14.05596	256.9640	36.26585	26.49134	1.884703	0.103093
13.51752	188.4786	33.70826	27.08790	2.003909	0.143718
12.87062	129.8780	30.63545	27.51692	2.137963	0.211867
12.35256	96.38739	28.17466	26.48422	2.144027	0.274768
11.76268	68.63572	25.37273	24.79511	2.107947	0.361256
12.56393	108.8589	29.17869	26.69689	2.124882	0.245243
13.05989	144.8282	31.53449	28.32915	2.169172	0.195605
13.59188	196.7216	34.06146	28.67726	2.109880	0.145775
12.34530	95.98539	28.14017	26.71541	2.164014	0.278327
11.79316	69.85075	25.51753	24.47398	2.075269	0.350375
11.54484	60.54683	24.33801	23.25353	2.014191	0.384058
11.12640	47.58627	22.35043	20.91267	1.879553	0.439468
11.13736	47.88751	22.40250	20.69860	1.858482	0.432233
10.89451	41.63973	21.24893	20.42010	1.874348	0.490399
10.56702	34.48556	19.69338	18.97833	1.795995	0.550327
10.39024	31.14881	18.85366	17.81906	1.714980	0.572062
10.40410	31.39835	18.91951	17.53044	1.684953	0.558323
10.07234	25.93973	17.34362	15.93091	1.581649	0.614150
9.786639	21.98061	15.97703	14.96067	1.528995	0.680630
9.615313	19.93922	15.17273	14.02709	1.458829	0.703492
9.392120	17.53517	14.11257	12.88903	1.372323	0.735038
9.145458	15.21404	12.94092	11.38407	1.244779	0.748261
8.924470	13.39669	11.89123	9.894330	1.108674	0.738564
8.573079	10.94333	10.22212	7.942142	0.926404	0.725751
8.298416	9.342952	8.917478	6.831011	0.823170	0.731140
7.908992	7.466691	7.067715	5.253404	0.664231	0.703578
7.415173	5.619186	4.722075	3.784160	0.510326	0.673435
7.079549	4.631986	3.127858	2.844808	0.401834	0.614165
6.674342	3.668306	1.203127	2.139276	0.320522	0.583178
6.139571	2.696328	-1.33703	1.463921	0.238440	0.542931
10.55127	34.17424	19.61856	18.39801	1.743677	0.538359
10.90820	41.96926	21.31397	19.65800	1.802129	0.468390
11.08192	46.38335	22.13916	20.69480	1.867436	0.446168
11.39102	55.41606	23.60735	21.93862	1.925957	0.395889

Y1P11452

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
2.422967	196.5787	0.384347	2.293536
1.878683	150.4451	0.273853	2.177378
1.259297	98.86924	0.100128	1.995061
0.926270	72.92936	-0.03326	1.862902
0.596989	45.02584	-0.22403	1.653461
0.341191	24.51857	-0.46700	1.389495
0.232892	15.22833	-0.63284	1.182652
0.146731	9.089592	-0.83347	0.958544
0.079997	4.592636	-1.09692	0.662062

Regression Output:

Constant	-1.68075
Std Err of Y Est	0.006826
R Squared	0.999756
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.881684
Std Err of Coef.	0.006875

Tw vs. K'*(8<U>/D)^n

K' =	0.020856	133483.4
n =	0.881684	

Tw)Retro=31.86397
Res/f)R= 905.0614

Regression Output:

Constant	-8.71213
Std Err of Y Est	0.283324
R Squared	0.964923
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	10.98835
Std Err of Coef.	0.936928

t = 23.97777 deg C
s.d.)t = 0.715351 deg C

Y2P11455 11/15/90 11:37

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.8 Z = 9.2 Z = 6.9 [NaCl]=

FlowCo= 0.019693

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
12	60	1.181580	24.7	2.993	0.0585	0.0905	2.9345
14	60	1.181580	24.7	9.6775	0.0585	0.0905	9.587
14	50	0.984650	24.7	6.261	0.0585	0.0905	6.1705
14	40	0.787720	24.7	4.085333	0.0585	0.0905	3.994833
14	30	0.590790	24.7	2.566666	0.0585	0.0905	2.476166
14	23	0.452939	24.7	1.706666	0.0585	0.0905	1.616166
14	16	0.315088	24.7	1.016333	0.0585	0.0905	0.925833
14	10	0.196930	24.7	0.518666	0.0585	0.0905	0.460166
14	8	0.157544	24.7	0.418666	0.0585	0.0905	0.360166
12	17	0.334781	24.9	3.32675	0.0285	0.041	3.28575
12	24	0.472632	24.9	5.544	0.0285	0.041	5.503
12	34	0.669562	24.9	9.46225	0.0285	0.041	9.42125
14	15	0.295395	24.9	7.770333	0.0365	0.0705	7.699833
14	10	0.196930	24.9	4.253	0.0365	0.0705	4.1825
14	8	0.157544	24.9	3.082571	0.0365	0.0705	3.012071
14			24.6	2.7768	0.0285	0.0255	2.7483
14			24.4	2.1066	0.0285	0.0245	2.0781
14			24.4	1.7332	0.0285	0.0265	1.7047
14			24.4	1.263166	0.0295	0.0275	1.233666
14			24.3	1.009	0.0285	0.0275	0.9805
14			24.2	6.227	0.0695	0.0725	6.1545
14			24.3	4.1	0.0735	0.0735	4.0265
14			24.3	3.235444	0.0735	0.0745	3.160944
14			24.2	2.667272	0.074	0.0745	2.592772
14			24.2	2.190416	0.073	0.0745	2.115916
14			24.2	1.691941	0.073	0.0755	1.616441
14			24.15	1.310090	0.073	0.0765	1.233590
14			24.1	0.982	0.0735	0.0755	0.9065
14			24	0.73296	0.0755	0.0785	0.65446
14			23.8	0.594166	0.078	0.077	0.517166
14			23.7	0.528083	0.075	0.0735	0.454583
14			23.65	0.49908	0.0735	0.0735	0.42558
14			23.6	0.318055	0.0715	0.0695	0.248555
14			23.5	0.359458	0.0695	0.0685	0.290958
14			23.4	0.265041	0.0675	0.0665	0.198541
14			23.4	0.225552	0.0655	0.0655	0.160052
14			23.65	7.73725	0.0625	0.0515	7.67475
14			23.9	10.39166	0.0475	0.0435	10.34816
14			24.05	8.22125	0.0415	0.1235	8.09775
13			24.1	11.1235	0.0335	0.003	11.09

		density	viscosity			
	co[NaCl]	1.000088	1.001574	ID(cm) =	1.02108	
20.00475	X coeff	-0.00025	-0.02281	K(V/psi)=	1.440682	13.4881
0.000100	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		2.036882	1442.958	163375.7	903.8504	0.000870	5.283076
		6.656487	1442.958	163375.7	984.4311	0.000948	5.201620
		4.283040	1202.465	136146.4	633.6114	0.000878	5.205939
		2.772876	961.9723	108917.1	410.2053	0.000888	5.111528
		1.718746	721.4792	81687.86	254.2626	0.000979	5.007669
		1.121806	553.1340	62627.36	165.9544	0.001087	4.915022
		0.642635	384.7889	43566.86	95.06823	0.001287	4.794045
		0.319408	240.4930	27229.28	47.25173	0.001638	4.642236
		0.249997	192.3944	21783.43	36.98334	0.002003	4.589031
		0.243603	408.8382	46499.12	108.0971	0.001296	4.555905
		0.407989	577.1833	65645.81	181.0420	0.001089	4.735888
		0.698486	817.6764	92998.24	309.9476	0.000929	4.832642
		0.570861	360.7396	41028.63	84.45032	0.001301	4.570299
		0.310088	240.4930	27352.42	45.87287	0.001590	4.437776
		0.223313	192.3944	21881.93	33.03583	0.001789	4.366491
2104	14.9	0.203757	172.4447	19480.67	30.14283	0.002032	4.343634
1665	14.9	0.154069	136.4641	15346.62	22.79220	0.002454	4.280965
1436	15	0.126385	116.9105	13147.65	18.69682	0.002742	4.237956
1490	20	0.091463	90.98019	10231.54	13.53062	0.003277	4.167731
1269	20	0.072693	77.48581	8694.344	10.75393	0.003591	4.116871
1272	20.1	0.075515	77.28258	8651.999	11.17135	0.003750	4.124155
1186	25	0.049404	57.93423	6500.546	7.308712	0.004366	4.033007
1138	29.9	0.038784	46.47952	5215.263	5.737596	0.005325	3.980452
1280	40.3	0.031813	38.78783	4342.405	4.706278	0.006272	3.936440
1156	44.9	0.025962	31.44141	3519.953	3.840711	0.007790	3.892307
1146	60.1	0.019833	23.28631	2606.967	2.934087	0.010849	3.833838
1101	80	0.015136	16.80691	1879.459	2.239155	0.015894	3.774651
976	100.1	0.011122	11.90710	1330.029	1.645435	0.023269	3.707257
632	100	0.008030	7.718051	860.1674	1.187944	0.039984	3.635529
435	100	0.006345	5.312266	589.3803	0.938736	0.066692	3.582433
378	100.1	0.005577	4.611564	510.4865	0.825138	0.077787	3.553439
331	99.9	0.005221	4.046253	447.4033	0.772492	0.094593	3.538630
166	100.1	0.003049	2.025184	223.6767	0.451166	0.220534	3.021359
188	100	0.003570	2.295876	253.0025	0.528133	0.200865	3.054577
106	100	0.002436	1.294483	142.3289	0.360383	0.431141	1.970602
112	150	0.001963	0.911837	100.2568	0.290519	0.700468	1.923808
1470	19.9	0.094168	90.21003	9974.725	13.93084	0.003431	3.766672
1414	15.1	0.126971	114.3570	12716.23	18.78350	0.002879	3.834034
1638	15	0.099358	133.3562	14879.16	22.04883	0.002485	3.870317
2076	15	0.136073	169.0155	18879.12	30.19623	0.002119	3.939093

81.5
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	DATA 1//f	1//f/Slv	1//f/L
14.33230	301.2703	37.57845	33.89309	2.364803	0.112500
14.40648	314.4131	37.93079	32.47631	2.254285	0.103291
14.02375	252.2432	36.11285	33.73391	2.405483	0.133735
13.64611	202.9591	34.31904	33.54034	2.457867	0.165256
13.23067	159.7898	32.34571	31.95127	2.414938	0.199958
12.86008	129.0929	30.58542	30.32087	2.357749	0.234876
12.37618	97.70702	28.28686	27.86830	2.251768	0.285223
11.76894	68.88377	25.40250	24.70582	2.099238	0.358659
11.55612	60.94121	24.39159	22.34061	1.933227	0.366592
12.49562	104.6611	28.85420	27.76764	2.222190	0.265309
12.94355	135.4466	30.98187	30.29137	2.340267	0.223640
13.41057	177.2240	33.20020	32.79684	2.445596	0.185058
12.28119	92.50796	27.83568	27.71966	2.257081	0.299646
11.75110	68.17991	25.31775	25.07375	2.133735	0.367758
11.46596	57.85902	23.96333	23.63712	2.061503	0.408529
11.37453	54.89274	23.52906	22.18038	1.950002	0.404067
11.12386	47.51663	22.33834	20.18586	1.814644	0.424816
10.95182	43.03645	21.52117	19.09377	1.743432	0.443665
10.67092	36.61098	20.18689	17.46666	1.636845	0.477088
10.46748	32.56499	19.22054	16.68652	1.594129	0.512406
10.49662	33.11578	19.35894	16.32907	1.555650	0.493090
10.13203	26.84650	17.62714	15.13359	1.493639	0.563708
9.921809	23.78659	16.62859	13.70326	1.381125	0.576091
9.745763	21.49418	15.79237	12.62668	1.295608	0.587446
9.569231	19.41725	14.95385	11.32997	1.184000	0.583500
9.335354	16.97143	13.84293	9.600569	1.028409	0.565689
9.098606	14.80920	12.71838	7.931973	0.871778	0.535611
8.829029	12.68052	11.43788	6.555473	0.742490	0.516971
8.542119	10.75003	10.07506	5.000957	0.585446	0.465203
8.329732	9.512904	9.066229	3.872242	0.464869	0.407051
8.213757	8.898553	8.515348	3.585460	0.436518	0.402926
8.154522	8.600242	8.233982	3.251386	0.398721	0.378057
7.685436	6.565067	6.005824	2.129421	0.277072	0.324356
7.818310	7.086922	6.636975	2.231244	0.285387	0.314839
7.482411	5.840942	5.041455	1.522966	0.203539	0.260739
7.295233	5.244311	4.152360	1.194828	0.163782	0.227833
10.66668	36.52180	20.16677	17.06981	1.600291	0.467386
10.93613	42.64958	21.44666	18.63476	1.703961	0.436927
11.08126	46.36572	22.13602	20.05678	1.809972	0.432577
11.35637	54.32168	23.44277	21.72143	1.912708	0.399866

Y2P11455

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.645435	93.29031	0.216280	1.969836
1.187944	60.46970	0.074796	1.781537
0.938736	41.62076	-0.02745	1.619310
0.825138	36.13087	-0.08347	1.557878
0.772492	31.70175	-0.11210	1.501083
0.451166	15.86699	-0.34566	1.200494
0.528133	17.98782	-0.27725	1.254978
0.360383	10.14207	-0.44323	1.006126
0.290519	7.144100	-0.53682	0.853947

Regression Output:

Constant	-1.13148
Std Err of Y Est	0.013828
R Squared	0.997278
No. of Observations	9
Degrees of Freedom	7

X Coefficient(s)	0.678567
Std Err of Coef.	0.013397

Tw vs. K'*(8<U>/D)^n

K' = 0.073877
n = 0.678567

Tw)Retro=331.9457
Res/f)R= 2921.202

Regression Output:

Constant	26.32042
Std Err of Y Est	0.000460
R Squared	0.999996
No. of Observations	3
Degrees of Freedom	1

X Coefficient(s)	2.056016
Std Err of Coef.	0.003791

t = 24.305 deg C
s.d.)t = 0.457684 deg C

Y5P11459 11/8/90 12:40

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
S =	1	S =	7.25	S =	9.9	<C>(ppm)=	
Z =	5.3	Z =	9.2	Z =	6.8	[NaCl]=	
FlowCo=	0.019693						

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
12	60	1.181580	24.9	2.017	0.0155	0.0225	2.0015
12	50	0.984650	24.9	1.469666	0.0155	0.0225	1.454166
12	40	0.787720	24.9	1.02525	0.0155	0.0225	1.00975
12	30	0.590790	24.9	0.661	0.0155	0.0225	0.6455
12	21	0.413553	24.9	0.39625	0.0155	0.0225	0.38075
14	21	0.413553	24.9	1.168333	0.0215	0.0215	1.146833
14	15	0.295395	24.9	0.700555	0.0215	0.0215	0.679055
14	10	0.196930	24.9	0.401375	0.0215	0.0215	0.379875
14	8	0.157544	24.9	0.299	0.0215	0.0215	0.2775
12	17	0.334781	25	3.133666	-0.0155	-0.0135	3.147166
12	26	0.512018	25	6.16925	-0.0155	-0.0135	6.18275
12	36	0.708948	25.1	10.14933	-0.0135	0.0005	10.14883
12	16	0.315088	25.1	2.992833	-0.0135	0.0005	2.992333
12	10	0.196930	25.1	1.5062	-0.0135	0.0005	1.5057
12	13	0.256009	25	2.1574	-0.0015	-0.0075	2.1649
14			24.7	3.0006	-0.0245	-0.0405	3.0251
14			24.5	2.1124	-0.0345	-0.0425	2.1469
14			24.4	1.7016	-0.0375	-0.0435	1.7391
14			24.4	1.29325	-0.0395	-0.0465	1.33275
14			24.3	8.2786	0.0775	0.0805	8.1981
14			24.3	6.565	0.0805	0.0865	6.4785
14			24.4	4.320857	0.0855	0.0925	4.228357
14			24.3	3.409	0.0905	0.0965	3.3125
14			24.3	2.743454	-0.0225	-0.0185	2.761954
14			24.2	2.059	-0.0195	-0.0155	2.0745
14			24.15	1.607176	-0.0175	-0.0135	1.620676
14			24	1.096476	-0.0155	-0.0125	1.108976
14			23.9	0.887206	-0.0135	-0.0095	0.896706
14			23.8	0.723576	-0.0105	-0.0105	0.734076
14			23.8	0.581592	-0.0115	-0.0115	0.593092
14			23.65	0.488	-0.0135	-0.0135	0.5015
14			23.55	0.342187	-0.0145	-0.0165	0.358687
14			23.5	0.211482	-0.0185	-0.0175	0.228982
14			23.75	10.843	-0.0205	-0.0215	10.8645
12			23.9	4.542666	-0.0345	-0.0015	4.544166
12			24	6.25625	-0.0095	0.0055	6.25075

		density	viscosity			
	co[NaCl]	1.000088	1.001574	ID(cm) = 1.02108		
50.01221	X coeff	-0.00025	-0.02281	K(V/psi)=	1.180945	13.84846
0.000100	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.694829	1442.958	164114.5	752.0670	0.000724	3.645126
		1.231358	1202.465	136762.1	546.4055	0.000757	3.575756
		0.855035	961.9723	109409.6	379.4152	0.000822	3.496555
		0.546596	721.4792	82057.27	242.5477	0.000934	3.399397
		0.322411	505.0354	57440.08	143.0674	0.001124	3.284768
		0.971114	505.0354	57440.08	143.6618	0.001129	3.285669
		0.575010	360.7396	41028.63	85.06411	0.001310	3.171871
		0.321670	240.4930	27352.42	47.58628	0.001650	3.045729
		0.234981	192.3944	21881.93	34.76194	0.001883	2.977550
		0.227257	408.8382	46604.14	100.8437	0.001209	3.209808
		0.446457	625.2819	71276.92	198.1120	0.001016	3.356439
		0.732849	865.7750	98914.02	325.1960	0.000870	3.465041
		0.216076	384.7889	43961.78	95.88244	0.001298	3.199838
		0.108726	240.4930	27476.11	48.24669	0.001672	3.050702
		0.156327	312.6409	35638.46	69.36924	0.001423	3.128567
1951	15	0.218443	158.8387	17984.16	32.31536	0.002568	2.959732
1594	15.1	0.155028	128.9145	14530.35	22.93406	0.002767	2.883298
1361	14.9	0.125580	111.5481	12544.60	18.57778	0.002993	2.836569
1433	19.9	0.096238	87.93943	9889.585	14.23698	0.003691	2.778781
1440	20	0.096865	87.92716	9865.922	14.32985	0.003716	2.779208
1210	20	0.076547	73.88324	8290.115	11.32408	0.004159	2.728088
1068	25.1	0.049960	51.96226	5843.627	7.390951	0.005488	2.636422
1127	35	0.039139	39.32298	4412.259	5.790079	0.007508	2.582429
1050	40	0.032634	32.05677	3596.950	4.827754	0.009419	2.542959
932	50	0.024511	22.76336	2548.422	3.626119	0.014031	2.479823
829	60	0.019149	16.87306	1886.856	2.832859	0.019951	2.425721
610	75	0.013103	9.932513	1106.966	1.938433	0.039395	2.341857
729	119.9	0.010595	7.425042	825.6471	1.567397	0.057001	2.294736
504	110	0.008673	5.595365	620.7892	1.283128	0.082168	2.250296
383	110	0.007007	4.252033	471.7505	1.036695	0.114960	2.203986
323	120	0.005925	3.287091	363.4611	0.876596	0.162648	2.166083
209	120	0.004238	2.126941	234.6507	0.626967	0.277841	2.092320
99	120	0.002705	1.007498	111.0250	0.400250	0.790498	1.994371
1351	15.1	0.128371	109.2619	12108.62	18.99058	0.003189	2.834937
1554	15	0.053692	126.5174	14068.43	23.82554	0.002984	2.885667
1920	15	0.073856	156.3149	17421.11	32.77333	0.002689	2.955891

84.63346
82.65316
84.63346
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	DATA 1//f	1//f/Slv	1//f/L
14.18050	276.0620	36.85740	37.15526	2.620164	0.134590
13.90302	235.3076	35.53936	36.32535	2.612766	0.154373
13.58622	196.0811	34.03456	34.87385	2.566854	0.177854
13.19758	156.7750	32.18854	32.71297	2.478708	0.208661
12.73907	120.4062	30.01060	29.81578	2.340498	0.247626
12.74267	120.6560	30.02771	29.75404	2.334991	0.246602
12.28748	92.84353	27.86556	27.61967	2.247772	0.297484
11.78295	69.44154	25.46904	24.61820	2.089306	0.354517
11.51020	59.35133	24.17345	23.04280	2.001946	0.388244
12.43923	101.3183	28.58635	28.74858	2.311121	0.283745
13.02575	142.0100	31.37234	31.36966	2.408279	0.220897
13.46016	182.3565	33.43578	33.90130	2.518639	0.185906
12.39935	99.01897	28.39692	27.74833	2.237885	0.280232
11.80281	70.23969	25.56334	24.44852	2.071415	0.348072
12.11426	84.03247	27.04277	26.50646	2.188036	0.315431
11.43893	56.96558	23.83491	19.73139	1.724933	0.346373
11.13319	47.77252	22.38266	19.00981	1.707490	0.397923
10.94627	42.89921	21.49481	18.27626	1.669632	0.426027
10.71512	37.55445	20.39684	16.45874	1.536028	0.438263
10.71683	37.59137	20.40495	16.40323	1.530604	0.436356
10.51235	33.41710	19.43368	15.50499	1.474931	0.463983
10.14569	27.05843	17.69202	13.49770	1.330387	0.498835
9.929718	23.89513	16.66616	11.54068	1.162236	0.482972
9.771839	21.81925	15.91623	10.30325	1.054382	0.472209
9.519292	18.86701	14.71663	8.442056	0.886836	0.447450
9.302887	16.65719	13.68871	7.079732	0.761025	0.425025
8.967428	13.73210	12.09528	5.038222	0.561835	0.366893
8.778944	12.32015	11.19998	4.188499	0.477107	0.339971
8.601185	11.12183	10.35563	3.488573	0.405592	0.313668
8.415947	9.996935	9.475750	2.949345	0.350447	0.295024
8.264333	9.161430	8.755582	2.479560	0.300031	0.270652
7.969282	7.730378	7.354093	1.897148	0.238057	0.245414
7.577485	6.169520	5.493056	1.124733	0.148430	0.182304
10.93975	42.73836	21.46381	17.70748	1.618637	0.414323
11.14267	48.03390	22.42768	18.30534	1.642815	0.381092
11.42356	56.46404	23.76194	19.28341	1.688037	0.341516

Y5P11459

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
3.626119	178.3473	0.559442	2.251266
2.832859	132.1977	0.452224	2.121224
1.938433	77.81966	0.287450	1.891089
1.567397	58.17402	0.195179	1.764729
1.283128	43.83879	0.108270	1.641858
1.036695	33.31400	0.015651	1.522626
0.876596	25.75384	-0.05720	1.410842
0.626967	16.66425	-0.20275	1.221785
0.400250	7.893593	-0.39766	0.897274

Regression Output:

Constant	-1.09192
Std Err of Y Est	0.003547
R Squared	0.999679
No. of Observations	6
Degrees of Freedom	4

X Coefficient(s) 0.729733
Std Err of Coef. 0.006533

Tw vs. K'*(8<U>/D)^n

K' = 0.080924 161141.7
n = 0.729733

Regression Output:

Constant	-41.4883
Std Err of Y Est	0.313166
R Squared	0.996593
No. of Observations	9
Degrees of Freedom	7

X Coefficient(s) 21.72891
Std Err of Coef. 0.480123

t = 24.45 deg C
s.d.)t = 0.500277 deg C

Y1P03144 10/31/90 15:34

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14
S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=
Z = 2.85 Z = 9.15 Z = 6.9 [NaCl]=
FlowCo= 0.019693

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
23	60	1.181580	24.9	9.925666	0.0475	0.0945	9.878166
23	50	0.984650	24.9	7.126333	0.0475	0.0945	7.078833
23	39	0.768027	24.9	4.45575	0.0475	0.0945	4.40825
23	31	0.610483	24.9	2.965	0.0475	0.0945	2.9175
14	35	0.689255	24.9	10.897	0.0495	0.055	10.8475
14	29	0.571097	24.9	7.823666	0.0495	0.055	7.768666
14	22	0.433246	24.9	4.733	0.0495	0.055	4.678
14	16	0.315088	24.9	2.721666	0.0495	0.055	2.666666
14	10	0.196930	24.9	1.2425	0.0495	0.055	1.1875
14	8	0.157544	24.9	0.867	0.0495	0.055	0.8175
12	45	0.886185	24.1	6.040333	0.0445	0.0515	5.995833
23	45	0.886185	24.1	5.985333	0.0445	0.0515	5.940833
34	45	0.886185	24.1	6.116333	0.0445	0.0515	6.071833
14	13	0.256009	24.1	1.971	0.0525	0.0465	1.9185
23	17	0.334781	24.9	11.863	0.0275	0.0415	11.8215
23	13	0.256009	24.9	7.450666	0.0275	0.0415	7.409166
23	9	0.177237	24.9	4.059	0.0275	0.0415	4.0175
14			24.7	5.3448	0.0345	-0.0195	5.3643
14			24.7	4.0696	-0.0325	-0.0375	4.1071
14			24.7	3.2868	-0.0445	-0.0475	3.3343
14			24.7	2.211833	-0.0525	-0.0575	2.269333
14			24.7	1.667166	-0.0605	-0.0665	1.733666
14			24.6	1.0045	-0.0665	-0.069	1.0735
14			24.5	6.767625	-0.0025	-0.0345	6.802125
14			24.5	4.6772	-0.04	-0.0355	4.7127
14			24.5	3.3921	-0.0455	-0.0425	3.4376
14			24.5	2.089461	-0.0485	-0.0505	2.137961
14			24.4	0.914823	-0.0545	-0.0575	0.969323
14			24.4	0.66245	-0.0585	-0.0575	0.72095
14			24.4	0.49856	-0.0585	-0.0565	0.55706
14			24.3	0.37315	-0.0575	-0.0565	0.42965
14			24.2	0.25696	-0.0565	-0.0545	0.31146
14			24.1	0.19275	-0.0545	-0.0525	0.24625
14			24.1	0.09976	-0.0535	-0.0525	0.15326
14			24	0.042125	-0.0535	-0.053	0.095125
14			23.9	-0.02288	-0.0535	-0.053	0.030611
14			24.1	10.54514	-0.0555	-0.0615	10.60664
13			24.3	9.088166	-0.0805	-0.1185	9.206666
13			24.2	12.3708	-0.0205	-0.0485	12.4193
12			24.3	7.4584	-0.0585	-0.0605	7.5189
12			24.7	8.282	-0.0745	-0.0745	8.3565

12	24.4	10.70066	-0.0845	0.1385 10.56216
23	24.4	10.903	-0.0845	0.1385 10.7645
34	24.4	10.87033	-0.0845	0.1385 10.73183

		density	viscosity			
	co[NaCl]	1.01234	1.029478	ID(cm) =	1.02108	
0.999734	X coeff	-0.00025	-0.02281	K(V/psi)=	1.098348	13.19
0.299950	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

Batch	Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		0						
			8.993658	1442.958	161622.2	3992.302	0.003798	3.998320
			6.444982	1202.465	134685.2	2860.940	0.003919	3.925962
			4.013527	937.9229	105054.4	1781.612	0.004012	3.823115
			2.656261	745.5285	83504.84	1179.119	0.004202	3.733487
			9.876195	841.7257	94279.66	1461.034	0.004085	3.780038
			7.073046	697.4299	78117.43	1046.350	0.004261	3.707547
			4.259123	529.0847	59261.50	630.0732	0.004459	3.597404
			2.427888	384.7889	43099.27	359.1695	0.004805	3.475358
			1.081169	240.4930	26937.04	159.9426	0.005478	3.299690
			0.744299	192.3944	21549.63	110.1079	0.005893	3.218617
			5.458955	1082.218	119048.6	2422.368	0.004096	3.881947
			5.408880	1082.218	119048.6	2401.012	0.004060	3.880024
			5.528150	1082.218	119048.6	2453.230	0.004149	3.884696
			1.746714	312.6409	34391.82	258.4000	0.005236	3.395973
			0.896247	408.8382	45792.97	397.8458	0.004715	3.497565
			0.561726	312.6409	35018.15	249.3512	0.005054	3.396114
			0.304586	216.4437	24243.34	135.2066	0.005717	3.263207
1668		15	0.406694	135.7986	15141.99	60.16432	0.006463	3.085407
1421		15	0.311379	115.6893	12899.74	46.06395	0.006818	3.027418
1250		15	0.252789	101.7675	11347.42	37.39647	0.007153	2.982153
1320		20	0.172049	80.59990	8967.157	25.45213	0.007761	2.898600
1400		25	0.131437	68.38779	7625.467	19.44426	0.008236	2.840133
1274		30	0.081387	51.86074	5769.615	12.04004	0.008868	2.735066
1266		29.9	0.082891	51.70744	5739.597	12.26259	0.009085	2.738058
1372		40	0.057429	41.88752	4649.572	8.495866	0.009592	2.658371
1142		39.9	0.041891	34.95294	3879.824	6.197167	0.010048	2.589864
1150		50	0.026053	28.08784	3117.789	3.854231	0.009677	2.486736
1078		60	0.011812	21.94108	2430.002	1.747457	0.007190	2.313985
1033		74.9	0.008785	16.84259	1865.338	1.299699	0.009075	2.249704
1091		100	0.006788	13.32340	1475.583	1.004245	0.011206	2.193702
934		109.9	0.005235	10.37862	1146.855	0.774555	0.014243	2.136323
627		100	0.003795	7.656990	844.2034	0.561487	0.018970	2.065482
496		100	0.003000	6.057204	666.3179	0.443929	0.023966	2.013483
309		99.9	0.001867	3.777318	415.5208	0.276290	0.038356	1.910510
191		100.2	0.001159	2.327856	255.4969	0.171487	0.062682	1.805958
93		150	0.000373	0.757150	82.91478	0.055184	0.190662	1.558765
1113		20	0.129254	67.96037	7475.925	19.12122	0.008200	2.830584
1860		29.1	0.112193	78.05676	8625.401	24.89707	0.008094	2.889871
1148		15	0.151343	93.46332	10304.57	33.58482	0.007615	2.953883
1290		15	0.091626	105.0241	11605.33	40.65856	0.007301	2.996373
1385		15	0.101833	112.7584	12572.94	45.18789	0.007040	3.023249

2140	20.1	0.128712	130.0194	14399.81	57.11507	0.006692	3.071157
2140	20.1	0.131177	130.0194	14399.81	58.23016	0.006823	3.075356
2140	20.1	0.130779	130.0194	14399.81	58.03626	0.006800	3.074632

82.06026
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.59328	622.5872	43.56808	16.22486	1.040503	0.026060
15.30385	527.0391	42.19329	15.97191	1.043653	0.030304
14.89246	415.9059	40.23918	15.78699	1.060066	0.037958
14.53394	338.3510	38.53626	15.42496	1.061305	0.045588
14.72015	376.6333	39.42073	15.64513	1.062837	0.041539
14.43018	318.7330	38.04339	15.31795	1.061521	0.048058
13.98961	247.3341	35.95067	14.97506	1.070441	0.060545
13.50143	186.7404	33.63180	14.42486	1.068394	0.077245
12.79876	124.6151	30.29412	13.51012	1.055580	0.108414
12.47447	103.3945	28.75373	13.02633	1.044239	0.125986
15.12778	476.2412	41.35699	15.62346	1.032765	0.032805
15.12009	474.1373	41.32045	15.69279	1.037876	0.033097
15.13878	479.2654	41.40922	15.52488	1.025503	0.032393
13.18389	155.5439	32.12349	13.81916	1.048185	0.088844
13.59026	196.5377	34.05375	14.56240	1.071531	0.074094
13.18445	155.5945	32.12617	14.06627	1.066882	0.090403
12.65283	114.5743	29.60094	13.22467	1.045194	0.115424
11.94163	76.08300	26.22274	12.43871	1.041626	0.163488
11.70967	66.57309	25.12095	12.11051	1.034231	0.181913
11.52861	59.98372	24.26091	11.82343	1.025573	0.197110
11.19440	49.48576	22.67340	11.35068	1.013961	0.229372
10.96053	43.25276	21.56254	11.01875	1.005311	0.254752
10.54026	33.95837	19.56627	10.61890	1.007461	0.312703
10.55225	34.19313	19.62312	10.49113	0.994209	0.306819
10.23348	28.46109	18.10905	10.21036	0.997741	0.358748
9.959457	24.30772	16.80742	9.975801	1.001641	0.410396
9.546946	19.16975	14.84799	10.16506	1.064745	0.530265
8.855943	12.87851	11.56573	11.79290	1.331637	0.915703
8.598816	11.10667	10.34437	10.49671	1.220716	0.945082
8.374809	9.762981	9.280346	9.446293	1.127941	0.967562
8.145294	8.554678	8.190149	8.378858	1.028674	0.979447
7.861928	7.267118	6.844161	7.260473	0.923497	0.999085
7.653935	6.447094	5.856195	6.459479	0.843942	1.001921
7.242041	5.086163	3.899693	5.106020	0.705052	1.003904
6.823832	3.997956	1.913202	3.994180	0.585328	0.999055
5.835060	2.262794	-2.78346	2.290165	0.392483	1.012096
10.92253	42.31212	21.36111	11.04282	1.011031	0.260984
11.15948	48.50109	22.50755	11.11495	0.996009	0.229169
11.41553	56.20353	23.72378	11.45899	1.003807	0.203883
11.58549	61.98025	24.53109	11.70265	1.010112	0.188812
11.69299	65.93700	25.04173	11.91757	1.019205	0.180741

11.88463	73.62713	25.95199	12.22359	1.028521	0.166020
11.90142	74.34239	26.03177	12.10599	1.017188	0.162841
11.89852	74.21851	26.01801	12.12619	1.019134	0.163305

Y1P03144

Tw dyne/cm2	B<U>/D (1/sec)	Log Tw	Log B<U>/D
0.774555	81.31487	-0.11094	1.910169
0.561487	59.99130	-0.25065	1.778088
0.443929	47.45723	-0.35268	1.676302
0.276290	29.59468	-0.55863	1.471213
0.171487	18.23838	-0.76576	1.260986
0.055184	5.932154	-1.25818	0.773212

Regression Output:

Constant	-2.03586
Std Err of Y Est	0.003147
R Squared	0.999954
No. of Observations	6
Degrees of Freedom	4

X Coefficient(s)	1.005452
Std Err of Coef.	0.003393

Tw vs. K'*(B<U>/D)^n

K' =	0.009207
n =	1.005452

Res/f* =	546.0208
Tw* =	12.21470

Regression Output:

Constant	-3.86420
Std Err of Y Est	0.065299
R Squared	0.997971
No. of Observations	9
Degrees of Freedom	7

X Coefficient(s)	5.265597
Std Err of Coef.	0.089726

t = 24.51818 deg C
s.d.)t = 0.316423 deg C

Page 1 Cyanamid 832A

Y2P03147 11/4/90 15:52

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.8 Z = 9.15 Z = 6.9 [NaCl]=

FlowCo= 0.019693

Tap Pair	Freq. (Hz)	G)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
23	60	1.181580	24.9	9.223666	0.0635	0.0685	9.160166
23	49	0.964957	24.9	6.21575	0.0635	0.0685	6.15225
23	39	0.768027	24.9	3.948	0.0635	0.0685	3.8845
23	30	0.590790	24.9	2.37425	0.0635	0.0685	2.31075
23	20	0.393860	24.9	1.1184	0.0635	0.0685	1.0549
23	14	0.275702	24.9	0.653333	0.0635	0.0685	0.589833
23	10	0.196930	24.9	0.393	0.0635	0.0685	0.3295
23	8	0.157544	24.9	0.291333	0.0635	0.0685	0.227833
12	35	0.689255	23.3	3.262	0.0635	0.0665	3.1985
23	35	0.689255	23.3	3.267	0.0635	0.0665	3.2035
34	35	0.689255	23.3	3.2965	0.0635	0.0665	3.233
23	20	0.393860	25	12.9006	0.0205	0.1	12.8801
23	15	0.295395	25	7.9542	0.0205	0.1	7.9337
23	10	0.196930	25	3.9912	0.0205	0.1	3.8912
23	8	0.157544	25	2.872	0.0205	0.1	2.772
			24.7	4.8392	0.0865	0.0775	4.7617
14			24.6	3.4262	0.0815	0.0765	3.3497
14			24.6	3.0914	0.0755	0.0755	3.0159
14			24.4	2.08	0.0345	0.0225	2.0575
14			24.4	1.614	0.0225	0.0175	1.5965
14			24.4	1.017	0.017	0.0145	1.0025
14			24.35	0.7227	0.0145	0.0145	0.7082
			24.3	4.5005	-0.0175	-0.0585	4.559
			24.25	3.098166	-0.0725	-0.0765	3.174666
14			24.2	2.206333	0.0105	0.0095	2.196833
14			24.1	0.989619	0.0015	0.0005	0.988119
14			24	0.704952	-0.0015	-0.0015	0.706452
14			23.9	0.575384	-0.0045	-0.0035	0.579884
14			23.85	0.440307	-0.0035	-0.0015	0.441807
14			23.7	0.32116	-0.0015	0.0015	0.32266
14			23.6	0.20532	0.0025	0.0085	0.20282
14			23.5	0.121375	0.0095	0.0145	0.109375
14			23.4	0.067937	0.0155	0.0245	0.047937
14			23.5	6.43375	0.0265	0.0205	6.41325
14			23.7	9.8712	0.0185	0.0205	9.8507
14			23.7	12.783	0.0145	0.0155	12.7685
24			23.75	12.47475	0.0535	0.0605	12.41425
23			23.8	7.7592	0.0625	0.0655	7.6937
23			23.7	10.00125	0.0575	0.0655	9.93575

Page 2 Cyanamid 832A

		density	viscosity			
	co[NaCl]	1.01234	1.029478	ID(cm) = 1.02108		
1.999589	X coeff	-0.00025	-0.02281	K(V/psi)=1.098348	13.19348	
0.300236	constant	0.003419	-4.14935	XS(cm2)= 0.818859		

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		8.339949	1442.958	161622.2	3702.119	0.003522	3.981933
		5.601366	1178.416	131991.5	2486.457	0.003547	3.895499
		3.536675	937.9229	105054.4	1569.936	0.003535	3.795649
		2.103841	721.4792	80811.13	933.8992	0.003554	3.682858
		0.960442	480.9861	53874.09	426.3422	0.003651	3.512587
		0.537018	336.6903	37711.86	238.3836	0.004166	3.386346
		0.299995	240.4930	26937.04	133.1687	0.004561	3.259909
		0.207432	192.3944	21549.63	92.07979	0.004928	3.179790
		2.912100	841.7257	90937.22	1292.221	0.003611	3.737613
		2.916653	841.7257	90937.22	1294.707	0.003618	3.738031
		2.943511	841.7257	90937.22	1306.243	0.003651	3.739957
		0.976247	480.9861	53995.76	433.3580	0.003711	3.517117
		0.601334	360.7396	40496.82	266.9337	0.004063	3.411895
		0.294933	240.4930	26997.88	130.9215	0.004484	3.257199
		0.210103	192.3944	21598.30	93.26547	0.004991	3.183554
1682	15	0.360913	136.9386	15269.09	53.39166	0.005640	3.059474
1318	15	0.253890	107.3037	11937.75	37.55928	0.006462	2.982111
1647	19.9	0.228590	101.0720	11244.47	33.81647	0.006557	2.959317
1285	19.9	0.155948	78.85706	8733.517	23.07019	0.007349	2.874308
1374	25	0.121006	67.11773	7433.371	17.90112	0.007871	2.819222
1233	30	0.075984	50.19175	5558.798	11.24076	0.008838	2.718180
1340	40	0.053678	40.91055	4525.786	7.940855	0.009398	2.642223
1341	40	0.054835	40.94108	4524.057	8.112048	0.009586	2.646362
1366	50	0.038184	33.36347	3682.562	5.648837	0.010052	2.567284
1409	60	0.026423	28.67809	3161.835	3.908931	0.009414	2.486841
1340	75	0.011885	21.81896	2400.177	1.758207	0.007315	2.312362
995	75	0.008497	16.20139	1778.205	1.257024	0.009485	2.238513
1107	100	0.006974	13.51880	1480.430	1.031816	0.011182	2.194657
899	105	0.005314	10.45588	1143.722	0.786129	0.014242	2.135111
829	99.9	0.003880	7.689104	838.2352	0.574124	0.019232	2.065389
397	100	0.002439	4.868206	527.3409	0.360887	0.030408	1.963586
216	100.2	0.001315	2.632549	285.6980	0.194616	0.055615	1.828505
93	100	0.000576	1.135725	122.9771	0.085297	0.130963	1.648398
1232	30.1	0.077137	49.98443	5424.571	11.41140	0.009045	2.712585
1077	20.1	0.118483	65.43501	7133.462	17.52782	0.008107	2.807750
1271	20.1	0.153578	77.22182	8418.413	22.71960	0.007545	2.864086
1215	15.1	0.149317	98.26297	10724.32	33.13625	0.006797	2.946530
1834	20	0.092539	111.9850	12235.72	41.07830	0.006487	2.993677
1632	15	0.119506	132.8677	14484.70	53.04908	0.005951	3.048225

83.13996
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.52773	599.5338	43.25674	16.84874	1.085074	0.028103
15.18199	491.3365	41.61448	16.78985	1.105905	0.034171
14.78259	390.4178	39.71734	16.81763	1.137664	0.043075
14.33143	301.1192	37.57431	16.77307	1.170369	0.055702
13.65035	203.4546	34.33916	16.54978	1.212407	0.081343
13.14538	152.1341	31.94058	15.49284	1.178576	0.101836
12.63963	113.7076	29.53828	14.80608	1.171400	0.130211
12.31916	94.55199	28.01602	14.24456	1.156293	0.150653
14.55045	341.5811	38.61466	16.63902	1.143539	0.048711
14.55212	341.9095	38.62259	16.62304	1.142310	0.048618
14.55982	343.4293	38.65919	16.54947	1.136653	0.048188
13.66846	205.5877	34.42522	16.41506	1.200943	0.079844
13.24758	161.3524	32.42601	15.68648	1.184101	0.097218
12.62879	113.0002	29.48678	14.93242	1.182410	0.132145
12.33421	95.37491	28.08752	14.15355	1.147503	0.148399
11.83789	71.67287	25.73002	13.31491	1.124769	0.185773
11.52844	59.97794	24.26011	12.43973	1.079047	0.207405
11.43726	56.91111	23.82702	12.34872	1.079691	0.216982
11.09723	46.79378	22.21185	11.66490	1.051154	0.249283
10.87689	41.21949	21.16523	11.27101	1.036235	0.273439
10.47272	32.66332	19.24562	10.63654	1.015642	0.325641
10.16889	27.42228	17.80224	10.31502	1.014370	0.376155
10.18545	27.68487	17.88088	10.21328	1.002733	0.368912
9.869137	23.07619	16.37840	9.973920	1.010617	0.432216
7.547364	19.17437	14.84998	10.30619	1.079480	0.537498
8.849448	12.83045	11.53487	11.69179	1.321189	0.911253
8.554056	10.82414	10.13175	10.26758	1.200317	0.948581
8.378631	9.784481	9.298498	9.456492	1.128644	0.966678
8.140444	8.530825	8.167109	8.379338	1.029346	0.982242
7.861556	7.265561	6.842394	7.210688	0.917208	0.992447
7.454347	5.747339	4.908149	5.734620	0.769298	0.997787
6.914021	4.211000	2.341599	4.240352	0.613297	1.006970
6.193594	2.781497	-1.08042	2.763284	0.446152	0.993452
10.45034	32.24521	19.13912	10.51429	1.006119	0.326072
10.83100	40.14488	20.94725	11.10580	1.025372	0.276643
11.05634	45.70530	22.01764	11.51181	1.041194	0.251870
11.38612	55.25994	23.58407	12.12940	1.065279	0.219497
11.57471	61.59672	24.47987	12.41515	1.072610	0.201555
11.79290	69.84013	25.51627	12.96237	1.099167	0.185600

Y2P03147

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.257024	126.9353	0.099343	2.103582
1.031816	105.9176	0.013602	2.024968
0.786129	81.92023	-0.10450	1.913391
0.574124	60.24291	-0.24099	1.779905
0.360887	37.98492	-0.44262	1.579611
0.194616	20.62561	-0.71082	1.314406
0.085297	8.898232	-1.06906	0.949303

Regression Output:

Constant	-2.02230
Std Err of Y Est	0.003437
R Squared	0.999940
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 1.000917
Std Err of Coef. 0.004464

Tw vs. K'*(8<U>/D)^n

K' = 0.009499 17289.45
n = 1.000917

116.5581 Tw* = 9.665741
Res/f* = 490.1467

Regression Output:

Constant	-9.82628
Std Err of Y Est	0.162904
R Squared	0.993608
No. of Observations	21
Degrees of Freedom	19

X Coefficient(s) 7.503770
Std Err of Coef. 0.138073

t = 24.24358 deg C
s.d.)t = 0.581022 deg C

Page 1 Cyanamid 832A

Y5P03150 11/8/90 12:40

10 PSID Taps 14	1.0 PSID Taps 14	0.1 PSID Taps 14	
S = 2.7	S = 7.25	S = 9.9	<C>(ppm)=
Z = 2.7	Z = 9.15	Z = 6.9	[NaCl]=
FlowCo= 0.019693			

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
12	60	1.181580	24.7	6.707333	0.0265	0.0315	6.675833
12	49	0.964957	24.7	4.126	0.0265	0.0315	4.0945
12	38	0.748334	24.7	2.349333	0.0265	0.0315	2.317833
14	35	0.689255	24.8	6.0655	0.0325	0.0325	6.033
14	28	0.551404	24.8	3.935	0.0325	0.0325	3.9025
14	21	0.413553	24.8	2.331666	0.0325	0.0325	2.299166
14	14	0.275702	24.8	1.223666	0.0325	0.0325	1.191166
14	10	0.196930	24.8	0.7227	0.0325	0.0325	0.6902
12	30	0.590790	22.7	1.553	0.0355	0.0315	1.5215
23	30	0.590790	22.7	1.601	0.0355	0.0315	1.5695
12	20	0.393860	24.9	8.457	0.0425	0.0645	8.4145
12	25	0.492325	24.9	12.40133	0.0425	0.0645	12.35883
12	16	0.315088	24.9	6.002	0.0425	0.0645	5.9375
12	12	0.236316	24.9	3.822	0.0425	0.0645	3.7575
12	9	0.177257	24.9	2.3885	0.0425	0.0645	2.324
14			24.6	3.9424	0.0335	-0.2965	3.9089
14			24.45	2.9902	0.0025	0.0015	2.9887
14			24.4	2.4362	0.0005	-0.0045	2.4407
14			24.3	1.6795	-0.0055	-0.0045	1.684
14			24.2	1.357666	-0.0045	-0.0075	1.365166
14			24.15	0.909333	-0.0085	-0.0095	0.918833
14			24	5.80175	0.0155	-0.0015	5.80325
14			24	4.186777	0.0065	0.0085	4.178277
14			24	3.2783	0.0095	0.0115	3.2668
14			23.9	2.273307	0.0085	0.0085	2.264807
14			23.85	1.003375	0.0065	0.0045	0.996875
14			23.75	0.641375	0.0015	0.0005	0.639875
14			23.86	0.495045	-0.0015	-0.0025	0.497545
14			23.5	0.343444	-0.0055	-0.0055	0.348944
14			23.4	0.2245	-0.0075	-0.0075	0.232
14			23.3	0.153083	-0.0085	-0.0095	0.162083
14			23.1	0.10075	-0.013	-0.0165	0.1155
14			23	0.051275	-0.0165	-0.019	0.070275
14			22.9	0.024689	-0.0205	-0.0225	0.047189
14			23.2	8.707571	-0.0235	-0.0265	8.731071
14			23.2	10.6575	-0.0275	-0.0245	10.682
14			23.35	12.3114	-0.0305	-0.0325	12.3439
24			23.2	10.056	0.0895	0.0955	9.9605
24			23.2	12.5344	0.0905	0.0955	12.4389

Page 2 Cyanamid 832A

		density	viscosity		
	co[NaCl]	1.01234	1.029478	ID(cm) = 1.02108	
5.000475	X coeff	-0.00025	-0.02281	K(V/psi)=1.098348	13.19348
0.300029	constant	0.003419	-4.14933	XS(cm2)= 0.818859	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		6.078067	1442.958	160894.6	2697.094	0.002566	3.911186
		3.727871	1178.416	131397.3	1654.213	0.002359	3.805033
		2.110290	913.8736	101899.9	936.4266	0.002221	3.681474
		5.492794	841.7257	94067.20	812.5762	0.002272	3.651655
		3.553063	673.3806	75253.76	525.6222	0.002296	3.557060
		2.093295	505.0354	56440.32	309.6715	0.002405	3.442173
		1.084507	336.6903	37626.88	160.4365	0.002803	3.299374
		0.628398	240.4930	26876.34	92.96206	0.003184	3.180876
		1.385262	721.4792	76898.22	614.6991	0.002338	3.570365
		1.428964	721.4792	76898.22	634.3199	0.002412	3.577188
		0.637777	480.9861	53874.09	283.0085	0.002423	3.423608
		0.936737	601.2326	67342.61	415.6700	0.002278	3.507082
		0.450032	384.7889	43099.27	199.6985	0.002672	3.347895
		0.284799	288.5916	32324.45	126.3776	0.003006	3.248543
		0.176147	216.4437	24243.34	78.16410	0.003305	3.144212
1748	15	0.296275	142.3117	15832.47	43.82944	0.004287	3.015635
1438	14.9	0.226578	117.8591	13067.77	33.51148	0.004779	2.955871
1264	15	0.184992	102.9073	11397.11	27.36691	0.005119	2.911395
1306	20.1	0.127638	79.34831	8768.119	18.88223	0.005940	2.829824
1103	20	0.103472	67.34976	7425.489	15.30724	0.006684	2.783260
1030	25	0.069642	50.31387	5540.984	10.30263	0.008061	2.696793
1234	30.1	0.070288	50.06557	5495.012	10.39816	0.008216	2.697320
1157	35	0.050607	40.36973	4430.832	7.486565	0.009099	2.625983
1131	40	0.039567	34.52973	3789.855	5.853395	0.009724	2.572545
1167	50	0.027431	28.50305	3121.340	4.058042	0.009893	2.492014
1081	60	0.012074	22.00214	2406.716	1.786183	0.007308	2.313326
1097	90	0.007750	14.88520	1624.556	1.146516	0.010248	2.216068
858	90	0.006026	11.64220	1273.776	0.891493	0.013027	2.162521
612	90.1	0.004226	8.295015	900.2183	0.625232	0.017996	2.081936
406	90	0.002809	5.509016	596.5199	0.415693	0.027125	1.992317
320	100	0.001963	3.907874	422.1936	0.290418	0.037660	1.913457
225	100.1	0.001398	2.744978	295.2232	0.206950	0.054389	1.837908
165	119.9	0.000851	1.680565	180.3379	0.125919	0.088286	1.729035
110	120.1	0.000571	1.118510	119.7546	0.084553	0.133830	1.641570
1111	20.1	0.105750	67.50074	7276.120	15.64418	0.006799	2.778136
950	15	0.129379	77.34334	8337.085	19.13982	0.006336	2.821929
1053	14.9	0.149508	86.30434	9334.555	22.11758	0.005880	2.854806
1230	15	0.120641	100.1392	10794.33	26.77246	0.005287	2.894804
1408	15	0.150659	114.6309	12356.43	33.43406	0.005038	2.943054

82.563
4
0.4

Solvent 1//f	L 1//f	HDR 1//f	1//f	1//f/Slv	1//f/L
15.24474	509.4085	41.91253	19.74037	1.294897	0.038751
14.82013	398.9457	39.89564	20.58508	1.388994	0.051598
14.32589	300.1612	37.54801	21.21775	1.481076	0.070687
14.20662	280.2433	36.98145	20.97890	1.476699	0.074859
13.82824	225.3928	35.18414	20.86738	1.509041	0.092582
13.36869	173.0031	33.00130	20.38992	1.525199	0.117858
12.79749	124.5245	30.28812	18.88527	1.475700	0.151659
12.32350	94.78862	28.03664	17.72123	1.438002	0.186955
13.88146	232.4050	35.43694	20.68001	1.489757	0.088982
13.90875	236.0849	35.56657	20.35766	1.463658	0.086230
13.29443	165.7632	32.64855	20.31288	1.527924	0.122541
13.62833	200.8921	34.23457	20.95111	1.537320	0.104290
12.99158	139.2438	31.21002	19.34525	1.489059	0.138930
12.59417	110.7703	29.32232	18.23843	1.448164	0.164650
12.17684	87.11485	27.34003	17.39323	1.428385	0.199658
11.66254	64.79118	24.89708	15.27259	1.309542	0.235720
11.42348	56.46144	23.76156	14.46537	1.266283	0.256199
11.24558	50.96540	22.91651	13.97653	1.242846	0.274235
10.91929	42.23807	21.36665	12.97425	1.188195	0.307169
10.73304	37.94378	20.48195	12.23106	1.139571	0.322347
10.38717	31.09378	18.83907	11.13764	1.072249	0.358195
10.38928	31.13149	18.84908	11.03185	1.061850	0.354363
10.10393	26.41575	17.49367	10.48340	1.037556	0.396861
9.890182	23.35746	16.47836	10.14091	1.025351	0.434161
9.568059	19.40416	14.94828	10.05370	1.050757	0.518121
8.853307	12.85899	11.55321	11.69763	1.321272	0.909684
8.464275	10.27895	9.705310	9.877926	1.167013	0.960985
8.250085	9.086601	8.687908	8.761362	1.061972	0.964206
7.927746	7.547733	7.156794	7.454376	0.940289	0.987631
7.569268	6.140407	5.454026	6.071664	0.802146	0.988804
7.253828	5.120792	3.955686	5.152932	0.710374	1.006276
6.951634	4.303171	2.520263	4.287873	0.616815	0.996445
6.516142	3.349002	0.451674	3.365515	0.516489	1.004930
6.166282	2.738108	-1.21015	2.733516	0.443300	0.998322
10.71254	37.49873	20.38459	12.12727	1.132063	0.323405
10.88771	41.47716	21.21665	12.56276	1.153847	0.302883
11.01922	44.73905	21.84132	13.04027	1.183411	0.291474
11.17921	49.05512	22.60128	13.75280	1.230212	0.280354
11.37221	54.81946	23.51804	14.08764	1.238777	0.256982

Y5P03150

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.891493	91.21485	-0.04988	1.960065
0.625232	64.99013	-0.20395	1.812847
0.415693	43.16227	-0.38122	1.635104
0.290418	30.61757	-0.53697	1.485970
0.206950	21.50647	-0.68413	1.332569
0.125919	13.16696	-0.89990	1.119485
0.084553	8.763356	-1.07286	0.942670

Regression Output:

Constant	-2.01700
Std Err of Y Est	0.003086
R Squared	0.999927
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.999316
Std Err of Coef.	0.004261

Tw vs. K'*(8<U>/D)^n

K' = 0.009616
n = 0.999316

Tw8 = 7.304254
Res/f8 = 424.1564

Regression Output:

Constant	-25.1818
Std Err of Y Est	0.173880
R Squared	0.994746
No. of Observations	14
Degrees of Freedom	12
X Coefficient(s)	13.43161
Std Err of Coef.	0.281777

t = 24.02076 deg C
s.d.)t = 0.719245 deg C

Y1P13153 11/11/90 15:35

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14
S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=
Z = 2.7 Z = 9.1 Z = 6.9 [NaCl]=
FlowCo= 0.019693 0.020236

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
13	60	1.181580	25.1	9.359666	0.09	0.0985	9.269666
13	50	0.984650	25.1	6.00375	0.09	0.0985	5.91375
13	40	0.787720	25.1	3.724	0.09	0.0985	3.634
13	30	0.590790	25.1	2.159333	0.09	0.0985	2.069333
13	21	0.413553	25.1	1.17675	0.09	0.0985	1.08675
13	16	0.315088	25.1	0.7978	0.09	0.0985	0.6993
13	13	0.256009	25.1	0.5922	0.09	0.0985	0.4937
13	9	0.177237	25.1	0.392571	0.09	0.0985	0.294071
14	30	0.590790	22.6	3.325	0.0675	0.0845	3.2405
14	40	0.787720	22.6	5.7595	0.0675	0.0845	5.675
14	20	0.393860	22.6	1.706	0.0675	0.0845	1.6215
12	30	0.590790	25	11.91525	0.0115	0.0235	11.90375
12	25	0.452939	25	7.437	0.0115	0.0235	7.4255
12	17	0.334781	25	4.513	0.0115	0.0235	4.4895
12	12	0.236316	25	2.698	0.0115	0.0235	2.6745
12	9	0.177237	25	1.787714	0.0115	0.0235	1.764214
14			24.6	3.219	-0.0115	-0.0155	3.2345
14			24.45	2.349	-0.0155	-0.0195	2.3685
14			24.4	1.9585	-0.0185	-0.0215	1.98
14			24.2	1.407166	-0.0205	-0.0235	1.430666
14			24.2	1.122142	-0.0235	-0.0245	1.146642
14			24.05	0.774714	-0.0245	-0.0235	0.798214
14			23.95	4.963833	0.0435	0.0035	4.960333
14			23.9	3.797111	0.003	-0.0125	3.809611
14			23.9	2.950545	-0.0085	-0.0185	2.959045
14			23.8	1.858687	-0.017	-0.0265	1.875687
14			23.7	0.974937	-0.0245	-0.0295	0.999437
14			23.6	0.716695	-0.0295	-0.0315	0.746195
14			23.6	0.590523	-0.0295	-0.0295	0.620023
14			23.45	0.44708	-0.0305	-0.0295	0.47758
14			23.25	0.312235	-0.0315	-0.0305	0.342735
14			23.1	0.211058	-0.0335	-0.0335	0.244558
14			22.9	0.153166	-0.0355	-0.0355	0.188666
14			22.8	0.100434	-0.0375	-0.0375	0.137934
14			22.7	0.045708	-0.0405	-0.0415	0.086708
14			22.5	-0.00458	-0.0435	-0.0445	0.039913
14			22.7	7.0888	-0.0465	-0.0645	7.1533
14			22.9	8.6646	-0.062	-0.0885	8.7531
14			23	11.7128	-0.0885	-0.0915	11.8043
13			23	9.7036	0.0135	0.0225	9.6811

13			22.9	13.1512	0.0535	0.0465	13.1047

		density	viscosity			
	co[NaCl]	1.01234	1.029478	ID(cm) =	1.02108	
9.999572	X coeff	-0.00025	-0.02281	K(V/psi)=	1.098348	13.19
0.300099	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		8.439644	1442.958	162353.1	1872.849	0.001782	3.835930
		5.384222	1202.465	135294.3	1194.818	0.001637	3.738329
		3.308605	961.9723	108235.4	734.2158	0.001571	3.632590
		1.884041	721.4792	81176.58	418.0895	0.001591	3.510313
		0.989440	505.0354	56823.60	219.5677	0.001705	3.370463
		0.636683	384.7889	43294.17	141.2870	0.001890	3.274730
		0.449493	312.6409	35176.51	99.74749	0.002021	3.199129
		0.267739	216.4437	24352.97	59.41439	0.002512	3.086624
		2.950339	721.4792	76724.93	436.4583	0.001660	3.495020
		5.166850	961.9723	102299.9	764.3577	0.001635	3.616697
		1.476308	480.9861	51149.95	218.3975	0.001869	3.344672
		0.902482	721.4792	80993.65	400.4696	0.001524	3.499978
		0.562964	553.1340	62095.13	249.8109	0.001617	3.397499
		0.340371	408.8382	45896.40	151.0371	0.001790	3.288235
		0.202767	288.5916	32397.46	89.97636	0.002140	3.175757
		0.133753	216.4437	24298.09	59.35224	0.002510	3.085412
1843	14.9	0.245223	151.0531	16804.96	36.27714	0.003149	2.974569
1481	14.9	0.179567	121.3834	13458.53	26.56435	0.003571	2.905424
1707	19.9	0.150113	104.7540	11601.64	22.20706	0.004008	2.866028
1323	20	0.108466	80.78308	8906.548	16.04591	0.004870	2.793494
1390	25	0.086932	67.89931	7486.078	12.86038	0.005525	2.745439
1050	25	0.060516	51.29084	5635.847	8.952523	0.006740	2.665307
1049	25	0.060447	51.24199	5617.791	8.942289	0.006745	2.664073
1188	35	0.046424	41.45137	4539.297	6.867813	0.007916	2.606265
1281	45	0.036059	34.76379	3806.947	5.334448	0.008742	2.551401
1368	60	0.022857	27.84360	3042.253	3.381414	0.008638	2.451420
1086	60	0.012179	22.10391	2409.679	1.801745	0.007303	2.313732
1251	89.9	0.009093	16.99370	1848.411	1.345211	0.009225	2.249296
1059	89.8	0.007555	14.40158	1566.464	1.117754	0.010673	2.209074
924	99.9	0.005819	11.29528	1224.440	0.860962	0.013364	2.150915
603	90	0.004176	8.182111	882.9713	0.617869	0.018277	2.076901
428	90.1	0.002980	5.801089	623.9088	0.440880	0.025943	2.002135
365	99.9	0.002299	4.461880	477.7162	0.340120	0.033830	1.943821
270	100	0.001680	3.297268	352.2302	0.248663	0.045289	1.874825
177	105	0.001056	2.058612	219.4153	0.156314	0.073035	1.773033
93	120	0.000486	0.946438	100.4211	0.071954	0.159051	1.602594
1105	19.9	0.087171	67.81094	7227.569	12.89568	0.005553	2.731256
985	15.1	0.106666	79.66175	8529.074	15.77973	0.004923	2.777054
1263	15	0.143849	102.8259	11034.03	21.28031	0.003985	2.842978
1458	15.1	0.117975	117.9155	12653.27	26.18005	0.003728	2.887975

1785	14.9	0.159696	146.2993	15663.70	35.43831	0.003278	2.952741

82.06026
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.94372	428.3614	40.48267	23.68810	1.585154	0.055299
14.55331	342.1447	38.62826	24.71437	1.698195	0.072233
14.13036	268.2074	36.61922	25.22195	1.784947	0.094038
13.64125	202.3921	34.29595	25.06785	1.837650	0.123857
13.08185	146.6706	31.63879	24.21395	1.850957	0.165090
12.69892	117.6549	29.81987	22.99849	1.811058	0.195474
12.39651	98.85756	28.38346	22.23939	1.794003	0.224964
11.94649	76.29652	26.24587	19.94928	1.669885	0.261470
13.58008	195.3891	34.00538	24.54235	1.807231	0.125607
14.06678	258.5695	36.31724	24.72737	1.757854	0.095631
12.97869	138.2142	31.14878	23.12983	1.782138	0.167347
13.59991	197.6325	34.09959	25.61370	1.883372	0.129602
13.18999	156.0915	32.15248	24.86326	1.885008	0.159286
12.75294	121.3711	30.07647	23.63431	1.853244	0.194727
12.30303	93.67806	27.93940	21.61489	1.756875	0.230735
11.94164	76.08381	26.22283	19.95997	1.671458	0.262341
11.49827	58.94534	24.11682	17.81838	1.549656	0.302286
11.22169	50.26952	22.80307	16.73296	1.491126	0.332865
11.06411	45.91008	22.05453	15.79397	1.427495	0.344019
10.77397	38.84850	20.67639	14.32897	1.329961	0.368842
10.58175	34.77916	19.76334	13.45287	1.271327	0.386808
10.26122	28.91925	18.24083	12.18013	1.187005	0.421177
10.25629	28.83722	18.21739	12.17564	1.187139	0.422219
10.02506	25.24328	17.11905	11.23887	1.121077	0.445222
9.805605	22.24750	16.07662	10.69487	1.090689	0.480722
9.405682	17.67260	14.17698	10.75907	1.143890	0.608799
8.854931	12.87101	11.56092	11.70109	1.321421	0.909103
8.597184	11.09625	10.33662	10.41123	1.211005	0.938266
8.436296	10.11472	9.572407	9.679357	1.147346	0.956957
8.203660	8.846982	8.467387	8.650130	1.054423	0.977749
7.907604	7.460726	7.061121	7.396827	0.935406	0.991435
7.608542	6.280808	5.640575	6.208483	0.815988	0.988484
7.375284	5.491627	4.532600	5.436869	0.737174	0.990028
7.099300	4.684952	3.221678	4.698956	0.661890	1.002989
6.692134	3.706069	1.287637	3.700270	0.552928	0.998435
6.010376	2.503077	-1.95070	2.507442	0.417185	1.001744
10.52502	33.66172	19.49387	13.41948	1.275007	0.398657
10.70821	37.40541	20.36403	14.25106	1.330853	0.380989
10.97191	43.53703	21.61659	15.84001	1.443687	0.363828
11.15190	48.28976	22.47152	16.37675	1.468517	0.339135

11.41096	56.05586	23.70208	17.46439	1.530492	0.311553

Cyanamid 832A

Y1P13153

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.860962	88.49674	-0.06501	1.946927
0.617869	64.10554	-0.20910	1.806895
0.440880	45.45061	-0.35567	1.657539
0.340120	34.95812	-0.46836	1.543548
0.248663	25.83357	-0.60438	1.412184
0.156314	16.12890	-0.80600	1.207604
0.071954	7.415193	-1.14293	0.870122

Regression Output:

Constant	-2.01440
Std Err of Y Est	0.001567
R Squared	0.999984
No. of Observations	7
Degrees of Freedom	5

X Coefficient(s) 1.000776
Std Err of Coef. 0.001741

Tw vs. K'*(8<U>/D)^n

K' = 0.009673
n = 1.000776

Tw* = 4.431038
Res/f* = 340.5648

Regression Output:

Constant	-37.1138
Std Err of Y Est	0.143522
R Squared	0.998573
No. of Observations	18
Degrees of Freedom	16

X Coefficient(s) 18.49878
Std Err of Coef. 0.174807

t = 23.93048 deg C
s.d.)t = 0.937229 deg C

Page 1 Cyanamid 832A

Y2P13156 11/15/90 14:33

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.8 Z = 9.2 Z = 6.9 [NaCl]=

FlowCo= 0.019693

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
14	60	1.181580	25.5	11.1005	0.0785	0.1115	10.989
14	48	0.945264	25.5	6.68575	0.0785	0.1115	6.57425
14	39	0.768027	25.5	4.44725	0.0785	0.1115	4.33575
14	31	0.610483	25.5	2.967333	0.0785	0.1115	2.855833
14	21	0.413553	25.5	1.669	0.0785	0.1115	1.5575
14	25	0.492325	25.6	2.1215	0.1025	0.0995	2.022
14	17	0.334781	25.6	1.18925	0.1025	0.0995	1.08975
14	14	0.275702	25.6	0.9298	0.1025	0.0995	0.8303
14	10	0.196930	25.6	0.595166	0.1025	0.0995	0.495666
14	7	0.137851	25.6	0.39675	0.1025	0.0995	0.29725
14	31	0.610483	24.05	2.96475	0.0555	0.0545	2.90925
14	22	0.433246	24.05	1.734333	0.0555	0.0545	1.678833
14	10	0.196930	24.1	0.51725	0.0295	0.0545	0.48775
12	25	0.492325	25.9	6.07375	0.0065	0.0135	6.06725
12	20	0.393860	25.9	4.4475	0.0065	0.0135	4.441
12	15	0.295395	25.9	2.845	0.0065	0.0135	2.8315
12	10	0.196930	25.9	1.612	0.0065	0.0135	1.5985
12	8	0.157544	25.9	1.159	0.0065	0.0135	1.1455
14			25.6	2.516	0.0385	-0.0125	2.4775
14			25.5	1.8858	-0.0125	-0.0165	1.9023
14			25.5	1.57075	-0.0155	-0.0215	1.59225
14			25.4	1.1655	-0.0205	-0.0235	1.189
14			25.35	0.964	-0.0225	-0.0225	0.9865
			25.2	6.0134	0.0555	0.0555	5.9579
14			25.15	4.295	0.0775	0.0615	4.2335
14			25.2	3.435	0.0835	0.0835	3.3515
14			25.1	2.6866	0.0165	-0.0775	2.7641
14			25	1.95525	0.0255	0.0115	1.92975
14			25	1.019277	0.0085	0.0065	1.010777
14			24.85	0.721863	0.0085	0.0145	0.707363
14			24.8	0.598363	0.0165	0.0255	0.572863
14			24.7	0.473842	0.0295	0.0385	0.435342
14			24.6	0.341103	0.0425	0.0515	0.289603
14			24.5	0.260148	0.0545	0.0595	0.200648
14			24.4	0.189875	0.0625	0.0675	0.122375
14			24.3	0.12532	0.0685	0.0715	0.05382
14			24.2	0.101785	0.0725	0.0745	0.027285
24			24.6	7.351	0.0755	-0.0175	7.2755
23			24.5	10.0445	-0.0165	-0.0375	10.061
23			24.5	11.98066	-0.0335	-0.0535	12.01416

Page 2 Cyanamid 832A

		density	viscosity			
	co[NaCl]	1.01234	1.029478	ID(cm) =	1.02108	
20.00475	X coeff	-0.00025	-0.02281	K(V/psi)=	1.440682	13.4081
0.300052	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

0

Batch Vol (al)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		7.627637	1442.958	163824.8	1128.394	0.001073	3.729850
		4.563290	1154.366	131059.8	675.0700	0.001003	3.618294
		3.009512	937.9229	106486.1	445.2120	0.001002	3.527903
		1.982278	745.5285	84642.84	293.2482	0.001045	3.437237
		1.081085	505.0354	57338.70	159.9302	0.001242	3.305585
		1.403501	601.2326	68414.53	207.6269	0.001138	3.363246
		0.756412	408.8382	46521.88	111.8998	0.001326	3.229019
		0.576324	336.6903	38312.13	85.25849	0.001490	3.169973
		0.344050	240.4930	27365.81	50.89701	0.001743	3.057951
		0.206325	168.3451	19156.06	30.52280	0.002134	2.946917
		2.019356	745.5285	81918.80	298.7333	0.001064	3.426976
		1.165304	529.0847	58135.92	172.3892	0.001219	3.307589
		0.338554	240.4930	26455.24	50.08410	0.001715	3.039676
		0.449822	601.2326	68879.13	199.6051	0.001094	3.357646
		0.329253	480.9861	55103.30	146.1034	0.001251	3.289890
		0.209925	360.7396	41327.47	93.15290	0.001418	3.192158
		0.118511	240.4930	27551.65	52.58870	0.001801	3.068006
		0.084926	192.3944	22041.32	37.68555	0.002017	2.995647
1856	15	0.183680	151.1044	17194.24	27.17275	0.002358	2.921671
1473	15.1	0.141035	119.1286	13525.15	20.86406	0.002913	2.863319
1271	15	0.118048	103.4772	11748.18	17.46349	0.003231	2.824685
1307	20	0.088151	79.80611	9040.290	13.04072	0.004057	2.760285
1388	25	0.073138	67.80161	7671.784	10.81974	0.004663	2.719250
1384	25	0.073103	67.60622	7623.832	10.81449	0.004688	2.717667
1228	30	0.051944	49.98822	5630.727	7.684448	0.006092	2.642977
1178	35	0.041122	41.10246	4635.051	6.083484	0.007134	2.592740
1118	40	0.033915	34.13283	3840.425	5.017263	0.008532	2.549912
1150	50.1	0.023677	28.03178	3146.863	3.502790	0.008831	2.470900
1274	70	0.012402	22.22603	2495.106	1.834715	0.007358	2.330478
1064	80	0.008679	16.24210	1817.187	1.283972	0.009642	2.251493
975	89.9	0.007029	13.24449	1480.141	1.039834	0.011743	2.205205
839	100	0.005341	10.24595	1142.458	0.790212	0.014912	2.144610
618	110	0.003553	6.860983	763.2985	0.525674	0.022122	2.055111
430	109.9	0.002461	4.778167	530.3830	0.364207	0.031601	1.974441
239	100	0.001501	2.918693	323.2488	0.222129	0.051653	1.866085
106	100	0.000660	1.270059	140.3436	0.097691	0.119968	1.686725
64	119.9	0.000334	0.651855	71.86879	0.049527	0.230883	1.538236
1296	19.9	0.089269	79.53210	8808.278	13.20614	0.004135	2.753170
1252	15	0.123447	101.9303	11314.41	18.26225	0.003481	2.824544
1444	15	0.147413	117.5618	13049.52	21.80754	0.003125	2.863071

81.5
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.51940	335.5290	38.46715	30.51614	2.101750	0.090949
14.07317	259.5219	36.34758	31.56281	2.242763	0.121619
13.71161	210.7575	34.63015	31.57839	2.303040	0.149832
13.34894	171.0477	32.90751	30.92807	2.316891	0.180815
12.82254	126.3179	30.40611	28.37022	2.212562	0.224593
13.05298	144.2536	31.50168	29.64159	2.270866	0.205482
12.51607	105.9009	28.95137	27.45602	2.193660	0.259261
12.27989	92.43868	27.82950	25.90375	2.109444	0.280226
11.83180	71.42184	25.70107	23.94734	2.023980	0.335294
11.38766	55.30917	23.59142	21.64657	1.900878	0.391374
13.30790	167.0537	32.71254	30.64837	2.303020	0.183464
12.83035	126.9022	30.44419	28.63223	2.231600	0.225624
11.75870	68.47891	25.35386	24.14542	2.053408	0.352596
13.03058	142.4053	31.39528	30.23022	2.319943	0.212282
12.75956	121.8346	30.10792	28.26746	2.215394	0.232015
12.36863	97.28338	28.25101	26.55096	2.146636	0.272923
11.87202	73.09484	25.89212	23.55813	1.984339	0.322295
11.58259	61.87681	24.51731	22.26330	1.922135	0.359800
11.28668	52.18572	23.11176	20.59260	1.824504	0.394602
11.05327	45.62461	22.00306	18.52777	1.676224	0.406091
10.89874	41.74123	21.26902	17.59079	1.614021	0.421424
10.64114	35.98863	20.04542	15.69990	1.475396	0.436246
10.47700	32.74390	19.26575	14.64353	1.397683	0.447214
10.47066	32.62475	19.23567	14.60515	1.394863	0.447670
10.17191	27.46995	17.81657	12.81110	1.259459	0.466368
9.970961	24.46922	16.86206	11.83897	1.187345	0.483831
9.799649	22.17136	16.04833	10.82597	1.104730	0.488286
9.483603	18.48335	14.54711	10.64086	1.122027	0.575699
8.921912	13.37698	11.87908	11.65764	1.306631	0.871470
8.605975	11.15254	10.37838	10.18370	1.183329	0.913128
8.420822	10.02502	9.498904	9.227788	1.095829	0.920475
8.178440	8.719469	8.347590	8.188990	1.001290	0.939161
7.820445	7.095636	6.647115	6.723309	0.859709	0.947527
7.497767	5.892802	5.114395	5.625327	0.750266	0.954609
7.064341	4.591615	3.055623	4.399988	0.622844	0.958266
6.346902	3.038125	-0.35221	2.887134	0.454888	0.950301
5.752945	2.158322	-3.17350	2.081153	0.361754	0.964245
10.61268	35.40385	19.91023	15.54964	1.465194	0.439207
10.89817	41.72774	21.26635	16.94677	1.555009	0.406127
11.05228	45.59856	21.99835	17.88643	1.618347	0.392258

Y2P13156

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.790212	80.27545	-0.10225	1.904582
0.525674	53.75471	-0.27928	1.730416
0.364207	37.43618	-0.43865	1.573291
0.222129	22.86750	-0.65339	1.359218
0.097691	9.950711	-1.01014	0.997854
0.049527	5.107184	-1.30515	0.708181

Regression Output:

Constant	-2.01232
Std Err of Y Est	0.002512
R Squared	0.999973
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	1.000947
Std Err of Coef.	0.003000

Tw vs. K'*(8<U>/D)^n

K' = 0.009720
n = 1.000947

Tw* = 3.696873
Res/f* = 307.9797

Regression Output:

Constant	-50.0767
Std Err of Y Est	0.413400
R Squared	0.994681
No. of Observations	10
Degrees of Freedom	8
X Coefficient(s)	23.96233
Std Err of Coef.	0.619472

t = 25.12375 deg C
s.d.)t = 0.575976 deg C

Y5P13160 11/24/90 15:40

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14
S =	1	S =	7.25	S =	9.9 <C>(ppm)=
Z =	5.3	Z =	9.2	Z =	6.8 [NaCl]=
FlowCo=	0.019693	0.020236			

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
12	60	1.181580	25.1	2.099333	0.0165	0.0255	2.073833
12	50	0.984650	25.1	1.54575	0.0165	0.0255	1.52025
12	40	0.787720	25.1	1.08825	0.0165	0.0255	1.06275
12	31	0.610483	25.1	0.73425	0.0165	0.0255	0.70875
12	21	0.413553	25.1	0.40775	0.0165	0.0255	0.38225
14	21	0.413553	25	1.233666	0.0245	0.0215	1.212166
14	15	0.295395	25	0.7398	0.0245	0.0215	0.7183
14	10	0.196930	25	0.412666	0.0245	0.0215	0.391166
12	25	0.492325	22.9	0.547	0.0215	0.0175	0.5295
14	25	0.492325	22.9	1.589	0.0215	0.0175	1.5715
12	36	0.708948	24.9	10.662	-0.0285	-0.0375	10.6905
12	30	0.590790	24.9	8.055	-0.0285	-0.0375	8.0835
12	21	0.413553	24.9	4.561333	-0.0285	-0.0375	4.598833
12	15	0.295395	24.9	2.68725	-0.0285	-0.0375	2.72475
12	10	0.196930	24.9	1.359285	-0.0285	-0.0375	1.396785
12	8	0.157544	24.9	1.053	-0.0285	-0.0375	1.0905
14			24.7	2.16675	-0.0565	-0.075	2.24175
14			24.6	1.515	-0.0815	-0.0875	1.6025
14			24.6	1.2672	-0.0715	-0.0995	1.3667
14			24.5	1.019666	0.0385	0.035	0.984666
14			24.4	6.072166	-0.0055	-0.0635	6.135666
14			24.4	4.833714	-0.0335	-0.0555	4.889214
14			24.2	3.408666	-0.0005	-0.0625	3.471166
14			24.2	2.597222	-0.059	-0.0685	2.656722
14			24.1	2.1845	-0.055	-0.0565	2.24
14			24.1	1.557428	-0.0555	-0.0565	1.612928
14			24	1.0144	-0.0505	-0.0485	1.0629
14			23.9	0.747473	-0.0435	-0.0385	0.790973
14			23.8	0.6014	-0.0335	-0.029	0.6304
14			23.75	0.467434	-0.0255	-0.0165	0.492934
14			23.6	0.342916	-0.0165	-0.0115	0.356916
14			23.5	0.24124	-0.0085	-0.0035	0.24724
14			23.4	0.18248	-0.0025	0.0015	0.18298
14			23.3	0.118636	0.0015	0.0045	0.114136
14			23.2	0.061114	0.0055	0.006	0.055614
14			23.1	0.033419	0.0055	0.0055	0.027919
14			23.3	8.18925	0.0055	-0.0375	8.22675
14			23.3	9.71	-0.0345	-0.0355	9.7455
14			23.3	13.4765	-0.0275	-0.0275	13.504

		density	viscosity			
	co[NaCl]	1.01234	1.029478	ID(cm) =	1.02108	
50.01221	X coeff	-0.00025	-0.02281	K(V/psi)=	1.180945	13.84846
0.299986	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.756079	1442.958	162353.1	779.2463	0.000741	3.645516
		1.287316	1202.465	135294.3	571.2365	0.000782	3.578086
		0.899914	961.9723	108235.4	399.3301	0.000854	3.500344
		0.600154	745.5285	83882.46	266.3140	0.000949	3.412375
		0.323681	505.0354	56823.60	143.6310	0.001115	3.278303
		1.026437	505.0354	56695.55	151.8460	0.001179	3.289395
		0.608241	360.7396	40496.82	89.98020	0.001369	3.175767
		0.331231	240.4930	26997.88	49.00077	0.001678	3.043795
		0.448369	601.2326	64371.64	198.9605	0.001089	3.327388
		1.330713	601.2326	64371.64	196.8590	0.001078	3.325082
		0.771963	865.7750	96973.36	342.5525	0.000905	3.465072
		0.583711	721.4792	80811.13	259.0171	0.000985	3.404372
		0.332082	505.0354	56567.79	147.3590	0.001144	3.281896
		0.196754	360.7396	40405.56	87.30835	0.001329	3.168236
		0.100862	240.4930	26937.04	44.75678	0.001533	3.023137
		0.078745	192.3944	21549.63	34.94256	0.001870	2.969385
1768	14.9	0.161877	144.9060	16157.50	23.94729	0.002259	2.885366
1416	15	0.115716	115.2822	12825.39	17.11856	0.002551	2.811486
1234	15	0.098689	100.4649	11176.93	14.59965	0.002865	2.776924
1294	20	0.071102	79.01232	8770.476	10.51861	0.003337	2.704746
1295	20	0.072496	79.07338	8757.474	10.72483	0.003397	2.707977
1369	25.1	0.057769	66.60706	7376.814	8.546095	0.003815	2.658666
1214	29.9	0.041014	49.58360	5466.723	6.067421	0.004888	2.582314
1130	35	0.031390	39.42765	4347.003	4.643813	0.005917	2.524249
1111	40.2	0.026467	33.75037	3712.682	3.915404	0.006808	2.486215
1143	49.9	0.019057	27.97282	3077.127	2.819316	0.007136	2.414898
1066	59.9	0.012558	21.73306	2385.340	1.857894	0.007791	2.323352
920	70	0.009345	16.05019	1757.640	1.382581	0.010639	2.258201
1065	100	0.007448	13.00589	1421.052	1.101906	0.012902	2.207943
846	100	0.005824	10.33144	1127.563	0.861624	0.015987	2.154037
607	99.9	0.004217	7.420168	807.0941	0.623871	0.022441	2.082448
419	99.9	0.002921	5.121994	555.8655	0.432162	0.032624	2.001739
311	100	0.002162	3.797965	411.2461	0.319839	0.043912	1.935396
213	109.9	0.001348	2.366859	255.7075	0.199504	0.070527	1.831921
141	150	0.000657	1.147938	123.7399	0.097210	0.146088	1.674817
71	150	0.000329	0.578039	62.16833	0.048801	0.289231	1.524191
1205	14.9	0.097204	98.76233	10669.95	14.37993	0.002919	2.760823
1382	14.9	0.115149	113.2693	12237.23	17.03463	0.002629	2.797611
1738	15	0.159558	141.4976	15286.92	23.60429	0.002334	2.868440

84.63346
82.65316
84.63346
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.18206	276.3098	36.86480	36.72353	2.589434	0.132907
13.91234	236.5739	35.58365	35.74313	2.569166	0.151086
13.60137	197.7993	34.10655	34.19987	2.514441	0.172901
13.24950	161.5310	32.43514	32.45602	2.449602	0.200927
12.71321	118.6268	29.88775	29.93819	2.354888	0.252372
12.75758	121.6957	30.09851	29.11746	2.282365	0.239264
12.30306	93.68006	27.93957	27.01803	2.196040	0.288407
11.77518	69.13137	25.43210	24.40813	2.072845	0.353068
12.90955	132.8213	30.82037	30.29051	2.346364	0.228054
12.90032	132.1181	30.77656	30.45175	2.360540	0.230488
13.46028	182.3694	33.43636	33.23382	2.469028	0.182233
13.21749	158.5816	32.28308	31.84919	2.409624	0.200837
12.72758	119.6125	29.95604	29.55781	2.322342	0.247112
12.27294	92.06963	27.79649	27.42867	2.234889	0.297912
11.69255	65.92011	25.03962	25.53947	2.184251	0.387430
11.47754	58.24597	24.01833	23.12352	2.014675	0.396997
11.14146	48.00056	22.42196	21.03817	1.888277	0.438290
10.84594	40.49175	21.01824	19.79630	1.825225	0.488897
10.70769	37.39419	20.36155	18.68092	1.744626	0.499567
10.41898	31.66846	18.99019	17.30916	1.661309	0.546574
10.43191	31.90492	19.05157	17.15541	1.644512	0.537704
10.23466	28.48042	18.11466	16.18834	1.581717	0.568402
9.929256	23.88879	16.66396	14.30253	1.440443	0.598713
9.696998	20.89919	15.56074	12.99991	1.340612	0.622029
9.544861	19.14675	14.83809	12.11916	1.269705	0.632961
9.259595	16.24721	13.48307	11.83713	1.278364	0.728564
8.893409	13.15928	11.74369	11.32917	1.273884	0.860926
8.632807	11.32613	10.50583	9.699027	1.123507	0.856340
8.431775	10.08843	9.550931	8.803722	1.044112	0.872654
8.216151	8.910823	8.526718	7.908665	0.962575	0.887534
7.929794	7.556639	7.166525	6.675372	0.841808	0.883378
7.606957	6.275082	5.633049	5.536436	0.727812	0.882288
7.341586	5.386128	4.372637	4.772051	0.650002	0.885989
6.927686	4.244257	2.406512	3.765493	0.543542	0.887197
6.299270	2.955954	-0.57846	2.616327	0.415338	0.885104
5.696767	2.089642	-3.44035	1.859418	0.326398	0.889826
10.64329	36.03328	20.05565	18.50711	1.738851	0.513611
10.79044	39.21857	20.75462	19.50166	1.807308	0.497255
11.07376	46.16585	22.10037	20.69566	1.868891	0.448289

YSP13160

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.861624	80.94521	-0.06468	1.908191
0.623871	58.13584	-0.20490	1.764443
0.432162	40.13001	-0.36435	1.603469
0.319839	29.75645	-0.49506	1.473581
0.199504	18.54396	-0.70004	1.268202
0.097210	8.993912	-1.01228	0.953948
0.048801	4.528849	-1.31156	0.655987

Regression Output:

Constant	-1.96389
Std Err of Y Est	0.001527
R Squared	0.999990
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	0.996524
Std Err of Coef.	0.001392

Tw vs. K'*(8<U>/D)^n

K' = 0.010866
n = 0.996524

Tw* = 2.078633
Res/f* = 223.2111

Regression Output:

Constant	-44.8353
Std Err of Y Est	0.137432
R Squared	0.998318
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	22.91901
Std Err of Coef.	0.383977

t = 24.22948 deg C
s.d.)t = 0.724101 deg C

B1P01496 B1120 7/23/90 12:06

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 9.05 Z = 7.05 [NaCl]=

Freq. (Hz)	Q)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	25.5	8.152	0.0215	0.0375	8.1145
50	1.0118	25.5	5.7775	0.0215	0.0375	5.74
40	0.80944	25.5	3.81575	0.0215	0.0375	3.77825
31	0.627316	25.5	2.43325	0.0215	0.0375	2.39575
23	0.465428	25.5	1.4464	0.0215	0.0375	1.4089
17	0.344012	25.5	0.8686	0.0215	0.0375	0.8311
12	0.242832	25.5	0.511	0.0215	0.0375	0.4735
9	0.182124	25.5	0.306222	0.0215	0.0375	0.268722
18	0.364248	25.5	10.2564	0.0185	0.1865	10.0699
15	0.30354	25.6	7.5735	0.0435	0.059	7.5145
10	0.20236	25.6	3.643888	0.0435	0.059	3.584888
8	0.161888	25.6	2.64125	0.0435	0.059	2.58225
		25.4	2.5652	0.0315	0.0205	2.5337
		25.4	1.7345	0.0175	0.0155	1.717
		25.4	1.34925	0.0145	0.013	1.33475
		25.4	0.8134	0.0135	0.0105	0.7999
		25.3	0.5942	0.0125	0.0115	0.5817
		25.3	0.350714	0.0125	0.0115	0.338214
		25.2	2.282	0.0045	0	2.282
		25.2	1.443428	-0.0085	-0.0125	1.455928
		25.25	1.094444	-0.0165	-0.0185	1.112944
		25.2	0.596615	-0.0225	-0.0255	0.622115
		25.2	0.344333	-0.0265	-0.0295	0.373833
		25.2	0.248777	-0.0305	-0.0315	0.280277
		25.2	0.196928	-0.0325	-0.0335	0.230428
		25.2	0.122	-0.0345	-0.0345	0.1565
		25.1	0.0508	-0.036	-0.036	0.0868
		25.05	-0.0002	-0.037	-0.037	0.0368
		25.1	3.8528	-0.0385	-0.0445	3.8973
		25.2	5.22025	-0.0445	-0.0445	5.26475
		25.3	8.339666	-0.0445	-0.0375	8.384166
		25.3	11.0502	-0.0375	-0.0305	11.0807

		density	viscosity			
	co)[NaCl]	1.000088	1.001574	ID(cm) =	1.45796	
1.000181	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08859	12.79437
0.000100	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		7.454137	727.2685	119716.0	1051.613	0.003987	3.878523
		5.272875	606.0571	99763.40	743.8861	0.004062	3.803348
		3.470774	484.8457	79810.72	489.6494	0.004177	3.712578
		2.200782	375.7554	61853.21	310.4817	0.004410	3.617613
		1.294243	278.7862	45891.16	182.5890	0.004712	3.498322
		0.763461	206.0594	33919.55	107.7079	0.005087	3.387719
		0.434966	145.4537	23943.21	61.36412	0.005817	3.261552
		0.246853	109.0902	17957.41	34.82556	0.005869	3.138544
		0.787057	218.1805	35914.82	111.0363	0.004678	3.390328
		0.587328	181.8171	29996.61	82.85907	0.005027	3.327750
		0.280192	121.2114	19997.74	39.52898	0.005596	3.167038
		0.201827	96.96914	15998.19	28.47333	0.006073	3.095799
2338	15	0.198032	73.36243	15333.80	27.93799	0.006428	3.089707
1880	14.9	0.134199	75.57714	12412.76	18.93260	0.006648	3.005215
1600	15	0.104323	63.89216	10493.62	14.71769	0.007231	2.950530
1590	20	0.062519	47.61963	7821.029	8.820144	0.007801	2.839348
1311	19.9	0.045465	39.46103	6466.461	6.414149	0.008261	2.769194
1206	25	0.026434	28.89523	4735.047	3.729339	0.008958	2.651441
1200	24.9	0.027798	28.86694	4719.752	3.921818	0.009439	2.661783
1116	30	0.017735	22.28239	3643.176	2.502141	0.010107	2.563795
1252	39.9	0.013557	18.79534	3076.511	1.912693	0.010859	2.505955
1153	45	0.007578	15.34743	2509.308	1.069160	0.009103	2.379161
1215	60	0.004553	12.12952	1983.180	0.642465	0.008758	2.268564
1190	75	0.003414	9.503959	1553.899	0.481682	0.010695	2.206020
784	60	0.002807	7.826790	1279.682	0.396011	0.012965	2.163493
675	75	0.001906	5.390901	881.4136	0.268959	0.018561	2.079482
378	75	0.001057	3.018904	492.4793	0.149173	0.032826	1.950500
189	89.9	0.000448	1.259276	205.1964	0.063244	0.079984	1.763671
1311	20	0.047476	39.26373	6405.163	6.697853	0.008713	2.776622
1181	15	0.064134	47.16040	7710.737	9.047937	0.008159	2.842914
1581	15	0.102134	63.13344	10345.64	14.40893	0.007250	2.944940
1860	15	0.134983	74.27464	12171.34	19.04316	0.006923	3.005494

Tap DL= 122.2234
82.0894 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.11409	472.5020	41.29194	15.83539	1.047723	0.033513
14.81339	397.4007	39.86362	15.68998	1.059175	0.039481
14.45015	322.4171	38.13822	15.47116	1.070657	0.047984
14.05445	256.7399	36.25865	15.05738	1.071360	0.058648
13.59333	196.8851	34.06832	14.56787	1.071692	0.073991
13.13487	151.2165	31.89066	14.01944	1.067344	0.092711
12.64621	114.1386	29.56950	13.11081	1.036738	0.114867
12.15417	85.98536	27.23234	13.05266	1.073924	0.151801
13.16131	153.5352	32.01623	14.61994	1.110827	0.095222
12.91100	132.9323	30.82726	14.10332	1.092349	0.106094
12.26815	91.81603	27.77373	13.61264	1.109591	0.148259
11.98319	77.92554	26.42019	12.83131	1.070775	0.164661
11.95883	76.84009	26.30444	12.47217	1.042925	0.162313
11.62086	63.25508	24.69909	12.26458	1.055394	0.193890
11.40212	55.77123	23.66007	11.75967	1.031358	0.210855
10.95739	43.17458	21.54761	11.32180	1.033257	0.262233
10.67677	36.73454	20.21469	11.00201	1.030461	0.299500
10.20576	28.01051	17.97737	10.56533	1.035232	0.377191
10.24553	28.65917	18.16628	10.29284	1.004617	0.359146
9.855183	22.89158	16.31212	9.946823	1.009298	0.434518
9.623820	20.03711	15.21314	9.596292	0.997139	0.478925
9.116645	14.96377	12.80406	10.48076	1.149629	0.700408
8.674259	11.59964	10.70273	10.68556	1.231870	0.921197
8.424080	10.04384	9.514382	9.669474	1.147837	0.962726
8.253975	9.106971	8.706385	8.782297	1.064008	0.964348
7.917931	7.505212	7.110176	7.340013	0.927011	0.977988
7.402001	5.576741	4.659508	5.519345	0.745655	0.989708
6.654687	3.627036	1.109766	3.535882	0.531337	0.974868
10.70649	37.36823	20.35582	10.71291	1.000600	0.286685
10.97165	43.53060	21.61537	11.07085	1.009041	0.254323
11.37976	55.05806	23.55387	11.74401	1.032008	0.213302
11.62197	63.29575	24.70439	12.01833	1.034103	0.189875

B1P01496

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.069160	84.21318	0.029042	1.925380
0.642465	66.55616	-0.19215	1.823188
0.481682	52.14935	-0.31723	1.717248
0.396011	42.94653	-0.40229	1.632928
0.268959	29.58051	-0.57031	1.471005
0.149173	16.56509	-0.82630	1.219193
0.063244	6.909798	-1.19898	0.839465

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-2.04722
Std Err of Y Est	0.004640
R Squared	0.999073
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 1.005978
Std Err of Coef. 0.006536

Tw = K'(8<U>/D)^n'

K' = 0.008969
n' = 1.005978

Regression Output:

Constant	0.566011
Std Err of Y Est	0.281963
R Squared	0.925815
No. of Observations	11
Degrees of Freedom	9

X Coefficient(s) 4.009097
Std Err of Coef. 0.378285

t = 25.35 deg C
s.d.)t = 0.159589 deg C

B2r01494 B1120 7/21/90 12:25

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14 <C>(ppm)=

S = 2.7 S = 7.25 S = 9.9

Z = 2.7 Z = 9 Z = 7.05 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25	6.42575	0.0135	0.0225	6.40325
49	0.991564	25	4.183	0.0135	0.0225	4.1605
41	0.829676	25	2.872333	0.0135	0.0225	2.849833
34	0.688024	25	2.024666	0.0135	0.0225	2.002166
26	0.526136	25	1.225666	0.0135	0.0225	1.203166
20	0.40472	25	0.776666	0.0135	0.0225	0.754166
15	0.30354	25	0.489666	0.0135	0.0225	0.467166
10	0.20236	25	0.256875	0.0135	0.0225	0.234375
18	0.364248	25.1	7.18	0.0655	0.085	7.1145
13	0.263068	25.1	4.3226	0.0655	0.085	4.2376
10	0.20236	25.1	2.061875	0.0655	0.085	1.976875
8	0.161888	25.1	1.92075	0.0655	0.085	1.83575
		24.9	2.1648	0.0715	0.0595	2.0933
		24.9	1.4642	0.0615	0.0565	1.4027
		24.8	1.0972	0.0605	0.0655	1.0367
		24.8	0.661	0.0615	0.0605	0.5995
		24.8	0.5252	0.0635	0.0625	0.4617
		24.8	0.353285	0.0645	0.0655	0.288785
		24.7	1.8815	0.0405	0.0405	1.841
		24.7	1.181285	0.0385	0.0355	1.145785
		24.7	0.806090	0.0335	0.0315	0.774590
		24.6	0.5711	0.0285	0.026	0.5451
		24.6	0.420846	0.0245	0.0245	0.396346
		24.6	0.341388	0.0235	0.0235	0.317888
		24.55	0.2516	0.0225	0.0235	0.2281
		24.5	0.185214	0.0235	0.0235	0.161714
		24.5	0.117	0.0235	0.0235	0.0935
		24.4	0.068272	0.0235	0.0235	0.044772
		24.4	0.046	0.0225	0.0205	0.0255
		24.4	4.0975	0.0205	0.0115	4.086
		24.5	6.493	0.0105	0.0095	6.4835
		24.6	8.4475	0.0075	0.0075	8.44
		24.6	13.009	0.0055	0.0105	12.9985

		density	viscosity			
	co)[NaCl]	1.000088	1.001574		ID(cm) =	1.45796
2.017038	X coeff	-0.00025	-0.02281		K(V/psi)=	1.08859 12.56699
0.000100	constant	0.003419	-4.14933		XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		5.882150	727.2685	118373.2	829.8412	0.003146	3.822166
		3.821916	593.9360	96671.50	539.1878	0.003065	3.728539
		2.617912	496.9668	80888.40	369.3295	0.002999	3.646376
		1.839229	412.1188	67078.18	259.4745	0.003063	3.569716
		1.105252	315.1497	51295.08	155.9266	0.003148	3.459129
		0.692792	242.4228	39457.75	97.73765	0.003335	3.357700
		0.429148	181.8171	29593.31	60.54334	0.003672	3.253702
		0.215301	121.2114	19728.87	30.37427	0.004146	3.103922
		0.566126	218.1805	35592.18	79.86785	0.003364	3.314840
		0.337200	157.5748	25705.46	47.57158	0.003842	3.202328
		0.157306	121.2114	19773.43	22.19253	0.003029	3.036758
		0.146077	96.96914	15818.75	20.60825	0.004395	3.020675
2526	15	0.166571	100.8697	16380.98	23.49952	0.004631	3.047213
1971	15	0.111617	78.70716	12781.83	15.74680	0.005097	2.960280
1652	15	0.082493	65.96866	10688.99	11.63806	0.005362	2.893639
1624	20	0.047704	48.63791	7880.871	6.730027	0.005705	2.774707
1338	19.9	0.036739	40.27373	6525.611	5.183075	0.006408	2.717992
1497	30	0.022979	29.88955	4843.047	3.241927	0.007277	2.616100
1489	29.9	0.022569	29.82925	4822.385	3.183996	0.007175	2.611200
1162	30	0.014046	23.20084	3750.794	1.981628	0.007382	2.508225
1316	40	0.009495	19.70674	3185.916	1.339649	0.006917	2.422209
1070	40	0.006682	16.02295	2584.535	0.942746	0.007363	2.345926
911	45	0.004858	12.12620	1955.980	0.685477	0.009348	2.276725
820	50	0.003897	9.823420	1584.537	0.549786	0.011424	2.228825
714	60	0.002796	7.127969	1148.459	0.394497	0.015569	2.156258
500	59.9	0.001982	4.999908	804.6779	0.279683	0.022434	2.081077
423	89.9	0.001146	2.818380	453.5859	0.161707	0.010822	1.962108
221	100	0.000548	1.323765	212.5648	0.077434	0.088606	1.801224
224	200.1	0.000312	0.670532	107.6713	0.044102	0.196686	1.678987
1200	14.9	0.050090	48.24073	7746.296	7.066708	0.006088	2.781366
1627	15	0.079482	64.97034	10456.23	11.21316	0.005326	2.882607
1948	15	0.103467	77.78871	12547.47	14.59692	0.004837	2.940859
2462	14.9	0.159350	98.97389	15964.68	22.48081	0.004602	3.034634

Tap DL= 122.2234
81.57181 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.88866	414.9989	40.22117	17.82734	1.197376	0.042957
14.51415	334.5180	38.44225	18.06171	1.244420	0.053993
14.18550	276.8576	36.88115	18.26037	1.287256	0.065955
13.87886	232.0581	35.42462	18.06610	1.301698	0.077851
13.43651	179.8911	33.32346	17.82157	1.326353	0.099068
13.03080	142.4231	31.39630	17.31537	1.328803	0.121577
12.61481	112.0940	29.42035	16.50026	1.308007	0.147200
12.01568	79.39669	26.57452	15.53030	1.292502	0.195603
12.85936	129.0389	30.58197	17.23907	1.340585	0.133595
12.40931	99.58834	28.44424	16.13232	1.300017	0.161990
11.74703	68.02023	25.29840	18.16870	1.546663	0.267107
11.68270	65.54737	24.99283	15.08331	1.291081	0.230113
11.78885	69.67770	25.49706	14.69353	1.246391	0.210878
11.44112	57.03750	23.84532	14.00595	1.224177	0.245556
11.17455	48.92372	22.57914	13.65518	1.221988	0.279111
10.69883	37.20381	20.31944	13.23935	1.237457	0.355860
10.47197	32.64922	19.24186	12.49189	1.192888	0.382609
10.06440	25.82145	17.30591	11.72243	1.164742	0.453980
10.04480	25.53172	17.21280	11.80488	1.175223	0.462361
9.632900	20.14211	15.25627	11.63853	1.208206	0.577820
9.292857	16.56111	13.64098	12.02333	1.293827	0.725997
8.983704	13.86137	12.17259	11.65349	1.297181	0.840717
8.706901	11.81967	10.85778	10.34282	1.187887	0.875051
8.515303	10.58536	9.947689	9.355709	1.098693	0.883834
8.225032	8.956496	8.568904	8.014152	0.974361	0.894786
7.924308	7.532811	7.140464	6.676440	0.842526	0.886314
7.448434	5.727811	4.880065	4.949380	0.664486	0.864096
6.804897	3.954617	1.823265	3.359440	0.493679	0.849498
6.315951	2.984474	-0.49923	2.254822	0.357004	0.755517
10.72546	37.77869	20.44597	12.81525	1.194843	0.339219
11.13043	47.69662	22.36954	13.70148	1.230992	0.287263
11.36343	54.54304	23.47632	14.37795	1.265281	0.263607
11.73853	67.68847	25.25805	14.74095	1.255774	0.217776

92P01494

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.942746	87.91987	-0.02560	1.944087
0.685477	66.53790	-0.16400	1.823069
0.549786	53.90227	-0.25980	1.731607
0.394497	39.11201	-0.40395	1.592310
0.279683	27.43509	-0.55333	1.438306
0.161707	15.46478	-0.79126	1.189343
0.077434	7.263660	-1.11106	0.861155
0.044102	3.679291	-1.35554	0.565764

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.89797
Std Err of Y Est	0.013716
R Squared	0.999080
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.934091
Std Err of Coef.	0.016359

Tw = K'(8<U>/D)^n'

K' = 0.012648
n' = 0.934091

Tw)Retro=0.353158
Res/f)R =136.9791

Regression Output:

Constant	-7.68893
Std Err of Y Est	0.199089
R Squared	0.989337
No. of Observations	18
Degrees of Freedom	16
X Coefficient(s)	7.434693
Std Err of Coef.	0.192955

t = 24.78030 deg C
s.d.)t = 0.228943 deg C

B5P01490 B1120 7/16/90 11:35

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14	
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)
Z =	2.7	Z =	9	Z =	7.1	[NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.05	4.134	0.0145	0.0195	4.1145
49	0.991564	25.05	2.568	0.0145	0.0195	2.5485
39	0.789204	25.05	1.640333	0.0145	0.0195	1.620833
31	0.627316	25.05	1.054666	0.0145	0.0195	1.035166
25	0.465428	25.05	0.609	0.0145	0.0195	0.5895
17	0.344012	25.05	0.364666	0.0145	0.0195	0.345166
14	0.283304	25.05	0.25425	0.0145	0.0195	0.23475
10	0.20236	25.05	0.158166	0.0145	0.0195	0.138666
20	0.40472	25	5.3235	0.0745	0.0925	5.231
16	0.323776	25	3.871	0.0745	0.0925	3.7785
12	0.242832	25	2.296	0.0745	0.0925	2.2035
9	0.182124	25	1.366142	0.0745	0.0925	1.273642
		24.9	1.3156	0.0885	0.0815	1.2341
		24.8	0.767	0.0785	0.0775	0.6895
		24.8	0.6232	0.0755	0.0755	0.5477
		24.7	3.75575	0.0315	0.0275	3.72425
		24.6	2.4115	0.0295	0.0285	2.382
		24.6	1.827	0.0285	0.0295	1.7985
		24.6	1.181833	0.0295	0.0295	1.152333
		24.6	0.884	0.0305	0.0305	0.8535
		24.6	0.737428	0.0315	0.0315	0.705928
		24.5	0.611142	0.0315	0.0315	0.579642
		24.5	0.455875	0.0325	0.0325	0.423375
		24.5	0.365875	0.0325	0.0335	0.333375
		24.5	0.275909	0.0325	0.0325	0.243409
		24.4	0.173857	0.0335	0.035	0.140357
		24.4	0.096214	0.035	0.0355	0.061214
		24.4	0.0625	0.0355	0.0355	0.027
		24.5	7.952666	0.036	0.0315	7.916666

		density	viscosity			
co)[NaCl]		1.000088	1.001574		ID(cm) =	1.45796
5.068331	X coeff	-0.00025	-0.02281		K(V/psi)=	1.08859 12.56699
0.000100	constant	0.003419	-4.14933		XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		3.779659	727.2685	118506.8	533.2264	0.002021	3.726617
		2.341101	593.9360	96780.61	330.2776	0.001877	3.622601
		1.488929	472.7245	77029.46	210.0549	0.001885	3.524328
		0.950924	375.7554	61228.55	134.1543	0.001905	3.426964
		0.541526	278.7862	45427.63	76.39736	0.001971	3.304701
		0.317076	206.0594	33576.94	44.73252	0.002112	3.188473
		0.215645	169.6960	27651.60	30.42286	0.002118	3.104762
		0.127381	121.2114	19751.14	17.97076	0.002453	2.990445
		0.416249	242.4228	39457.75	58.72355	0.002003	3.247075
		0.300668	193.9382	31566.20	42.41769	0.002261	3.176443
		0.175340	145.4537	23674.65	24.73663	0.002344	3.059339
		0.101348	109.0902	17755.99	14.29800	0.002409	2.960307
2420	14.9	0.098201	97.28547	15798.90	13.85408	0.002935	2.932473
1855	15	0.054865	74.07498	12002.47	7.740373	0.002828	2.805080
1560	15	0.043582	62.29486	10093.72	6.148517	0.003177	2.755084
1557	15	0.047031	62.17506	10051.61	6.635086	0.003441	2.770637
1154	15	0.030080	46.08222	7433.155	4.243747	0.004007	2.672603
1272	20	0.022712	38.09570	6144.913	3.204189	0.004427	2.611587
946	20	0.014552	28.33218	4570.038	2.052985	0.005128	2.514921
746	20	0.010778	22.34229	3603.856	1.520587	0.006108	2.449734
791	25.1	0.008914	18.87650	3044.818	1.257675	0.007077	2.408512
646	25	0.007319	15.47787	2490.986	1.032685	0.008643	2.364727
570	29.9	0.005346	11.41885	1837.733	0.754280	0.011599	2.296509
525	35	0.004209	8.984836	1446.006	0.593937	0.014753	2.244613
446	45	0.003073	5.936647	955.4352	0.433655	0.024673	2.176315
337	60	0.001772	3.364521	540.2288	0.250058	0.044299	2.055779
126	60.1	0.000773	1.255784	201.6485	0.109058	0.138671	1.875588
156	200	0.000340	0.467211	75.02288	0.048102	0.441876	1.697844
2382	14.9	0.099974	95.75785	15411.12	14.10425	0.003084	2.932418

Tap DL= 122.2234
79.1865 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.50647	333.0411	38.40574	22.23953	1.533076	0.066777
14.09040	262.1088	36.42943	23.07739	1.637808	0.088045
13.69731	209.0299	34.56224	23.03182	1.681484	0.110184
13.30785	167.0492	32.71232	22.90812	1.721398	0.137133
12.81880	126.0611	30.38932	22.52261	1.756998	0.178664
12.35389	96.46145	28.18100	21.75541	1.761016	0.225534
12.01904	79.55036	26.59048	21.72691	1.807540	0.273096
11.56178	61.13999	24.41846	20.19049	1.746313	0.330233
12.58830	110.3965	29.29443	22.33864	1.774555	0.202349
12.30577	93.82596	27.95241	21.02710	1.708718	0.224107
11.83735	71.65060	25.72745	20.65113	1.744572	0.288219
11.36122	54.47373	23.46583	20.37219	1.793132	0.373981
11.32989	53.49994	23.31699	18.45668	1.629025	0.344985
10.82032	39.89882	20.89652	18.80142	1.737603	0.471227
10.62033	35.56020	19.94660	17.74055	1.670432	0.498887
10.68254	36.85676	20.24210	17.04506	1.595598	0.462467
10.29041	29.40921	18.37946	15.79682	1.535100	0.537138
10.04635	25.55452	17.22016	15.02892	1.495958	0.588112
9.659686	20.45510	15.38351	13.96362	1.445556	0.682647
9.398937	17.60412	14.14495	12.79479	1.361301	0.726806
9.234051	16.01006	13.36174	11.88634	1.287230	0.742429
9.058910	14.47463	12.52982	10.75582	1.187320	0.743080
8.786039	12.37057	11.23368	9.284800	1.056767	0.750555
8.578455	10.97725	10.24766	8.232965	0.959725	0.750001
8.305263	9.379847	8.949999	6.366276	0.766535	0.678718
7.823117	7.106560	6.659809	4.751143	0.607321	0.668557
7.102354	4.693194	3.236182	2.685385	0.378097	0.572187
6.391376	3.116908	-0.14096	1.504352	0.235372	0.482642
11.32967	53.49319	23.31595	18.00594	1.589272	0.336602

B5P01490

Tw dyne/cm2	B<U>/D (1/sec)	Log Tw	Log B<U>/D
0.593937	49.30086	-0.22625	1.692854
0.433655	32.57508	-0.36285	1.512885
0.250058	18.46043	-0.60195	1.266241
0.109058	6.890636	-0.96233	0.838259
0.048102	2.563644	-1.31782	0.408857

Log Tw vs. Log B<U>/D

Regression Output:

Constant	-1.67442
Std Err of Y Est	0.012545
R Squared	0.999408
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s)	0.856928
Std Err of Coef.	0.012037

Tw = K'(B<U>/D)^n'

K' = 0.021163
n' = 0.856928

Tw)Retro=4.896452
Res/f)R =512.1444

Regression Output:

Constant	4.756168
Std Err of Y Est	0.389394
R Squared	0.877390
No. of Observations	10
Degrees of Freedom	8

X Coefficient(s)	5.286162
Std Err of Coef.	0.698653

t = 24.76896 deg C
s.d.)t = 0.247892 deg C

B1P11486 B1120 7/9/90 11:53

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 8.9 Z = 7.15 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.9	2.715666	0.0365	0.0385	2.677166
50	1.0118	24.9	1.874666	0.0365	0.0385	1.836166
39	0.789204	24.9	1.094	0.0365	0.0385	1.0555
31	0.627316	24.9	0.7416	0.0365	0.0385	0.7031
24	0.485664	24.9	0.4844	0.0365	0.0385	0.4459
16	0.323776	24.9	0.267	0.0365	0.0385	0.2285
13	0.263068	24.9	0.2464	0.0365	0.0385	0.2079
8	0.161888	24.9	0.122	0.0365	0.0385	0.0835
18	0.364248	24.9	3.595	0.0325	0.034	3.561
24	0.485664	24.9	4.9985	0.0325	0.034	4.9645
32	0.647552	24.9	8.568333	0.0325	0.034	8.534333
15	0.30354	24.9	2.249375	0.036	0.0435	2.205875
9	0.182124	24.9	1.1752	0.036	0.0435	1.1317
13	0.263068	24.9	1.7873	0.036	0.0435	1.7438
		24.7	1.1704	0.0635	0.06	1.1104
		24.6	0.804	0.0635	0.0625	0.7415
		24.5	0.6176	0.0655	0.0635	0.5541
		24.5	0.451833	0.0665	0.0635	0.388333
		24.4	2.632	0.0445	0.0445	2.5875
		24.4	2.2112	0.0665	0.0745	2.1367
		24.4	1.462	0.0815	0.085	1.377
		24.4	1.127555	0.0905	0.094	1.033555
		24.3	0.6927	-0.0185	-0.0165	0.7092
		24.3	0.536214	-0.0145	-0.0125	0.548714
		24.2	0.333692	-0.012	-0.0065	0.340192
		24.2	0.249733	-0.0055	-0.0045	0.254233
		24.1	0.1846	-0.0035	-0.0015	0.1861
		24.1	0.098363	-0.0005	0.0005	0.097863
		24	0.043666	-0.001	0.0005	0.043166
		24.2	3.5934	0.0005	-0.0105	3.6039
		24.3	4.854	-0.0105	-0.0075	4.8615
		24.4	6.8355	-0.007	-0.0065	6.842

		density	viscosity		
	co)[NaCl]	1.000088	1.001574	ID(cm) =	1.45796
9.963670	X coeff	-0.00025	-0.02281	K(V/psi)=	1.086516 12.44018
0.000099	constant	0.003419	-4.14733	XS(cm2)=	1.669479
					1.085095

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		2.463991	727.2685	118106.5	347.6147	0.001318	3.632233
		1.689958	606.0571	98422.10	238.4157	0.001301	3.550351
		0.971453	472.7245	76769.24	137.0506	0.001229	3.430124
		0.647114	375.7554	61021.70	91.29350	0.001296	3.341904
		0.410394	290.9074	47242.61	57.89756	0.001372	3.243014
		0.210305	193.9382	31495.07	29.66941	0.001581	3.097828
		0.191345	157.5748	25589.74	26.99462	0.002180	3.077322
		0.076851	96.96914	15747.53	10.84199	0.002312	2.879238
		0.286249	218.1805	35431.95	40.38352	0.001701	3.164786
		0.399069	290.9074	47242.61	56.29991	0.001334	3.236938
		0.686029	387.8765	62990.14	96.78361	0.001290	3.354585
		0.177318	181.8171	29526.63	25.01572	0.001517	3.060790
		0.090971	109.0902	17715.97	12.83404	0.002162	2.915866
		0.140174	157.5748	25589.74	19.77556	0.001597	3.009748
2515	15	0.089259	100.4305	16236.22	12.59249	0.002503	2.909769
1911	14.9	0.059605	76.82336	12391.76	8.408981	0.002857	2.821100
1600	15	0.044541	63.89216	10282.71	6.283771	0.003086	2.756853
1615	20	0.031216	48.36836	7784.333	4.403894	0.003774	2.679661
1601	19.8	0.032676	48.43340	7777.236	4.609864	0.003940	2.688602
1350	20	0.026983	40.43176	6492.364	3.806723	0.004669	2.647033
1241	25	0.017389	29.73381	4774.533	2.453249	0.005564	2.551629
1167	30	0.013052	23.30067	3741.525	1.841372	0.006800	2.489329
1075	40	0.008956	16.09783	2579.097	1.263503	0.009776	2.406561
1025	49.9	0.006929	12.30388	1971.254	0.977583	0.012948	2.350850
731	60	0.004296	7.297683	1166.556	0.606083	0.022819	2.246054
508	60	0.003210	5.071440	810.6848	0.452939	0.035311	2.182808
349	59.9	0.002350	3.489936	556.6195	0.331553	0.054581	2.114079
239	90	0.001235	1.590648	253.6969	0.174352	0.138166	1.974517
96	99.9	0.000545	0.575605	91.59796	0.076905	0.465392	1.795795
1572	15	0.045511	62.77405	10034.61	6.420672	0.003267	2.758578
1905	15.1	0.061393	75.56782	12107.02	8.661199	0.003041	2.824562
2459	14.9	0.086403	98.85329	15873.45	12.18963	0.002501	2.899753

Tap DL= 122.2234
79.1365 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.12893	267.9867	36.61243	27.54485	1.949535	0.102784
13.80140	221.9380	35.05668	27.71666	2.008249	0.124884
13.32049	168.2692	32.77237	28.51428	2.140631	0.169456
12.96761	137.3359	31.09618	27.77027	2.141509	0.202206
12.57205	109.3690	29.21727	26.99724	2.147400	0.246845
11.99135	78.29225	26.45893	25.14223	2.096696	0.321133
11.90929	74.67976	26.06913	21.41623	1.798279	0.286774
11.11695	47.32808	22.30553	20.79570	1.870629	0.439394
12.25914	91.34113	27.73094	24.24425	1.977645	0.265425
12.54775	107.8495	29.10182	27.37762	2.181874	0.253850
13.01834	141.4051	31.33711	27.84116	2.138610	0.196889
11.84316	71.89039	25.75502	25.66983	2.167481	0.357069
11.26346	51.49274	23.00145	21.50300	1.909093	0.417592
11.63899	63.91882	24.78522	25.02172	2.149818	0.391460
11.23907	50.77497	22.88562	19.98551	1.778216	0.393609
10.88440	41.39810	21.20090	18.70822	1.718811	0.451910
10.62741	35.70538	19.98022	17.99923	1.693660	0.504104
10.31864	29.89110	18.51357	16.27644	1.577381	0.544524
10.35440	30.51282	18.68344	15.93026	1.538500	0.522084
10.18813	27.72770	17.89364	14.63419	1.436396	0.527782
9.806516	22.25918	16.08095	13.40607	1.367058	0.602271
9.557316	19.28453	14.89725	12.12605	1.268772	0.628797
9.226245	15.93827	13.32466	10.11361	1.096179	0.634548
9.003400	14.01942	12.26615	8.788056	0.976081	0.626848
8.584216	11.01372	10.27502	6.619904	0.771171	0.601059
8.331232	9.521120	9.073352	5.321622	0.638755	0.558928
8.056319	8.127552	7.767515	4.280343	0.531302	0.526646
7.498069	5.893825	5.115828	2.690282	0.358796	0.456457
6.783182	3.905491	1.720117	1.465852	0.216100	0.375331
10.63431	35.84744	20.01298	17.49535	1.645179	0.488050
10.89824	41.72940	21.26668	18.13323	1.663866	0.434543
11.19901	49.61736	22.69532	19.99482	1.785409	0.402980

B1P11486

Tw dyne/cm2	B<U>/D (1/sec)	Log Tw	Log B<U>/D
1.263503	88.33071	0.101576	1.946111
0.977583	67.51287	-0.00984	1.829386
0.606083	40.04325	-0.21746	1.602529
0.452939	27.82759	-0.34395	1.444475
0.331553	19.14969	-0.47944	1.282161
0.174352	8.728079	-0.75857	0.940918
0.076905	3.158413	-1.11404	0.499469

Log Tw vs. Log B<U>/D

Regression Output:

Constant	-1.52221
Std Err of Y Est	0.002184
R Squared	0.999972
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.814203
Std Err of Coef.	0.002480

Tw = K'(B<U>/D)^n'

K' = 0.030045
n' = 0.814203

Tw)Retro=23.45311
Res/f)R =1113.741

Regression Output:

Constant	1.175836
Std Err of Y Est	0.196362
R Squared	0.979521
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	7.979911
Std Err of Coef.	0.516009

t = 24.58125 deg C
s.d.)t = 0.310682 deg C

B2P11483 B1120 7/4/90 12:38

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=	
Z =	2.7	Z =	8.9	Z =	7.2	[NaCl]=	

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
20	0.40472	24.7	0.364666	0.041	0.04	0.324666
29	0.586844	24.7	0.5845	0.041	0.04	0.5445
38	0.768968	24.7	0.9144	0.041	0.04	0.8744
46	0.930856	24.7	1.26325	0.041	0.04	1.22325
54	1.092744	24.7	1.5915	0.041	0.04	1.5515
60	1.21416	24.7	1.933666	0.041	0.04	1.893666
20	0.40472	24.6	0.363	0.0495	0.0405	0.3225
14	0.283304	24.6	0.222428	0.0495	0.0405	0.181928
10	0.20236	24.6	0.157333	0.0495	0.0405	0.116833
18	0.364248	24.5	2.76975	0.0255	0.0645	2.74425
16	0.323776	24.5	2.677	0.0255	0.0645	2.6125
11	0.222596	24.5	2.504625	0.0255	0.0645	2.440125
7	0.141652	24.5	0.593857	0.0255	0.0645	0.529357
25	0.5059	24.6	5.211333	0.0645	0.0245	5.186833
33	0.667788	24.6	8.162	0.0645	0.0245	8.1375
		24.3	1.07725	0.0235	0.0295	1.05375
		24.2	0.7884	0.0325	0.029	0.7559
		24.2	0.618	0.0315	0.0275	0.5865
		24.2	0.4516	0.0305	0.0255	0.4211
		24.1	2.561166	-0.0385	-0.0425	2.603666
		24.1	2.076166	-0.0275	-0.029	2.105166
		23.95	1.409142	-0.0245	-0.0275	1.436642
		23.9	1.076444	-0.0265	-0.0265	1.102944
		23.9	0.884125	-0.0285	-0.0285	0.912625
		23.9	0.699111	-0.0285	-0.0285	0.727611
		23.8	0.521625	-0.0295	-0.0285	0.550125
		23.8	0.339266	-0.0285	-0.0265	0.365766
		23.75	0.282368	-0.0275	-0.0275	0.309868
		23.7	0.155428	-0.0275	-0.0255	0.180928
		23.6	0.077833	-0.0255	-0.0285	0.106333
		23.5	0.022555	-0.0285	-0.0315	0.051055
		23.5	0.207454	-0.0325	-0.0335	0.239954
		23.7	3.632285	-0.0355	-0.045	3.677285
		23.9	4.916166	-0.0455	-0.035	4.951166
		24	6.9344	-0.0365	-0.0275	6.9619

		density	viscosity			
	co)[NaCl]	1.000088	1.001574		ID(cm) =	1.45796
20.01199	X coeff	-0.00025	-0.02281		K(V/psi)=	1.086516 12.44018
0.000100	constant	0.003419	-4.14933		XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		0.298814	242.4228	39191.61	42.15610	0.001438	3.172144
		0.501143	351.5131	56827.83	70.70020	0.001147	3.284424
		0.804774	460.6034	74464.05	113.5358	0.001073	3.387280
		1.125846	557.5725	90140.70	158.8320	0.001024	3.460182
		1.427958	654.5417	105817.3	201.4533	0.000942	3.511801
		1.742879	727.2685	117574.8	245.8817	0.000932	3.555077
		0.296820	242.4228	39103.29	41.87477	0.001428	3.169704
		0.167442	169.6960	27372.30	23.62238	0.001644	3.045390
		0.107530	121.2114	19551.64	15.17013	0.002070	2.949223
		0.220595	218.1805	35113.65	31.12117	0.001310	3.104271
		0.210004	193.9382	31212.14	29.62705	0.001579	3.093587
		0.196148	133.3325	21458.34	27.67224	0.003121	3.078765
		0.042552	84.84800	13655.31	6.003175	0.001672	2.746934
		0.416941	303.0285	48879.11	58.82129	0.001284	3.243495
		0.654130	399.9977	64520.43	92.28332	0.001156	3.341290
2460	15	0.084705	98.23420	15738.49	11.95005	0.002483	2.894458
1875	14.9	0.060762	75.37614	12049.09	8.572284	0.003025	2.821336
1570	14.9	0.047145	63.11495	10089.11	6.651204	0.003347	2.766238
1601	20.1	0.033849	47.71052	7626.668	4.775485	0.004206	2.694296
1595	20	0.032880	47.76937	7618.869	4.638666	0.004075	2.686999
1340	20.1	0.026584	39.93260	6368.960	3.750543	0.004715	2.640849
1225	25.1	0.018142	29.23353	4646.784	2.559508	0.006004	2.556403
1135	30	0.013928	22.66175	3598.113	1.964994	0.007671	2.498513
972	30	0.011525	19.40724	3081.380	1.625923	0.008655	2.457382
770	29.9	0.009188	15.42547	2449.175	1.296304	0.010922	2.408185
1106	59.9	0.006947	11.05979	1752.059	0.980097	0.016064	2.346481
757	59.9	0.004619	7.569861	1199.194	0.651646	0.022799	2.257853
735	75	0.003913	5.870092	928.8738	0.552058	0.032120	2.221347
471	90	0.002284	3.134709	495.4720	0.322340	0.065765	2.104019
272	99.9	0.001342	1.630881	257.1961	0.189442	0.142791	1.987615
115	100.1	0.000644	0.688149	108.2791	0.090960	0.385073	1.827316
486	70	0.003030	4.158695	654.3640	0.427500	0.049554	2.163359
1551	15	0.046438	61.93547	9789.517	6.551415	0.003424	2.758029
1860	15	0.062525	74.27464	11792.93	8.820949	0.003205	2.824589
2415	15	0.087917	96.43724	15346.37	12.40325	0.002673	2.899585

Tap DL= 122.2234
79.1865 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
12.28857	92.90180	27.87073	26.36628	2.145593	0.283808
12.73769	120.3106	30.00406	29.52139	2.317639	0.245376
13.14912	152.4615	31.95832	30.52575	2.321504	0.200219
13.44073	180.3278	33.34347	31.24194	2.324422	0.173250
13.64720	203.0865	34.32422	32.56534	2.386228	0.160352
13.82030	224.3660	35.14646	32.75196	2.369843	0.145975
12.27881	92.38149	27.82439	26.45503	2.154526	0.286367
11.78156	69.38579	25.46242	24.65589	2.092752	0.355345
11.39689	55.60367	23.63524	21.97656	1.928294	0.395235
12.01708	79.46053	26.58115	27.61878	2.298293	0.347578
11.97435	77.52964	26.37816	25.16145	2.101279	0.324539
11.91506	74.92826	26.09654	17.89907	1.502222	0.238882
10.58773	34.89908	19.79174	24.45499	2.309747	0.700734
12.57398	109.4903	29.22642	27.90148	2.218985	0.254830
12.96516	137.1419	31.08451	29.40403	2.267926	0.214405
11.17783	49.01601	22.59470	20.06805	1.795343	0.409416
10.88534	41.42058	21.20538	18.18102	1.670229	0.438936
10.66495	36.48531	20.15852	17.28283	1.620526	0.473692
10.37718	30.91552	18.79163	15.41836	1.485793	0.498725
10.34799	30.40040	18.65298	15.66358	1.513683	0.515242
10.16339	27.33567	17.77614	14.56192	1.432780	0.532707
9.825612	22.50521	16.17166	12.90474	1.313377	0.573411
9.594052	19.69668	15.07174	11.41725	1.190035	0.579654
9.429529	17.91688	14.29026	10.74887	1.139916	0.599929
9.232743	15.99800	13.35553	9.568282	1.036342	0.598092
8.985926	13.87911	12.18315	7.889820	0.878019	0.568467
8.631412	11.31704	10.49920	6.622721	0.767281	0.585198
8.485388	10.40464	9.805594	5.579684	0.657563	0.536268
8.016077	7.941442	7.576368	3.899417	0.486449	0.491021
7.550461	6.074287	5.364691	2.646360	0.350489	0.435666
6.909267	4.199493	2.319021	1.611491	0.233236	0.383734
8.253439	9.104160	8.703838	4.492204	0.544282	0.493423
10.63211	35.80218	20.00256	17.08959	1.607355	0.477333
10.89835	41.73207	21.26720	17.66167	1.620581	0.423215
11.19834	49.59813	22.69212	19.33840	1.726899	0.389901

B2P11483

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.296304	84.64139	0.112707	1.927582
0.980097	60.68642	-0.00873	1.783091
0.651646	41.53673	-0.18598	1.618432
0.552058	32.20989	-0.25801	1.507989
0.322340	17.20052	-0.49168	1.235541
0.189442	8.948838	-0.72252	0.951766
0.090960	3.775957	-1.04114	0.577027
0.427500	22.81925	-0.36906	1.358301

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.52870
Std Err of Y Est	0.008255
R Squared	0.999474
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.845570
Std Err of Coef.	0.011196

Tw = K'(8<U>/D)^n'

K' = 0.029600
n' = 0.845570

Regression Output:

Constant	-30.8401
Std Err of Y Est	0.526733
R Squared	0.982004
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	18.09186
Std Err of Coef.	0.999836

t = 24.20571 deg C
s.d.)t = 0.396911 deg C

B5P11480 B1120 6/28/90 13:02

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 8.9 Z = 7.4 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.1	1.78475	0.0325	0.0375	1.74725
50	1.0118	25.1	1.358666	0.0325	0.0375	1.321166
40	0.80944	25.1	0.953666	0.0325	0.0375	0.916166
30	0.60708	25.1	0.644333	0.0325	0.0375	0.606833
21	0.424956	25.1	0.3755	0.0325	0.0375	0.338
14	0.283304	25.1	0.2398	0.0325	0.0375	0.2023
10	0.20236	25.1	0.155714	0.0325	0.0375	0.118214
7	0.141652	25.1	0.110428	0.0325	0.0375	0.072928
18	0.364248	25.2	2.8475	-0.0035	0.0035	2.844
26	0.526136	25.2	5.685	-0.0035	0.0035	5.6815
35	0.70826	25.2	8.605	-0.0035	0.0035	8.6015
15	0.30354	25	2.4316	0.0025	0.0165	2.4151
11	0.222596	25	2.064	0.0025	0.0165	2.0475
7	0.141652	25	0.6944	0.0025	0.0165	0.6779
		24.8	1.2825	0.0235	-0.0055	1.259
		24.7	0.88125	-0.0035	-0.0045	0.88475
		24.7	0.7238	-0.0035	-0.0035	0.7273
		24.6	0.528571	-0.0035	-0.0035	0.532071
		24.6	0.422375	-0.003	-0.0015	0.425375
		24.5	2.587333	-0.0395	-0.0645	2.626833
		24.5	1.890571	-0.0725	-0.073	1.963071
		24.5	1.357777	-0.077	-0.076	1.434777
		24.5	1.158777	-0.0795	-0.0785	1.238277
		24.4	1.028916	-0.0805	-0.0805	1.109416
		24.4	0.795538	-0.0835	-0.081	0.879038
		24.25	0.67275	-0.0905	-0.0865	0.76325
		24.2	0.5316	-0.09	-0.0885	0.6216
		24.2	0.418866	-0.0905	-0.0895	0.509366
		24.1	0.214045	-0.0905	-0.0905	0.304545
		23.9	0.096541	-0.0905	-0.0905	0.187041
		24	4.3844	-0.0905	-0.112	4.4749
		24.2	7.51	-0.114	-0.106	7.624
		24.2	5.4125	-0.1095	-0.1065	5.522

		density	viscosity			
	co)[NaCl]	1.000088	1.001574	ID(cm) =	1.45796	
49.91302	X coeff	-0.00025	-0.02281	K(V/psi)=	1.085095	12.37189
0.000099	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.610227	727.2685	118640.6	227.1675	0.000861	5.541827
		1.217558	606.0571	98867.18	171.7705	0.000937	5.481129
		0.844319	484.8457	79093.75	119.1147	0.001016	5.401637
		0.559244	363.6342	59320.31	78.89701	0.001196	5.312184
		0.311493	254.5440	41524.21	43.94483	0.001360	5.185108
		0.186435	169.6960	27682.81	26.30189	0.001831	5.073648
		0.108943	121.2114	19773.43	15.36954	0.002098	2.956985
		0.067209	84.84800	13841.40	9.481757	0.002641	2.852099
		0.229875	218.1805	35672.57	32.43041	0.001366	5.120116
		0.459226	315.1497	51527.05	64.78670	0.001308	5.270382
		0.695245	424.2400	69363.34	98.08375	0.001092	5.360438
		0.195208	181.8171	29593.31	27.53962	0.001670	5.082648
		0.165496	133.3325	21701.76	23.34784	0.002633	5.046792
		0.054793	84.84800	13810.21	7.730160	0.002153	2.806762
2235	14.9	0.101762	89.84836	14558.25	14.35650	0.003566	2.939223
1750	14.9	0.071512	70.35106	11373.39	10.08889	0.004087	2.861635
1982	20.1	0.058786	59.06449	9548.739	8.293473	0.004767	2.819082
1495	19.9	0.043006	44.99943	7258.498	6.067262	0.006008	2.750225
1524	24.9	0.034382	36.66101	5913.495	4.850592	0.007237	2.701626
1526	25	0.033643	36.56229	5884.281	4.746334	0.007119	2.695922
1037	24.9	0.025142	24.94585	4014.748	3.547006	0.011429	2.632674
836	30	0.018576	16.69182	2686.358	2.592450	0.018658	2.564598
755	35	0.015859	12.92105	2079.494	2.237401	0.026872	2.532615
731	40.1	0.014208	10.91922	1753.364	2.004566	0.033712	2.507768
567	50	0.011258	6.792536	1090.717	1.588304	0.069028	2.457225
585	59.9	0.009775	5.849893	936.1782	1.379090	0.080804	2.425076
405	60	0.007961	4.043176	646.3137	1.123147	0.137760	2.380006
284	60	0.006523	2.835214	453.2175	0.920357	0.229571	2.336766
157	90	0.003900	1.044903	166.6544	0.550272	1.010530	2.224091
66	100	0.002395	0.395332	62.76885	0.337959	4.335511	2.116264
1466	15	0.057312	58.54119	9315.856	8.085542	0.004730	2.806672
2215	15	0.097644	88.45071	14139.10	13.77554	0.003530	2.924342
1740	15	0.070723	69.48273	11107.02	9.977511	0.004143	2.854299

Tap DL= 122.2234
78.07879 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.76731	217.6245	34.89472	34.07262	2.474893	0.156566
13.52451	189.2383	33.74145	32.65300	2.414356	0.172549
13.20654	157.5859	32.23111	31.36928	2.375282	0.199061
12.84873	128.2522	30.53151	28.90802	2.249872	0.225399
12.34043	95.71689	28.11706	27.11395	2.197163	0.283272
11.89459	74.05053	25.99931	23.36479	1.964320	0.315525
11.42794	56.60636	23.78271	21.83217	1.910420	0.385684
11.00839	44.46098	21.78988	19.45723	1.767490	0.437624
12.08046	82.41307	26.88220	27.05318	2.239415	0.328263
12.68153	116.4830	29.73727	27.64728	2.180121	0.237350
13.04175	143.3238	31.44832	30.24764	2.319292	0.211044
11.93059	75.60116	26.17032	24.46499	2.050610	0.323606
11.78717	69.61020	25.48906	19.48508	1.653075	0.279917
10.82705	40.05380	20.92851	21.54947	1.990335	0.538013
11.35689	54.33796	23.44524	16.74503	1.474438	0.308164
11.04654	45.44808	21.97107	15.64064	1.415885	0.344143
10.87632	41.20615	21.16256	14.48317	1.331623	0.351480
10.60090	35.16455	19.85427	12.90095	1.216967	0.366873
10.40650	31.44170	18.93089	11.75487	1.129570	0.373862
10.38369	31.03149	18.82253	11.85142	1.141350	0.381916
10.13069	26.82591	17.62081	9.353708	0.923303	0.348681
9.858394	22.93394	16.32737	7.320912	0.742606	0.319217
9.730461	21.30568	15.71969	6.100175	0.626915	0.286316
9.631074	20.12095	15.24760	5.446325	0.565495	0.270679
9.428900	17.91039	14.28727	3.806159	0.403669	0.212511
9.300307	16.63247	13.67645	3.517885	0.378254	0.211507
9.120025	14.99292	12.82012	2.694244	0.295420	0.179701
8.947064	13.57207	11.99855	2.087087	0.233270	0.153778
8.496366	10.47060	9.857742	0.994775	0.117082	0.095006
8.065057	8.168539	7.809023	0.480263	0.059548	0.058794
10.82668	40.04535	20.92676	14.53954	1.342935	0.363076
11.29736	52.50761	23.16250	16.82983	1.489712	0.320521
11.01719	44.68677	21.83168	15.53454	1.410027	0.347631

B5P11480

Tw dyne/cm2	B<U>/D (1/sec)	Log Tw	Log B<U>/D
2.237401	70.89933	0.349743	1.850642
2.004566	59.91509	0.302020	1.777536
1.588304	37.27145	0.200933	1.571376
1.379090	32.09906	0.139592	1.506492
1.123147	22.18538	0.050436	1.346067
0.920357	15.55716	-0.03604	1.191930
0.550272	5.733507	-0.25942	0.758420
0.337959	2.169238	-0.47113	0.336307

Log Tw vs. Log B<U>/D

Regression Output:

Constant	-0.66765
Std Err of Y Est	0.013784
R Squared	0.997953
No. of Observations	8
Degrees of Freedom	6

X Coefficient(s) 0.543329
Std Err of Coef. 0.010045

Tw = K'(B<U>/D)^n'

K' = 0.214954
n' = 0.543329

Regression Output:

Constant	-41.3077
Std Err of Y Est	0.442050
R Squared	0.994154
No. of Observations	8
Degrees of Freedom	6

X Coefficient(s) 21.28429
Std Err of Coef. 0.666289

t = 24.68636 deg C
s.d.)t = 0.402882 deg C

B1P21477 B1120 6/18/90 13:08

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14	
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=
Z =	2.7	Z =	8.85	Z =	7.4	[NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.9	1.9095	0.0325	0.0575	1.852
48	0.971328	24.9	1.328	0.0325	0.0575	1.2705
37	0.748732	24.9	0.926	0.0325	0.0575	0.8685
27	0.546372	24.9	0.56725	0.0325	0.0575	0.50975
19	0.384484	24.9	0.362	0.0325	0.0575	0.3045
12	0.242832	24.9	0.222333	0.0325	0.0575	0.164833
7	0.141652	24.9	0.164	0.0325	0.0575	0.1065
18	0.364248	24.9	3.3945	0.082	0.085	3.3095
25	0.5059	24.9	5.605	0.082	0.085	5.52
36	0.728496	24.9	9.705	0.082	0.085	9.62
15	0.30354	24.9	2.749	0.084	0.1105	2.6385
10	0.20236	24.9	1.653571	0.084	0.1105	1.543071
7	0.141652	24.9	1.2292	0.084	0.1105	1.1187
		24.7	1.289333	0.0305	0.0125	1.276833
		24.7	1.0235	0.0175	0.0125	1.011
		24.7	0.8324	0.0175	0.0145	0.8179
		24.65	0.624	0.0185	0.0095	0.6145
		24.6	4.1025	-0.0025	-0.0015	4.105
		24.6	3.608	-0.0105	-0.0135	3.6215
		24.6	2.6557	-0.0195	-0.0185	2.6742
		24.6	1.949	-0.021	-0.021	1.97
		24.55	1.917071	-0.0175	-0.0135	1.934571
		24.3	1.540562	-0.017	-0.0115	1.552062
		24.5	1.279375	-0.0115	-0.0105	1.289875
		24.5	0.959	-0.0135	-0.0055	0.9645
		24.5	0.851066	-0.0065	-0.0055	0.856566
		24.45	0.541652	-0.0075	-0.0065	0.548152
		24.4	5.3302	0.0045	-0.0195	5.3377
		24.5	6.252	-0.0275	-0.0355	6.2835
		24.6	7.8668	-0.0345	-0.0285	7.8983

		density	viscosity		
	co)[NaCl]	1.000088	1.001574	ID(cm) =	1.45796
100.0044	X coeff	-0.00025	-0.02281	K(V/psi)=	1.091023 12.37189
0.000099	constant	0.003419	-4.14933	XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.697489	727.2685	118106.5	239.4782	0.000908	3.551317
		1.164503	581.8148	94485.22	164.2856	0.000973	3.469484
		0.796041	448.4822	72832.35	112.3038	0.001119	3.386881
		0.467222	327.2708	53147.93	65.91469	0.001234	3.271175
		0.279095	230.3017	37400.40	39.37425	0.001488	3.159290
		0.151081	145.4537	23621.30	21.31424	0.002020	3.026019
		0.097614	84.84800	13779.09	13.77128	0.003836	2.931171
		0.267501	218.1805	35431.95	37.73855	0.001589	3.150076
		0.446172	303.0285	49211.05	62.94510	0.001374	3.261165
		0.777569	436.3611	70863.91	109.6978	0.001155	3.381783
		0.213265	181.8171	29526.63	30.08707	0.001825	3.100874
		0.124723	121.2114	19684.42	17.59579	0.002401	2.984388
		0.090422	84.84800	13779.09	12.75664	0.003553	2.914552
2176	15	0.103204	86.89334	14047.72	14.55985	0.003866	2.941292
1815	15	0.081717	72.47767	11717.19	11.52853	0.004401	2.890600
1406	15	0.066109	56.14524	9076.794	9.326594	0.005933	2.844575
1346	20	0.049669	40.31196	6509.739	7.007203	0.008646	2.781993
1342	20	0.052575	40.19216	6483.077	7.417183	0.009207	2.793848
1040	19.9	0.046382	31.30395	5049.390	6.543563	0.013090	2.766635
1184	34.8	0.034250	20.37939	3287.237	4.831919	0.023330	2.700788
977	45	0.025230	13.00471	2097.687	3.559525	0.042205	2.634424
947	50	0.024777	11.34485	1827.884	3.495510	0.054460	2.629991
875	60	0.019878	8.735257	1405.839	2.804368	0.073697	2.581661
611	59.9	0.016520	6.109888	983.3164	2.330630	0.125191	2.561480
350	60.1	0.012352	3.488289	561.4000	1.742721	0.287190	2.478357
261	59.9	0.010970	2.609952	420.0418	1.547700	0.455605	2.452587
174	99	0.007020	1.052768	169.2400	0.990437	1.791936	2.355164
1390	15	0.068362	55.50632	8912.974	9.644506	0.006276	2.848898
1685	15	0.080476	67.28643	10828.97	11.35343	0.005028	2.885307
2122	14.8	0.101158	85.88208	13852.95	14.27116	0.003880	2.935958

Tap DL= 122.2234
78.07879 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.80526	222.4320	35.07502	33.18613	2.403874	0.149196
13.47793	184.2316	33.52019	32.05381	2.378243	0.173986
13.14752	152.3216	31.95075	29.88427	2.272995	0.196191
12.68470	116.6958	29.75233	28.46498	2.244040	0.243924
12.23716	90.19250	27.62651	25.91706	2.117898	0.287352
11.70407	66.35892	25.09436	22.24767	1.900848	0.335262
11.32468	53.33982	23.29226	16.14541	1.425682	0.302689
12.20030	88.29923	27.45146	25.07946	2.055641	0.284028
12.64466	114.0368	29.56213	26.97102	2.132996	0.236511
13.12713	150.5439	31.85388	29.41994	2.241155	0.195424
12.00349	78.84139	26.51661	23.40667	1.949987	0.296883
11.53755	60.29325	24.30338	20.40487	1.768561	0.338427
11.25821	51.33724	22.97649	16.77521	1.490043	0.326765
11.36516	54.59746	23.48455	16.08102	1.414939	0.294537
11.16240	48.58261	22.52141	15.07380	1.350408	0.310271
10.97830	43.69738	21.64693	12.98246	1.182556	0.297099
10.72797	37.83325	20.45787	10.75399	1.002425	0.284247
10.77539	38.88017	20.68311	10.42156	0.967163	0.268043
10.66654	36.51874	20.16608	8.641777	0.810175	0.236639
10.40315	31.38112	18.91498	6.547003	0.629328	0.208628
10.13769	26.93424	17.65406	4.867612	0.480149	0.180722
10.11996	26.66069	17.56983	4.285064	0.423426	0.160725
9.926644	23.85289	16.65155	3.683618	0.371084	0.154430
9.765920	21.74504	15.88812	2.826266	0.289400	0.129972
9.513430	18.80345	14.68879	1.866014	0.196145	0.099237
9.410348	17.72013	14.19915	1.481513	0.157434	0.083606
9.020657	14.15938	12.34812	0.747031	0.082813	0.052758
10.99559	44.13451	21.72906	12.62188	1.147904	0.285986
11.14122	47.99403	22.42083	14.10198	1.265747	0.293827
11.34383	53.93099	23.38321	16.05402	1.415220	0.297677

B1P21477

Tw dyne/cm2	B<U>/D (1/sec)	Log Tw	Log B<U>/D
3.559525	71.35843	0.551392	1.853445
3.495510	62.25055	0.543510	1.794143
2.804368	47.93139	0.447835	1.680620
2.330630	33.52568	0.367473	1.525377
1.742721	19.14065	0.241228	1.281956
1.547700	14.32111	0.189687	1.155976
0.990437	5.776666	-0.00417	0.761677

Log Tw vs. Log B<U>/D

Regression Output:

Constant	-0.37927
Std Err of Y Est	0.005228
R Squared	0.999323
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.489946
Std Err of Coef.	0.007359

Tw = K'(B<U>/D)^n'

K' = 0.417569
n' = 0.489946

Regression Output:

Constant	-32.1506
Std Err of Y Est	0.347174
R Squared	0.989161
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	18.42598
Std Err of Coef.	1.113593

t = 24.71166 deg C
s.d.)t = 0.177333 deg C

B1P03197 B1120 7/23/90 15:00

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 9.05 Z = 7.05 [NaCl]=

Freq. (Hz)	θ)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.1	8.438	0.0315	0.0315	8.4065
49	0.991564	25.1	5.7725	0.0315	0.0315	5.741
43	0.870148	25.1	4.561	0.0315	0.0315	4.5295
36	0.728496	25.1	3.328666	0.0315	0.0315	3.297166
29	0.586844	25.1	2.280666	0.0315	0.0315	2.249166
24	0.485664	25.1	1.6635	0.0315	0.0315	1.632
18	0.364248	25.1	1.04225	0.0315	0.0315	1.01075
14	0.283304	25.1	0.67775	0.0315	0.0315	0.64625
10	0.20236	25.1	0.391	0.0315	0.0315	0.3595
32	0.647552	24.6	2.8225	0.0145	0.0455	2.777
16	0.323776	24.5	0.872	0.0465	0.0035	0.8255
18	0.364248	25	11.2955	0.0525	-0.076	11.3715
13	0.263068	25	5.942666	0.0525	-0.076	6.018666
10	0.20236	25	3.844111	0.0525	-0.076	3.920111
8	0.161888	25	2.604666	0.0525	-0.076	2.680666
		25	2.044666	0.0745	0.0675	1.977166
		24.9	1.4395	0.0645	0.0635	1.376
		24.9	1.073	0.0615	0.0605	1.0125
		24.9	0.6526	0.0595	0.0585	0.5941
		24.9	0.481142	0.0585	0.0585	0.422642
		24.9	3.021833	-0.0255	-0.027	3.048833
		24.9	1.752857	-0.0285	-0.0305	1.783357
		24.85	1.107142	-0.0305	-0.0315	1.138642
		24.8	0.692083	-0.0325	-0.0335	0.725583
		24.8	0.384571	-0.0345	-0.0355	0.420071
		24.8	0.276266	-0.0355	-0.0375	0.313766
		24.8	0.183285	-0.0375	-0.0375	0.220785
		24.8	0.097	-0.0375	-0.0375	0.1345
		24.7	0.025642	-0.0385	-0.0385	0.064142
		24.7	-0.00759	-0.0395	-0.041	0.031909
		24.7	4.0604	-0.0415	-0.0425	4.1019
		24.7	6.7314	-0.0435	-0.0435	6.7749
		24.65	8.897	-0.0445	-0.0415	8.9415
		24.6	12.5275	-0.0445	-0.0345	12.572

		density	viscosity			
	co)[NaCl]	1.01254	1.029478	ID(cm) =	1.45796	
1.000181	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08859	12.79437
0.299990	constant	0.003419	-4.14933	XS(cm2)=	1.669479	
					1.085095	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		7.722374	727.2685	116838.9	1089.456	0.004080	5.872969
		5.273794	593.9360	95418.46	744.0157	0.004178	5.790155
		4.160887	521.2091	83734.57	587.0091	0.004281	5.738687
		3.028841	436.3611	70103.36	427.3025	0.004446	5.669732
		2.066128	351.5131	56472.15	291.4850	0.004673	5.586672
		1.499187	290.9074	46735.57	211.5021	0.004951	5.517022
		0.928494	218.1805	35051.68	130.9900	0.005451	5.412983
		0.593657	169.6960	27262.41	83.75199	0.005762	5.315862
		0.330243	121.2114	19473.15	46.59008	0.006282	5.188511
		2.551006	387.8765	61615.14	359.8905	0.004738	5.627523
		0.758320	193.9382	30738.14	106.9822	0.005634	5.363109
		0.888789	218.1805	34972.69	125.3885	0.005218	5.402508
		0.470415	157.5748	25258.05	66.36518	0.005295	5.264349
		0.306393	121.2114	19429.27	43.22533	0.005828	5.171248
		0.209519	96.96914	15543.41	29.55852	0.006228	5.088720
1969	15	0.154534	78.62729	12603.36	21.80134	0.006986	5.022621
1609	15.1	0.107547	63.82605	10207.77	15.17254	0.007378	4.942923
1356	15	0.079136	54.14861	8660.053	11.16439	0.007543	4.876511
1346	20	0.046434	40.31196	6447.141	6.550878	0.007986	4.760544
1412	25.1	0.033033	33.69611	5389.061	4.660296	0.008131	4.686601
1400	25	0.037140	33.54338	5364.634	5.239689	0.009226	4.712047
1241	30	0.021724	24.77818	3962.804	3.064856	0.009889	4.595599
969	30	0.013870	19.34734	3090.756	1.956858	0.010356	4.497681
1080	39.9	0.008838	16.21325	2587.159	1.246978	0.009397	4.599338
1076	50	0.005117	12.89024	2056.906	0.721929	0.008607	4.280656
1026	60	0.003822	10.24271	1634.438	0.539235	0.010182	4.217298
740	60	0.002689	7.387531	1178.834	0.379439	0.013773	4.140980
575	75	0.001638	4.592249	732.7890	0.231150	0.021714	4.033256
330	90	0.000781	2.196293	349.6745	0.110235	0.045273	3.871584
181	99.9	0.000388	1.085255	172.7848	0.054838	0.092240	3.719967
1320	19.9	0.049968	39.73193	6325.770	7.049477	0.008846	4.774502
1323	15	0.082530	52.83083	8411.262	11.64326	0.008264	4.883461
2076	20	0.108923	62.17506	9897.808	15.36675	0.007874	4.943222
1930	15.1	0.153150	76.55953	12161.66	21.60609	0.007302	5.016726

Tap DL= 122.2234
82.0894 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.09187	466.4978	41.18642	15.65373	1.037228	0.033555
14.76062	385.5101	39.61296	15.46951	1.048025	0.040127
14.55474	342.4263	38.63505	15.28331	1.050057	0.044632
14.27892	292.1544	37.32491	14.99706	1.050293	0.051332
13.94669	241.2975	35.74678	14.62720	1.048794	0.060618
13.66808	205.5427	34.42342	14.21102	1.039723	0.069139
13.25193	161.7573	32.44669	13.54331	1.021987	0.083726
12.86344	129.3428	30.60138	13.17352	1.024105	0.101849
12.35404	96.46982	28.18171	12.61609	1.021211	0.130777
14.11009	265.0965	36.52295	14.52658	1.029517	0.054797
13.05243	144.2080	31.49907	13.32196	1.020649	0.092380
13.21003	157.9022	32.24766	13.84269	1.047892	0.087666
12.65739	114.8761	29.62264	13.74200	1.085689	0.119624
12.28499	92.71946	27.85372	13.09808	1.066185	0.141279
11.95488	76.66567	26.28569	12.67142	1.059937	0.165281
11.69048	65.84172	25.02980	11.96369	1.023369	0.181703
11.37169	54.80290	23.51554	11.64146	1.023723	0.212424
11.10524	47.01017	22.24992	11.51353	1.036765	0.244915
10.64217	36.01008	20.05033	11.18981	1.051459	0.310741
10.34640	30.37234	18.64542	11.08950	1.071821	0.365115
10.44818	32.20528	19.12889	10.41101	0.996442	0.323270
9.982397	24.63085	16.91638	10.05548	1.007322	0.408247
9.590725	19.65900	15.05594	9.826148	1.024546	0.499829
9.197354	15.67540	13.18743	10.31536	1.121557	0.658060
8.722626	11.92714	10.93247	10.77849	1.235693	0.903693
8.469193	10.30809	9.728670	9.909916	1.170113	0.961372
8.163922	8.646902	8.278630	8.520641	1.043694	0.985398
7.733424	6.748950	6.233767	6.786138	0.877507	1.005510
7.086336	4.650118	3.160096	4.699806	0.663220	1.010685
6.479868	3.279798	0.279374	3.292597	0.508127	1.003902
10.69800	37.18625	20.31554	10.63190	0.993820	0.285909
11.13384	47.79047	22.38576	11.00018	0.987994	0.230175
11.37288	54.84063	23.52122	11.26879	0.990847	0.205482
11.66690	64.95414	24.91781	11.70216	1.003022	0.180160

B1P03197

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.721929	70.73030	-0.14150	1.849605
0.539235	56.20298	-0.26822	1.749759
0.379439	40.53626	-0.42085	1.607843
0.231150	25.19821	-0.63610	1.401369
0.110235	12.05132	-0.95767	1.081034
0.054838	5.954925	-1.26091	0.774876

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-2.04384
Std Err of Y Est	0.004455
R Squared	0.999902
No. of Observations	4
Degrees of Freedom	2

X Coefficient(s) 1.007135
Std Err of Coef. 0.007039

Tw = K'(8<U>/D)^n'

K' = 0.009039
n' = 1.007135

Tw@ = 17.82578
Res/f@ = 963.4034

Regression Output:

Constant	-3.13742
Std Err of Y Est	0.101088
R Squared	0.990347
No. of Observations	10
Degrees of Freedom	8

X Coefficient(s) 4.917425
Std Err of Coef. 0.171643

t = 24.89117 deg C
s.d.)t = 0.173404 deg C

B2P03195 B1120 7/21/90 15:01

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
S =	2.7	S =	7.25	S =	9.9	<C> (ppm)=	
Z =	2.7	Z =	9	Z =	7.05	[NaCl]=	

Freq. (Hz)	Q)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.1	6.969	0.0135	0.0245	6.9445
49	0.991564	25.1	4.67525	0.0135	0.0245	4.65075
40	0.80944	25.1	3.160666	0.0135	0.0245	3.136166
33	0.667788	25.1	2.236	0.0135	0.0245	2.2115
25	0.5059	25.1	1.378666	0.0135	0.0245	1.365166
19	0.384484	25.1	0.87875	0.0135	0.0245	0.85425
15	0.30354	25.1	0.6004	0.0135	0.0245	0.5759
10	0.20236	25.1	0.3115	0.0135	0.0245	0.287
8	0.161888	25.1	0.236428	0.0135	0.0245	0.211928
30	0.60708	24.3	2.107333	0.0135	0.0125	2.093833
15	0.30354	24.2	0.656666	0.0105	0.0155	0.641166
20	0.40472	25.1	10.886	0.0125	0.005	10.8735
15	0.30354	25.1	6.864111	0.0125	0.005	6.851611
10	0.20236	25.1	3.5896	0.0125	0.005	3.5771
10	0.20236	25	3.538428	-0.0005	0.0015	3.536928
8	0.161888	25	2.50575	-0.0005	0.0015	2.50425
		24.8	2.0746	0.0745	0.0675	2.0001
		24.7	1.4474	0.0645	0.0635	1.3839
		24.6	1.10675	0.0615	0.0605	1.04625
		24.6	0.72	0.0595	0.0585	0.6615
		24.5	0.5296	0.0585	0.0585	0.4711
		24.5	0.3215	0.0575	0.0575	0.264
		24.7	1.703428	0.0235	0.0245	1.678928
		24.6	0.992333	0.0215	0.0195	0.972833
		24.5	0.537083	0.0185	0.0165	0.520583
		24.6	0.3655	0.0165	0.0145	0.351
		24.5	0.227866	0.014	0.014	0.213866
		24.5	0.1324	0.0135	0.0145	0.1179
		24.5	0.0705	0.0135	0.0145	0.057
		24.4	0.033235	0.0145	0.0145	0.018735
		24.4	2.3778	0.0135	0.008	2.3643
		24.5	3.6228	0.0075	0.0065	3.6153
		24.5	6.373833	0.0055	0.0055	6.368333
		24.5	9.258166	0.0145	0.0145	9.243666
		24.3	13.0615	0.0075	0.0105	13.054

		density	viscosity			
co)[NaCl]		1.01234	1.029478	ID(cm) =	1.45796	
2.017038	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08859	12.56
0.300079	constant	0.003419	-4.14933	XS(cm2)=	1.669479	
					1.085095	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
	0						
		6.379353	727.2685	116838.9	899.9856	0.003571	5.831482
		4.272269	593.9360	95418.46	602.7227	0.003585	5.744423
		2.880943	484.8457	77892.62	406.4374	0.003625	5.658861
		2.031527	399.9977	64261.41	286.6035	0.003549	5.583005
		1.254068	303.0285	48682.88	176.9213	0.003817	5.478254
		0.784730	230.3017	36998.99	110.7081	0.004135	5.376454
		0.529032	181.8171	29209.73	74.63484	0.004473	5.290835
		0.263643	121.2114	19473.15	37.19430	0.005015	5.139602
		0.194681	96.96914	15578.52	27.46528	0.005787	5.073756
		1.923436	363.6342	57374.57	271.3542	0.004065	5.563251
		0.588988	181.8171	28622.63	83.09320	0.004978	5.305280
		0.865724	242.4228	38946.31	122.1345	0.004117	5.397784
		0.545510	181.8171	29209.73	76.95945	0.004612	5.297495
		0.284800	121.2114	19473.15	40.17911	0.005418	5.156364
		0.281602	121.2114	19429.27	39.72789	0.005357	5.152927
		0.199382	96.96914	15543.41	28.12852	0.005926	5.077953
2046	15	0.159243	81.70210	13037.27	22.46575	0.006667	5.027169
1624	15	0.110183	64.85055	10324.93	15.54440	0.007322	4.946210
1370	15.1	0.083300	54.34536	8632.894	11.75180	0.007882	4.884491
1026	15.1	0.052667	40.69952	6465.218	7.430176	0.008886	4.784958
1119	20	0.037507	33.51343	5311.695	5.291543	0.009333	4.710244
1020	25	0.021019	24.43875	3873.407	2.965331	0.009835	4.584490
1198	29.9	0.020586	23.99962	3821.010	2.904236	0.009989	4.581939
1059	35	0.011928	18.12369	2878.993	1.682822	0.010149	4.462457
980	40	0.006383	14.67523	2325.943	0.900513	0.008283	4.325698
950	50	0.004303	11.38079	1807.866	0.607165	0.009286	4.241092
725	59.9	0.002622	7.249867	1149.064	0.369949	0.013943	4.132524
401	59.9	0.001445	4.009926	635.5512	0.203945	0.025125	4.003210
195	60.1	0.000698	1.943475	308.0301	0.098599	0.051712	3.845390
106	100	0.000229	0.634928	100.4058	0.032408	0.159249	3.602798
1216	25	0.028989	29.13482	4607.303	4.089802	0.009544	4.653319
1241	20	0.044328	37.16727	5890.807	6.253801	0.008968	4.746525
1720	20	0.078084	51.51306	8164.536	11.01604	0.008223	4.869466
1591	15.1	0.113340	63.11202	10002.90	15.98983	0.007952	4.950375
1970	15	0.160060	78.66723	12412.19	22.58100	0.007227	5.023354

Tap DL= 122.2234
81.55661 40.77743
4
0.4

Solvent 1/f	L 1/f	MDR 1/f	1/f	1/f/Slv	1/f/L
14.92593	423.9967	40.39816	17.22285	1.153888	0.040620
14.57769	346.9792	38.74404	17.18734	1.179016	0.049534
14.23544	284.9322	37.11837	17.08577	1.200227	0.059964
13.93202	239.2684	35.67710	16.78590	1.204843	0.070155
13.51301	187.9900	33.68684	16.18532	1.197757	0.086096
13.10581	148.7080	31.75263	15.55017	1.186509	0.104568
12.76334	122.0999	30.12587	14.95175	1.171460	0.122454
12.15841	86.19518	27.25245	14.11995	1.161332	0.163813
11.89502	74.06905	26.00137	13.14527	1.105106	0.177473
13.85300	228.6291	35.30177	15.68440	1.132201	0.068601
12.82112	126.2294	30.40033	14.17192	1.105357	0.112271
13.19113	156.1939	32.15789	15.58411	1.181408	0.099774
12.78998	123.9868	30.25241	14.72420	1.151229	0.118756
12.22545	89.58698	27.57093	13.58536	1.111235	0.151644
12.21170	88.88067	27.50561	13.66247	1.118800	0.153716
11.91181	74.78819	26.08110	12.98953	1.090474	0.173684
11.70867	66.53492	25.11622	12.24664	1.045945	0.184063
11.38484	55.21930	23.57800	11.68628	1.026477	0.211634
11.13796	47.96393	22.40533	11.26329	1.011252	0.235122
10.73975	38.09064	20.51382	10.60827	0.987758	0.278500
10.44097	32.07190	19.09465	10.35114	0.991396	0.322748
9.937960	24.00878	16.70531	10.08330	1.014625	0.419984
9.927759	23.86821	16.65685	10.00548	1.007829	0.419197
9.449831	18.12749	14.38669	9.926196	1.050409	0.547576
8.902794	13.23057	11.78827	10.98754	1.234167	0.830466
8.564368	10.88860	10.18075	10.37705	1.211654	0.953020
8.130099	8.480178	8.117974	8.468748	1.041653	0.998652
7.612841	6.296371	5.660996	6.308705	0.828692	1.001958
6.981563	4.377950	2.662426	4.397464	0.629868	1.004457
6.011193	2.504254	-1.94682	2.505882	0.416869	1.000649
10.21327	28.13193	18.01307	10.23593	1.002217	0.363854
10.58610	34.86628	19.78398	10.55964	0.997500	0.302861
11.07786	46.27499	22.11986	11.02719	0.995426	0.238297
11.40150	55.75137	23.65713	11.21374	0.983532	0.201138
11.69341	65.95304	25.04374	11.76233	1.005893	0.178344

B2P03195

Tw dyne/cm2	B<U>/D (1/sec)	Log Tw	Log B<U>/D
0.607165	62.44776	-0.21669	1.795516
0.369949	39.78088	-0.43185	1.599674
0.203945	22.00294	-0.69048	1.342480
0.032408	3.483927	-1.48933	0.542069
0.098599	10.66408	-1.00612	1.027923
0.032408	3.483927	-1.48933	0.542069

Log Tw vs. Log B<U>/D

Regression Output:

Constant	-2.03025
Std Err of Y Est	0.000996
R Squared	0.999995
No. of Observations	4
Degrees of Freedom	2

X Coefficient(s) 0.997452
Std Err of Coef. 0.001463

Tw = K'(B<U>/D)^n'

K' = 0.009327
n' = 0.997452

Tw& = 6.497072
Res/f& = 576.3994

Regression Output:

Constant	-10.6178
Std Err of Y Est	0.140911
R Squared	0.989342
No. of Observations	9
Degrees of Freedom	7

X Coefficient(s) 7.701142
Std Err of Coef. 0.302104

t = 24.74 deg C
s.d.)t = 0.302560 deg C

B5P03191 B1120 7/16/90 15:33

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 9 Z = 7.1 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.3	5.183666	0.03	0.0365	5.147166
49	0.991564	25.3	3.500333	0.03	0.0365	3.463833
41	0.829676	25.3	2.529333	0.03	0.0365	2.492833
34	0.688024	25.3	1.8205	0.03	0.0365	1.784
27	0.546372	25.3	1.236	0.03	0.0365	1.206
21	0.424956	25.3	0.834333	0.03	0.0365	0.797833
14	0.283304	25.3	0.469	0.03	0.0365	0.4325
10	0.20236	25.3	0.296625	0.03	0.0365	0.260125
25	0.5059	24.6	1.23	0.0285	0.0315	1.1985
19	0.384484	24.6	0.821	0.0285	0.0315	0.7895
15	0.30354	24.6	0.5532	0.0285	0.0315	0.5217
10	0.20236	24.6	0.311285	0.0285	0.0315	0.279785
25	0.5059	25.3	12.428	0.0735	0.0905	12.3375
20	0.40472	25.3	8.7568	0.0735	0.0905	8.6663
15	0.30354	25.3	5.5	0.0735	0.0905	5.4095
10	0.20236	25.3	3.130444	0.0735	0.0905	3.039944
8	0.161888	25.3	2.2705	0.0735	0.0905	2.18
		25.15	1.9586	0.0845	0.0795	1.8741
		25.1	1.37825	0.0735	0.0725	1.30575
		25.1	1.0578	0.0685	0.0685	0.9893
		25	0.6946	0.0655	0.0635	0.6311
		25	0.5278	0.0625	0.0615	0.4663
		24.9	3.0878	0.0635	0.055	3.0328
		24.9	1.763142	0.0505	0.05	1.713142
		24.9	1.038444	0.0465	0.046	0.992444
		24.8	0.563153	0.0435	0.0435	0.519653
		24.8	0.3475	0.0425	0.0415	0.306
		24.7	0.213846	0.0405	0.0385	0.175346
		24.65	0.105166	0.0375	0.0375	0.067666
		24.6	0.051933	0.0365	0.0365	0.015433
		24.6	1.445	0.036	0.0345	1.4105
		24.6	3.222	0.0325	0.033	3.189
		24.7	5.90225	0.0305	0.0295	5.87275
		24.7	7.72525	0.0295	0.0275	7.69775
		24.7	11.98866	0.029	0.0315	11.95716

		density	viscosity			
	co)[NaCl]	1.0123,	1.029478	ID(cm) =	1.45796	
5.068331	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08859	12.56699
0.300099	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		4.728287	727.2685	117367.3	667.0567	0.002498	3.768416
		3.181944	593.9360	95849.96	448.9020	0.002521	3.682410
		2.289965	496.9668	80200.99	323.0634	0.002591	3.610979
		1.638817	412.1188	66508.13	231.2008	0.002697	3.538329
		1.107855	327.2708	52815.28	156.2938	0.002891	3.453706
		0.732905	254.5440	41078.55	103.3967	0.003161	3.363588
		0.397302	169.6960	27385.70	56.05065	0.003856	3.230625
		0.238955	121.2114	19561.21	33.71139	0.004546	3.120223
		1.100965	303.0285	48136.83	155.3218	0.003350	3.445055
		0.725250	230.3017	36583.99	102.3167	0.003821	3.354412
		0.479243	181.8171	28882.09	67.61069	0.004051	3.264446
		0.257016	121.2114	19254.73	36.25935	0.004889	3.129148
		0.981738	303.0285	48903.04	138.5016	0.002988	3.427062
		0.689608	242.4228	39122.43	97.28846	0.003280	3.350365
		0.430453	181.8171	29341.82	60.72741	0.003639	3.248027
		0.241899	121.2114	19561.21	34.12662	0.004602	3.122881
		0.173470	96.96914	15648.97	24.47282	0.005156	3.050677
2100	14.9	0.149128	84.42127	13577.96	21.03877	0.005848	3.016367
1655	15	0.103903	66.08846	10617.40	14.65843	0.006649	2.937408
1375	14.8	0.078722	55.64932	8940.311	11.10594	0.007105	2.877142
1371	20	0.050218	41.06070	6581.719	7.084771	0.008325	2.778542
1127	19.9	0.037105	33.92264	5437.543	5.234715	0.009012	2.712826
1118	19.9	0.038299	33.65174	5381.964	5.403206	0.009452	2.718720
1219	30	0.021634	24.33892	3892.553	3.052118	0.010207	2.594695
1072	34.9	0.012533	18.59874	2942.534	1.768129	0.010348	2.476151
1100	45.1	0.006562	14.60948	2331.248	0.925810	0.008593	2.334670
1038	59.9	0.003864	10.37981	1656.314	0.545166	0.010024	2.219673
595	60	0.002214	5.939974	945.7107	0.312394	0.017540	2.097775
285	75	0.000854	2.276158	361.9814	0.120554	0.046096	1.890522
87	100.1	0.000194	0.520599	82.69857	0.027495	0.200978	1.569072
928	25	0.017812	22.23447	3532.000	2.512932	0.010069	2.549529
1172	20	0.040272	35.10075	5575.841	5.681490	0.009135	2.726669
1279	15	0.074163	51.07380	8131.522	10.46283	0.007946	2.860248
1591	15	0.097210	63.53277	10115.13	13.71423	0.006730	2.919009
2038	15.1	0.151000	80.84369	12871.22	21.30276	0.006457	3.014641

Tap DL= 122.2234
79.1865 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.67366	366.6878	39.19991	20.00463	1.363301	0.054554
14.32964	300.8090	37.56580	19.91503	1.389778	0.066204
14.04391	255.1873	36.20860	19.64267	1.398660	0.076973
13.75331	215.8787	34.82826	19.25506	1.400030	0.089193
13.41322	177.4949	33.21281	18.59745	1.386501	0.104777
13.05435	144.3671	31.50818	17.78388	1.362295	0.123185
12.52250	106.2932	28.98188	16.10269	1.285900	0.151493
12.08089	82.43345	26.88424	14.83106	1.227646	0.179915
13.38022	174.1546	33.05604	17.27517	1.291097	0.099194
13.01764	141.3488	31.33383	16.17629	1.242643	0.114442
12.65778	114.9017	29.62448	15.71022	1.241150	0.136727
12.11659	84.14509	27.05382	14.30173	1.180342	0.169965
13.30825	167.0869	32.71418	18.29251	1.374524	0.109478
13.00146	140.0379	31.25695	17.46063	1.342974	0.124685
12.59211	110.6388	29.31252	16.57523	1.316318	0.149813
12.09152	82.93957	26.93475	14.74056	1.219082	0.177726
11.80270	70.23558	25.56286	13.92543	1.179850	0.198267
11.66547	64.90042	24.91098	13.07576	1.120894	0.201474
11.34963	54.11137	23.41076	12.26336	1.080507	0.226631
11.10857	47.10018	22.26570	11.86342	1.067952	0.251876
10.71416	37.53379	20.39230	10.95965	1.022912	0.291994
10.45130	32.26309	19.14369	10.53359	1.007873	0.326490
10.47488	32.70394	19.25568	10.28538	0.981909	0.314499
9.978780	24.57961	16.89920	9.897820	0.991886	0.402684
9.504605	18.70817	14.64687	9.830376	1.034275	0.525458
8.938680	13.50672	11.95873	10.78744	1.206826	0.798671
8.478694	10.36462	9.773801	9.987784	1.177986	0.963641
7.991103	7.828092	7.457743	7.550615	0.944877	0.964553
7.162090	4.857386	3.519929	4.657615	0.650315	0.958872
5.876290	2.317141	-2.58762	2.230619	0.379596	0.962660
9.798116	22.15180	16.04105	9.965328	1.017065	0.449865
10.50667	33.30810	19.40672	10.46262	0.995806	0.314116
11.04099	45.30317	21.94472	11.21820	1.016050	0.247625
11.27603	51.86683	23.06118	12.18882	1.080949	0.235002
11.65856	64.64307	24.87819	12.44451	1.067413	0.192511

B5P03191

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
3.052118	133.5505	0.484601	2.125645
1.768129	100.9561	0.247513	2.004132
0.925810	80.16400	-0.03347	1.903979
0.545166	56.95525	-0.26347	1.755533
0.312394	32.59334	-0.50529	1.513128
0.120554	12.48955	-0.91881	1.096546
0.027495	2.856593	-1.56073	0.455848

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-2.0149
Std Err of Y Est	0.00[illegible]5
R Squared	0.9[illegible]995
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	0.997905
Std Err of Coef.	0.001465

Tw = K'(8<U>/D)^n'

K' = 0.009664
n' = 0.997905

Tw# = 7.451550
Res/f# = 641.2683

Regression Output:

Constant	-23.8737
Std Err of Y Est	0.194827
R Squared	0.993206
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	12.36246
Std Err of Coef.	0.340796

t = 24.97714 deg C
s.d.)t = 0.288182 deg C

B1P13187 B1120 7/9/90 14:07

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14
S =	2.7	S =	7.25	S =	9.9 <C>(ppm)=
Z =	2.7	Z =	8.95	Z =	7.2 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25	3.383	0.0345	0.039	3.344
51	1.032036	25	2.493	0.0345	0.039	2.454
43	0.870148	25	1.838	0.0345	0.039	1.799
34	0.688024	25	1.24025	0.0345	0.039	1.20125
27	0.546372	25	0.8735	0.0345	0.039	0.839
19	0.384484	25	0.53475	0.0345	0.039	0.49575
16	0.323776	25	0.4306	0.0345	0.039	0.3916
12	0.242832	25	0.244666	0.0345	0.039	0.210166
9	0.182124	25	0.214444	0.0345	0.039	0.175444
20	0.40472	24.2	0.615333	0.0375	0.0385	0.576833
15	0.30354	24.1	0.421666	0.0375	0.0385	0.383166
30	0.60708	25.1	11.547	0.0885	0.1055	11.4585
23	0.465428	25.1	7.6785	0.0885	0.1055	7.573
17	0.344012	25.1	5.08	0.0885	0.1055	4.9745
12	0.242832	25.1	3.2551	0.0885	0.1055	3.1496
8	0.161888	25.1	1.780714	0.0885	0.1055	1.675214
		25	1.5405	0.0385	0.031	1.5095
		24.9	1.087	0.0315	0.0225	1.0645
		24.8	0.87125	0.0235	0.0165	0.85475
		24.8	0.0886	0.0185	0.0125	0.0761
		24.75	0.5856	0.0145	0.0095	0.5761
		24.75	0.4542	0.0135	0.0085	0.4457
		24.6	2.8594	-0.029	-0.07	2.8884
		24.6	1.839833	0.0105	0.0055	1.829333
		24.6	1.20925	-0.002	-0.002	1.21125
		24.55	0.842666	-0.0055	-0.006	0.848666
		24.5	0.42225	-0.0085	-0.009	0.43125
		24.5	0.314	-0.0125	-0.0135	0.3275
		24.45	0.250285	-0.015	-0.0175	0.265285
		24.4	0.207857	-0.0175	-0.0175	0.225357
		24.4	0.116214	-0.019	-0.0195	0.135714
		24.3	0.049266	-0.0195	-0.0195	0.068766
		24.25	0.003956	-0.0205	-0.0215	0.024956
		24.3	3.67925	-0.0215	-0.004	3.70075
		24.3	5.379	-0.0185	0.0005	5.3975
		24.3	6.8586	-0.0155	-0.011	6.8741
		24.3	9.6336	-0.0195	-0.0195	9.6531

		density	viscosity		
	co)[NaCl]	1.01234	1.029478		s.d.)t = 0.310682 deg C
9.963670	X coeff	-0.00025	-0.02281		ID(cm) = 1.45796
0.300097	constant	0.003419	-4.14933		K(V/psi)=1.086516 12.44018
					XS(cm2)= 1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		3.077727	727.2685	116575.6	434.1992	0.001626	3.672224
		2.258595	618.1782	99089.29	318.6378	0.001651	3.605028
		1.655751	521.2091	83545.87	233.5898	0.001703	3.537606
		1.105598	412.1188	66059.53	155.9754	0.001819	3.449907
		0.772192	327.2708	52459.03	108.9393	0.002015	3.371971
		0.456274	230.3017	36915.62	64.37029	0.002404	3.257722
		0.360418	193.9382	31086.83	50.84701	0.002678	3.206512
		0.193431	145.4537	23315.12	27.28893	0.002555	3.071372
		0.161474	109.0902	17486.34	22.78045	0.003792	3.032160
		0.530901	242.4228	38163.51	74.89850	0.002524	3.282734
		0.352656	181.8171	28558.13	49.75199	0.002981	3.192918
		0.921087	363.6342	58419.46	129.9451	0.001947	3.411244
		0.608753	278.7862	44788.25	85.88161	0.002189	3.321314
		0.399873	206.0594	33104.36	56.41332	0.002632	3.230055
		0.253179	145.4537	23367.78	35.71804	0.003364	3.130808
		0.134661	96.96914	15578.52	18.99776	0.004002	2.993716
2115	15	0.121340	84.45745	13537.89	17.11848	0.004754	2.970112
1640	14.9	0.085569	65.92899	10544.10	12.07196	0.005502	2.893283
1381	15	0.068708	55.14692	8799.840	9.693293	0.006314	2.844644
825	35	0.006117	14.11902	2252.984	0.863012	0.008576	2.319417
1379	19.9	0.046309	41.50783	6615.972	6.533262	0.007512	2.758481
1151	20	0.035827	34.47182	5494.495	5.054461	0.008426	2.702753
1151	20	0.036475	34.47182	5475.933	5.145944	0.008578	2.705171
1061	25	0.023101	25.42109	4038.203	3.259122	0.009990	2.605989
1165	35	0.015296	19.93777	3167.165	2.157950	0.010754	2.516459
1126	40	0.010717	16.86154	2675.477	1.511976	0.010535	2.438718
1145	50.1	0.005446	13.68947	2169.705	0.768310	0.008121	2.291221
1066	60	0.004135	10.64203	1686.704	0.583470	0.010205	2.231463
887	60	0.003350	8.855055	1401.895	0.472630	0.011940	2.185221
759	60	0.002845	7.577211	1198.240	0.401494	0.013852	2.149307
457	60	0.001713	4.562300	721.4699	0.241787	0.023010	2.039185
234	60	0.000868	2.336057	368.5854	0.122514	0.044470	1.890576
140	100.2	0.000315	0.836910	131.8997	0.044462	0.125743	1.669986
1012	14.9	0.046734	40.68301	6419.005	6.593219	0.007890	2.756031
1345	14.9	0.068161	54.06981	8531.188	9.616132	0.006515	2.837983
1605	14.9	0.086808	64.52197	10180.34	12.24682	0.005827	2.890494
2057	14.9	0.121903	82.69265	13047.32	17.19786	0.004981	2.964220

Tap DL= 122.2234
79.1865 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.28889	293.8353	37.37225	24.79612	1.735341	0.084387
14.02011	251.7145	36.09553	24.60359	1.754878	0.097744
13.75042	215.5194	34.81452	24.22805	1.761985	0.112416
13.39963	176.1114	33.14824	23.44379	1.749584	0.133119
13.08788	147.1810	31.66746	22.27657	1.702075	0.151354
12.63088	113.1363	29.49672	20.39331	1.614559	0.180254
12.42604	100.5523	28.52373	19.32254	1.555002	0.192163
11.88549	73.66358	25.95608	19.78176	1.664362	0.268541
11.72864	67.30398	25.21105	16.23821	1.384492	0.241266
12.73093	119.8435	29.97195	19.90278	1.563340	0.166073
12.37167	97.45363	28.26544	18.31520	1.480415	0.187937
13.24497	161.1108	32.41365	22.66276	1.711045	0.140665
12.88525	130.9769	30.70498	21.37220	1.658655	0.163175
12.52022	106.1538	28.97105	19.49080	1.556745	0.183609
12.12323	84.46729	27.08536	17.29055	1.426233	0.204701
11.57486	61.60217	24.48060	15.80557	1.365508	0.256574
11.48044	58.34346	24.03213	14.50236	1.263222	0.248568
11.17313	48.88361	22.57238	13.48113	1.206566	0.275780
10.97857	43.70436	21.64825	12.58432	1.146261	0.287942
8.877670	13.04060	11.66893	10.79793	1.216302	0.828024
10.63392	35.82947	20.01115	11.53750	1.084971	0.321921
10.41101	31.52346	18.95232	10.89365	1.046358	0.345572
10.42068	31.69942	18.99825	10.79659	1.036073	0.340592
10.02395	25.22720	17.11379	10.00458	0.998067	0.396579
9.665838	20.52766	15.41273	9.642977	0.997634	0.469755
9.354874	17.16321	13.93565	9.742776	1.041465	0.567654
8.764887	12.22086	11.13321	11.09631	1.265996	0.907981
8.525852	10.64984	9.997798	9.898648	1.161015	0.929464
8.340887	9.574184	9.119213	9.151531	1.097189	0.955854
8.197231	8.814302	8.436850	8.496418	1.036498	0.963935
7.756740	6.840140	6.344515	6.592243	0.849872	0.963758
7.162304	4.857983	3.520944	4.742005	0.662078	0.976126
6.279945	2.923253	-0.67025	2.820054	0.449057	0.964697
10.62412	35.63788	19.96460	11.25734	1.059601	0.315881
10.95193	43.03912	21.52168	12.38871	1.131189	0.287847
11.16197	48.57077	22.51940	13.09988	1.173616	0.269707
11.45688	57.55730	23.92018	14.16775	1.236615	0.246150

B1P13187

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.768310	75.11575	-0.11446	1.875731
0.583470	58.39413	-0.23398	1.766369
0.472630	48.58874	-0.32547	1.686535
0.401494	41.57706	-0.39632	1.618853
0.241787	25.03388	-0.61656	1.398528
0.122514	12.81822	-0.91181	1.107827
0.044462	4.592229	-1.35200	0.662023

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-2.01768
Std Err of Y Est	0.003089
R Squared	0.999959
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 1.001928
Std Err of Coef. 0.003680

Tw = K'(8<U>/D)^n'

K' = 0.009600
n' = 1.001928

Tw# = 5.111821
Res/f# = 510.1141

Regression Output:

Constant	-36.1219
Std Err of Y Est	0.399325
R Squared	0.992176
No. of Observations	23
Degrees of Freedom	21

X Coefficient(s) 17.19286
Std Err of Coef. 0.333158

t = 24.70675 deg C
s.d.)t = 0.318391 deg C

Page 1 Betz 1120

B2P13184 B1120 7/4/90 15:17

	10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14	
	S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=
	Z =	2.7	Z =	8.9	Z =	7.2	[NaCl]=

	Freq. (Hz)	Q)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
	20	0.40472	25.2	0.483333	0.0375	0.0395	0.443833
	29	0.586844	25.2	0.761	0.0375	0.0395	0.7215
	38	0.768968	25.2	1.160666	0.0375	0.0395	1.121166
	46	0.930856	25.2	1.52925	0.0375	0.0395	1.48975
	56	1.133216	25.2	2.171	0.0375	0.0395	2.1335
	60	1.21416	25.2	2.475	0.0375	0.0395	2.4355
	15	0.30354	25.2	0.357333	0.0375	0.0395	0.317833
	10	0.20236	25.2	0.208888	0.0375	0.0395	0.169388
Triggered	20	0.40472	24	0.5246	0.033	0.0355	0.4891
	20	0.40472	24	0.496333	0.033	0.0355	0.460833
	10	0.20236	24	0.216	0.0475	0.035	0.181
	20	0.40472	25.1	4.980333	0.0245	0.0325	4.955833
	16	0.323776	25.1	3.5955	0.0245	0.0325	3.563
	11	0.222596	25.1	2.356625	0.0245	0.0325	2.324125
	8	0.161888	25.1	1.544714	0.0245	0.0325	1.512214
			24.8	1.374	0.0285	0.0295	1.3455
			24.7	1.0286	0.0315	0.0285	1.0001
			24.6	0.7552	0.0315	0.0195	0.7357
			24.6	0.55325	0.0225	0.0205	0.53275
			24.5	0.456	0.0235	0.0195	0.4365
			24.4	2.805	0.0905	0.1325	2.7145
			24.3	1.7516	0.0145	0.0145	1.7371
			24.3	1.213833	0.0125	0.0075	1.206333
			24.3	0.833571	0.003	0.0005	0.833071
			24.3	0.448666	-0.0025	-0.003	0.451666
			24.2	0.322062	-0.0095	-0.012	0.334062
			24.2	0.217076	-0.0145	-0.0145	0.231576
			24.1	0.120333	-0.0175	-0.0175	0.137833
			24.05	0.063222	-0.0195	-0.02	0.083222
			24	-0.00104	-0.0215	-0.0235	0.022452
			23.8	0.025	-0.0255	-0.0275	0.0505
			23.9	3.4065	-0.0295	-0.015	3.436
			24	4.90975	-0.0155	0.003	4.92525
			24.1	6.205	0.001	0.0165	6.204
			24.1	8.8412	0.0135	0.0215	8.8277
		Triggered	24.1	8.4165	0.0175	0.0255	8.399

Page 2 Betz 1120

		density	viscosity		
	co)[NaCl]	1.01234	1.029478	ID(cm) =	1.45796
20.01199	X coeff	-0.00025	-0.02281	K(V/psi)=	1.086516 12.44018
0.300113	constant	0.003419	-4.14933	XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		0.408492	242.4228	39034.27	57.62921	0.001942	3.235671
		0.664049	351.5131	56599.69	93.68264	0.001502	3.341179
		1.031891	460.6034	74165.12	145.5770	0.001359	3.436896
		1.371125	557.5725	89778.82	193.4355	0.001232	3.498618
		1.963615	678.7840	109295.9	277.0227	0.001191	3.576607
		2.241568	727.2685	117102.8	316.2357	0.001184	3.605355
		0.292525	181.8171	29275.70	41.26883	0.002473	3.168161
		0.155900	121.2114	19517.13	21.99417	0.002966	3.026507
		0.450154	242.4228	37991.71	63.50683	0.002140	3.244937
		0.424178	242.4228	37991.71	59.83656	0.002016	3.292010
		0.166587	121.2114	18995.85	23.50181	0.003168	3.029078
		0.398373	242.4228	38946.31	56.20163	0.001894	3.229239
		0.286410	193.9382	31157.04	40.40620	0.002126	3.157588
		0.186824	133.3325	21420.47	26.35674	0.002937	3.064810
		0.121558	96.96914	15578.52	17.14926	0.003613	2.971487
2116	15	0.108157	84.49739	13483.31	15.25864	0.004233	2.943167
1640	15	0.080392	65.48947	10426.65	11.34163	0.005238	2.877761
1372	14.9	0.059139	55.15523	8761.544	8.343206	0.005433	2.810105
1043	15	0.042824	41.64970	6616.158	6.041652	0.006899	2.740016
880	15.1	0.035087	34.90797	5532.721	4.950128	0.008047	2.695761
879	15.1	0.034279	34.86830	5513.980	4.836126	0.007879	2.689717
855	19.9	0.021936	25.73546	4060.565	3.094800	0.009256	2.591799
842	25	0.015234	20.17395	3183.065	2.149191	0.010460	2.512620
855	30	0.010520	17.07118	2693.508	1.484191	0.010088	2.432228
1036	45	0.005703	13.79005	2175.808	0.804484	0.008382	2.299296
1080	60	0.004218	10.78180	1697.329	0.595162	0.010141	2.222815
765	59.9	0.002924	7.649860	1204.282	0.412575	0.013965	2.153249
466	60	0.001740	4.652148	730.7160	0.245562	0.022474	2.029593
346	75	0.001050	2.763336	433.5497	0.148267	0.038460	1.929543
111	90	0.000283	0.738753	115.7749	0.040000	0.145176	1.644562
497	180	0.000637	1.653875	258.0230	0.089970	0.065147	1.818606
1030	15.1	0.043391	40.85819	6388.732	6.121543	0.007263	2.735972
1356	15	0.062198	54.14861	8485.992	8.774776	0.005927	2.815145
1615	15	0.078346	64.49115	10129.66	11.05298	0.005263	2.866252
2071	15	0.111479	82.70042	12989.81	15.72734	0.004554	2.942840
1991	15	0.106066	79.50581	12488.03	14.96557	0.004688	2.932030

Tap DL= 122.2234
79.1865 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
12.54268	107.5353	29.07775	22.68688	1.808773	0.210971
12.96471	137.1069	31.08241	25.80088	1.990084	0.188180
13.34758	170.9135	32.90103	27.12084	2.031891	0.158681
13.59447	197.0144	34.07374	28.48104	2.095045	0.144563
13.90643	235.7695	35.55554	28.97320	2.083439	0.122887
14.02142	251.9042	36.10175	29.05440	2.072143	0.115339
12.25264	90.99993	27.70006	20.10695	1.641029	0.220955
11.70601	66.43299	25.10357	18.36167	1.568567	0.276393
12.57975	109.8544	29.25381	21.61479	1.718221	0.196758
12.52804	106.6328	29.00820	22.26783	1.777439	0.208827
11.71631	66.82797	25.15248	17.76563	1.516315	0.265841
12.51695	105.9544	28.95554	22.97349	1.835390	0.216824
12.23035	89.83980	27.59418	21.67542	1.772264	0.241267
11.85924	72.55888	25.83140	18.45093	1.555827	0.254289
11.48595	58.52852	24.05826	16.63561	1.448344	0.284230
11.37266	54.83364	23.52017	15.36843	1.351348	0.280273
11.11104	47.16738	22.27747	13.81603	1.243450	0.292914
10.84042	40.36317	20.99199	13.56673	1.251495	0.336116
10.56006	34.34761	19.66031	12.03896	1.140046	0.350503
10.38304	31.02000	18.81947	11.14748	1.073623	0.359364
10.35886	30.59124	18.70462	11.26543	1.087516	0.368256
9.967197	24.41627	16.84418	10.39410	1.042831	0.425703
9.650482	20.34701	15.33979	9.777433	1.013154	0.480534
9.328912	16.90862	13.81233	9.956122	1.067232	0.588819
8.797184	12.45019	11.28662	10.92256	1.241598	0.877300
8.531262	10.68306	10.02349	9.930029	1.163957	0.929511
8.212997	8.894663	8.511740	8.462114	1.030331	0.951369
7.758375	6.846581	6.352281	6.670445	0.859773	0.974273
7.318174	5.314026	4.261330	5.099119	0.696774	0.959558
6.178250	2.757037	-1.15330	2.624532	0.424801	0.951939
6.874427	4.116108	2.153528	3.917886	0.569921	0.951842
10.54389	34.02928	19.58348	11.73388	1.112861	0.344817
10.86058	40.83434	21.08776	12.98844	1.195924	0.318076
11.06501	45.93382	22.05879	13.78296	1.245635	0.300061
11.37136	54.79241	23.51396	14.81707	1.303016	0.270421
11.32812	53.44541	23.30857	14.60372	1.289156	0.273245

B2P13184

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.484191	93.67164	0.171490	1.971608
0.804684	75.66769	-0.09437	1.878910
0.595162	59.16103	-0.22536	1.772035
0.412575	41.97569	-0.38449	1.622997
0.245562	25.52689	-0.60983	1.406997
0.148267	15.16275	-0.82895	1.180778
0.089970	9.075011	-1.04590	0.957847
0.040000	4.053626	-1.39792	0.607843

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-2.00914
Std Err of Y Est	0.007164
R Squared	0.999782
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	1.001839
Std Err of Coef.	0.007396

Tw = K'(8<U>/D)^n'

K' = 0.009791
n' = 1.001839

Tw# = 4.490478
Res/f# = 480.2819

Regression Output:

Constant	-48.8089
Std Err of Y Est	0.640957
R Squared	0.982633
No. of Observations	17
Degrees of Freedom	15
X Coefficient(s)	22.05294
Std Err of Coef.	0.756964

t = 24.5375 deg C
s.d.)t = 0.493059 deg C

B5P131B1 B1120 6/28/90 15:40

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14
S =	2.7	S =	7.25	S =	9.9 <C>(pp
Z =	2.7	Z =	8.9	Z =	7.4 [NaCl]

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>co (volts
60	1.21416	24.9	1.883333	0.0385	0.0395	1.8438
52	1.052272	24.9	1.47925	0.0385	0.0395	1.439
43	0.870148	24.9	1.0945	0.0385	0.0395	1.0
36	0.728496	24.9	0.852	0.0385	0.0395	0.81
29	0.586844	24.9	0.6075	0.0385	0.0395	0.5
21	0.424956	24.9	0.384	0.0385	0.0395	0.34
15	0.30354	24.9	0.2446	0.0385	0.0395	0.20
11	0.222596	24.9	0.169	0.0385	0.0395	0.12
7	0.141652	24.9	0.100666	0.0385	0.0395	0.0621
15	0.30354	23.7	0.2406	0.0375	0.0395	0.20
30	0.60708	24.8	6.813	0.0115	0.0105	6.80
25	0.5059	24.8	5.3315	0.0115	0.0105	5.3
20	0.40472	24.8	3.903	0.0115	0.0105	3.89
15	0.30354	24.7	2.3685	0.0115	0.0155	2.3
12	0.242832	24.7	1.947666	0.0115	0.0155	1.9321
8	0.161888	24.7	1.169166	0.0115	0.0155	1.1536
		24.8	0.9138	0.0185	-0.0075	0.89
		24.8	0.604	-0.0045	-0.0075	0.61
		24.8	0.4942	-0.0065	-0.0075	0.50
		24.8	0.349166	-0.0065	-0.0065	0.3556
		24.8	0.263166	-0.0065	-0.0065	0.2696
		24.2	1.644666	-0.0465	-0.15	1.6911
		24.2	1.26	-0.039	-0.1265	1.29
		24.1	0.99	-0.0105	-0.0145	1.00
		24.1	0.437285	-0.0165	-0.0195	0.4567
		24.05	0.325875	-0.0225	-0.0245	0.3503
		24	0.229111	-0.0275	-0.028	0.25711
		23.9	0.15725	-0.0315	-0.033	0.190
		23.9	0.1076	-0.0345	-0.035	0.142
		23.8	0.061785	-0.036	-0.036	0.0977
		23.8	0.006	-0.0365	-0.037	0.04
		23.8	3.2236	-0.039	-0.048	3.271
		23.8	3.6932	-0.0495	-0.0515	3.742

		density	viscosity		
	co)[NaCl]	1.01234	1.029478	ID(cm) =	1.45796
49.91302	X coeff	-0.00025	-0.02281	K(V/psi)=	1.085095 12.37189
0.300037	constant	0.003419	-4.14933	XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.699236	727.2685	116312.9	239.7247	0.000897	3.542250
		1.326842	630.2994	100804.5	187.1881	0.000933	3.488533
		0.972265	521.2091	83357.61	137.1650	0.001000	3.421016
		0.748782	436.3611	69787.76	105.6366	0.001099	3.364301
		0.524378	351.5131	56217.92	73.97814	0.001186	3.286946
		0.317483	254.5440	40709.53	44.78992	0.001369	3.177984
		0.189015	181.8171	29078.23	26.66593	0.001598	3.065372
		0.119344	133.3325	21324.03	16.83685	0.001876	2.965524
		0.057291	84.84800	13569.84	8.082556	0.002224	2.806168
		0.187172	181.8171	28301.59	26.40590	0.001582	3.051422
		0.549754	363.6342	58025.41	77.55817	0.001162	3.296222
		0.430087	303.0285	48354.51	60.67588	0.001309	3.242917
		0.314624	242.4228	38683.61	44.38656	0.001496	3.175034
		0.190189	181.8171	28947.33	26.83149	0.001607	3.064746
		0.156173	145.4537	23157.86	22.03268	0.002063	3.021957
		0.093249	96.96914	15438.57	13.15537	0.002771	2.909975
2022	15	0.072365	80.74372	12884.34	10.20919	0.003102	2.855904
1575	15.1	0.049426	62.47733	9969.559	6.972994	0.003539	2.773118
1296	15.1	0.040551	51.40992	8203.523	5.720934	0.004288	2.730142
1245	20	0.028747	37.28706	5949.928	4.055701	0.005779	2.655442
1222	25	0.021796	29.27858	4672.007	3.075035	0.007106	2.595334
1215	24.8	0.021659	29.34563	4619.748	3.055710	0.007028	2.588054
1235	30.1	0.016637	24.57646	3868.959	2.347118	0.007697	2.520765
1130	34.9	0.012865	19.39420	3046.260	1.814996	0.009558	2.473950
915	40.1	0.005850	13.66770	2146.795	0.825350	0.008751	2.302831
790	45	0.004487	10.51558	1649.828	0.633080	0.011340	2.244749
620	50	0.003292	7.427464	1164.007	0.464565	0.016679	2.177050
555	60	0.002436	5.540648	866.3555	0.343756	0.022179	2.110667
436	60	0.001826	4.352653	680.5964	0.257659	0.026937	2.048065
291	60.1	0.001252	2.900263	452.4735	0.176685	0.041603	1.965157
194	90	0.000550	1.291154	201.4345	0.077695	0.092308	1.786754
1310	15	0.041901	52.31171	8161.213	5.911341	0.004278	2.727400
1495	15	0.047934	59.69924	9313.750	6.762555	0.003758	2.756612

Tap DL= 122.2234
78.07879 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.76900	217.8365	34.90276	33.37162	2.423677	0.153195
13.55413	192.4923	33.88213	32.73005	2.414765	0.170032
13.28406	164.7768	32.59930	31.61761	2.380116	0.191881
13.05720	144.6044	31.52173	30.16321	2.310082	0.208591
12.74778	121.0113	30.05197	29.03546	2.277686	0.239940
12.31193	94.15958	27.98170	27.02163	2.194750	0.286976
11.86149	72.65286	25.84208	25.01470	2.108900	0.344304
11.46209	57.73043	23.94497	23.08578	2.014097	0.399889
10.82467	39.99896	20.91720	21.20343	1.958805	0.530099
11.80569	70.35622	25.57702	25.14133	2.129594	0.357343
12.78489	123.6240	30.22823	29.33562	2.294554	0.237297
12.57166	109.3445	29.21542	27.63884	2.198502	0.252768
12.30013	93.52224	27.92566	25.85188	2.101755	0.276424
11.85898	72.54815	25.83018	24.93803	2.102880	0.343744
11.68783	65.74121	25.01719	22.01612	1.883679	0.334890
11.23990	50.79904	22.88953	18.99466	1.689931	0.373917
11.02361	44.85231	21.86219	17.95384	1.628670	0.400287
10.69247	37.06797	20.28925	16.80959	1.572095	0.453480
10.52057	33.57551	19.47271	15.27065	1.451504	0.454815
10.22176	28.26976	18.05340	13.15435	1.286896	0.465315
9.981336	24.61581	16.91135	11.86231	1.188449	0.481897
9.952216	24.20661	16.77302	11.92790	1.198517	0.492753
9.723061	21.21511	15.68454	11.39800	1.172264	0.537258
9.495802	18.61361	14.60506	10.22860	1.077171	0.549522
8.811327	12.55197	11.35380	10.68953	1.213158	0.851621
8.578998	10.98069	10.25024	9.390506	1.094592	0.855183
8.308203	9.395738	8.963967	7.742923	0.931961	0.824088
8.042670	8.063946	7.702684	6.714729	0.834888	0.832685
7.792260	6.981441	6.513236	6.092908	0.781917	0.872729
7.460631	5.768166	4.937998	4.902700	0.657142	0.849958
6.747017	3.825025	1.548332	3.291391	0.487829	0.860488
10.50960	33.36416	19.42060	15.28813	1.454682	0.458220
10.62645	35.68556	19.97563	16.31217	1.535054	0.457108

B5P13181

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.825350	74.99632	-0.08336	1.87504
0.633080	57.70027	-0.19854	1.761177
0.464565	40.75538	-0.33295	1.610184
0.343756	30.40219	-0.46374	1.482905
0.257659	23.88353	-0.58895	1.378098
0.176685	15.91408	-0.75279	1.201781
0.077695	7.084716	-1.10960	0.850322

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.96156
Std Err of Y Est	0.008931
R Squared	0.999458
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	1.004084
Std Err of Coef.	0.010449

Tw = K'(8<U>/D)^n'

K' = 0.010925
n' = 1.004084

Res/f# = 288.7293
Tw# = 1.652584

Regression Output:

Constant	-44.2435
Std Err of Y Est	0.441555
R Squared	0.988503
No. of Observations	10
Degrees of Freedom	8
X Coefficient(s)	21.81904
Std Err of Coef.	0.831931

t = 24.48333 deg C
s.d.)t = 0.445289 deg C

B1P23178 B1120 6/18/90 14:47
B1120 10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14
S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=
Z = 2.7 Z = 8.85 Z = 7.4 [NaCl]=

Freq. (Hz)	Θest (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	25.1	1.828666	0.0345	0.0385	1.790166
49	0.991564	25.1	1.374	0.0345	0.0385	1.3355
42	0.849912	25.1	1.06775	0.0345	0.0385	1.02925
32	0.647552	25.1	0.7425	0.0345	0.0385	0.704
24	0.485664	25.1	0.48975	0.0345	0.0385	0.45525
18	0.364248	25.1	0.3265	0.0345	0.0385	0.288
14	0.283304	25.1	0.232	0.0345	0.0385	0.1935
10	0.20236	25.1	0.161	0.0345	0.0385	0.1225
8	0.161888	25.1	0.1325	0.0345	0.0385	0.098
60	1.21416	24.3	1.842666	0.032	0.0315	1.810666
36	0.728496	25.1	9.51175	0.0095	0.019	9.50225
28	0.566608	25.1	6.230166	0.0095	0.019	6.211166
21	0.424956	25.1	4.11725	0.0095	0.019	4.09825
15	0.30354	25.1	2.451142	0.0095	0.019	2.432142
11	0.222596	25.1	1.76225	0.0095	0.019	1.74325
8	0.161888	25.1	1.0725	0.0095	0.019	1.0535
		25.1	0.8515	0.0135	0.0055	0.838
		25	0.608888	0.0085	0.0055	0.603388
		24.9	0.4782	0.0055	-0.0035	0.4817
		24.9	0.3762	-0.0015	-0.0015	0.3777
		24.9	2.319	0.0295	-0.0225	2.2895
		24.8	1.8342	-0.023	-0.0255	1.8572
		24.8	1.219444	-0.0275	-0.026	1.245444
		24.8	0.6704	-0.0275	-0.0275	0.6979
		24.7	0.553181	-0.029	-0.029	0.582181
		24.7	0.429928	-0.03	-0.0305	0.460428
		24.7	0.30665	-0.033	-0.0325	0.33965
		24.6	0.230666	-0.034	-0.034	0.264666
		24.6	0.165428	-0.0335	-0.033	0.198428
		24.5	0.085333	-0.033	-0.0335	0.118833
		24.5	0.019333	-0.033	-0.0335	0.052833
		24.5	-0.02326	-0.0355	-0.0445	0.012230
		24.5	3.0602	-0.045	-0.0385	3.0987
		24.5	5.2962	-0.033	-0.033	5.3292

		density	viscosity		
	co)[NaCl]	1.01234	1.029478	ID(cm) =	1.45796
100.0044	X coeff	-0.00025	-0.02281	K(V/psi)=	1.091023 12.37189
0.300112	constant	0.003419	-4.14933	XS(cm2)-	1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.640814	727.2685	116838.9	231.4826	0.000867	3.536623
		1.224080	593.9360	95418.46	172.6906	0.000969	3.472999
		0.943380	509.0880	81787.25	133.0901	0.001017	3.416437
		0.645265	387.8765	62314.09	91.03275	0.001198	3.333963
		0.417268	290.9074	46735.57	58.86741	0.001378	3.259302
		0.263972	218.1805	35051.68	37.24067	0.001549	3.189873
		0.177356	169.6960	27262.41	25.02107	0.001721	3.053517
		0.112279	121.2114	19473.15	15.84021	0.002126	2.954245
		0.089823	96.96914	15578.52	12.67217	0.002670	2.905790
		1.659604	727.2685	114749.1	234.1334	0.000876	3.531214
		0.768051	436.3611	70103.36	108.3550	0.001127	3.371789
		0.502038	339.3920	54524.83	70.82654	0.001218	3.279462
		0.331254	254.5440	40893.62	46.73274	0.001429	3.189175
		0.196586	181.8171	29209.73	27.73396	0.001662	3.075870
		0.140904	133.3325	21420.47	19.87845	0.002215	3.003556
		0.085152	96.96914	15578.52	12.01316	0.002531	2.894193
2639	19.9	0.067734	79.43377	12761.39	9.555796	0.003000	2.844498
3075	29.9	0.048770	61.60171	9874.288	6.880502	0.003592	2.772189
1314	15	0.038935	52.47144	8391.821	5.492872	0.003952	2.722294
1327	19.9	0.030528	39.94263	6388.074	4.306950	0.005348	2.669479
1662	25	0.029322	39.82079	6368.587	4.136818	0.005168	2.660727
1360	25.1	0.023786	32.45518	5178.900	3.355710	0.006311	2.614701
1175	30	0.015951	23.46040	3743.596	2.250350	0.008100	2.527534
1054	35	0.008938	18.03812	2878.358	1.261011	0.007677	2.401768
1151	45	0.007456	15.32080	2439.244	1.051924	0.008878	2.361416
1264	60	0.005896	12.61870	2009.039	0.831932	0.010350	2.310468
1140	74.9	0.004350	9.116789	1451.495	0.613701	0.014627	2.244402
674	60.1	0.003389	6.717448	1067.083	0.478217	0.020994	2.189251
493	59.9	0.002541	4.929910	783.1283	0.358533	0.029224	2.126703
450	90	0.001521	2.994945	474.6823	0.214715	0.047420	2.014385
200	90	0.000676	1.331086	210.9699	0.095462	0.106733	1.838370
50	120	0.000156	0.249578	39.55686	0.022099	0.702818	1.520643
1301	15	0.039686	51.95231	8234.156	5.598934	0.004109	2.722506
1960	15.3	0.068254	76.73324	12161.79	9.629148	0.003239	2.840247

Tap DL= 122.2234
78.07879 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.74669	215.0324	34.79585	33.95968	2.470424	0.157928
13.49199	185.7287	33.58698	32.10947	2.379890	0.172883
13.26575	163.0488	32.51231	31.35075	2.363285	0.192278
12.93385	134.8477	30.94530	28.88169	2.232685	0.214180
12.55720	108.4381	29.14674	26.93676	2.145123	0.248406
12.15949	86.24888	27.25759	25.40009	2.088910	0.294497
11.81407	70.69647	25.61683	24.10164	2.040079	0.340917
11.41698	56.25036	23.73066	21.63670	1.895133	0.384650
11.22316	50.31185	22.81001	19.35245	1.724331	0.384650
13.72485	212.3708	34.69308	33.77026	2.460518	0.159015
13.08715	147.1192	31.66399	29.78169	2.275642	0.202432
12.71785	118.9440	29.90979	28.65046	2.252775	0.240873
12.35670	96.61741	28.19433	26.45332	2.140807	0.273794
11.90348	74.43046	26.04154	24.52770	2.060548	0.329538
11.61422	63.01385	24.66756	21.24579	1.829291	0.337160
11.17677	48.98616	22.58967	19.87617	1.778346	0.405750
10.97799	43.68961	21.64546	18.25575	1.662961	0.417851
10.68875	36.98874	20.27160	16.68461	1.560949	0.451072
10.48917	32.97418	19.32358	15.90604	1.516424	0.482378
10.27791	29.19841	18.32010	13.67384	1.330410	0.468307
10.24291	28.61591	18.15382	13.90962	1.357976	0.486080
10.05720	25.71469	17.27172	12.58740	1.251580	0.489502
9.710137	21.05786	15.62315	11.11104	1.144272	0.527643
9.207074	15.76335	13.23360	11.41238	1.239523	0.723981
9.045664	14.36468	12.46690	10.61302	1.173272	0.738827
8.841872	12.77462	11.49889	9.829250	1.111670	0.769435
8.577610	10.97192	10.24365	8.268237	0.963932	0.753581
8.357005	9.663430	9.195774	6.901554	0.825840	0.714193
8.106815	8.367270	8.007371	5.849640	0.721570	0.699109
7.657542	6.460492	5.873326	4.592164	0.599691	0.710807
6.953481	4.307750	2.529039	3.060906	0.440197	0.710558
5.682573	2.072637	-3.50777	1.192829	0.209910	0.575512
10.49002	32.99029	19.32761	15.59957	1.487086	0.472853
10.98098	43.26408	21.56470	17.56912	1.602877	0.406090

B1P23178

Tw dyne/cm2	B<U>/D (1/sec)	Log Tw	Log B<U>/D
0.613701	50.02490	-0.21204	1.699186
0.478217	36.85943	-0.32037	1.566548
0.358533	27.05100	-0.44546	1.432183
0.214715	16.43362	-0.66813	1.215733
0.095462	7.303831	-1.02016	0.863550

Log Tw vs. Log B<U>/D

Regression Output:

Constant	-1.88322
Std Err of Y Est	0.004755
R Squared	0.999839
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	1.000148
Std Err of Coef.	0.008949

Tw = K'(B<U>/D)^n'

K' = 0.013084
n' = 1.000148

Tw* = 1.851011
Res/f* = 307.6587

Regression Output:

Constant	-51.8590
Std Err of Y Est	0.510683
R Squared	0.985478
No. of Observations	15
Degrees of Freedom	13
X Coefficient(s)	24.68231
Std Err of Coef.	0.830988

t = 24.87647 deg C
s.d.)t = 0.249774 deg C

B1P11499 B1120 7/26/90 12:35

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 9.05 Z = 7.05 [NaCl]=

	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
Taps 23	60	1.21416	25	1.0835	0.0225	0.0215	1.062
	50	1.0118	25	0.7225	0.0225	0.0215	0.701
	40	0.80944	25	0.4515	0.0225	0.0215	0.43
	30	0.60708	25	0.2542	0.0225	0.0215	0.2327
	20	0.40472	25	0.1445	0.0225	0.0215	0.123
Taps 12	60	1.21416	24.8	1.061333	0.0175	0.0205	1.040833
	48	0.971328	24.8	0.6154	0.0175	0.0205	0.5949
	40	0.80944	24.8	0.4138	0.0175	0.0205	0.3933
	30	0.60708	24.8	0.232666	0.0175	0.0205	0.212166
	20	0.40472	24.8	0.13375	0.0175	0.0205	0.11325
Taps 34	60	1.21416	24.85	1.036666	0.0205	0.0195	1.017166
	50	1.0118	24.85	0.716333	0.0205	0.0195	0.696833
	42	0.849912	24.85	0.52075	0.0205	0.0195	0.50125
	35	0.70826	24.85	0.374	0.0205	0.0195	0.3545
	27	0.546372	24.85	0.23125	0.0205	0.0195	0.21175
	19	0.384484	24.85	0.11725	0.0205	0.0195	0.09775
Taps 34	25	0.5059	24.7	2.101	0.0325	-0.0055	2.1065
	20	0.40472	24.7	1.306333	0.0325	-0.0055	1.311833
	16	0.323776	24.7	0.903833	0.0325	-0.0055	0.909333
	10	0.20236	24.7	0.4468	0.0325	-0.0055	0.4523
	28	0.566608	24.7	2.464333	0.0325	-0.0055	2.469833
	43	0.870148	24.7	5.729333	0.0325	-0.0055	5.734833
Taps 23	25	0.5059	25	1.96575	0.0285	-0.3525	1.93725
	20	0.40472	25	1.4915	0.0285	-0.3525	1.463
	15	0.30354	25	0.838	0.0285	-0.3525	0.8095
	10	0.20236	25	0.45575	0.0285	-0.3525	0.42725
			24.7	0.2956	-0.0145	-0.0245	0.3101
			24.6	0.165666	-0.0285	-0.0295	0.194166
Taps 23			24.5	1.42825	-0.0505	1.165	1.47875
			24.5	1.142	-0.0205	-0.0485	1.1625
			24.4	0.71625	-0.0555	-0.0565	0.77175
			24.4	0.5634	-0.0625	-0.064	0.6259
			24.3	0.3324	-0.0675	-0.069	0.3999
			24.3	0.222714	-0.0715	-0.071	0.294214
			24.2	0.17025	-0.0745	-0.0745	0.24475
			24.2	0.129	-0.076	-0.076	0.205
			24.2	0.0758	-0.078	-0.0795	0.1538
			24.1	0.031125	-0.081	-0.081	0.112125

24.05	-0.01155	-0.0815	-0.0815	0.069944
24	-0.03366	-0.083	-0.084	0.049333
23.95	-0.05625	-0.0845	-0.086	0.02825

		density	viscosity			
	cg)[NaCl]	1.000088	1.001574	ID(cm) =	1.45796	12.56946
10.04584	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08859	12.56946
0.000100	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		0.975573	727.2685	118373.2	413.0796	0.001566	3.670686
		0.643952	606.0571	98644.39	272.6637	0.001488	3.580483
		0.395006	484.8457	78915.51	167.2544	0.001426	3.474358
		0.213762	363.6342	59186.63	90.51190	0.001372	3.341022
		0.112990	242.4228	39457.75	47.84256	0.001632	3.202576
		0.956129	727.2685	117840.3	404.3961	0.001532	3.664054
		0.546486	581.8148	94272.30	231.0857	0.001368	3.542585
		0.361293	484.8457	78560.25	152.7752	0.001303	3.452725
		0.194900	363.6342	58920.18	82.41499	0.001249	3.318702
		0.104033	242.4228	39280.12	43.99135	0.001501	3.182382
		0.934389	727.2685	117973.3	395.6411	0.001500	3.659842
		0.640124	606.0571	98311.14	271.0430	0.001479	3.577710
		0.460458	509.0880	82581.36	194.9681	0.001508	3.506173
		0.325650	424.2400	68817.80	137.8877	0.001536	3.430954
		0.194517	327.2708	53088.02	82.36311	0.001542	3.319058
		0.089795	230.3017	37358.23	38.02122	0.001437	3.151204
		0.167588	303.0285	48989.51	70.96080	0.001549	3.285223
		0.104366	242.4228	39191.61	44.19119	0.001507	3.182381
		0.072344	193.9382	31353.28	30.63233	0.001633	3.102803
		0.035984	121.2114	19595.80	15.23644	0.002079	2.951155
		0.196494	339.3920	54868.25	83.20026	0.001448	3.319776
		0.456251	521.2091	84261.96	193.1869	0.001426	3.502702
		0.154123	303.0285	49322.19	65.25934	0.001425	3.269990
		0.116393	242.4228	39457.75	49.28348	0.001681	3.209020
		0.064402	181.8171	29593.31	27.26929	0.001654	3.080506
		0.033991	121.2114	19728.87	14.39259	0.001964	2.941739
2425	15	0.024670	96.83656	15655.21	10.44621	0.002233	2.869193
1845	14.9	0.015447	74.17012	11963.78	6.540812	0.002384	2.766544
1851	15.1	0.018013	73.42574	11817.03	7.627484	0.002836	2.798934
1538	15	0.014141	61.41434	9884.255	5.776247	0.003187	2.746683
1156	15	0.009401	46.16209	7412.517	3.980734	0.003745	2.656739
960	14.9	0.007624	38.59258	6197.037	3.228431	0.004346	2.611254
709	15.1	0.004871	28.12471	4505.973	2.062709	0.005228	2.512992
912	25	0.003584	21.85112	3500.855	1.517575	0.006373	2.446348
772	24.9	0.002981	18.57106	2968.640	1.262435	0.007339	2.405392
645	24.9	0.002497	15.51598	2480.275	1.057402	0.008806	2.366908
575	29.9	0.001873	11.51902	1841.349	0.793309	0.011987	2.304509
409	30.1	0.001365	8.139087	1298.125	0.578347	0.017504	2.234897

315	40	0.000852	4.717038	751.4853	0.360777	0.032510	2.131930
212	39.9	0.000600	3.182598	506.4575	0.254464	0.050370	2.055631
205	74.9	0.000344	1.639422	260.5926	0.145715	0.108700	1.934077

			Tap 14	122.2234		
82.0894			Tap 12	40.77743		
4			Tap 23	40.72299		
0.4			Tap 34	40.72299		
Solvent	L	MDR				
1//f	1//f	1//f	1//f	1//f/Slv	1//f/L	
14.28274	292.7968	37.34304	25.26779	1.769112	0.086298	
13.92193	237.8828	35.62917	25.91727	1.861614	0.108949	
13.49743	186.3109	33.61280	26.47305	1.961339	0.142090	
12.96408	137.0573	31.07942	26.98990	2.081897	0.196924	
12.41030	99.64527	28.44895	24.74888	1.994220	0.248369	
14.25621	288.3594	37.21703	25.54111	1.791577	0.088573	
13.77034	218.0045	34.90912	27.02704	1.962699	0.123974	
13.41090	177.2579	33.20178	27.69983	2.065471	0.156268	
12.87480	130.1913	30.65534	28.28537	2.196954	0.217259	
12.32953	95.11801	28.06527	25.81012	2.093358	0.271348	
14.23936	285.5764	37.13700	25.81913	1.813221	0.090410	
13.91084	236.3691	35.57650	25.99512	1.868695	0.109976	
13.62469	200.4719	34.21729	25.74592	1.889651	0.128426	
13.32381	168.5910	32.78813	25.51210	1.914774	0.151325	
12.87623	130.2960	30.66210	25.46469	1.977651	0.195434	
12.20481	88.52883	27.47288	26.37434	2.160977	0.297918	
12.74089	120.5322	30.01923	25.40270	1.993793	0.210754	
12.32952	95.11779	28.06525	25.75202	2.088646	0.270738	
12.01121	79.19248	26.55327	24.74452	2.069118	0.312460	
11.40462	55.85161	23.67195	21.92842	1.922766	0.392619	
12.87910	130.5137	30.67574	26.27513	2.040136	0.201320	
13.61081	198.8762	34.15135	26.48065	1.945560	0.133151	
12.67996	116.3779	29.72982	26.48814	2.088976	0.227604	
12.43608	101.1346	28.57138	24.38440	1.960779	0.241108	
11.92202	75.22920	26.12962	24.58596	2.062230	0.326814	
11.36695	54.65363	23.49304	22.56126	1.984811	0.412804	
11.07677	46.24590	22.11467	21.15756	1.910083	0.457501	
10.66617	36.51107	20.16434	20.47972	1.920062	0.560918	
10.79573	39.33817	20.77974	18.77475	1.739089	0.477265	
10.58673	34.87894	19.78698	17.71171	1.673010	0.507805	
10.22695	28.35436	18.07805	16.33901	1.597641	0.576243	
10.04501	25.53489	17.21382	15.16805	1.510008	0.594013	
9.651968	20.36442	15.34684	13.82918	1.432783	0.679085	
9.385393	17.46740	14.08061	12.52638	1.334668	0.717129	
9.221570	15.89544	13.30245	11.67253	1.265785	0.734331	
9.067632	14.54749	12.57125	10.65594	1.175162	0.732493	
8.818037	12.60054	11.38567	9.133282	1.035750	0.724832	
8.539588	10.73438	10.06304	7.558218	0.885079	0.704112	

8.127720	8.468569	8.106670	5.546135	0.682372	0.654908
7.822524	7.104132	6.656989	4.455659	0.569593	0.627192
7.336309	5.369791	4.347471	3.033086	0.413434	0.564842

B1P11499

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.517575	119.8997	0.181150	2.078818
1.262435	101.9016	0.101209	2.008181
1.057402	85.13803	0.024240	1.930123
0.793309	63.20623	-0.10055	1.800759
0.578347	44.66014	-0.23781	1.649920
0.360777	25.88295	-0.44276	1.413013
0.254464	17.46329	-0.59437	1.242126
0.145715	8.995707	-0.83649	0.954035

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.66942
Std Err of Y Est	0.004331
R Squared	0.999833
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.869016
Std Err of Coef.	0.006482

Tw = K'(8<U>/D)^n'

K' = 0.021407
n' = 0.869016

t = 24.65121 deg C
s.d.)t = 0.315163 deg C

B5P01401 B1120 7/30/90 13:17

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14	
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=
Z =	2.7	Z =	9.05	Z =	7.05	[NaCl]=

	Freq. (Hz)	B)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
Taps 23	60	1.21416	24.9	1.473	0.0185	0.0245	1.4485
	50	1.0118	24.9	0.99075	0.0185	0.0245	0.96625
	40	0.80944	24.9	0.66175	0.0185	0.0245	0.63725
	30	0.60708	24.9	0.3865	0.0185	0.0245	0.362
	21	0.424956	24.9	0.2322	0.0185	0.0245	0.2077
	15	0.30354	24.9	0.147142	0.0185	0.0245	0.122642
	10	0.20236	24.9	0.078428	0.0185	0.0245	0.053928
Taps 12	60	1.21416	24.9	1.400666	0.0235	0.0265	1.377166
	50	1.0118	24.9	0.96975	0.0235	0.0265	0.94625
	39	0.789204	24.9	0.60475	0.0235	0.0265	0.58125
	31	0.627316	24.9	0.397	0.0235	0.0265	0.3735
	24	0.485664	24.9	0.269833	0.0235	0.0265	0.246333
	18	0.364248	24.9	0.169666	0.0235	0.0265	0.146166
	14	0.283304	24.9	0.117888	0.0235	0.0265	0.094388
	10	0.20236	24.9	0.079428	0.0235	0.0265	0.055928
Taps 34	60	1.21416	25	1.437333	0.027	0.027	1.410333
	49	0.991564	25	0.945	0.027	0.027	0.918
	41	0.829676	25	0.676	0.027	0.027	0.649
	33	0.667788	25	0.4526	0.027	0.027	0.4256
	26	0.526136	25	0.314	0.027	0.027	0.287
	20	0.40472	25	0.20875	0.027	0.027	0.18175
	10	0.20236	25	0.087	0.027	0.027	0.06
Taps 23	30	0.60708	24.9	4.303666	0.0185	0.009	4.285166
	22	0.445192	24.9	2.4665	0.0185	0.009	2.448
	16	0.323776	24.9	1.440428	0.0185	0.009	1.421928
	10	0.20236	24.9	0.692071	0.0185	0.009	0.673571
	8	0.161888	24.9	0.479	0.0185	0.009	0.4605
			24.7	0.4694	-0.0095	-0.0095	0.4789
			24.6	0.3106	-0.0185	-0.0205	0.3291
Taps 23			24.4	2.001	-0.0425	-0.045	2.0435
			24.4	1.39725	-0.0495	-0.0495	1.44675
			24.4	0.844	-0.0535	-0.054	0.8975
			24.3	0.54775	-0.0575	-0.0585	0.60525
			24.3	0.4545	-0.0605	-0.0605	0.515
			24.3	0.327285	-0.0625	-0.063	0.389785
			24.2	0.213	-0.0675	-0.0685	0.2805
			24.2	0.175583	-0.0695	-0.0695	0.245083
			24.2	0.125846	-0.0695	-0.0695	0.195346
			24.2	0.077333	-0.0705	-0.0705	0.147833

24.15	0.044277	-0.0715	-0.0715	0.115777
24.1	0.006315	-0.0725	-0.0725	0.078815
24	-0.03016	-0.0735	-0.0735	0.04334
23.9	-0.055	-0.0735	-0.0735	0.0185
24.2	2.926	-0.0735	-0.0735	2.9995

		density	viscosity			
	co)[NaCl]	1.000088	1.001574	ID(cm) =	1.45796	
4.992685	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08859	12.56946
0.000100	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch	Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		0						
			1.330620	727.2685	118106.5	563.4142	0.002136	3.737098
			0.887616	606.0571	98422.10	375.8363	0.002052	3.649183
			0.585390	484.8457	78737.68	247.8672	0.002114	3.558793
			0.332540	363.6342	59053.26	140.8049	0.002135	3.435993
			0.190797	254.5440	41337.28	80.78780	0.002500	3.315357
			0.112662	181.8171	29526.63	47.70364	0.002893	3.200960
			0.049539	121.2114	19684.42	20.97626	0.002863	3.022548
			1.265092	727.2685	118106.5	534.9529	0.002028	3.725842
			0.869243	606.0571	98422.10	367.5657	0.002006	3.644351
			0.533947	472.7245	76769.24	225.7834	0.002026	3.538530
			0.343104	375.7554	61021.70	145.0840	0.002060	3.442494
			0.226286	290.9074	47242.61	95.68685	0.002267	3.352110
			0.134271	218.1805	35431.95	56.77765	0.002391	3.238773
			0.086707	169.6960	27558.18	36.66485	0.002553	3.143809
			0.051377	121.2114	19684.42	21.72515	0.002965	3.030165
			1.295559	727.2685	118373.2	548.5687	0.002079	3.732285
			0.843292	593.9360	96671.50	357.0688	0.002029	3.639045
			0.596184	496.9668	80888.40	252.4375	0.002049	3.563746
			0.390964	399.9977	65105.30	165.5430	0.002074	3.472124
			0.263643	315.1497	51295.08	111.6326	0.002254	3.386565
			0.166959	242.4228	39457.75	70.69419	0.002412	3.287361
			0.055117	121.2114	19728.87	23.33783	0.003185	3.046699
			0.340918	363.6342	59053.26	144.3526	0.002189	3.441396
			0.194757	266.6651	43305.72	82.46477	0.002325	3.319818
			0.113125	193.9582	31495.07	47.89992	0.002553	3.201851
			0.053587	121.2114	19684.42	22.69032	0.003097	3.039604
			0.036636	96.96914	15747.53	15.51267	0.003308	2.957027
2450		15	0.038100	97.83488	15816.60	16.13250	0.003379	2.963564
1868		14.9	0.026182	75.09473	12112.93	11.08625	0.003942	2.881121
1867		15	0.025660	74.55417	11971.59	10.86511	0.003919	2.874775
1569		15	0.018166	62.65425	10060.76	7.692243	0.003929	2.799784
1184		15.2	0.011269	46.65809	7492.163	4.771929	0.004395	2.696105
1271		20	0.007600	38.06575	6098.667	3.218061	0.004453	2.609570
1391		25	0.006466	33.32775	5339.572	2.738210	0.004943	2.574506
1399		30	0.004894	27.93285	4475.234	2.072456	0.005325	2.514015
1460		40.1	0.003522	21.80857	3486.166	1.491394	0.006287	2.441564
1438		44.8	0.003077	19.22647	3073.409	1.303086	0.007068	2.412274
1266		50	0.002452	15.16640	2424.394	1.038638	0.009053	2.363020
1167		60	0.001856	11.65033	1862.341	0.786016	0.011611	2.302503

1119		75	0.001453	8.936916	1426.982	0.615580	0.015453	2.248937
875		89.9	0.000989	5.829982	929.8399	0.419056	0.024720	2.164939
476		99.9	0.000544	2.854042	454.1732	0.230435	0.056720	2.034091
181		99.9	0.000232	1.085255	172.3111	0.098362	0.167443	1.848247
2386		15	0.037664	95.27919	15230.66	15.94807	0.003522	2.956142

			Tap 14	122.2234		
79.63686			Tap 12	40.77743		
4			Tap 23	40.72299		
0.4			Tap 34	40.72299		
Solvent	L	MDR				
1//f	1//f	1//f	1//f	1//f/Slv	1//f/L	
14.54839	341.1757	38.60486	21.63593	1.487170	0.063415	
14.19673	278.6529	36.93449	22.07541	1.554964	0.079221	
13.83517	226.2944	35.21708	21.74647	1.571824	0.096098	
13.34397	170.5584	32.88387	21.63967	1.621681	0.126875	
12.86142	129.1924	30.59178	19.99791	1.554875	0.154791	
12.40384	99.27504	28.41824	18.58890	1.498641	0.187246	
11.69019	65.83069	25.02841	18.66849	1.598646	0.283887	
14.50336	332.4467	38.39099	22.20403	1.530956	0.066789	
14.17740	275.5699	36.84268	22.32239	1.574505	0.081004	
13.75412	215.9784	34.83207	22.21554	1.615191	0.102860	
13.36997	173.1307	33.00738	22.02876	1.647629	0.127237	
13.00844	140.6016	31.29009	21.00020	1.614351	0.149359	
12.55509	108.3061	29.13668	20.44664	1.628554	0.188785	
12.17523	87.03406	27.33237	19.78980	1.625413	0.227379	
11.72066	66.99551	25.17314	18.36356	1.566768	0.274101	
14.52914	337.4155	38.51341	21.92646	1.509137	0.064983	
14.15618	272.2234	36.74186	22.19489	1.567858	0.081531	
13.85498	228.8898	35.31118	22.08715	1.594166	0.096496	
13.48849	185.3552	33.57037	21.95287	1.627525	0.118436	
13.14626	152.2106	31.94473	21.06253	1.602169	0.138377	
12.74944	121.1271	30.05986	20.35968	1.596907	0.168085	
11.78679	69.59527	25.48729	17.71750	1.503165	0.254579	
13.36558	172.6737	32.98653	21.37210	1.599039	0.123757	
12.87927	130.5264	30.67655	20.73608	1.610035	0.158865	
12.40740	99.47906	28.43518	19.78750	1.594813	0.198911	
11.75841	68.46752	25.35248	17.96875	1.528160	0.262442	
11.42811	56.61188	23.78352	17.38541	1.521284	0.307098	
11.45425	57.47048	23.90773	17.20079	1.501693	0.299297	
11.12448	47.53365	22.34130	15.92678	1.431687	0.335063	
11.09910	46.84415	22.22073	15.97264	1.439093	0.340974	
10.79913	39.41529	20.79591	15.95313	1.477259	0.404744	
10.38442	31.04454	18.82600	15.08349	1.452511	0.485866	
10.03828	25.43608	17.18183	14.98527	1.492812	0.589134	
9.898025	23.46315	16.51562	14.22328	1.436982	0.606196	
9.656063	20.41248	15.36630	13.70250	1.419057	0.671280	
9.366336	17.27683	13.99009	12.61141	1.346462	0.729961	
9.249098	16.14933	13.43321	11.89449	1.286016	0.736531	
9.052080	14.41783	12.49738	10.50952	1.161006	0.728925	
8.810015	12.54249	11.34757	9.280157	1.053364	0.739897	

8.595750	11.08709	10.32981	8.044162	0.935830	0.725543
8.259756	9.137325	8.733842	6.360175	0.770019	0.696065
7.736366	6.760389	6.247742	4.198844	0.542741	0.621095
6.992991	4.406846	2.716710	2.443798	0.349463	0.554545
11.42456	56.49657	23.76670	16.84909	1.474812	0.298232

B5P01401
B5P01401

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.303086	105.4979	0.114973	2.023244
1.038638	83.21985	0.016484	1.920226
0.786016	63.92678	-0.10456	1.805682
0.615580	49.03792	-0.21071	1.690532
0.419056	31.98980	-0.37772	1.505011
0.230435	15.66046	-0.63745	1.194804
0.098362	5.954925	-1.00716	0.774876

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.67707
Std Err of Y Est	0.004784
R Squared	0.999873
No. of Observations	4
Degrees of Freedom	2

X Coefficient(s) 0.866416
Std Err of Coef. 0.006898

Tw = K'(8<U>/D)^n'

K' = 0.021034
n' = 0.866416

Tw)Retro=0.856597
Res/f)R =212.8495

Regression Output:

Constant	-8.41594
Std Err of Y Est	0.477739
R Squared	0.975533
No. of Observations	32
Degrees of Freedom	30

X Coefficient(s) 8.697891
Std Err of Coef. 0.251490

t = 24.67159 deg C
s.d.)t = 0.343676 deg C

V1F11434 Pusher 500 9/22/90 12:56

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 [C](ppm)=

Z = 2.7 Z = 9.1 Z = 6.8 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	24.9	4.632333	0.0805	0.1045	4.527833
50	1.0118	24.9	3.253666	0.0805	0.1045	3.149166
39	0.789204	24.9	2.086	0.0805	0.1045	1.9815
30	0.60708	24.9	1.307666	0.0905	0.0925	1.215166
24	0.485664	24.9	0.927333	0.0905	0.0925	0.834833
18	0.364248	24.9	0.607	0.0905	0.0925	0.5145
15	0.30354	24.9	0.4915	0.0905	0.0925	0.399
10	0.20236	24.9	0.283125	0.0905	0.0925	0.190625
8	0.161888	24.9	0.225	0.0905	0.0925	0.1325
18	0.364248	24.9	6.43525	-0.0145	0.0025	6.43275
25	0.5059	24.9	10.99466	-0.0145	0.0025	10.99216
15	0.30354	24.9	4.436888	-0.0145	0.0025	4.434388
9	0.182124	24.9	2.02525	-0.0145	0.0025	2.02275
		24.7	1.7866	-0.0195	-0.0335	1.8061
		24.6	1.13575	-0.0275	-0.0405	1.16325
		24.6	0.882	-0.0355	-0.0415	0.9175
		24.5	0.5376	-0.0385	-0.0395	0.5761
		24.5	0.386166	-0.0385	-0.0415	0.424666
		24.5	2.6992	0.0705	0.0765	2.6227
		24.5	1.690285	0.0835	0.0855	1.604785
		24.5	1.095875	0.0875	0.0875	1.008375
		24.5	0.957	0.0875	0.0875	0.8695
		24.4	0.809181	0.0865	0.0865	0.722681
		24.4	0.626153	0.0855	0.0855	0.540653
		24.4	0.479125	0.0845	0.0845	0.394625
		24.3	0.375869	0.0835	0.0845	0.291369
		24.2	0.296090	0.0825	0.0845	0.211590
		24.2	0.21555	0.0825	0.0815	0.13405
		24.1	0.148391	0.0815	0.0805	0.066891
		24.1	0.182083	0.0805	0.0785	0.103583
		24	0.113344	0.0775	0.0755	0.035844
		24	3.7032	0.0745	0.0625	3.6347
		24.2	6.0494	0.0615	0.0605	5.9884
		24.3	7.48	0.0585	0.0585	7.4215
		24.5	11.16033	0.0575	0.0595	11.10183

		density	viscosity		
	co)[NaCl]	1.000088	1.001574	ID(cm) =	1.45796
10.01047	X coeff	-0.00025	-0.02281	K(V/psi)=	1.085245 12.35245
0.000100	constant	0.007419	-4.14933	XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	DP (psid)	U (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		4.172176	727.2685	118106.5	588.6017	0.002231	3.746595
		2.901802	606.0571	98422.10	409.3801	0.002235	3.667747
		1.825854	472.7245	76769.24	257.5877	0.002311	3.567146
		1.119716	363.6342	59053.26	157.9672	0.002395	3.460967
		0.769257	290.9074	47242.61	108.5252	0.002571	3.379449
		0.474086	218.1805	35431.95	66.88311	0.002817	3.274342
		0.367658	181.8171	29526.63	51.86853	0.003146	3.219176
		0.175651	121.2114	19684.42	24.78055	0.003382	3.059759
		0.122092	96.96914	15747.53	17.22451	0.003673	2.979757
		0.500507	218.1805	35431.95	70.61056	0.002974	3.286119
		0.855258	303.0285	49211.05	120.6580	0.002635	3.402462
		0.345022	181.8171	29526.63	48.67509	0.002952	3.205337
		0.157382	109.0902	17715.97	22.20318	0.003741	3.034891
2536	15	0.140525	101.2690	16371.80	19.82507	0.003876	3.008321
1976	15	0.090508	78.93682	12727.82	12.76868	0.004112	2.911801
1661	15	0.071387	66.32805	10698.84	10.07115	0.004590	2.860268
1241	15	0.044824	49.55636	7975.527	6.323694	0.005163	2.758228
1365	19.9	0.033041	41.08643	6612.390	4.661451	0.005537	2.692004
1365	20	0.032525	40.88100	6579.328	4.588621	0.005505	2.688584
1249	24.8	0.019901	30.16682	4855.004	2.807700	0.006186	2.581918
1191	30	0.012505	23.77986	3827.096	1.764222	0.006256	2.481021
1185	35	0.010783	20.28005	3263.842	1.521259	0.007417	2.448845
1123	40	0.008962	16.81661	2700.342	1.264389	0.008965	2.407698
1056	50	0.006704	12.65064	2031.388	0.945916	0.011051	2.344684
883	59.9	0.004893	8.829838	1417.858	0.690427	0.017756	2.276317
964	90	0.003613	6.415838	1027.907	0.509774	0.024832	2.209462
686	90.1	0.002624	4.560560	729.0191	0.370195	0.035688	2.139003
452	100	0.001662	2.707430	432.7908	0.234531	0.064157	2.037988
190	100	0.000829	1.138079	181.5153	0.117031	0.181168	1.887954
317	100	0.001284	1.898795	302.8440	0.181227	0.100783	1.982914
156	150	0.000444	0.622948	99.13189	0.062713	0.324017	1.751497
1231	15	0.045075	49.15703	7822.523	6.359196	0.005276	2.754518
1646	15	0.074265	65.72906	10506.98	10.47718	0.004862	2.864910
1943	15	0.092037	77.58905	12430.85	12.98450	0.004324	2.912485
2498	15	0.137679	99.75164	16052.98	19.42253	0.003914	3.001707

Tap DL= 122.2234
80.63531 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.58638	348.7185	38.78530	21.16795	1.451213	0.060702
14.27099	290.8222	37.28720	21.15168	1.482145	0.072730
13.86858	230.6890	35.37579	20.79890	1.499712	0.090159
13.44387	180.6540	33.35838	20.43036	1.519678	0.113091
13.11779	149.7372	31.80954	19.71896	1.503222	0.131690
12.69737	117.5499	29.81250	18.83877	1.483675	0.160261
12.47654	103.5181	28.76358	17.82697	1.428838	0.172211
11.83495	71.55167	25.71605	17.19423	1.452834	0.240305
11.51903	59.65375	24.21539	16.49889	1.432316	0.276577
12.74447	120.7811	30.03626	18.33479	1.438646	0.151801
13.20984	157.8855	32.24678	19.48050	1.474695	0.123383
12.42135	100.2807	28.50141	18.40247	1.481519	0.183509
11.73956	67.72956	25.26294	16.34832	1.392583	0.241380
11.63328	63.70907	24.75810	16.06109	1.380615	0.252100
11.24720	51.01310	22.92423	15.59382	1.386461	0.305682
11.04107	45.30522	21.94509	14.75940	1.336772	0.325777
10.63291	35.81862	20.00634	13.91651	1.308814	0.388527
10.36801	30.75275	18.74807	13.43861	1.296160	0.436988
10.35433	30.51157	18.68310	13.47711	1.301591	0.441704
9.927675	25.86705	16.65645	12.71366	1.280628	0.532686
9.524085	18.91913	14.73940	12.64293	1.327470	0.668261
9.395380	17.56811	14.12805	11.61138	1.235861	0.660935
9.230794	15.98007	13.34627	10.56136	1.144145	0.660908
8.978739	13.82180	12.14901	9.185615	1.023040	0.664574
8.705269	11.80857	10.85003	7.504393	0.862051	0.635503
8.437848	10.12376	9.579778	6.345880	0.752073	0.626830
8.156012	8.607623	8.241061	5.293411	0.649019	0.614967
7.759552	6.851223	6.357874	3.948115	0.508807	0.576264
7.151817	4.828746	3.471133	2.349411	0.328505	0.486546
7.531657	6.008893	5.275375	3.149956	0.418228	0.524215
6.605990	3.526773	0.878454	1.756773	0.265936	0.498124
10.61807	35.51392	19.93585	13.76664	1.296529	0.387640
11.05964	45.79205	22.03329	14.34062	1.296662	0.313168
11.24994	51.09351	22.93722	15.20600	1.351651	0.297611
11.60763	62.77514	24.63624	15.98351	1.376983	0.254615

V1P11434

Tw dyne/cm2	8 U /D (1/sec)	Log Tw	Log 8<U>/D
1.764232	130.4829	0.246555	2.115557
1.521259	111.2790	0.182203	2.046413
1.264389	92.27478	0.101880	1.965083
0.945916	69.41561	-0.02414	1.841457
0.690427	48.45037	-0.16088	1.685297
0.509774	35.20446	-0.29262	1.546597
0.370195	25.02433	-0.43156	1.398362
0.234531	14.85599	-0.62979	1.171901
0.117031	6.244776	-0.93169	0.795516

Log Tw vs. Log 8<U>/D
Regression Output:

Constant	-1.71925
Std Err of Y Est	0.007629
R Squared	0.999429
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	0.925249
Std Err of Coef.	0.009888

Tw = K'(8<U>/D)^n'

K' = 0.019087
n' = 0.925249

Tw)Retro=0.395342
Res/f)R =144.6008

Regression Output:

Constant	-10.6865
Std Err of Y Est	0.308318
R Squared	0.982997
No. of Observations	21
Degrees of Freedom	19
X Coefficient(s)	8.948258
Std Err of Coef.	0.269989

t = 24.56285 deg C
s.d.)t = 0.302452 deg C

V3P11437 Pusher 500 9/26/90 11:55

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=	
Z =	2.7	Z =	9.05	Z =	6.85	[NaCl]=	

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25	2.778666	0.093	0.095	2.683666
49	0.991564	25	1.9105	0.093	0.095	1.8155
39	0.789204	25	1.285333	0.093	0.095	1.190333
30	0.60708	25	0.856333	0.094	0.0945	0.761833
23	0.465428	25	0.558666	0.094	0.0945	0.464166
15	0.30354	25	0.325	0.094	0.0945	0.2295
10	0.20236	25	0.2066	0.094	0.0945	0.1121
8	0.161888	25	0.1915	0.094	0.0945	0.097
18	0.364248	24.9	3.507	-0.0535	0.0545	3.4525
28	0.566608	24.9	7.916	-0.0535	0.0545	7.8615
35	0.70826	24.9	11.69766	-0.0535	0.0545	11.64316
15	0.30354	24.9	2.485	0.0735	-0.0545	2.5395
10	0.20236	24.9	1.382571	0.0735	-0.0545	1.437071
		24.5	1.2258	-0.0365	-0.0505	1.2623
		24.3	0.7766	-0.0465	-0.0605	0.8231
		24.2	0.6295	-0.0555	-0.0605	0.685
		24.1	0.41	-0.0555	-0.0575	0.4655
		24.05	2.7265	-0.0805	-0.0815	2.808
		24.1	2.18	-0.0815	-0.0845	2.2645
		24	1.630714	-0.0875	-0.0905	1.721214
		24	1.375444	-0.0075	-0.0105	1.385944
		24	1.1905	-0.0115	-0.0145	1.202
		23.9	1.023	-0.0155	-0.0195	1.0425
		23.9	0.806176	-0.0205	-0.0245	0.830676
		23.8	0.60055	-0.0255	-0.028	0.62855
		23.75	0.45075	-0.028	-0.0285	0.47925
		23.6	0.26295	-0.0295	-0.0305	0.29345
		23.5	0.358791	-0.0305	-0.0345	0.391291
		23.4	0.193478	-0.0355	-0.0355	0.228978
		23.3	0.115142	-0.037	-0.04	0.155642
		23.2	0.081	-0.04	-0.0425	0.12225
		23.5	4.043	-0.0445	-0.0585	4.0945
		23.75	5.0862	-0.0585	-0.0645	5.1477
		24	7.400333	-0.065	-0.0675	7.466583

		density	viscosity			
	co)[NaCl]	1.000088	1.001574		1D(cm) =	1.45796
29.98515	X coeff	-0.00025	-0.02281		K(V/psi)=	1.085245 12.85245
0.000100	constant	0.003419	-4.14933		XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		2.472867	727.2685	118373.2	348.8668	0.001322	3.633999
		1.672894	593.9360	96671.50	236.0083	0.001341	3.549133
		1.096833	472.7245	76942.62	154.7389	0.001388	3.457469
		0.701992	363.6342	59186.63	99.03554	0.001502	3.360585
		0.427706	278.7862	45376.42	60.33996	0.001556	3.252972
		0.210551	181.8171	29593.31	29.70416	0.001802	3.099078
		0.103294	121.2114	19728.87	14.57258	0.001989	2.944437
		0.089380	96.96914	15783.10	12.60964	0.002689	2.913020
		0.268625	218.1805	35431.95	37.89716	0.001596	3.150987
		0.611677	339.3920	55116.37	86.29356	0.001502	3.329677
		0.905910	424.2400	68895.47	127.8039	0.001424	3.414956
		0.197588	181.8171	29526.63	27.87540	0.001691	3.084294
		0.111813	121.2114	19684.42	15.77434	0.002153	2.969659
2487	15	0.098214	99.31238	15983.18	13.85592	0.002817	2.928561
1901	15	0.064042	75.91188	12162.14	9.034946	0.003143	2.833735
1600	15	0.053297	63.89216	10213.35	7.519060	0.003693	2.792869
1599	20	0.036219	47.88917	7637.976	5.109667	0.004467	2.707999
1595	20	0.035582	47.76937	7610.280	5.019914	0.004410	2.707658
1329	20	0.028695	39.80282	6348.261	4.048289	0.005123	2.657438
1235	24.9	0.021810	29.70889	4727.675	3.077047	0.006989	2.596884
1166	30	0.017562	23.28070	3704.736	2.477678	0.009165	2.549840
1147	35	0.015231	19.62972	3123.744	2.148837	0.011181	2.518919
1230	45	0.013210	16.37236	2599.518	1.863696	0.013939	2.487019
1202	60	0.010526	11.99974	1905.256	1.485015	0.020677	2.437697
1025	75	0.007964	8.186184	1296.830	1.123670	0.033617	2.376166
962	100.1	0.006072	5.756518	910.9019	0.856764	0.051835	2.316785
476	100	0.003718	2.851187	449.6431	0.524606	0.129375	2.208792
680	110	0.004956	3.702841	582.6361	0.699519	0.102279	2.270291
330	100	0.002901	1.976663	310.3240	0.409348	0.210027	2.152953
177	100.2	0.001946	1.058094	165.7399	0.274670	0.491812	2.065726
123	100.1	0.001549	0.736020	115.0304	0.218548	0.808712	2.014709
1565	14.9	0.051884	62.91395	9899.409	7.319814	0.003707	2.780141
1870	15	0.065230	74.67397	11816.28	9.202639	0.003308	2.872510
2416	15	0.094615	96.47717	15352.73	13.34815	0.002875	2.915528

Tap DL= 122.2234
78.91503 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.13599	269.0787	36.64598	27.49503	1.945037	0.102182
13.79653	221.3161	35.03353	27.30016	1.978770	0.123353
13.42987	179.2046	33.29191	26.83475	1.998138	0.149743
13.04226	143.3656	31.45073	25.80231	1.978362	0.179975
12.61188	111.9056	29.40646	25.34301	2.009454	0.226467
11.99631	78.51599	26.48248	23.55675	1.963666	0.300024
11.37775	54.99432	23.54431	22.42149	1.970643	0.407705
11.25208	51.15651	22.94739	19.28286	1.713714	0.376938
12.20395	88.48458	27.46876	25.02692	2.050723	0.282839
12.91869	133.5222	30.86379	25.79925	1.997048	0.193220
13.25982	162.4936	32.48417	26.49929	1.998465	0.163078
11.93717	75.88831	26.20160	24.31750	2.037123	0.320438
11.44263	57.08736	23.85253	21.55076	1.883373	0.377505
11.31424	53.02019	23.24266	18.84092	1.665238	0.355353
10.93494	42.62024	21.44098	17.83504	1.631014	0.418464
10.77147	38.79267	20.66452	16.45502	1.527648	0.424178
10.43199	31.90649	19.05198	14.96164	1.434206	0.468921
10.41463	31.58917	18.96950	15.05713	1.445767	0.476654
10.22975	28.40000	18.09133	13.97064	1.365686	0.491923
9.987538	24.70384	16.94080	11.96087	1.197580	0.484170
9.799360	22.16766	16.04696	10.44521	1.065907	0.471191
9.675677	20.64426	15.45946	9.457058	0.977405	0.458096
9.548079	19.19226	14.85337	8.469796	0.887068	0.441542
9.350791	17.12292	13.91625	6.954335	0.743716	0.406141
9.104666	14.86095	12.74716	5.454017	0.599035	0.367003
8.867140	12.96179	11.61891	4.392244	0.495339	0.338860
8.435173	10.10818	9.567074	2.780190	0.329594	0.275043
8.681165	11.64585	10.73553	3.126842	0.360186	0.268494
8.211912	8.888593	8.506107	2.182038	0.265719	0.245487
7.861307	7.264520	6.841211	1.425936	0.181386	0.196287
7.658839	6.465319	5.879489	1.111995	0.145191	0.171993
10.72056	37.67225	20.42268	16.42357	1.531969	0.435959
10.92924	42.48061	21.41390	17.38482	1.590670	0.409241
11.26211	51.45268	22.99503	18.64909	1.655914	0.362451

viscosity

Tw dyne/cm2	8 U /D (1/sec)	Log Tw	Log 8'U /D
3.077047	163.0162	0.488134	2.212230
2.477678	127.7440	0.394045	2.106340
2.140837	107.7106	0.330203	2.032258
1.863696	89.83713	0.270375	1.953455
1.485015	65.84404	0.171731	1.818516
1.123670	44.91856	0.050639	1.652425
0.856764	31.58670	-0.06713	1.499504
0.524606	15.64480	-0.28016	1.194370
0.699519	20.31793	-0.15520	1.307879

Log Tw vs. Log 8'U /D
Regression Output:

Constant	-1.15829
Std Err of Y Est	0.004095
R Squared	0.999742
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.731725
Std Err of Coef.	0.005872

Tw = K'(8'U/D)^n'

K' = 0.069455
n' = 0.731725

Tw)Retro=14.84397
Res/f)R =888.0646

Regression Output:

Constant	6.212058
Std Err of Y Est	0.183724
R Squared	0.974151
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	5.904261
Std Err of Coef.	0.363515

t = 24.275 deg C
s.d.)t = 0.599417 deg C

V1P21431 Pusher 500 9/15/90 12:42

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14	
S =	2.7	S =	7.25	S =	9.9	C (ppm)=
Z =	2.7	Z =	9.1	Z =	6.85	[NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	24.9	1.909666	0.0875	0.0755	1.834166
46	0.930856	24.9	1.272	0.0875	0.0755	1.1965
36	0.728496	24.9	0.889	0.0875	0.0755	0.8135
26	0.526136	24.9	0.5685	0.0875	0.0755	0.493
20	0.40472	24.9	0.41325	0.0875	0.0755	0.33775
14	0.283304	24.9	0.291	0.0875	0.0755	0.2155
10	0.20236	24.9	0.2295	0.0875	0.0755	0.154
8	0.161888	24.9	0.18825	0.0875	0.0755	0.11275
18	0.364248	25	3.3414	0.0075	0.012	3.3294
26	0.526136	25	5.90475	0.0075	0.012	5.89275
35	0.70826	25	9.045333	0.0115	0.0265	9.018833
15	0.30354	25	2.745333	0.0115	0.0265	2.718833
10	0.20236	25	1.89975	0.0115	0.0265	1.87325
		24.9	1.3645	0.0165	0.0095	1.348
		24.8	1.0806	0.0115	0.0065	1.0691
		24.7	0.8938	0.0115	0.0065	0.8823
		24.7	0.685833	0.0115	0.0065	0.674333
		24.6	0.6045	0.0115	0.0095	0.593
		24.6	0.325363	0.0125	0.0145	0.310863
		24.45	2.9386	0.0115	0.0135	2.9251
		24.5	2.34975	0.0135	0.0205	2.32925
		24.5	2.110583	0.0205	0.0245	2.086083
		24.4	1.718555	0.0255	0.0295	1.689055
		24.4	1.385045	0.0285	0.0305	1.356545
		24.3	1.106772	0.0295	0.0325	1.074272
		24.2	0.884260	0.0335	0.0335	0.850760
		24.1	0.682535	0.0305	0.0325	0.650035
		24	0.563318	0.0295	0.0295	0.533818
		23.9	0.481714	0.0275	0.0275	0.454214
		23.8	0.387636	0.0245	0.0235	0.364136
		23.9	4.180833	0.0205	-0.0005	4.170833
		24.1	5.462	-0.0005	-0.0025	5.4635
		24.2	6.7445	-0.0055	-0.0105	6.7525
		24.4	8.739	-0.0105	-0.0145	8.7515

		density	viscosity		
	co)[NaCl]	1.000088	1.001574	ID(cm) =	1.45796
100.1166	X coeff	-0.00025	-0.02201	K(V/psi)=	1.085245 12.85245
0.000100	constant	0.003419	-4.14933	XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	DP (psid)	U (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.690094	727.2685	118106.5	238.4349	0.000904	3.550369
		1.102516	557.5725	90548.33	155.5406	0.001003	3.457606
		0.749600	436.3611	70863.91	105.7520	0.001113	3.373828
		0.454275	315.1497	51179.49	64.08819	0.001294	3.265073
		0.311220	242.4228	39368.84	43.90626	0.001498	3.182947
		0.198572	169.6960	27558.18	28.01421	0.001950	3.065373
		0.141903	121.2114	19684.42	20.01943	0.002732	3.012410
		0.103893	96.96914	15747.53	14.65708	0.003126	2.944708
		0.259047	218.1805	35511.98	36.54592	0.001539	3.144088
		0.458492	315.1497	51295.08	64.68312	0.001306	3.268064
		0.701720	424.2400	69051.07	98.99730	0.001107	3.360481
		0.211542	181.8171	29593.31	29.84390	0.001810	3.100097
		0.145750	121.2114	19728.87	20.56216	0.002806	3.019203
2310	14.9	0.104882	92.86340	15080.77	14.79663	0.003440	2.946765
1785	14.9	0.083182	71.75808	11627.06	11.73522	0.004570	2.895444
1496	14.8	0.068648	60.54646	9788.323	9.684769	0.005297	2.852758
1552	19.9	0.052467	46.71512	7552.262	7.401975	0.006801	2.794387
1297	19.9	0.046139	39.03963	6297.172	6.509201	0.008564	2.765492
997	40	0.024187	14.92980	2408.207	3.412266	0.030698	2.625250
1156	24.9	0.036143	27.80848	4470.411	5.099075	0.013222	2.710996
1146	34.9	0.028781	19.66881	3165.469	4.060381	0.021046	2.662026
1194	44.9	0.025776	15.92857	2563.521	3.636489	0.028740	2.638084
1252	64.9	0.020870	11.55522	1855.490	2.944385	0.044217	2.591255
1056	80	0.016762	7.906655	1269.617	2.364749	0.075849	2.543650
722	80	0.013274	5.405876	866.0970	1.872687	0.128492	2.492005
606	100	0.010512	3.629873	580.2460	1.483058	0.225688	2.440767
455	120.1	0.008032	2.269275	361.9339	1.133151	0.441201	2.380946
265	100	0.006596	1.587321	252.5956	0.930559	0.740503	2.337189
194	99.9	0.005612	1.163202	184.6870	0.791792	1.173283	2.301138
135	99.9	0.004499	0.809444	128.2297	0.634767	1.942367	2.252154
1462	19.9	0.051536	44.00613	6987.061	7.270655	0.007527	2.782619
1491	14.9	0.067509	59.93910	9559.852	9.524050	0.005515	2.843213
1762	15	0.083436	70.36124	11247.45	11.77105	0.004767	2.890195
2281	15	0.108136	91.08627	14626.25	15.25573	0.003687	2.948474

Tap DL= 122.2234
40.77743

80.92975
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.80147	221.9469	35.05701	33.25865	2.409789	0.149849
13.43042	179.2611	33.29451	31.56997	2.350631	0.176111
13.09531	147.8116	31.70274	29.96377	2.288129	0.202715
12.66029	115.0676	29.63639	27.79858	2.195729	0.241584
12.33179	95.24178	28.07600	25.83480	2.094975	0.271254
11.94149	76.07702	26.22209	22.64004	1.895913	0.297593
11.64964	64.31173	24.83579	19.12988	1.642101	0.297455
11.37883	55.02855	23.54945	17.88564	1.571834	0.325024
12.17635	87.09013	27.33769	25.48507	2.092997	0.292628
12.67225	115.8630	29.69323	27.67010	2.183517	0.238817
13.04192	143.3379	31.44914	30.10851	2.308594	0.210052
12.00038	78.70046	26.50184	23.50154	1.958398	0.298620
11.67681	65.32566	24.96487	18.87550	1.616494	0.288944
11.38706	55.28989	23.58854	17.04739	1.497084	0.308327
11.18177	49.12751	22.61345	14.79194	1.322861	0.301092
11.01103	44.52854	21.80241	13.73883	1.247733	0.308539
10.77755	38.92850	20.69336	12.12521	1.125043	0.311473
10.66197	36.42273	20.14435	10.80570	1.013480	0.296674
10.10100	26.37121	17.47975	5.707470	0.565040	0.216428
10.44398	32.12747	19.10893	8.696627	0.832692	0.270691
10.24810	28.70165	18.17851	6.893046	0.672616	0.240161
10.15233	27.16218	17.72360	5.898644	0.581013	0.217163
9.965022	24.38572	16.83385	4.755576	0.477226	0.195014
9.774603	21.85399	15.92936	3.630966	0.371469	0.166146
9.568022	19.40375	14.94810	2.789721	0.291567	0.143772
9.361468	17.22848	13.96697	2.104966	0.224854	0.122179
9.123786	15.02542	12.83798	1.505502	0.165008	0.100197
8.948758	13.58531	12.00660	1.162080	0.129859	0.085539
8.804552	12.50311	11.32162	0.923205	0.104855	0.073838
8.608618	11.16952	10.39093	0.717520	0.083349	0.064239
10.73047	37.88777	20.46976	11.52591	1.074129	0.304212
10.97285	43.56057	21.62105	13.71632	1.250023	0.314879
11.16078	48.53729	22.51371	14.48300	1.297669	0.298389
11.39389	55.50791	23.62102	16.46865	1.445392	0.296690

V1P21431

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
3.636489	87.40197	0.560682	1.941521
2.944385	63.40491	0.468994	1.802122
2.364749	43.38476	0.373785	1.637337
1.872687	29.66268	0.272465	1.472210
1.483058	19.91754	0.171158	1.299235
1.133151	12.45178	0.054287	1.095231
0.930559	8.709819	-0.03125	0.940009
0.791792	6.382627	-0.10138	0.804999
0.634767	4.441519	-0.19738	0.647531

Log Tw vs. Log 8<U>/D
Regression Output:

Constant	-0.56127
Std Err of Y Est	0.003444
R Squared	0.999687
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.564852
Std Err of Coef.	0.004991

Tw = K'(8<U>/D)^n'

K' = 0.274615
n' = 0.564852

Tw* = 0.636630
Res/f* = 183.4965

Regression Output:

Constant	-34.7083
Std Err of Y Est	0.060220
R Squared	0.999553
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	19.15634
Std Err of Coef.	0.286211

t = 24.57794 deg C
s.d.)t = 0.372035 deg C

V1P13135 Pusher 500 9/22/90 15:32

10 PSID Taps 14		1.0 PSID Taps 14		0.1 PSID Taps 14		
S =	2.7	S =	7.25	S =	9.9	<C> (ppm)=
Z =	2.7	Z =	9.1	Z =	6.8	[NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	25.3	5.212	0.089	0.0975	5.1145
50	1.0118	25.3	3.735	0.089	0.0975	3.6375
41	0.829676	25.3	2.656333	0.089	0.0975	2.558833
35	0.70826	25.3	2.057666	0.097	0.0925	1.965166
29	0.586844	25.3	1.53725	0.097	0.0925	1.44025
22	0.445192	25.3	1.031	0.097	0.0925	0.9385
15	0.30354	25.3	0.575	0.097	0.0925	0.4825
10	0.20236	25.3	0.377857	0.097	0.0925	0.285357
8	0.161888	25.3	0.29	0.097	0.0925	0.1975
25	0.5059	24.2	1.288333	0.091	0.0785	1.209833
20	0.40472	24.2	0.9255	0.091	0.0785	0.847
15	0.30354	24.2	0.605	0.091	0.0785	0.5265
10	0.20236	24.2	0.3816	0.091	0.0785	0.3031
25	0.5059	25.3	13.35033	-0.0495	-0.0255	13.37583
20	0.40472	25.3	9.577	-0.0495	-0.0255	9.6025
15	0.30354	25.3	6.7185	-0.0495	-0.0255	6.744
10	0.20236	25.3	3.525	-0.0495	-0.0255	3.5505
7	0.141652	25.3	1.9045	-0.0495	-0.0255	1.93
		25.1	1.9646	-0.0165	-0.0235	1.9811
		25.1	1.3606	-0.0225	-0.0305	1.3831
		25	1.0652	-0.0285	-0.0225	1.0937
		25	0.67475	-0.0175	-0.0265	0.70125
		25	0.485833	-0.0215	-0.0295	0.515333
		24.9	0.2795	-0.0255	-0.0305	0.305
		24.9	2.023	0.0645	0.0765	1.9585
		24.8	1.35725	0.0855	0.0915	1.27175
		24.8	1.026714	0.0955	0.0995	0.927214
		24.8	0.928625	0.0085	0.0105	0.918125
		24.8	0.471785	0.0115	0.0135	0.458285
		24.7	0.360733	0.0135	0.0155	0.347233
		24.7	0.253304	0.0155	0.0165	0.236804
		24.6	0.20568	0.0165	0.0165	0.18918
		24.5	0.138740	0.0165	0.0175	0.121240
		24.5	0.105777	0.0175	0.0165	0.088277
		24.4	0.07595	0.0165	0.0155	0.06045
		24.3	0.037272	0.0155	0.0135	0.023772
		24.4	3.111	0.0125	0.0055	3.102
		24.5	4.287	0.0035	0.0015	4.2855
		24.5	6.87175	0.0005	0.0015	6.87025
		24.5	8.3506ee	0	0.0045	8.846166

24.5 12.21275 0.0015 0.0055 12.23725

		density	viscosity				
	co)[NaCl]	1.01234	1.029478	ID(cm) =	1.45796		
10.01047	X coeff	-0.00025	-0.02281	K(V/psi)=	1.085245	12.85245	
0.300147	constant	0.003419	-4.14933	XS(cm2)=	1.669479		

Batch Vol (ml)	0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		4.712760	727.2685	117367.3	664.8662	0.002490	3.767702
		3.351777	606.0571	97806.08	472.8616	0.002550	3.693702
		2.357839	496.9668	80200.99	332.6389	0.002668	3.617321
		1.810804	424.2400	68464.26	255.4644	0.002812	3.560000
		1.327119	351.5131	56727.52	187.2272	0.003002	3.492519
		0.864781	266.6651	43034.67	122.0015	0.003399	3.399517
		0.444600	181.8171	29341.82	62.72323	0.003759	3.255049
		0.262942	121.2114	19561.21	37.09538	0.005002	3.140995
		0.181986	96.96914	15648.97	25.67427	0.005409	3.061084
		1.114802	303.0285	47704.39	157.2739	0.003392	3.443826
		0.780468	242.4228	38163.51	110.1069	0.003711	3.366405
		0.485143	181.8171	28622.63	68.44307	0.004101	3.263162
		0.279291	121.2114	19081.75	39.40189	0.005312	3.143256
		1.040722	303.0285	48903.04	146.8229	0.003168	3.439732
		0.747133	242.4228	39122.43	105.4040	0.003553	3.367763
		0.524724	181.8171	29341.82	74.02706	0.004436	3.291030
		0.276250	121.2114	19561.21	38.97288	0.005255	3.151716
		0.150165	84.84800	13692.85	21.18508	0.005830	3.019350
2072	14.9	0.154141	83.29566	13381.81	21.74600	0.006209	3.023054
1665	15.1	0.107613	66.04747	10610.82	15.18191	0.006895	2.945028
1416	15	0.085096	56.54456	9063.666	12.00525	0.007439	2.893065
1049	14.9	0.054561	42.17043	6759.601	7.697432	0.008575	2.796552
1458	25	0.040096	34.93304	5599.502	5.656675	0.009183	2.729660
1086	25	0.023730	26.02008	4161.423	3.347902	0.009796	2.614730
1299	29.9	0.024288	26.02297	4161.885	3.426551	0.010024	2.619822
1190	34.9	0.015771	20.42398	3259.071	2.225027	0.010567	2.525076
1150	39.9	0.011498	17.26409	2754.845	1.622235	0.010782	2.456466
1150	40	0.011386	17.22093	2747.958	1.606332	0.010730	2.454326
1166	50.1	0.005683	13.94054	2224.503	0.801807	0.008173	2.303444
1095	60.1	0.004306	10.91336	1737.529	0.607512	0.010105	2.242201
1145	89.8	0.002936	7.637444	1215.966	0.414308	0.014071	2.159085
1025	100	0.002346	6.139638	975.2965	0.330985	0.017394	2.109343
805	119.9	0.001503	4.021569	637.3963	0.212120	0.025981	2.011744
494	100	0.001094	2.959006	468.9861	0.156448	0.034943	1.942846
335	100	0.000749	2.006613	317.3204	0.105762	0.052031	1.859633
130	99.9	0.000294	0.779465	122.9847	0.041592	0.135605	1.655989
1140	20	0.038469	34.14237	5399.184	5.427195	0.009222	2.714756
1049	15.2	0.053146	41.33812	6551.865	7.497822	0.008691	2.785921
1375	15	0.085201	54.90733	8702.509	12.02004	0.007898	2.888406
1615	15	0.109705	64.49115	10221.49	15.47707	0.007371	2.943297

2015	14.9	0.151388	81.00422	12838.72	21.35755	0.006447	3.013229

80.63 Tap DL= 122.2234
80.63531 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.67080	366.0853	39.18634	20.03756	1.365811	0.054734
14.37480	308.7324	37.78034	19.79993	1.377404	0.064132
14.06928	258.9415	36.32911	19.35789	1.375897	0.074757
13.84000	226.9239	35.24000	18.85660	1.362471	0.083096
13.57007	194.2672	33.95787	18.25047	1.344905	0.093945
13.19807	156.8187	32.19083	17.15144	1.299541	0.109371
12.62019	112.4422	29.44593	16.30939	1.292324	0.145046
12.16398	86.47191	27.27890	14.13841	1.162318	0.163502
11.84433	71.93897	25.76060	13.59570	1.147865	0.188989
13.37530	173.6626	33.03269	17.16849	1.283596	0.098861
13.06562	145.3065	31.56169	16.41508	1.256357	0.112968
12.65265	114.5625	29.60009	15.61517	1.234142	0.136302
12.17302	86.92336	27.32187	13.72024	1.127102	0.157843
13.35892	172.0331	32.95490	17.76657	1.329940	0.103274
13.07105	145.7618	31.58751	16.77498	1.283368	0.115084
12.76412	122.1547	30.12957	15.01262	1.176158	0.122898
12.20686	88.63319	27.48261	13.79365	1.129991	0.155626
11.67740	65.34769	24.96765	13.09614	1.121495	0.200407
11.69221	65.90744	25.03803	12.68997	1.085335	0.192542
11.38011	55.06910	23.55553	12.04261	1.058216	0.218681
11.17226	48.85906	22.56823	11.59414	1.037761	0.237297
10.78620	39.12303	20.73449	10.79862	1.001151	0.276017
10.51864	33.53823	19.46354	10.43492	0.992041	0.311135
10.05912	25.74309	17.28083	10.10325	1.004386	0.392464
10.07929	26.04371	17.37663	9.987737	0.990916	0.383498
9.700307	20.93904	15.57646	9.727854	1.002839	0.464579
9.425864	17.87911	14.27285	9.630110	1.021668	0.538623
9.417307	17.79126	14.23221	9.653467	1.025077	0.542595
8.813776	12.56967	11.36543	11.06086	1.254951	0.879963
8.568805	10.91645	10.20182	9.947885	1.160941	0.911274
8.236342	9.014997	8.622626	8.430166	1.023532	0.935126
8.037372	8.039392	7.677520	7.582169	0.943364	0.943127
7.646978	6.421325	5.823148	6.203904	0.811288	0.966140
7.371384	5.479312	4.514075	5.349509	0.725712	0.976310
7.038533	4.523903	2.933033	4.385941	0.622848	0.969061
6.223957	2.830541	-0.93619	2.715575	0.436310	0.959383
10.45902	32.40679	19.18036	10.41290	0.995590	0.321318
10.74368	38.17694	20.53250	10.72614	0.998367	0.280958
11.15362	48.33777	22.47972	11.25221	1.008838	0.232782
11.37319	54.85016	23.52266	11.64706	1.024080	0.212345

11.65291 54.43314 24.85135 12.45353 1.068705 0.193278

V1P13135

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.414308	41.90756	-0.38267	1.622292
0.330985	33.68892	-0.48019	1.527487
0.212120	22.06683	-0.67381	1.343739
0.154448	16.23641	-0.81121	1.210490
0.105762	11.01052	-0.97567	1.041808
0.041592	4.277018	-1.38098	0.631141

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-2.01701
Std Err of Y Est	0.006224
R Squared	0.999750
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 1.001548
Std Err of Coef. 0.009131

Tw = K'(8<U>/D)^n'

K' = 0.009615
n' = 1.001548

Tw* = 9.524208
Res/f* = 701.0509

Regression Output:

Constant	-19.6566
Std Err of Y Est	0.336817
R Squared	0.981955
No. of Observations	18
Degrees of Freedom	16

X Coefficient(s) 10.76679
Std Err of Coef. 0.364880

t = 24.86097 deg C
s.d.)t = 0.391294 deg C

V3P13138 Pusher 500 9/26/90 14:42

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14	
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=
Z =	2.7	Z =	9.1	Z =	6.8	[NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.2	3.412333	0.0905	0.0895	3.322833
49	0.991564	25.2	2.4605	0.0905	0.0895	2.371
39	0.789204	25.2	1.727	0.0905	0.0895	1.6375
29	0.586844	25.2	1.10825	0.0905	0.0895	1.01875
22	0.445192	25.2	0.77975	0.0905	0.0895	0.69025
15	0.30354	25.2	0.4835	0.0905	0.0895	0.394
10	0.20236	25.2	0.326714	0.0905	0.0895	0.237214
26	0.526136	23.4	0.9554	0.0875	0.0885	0.8679
17	0.344012	23.4	0.579	0.0875	0.0885	0.4915
30	0.60708	25.2	12.683	-0.0495	-0.0275	12.7105
20	0.40472	25.2	6.96725	-0.0495	-0.0275	6.99475
15	0.30354	25.2	4.731888	-0.0495	-0.0275	4.759388
10	0.20236	25.2	2.965	-0.0495	-0.0275	2.9925
8	0.161888	25.2	2.067	-0.0495	-0.0275	2.0945
24	0.485664	25.2	9.325666	-0.0495	-0.0275	9.353166
		24.9	1.6386	-0.0245	-0.0165	1.6551
		24.9	1.101	-0.0215	-0.0225	1.1235
		24.8	0.9286	-0.0225	-0.0265	0.9551
		24.8	0.6135	-0.0265	-0.0355	0.649
		24.8	0.4598	-0.0305	-0.0315	0.4913
		24.6	0.264	-0.0315	-0.0445	0.3085
		24.5	1.882	0.0525	0.0275	1.8295
		24.5	1.1248	0.0205	0.0125	1.1043
		24.5	0.817090	0.0065	0	0.817090
		24.4	0.477071	-0.0025	-0.0005	0.477571
		24.4	0.346466	-0.0045	-0.0085	0.354966
		24.3	0.241166	-0.0105	-0.0105	0.251666
		24.2	0.205263	-0.0115	-0.0115	0.216763
		24.05	0.143611	-0.0135	-0.0135	0.157111
		23.9	0.108363	-0.0145	-0.0145	0.122863
		23.8	0.057238	-0.0155	-0.0165	0.073238
		23.7	0.02175	-0.0175	-0.019	0.04075
		23.8	3.082	-0.0195	-0.0735	3.1015
		23.9	3.8396	-0.0735	-0.0935	3.9129
		23.8	5.88025	-0.0165	-0.0025	5.89675
		23.9	7.1856	0.0065	0.0115	7.1791
		23.9	10.1404	0.0185	0.0225	10.1219

co)[NaCl] 1.01274 1.029478 ID(cm) = 1.45796
29.98515 X coeff -0.00025 -0.02281 K(V/psi)=1.085245 12.85245
0.300052 constant 0.003419 -4.14933 XS(cm2)= 1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		3.061827	727.2685	117102.8	431.9561	0.001618	3.673069
		2.184760	593.9360	95633.97	308.2213	0.001731	3.599781
		1.508875	472.7245	76116.83	212.9690	0.001887	3.519406
		0.938728	351.5131	56599.69	132.4337	0.002123	3.416249
		0.636031	266.6651	42937.70	89.72997	0.002500	3.331818
		0.363051	181.8171	29275.70	51.21855	0.003069	3.210067
		0.218581	121.2114	19517.13	30.83698	0.004158	3.099885
		0.799727	315.1497	48725.19	112.8238	0.002249	3.363816
		0.452893	206.0594	31858.78	63.89320	0.002980	3.240347
		0.988955	363.6342	58551.41	139.5197	0.002090	3.427667
		0.544234	242.4228	39034.27	76.77948	0.002588	3.297972
		0.370309	181.8171	29275.70	52.24252	0.003131	3.214362
		0.232834	121.2114	19517.13	32.84786	0.004429	3.113603
		0.162965	96.96914	15613.70	22.99076	0.004844	3.036126
		0.727734	290.9074	46841.12	102.6671	0.002405	3.361065
2085	14.9	0.126777	83.81826	13405.15	18.16758	0.005123	2.982042
1643	15	0.087415	65.60926	10492.97	12.33235	0.005675	2.897917
1395	15	0.074312	55.70598	8889.049	10.48387	0.006693	2.861670
1390	20	0.050496	41.62974	6642.891	7.123898	0.008143	2.777767
1176	20.2	0.038226	34.87183	5564.527	5.392867	0.008785	2.717319
1276	29.9	0.024003	25.56220	4060.619	3.386321	0.010266	2.614302
1281	30	0.023183	25.57683	4053.787	3.270631	0.009904	2.605769
1165	35	0.013993	19.93777	3160.028	1.974177	0.009858	2.496146
1141	39.9	0.010354	17.12898	2714.849	1.460728	0.009862	2.430738
1184	49.9	0.006051	14.21248	2247.524	0.853763	0.008372	2.315137
1076	60	0.004498	10.74187	1698.690	0.634580	0.010894	2.248711
987	75	0.003189	7.882696	1243.739	0.449909	0.014742	2.177045
1025	90	0.002746	6.821820	1073.927	0.387511	0.016494	2.139640
750	89.9	0.001990	4.997127	784.0173	0.280870	0.022278	2.068273
590	90.1	0.001556	3.922347	613.3122	0.219645	0.028277	2.013403
360	90.1	0.000928	2.393297	373.3811	0.130929	0.045273	1.900075
216	100	0.000516	1.293816	201.3949	0.072849	0.086193	1.771785
1146	20	0.029301	34.32207	5354.627	5.544609	0.009322	2.713492
1372	20.1	0.049583	40.88621	6393.114	6.995164	0.008288	2.764941
1366	15	0.074722	54.54793	8510.089	10.54173	0.007017	2.853013
1606	15	0.090972	64.13176	10027.87	12.83421	0.006180	2.896726
2041	15	0.128263	81.50244	12744.01	18.09511	0.005395	2.971322

80.63 Tap DL= 122.2234
78.91503 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.29227	294.4081	37.38832	24.85979	1.739386	0.084439
13.99912	248.6917	35.99584	24.03426	1.716840	0.096642
13.67762	206.6741	34.46871	23.01836	1.682921	0.111375
13.26539	163.0156	32.51063	21.70025	1.635853	0.133117
12.92727	134.1833	30.90455	19.99954	1.547081	0.149046
12.44025	101.3779	28.59120	18.04860	1.450823	0.178032
11.99954	78.66217	26.49783	15.50708	1.292306	0.197135
13.05526	144.4431	31.51251	21.08321	1.614920	0.145962
12.56137	108.6985	29.16653	18.31831	1.458304	0.168523
13.31067	167.3199	32.72568	21.87104	1.643121	0.130713
12.79189	124.1230	30.26147	19.65502	1.536522	0.158351
12.45744	102.3863	28.67287	17.87085	1.434551	0.174543
12.05441	81.18644	26.75846	15.02493	1.246425	0.185067
11.74450	67.92140	25.28640	14.36744	1.223333	0.211530
13.04426	143.5310	31.46024	20.39677	1.563658	0.142107
11.52817	59.96847	24.25881	13.97104	1.211904	0.232973
11.19166	49.40801	22.66043	13.27336	1.186004	0.268648
11.04668	45.45169	21.97173	12.22320	1.106505	0.268927
10.71107	37.46692	20.37759	11.08126	1.034561	0.295761
10.46927	32.59860	19.22906	10.66864	1.019043	0.327273
10.05721	25.71478	17.27175	9.869371	0.981322	0.383801
10.02307	25.21444	17.10961	10.04827	1.002514	0.398512
9.584586	19.58965	15.02678	10.08194	1.051891	0.514656
9.322953	16.85071	13.78402	10.06948	1.080075	0.597570
8.852548	12.85337	11.54960	10.92867	1.234522	0.850256
8.594846	11.08132	10.32552	9.580817	1.114716	0.864591
8.292182	9.309484	8.887866	8.349948	1.006766	0.896929
8.158561	8.620259	8.253165	7.786365	0.954379	0.903263
7.873092	7.313971	6.897191	6.699655	0.850955	0.916007
7.653614	6.445901	5.954669	5.946727	0.776982	0.922559
7.200301	4.965412	3.701430	4.699775	0.652719	0.946002
6.687141	3.695433	1.263922	3.406145	0.509367	0.921717
10.45397	32.31265	19.15636	10.35706	0.990730	0.320526
10.65976	36.37652	20.13388	10.98426	1.030441	0.301960
11.01205	44.55466	21.80724	11.93770	1.084058	0.267934
11.18690	49.27277	22.63781	12.71984	1.137029	0.258151
11.48529	58.50635	24.05513	13.61392	1.185335	0.232691

VDF13138

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.634580	58.94192	-0.19751	1.770424
0.449909	43.25329	-0.34687	1.636019
0.387511	37.43213	-0.41171	1.573244
0.280870	27.41983	-0.55149	1.438064
0.219645	21.52239	-0.65827	1.332890
0.130929	13.13230	-0.88296	1.118340
0.072849	7.099324	-1.13757	0.851217

Log Tw vs. Log 8<U>/D
Regression Output:

Constant	-2.00171
Std Err of Y Est	0.006506
R Squared	0.999612
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	1.008362
Std Err of Coef.	0.011461

Tw = K'(8<U>/D)^n'

K' = 0.009960
n' = 1.008362

Tw* = 5.927007
Res/f* = 551.7821

Regression Output:

Constant	-32.4486
Std Err of Y Est	0.552739
R Squared	0.986728
No. of Observations	26
Degrees of Freedom	24
X Coefficient(s)	15.68904
Std Err of Coef.	0.371412

t = 24.56091 deg C
s.d.)t = 0.596287 deg C

V1P23132 Pusher 500 9/15/90 15:48

10 PSID Taps 14	1.0 PSID Taps 14	0.1 PSID Taps 14	
S = 2.7	S = 7.25	S = 9.9	<C>(ppm)=
Z = 2.7	Z = 9.1	Z = 6.85	[NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.2	2.138333	0.074	0.0765	2.061833
49	0.991564	25.2	1.5955	0.074	0.0765	1.519
40	0.80944	25.2	1.19175	0.074	0.0765	1.11525
29	0.586844	25.2	0.77475	0.074	0.0765	0.69825
21	0.424956	25.2	0.531333	0.074	0.0765	0.457333
14	0.283304	25.2	0.349	0.074	0.0765	0.2725
10	0.20236	25.2	0.257071	0.074	0.0765	0.180571
8	0.161888	25.2	0.2156	0.074	0.0765	0.1391
30	0.60708	23.85	0.815	0.0865	0.1	0.715
15	0.30354	23.8	0.408333	0.0725	0.1045	0.303833
35	0.70826	25.2	10.87366	0.0185	0.0445	10.82916
28	0.566608	25.2	7.794333	0.0185	0.0445	7.749833
22	0.445192	25.2	6.1818	0.0185	0.0445	6.1373
16	0.323776	25.2	3.84025	0.0185	0.0445	3.79575
14	0.283304	25.2	3.304428	0.0185	0.0445	3.259928
9	0.182124	25.2	2.017428	0.0185	0.0445	1.972928
		25	1.3404	0.0125	0.0085	1.3279
		24.9	1.0688	0.0095	0.0035	1.0653
		24.8	0.84375	0.0055	0.0015	0.84225
		24.8	0.6044	0.0035	0.0015	0.6029
		24.7	3.7445	0.0445	0.0155	3.7
		24.6	2.9826	0.0195	0.0195	2.9631
		24.6	1.891857	0.0205	0.0225	1.869357
		24.5	1.23525	0.0225	0.0225	1.21275
		24.5	0.688333	0.0225	0.0215	0.666833
		24.45	0.523125	0.0215	0.0205	0.501625
		24.4	0.403812	0.0195	0.0195	0.384312
		24.3	0.304142	0.0195	0.0195	0.284642
		24.2	0.2235	0.0185	0.0185	0.205
		24.1	0.16604	0.0175	0.0175	0.14854
		24	0.117133	0.0165	0.0155	0.101633
		23.8	0.081208	0.0155	0.0145	0.066708
		23.7	0.045541	0.0135	0.0125	0.032541
		23.9	5.135166	0.0115	-0.0065	5.141666
		24	6.2404	-0.0075	-0.0075	6.2479
		24	8.5568	-0.0195	-0.0295	8.5863

		density	viscosity			
	co)[NaCl]	1.01234	1.029479	ID(cm) = 1.45795		
100.1166	X coeff	-0.00025	-0.02231	K(V/psi)=1.085245	12.85245	
0.300060	constant	0.003419	-4.14933	XS(cm2)= 1.669479		

Batch Vol (ml)	t)samp (sec)	DP (psid)	U (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.899878	727.2685	117102.8	268.0307	0.001004	5.569442
		1.399685	593.9360	95633.97	197.4644	0.001109	5.503094
		1.027648	484.8457	78068.54	144.9784	0.001221	5.436001
		0.643403	351.5131	56599.69	90.76994	0.001455	5.334320
		0.421410	254.5440	40985.98	59.45165	0.001817	5.242431
		0.251095	169.6960	27323.99	35.42400	0.002437	5.129998
		0.166387	121.2114	19517.13	23.47362	0.003165	5.040640
		0.128173	96.96914	15613.70	18.08249	0.003810	2.989979
		0.658837	363.6342	56795.05	92.94738	0.001392	5.326168
		0.279967	181.8171	28365.51	39.49722	0.002366	5.139840
		0.842576	424.2400	68309.97	118.8688	0.001708	5.392883
		0.602984	339.3920	54647.98	85.06785	0.001463	5.320232
		0.477519	266.6651	42937.70	67.36748	0.001877	5.269575
		0.295302	193.9382	31227.41	41.66492	0.002194	5.165235
		0.253642	169.6960	27323.99	35.78335	0.002462	5.132190
		0.153506	109.0902	17565.42	21.65630	0.003605	5.023142
2066	14.9	0.103318	80.05445	13313.00	14.57600	0.004186	2.975198
1616	15	0.082886	64.53108	10320.53	11.69351	0.005563	2.886766
1575	15.1	0.065552	54.54370	8702.583	9.245151	0.006156	2.834766
1390	20	0.046909	41.62974	6642.891	6.617870	0.007565	2.761768
1385	19.9	0.045718	41.68843	6637.267	6.449892	0.007352	2.755200
1161	20	0.036613	34.77131	5523.508	5.165317	0.008463	2.705987
1270	29.9	0.023098	25.44201	4041.525	3.258689	0.009973	2.605960
1181	35	0.014985	20.21160	3203.427	2.114082	0.010251	2.511014
1272	45	0.008239	16.93142	2683.537	1.162433	0.008032	2.521157
1171	49.9	0.006198	14.05643	2225.356	0.874439	0.008767	2.318825
1082	60	0.004748	10.80176	1708.162	0.669928	0.011374	2.260485
1070	80	0.003517	8.011478	1264.058	0.496193	0.015313	2.194708
851	89.9	0.002533	5.670074	892.6138	0.357358	0.022017	2.122050
694	100.1	0.001835	4.152831	652.2879	0.258937	0.029739	2.051109
480	99.9	0.001255	2.879025	451.0347	0.177168	0.042366	1.967721
311	100	0.000824	1.862856	290.6264	0.116286	0.066370	1.874322
152	100	0.000402	0.910463	141.7224	0.056727	0.135536	1.717467
1736	19.9	0.036832	32.75351	8402.873	8.963025	0.006142	2.813769
1576	14.9	0.077201	67.35615	9928.969	16.89142	0.005374	2.866269
2027	15.1	0.106095	80.40734	12601.17	14.96775	0.004585	2.931105

Tap DL= 122.2234
80.92975 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
13.87776	231.9115	35.41940	31.55913	2.274078	0.136082
13.61237	199.0556	34.15879	30.02740	2.205889	0.150849
13.34400	170.5617	32.88403	28.60714	2.143819	0.167713
12.93728	134.9587	30.95209	26.21157	2.026049	0.194219
12.56972	109.2224	29.20620	23.45327	1.865853	0.214729
12.11999	84.30993	27.06997	20.25561	1.671255	0.240251
11.76256	68.63095	25.37216	17.77362	1.511034	0.258973
11.53591	60.23641	24.29560	16.20044	1.404348	0.268947
12.90467	132.4489	30.79719	26.80045	2.076802	0.202345
12.15936	86.24232	27.25696	20.55654	1.690594	0.238357
13.17153	154.4414	32.06479	27.64395	2.098764	0.178993
12.88093	130.6509	30.68441	26.14216	2.029524	0.200091
12.67830	116.2666	29.72192	23.08148	1.820550	0.198521
12.26094	91.43558	27.73946	21.34523	1.740912	0.233445
12.12876	84.73649	27.11161	20.15364	1.661640	0.237839
11.69256	65.92074	25.03970	16.65392	1.424316	0.252635
11.34079	53.83673	23.36877	15.45529	1.362805	0.287077
11.14546	48.11127	22.44096	13.40711	1.202921	0.278668
10.93746	42.68213	21.45295	12.74476	1.165239	0.298597
10.64707	36.11173	20.07359	11.49711	1.079838	0.318376
10.62080	35.56969	19.94880	11.66243	1.098074	0.327875
10.42394	31.75903	19.01375	10.86995	1.042786	0.342263
10.02384	25.22552	17.11324	10.01348	0.998966	0.396958
9.644058	20.27190	15.30927	9.876438	1.024095	0.487198
9.124550	15.03202	12.84161	11.15758	1.222808	0.742253
8.875303	13.02284	11.65769	10.68005	1.203345	0.820101
8.641943	11.38586	10.54923	9.376555	1.085005	0.823526
8.377234	9.776618	9.291864	8.080879	0.964623	0.826551
8.088201	8.278092	7.918954	6.739277	0.833223	0.814110
7.804439	7.030558	6.571086	5.798685	0.742998	0.824782
7.470884	5.802311	4.986699	4.858351	0.650304	0.837313
7.097290	4.679533	3.212129	3.881615	0.546915	0.829487
6.469868	3.260973	0.231877	2.716259	0.419832	0.832959
10.87507	41.17652	21.15662	12.75889	1.173223	0.309858
11.04827	45.49356	21.97932	13.64062	1.234637	0.299836
11.32442	53.33176	23.29101	14.76743	1.304034	0.276897

V1F23132

Tw dyne/cm2	8*U /D (1/sec)	Log Tw	Log 8*U/D
0.669938	59.27059	-0.17396	1.772839
0.496193	43.95993	-0.30434	1.643057
0.357358	31.11237	-0.44689	1.492933
0.258937	22.78707	-0.58680	1.357688
0.177168	15.79206	-0.75161	1.198439
0.116286	10.22171	-0.93446	1.009523
0.056727	4.995820	-1.24620	0.698606

Log Tw vs. Log 8*U/D
Regression Output:

Constant	-1.94679
Std Err of Y Est	0.003608
R Squared	0.999922
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	1.000576
Std Err of Coef.	0.003943

Tw = K'(8*U/D)^n'

K' = 0.011303
n' = 1.000576

Tw# = 6.497523
Res/f# = 577.7285

Regression Output:

Constant	-61.7698
Std Err of Y Est	0.513013
R Squared	0.989325
No. of Observations	17
Degrees of Freedom	15
X Coefficient(s)	26.22155
Std Err of Coef.	0.703274

t = 24.65833 deg C
s.d.)t = 0.528690 deg C

Page 1 Dow Pusher 500-F

W1P11462 Pusher 500-F 11/28/90 11:26

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 1 S = 7.25 S = 9.9 C (ppm)=

Z = 5 Z = 6.85 Z = 6.9 [NaCl]=

FlowCo= 0.019693 0.020236

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V.)corr (volts)
12	60	1.181580	25	6.5195	0.0495	0.0595	6.46
12	50	0.984650	25	4.4155	0.0495	0.0595	4.356
12	40	0.787720	25	2.824	0.0495	0.0595	2.7645
12	30	0.590790	25	1.63975	0.0495	0.0595	1.58025
12	20	0.393860	25	0.831666	0.0495	0.0595	0.772166
12	15	0.295395	25	0.54625	0.0495	0.0595	0.48675
12	10	0.196930	25	0.325	0.0495	0.0595	0.2655
12	8	0.157544	25	0.245833	0.0495	0.0595	0.186333
12	17	0.334781	24.9	6.885333	0.0065	0.0275	6.857833
12	23	0.452939	24.9	11.3125	0.0065	0.0275	11.285
12	14	0.275702	24.9	4.9296	0.0065	0.0275	4.9021
12	10	0.196930	24.9	2.9388	0.0065	0.0275	2.9113
12	8	0.157544	24.9	1.9135	0.0065	0.0275	1.886
14			24.8	5.018666	-0.0195	-0.0305	5.049166
14			24.8	3.5428	-0.0305	-0.0425	3.5853
14			24.7	2.8268	-0.0395	-0.0505	2.8773
14			24.6	1.8878	-0.0475	-0.0565	1.9443
14			24.7	1.387333	-0.0545	-0.0565	1.443833
14			24.6	0.863	-0.054	-0.0555	0.9185
14			24.5	5.724333	0.0475	0.0195	5.704833
14			24.5	3.936857	0.0345	0.0155	3.921357
14			24.5	2.795818	0.0355	0.0235	2.772318
14			24.5	1.857083	0.0315	0.0065	1.850583
14			24.4	1.444352	0.0515	0.0445	1.399852
14			24.4	1.089411	0.0785	0.0715	1.017911
14			24.3	0.829652	0.0815	0.0825	0.747152
14			24.3	0.667045	0.0885	0.0915	0.575545
14			24.25	0.496521	0.0935	0.0955	0.401021
14			24.2	0.281	-0.0115	-0.0115	0.2925
14			24.1	0.18036	-0.0125	-0.0135	0.19286
14			24	0.1105	-0.0155	-0.0165	0.127
14			23.95	0.072571	-0.0185	-0.0215	0.094071
14			23.9	0.023055	-0.0225	-0.0255	0.048555
14			24.1	9.136	-0.0275	-0.1495	9.1635
14			24.2	11.71475	0.0035	0.0025	11.71225
12			24.3	5.9002	0.0095	0.0315	5.8687
12			24.4	7.28525	0.0425	0.0125	7.27275
12			24.4	10.1755	0.0425	0.0225	10.153

Page 2 Dow Pusher 500-F

		density	viscosity/			
	co[NaCl]	1.000030	1.001574	ID(cm) =	1.02106	
0.00012	X coeff	-0.00025	-0.02281	K(V/psi)=	1.17915	13.79691
).000100	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

	0						
Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		5.478522	1442.958	164485.2	2431.951	0.002341	3.900880
		3.694186	1202.465	137071.0	1639.265	0.002273	3.815308
		2.344485	961.9723	109656.8	1040.34o	0.002254	3.716572
		1.340160	721.4792	82242.30	594.6855	0.002291	3.575127
		0.654850	480.9861	54828.40	290.5846	0.002519	3.439619
		0.412797	360.7396	41121.30	183.1755	0.002822	3.339417
		0.225162	240.4930	27414.20	99.91393	0.003464	3.207796
		0.158023	192.3944	21931.36	70.12164	0.003799	3.139909
		0.497055	408.8082	46499.12	220.5645	0.002646	3.775786
		0.817936	553.1340	62910.57	362.9529	0.002579	3.838723
		0.355304	336.6903	38293.39	157.6624	0.002789	3.705883
		0.211011	240.4930	27352.42	93.63446	0.003246	3.192716
		0.136697	192.3944	21881.93	60.65833	0.003296	3.099443
2165	15	0.365963	176.2614	20001.87	54.17880	0.003494	3.072767
1784	15.1	0.259862	144.2807	16372.76	38.44274	0.003702	2.998420
1540	15	0.208546	125.3776	14195.59	30.85134	0.003975	2.949665
1182	15	0.140922	96.23139	10871.03	20.84741	0.004514	2.8o35o8
1722	19.9	0.104649	81.12766	9185.497	15.48124	0.004716	2.799971
1002	20.1	0.066572	60.87826	6877.271	9.848454	0.005328	2.700726
1238	24.9	0.068416	60.71721	6843.622	10.12123	0.005505	2.705674
1180	30.1	0.047027	47.87470	5396.103	6.957081	0.006086	2.624271
1347	40	0.033247	41.12426	4635.241	4.918512	0.005831	2.548974
1226	44.9	0.022193	33.34530	3758.450	3.287215	0.005921	2.481207
1273	60	0.016798	25.91001	2913.816	2.483551	0.007418	2.599609
938	60	0.012207	19.09159	2147.022	1.805929	0.009935	2.730422
1046	90	0.008960	14.19318	1592.554	1.325561	0.013194	2.262287
794	89.9	0.006902	10.78577	1210.224	1.021104	0.017600	2.205622
542	90	0.004809	7.354401	824.2749	0.711473	0.026375	2.126677
419	100	0.003507	5.116872	572.8480	0.518939	0.039741	2.057660
263	99.9	0.002312	3.214998	359.1169	0.342162	0.066377	1.9oo277
163	100	0.001523	1.990573	221.8469	0.225317	0.114012	1.874528
114	100	0.001123	1.392180	154.9818	0.166896	0.172649	1.8 [illegible]
83	150	0.000582	0.675736	75.14030	0.086144	0.378247	1.666751
1319	20	0.109895	80.53884	8996.228	16.25743	0.005025	2.804642
1170	15.1	0.140462	94.62360	10593.37	20.77930	0.004653	2.853917
1522	15	0.070382	133.9121	13903.64	31.23147	0.004078	2.948783
1757	15	0.087220	141.4161	15903.53	38.70340	0.003880	2.975947
2123	15.1	0.121762	171.6973	19308.92	54.03123	0.003675	3.063394

83.38349
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	DATA 1//f	1//f/Slv	1//f/L
15.20352	497.4628	41.71673	20.66551	1.359258	0.041541
14.86123	408.4965	40.09085	20.97187	1.411179	0.051339
14.46629	325.4263	38.21489	21.06021	1.455813	0.064715
13.98050	246.0409	35.90741	20.89149	1.494330	0.084910
13.35847	171.9887	32.95277	19.92441	1.491518	0.115847
12.95766	136.5517	31.04893	18.82129	1.452521	0.137832
12.43118	100.8501	28.54813	16.98943	1.366678	0.168462
12.12363	84.48696	27.08728	16.22392	1.338205	0.192028
13.11506	149.5017	31.79655	19.43920	1.482204	0.130026
13.54769	191.7801	33.85154	20.50217	1.513333	0.106904
12.82345	126.3990	30.41141	18.93476	1.476572	0.149801
12.37086	97.40838	28.26160	17.55009	1.418663	0.180170
11.99377	78.40137	26.47042	17.44384	1.454407	0.222494
11.89107	73.90053	25.98258	16.91621	1.422597	0.228905
11.59368	62.27309	24.56998	16.43241	1.417359	0.263876
11.39866	55.66024	23.64363	15.94001	1.398411	0.286380
11.05427	45.65086	22.00781	14.88338	1.346391	0.326026
10.79972	39.42857	20.79868	14.56034	1.348214	0.369284
10.40290	31.37667	18.91381	13.69901	1.316844	0.436598
10.42269	31.73616	19.00781	13.47756	1.293097	0.424675
10.09708	26.31183	17.46115	12.81766	1.269442	0.487144
9.795898	22.12353	16.03051	13.09476	1.336760	0.591892
9.444829	18.07537	14.36293	12.99575	1.375965	0.718975
9.198436	15.68516	13.19257	11.61055	1.262231	0.740225
8.921691	13.37528	11.87803	10.03260	1.124518	0.750085
8.649148	11.43318	10.58345	8.705771	1.006546	0.761447
8.422489	10.03465	9.506826	7.537782	0.894958	0.751175
8.106695	8.366695	8.006805	6.157410	0.759546	0.735942
7.830641	7.137405	6.695546	5.016249	0.640592	0.702811
7.464933	5.782468	4.958432	3.881527	0.519968	0.671257
7.098115	4.681757	3.216048	2.961587	0.417235	0.632590
6.835453	4.024790	1.968402	2.406675	0.352087	0.597962
6.259045	2.888293	-0.76953	1.625966	0.259778	0.562950
10.81857	39.85868	20.88821	14.10644	1.303910	0.353911
11.03567	45.16454	21.91943	14.65941	1.328366	0.324578
11.39353	55.49623	23.61928	15.65831	1.374316	0.282151
11.58378	61.91944	24.52299	16.05264	1.385785	0.259250
11.87357	73.16020	25.89950	16.49540	1.389257	0.225469

WIP11462

Tw dyne/cm2	8 U /D (1/sec)	Log Tw	Log 8 U /D
2.483551	203.0008	0.395073	2.307497
1.805929	149.5796	0.256700	2.174872
1.325561	111.2013	0.122399	2.046109
1.021104	84.50484	0.009070	1.926881
0.711473	57.62057	-0.14784	1.760577
0.518937	40.08988	-0.28488	1.603034
0.342162	25.18900	-0.46576	1.401211
0.225317	15.59582	-0.64720	1.193008
0.166876	10.90751	-0.77755	1.037725
0.086144	5.294288	-1.06477	0.723807

Regression Output:

Constant	-1.71012
Std Err of Y Est	0.006048
R Squared	0.999811
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	0.891564
Std Err of Coef.	0.004993

Tw vs. K'*(8*U./D)^n

K' = 0.019492
n = 0.891564

Tw)Retro=0.905542
Res/f)R =153.6165

Regression Output:

Constant	-9.62828
Std Err of Y Est	0.230677
R Squared	0.991288
No. of Observations	21
Degrees of Freedom	19
X Coefficient(s)	8.585017
Std Err of Coef.	0.184629

t = 24.57631 deg C
s.d.)t = 0.343882 deg C

Page 1 Dow Pusher 500-F

W3P11465 Pusher 500-F 12/4/90 12:08
10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14
S = 1 S = 7.25 S = 9.9 Cv(ppm)=
Z = 4.7 Z = 9.2 Z = 6.8 [NaCl]=
FlowCo= 0.019693

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
12	60	1.181580	25.2	3.436	0.0145	0.0195	3.4165
12	50	0.984650	25.2	2.395333	0.0145	0.0195	2.375833
12	40	0.787720	25.2	1.54	0.0145	0.0195	1.5205
12	30	0.590790	25.2	0.88325	0.0145	0.0195	0.86375
12	22	0.433246	25.2	0.5182	0.0145	0.0195	0.4987
12	15	0.295395	25.2	0.286571	0.0145	0.0195	0.267071
14	15	0.295395	25.2	0.8055	0.0145	0.0195	0.786
14	10	0.196930	25.2	0.443	0.0145	0.0195	0.4235
14	25	0.492325	25.2	2.008	0.0145	0.0195	1.9885
12	15	0.295395	25.1	3.2225	0.0345	0.0575	3.165
12	24	0.472632	25.1	7.00975	0.0345	0.0575	6.95225
12	32	0.630176	25.1	11.7025	0.0345	0.0575	11.645
12	20	0.393860	25.1	5.15475	0.0545	0.0565	5.09825
12	10	0.196930	25.1	1.691714	0.0545	0.0565	1.635214
14			24.9	3.30375	0.0665	0.0575	3.24625
14			24.8	2.40725	0.0595	0.0525	2.35475
14			24.7	1.9865	0.0555	0.0565	1.93
14			24.7	1.3455	0.0565	0.0535	1.292
14			24.7	1.0324	0.0555	0.0545	0.9779
14			24.6	6.555	0.0745	0.0775	6.4775
14			24.6	4.367833	0.0745	0.0735	4.294333
14			24.6	3.339875	0.0705	0.0685	3.271375
14			24.6	2.8665	0.0645	0.0645	2.802
14			24.5	2.371	0.0585	0.0575	2.3135
14			24.45	1.744357	0.0555	0.0555	1.688857
14			24.4	1.284705	0.0555	0.0545	1.230205
14			24.4	0.976227	0.0545	0.0575	0.918727
14			24.3	0.766818	0.0555	0.0555	0.711318
14			24.2	0.491545	0.0555	0.0585	0.433045
14			24.2	0.63036	0.0575	0.0545	0.57286
14			24.15	0.349083	0.0535	0.0545	0.294583
14			24.1	0.269375	0.0535	0.0535	0.215875
14			24	0.218038	0.0525	0.0515	0.166538
14			24	0.159416	0.0505	0.0495	0.109416
14			24.1	8.245	0.0495	0.0325	8.2125
14			24.3	11.4675	0.0275	0.0135	11.454

Page 2 Dow Pusher 500-F

		density	viscosity			
	co[NaCl]	1.000088	1.001574	ID(cm) =	1.02108	
30.00531	X coeff	-0.00025	-0.02281	K(V/psi)=	1.17915	13.79691
0.000100	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		2.897426	1442.958	165229.0	1285.709	0.001238	3.764525
		2.014869	1202.465	137690.8	894.0823	0.001240	3.685642
		1.289488	961.9723	110152.6	572.2001	0.001240	3.588728
		0.732519	721.4792	82614.51	325.0495	0.001252	3.465928
		0.422931	529.0847	60583.98	187.6726	0.001344	3.346654
		0.226494	360.7396	41307.25	100.5053	0.001548	3.211048
		0.666581	360.7396	41307.25	98.61074	0.001519	3.206916
		0.359157	240.4930	27538.17	53.13187	0.001842	3.072631
		1.686384	601.2326	68845.43	249.4751	0.001384	3.408467
		0.229399	360.7396	41214.17	101.7940	0.001568	3.212830
		0.503899	577.1833	65942.68	223.6012	0.001546	3.383705
		0.844029	769.5778	87923.57	374.5314	0.001268	3.495712
		0.369521	480.9861	54952.23	163.9720	0.001421	3.516353
		0.118520	240.4930	27476.11	52.59245	0.001823	3.069430
2205	15	0.235288	179.5179	20417.43	34.80734	0.002166	2.977833
1769	15.1	0.170672	143.0676	16235.09	25.24839	0.002473	2.907130
1506	15	0.139886	122.6095	13882.19	20.69408	0.002760	2.862951
1162	15	0.093644	94.60311	10711.22	13.85324	0.003104	2.775803
1305	20	0.070878	79.68399	9022.041	10.48536	0.003311	2.715319
1305	19.9	0.076215	80.08441	9046.944	11.27487	0.003525	2.730098
991	20	0.050527	60.51098	6835.781	7.474809	0.004093	2.640842
1171	30	0.038491	47.66792	5384.931	5.694225	0.005025	2.581760
1335	39.9	0.032968	40.86005	4615.862	4.877221	0.005858	2.548129
1108	40	0.027220	33.82753	3812.804	4.026928	0.007056	2.505544
1012	50	0.019871	24.71730	2782.821	2.939661	0.009648	2.436713
873	60.1	0.014474	17.73904	1994.916	2.141322	0.013645	2.367413
896	90.1	0.010809	12.14433	1365.740	1.599156	0.021742	2.304017
650	90	0.008369	8.819854	989.6372	1.238135	0.031914	2.247471
363	89.9	0.005095	4.931028	552.0623	0.753768	0.062158	2.138720
594	110	0.006740	6.594537	738.2767	0.997132	0.045974	2.199478
254	100	0.003466	3.101875	346.8720	0.512758	0.106854	2.054565
168	100	0.002540	2.051633	229.1685	0.375756	0.178990	1.986570
132	105	0.001959	1.535236	171.1002	0.289880	0.246593	1.929241
76	100	0.001287	0.928120	103.4378	0.190453	0.443294	1.828025
1158	15.1	0.096629	93.65310	10461.09	14.29485	0.003267	2.776706
1490	15	0.134769	121.3069	13611.31	19.93707	0.002716	2.850918

Page 3 Dow Pusher 500-F

84.98972
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	DATA 1//f	1//f/Slv	1//f/L
14.65810	363.4172	39.12598	28.41586	1.938577	0.078190
14.34257	303.0559	37.62721	28.39633	1.979863	0.093699
13.95491	242.4421	35.78583	28.39664	2.034885	0.117127
13.46371	192.7295	33.45264	28.25709	2.098759	0.154638
12.98661	138.8463	31.18643	27.27114	2.099941	0.196412
12.44419	101.6081	28.60992	25.40843	2.041790	0.250062
12.42766	100.6459	28.53160	25.65134	2.064052	0.254867
11.89052	73.87740	25.98000	23.29718	1.959306	0.315349
13.23387	160.0839	32.36088	26.87864	2.031049	0.167903
12.45132	102.0258	28.64377	25.24739	2.027687	0.247460
13.13482	151.2118	31.89041	27.25590	2.075087	0.180249
13.58285	195.7009	34.01854	28.07969	2.067289	0.143482
12.86541	129.4892	30.61072	26.52354	2.061615	0.204831
11.87772	73.53487	25.91918	23.41665	1.971476	0.319311
11.51133	59.39007	24.17884	21.48657	1.866558	0.361787
11.22852	50.46730	22.83547	20.10596	1.790615	0.398395
11.05180	45.58596	21.99607	19.03298	1.722160	0.417518
10.70321	37.29784	20.34027	17.94879	1.676953	0.481228
10.46127	32.44888	19.19107	17.37741	1.661117	0.535531
10.52039	33.57211	19.47187	16.84237	1.600925	0.501677
10.16337	27.33524	17.77601	15.62950	1.537826	0.571771
9.927040	23.85833	16.65344	14.10652	1.421019	0.591261
9.792516	22.08051	16.01445	13.06543	1.334226	0.591717
9.622178	20.01818	15.20534	11.90419	1.237161	0.594669
9.346854	17.08416	13.89756	10.18056	1.089196	0.595906
9.069654	14.56443	12.58085	8.560738	0.943888	0.587783
8.816071	12.58629	11.37634	6.781882	0.769263	0.538830
8.589885	11.04972	10.30195	5.597636	0.651654	0.506586
8.154883	8.602031	8.235698	4.010988	0.491851	0.466283
8.397913	9.893694	9.390091	4.663808	0.555353	0.471391
7.818262	7.086727	6.636748	3.059169	0.391285	0.431675
7.546280	6.059687	5.344834	2.363658	0.313221	0.390062
7.316964	5.310325	4.255581	2.013767	0.275219	0.379217
6.952102	4.304330	2.522486	1.501944	0.216041	0.348938
10.70682	37.37547	20.35742	17.49325	1.633840	0.468040
11.00367	44.34024	21.76744	19.18590	1.743590	0.432697

Page 4 Dow Pusher 500-F

W3P11465

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8 U>/D
1.238135	69.10216	0.092768	1.839491
0.997132	51.66715	-0.00124	1.713214
0.753768	38.63382	-0.12276	1.586967
0.512758	24.30269	-0.29008	1.385654
0.375756	16.07422	-0.42509	1.206130
0.289880	12.02833	-0.53778	1.080205
0.190453	7.271673	-0.72021	0.861634

Regression Output:

Constant	-1.44127
Std Err of Y Est	0.007797
R Squared	0.999317
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.835928
Std Err of Coef.	0.010923

Tw vs. K'x(8<U>/D)^n

K' = 0.036201
n = 0.835928

Tw)Retro=24.65887
Res/f)R =805.2684

Regression Output:

Constant	-3.25237
Std Err of Y Est	0.459649
R Squared	0.891827
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	9.004054
Std Err of Coef.	1.185241

t = 24.71111 deg C
s.d.)t = 0.416351 deg C

Page 1 Dow Pusher 500-F

W1P21468 Pusher 500-F 12/11/90 12:05
10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14
S = 1 S = 7.25 S = 9.9 C (ppm)=
Z = 4.5 Z = 9.2 Z = 6.9 [NaCl]=
FlowCo= 0.019693

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	V)corr (volts)
12	60	1.181580	25	2.015	-0.0545	-0.0425	2.0695
12	50	0.984650	25	1.468666	-0.0545	-0.0425	1.523166
12	39	0.768027	25	0.9545	-0.0545	-0.0425	1.009
12	30	0.590790	25	0.611666	-0.0545	-0.0425	0.666166
12	22	0.433246	25	0.365	-0.0545	-0.0425	0.4195
14	22	0.433246	25	1.204333	-0.0545	-0.0425	1.258833
14	14	0.275702	25	0.573333	-0.0545	-0.0425	0.627833
14	10	0.196930	25	0.349571	-0.0545	-0.0425	0.404071
12	16	0.315098	24.9	3.1812	0.0695	0.02	3.1117
12	25	0.492939	24.9	5.624333	0.0695	0.02	5.554833
12	34	0.669562	24.9	10.17566	0.0695	0.02	10.10616
12	20	0.393860	24.8	4.47375	0.0235	0.0185	4.45525
12	15	0.295395	24.8	2.948	0.0235	0.0185	2.9295
12	10	0.196930	24.8	1.7	0.0235	0.0185	1.6815
14			24.6	3.2245	0.0485	0.0505	3.174
14			24.4	2.47025	0.0565	0.0565	2.41375
14			24.3	1.9922	0.0605	0.0595	1.9327
14			24.3	1.5508	0.0645	0.0605	1.4903
14			24.3	1.353666	0.0635	0.0615	1.292166
14			24.3	1.023142	0.0655	0.0635	0.959642
14			24.2	5.94	-0.0105	-0.0055	5.9455
14			24.2	4.748125	-0.0115	-0.0105	4.758625
14			24.2	4.120545	-0.0145	-0.0105	4.131045
14			24.25	3.352230	-0.0145	-0.0135	3.365730
14			24.2	2.664941	-0.0155	-0.0145	2.679441
14			24.1	2.069954	-0.0155	-0.0115	2.081454
14			24	1.331692	-0.0155	-0.0065	1.338192
14			24	1.763	-0.0085	-0.0125	1.7755
14			23.9	0.86596	-0.0155	-0.0085	0.87446
14			23.9	1.128642	-0.0085	-0.0095	1.138142
14			23.8	0.72524	-0.0115	-0.0085	0.73674
14			23.75	0.629083	-0.0105	-0.0105	0.639583
14			23.7	0.496875	-0.0115	-0.0115	0.508375
14			23.6	0.407333	-0.0125	-0.0125	0.419833
14			23.5	0.3155	-0.0125	-0.0125	0.328
14			23.4	0.219878	-0.0135	-0.0145	0.234378
14			23.75	7.3484	-0.0145	-0.0275	7.3759
14			23.9	9.1752	-0.0335	-0.0355	9.2107
14			24	11.9302	-0.0395	-0.0395	11.9697
12			24.1	4.9714	-0.0195	-0.0265	4.9979
12			24.2	6.63625	-0.0295	-0.0295	6.66575

Page 2 Dow Pusher 500-F

	density	viscosity	
cg[NaCl]	1.000098	1.001574	ID(cm) = 1.0[illegible]
99.78648 X coeff	-0.00025	-0.02231	K*V/psi)=1.15785[illegible]
0.000100 constant	0.003419	-4.14935	XS(cm2)= 0.81805[illegible]

Batch Vol (ml)	t)samp (sec)	DP (psid)	U (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.784277	1442.958	164485.2	791.7591	0.000782	3.657290
		1.313241	1062.465	137071.0	582.7403	0.000808	3.590721
		0.869937	937.7229	106915.3	386.0280	0.000880	3.501295
		0.574384	721.4792	82242.60	254.8652	0.000981	3.411178
		0.761687	529.0847	60311.24	160.4943	0.001149	3.319711
		1.085338	529.0847	60311.24	160.5595	0.001150	3.319801
		0.541304	336.6903	38379.88	80.07780	0.001416	3.159777
		0.348381	240.4930	27414.20	51.53780	0.001787	3.064046
		0.225536	384.7889	43863.87	100.0798	0.001755	3.207171
		0.402614	553.1740	62910.57	178.6589	0.001711	3.337003
		0.732494	817.6784	92998.24	325.0988	0.000974	3.481966
		0.322916	480.9681	54581.57	143.2916	0.001242	3.284121
		0.212330	360.7256	40936.17	94.21982	0.001451	3.197184
		0.121875	240.4930	27290.78	54.08111	0.001875	3.072576
2714	19.9	0.230051	166.5510	18814.67	34.03265	0.002160	2.969990
1629	15	0.174948	132.6234	14914.70	25.88100	0.002950	2.908563
1414	15	0.140082	115.1194	12917.05	20.72203	0.003175	2.859217
1114	15	0.108016	90.69524	10176.51	15.97947	0.003895	2.802868
1263	20	0.093656	77.11945	8653.276	13.85502	0.004671	2.771370
944	20.1	0.069554	57.35437	6435.482	10.28960	0.006272	2.707286
1171	25	0.070914	57.20150	6403.867	10.49078	0.006428	2.710106
1110	30.1	0.056758	45.07467	5041.757	8.396551	0.008301	2.662152
1208	40	0.049272	38.58056	4328.881	7.289193	0.010745	2.671441
1141	50	0.040144	27.86802	3123.424	5.938802	0.015772	2.587444
994	59.9	0.031958	20.26516	2268.741	4.727950	0.023005	2.537477
929	80	0.024826	14.18130	1584.059	3.672708	0.036516	2.481610
612	99.9	0.015961	7.481290	833.7306	2.361228	0.084595	2.384700
566	60	0.021177	11.52009	1283.899	3.132854	0.047330	2.446101
710	99.9	0.010430	3.789542	421.3881	1.542976	0.215420	2.291726
278	59.9	0.013575	5.667722	630.2577	2.008243	0.125547	2.348554
240	100	0.008737	2.930905	325.1753	1.299971	0.307407	2.253128
139	99.9	0.007628	2.310398	256.0429	1.128529	0.427865	2.221926
134	100	0.006863	1.636422	181.1471	0.897023	0.671577	2.171577
100	100	0.005007	1.221210	134.8797	0.740792	0.995828	2.129609
104	150	0.003912	0.846706	93.30590	0.578753	1.618402	2.074452
64	150	0.002795	0.521049	57.28962	0.417559	3.053702	2.000489
1144	19.9	0.037975	70.20426	7780.176	13.01471	0.005294	2.752882
1101	15.1	0.139860	89.04323	9901.397	16.25219	0.004109	2.802560
1377	15.1	0.142788	111.3647	12411.46	21.12045	0.003414	2.856487
1594	15	0.159612	125.7729	13995.31	26.45251	0.003147	2.911756
2015	15.1	0.079502	162.7628	18244.14	35.27978	0.002643	2.927386

83.84
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	DATA 1//f	1//f/Slv	1//f/L
14.22912	283.8966	37.08832	36.21151	2.544887	0.127551
13.96288	243.5573	35.82370	35.17421	2.519122	0.144418
13.60517	198.2316	34.12456	33.70909	2.477667	0.170048
13.24455	161.0715	32.41163	31.91228	2.409464	0.198124
12.84285	127.8184	30.50355	29.49068	2.296271	0.230723
12.84320	127.8443	30.50523	29.48469	2.295742	0.230629
12.23895	90.28586	27.63505	26.56830	2.170797	0.294368
11.85618	72.43135	25.81688	23.65532	1.995188	0.326589
12.42868	100.7051	28.53626	27.16089	2.185339	0.269707
12.93203	134.5514	30.92715	29.22236	2.259688	0.217183
13.45186	181.4872	33.39635	32.02644	2.380817	0.176466
12.73649	120.2274	29.99834	28.37411	2.227780	0.236003
12.37233	97.49097	28.26860	26.24357	2.121148	0.269189
11.89014	73.86115	25.97818	23.09297	1.942195	0.312653
11.47996	58.32715	24.02982	20.16092	1.756183	0.345652
11.23425	50.63409	22.86269	18.40991	1.638730	0.363587
11.03725	45.20577	21.92696	17.85868	1.618036	0.395053
10.81147	39.69616	20.85450	16.02251	1.481991	0.403628
10.68756	36.96332	20.26592	14.63145	1.369017	0.395837
10.42914	31.85418	19.03844	12.62693	1.210725	0.396394
10.44202	32.09120	19.09961	12.47200	1.194405	0.388642
10.24861	28.70995	18.18089	10.97562	1.070938	0.382293
10.12576	26.74987	17.59739	9.646962	0.952714	0.360635
9.949776	24.17264	16.76143	8.075824	0.811658	0.334089
9.749735	21.54338	15.81124	6.581896	0.675084	0.305518
9.526440	18.94480	14.75059	5.225902	0.548568	0.275848
9.138802	15.15586	12.90931	3.438358	0.376237	0.226866
9.384407	17.45748	14.07593	4.596521	0.489804	0.263297
8.765304	12.22379	11.13519	2.154547	0.245804	0.176258
8.994218	13.94551	12.22253	2.824551	0.314040	0.202541
8.612512	11.19458	10.40943	1.815471	0.210794	0.162174
8.487707	10.41854	9.816612	1.535980	0.180965	0.147427
8.286311	9.278076	8.859980	1.220263	0.147262	0.131521
8.116156	8.412384	8.051742	1.002092	0.123468	0.119121
7.897809	7.418777	7.014594	0.786061	0.099529	0.105955
7.501957	6.257046	5.609298	0.572251	0.075276	0.091457
10.61154	35.38066	19.90483	13.74369	1.295164	0.388452
10.81041	39.67185	20.84944	15.59889	1.442951	0.393198
11.04193	45.72763	21.94917	17.11353	1.549868	0.377552
11.24140	50.84290	22.89665	17.81937	1.585155	0.350479
11.49546	58.84997	24.10345	19.37569	1.685507	0.329238

WIP21468

Tw dyne/cm2	8 U /D (1/sec)	Log Tw	Log 8 U /D
3.132854	90.25805	0.495940	1.955485
1.542976	29.69046	0.188359	1.472617
2.008243	44.40570	0.302816	1.647438
1.299971	22.96318	0.113933	1.361032
1.128539	18.10160	0.052516	1.257717
0.897023	12.82110	-0.04719	1.107925
0.740792	9.567991	-0.13030	0.980820
0.573753	6.633807	-0.23750	0.821762
0.413559	4.082343	-0.38346	0.610909

Regression Output:

Constant	-0.77399
Std Err of Y Est	0.004918
R Squared	0.999716
No. of Observations	9
Degrees of Freedom	7

X Coefficient(s) 0.652753
Std Err of Coef. 0.004154

Tw vs. K'*(8 U/D)^n

K' = 0.168267
n = 0.652753

Regression Output:

Constant	-33.9491
Std Err of Y Est	0.287448
R Squared	0.991330
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 19.24565
Std Err of Coef. 1.039073

t = 24.34024 deg C
s.d.)t = 0.489427 deg C

Page 1 Dow Pusher 500-F

W3P11371 Pusher 500-F 12/25/90 12:30

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 1 S = 7.25 S = 9.9 <C>(ppm)=

Z = 4 Z = 9.3 Z = 6.95 [NaCl]=

FlowCo= 0.019693

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
12	60	1.181580	24.8	3.3375	-0.0005	0.0115	3.338
12	50	0.984650	24.8	2.333	-0.0005	0.0115	2.2335
12	41	0.807413	24.8	1.50625	-0.0005	0.0115	1.50675
12	31	0.610483	24.8	0.8752	-0.0005	0.0115	0.8757
12	20	0.393860	24.8	0.4156	-0.0005	0.0115	0.4161
14	20	0.393860	24.8	1.24125	-0.0005	0.0115	1.24175
14	15	0.295395	24.8	0.783	-0.0005	0.0115	0.7835
14	10	0.196930	24.8	0.426	-0.0005	0.0115	0.4265
12	16	0.315088	25.15	3.587166	0.0595	0.0395	3.527666
12	26	0.512018	25.15	7.993	0.0595	0.0395	7.9335
12	33	0.649869	25.15	12.241	0.0595	0.0395	12.1815
12	20	0.393860	25.1	5.099333	0.0565	0.0345	5.042833
12	10	0.196930	25.1	1.707666	0.0565	0.0345	1.651166
12	8	0.157544	25.1	1.204333	0.0565	0.0345	1.147833
14			24.8	3.44425	0.0375	0.0355	3.40875
14			24.7	2.445333	0.0335	0.0305	2.414833
14			24.6	1.923	0.0305	0.0255	1.8925
14			24.6	1.3416	0.0285	0.0195	1.3221
14			24.6	1.0515	0.0205	0.0175	1.034
14			24.5	6.4166	0.0155	0.0185	6.3981
14			24.5	4.111	0.0125	0.0145	4.0965
14			24.5	3.1469	0.0085	0.008	3.1389
14			24.4	2.6266	0.0005	0.0035	2.6231
14			24.4	2.113454	-0.0015	0.0015	2.111954
14			24.4	1.506	-0.0015	0	1.506
14			24.35	1.081714	-0.0025	-0.0005	1.082214
14			24.3	0.715545	-0.0025	0.001	0.714545
14			24.2	0.5405	-0.0005	0.0025	0.541
14			24.1	0.3755	0.0005	0.003	0.3725
14			24	0.291875	0.0015	0.0015	0.290375
14			24	0.21076	0.0005	0.0005	0.21026
14			23.9	0.159	-0.0005	-0.0015	0.1605
14			23.8	0.109964	-0.0025	-0.0035	0.113464
14			23.75	0.056896	-0.0045	-0.0055	0.062396
14			23.95	7.957	-0.0065	0.0065	7.9505
14			24	11.5648	-0.0045	0.019	11.5458
12			24.2	4.691	0.0135	0.0355	4.6555
12			24.3	6.885	0.0315	0.0325	6.8525

Page 2 Dow Pusher 500-F

		density	viscosity			
	coCNaCl]	1.000125	1.001657	ID(cm) =	1.02108	
30.00705	X coeff	-0.00025	-0.02281	K(V/psi)=	1.159853	13.79691
0.001000	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		2.877950	1442.958	163737.2	1277.067	0.001229	3.759092
		1.925675	1202.465	136447.6	854.5030	0.001185	3.671842
		1.299087	986.0216	111887.0	576.4595	0.001188	3.586369
		0.755009	745.5285	84597.55	335.0294	0.001208	3.468526
		0.358752	480.9861	54579.06	159.1935	0.001379	3.306947
		1.070609	480.9861	54579.06	158.3805	0.001372	3.305836
		0.675516	360.7396	40934.30	99.93251	0.001539	3.205838
		0.367719	240.4930	27289.53	54.39849	0.001886	3.073778
		0.255685	384.7889	44009.38	113.4585	0.001536	3.256851
		0.575020	625.2819	71515.25	255.1605	0.001308	3.412840
		0.882915	793.6271	90769.35	391.7865	0.001247	3.505958
		0.365504	480.9861	54949.71	162.1897	0.001405	3.310952
		0.119676	240.4930	27474.85	53.10552	0.001841	3.071510
		0.083194	192.3944	21979.88	36.91710	0.002000	2.992554
2207	15.1	0.247066	178.4908	20253.93	36.54972	0.002300	2.987427
1754	15	0.175027	142.8002	16167.49	25.89262	0.002546	2.911588
1498	14.9	0.137168	122.7767	13869.15	20.29199	0.002699	2.857677
1164	15	0.095825	94.76594	10704.99	14.17598	0.003165	2.779791
1301	19.9	0.074964	79.83894	9018.801	11.08688	0.003487	2.726419
1307	20	0.075678	79.80611	8994.777	11.19548	0.003524	2.727551
1237	25	0.048454	60.42550	6810.429	7.168111	0.003936	2.630732
1374	35	0.037127	47.94124	5403.355	5.492489	0.004791	2.572914
1167	35	0.031026	40.71865	4578.970	4.589935	0.005550	2.532947
1100	40.1	0.024980	33.49954	3767.153	3.695526	0.006602	2.485882
1164	60	0.017813	23.69148	2664.199	2.635219	0.009413	2.412452
1092	80	0.012800	16.66952	1872.439	1.893673	0.013664	2.340204
799	90	0.008451	10.84163	1216.436	1.250321	0.021328	2.249570
637	99.8	0.006399	7.794701	872.5983	0.946649	0.031239	2.188168
422	100.1	0.004406	5.148360	575.0480	0.651805	0.049304	2.106147
315	100	0.003434	3.846813	428.7030	0.508102	0.068840	2.051079
220	100.1	0.002487	2.683979	299.1125	0.367915	0.102396	1.980977
160	100	0.001898	1.953937	217.2632	0.280845	0.147479	1.921351
130	119.9	0.001342	1.324081	146.8962	0.198541	0.227036	1.845058
69	120	0.000738	0.702196	77.81519	0.109182	0.443920	1.714716
1532	20	0.094040	93.54473	10413.21	13.91189	0.003187	2.769304
1490	15.1	0.136566	120.5035	13429.35	20.20299	0.002789	2.850811
1760	15	0.055066	143.2887	16040.83	24.43531	0.002386	2.894083
2156	15	0.081053	175.5286	19694.41	35.96670	0.002340	2.979009

84.54326
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	DATA 1//f	1//f/Slv	1//f/L
14.63636	358.8990	39.02275	28.51379	1.948147	0.079447
14.28736	293.5770	37.36499	29.04852	2.033161	0.098946
13.94547	241.1291	35.74102	29.00081	2.079585	0.120270
13.47410	183.8259	33.50200	28.76279	2.134671	0.156467
12.82779	126.7149	30.43201	26.92019	2.098583	0.212446
12.82334	126.3910	30.41088	26.98918	2.104691	0.213537
12.42335	100.3965	28.51093	25.48289	2.051208	0.253822
11.89511	74.07279	26.00179	23.02594	1.935747	0.310855
12.54740	107.8280	29.10018	25.50901	2.033010	0.236571
13.25136	161.7038	32.44396	27.64129	2.085921	0.170937
13.62383	200.3725	34.21320	28.31268	2.078172	0.141300
12.85581	128.7753	30.56509	26.66937	2.074499	0.207100
11.88604	73.68697	25.95870	23.30369	1.960592	0.316252
11.57021	61.43766	24.45853	22.35994	1.932542	0.363945
11.54970	60.71658	24.36111	20.84885	1.805140	0.343379
11.24635	50.98802	22.92017	19.81775	1.762149	0.388674
11.03070	45.03574	21.89586	19.24743	1.744895	0.427381
10.71916	37.64189	20.41603	17.77439	1.658188	0.472197
10.50567	33.28891	19.40197	16.93281	1.611777	0.508662
10.51020	33.37575	19.42347	16.84377	1.602611	0.504670
10.12292	26.70619	17.58390	15.93831	1.574476	0.596802
9.891657	23.37729	16.48537	14.44605	1.460427	0.617952
9.731791	21.32199	15.72600	13.42208	1.379200	0.629494
9.543530	19.13210	14.83177	12.30639	1.289500	0.643232
9.249811	16.15596	13.43660	10.30656	1.114245	0.637941
8.960817	13.67994	12.06388	8.554672	0.954675	0.625343
8.598280	11.10325	10.34183	6.847301	0.796357	0.616693
8.352674	9.639369	9.175203	5.657776	0.677361	0.586944
8.024591	7.980460	7.616810	4.503562	0.561220	0.564323
7.804316	7.030063	6.570505	3.811336	0.488362	0.542148
7.523911	5.982158	5.238580	3.125047	0.415348	0.522394
7.285407	5.214731	4.105686	2.603959	0.357421	0.499346
6.980235	4.374604	2.656117	2.098707	0.300664	0.479747
6.458867	3.240387	0.179621	1.500885	0.232375	0.463180
10.67721	36.74381	20.21678	17.71253	1.658909	0.482054
11.00324	44.32937	21.76542	18.93405	1.720770	0.427122
11.17633	48.97372	22.58757	20.47122	1.831658	0.418004
11.51603	59.55108	24.20118	20.66965	1.794857	0.347091

W3P11371

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.893673	130.6030	0.277305	2.115953
1.250321	84.94250	0.097021	1.929125
0.946649	61.07024	-0.02381	1.785829
0.508102	30.13917	-0.29404	1.479131
0.651805	40.33658	-0.18588	1.605699
0.367915	21.02855	-0.43425	1.322809
0.280845	15.30878	-0.55153	1.184940
0.198541	10.37396	-0.70214	1.015944
0.109182	5.501595	-0.96184	0.740488

Regression Output:

Constant	-1.61444
Std Err of Y Est	0.005571
R Squared	0.999746
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	0.891927
Std Err of Coef.	0.006353

Tw vs. K'*(8<U>/D)^n

K' = 0.024296
n = 0.891927

Tw)Retro=37.35936
Res/f)R =982.1663

Regression Output:

Constant	1.728273
Std Err of Y Est	0.145225
R Squared	0.979781
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	7.594196
Std Err of Coef.	0.545460

t = 24.52631 deg C
s.d.)t = 0.401925 deg C

WSP11272 Pusher 500-F 12/25/90 15:26

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
S =	1	S =	7.25	S =	9.9	<C> (ppm)=	
Z =	4	Z =	9.3	Z =	6.95	[NaCl]=	
FlowCo=	0.019693	0.020236					

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
12	60	1.181580	25.4	3.404	0.0075	0.0145	3.3965
12	50	0.984650	25.4	2.3625	0.0075	0.0145	2.355
12	40	0.787720	25.4	1.542	0.0075	0.0145	1.5345
12	30	0.590790	25.4	0.912666	0.0075	0.0145	0.905166
12	20	0.393860	25.4	0.45425	0.0075	0.0145	0.44675
14	20	0.393860	25.4	1.4135	0.0075	0.0145	1.406
14	15	0.295395	25.4	0.882	0.0075	0.0145	0.8745
14	10	0.196930	25.4	0.47925	0.0075	0.0145	0.47175
12	35	0.689255	23.7	1.222	-0.0055	0.0075	1.2275
14	35	0.689255	23.7	3.863333	-0.0055	0.0075	3.868833
12	30	0.590790	25.4	11.284	0.0445	0.0525	11.2315
12	20	0.393860	25.4	5.824	0.0445	0.0525	5.7715
12	15	0.295395	25.4	3.727666	0.0445	0.0525	3.675166
12	10	0.196930	25.4	2.003857	0.0445	0.0525	1.951357
12	8	0.157544	25.4	1.4835	0.0445	0.0525	1.431
14			25.2	3.0712	0.0675	0.0515	3.0197
14			25.1	2.305	0.0465	0.0405	2.2585
14			25	1.8436	0.04	0.035	1.8036
14			25	1.33	0.0355	0.0315	1.2945
14			24.9	1.079666	0.0315	0.0295	1.048166
14			24.8	6.477	0.0115	0.0225	6.4655
14			24.7	4.269166	-0.0075	-0.0165	4.276666
14			24.7	3.013777	-0.0225	-0.0285	3.036277
14			24.7	2.237818	-0.0325	-0.039	2.270318
14			24.7	1.522571	-0.0425	-0.0475	1.565071
14			24.6	1.088785	-0.0535	-0.0585	1.142285
14			24.6	0.729173	-0.0625	-0.0635	0.791673
14			24.5	0.5594	-0.0665	-0.0695	0.6289
14			24.5	0.413333	-0.0715	-0.073	0.486333
14			24.35	0.303347	-0.0765	-0.0765	0.379847
14			24.3	0.215583	-0.0795	-0.08	0.295083
14			24.2	0.10748	-0.0825	-0.083	0.18998
14			24.1	0.11972	0.0175	0.0145	0.10222
14			24	0.054	0.0135	0.0105	0.0405
14			24.15	7.7522	0.0095	0.0215	7.7307
14			24.2	11.069	0.0155	0.0455	11.0235
12			24.1	4.4134	0.0345	0.0635	4.3499
12			24.1	6.054666	0.0585	0.0795	5.975166

		density	viscosity		
	co[NaCl]	1.000493	1.002495	ID(cm) =	1.02108
30.00705	X coeff	-0.00025	-0.02281	K(V/psi)=	1.159855 13.79691
0.010017	constant	0.003419	-4.14933	XS(cm2)=	0.818859

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		2.928388	1442.958	165890.9	1299.449	0.001251	3.768492
		2.030429	1202.465	138242.4	900.9871	0.001249	3.688972
		1.323012	961.9723	110593.9	587.0763	0.001271	3.595960
		0.780414	721.4792	82945.45	346.3029	0.001333	3.481341
		0.385178	480.9861	55296.96	170.9197	0.001481	3.328009
		1.212222	480.9861	55296.96	179.3300	0.001554	3.308439
		0.753974	360.7396	41472.72	111.5392	0.001718	3.235326
		0.406732	240.4930	27648.48	60.16995	0.002085	3.101303
		1.058323	841.7257	93128.64	469.6227	0.001328	3.530739
		3.335623	841.7257	93128.64	493.4553	0.001395	3.541488
		0.814059	721.4792	82945.45	361.2322	0.001391	3.490506
		0.418318	480.9861	55296.96	185.6254	0.001608	3.345931
		0.266376	360.7396	41472.72	118.2022	0.001821	3.247926
		0.141434	240.4930	27648.48	62.76037	0.002175	3.110455
		0.103718	192.3944	22118.78	46.02442	0.002492	3.043107
1841	15	0.218867	149.8832	17153.87	32.37820	0.002889	2.964769
1472	14.9	0.163696	120.6457	13776.58	24.21636	0.003335	2.900712
1285	15	0.130724	104.6170	11919.33	19.33878	0.003542	2.850886
1326	20.1	0.093825	80.56344	9178.838	13.88004	0.004287	2.778867
1120	20	0.075971	68.38779	7774.071	11.23878	0.004817	2.732046
1115	19.9	0.076475	68.42461	7760.728	11.31341	0.004843	2.732498
1064	25.2	0.050585	51.56222	5835.015	7.483369	0.005642	2.641765
1153	34.8	0.035913	40.46137	4578.792	5.312919	0.006505	2.567385
1140	39.9	0.026853	34.89173	3948.506	3.972633	0.006541	2.504256
1191	50	0.018512	29.08923	3291.870	2.738583	0.006487	2.423479
1101	60	0.013511	22.40921	2530.213	1.998786	0.007978	2.354114
1156	90	0.009364	15.68577	1771.073	1.385281	0.011285	2.274500
1041	99.9	0.007438	12.72552	1433.595	1.100457	0.013621	2.223533
806	100	0.005752	9.842957	1108.859	0.850992	0.017606	2.167709
606	100	0.004492	7.400536	830.8916	0.664662	0.024324	2.112569
476	100.1	0.003490	5.807155	651.2605	0.516240	0.030688	2.057244
306	100	0.002247	3.736904	418.1417	0.332429	0.047712	1.960640
164	99.9	0.001209	2.004790	223.8209	0.178865	0.089194	1.825069
96	150.1	0.000479	0.781054	87.00277	0.070867	0.232820	1.623043
1300	20	0.091440	79.37869	8872.082	13.52728	0.004302	2.764903
1258	15	0.130388	102.4188	11460.18	19.28906	0.003685	2.842446
1448	15	0.051451	117.8875	13161.52	22.83131	0.003292	2.878071
2391	20.1	0.070675	145.2693	16218.31	31.36184	0.002978	2.947006

84.54326
82.58
84.54326
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.67397	366.7522	39.20136	28.27025	1.926558	0.077082
14.35588	305.3883	37.69047	28.29233	1.970782	0.092643
13.98384	246.5133	35.92324	28.03953	2.005138	0.113744
13.52536	189.3308	33.74548	27.38112	2.024427	0.144620
12.91203	133.0115	30.83217	25.98316	2.012321	0.195345
12.95375	136.2447	31.03035	25.36656	1.958239	0.186183
12.54130	107.4501	29.07121	24.12323	1.923502	0.224506
12.00521	78.91926	26.52475	21.89617	1.823889	0.277450
13.72295	212.1384	34.68404	27.43745	1.999383	0.129337
13.76595	217.4566	34.88828	26.76668	1.944411	0.123090
13.56202	193.3688	33.91962	26.80934	1.976794	0.138643
12.98372	138.6155	31.17270	24.93270	1.920304	0.179869
12.59170	110.6129	29.31059	23.43346	1.861024	0.211850
12.04182	80.60017	26.69866	21.43953	1.780422	0.265998
11.77242	69.02197	25.41904	20.02875	1.701327	0.290179
11.45907	57.63007	23.93061	18.60343	1.623467	0.322807
11.20284	49.72698	22.71352	17.31527	1.545613	0.348206
11.00354	44.33706	21.76685	16.80216	1.526976	0.378964
10.71547	37.56192	20.39848	15.27283	1.425307	0.406604
10.52818	33.72304	19.50888	14.40793	1.368510	0.427242
10.52999	33.75817	19.51747	14.36823	1.364505	0.425622
10.16706	27.39336	17.79354	13.31302	1.309426	0.485994
9.869533	23.08146	16.38028	12.39845	1.256235	0.537160
9.617024	19.95887	15.18086	12.36450	1.285689	0.619499
9.293919	16.57142	13.64611	12.41546	1.335869	0.749209
9.016459	14.12520	12.32818	11.19547	1.241670	0.792588
8.698002	11.75927	10.81551	9.413168	1.082221	0.800488
8.494132	10.45714	9.847128	8.568278	1.008729	0.819370
8.270837	9.195795	8.706476	7.536455	0.911208	0.819554
8.050277	8.099334	7.738816	6.411727	0.796460	0.791636
7.828976	7.130570	6.687640	5.708348	0.729130	0.800545
7.442562	5.708482	4.852172	4.578074	0.615120	0.801977
6.900277	4.177817	2.276319	3.348353	0.485249	0.801459
6.092175	2.623758	-1.56216	2.072474	0.340186	0.789887
10.65961	36.37336	20.13316	15.24481	1.430146	0.419120
10.96978	43.48369	21.60648	16.47195	1.501574	0.378807
11.11228	47.20098	22.28335	17.42723	1.568285	0.369213
11.38802	55.32054	23.59312	18.32311	1.608981	0.331217

W3P11272

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.100457	99.70249	0.041573	1.998706
0.850992	77.11801	-0.07007	1.887155
0.664662	57.98203	-0.17739	1.763293
0.516340	45.49814	-0.28706	1.657993
0.332429	29.27805	-0.47830	1.466542
0.178865	15.70721	-0.74747	1.196099
0.070867	6.119435	-1.14955	0.786711

Regression Output:

Constant	-1.92379
Std Err of Y Est	0.005386
R Squared	0.999862
No. of Observations	7
Degrees of Freedom	5

X Coefficient(s)	0.985289
Std Err of Coef.	0.005169

Tw vs. K'*(8<U>/D)^n

K' = 0.011918
n = 0.985289

Tw* = 2.910660
Res/f* = 277.7211

Regression Output:

Constant	-34.6655
Std Err of Y Est	0.366634
R Squared	0.992509
No. of Observations	19
Degrees of Freedom	17

X Coefficient(s)	18.02250
Std Err of Coef.	0.379730

t = 24.79210 deg C
s.d.)t = 0.548745 deg C

W1P13163 Pusher 500-F 11/28/90 14:48

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14
S =	1	S =	7.25	S =	9.9 <C>(ppm)=
Z =	5	Z =	6.85	Z =	6.9 [NaCl]=
FlowCo=	0.019693	0.020236			

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
12	60	1.181580	25.3	7.188333	0.0495	0.0725	7.115833
12	50	0.984650	25.3	4.9385	0.0495	0.0725	4.866
12	39	0.768027	25.3	3.0885	0.0495	0.0725	3.016
12	29	0.571097	25.3	1.8316	0.0495	0.0725	1.7591
12	21	0.413553	25.3	1.077666	0.0495	0.0725	1.005166
12	15	0.295395	25.3	0.655666	0.0495	0.0725	0.583166
12	10	0.196930	25.3	0.388428	0.0495	0.0725	0.315928
12	7	0.137851	25.3	0.258666	0.0495	0.0725	0.186166
12	25	0.492325	24.6	1.54	0.0275	0.0625	1.4775
23	25	0.492325	24.6	1.539333	0.0275	0.0625	1.476833
34	25	0.492325	24.6	1.54475	0.0275	0.0625	1.48225
12	15	0.295395	24.55	0.68	0.0585	0.0165	0.6215
23	15	0.295395	24.55	0.693333	0.0585	0.0165	0.634833
34	15	0.295395	24.55	0.69725	0.0585	0.0165	0.63875
12	21	0.413553	25.4	12.2485	-0.0195	0.0085	12.24
12	15	0.295395	25.4	7.277333	-0.0195	0.0085	7.268833
12	10	0.196930	25.4	3.786666	-0.0195	0.0085	3.778166
12	8	0.157544	25.4	2.780333	-0.0195	0.0085	2.771833
12	6	0.118158	25.4	1.852	-0.0195	0.0085	1.8435
14			25.25	4.913	-0.0425	-0.036	4.949
14			25.2	3.749	-0.0365	-0.0405	3.7895
14			25.2	3.0848	-0.0405	-0.0425	3.1273
14			25.1	2.113	-0.0425	-0.0425	2.1555
14			25.1	1.6335	-0.0405	-0.0425	1.676
14			25	1.044571	-0.0395	-0.0405	1.085071
14			25	6.712333	0.0135	0.0045	6.707833
14			25	4.625875	0.0085	0.0015	4.624375
14			25	3.4397	0.0065	0.0045	3.4332
14			25	2.271538	0.0055	0.0075	2.266038
14			24.9	0.999941	0.0085	0.0105	0.991441
14			24.9	0.71175	0.0135	0.0195	0.69825
14			24.9	0.55175	0.0225	0.0305	0.50925
14			24.8	0.38264	0.0345	0.0435	0.34814
14			24.7	0.2776	0.0465	0.0555	0.2266
14			24.6	0.200888	0.0595	0.0655	0.136588
14			24.5	0.127111	0.0675	0.0725	0.055611
14			24.5	0.10604	0.0745	0.0785	0.02914
14			24.4	0.154035	0.0805	0.0835	0.071735
14			24.55	10.243	0.0845	0.0305	10.2125
14			24.7	13.2358	0.0315	0.0295	13.2063

12	24.7	8.463	0.0255	0.0635	8.3975
12	24.7	7.87	0.0695	0.0715	7.7985
12	24.7	10.1576	0.0835	0.0845	10.0731

	density	viscosity			
co[NaCl]	1.01234	1.029478	ID(cm) =	1.02108	
10.00012 X coeff	-0.00025	-0.02281	K(V/psi)=	1.17915	13.79691
0.300100 constant	0.003419	-4.14933	XS(cm2)=	0.818859	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		6.034714	1442.958	163087.3	2677.856	0.002548	3.915542
		4.126701	1202.465	135906.1	1831.191	0.002509	3.833016
		2.557774	937.9229	106006.7	1134.992	0.002556	3.729145
		1.491837	697.4299	78825.55	661.9910	0.002696	3.612075
		0.852450	505.0354	57080.57	378.2680	0.002938	3.490549
		0.494565	360.7396	40771.83	219.4594	0.003341	3.372326
		0.267929	240.4930	27181.22	118.8914	0.004072	3.239224
		0.157882	168.3451	19026.85	70.05892	0.004898	3.124381
		1.253021	601.2326	66888.37	556.0182	0.003047	3.567297
		1.252455	601.2326	66888.37	555.9675	0.003046	3.567277
		1.257049	601.2326	66888.37	557.8415	0.003057	3.568008
		0.527074	360.7396	40087.78	233.8851	0.003560	3.378761
		0.538382	360.7396	40087.78	238.9888	0.003638	3.383449
		0.541703	360.7396	40087.78	240.3921	0.003659	3.384720
		0.887155	505.0354	57209.49	393.6680	0.003058	3.500199
		0.526845	360.7396	40863.92	233.7833	0.003559	3.387041
		0.273841	240.4930	27242.61	121.5150	0.004162	3.244949
		0.200902	192.3944	21794.09	89.14888	0.004772	3.177692
		0.133616	144.2958	16345.56	59.29143	0.005642	3.089130
1696	15	0.358703	138.0782	15588.40	53.06478	0.005514	3.063559
1424	15	0.274662	115.9335	13073.62	40.63224	0.005989	3.005099
1255	15	0.226666	102.1746	11522.04	33.53192	0.006363	2.963393
1293	19.9	0.156230	79.34800	8927.769	23.11196	0.007272	2.881597
1105	20	0.121476	67.47188	7591.538	17.97061	0.007820	2.826960
1050	25	0.078645	51.29084	5757.933	11.63448	0.008761	2.731567
1052	25	0.080445	51.38854	5768.906	11.90071	0.008928	2.736480
1178	35	0.055459	41.10246	4614.184	8.204341	0.009621	2.655715
1141	40.2	0.041173	34.66172	3891.144	6.091016	0.010044	2.591038
1157	49.9	0.027176	28.31544	3178.707	4.020295	0.009934	2.500822
1074	60	0.011890	21.85967	2448.448	1.758966	0.007292	2.320337
1183	89.9	0.008373	16.06999	1799.960	1.238801	0.009503	2.244209
977	99.9	0.006107	11.94317	1337.725	0.903486	0.012548	2.175669
676	99.9	0.004175	8.263647	923.5053	0.617653	0.017918	2.092095
543	120	0.002717	5.525978	616.1549	0.402022	0.026031	1.997863
273	99.9	0.001638	3.337242	371.2751	0.242329	0.043104	1.886955
134	120	0.000666	1.363685	151.3709	0.098662	0.105100	1.690843
70	120.3	0.000349	0.710596	78.87716	0.051698	0.202821	1.550507
157	109.9	0.000860	1.744536	193.2151	0.127270	0.082834	1.745145
1080	20	0.122476	65.94537	7328.288	18.11852	0.008253	2.823321
1275	20	0.158380	77.85217	8680.777	23.42997	0.007658	2.880624

1220	15	0.076723	99.32513	11075.08	34.04558	0.006836	2.961788
1383	14.9	0.093525	117.3512	12839.04	41.50127	0.006398	3.004768
1627	14.9	0.120804	133.3496	14868.93	53.60603	0.005972	3.060344

83.38349
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.26217	514.5445	41.99531	19.80967	1.297959	0.038499
14.93206	425.4966	40.42730	19.96286	1.336912	0.046916
14.51658	334.9853	38.45376	19.77825	1.362459	0.059042
14.04830	255.8322	36.22943	19.25713	1.370780	0.075272
13.56219	193.3878	33.92043	18.44757	1.360220	0.095391
13.08930	147.3012	31.67420	17.29951	1.321652	0.117443
12.55689	108.4187	29.14526	15.66911	1.247849	0.144524
12.09752	83.22638	26.96323	14.28848	1.181107	0.171682
13.86918	230.7689	35.37865	18.11562	1.306177	0.078501
13.86911	230.7584	35.37827	18.11644	1.306244	0.078508
13.87203	231.1470	35.39215	18.08599	1.303773	0.078244
13.11504	149.5001	31.79647	16.75908	1.277851	0.112100
13.13379	151.1225	31.88553	16.57917	1.262329	0.109706
13.13888	151.5655	31.90968	16.53071	1.258152	0.109066
13.60079	197.7332	34.10379	18.08291	1.329548	0.091451
13.14816	152.3776	31.95378	16.76095	1.274775	0.109996
12.57979	109.8574	29.25403	15.49884	1.232042	0.141081
12.31076	94.09628	27.97615	14.47592	1.175874	0.153841
11.95652	76.73799	26.29347	13.31280	1.113434	0.173483
11.85423	72.35022	25.80763	13.46610	1.135973	0.186123
11.62039	63.23820	24.69689	12.92101	1.111924	0.204322
11.45357	57.44779	23.90447	12.53534	1.094448	0.218204
11.12638	47.58580	22.35035	11.72583	1.053880	0.246415
10.90784	41.96047	21.31224	11.30757	1.036646	0.269481
10.52626	33.68583	19.49977	10.68315	1.014904	0.317140
10.54592	34.06906	19.59312	10.58310	1.003526	0.310636
10.22286	28.28756	18.05859	10.19481	0.997256	0.360399
9.964154	24.37354	16.82973	9.977890	1.001378	0.409373
9.603290	19.80171	15.11563	10.03293	1.044738	0.506669
8.881349	13.06824	11.68640	11.70991	1.318483	0.896058
8.576837	10.96703	10.23997	10.25778	1.195987	0.935328
8.302677	9.365897	8.937718	8.926838	1.075175	0.953121
7.968382	7.726372	7.349816	7.470398	0.937505	0.966870
7.591453	6.219327	5.559404	6.192037	0.815659	0.995612
7.147823	4.817657	3.452162	4.816592	0.673854	0.999778
6.363375	3.067071	-0.27396	3.084598	0.484742	1.005714
5.802031	2.220178	-2.94035	2.220462	0.382704	1.000128
6.580582	3.475566	0.757766	3.474525	0.527996	0.999700
10.89328	41.61038	21.24311	11.00730	1.010466	0.264532
11.12249	47.47927	22.33185	11.42706	1.027382	0.240674

11.44707	57.23326	23.87760	12.09423	1.056535	0.211314
11.61707	63.19008	24.67060	12.50101	1.075904	0.197831
11.84137	71.81662	25.74655	12.94001	1.092779	0.180181

W1P13163

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.617653	64.74436	-0.20925	1.811202
0.402022	43.29516	-0.39574	1.636439
0.242329	26.14676	-0.61559	1.417417
0.127270	13.66855	-0.89527	1.135722
0.098662	10.68425	-1.00584	1.028744
0.051698	5.567410	-1.28651	0.745653

Regression Output:

Constant	-2.03292
Std Err of Y Est	0.001529
R Squared	0.999985
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 1.000281
Std Err of Coef. 0.002214

Tw vs. K'*(8<U>/D)^n

K' = 0.009269 958.4034
n = 1.000281

Tw* = 16.04068
Res/f* = 637.1778

Regression Output:

Constant	-18.9566
Std Err of Y Est	0.267569
R Squared	0.989581
No. of Observations	15
Degrees of Freedom	13

X Coefficient(s) 10.61729
Std Err of Coef. 0.302153

t = 24.95930 deg C
s.d.)t = 0.321380 deg C

WSP13166 Pusher 500-F 12/4/90 15:25

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 1 S = 7.25 S = 9.9 [C] (ppm)=

Z = 4.7 Z = 9.2 Z = 6.8 [NaCl]=

FlowCo= 0.019693

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
12	60	1.181580	24.9	3.944333	0.0135	0.0245	3.919833
12	50	0.984650	24.9	2.781	0.0135	0.0245	2.7565
12	40	0.787720	25.2	1.867666	0.0205	0.0215	1.846166
12	30	0.590790	25.2	1.1485	0.0205	0.0215	1.127
12	20	0.393860	25.2	0.6152	0.0205	0.0215	0.5937
12	15	0.295395	25.2	0.4098	0.0205	0.0215	0.3883
12	10	0.196930	25.2	0.24	0.0205	0.0215	0.2185
12	25	0.492325	24	0.876	0.0065	0.0295	0.8465
23	25	0.492325	24	0.885	0.0065	0.0295	0.8555
34	25	0.492325	24	0.8658	0.0065	0.0295	0.8363
12	35	0.689255	23.9	1.47475	0.0325	0.0195	1.44225
12	15	0.295395	23.9	0.417666	0.0325	0.0195	0.385166
12	30	0.590790	25.15	13.41	0.0515	0.0785	13.3315
12	25	0.492325	25.15	10.25766	0.0515	0.0785	10.17916
12	20	0.393860	25.15	7.23275	0.0515	0.0785	7.15425
12	15	0.295395	25.15	4.798166	0.0515	0.0785	4.719666
12	10	0.196930	25.15	2.6805	0.0515	0.0785	2.602
12	8	0.157544	25.15	2.0228	0.0515	0.0785	1.9443
14			24.9	4.0262	-0.0015	-0.0055	4.0317
14			24.9	3.0386	0.0115	-0.0095	3.0481
14			24.8	2.6102	0.0025	-0.0045	2.6147
14			24.8	1.8036	-0.0025	0.0125	1.7911
14			24.6	1.4602	0.0125	-0.0065	1.4667
14			24.6	0.989333	-0.0045	0.0165	0.972833
14			24	6.197	0.0565	-0.0005	6.1405
14			24.2	4.53725	0	0.0025	4.53725
14			24.2	3.476222	0	0.0015	3.476222
14			24.2	2.495	-0.0025	-0.0025	2.4975
14			24.2	1.07725	-0.0065	-0.0085	1.08375
14			24.2	0.77275	-0.0115	-0.0135	0.78425
14			24.1	0.559636	-0.0165	-0.0175	0.576636
14			24.1	0.410740	-0.0185	-0.0175	0.428740
14			23.9	0.284961	-0.0215	-0.0215	0.306461
14			23.9	0.197681	-0.0235	-0.0235	0.221181
14			23.8	0.151153	-0.0235	-0.0245	0.175653
14			23.8	0.10475	-0.0265	-0.0275	0.13225
14			23.7	0.051666	-0.0285	-0.0305	0.080166
14			23.7	0.012928	-0.0305	-0.0325	0.045428
14			23.8	9.0296	-0.0335	-0.0395	9.0691
14			23.9	10.96475	-0.0525	-0.0525	11.01725

		density	viscosity			
	co[NaCl]	1.01234	1.029473	ID(cm) =	1.02108	
30.00531	X coeff	-0.00025	-0.02281	K(V/psi)=	1.17915	13.79691
0.300089	constant	0.003419	-4.14933	XS(cm2)=	0.818859	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		3.324287	1442.958	161622.2	1475.126	0.001403	3.782123
		2.337700	1202.465	134685.2	1037.336	0.001421	3.705668
		1.585675	961.9723	108479.8	694.7562	0.001487	3.621580
		0.955773	721.4792	81359.92	424.1167	0.001614	3.514406
		0.503498	480.9861	54239.94	223.4233	0.001913	3.375223
		0.329305	360.7396	40679.96	146.1264	0.002224	3.283028
		0.185302	240.4930	27119.97	82.22672	0.002816	3.153170
		0.717890	601.2326	65989.07	318.5580	0.001745	3.440435
		0.725522	601.2326	65989.07	322.0608	0.001764	3.442810
		0.709239	601.2326	65989.07	314.7396	0.001724	3.437817
		1.223126	841.7257	92176.52	542.7528	0.001517	3.555157
		0.326647	360.7396	39504.22	144.9473	0.002206	3.268461
		0.966267	721.4792	81268.20	428.7733	0.001632	3.516285
		0.737785	601.2326	67723.50	327.3866	0.001794	3.457702
		0.518540	480.9861	54178.80	230.0980	0.001970	3.381127
		0.342081	360.7396	40634.10	151.7959	0.002211	3.290801
		0.188592	240.4930	27089.40	83.68662	0.002866	3.161499
		0.140722	192.3944	21671.52	62.53340	0.003347	3.098227
1840	15.1	0.292217	148.8097	16667.82	43.22919	0.007867	3.015597
1493	15	0.220926	121.5511	13614.65	32.68271	0.004382	2.954867
1294	14.9	0.189513	106.0568	11852.39	28.03566	0.004937	2.920578
1335	20	0.129818	81.51581	9109.813	19.20475	0.005725	2.838427
1143	20	0.106306	69.73112	7757.732	15.72643	0.006407	2.797068
843	19.9	0.070510	51.73269	5755.368	10.43103	0.007721	2.703916
1060	24.9	0.077108	51.98729	5705.931	10.81537	0.007926	2.705862
1193	34.9	0.054020	41.74510	4602.508	7.991541	0.009083	2.642127
1158	40	0.041388	35.35404	3897.877	6.122733	0.009703	2.584284
1095	45.2	0.029735	29.58463	3261.784	4.398892	0.009955	2.512483
1115	60	0.012903	22.69416	2502.091	1.908828	0.007741	2.371195
1266	90	0.009337	17.17836	1893.959	1.381313	0.009272	2.260958
945	90.3	0.006665	12.78011	1405.865	1.015640	0.012317	2.192196
875	109.9	0.005104	9.723014	1069.572	0.755148	0.015822	2.129843
627	110	0.003648	6.960900	762.2910	0.539776	0.022064	2.053963
411	99.9	0.002633	5.024199	550.1949	0.389571	0.030568	1.987150
328	100.1	0.002091	4.001569	437.2202	0.309382	0.038268	1.932119
246	99.9	0.001574	3.007185	328.5716	0.232934	0.051017	1.870488
149	100	0.000954	1.819603	198.3659	0.141199	0.084463	1.769801
89	105	0.000540	1.025121	112.8447	0.080014	0.147902	1.677469
1130	20.1	0.107977	68.65512	7501.410	15.97357	0.006712	2.703572
981	15	0.131171	79.86717	8746.172	19.40488	0.006025	2.871812

83.99103
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.72849	378.4452	39.46033	26.69181	1.812257	0.070530
14.42267	317.3571	38.00769	26.52477	1.839102	0.083580
14.08632	261.4931	36.41002	25.92799	1.840650	0.099153
13.65762	204.3086	34.37372	24.88878	1.822335	0.121819
13.10091	148.2888	31.72933	22.86077	1.744975	0.154163
12.73211	119.9246	29.97754	21.20078	1.665142	0.176784
12.23268	89.96024	27.60524	18.84163	1.540270	0.209444
13.36174	172.3121	32.96828	23.93514	1.791318	0.138905
13.37124	173.2569	33.01340	23.80462	1.780285	0.137394
13.35126	171.2763	32.91853	24.07989	1.803565	0.140590
13.82063	224.4076	35.14799	25.67217	1.857525	0.114399
12.67384	115.9689	29.70077	21.29030	1.679861	0.183586
13.66514	205.1945	34.40942	24.75342	1.811428	0.120634
13.43080	179.3007	33.29633	23.60681	1.757661	0.131660
13.12451	150.3169	31.84143	22.52690	1.716399	0.149862
12.76320	122.0904	30.12522	20.80123	1.629781	0.170375
12.24599	90.65245	27.66849	18.67868	1.525125	0.206025
11.99291	78.36236	26.46632	17.28470	1.441243	0.220573
11.66238	64.78539	24.89634	16.07984	1.378777	0.248201
11.41947	56.33101	23.74248	15.10563	1.322796	0.268158
11.28231	52.05455	23.09099	14.23074	1.261331	0.273381
10.95371	43.08317	21.53012	13.21544	1.206481	0.306742
10.77227	38.81039	20.66829	12.49300	1.159736	0.321898
10.41566	31.60797	18.97441	11.38037	1.092620	0.360047
10.42345	31.74991	19.01138	11.23217	1.077587	0.353770
10.16850	27.41621	17.80042	10.49221	1.031834	0.382701
9.937139	23.99743	16.70141	10.15180	1.021602	0.423037
9.649935	20.34060	15.33719	10.02239	1.038597	0.492728
8.924782	13.39909	11.89271	11.67098	1.307705	0.871027
8.643833	11.39825	10.55820	10.38514	1.201451	0.911116
8.372787	9.751622	9.270740	9.010461	1.076160	0.923996
8.115372	8.408591	8.048021	7.949996	0.979621	0.945461
7.815853	7.076906	6.625305	6.732117	0.861341	0.951279
7.532600	6.012155	5.279853	5.719610	0.759314	0.951341
7.328476	5.345632	4.510262	5.111886	0.697557	0.956273
7.081952	4.638099	3.139274	4.427331	0.625156	0.954495
6.643207	3.603147	1.055257	3.440844	0.517949	0.954955
6.149878	2.712374	-1.28807	2.600230	0.422810	0.958654
10.75428	38.41071	20.58287	12.20592	1.134981	0.317773
10.92724	42.43186	21.40442	12.88267	1.178949	0.303608

W3P13166

Tw dyne/cm2	8 U>/D (1/sec)	Log Tw	Log 8 U>/D
0.755140	76.17827	-0.12196	1.881831
0.539776	54.53755	-0.26778	1.736695
0.389571	39.36381	-0.40941	1.595097
0.309382	31.35166	-0.50950	1.496260
0.232934	23.56082	-0.63276	1.372190
0.141199	14.25630	-0.85016	1.154007
0.080014	8.110012	-1.09683	0.909021

Regression Output:

Constant	-2.00575
Std Err of Y Est	0.000732
R Squared	0.999993
No. of Observations	6
Degrees of Freedom	4

X Coefficient(s) 1.000737
Std Err of Coef. 0.001260

Tw vs. K'*(8<U>/D)^n

K' = 0.009868
n = 1.000737

Tw* = 8.454763
Res/f* = 458.4154

Regression Output:

Constant	-35.5759
Std Err of Y Est	0.328825
R Squared	0.995960
No. of Observations	24
Degrees of Freedom	22

X Coefficient(s) 17.21778
Std Err of Coef. 0.233775

t = 24.47 deg C
s.d.)t = 0.550204 deg C

W1P23169 Pusher 500-F 12/11/90 16:00

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 1 S = 7.25 S = 9.9 <C>(ppm)=

Z = 4.5 Z = 9.2 Z = 6.9 [NaCl]=

FlowCo= 0.019693

Tap Pair	Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
12	60	1.181580	25.4	2.096	-0.0445	-0.0405	2.1365
12	49	0.964957	25.4	1.49	-0.0445	-0.0405	1.5305
12	41	0.807413	25.4	1.070666	-0.0445	-0.0405	1.111166
12	32	0.630176	25.4	0.7315	-0.0445	-0.0405	0.772
12	23	0.452939	25.4	0.439	-0.0445	-0.0405	0.4795
12	25	0.492325	25.4	0.493	-0.0445	-0.0405	0.5335
14	25	0.492325	25.4	1.533	-0.0425	-0.0465	1.5795
14	20	0.393860	25.4	1.0918	-0.0425	-0.0465	1.1383
14	15	0.295395	25.4	0.6528	-0.0425	-0.0465	0.6993
14	10	0.196930	25.4	0.3744	-0.0425	-0.0465	0.4209
14	30	0.590790	25.4	2.0135	-0.0425	-0.0465	2.06
14	40	0.787720	25.4	3.228	-0.0425	-0.0465	3.2745
12	20	0.393860	25.5	0.354	-0.0745	-0.0455	0.3995
14	20	0.393860	25.5	1.08425	-0.0745	-0.0455	1.12975
12	30	0.590790	25.35	8.7035	0.0725	0.0325	8.631
12	25	0.492325	25.35	6.6485	0.0725	0.0325	6.576
12	20	0.393860	25.35	4.677	0.0725	0.0325	4.6045
12	15	0.295395	25.35	3.1005	0.0725	0.0325	3.028
12	10	0.196930	25.35	1.7535	0.0725	0.0325	1.681
12	35	0.689255	25.35	11.0305	0.0725	0.0325	10.958
14			25.1	2.9442	0.0295	0.0285	2.9157
14			25	2.25075	0.0285	0.0235	2.22725
14			25	1.9242	0.0245	0.0225	1.9017
14			25	1.447166	0.0245	0.0235	1.423666
14			24.9	1.261	0.0245	0.0225	1.2385
14			24.9	7.482833	0.0195	0.0255	7.457333
14			24.8	5.136428	0.0195	0.0195	5.116928
14			24.8	3.811625	0.0185	0.0175	3.793125
14			24.7	3.0495	0.0155	0.0155	3.034
14			24.7	1.647	0.0145	0.0135	1.6325
14			24.6	1.176437	0.0125	0.0125	1.163937
14			24.5	0.8455	0.0115	0.0115	0.834
14			24.5	0.700227	0.0115	0.0125	0.688727
14			24.4	0.558227	0.0115	0.0135	0.545727
14			24.3	0.440043	0.0125	0.0135	0.426743
14			24.2	0.339136	0.0125	0.0135	0.325836
14			24.1	0.257818	0.0125	0.0125	0.245318
14			24	0.201681	0.0125	0.0125	0.189181
14			23.9	0.153636	0.0115	0.0115	0.142136
14			23.8	0.105045	0.0105	0.0095	0.094545

14	23.8	0.058818	0.0095	0.0085	0.060318
14	24.1	8.6148	0.0075	0.0015	8.6133
14	24.1	11.32175	-0.0045	-0.0045	11.32625
14	24.1	13.1175	-0.0065	-0.0055	13.123
12	23.9	4.518	0.0515	0.0495	4.4685
12	23.8	5.8448	0.0485	0.0485	5.7963

		density	viscosity			
	co[NaCl]	1.01234	1.029478	ID(cm) = 1.02108		
99.78648	X coeff	-0.00025	-0.02281	K(V/ps1)=1.159853	13.79691	
0.299942	constant	0.003419	-4.14933	XS(cm2)= 0.818859		

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		1.842043	1442.958	163455.6	817.3923	0.000777	3.658849
		1.319563	1178.416	133488.8	585.5459	0.000835	3.586414
		0.958023	986.0216	111694.7	425.1154	0.000866	3.516887
		0.665601	769.5778	87176.37	295.3554	0.000988	3.437806
		0.413414	553.1340	62658.01	183.4493	0.001188	3.334392
		0.459972	601.2326	68106.54	204.1089	0.001118	3.357565
		1.361810	601.2326	68106.54	201.4593	0.001104	3.354728
		0.981417	480.9861	54485.23	145.1859	0.001243	3.283596
		0.602921	360.7396	40863.92	89.19311	0.001358	3.177800
		0.362890	240.4930	27242.61	53.68423	0.001839	3.067557
		1.776087	721.4792	81727.84	262.7453	0.001000	3.412402
		2.823202	961.9723	108970.4	417.6503	0.000894	3.513040
		0.344440	480.9861	52199.12	152.8426	0.001308	3.276037
		0.974045	480.9861	52199.12	144.0954	0.001233	3.263240
		0.625574	721.4792	81635.71	277.5938	0.001056	3.423846
		0.476628	601.2326	68029.75	211.5001	0.001159	3.364797
		0.333734	480.9861	54423.80	148.0918	0.001268	3.287407
		0.219469	360.7396	40817.85	97.38782	0.001482	3.196394
		0.121838	240.4930	27211.90	54.06503	0.001852	3.068600
		0.794235	841.7257	95241.66	352.4358	0.000985	3.475681
1792	14.9	0.211329	146.8731	16525.29	31.26308	0.002871	2.947194
1448	15.1	0.161431	117.1068	13146.47	23.88129	0.003450	2.887722
1253	14.9	0.137835	102.6964	11528.75	20.39064	0.003830	2.853409
1311	20	0.103187	80.05035	8986.497	15.26501	0.004719	2.790542
1110	20	0.089766	67.77719	7591.558	13.27959	0.005727	2.759300
1110	20	0.087959	67.77719	7591.558	13.01229	0.005611	2.754885
1033	25	0.060354	50.46042	5639.213	8.928522	0.006946	2.672113
969	30	0.044740	39.44510	4408.194	6.618619	0.008427	2.607107
1129	40	0.035786	34.46867	3843.371	5.294022	0.008827	2.557631
1043	44.9	0.019255	28.36798	3163.125	2.848547	0.007012	2.423049
1099	60	0.013728	22.36850	2488.542	2.030953	0.008041	2.348602
1018	74.9	0.009837	16.59802	1842.403	1.455245	0.010464	2.275235
1016	90.1	0.008123	13.77081	1528.578	1.201759	0.012553	2.233676
809	90	0.006436	10.97732	1215.752	0.952238	0.015653	2.182155
632	90	0.005033	8.575612	947.6193	0.744624	0.020056	2.127765
484	89.9	0.003843	6.574704	724.8785	0.568551	0.026053	2.068197
364	90	0.002893	4.939118	543.3237	0.428055	0.034756	2.005576
280	89.9	0.002231	3.803548	417.4633	0.330103	0.045195	1.948166
209	90	0.001676	2.835922	310.5589	0.248013	0.061080	1.885094
139	89.9	0.001115	1.888189	206.3077	0.164972	0.091647	1.795576

74	90	0.000587	1.004106	109.7108	0.087800	0.172479	1.638618
1600	25.1	0.101594	77.84607	8563.397	15.02933	0.004912	2.773296
1231	15	0.133593	100.2206	11024.69	19.76315	0.003897	2.837755
1411	15	0.154786	114.8752	12636.75	22.89830	0.003437	2.869728
1402	14.9	0.052706	114.9085	12583.51	23.38793	0.003508	2.872352
1747	15	0.068367	142.2303	15540.39	30.33758	0.002970	2.927861

84.78139
4
C.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.23539	284.9244	37.11814	35.85504	2.518724	0.125840
13.94565	241.1542	35.74188	34.59631	2.480794	0.143461
13.66755	205.4792	34.42087	33.97384	2.485730	0.165339
13.35122	171.2722	32.91833	31.81206	2.382706	0.185739
12.93757	134.9810	30.95345	29.01242	2.242493	0.214937
13.03026	142.3788	31.39374	29.89670	2.294405	0.209979
13.01891	141.4517	31.33983	30.09266	2.311457	0.212741
12.73438	120.0816	29.96833	28.35842	2.226916	0.236159
12.31120	94.11962	27.97820	27.13563	2.204141	0.288310
11.87023	73.01933	25.88359	23.31798	1.964408	0.319339
13.24960	161.5407	32.43563	31.62045	2.386519	0.195742
13.65216	203.6671	34.34777	33.44012	2.449437	0.164190
12.70415	118.0097	29.84472	27.64555	2.176103	0.234264
12.65296	114.5831	29.60157	28.47228	2.250246	0.248485
13.29538	165.8543	32.65309	30.76332	2.313834	0.185484
13.05918	144.7695	31.53114	29.36985	2.248979	0.202873
12.74963	121.1399	30.06074	28.07898	2.202337	0.231789
12.38557	98.23680	28.33149	25.96904	2.096716	0.264351
11.87440	73.19478	25.90340	23.23586	1.956802	0.317452
13.50272	186.8796	33.63795	31.85261	2.358976	0.170444
11.38877	55.34454	23.59670	18.66183	1.638616	0.337193
11.15089	48.26170	22.46673	17.02498	1.526782	0.352763
11.01363	44.59531	21.81477	16.15747	1.467042	0.362313
10.76216	38.58534	20.62030	14.55620	1.352534	0.377246
10.63720	35.90715	20.02671	13.21386	1.242231	0.368000
10.61954	35.54392	19.94282	13.34890	1.257013	0.375560
10.28845	29.37603	18.37014	11.99790	1.166152	0.408424
10.02842	25.29222	17.13503	10.89315	1.086227	0.430691
9.830524	22.56893	16.19498	10.64342	1.082691	0.471596
9.292199	16.55502	13.63794	11.94171	1.285132	0.721334
8.994411	13.94706	12.22345	11.15173	1.239851	0.799575
8.700943	11.77920	10.82948	9.775725	1.123524	0.829914
8.534705	10.70425	10.03985	8.925064	1.045737	0.833786
8.328621	9.506824	9.060953	7.992629	0.959658	0.840725
8.111063	8.387758	8.027551	7.061029	0.870543	0.841825
7.872788	7.312687	6.895743	6.195384	0.786936	0.847210
7.622307	6.330775	5.705961	5.363913	0.703712	0.847275
7.392666	5.546851	4.615164	4.703832	0.636283	0.848018
7.140376	4.797050	3.416790	4.046222	0.566667	0.843481
6.782307	3.903523	1.715959	3.303230	0.487036	0.846217

6.234475	2.847730	-0.38624	2.407857	0.386216	0.845535
10.71318	37.51257	20.38763	14.26754	1.331774	0.380340
10.95102	43.01650	21.51734	16.01811	1.462705	0.372371
11.07891	46.30294	22.12484	17.05716	1.539606	0.368381
11.08940	46.58353	22.17469	16.80299	1.522443	0.362424
11.31144	52.93486	23.22937	18.34849	1.622117	0.346623

W1P23169

Tw dyne/cm2	B<U>/D (1/sec)	Log Tw	Log B<U>/D
0.744624	67.18856	-0.12806	1.827295
0.330103	29.80019	-0.48135	1.474219
0.568351	51.51176	-0.24523	1.711906
0.428055	38.69721	-0.36850	1.587679
0.330103	29.80019	-0.48135	1.474219
0.248013	22.21900	-0.60552	1.346724
0.164972	14.79366	-0.78258	1.170075
0.087800	7.867015	-1.05650	0.895810

Regression Output:

Constant	-1.94712
Std Err of Y Est	0.001210
R Squared	0.999985
No. of Observations	8
Degrees of Freedom	6

X Coefficient(s)	0.994774
Std Err of Coef.	0.001530

Tw vs. K'*(B<U>/D)^n

K' =	0.011294
n =	0.994774

Tw* = 8.152721
Res/f* = 455.2875

Regression Output:

Constant	-72.6186
Std Err of Y Est	0.298369
R Squared	0.992233
No. of Observations	13
Degrees of Freedom	11

X Coefficient(s)	31.16738
Std Err of Coef.	0.831407

t = 24.75869 deg C
s.d.)t = 0.623742 deg C

A3P11409 ALCOMER 507 8/10/90 12:11

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C> (ppm)=

Z = 2.7 Z = 9.05 Z = 6.85 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.8	8.278333	0.0245	0.0455	8.253833
51	1.032036	24.8	6.184	0.0245	0.0455	6.1595
42	0.849912	24.8	4.415666	0.0245	0.0455	4.391166
34	0.688024	24.8	3.027	0.0245	0.0455	3.0025
30	0.60708	24.8	2.451333	0.0395	0.0385	2.412833
24	0.485664	24.8	1.6545	0.0395	0.0385	1.616
17	0.344012	24.8	0.919666	0.0395	0.0385	0.881166
13	0.263068	24.8	0.618	0.0395	0.0385	0.5795
10	0.20236	24.8	0.3846	0.0395	0.0385	0.3461
8	0.161888	24.8	0.271	0.0395	0.0385	0.2325
18	0.364248	24.8	11.3605	0.0375	0.0665	11.294
13	0.263068	24.8	6.64725	0.0375	0.0665	6.58075
10	0.20236	24.8	4.281125	0.0375	0.0665	4.214625
8	0.161888	24.8	2.903	0.0375	0.0665	2.8365
		24.6	2.7774	0.0735	0.0635	2.7139
		24.6	1.946	0.0645	0.0635	1.8815
		24.5	1.5126	0.0635	0.0625	1.4491
		24.5	0.957	0.0645	0.0625	0.8925
		24.45	0.70425	0.0605	0.0585	0.64375
		24.4	0.4452	0.0605	0.0605	0.3847
		24.3	2.486285	0.0075	0.0095	2.476785
		24.2	1.638571	0.0105	0.0145	1.624071
		24.2	1.118888	0.0155	0.0165	1.102388
		24.2	0.613833	0.0175	0.0175	0.596333
		24.15	0.443928	0.0175	0.0175	0.426428
		24.1	0.3276	0.0175	0.0185	0.3091
		24.1	0.228818	0.0185	0.0185	0.210318
		24	0.14976	0.0185	0.0195	0.13026
		23.9	0.08775	0.0195	0.0195	0.06825
		23.8	0.0361	0.0195	0.0195	0.0166
		23.7	0.05712	0.0195	0.017	0.04012
		23.8	4.088	0.017	0.0125	4.071
		24	5.531	0.0115	0.0145	5.5165
		24.1	8.894	0.0135	0.0165	8.8805
		24.2	11.93475	0.0155	0.0165	11.91925

		density	viscosity			
	co)[NaCl]	1.000088	1.001574		ID(cm) = 1.45796	
29.97317	X coeff	-0.00025	-0.02281		K(V/psi)=1.077888	12.75206
0.000100	constant	0.003419	-4.14933		XS(cm2)= 1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		7.657412	727.2685	117840.3	1080.291	0.004095	3.877469
		5.714415	618.1782	100164.3	806.1776	0.004230	3.813914
		4.073861	509.0880	82488.26	574.7317	0.004447	3.740431
		2.785539	412.1188	66776.21	392.9780	0.004640	3.657883
		2.238482	363.6342	58920.18	315.8003	0.004789	3.610405
		1.499228	290.9074	47136.15	211.5079	0.005012	3.523362
		0.817493	206.0594	33388.10	115.3302	0.005447	3.391670
		0.537625	157.5748	25532.08	75.84705	0.006125	3.300668
		0.321090	121.2114	19640.06	45.29881	0.006183	3.188742
		0.215699	96.96914	15712.05	30.43044	0.006489	3.102353
		0.885660	218.1805	35352.11	124.9471	0.005263	3.409062
		0.516053	157.5748	25532.08	72.80378	0.005880	3.291776
		0.330505	121.2114	19640.06	46.62700	0.006364	3.195017
		0.222434	96.96914	15712.05	31.38060	0.006692	3.109029
2365	15.1	0.212820	93.81517	15132.57	30.02426	0.006840	3.097464
1904	15	0.147544	76.03167	12264.06	20.81530	0.007220	3.017920
1626	15	0.113636	64.93041	10449.80	16.03160	0.007625	2.960231
1216	15	0.069988	48.55804	7814.860	9.873856	0.008397	2.854986
1242	20	0.050482	40.19216	6461.175	7.121899	0.008840	2.783548
1005	20	0.030167	30.09920	4833.204	4.255991	0.009419	2.671258
1256	25	0.030601	30.09321	4821.353	4.317263	0.009559	2.673377
1174	29.9	0.020066	23.51883	3759.555	2.830904	0.010261	2.580750
1165	35.2	0.013620	19.82449	3169.004	1.921564	0.009803	2.496615
1057	40	0.007368	15.82828	2530.198	1.039463	0.008319	2.363192
1027	49.9	0.005268	12.32789	1968.428	0.743303	0.009806	2.289878
916	60.1	0.003819	9.129350	1456.065	0.538789	0.012961	2.219512
637	59.8	0.002598	6.380535	1017.649	0.366603	0.018055	2.135901
650	100	0.001609	3.893428	619.5743	0.227055	0.030031	2.030883
342	100	0.000843	2.048542	325.2568	0.118965	0.056837	1.889543
87	100.1	0.000205	0.520599	82.47184	0.028935	0.214047	1.581561
201	99.9	0.000495	1.205173	190.4896	0.069932	0.096529	1.772202
1330	20	0.050299	39.85277	6310.186	7.096124	0.008966	2.776357
1200	15	0.068159	47.91912	7625.530	9.615763	0.008396	2.844309
1601	15	0.109723	63.93210	10196.70	15.47952	0.007593	2.948681
1865	14.9	0.147268	74.97413	11984.83	20.77634	0.007411	3.013572

Tap DL= 122.2234
80.93545 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.10987	471.3565	41.27192	15.62516	1.034102	0.033149
14.85565	407.1875	40.06437	15.37441	1.034919	0.037757
14.56172	343.8046	38.66820	14.99548	1.029787	0.043616
14.23153	284.2910	37.09978	14.68042	1.031541	0.051638
14.04162	254.8504	36.19770	14.44969	1.029061	0.056698
13.69344	208.5654	34.54388	14.12510	1.031522	0.067725
13.16668	154.0106	32.04174	13.54943	1.029069	0.087977
12.80267	124.8959	30.31270	12.77667	0.997969	0.102298
12.35497	96.52116	28.18610	12.71745	1.029339	0.131758
12.00941	79.11033	26.54471	12.41308	1.033612	0.156908
13.23624	160.3032	32.37218	13.78329	1.041329	0.085982
12.76710	122.3646	30.14374	13.04097	1.021451	0.106574
12.38007	97.92596	28.30533	12.53502	1.012515	0.128005
12.03611	80.33592	26.67156	12.22371	1.015585	0.152157
11.98985	78.22488	26.45183	12.09060	1.008402	0.154562
11.67168	65.13285	24.94048	11.76831	1.008279	0.180681
11.44092	57.03112	23.84440	11.45186	1.000955	0.200800
11.01994	44.75761	21.84475	10.91275	0.990272	0.243818
10.73419	37.96897	20.48742	10.63561	0.990816	0.280113
10.28503	29.31829	18.35391	10.30330	1.001776	0.351429
10.29350	29.46167	18.39417	10.22802	0.993637	0.347163
9.923002	23.80293	16.63426	9.871564	0.994816	0.414720
9.586461	19.61080	15.03569	10.09967	1.053535	0.515005
9.052770	14.42356	12.50065	10.96382	1.211101	0.760132
8.759514	12.18312	11.10769	10.09813	1.152818	0.828862
8.478049	10.36077	9.770733	8.783519	1.036030	0.847766
8.143604	8.546360	8.182122	7.442123	0.913861	0.870794
7.723532	6.710627	6.186779	5.770458	0.747126	0.859898
7.158174	4.846449	3.501330	4.194524	0.585976	0.865483
5.926244	2.384741	-2.35033	2.161446	0.364724	0.906365
6.688809	3.698984	1.271846	3.218613	0.481193	0.870134
10.70543	37.34545	20.35079	10.56049	0.986461	0.282778
10.97723	43.67062	21.64187	10.91341	0.994185	0.249902
11.39472	55.53432	23.62494	11.47567	1.007104	0.206641
11.65428	64.48407	24.85787	11.61608	0.996721	0.180138

A3F11409

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.921564	108.7793	0.283654	2.036546
1.039463	86.85169	0.016809	1.938778
0.743303	67.64460	-0.12883	1.830233
0.538789	50.09383	-0.26858	1.699784
0.227055	21.36370	-0.64386	1.329676
0.118965	11.24059	-0.92457	1.050789
0.069932	6.612928	-1.15531	0.820393
0.028935	2.856593	-1.53857	0.455848

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.98364
Std Err of Y Est	0.001319
R Squared	0.999992
No. of Observations	4
Degrees of Freedom	2

X Coefficient(s) 1.008488
Std Err of Coef. 0.002011

Tw = K'(8<U>/D)^n'

K' = 0.010383
n' = 1.008488

Tw* = 0.189848
Res/f* = 99.97756

Regression Output:

Constant	-0.94047
Std Err of Y Est	0.026063
R Squared	0.998909
No. of Observations	7
Degrees of Freedom	5

X Coefficient(s) 4.270249
Std Err of Coef. 0.063104

t = 24.42857 deg C
s.d.)t = 0.362390 deg C

A1P21403 ALCOMER 507 8/4/90 12:25

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)

Z = 2.7 Z = 9 Z = 6.9 [NaCl]=

-

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.8	7.221666	0.0245	0.0345	7.187166
50	1.0118	24.8	5.175666	0.0245	0.0345	5.141166
41	0.829676	24.8	3.644	0.0245	0.0345	3.6095
32	0.647552	24.8	2.374	0.0245	0.0345	2.3395
25	0.5059	24.7	1.554	0.0335	0.0315	1.5225
19	0.384484	24.7	0.98875	0.0335	0.0315	0.95725
14	0.283304	24.7	0.61375	0.0335	0.0315	0.58225
10	0.20236	24.7	0.357166	0.0335	0.0315	0.325666
7	0.141652	24.7	0.220571	0.0335	0.0315	0.189071
18	0.364248	24.4	10.2885	0.0395	0.0575	10.231
14	0.283304	24.4	7.1415	0.0395	0.0575	7.084
10	0.20236	24.4	3.687909	0.0395	0.0575	3.630409
7	0.141652	24.4	2.16325	0.0395	0.0575	2.10575
		23.8	2.7208	0.0315	0.0205	2.6893
		23.8	1.89875	0.0175	0.0155	1.88125
		23.75	1.388	0.0145	0.013	1.3735
		23.8	0.721666	0.0135	0.0105	0.708166
		23.7	0.554	0.0125	0.0115	0.5415
		23.6	3.424166	0.0185	0.0195	3.404666
		23.6	2.58	0.0195	0.0205	2.5595
		23.6	2.122222	0.0205	0.0205	2.101722
		23.6	1.796363	0.0195	0.0195	1.776863
		23.55	1.536583	0.0175	0.0175	1.517083
		23.5	1.22675	0.0165	0.0165	1.21025
		23.4	0.949187	0.0145	0.0145	0.934687
		23.3	0.6514	0.0125	0.0155	0.6359
		23.1	0.318	0.0125	0.0145	0.3035
		23.05	0.475235	0.0145	0.0135	0.460735
		22.95	0.247041	0.0125	0.0135	0.233541
		22.85	0.17504	0.0135	0.0125	0.16154
		22.75	0.117583	0.0125	0.0115	0.105083
		22.6	0.064666	0.0105	0.0095	0.054166
		22.8	4.233	0.0095	0.0045	4.2285
		23.1	8.6026	0.003	0.0055	8.5971
		23.4	11.4785	0.0025	0.0045	11.474

		density	viscosity			
	co)[NaCl]	1.000088	1.001574	ID(cm) =	1.45796	
99.94837	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08859	12.79437
0.000100	constant	0.003419	-4.14933	AS(cm2)=	1.669479	

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		6.602271	727.2685	117840.3	931.4344	0.003531	3.845275
		4.722775	606.0571	98200.31	666.2792	0.003637	3.772527
		3.315757	496.9668	80524.25	467.7799	0.003798	3.695719
		2.149110	387.8765	62848.20	303.1919	0.004041	3.601557
		1.398598	303.0285	48989.51	197.3112	0.004308	3.507289
		0.879348	230.3017	37232.02	124.0566	0.004690	3.406525
		0.534866	169.6960	27434.12	75.45778	0.005254	3.298565
		0.299163	121.2114	19595.80	42.20538	0.005760	3.172397
		0.173684	84.84800	13717.06	24.50306	0.006825	3.054324
		0.799648	218.1805	35034.53	112.8127	0.004752	3.382937
		0.553681	169.6960	27249.07	78.11214	0.005439	3.303117
		0.283750	121.2114	19463.62	40.03092	0.005463	3.157956
		0.164584	84.84800	13624.53	23.21917	0.006467	3.039681
2435	15	0.210194	97.23589	15403.81	29.65372	0.006288	3.086886
1918	14.9	0.147037	77.10476	12214.70	20.74371	0.006995	3.009290
1630	15	0.107351	65.09014	10299.75	15.14497	0.007166	2.940488
1615	19.9	0.055349	48.61142	7700.873	7.808641	0.006625	2.797134
1340	20	0.042323	40.13226	6343.304	5.970881	0.007432	2.737881
1340	20	0.042797	40.13226	6329.010	6.037731	0.007515	2.739313
1250	25	0.032173	29.94945	4723.141	4.538938	0.010144	2.677353
1175	30	0.026418	23.46040	3699.794	3.727129	0.013576	2.634563
1297	40	0.022335	19.42222	3062.957	3.151035	0.016746	2.598103
1200	44.9	0.019069	16.00861	2521.773	2.690349	0.021045	2.563288
1228	60.1	0.015213	12.23891	1925.773	2.146220	0.028724	2.513728
911	60	0.011749	9.094650	1427.803	1.657546	0.040173	2.456639
585	59.9	0.007993	5.849893	916.3275	1.127685	0.066058	2.372015
430	100	0.003815	2.575653	401.6341	0.538217	0.162629	2.209429
495	74.8	0.005791	3.963898	617.4131	0.817053	0.104255	2.299583
320	100	0.002935	1.916765	297.8807	0.414155	0.225956	2.151054
216	99.9	0.002030	1.295111	200.8172	0.286470	0.342336	2.070027
138	100.1	0.001320	0.825779	127.7550	0.186351	0.547749	1.975669
203	300.1	0.000680	0.405180	62.47314	0.096057	1.172719	1.830290
1600	20	0.053152	47.91912	7421.861	7.498692	0.006545	2.778487
2140	20	0.108066	64.09183	9994.151	15.24583	0.007479	2.935526
1888	15	0.144229	75.39275	11836.19	20.34763	0.007176	3.001163

Page 3 Alcomer 507

Tap DL= 122.2234
79.55358 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.98110	437.6785	40.66022	16.82747	1.123246	0.038447
14.69010	370.1751	39.27801	16.58004	1.128653	0.044789
14.38287	310.1700	37.81867	16.22582	1.128134	0.052312
14.00623	249.7111	36.02960	15.73022	1.123087	0.062993
13.62915	200.9878	34.23850	15.23397	1.117748	0.075795
13.22609	159.3690	32.32395	14.60134	1.103979	0.091619
12.79426	124.2927	30.27275	13.79511	1.078226	0.110988
12.28959	92.95609	27.87555	13.17544	1.072081	0.141738
11.81729	70.82786	25.63215	12.10422	1.024280	0.170896
13.13174	150.9445	31.87580	14.50637	1.104679	0.096104
12.81247	125.6023	30.35923	13.55920	1.058281	0.107953
12.23182	89.91581	27.60116	13.52906	1.106054	0.150463
11.75872	68.47968	25.35395	12.43483	1.057498	0.181584
11.94754	76.34256	26.25084	12.61076	1.055510	0.165186
11.63716	63.85139	24.77651	11.95618	1.027413	0.187250
11.36195	54.49653	23.46928	11.81239	1.039644	0.216755
10.78853	39.17552	20.74556	12.28584	1.138786	0.313610
10.55152	34.17914	19.61974	11.59937	1.099307	0.339369
10.55725	34.29206	19.64695	11.53512	1.092625	0.336378
10.30941	29.73266	18.46972	9.928350	0.963037	0.333920
10.13825	26.94287	17.65671	8.582496	0.846545	0.318544
9.992413	24.77327	16.96396	7.727474	0.773334	0.311927
9.853153	22.86485	16.30248	6.893147	0.699587	0.301473
9.654914	20.39899	15.36084	5.900332	0.611122	0.289246
9.426556	17.88624	14.27614	4.989183	0.529268	0.278939
9.088060	14.71957	12.66828	3.890770	0.428118	0.264326
8.437718	10.12301	9.579163	2.479710	0.293883	0.244957
8.798333	12.45843	11.29208	3.097365	0.352039	0.248615
8.204218	8.849826	8.470039	2.103719	0.256419	0.237713
7.880109	7.343572	6.930520	1.709124	0.216890	0.232737
7.502676	5.909477	5.137712	1.351166	0.180091	0.228644
6.921161	4.228345	2.375517	0.923427	0.133420	0.218389
10.71395	37.52908	20.39127	12.36018	1.153653	0.329349
11.34210	53.87736	23.37500	11.59363	1.022176	0.215185
11.60465	62.66764	24.62210	11.80453	1.017224	0.188367

Page 4 Alcomer 507

A1F21403

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
2.690349	87.84118	0.429808	1.943698
2.146220	67.15636	0.331674	1.827087
1.657546	49.90343	0.219465	1.698130
1.127605	32.09906	0.052188	1.506492
0.538217	14.13291	-0.26904	1.150231
0.817053	21.75038	-0.08774	1.337466
0.414155	10.51751	-0.38283	1.021913
0.286470	7.106430	-0.54292	0.851651
0.186351	4.531148	-0.72966	0.656208
0.096057	2.223275	-1.01746	0.346993

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.34315
Std Err of Y Est	0.002817
R Squared	0.999943
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.937511
Std Err of Coef.	0.003531

Tw = K'(8<U>/D)^n'

K' = 0.045377
n' = 0.937511

Tw* = 2.900533
Res/f* = 390.7851

Regression Output:

Constant	-4.57007
Std Err of Y Est	0.119655
R Squared	0.993003
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	5.608864
Std Err of Coef.	0.192205

t = 23.82571 deg C
s.d.)t = 0.698403 deg C

A3P21406 ALCOMER 507 8/6/90 11:55

	10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
	S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=	
	Z =	2.7	Z =	9	Z =	6.9	[NaCl]=	

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.7	6.088666	0.0395	0.0565	6.049166
51	1.032036	24.7	4.633	0.0395	0.0565	4.5935
44	0.890384	24.7	3.60375	0.0395	0.0565	3.56425
38	0.768968	24.7	2.850666	0.0395	0.0565	2.811166
32	0.647552	24.6	2.155333	0.0375	0.0375	2.117833
25	0.5059	24.6	1.4815	0.0375	0.0375	1.444
19	0.384484	24.6	0.975	0.0375	0.0375	0.9375
14	0.283304	24.6	0.606666	0.0375	0.0375	0.569166
9	0.182124	24.6	0.333333	0.0375	0.0375	0.295833
18	0.364248	24.6	10.33625	0.0495	0.0765	10.25975
15	0.30354	24.6	7.519833	0.0495	0.0765	7.443333
10	0.20236	24.6	4.092142	0.0495	0.0765	4.015642
8	0.161888	24.6	2.893125	0.0495	0.0765	2.816625
		24	2.89725	0.0645	0.0445	2.83275
		24	1.9844	0.0595	0.0385	1.9249
		23.9	1.4578	0.0465	0.0375	1.4113
		23.9	0.772	0.0445	0.0365	0.7275
		23.8	0.634428	0.0415	0.0355	0.592928
		23.8	0.48	0.0405	0.0355	0.4395
		23.7	2.831714	0.0125	0.0065	2.825214
		23.6	2.230222	0.0015	0	2.230222
		23.55	1.9555	-0.004	-0.004	1.9595
		23.5	1.634	-0.006	-0.006	1.64
		23.5	1.25425	-0.0075	-0.0075	1.26175
		23.4	0.916058	-0.0085	-0.0085	0.924558
		23.4	0.6715	-0.0085	-0.0085	0.68
		23.3	0.426727	-0.0085	-0.0075	0.434227
		23.25	0.27124	-0.0085	-0.0085	0.27974
		23.05	0.118916	-0.0085	-0.0115	0.128916
		22.9	0.042590	-0.0115	-0.0135	0.056090
		23	3.854666	-0.0135	-0.0195	3.854166
		23.2	5.4254	-0.0195	-0.0255	5.4509
		23.45	7.914	-0.0255	-0.0215	7.9355
		23.4	11.8768	-0.0215	-0.0145	11.8913

		density	viscosity			
	co)[NaCl]	1.000088	1.001574		ID(cm) =	1.45796	
299.7163	X coeff	-0.00025	-0.02281		K(V/psi)=	1.08859	12.79437
0.000100	constant	0.003419	-4.14933		XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		5.556882	727.2685	117574.8	783.9531	0.002972	3.806858
		4.219678	618.1782	99938.60	595.3033	0.003123	3.747083
		3.274189	533.3302	86221.54	461.9157	0.003256	3.691995
		2.582392	460.6034	74464.05	364.3184	0.003443	3.640454
		1.945482	387.8765	62695.26	274.4646	0.003658	3.577971
		1.326486	303.0285	48879.11	187.1379	0.004086	3.494809
		0.861205	230.3017	37148.12	121.4970	0.004593	3.401011
		0.522847	169.6960	27372.30	73.76222	0.005136	3.292645
		0.271758	109.0902	17596.48	38.33907	0.006460	3.150549
		0.801895	218.1805	35192.96	113.1297	0.004765	3.385517
		0.581766	181.8171	29327.47	82.07435	0.004978	3.315832
		0.313860	121.2114	19551.64	44.27872	0.006043	3.181826
		0.220145	96.96914	15641.31	31.05768	0.006623	3.104813
2392	14.9	0.221405	96.15985	15502.23	31.23548	0.006772	3.100141
1896	15	0.150448	75.71221	12048.33	21.22502	0.007423	3.016241
1593	14.9	0.110306	64.03957	10167.86	15.56178	0.007607	2.947861
1592	20	0.056860	47.67953	7570.304	8.021821	0.007074	2.803968
1315	19.9	0.046342	39.58143	6270.370	6.537961	0.008366	2.758568
1219	24.9	0.034351	29.32400	4645.418	4.846172	0.011299	2.693546
1217	24.9	0.035513	29.27589	4627.346	5.010148	0.011719	2.699787
1156	30	0.028034	23.08104	3639.968	3.955007	0.014883	2.647450
1138	35	0.024631	19.47570	3067.929	3.474917	0.018266	2.618856
1075	39.9	0.020615	16.13817	2539.316	2.908325	0.022586	2.579713
1206	60	0.015860	12.03968	1894.424	2.237548	0.030945	2.522777
1004	69.9	0.011621	8.603505	1350.697	1.639584	0.044404	2.454273
835	80	0.008547	6.251948	981.5172	1.205891	0.061847	2.387560
582	89.9	0.005458	3.877771	607.4142	0.770045	0.102657	2.289179
411	100	0.003516	2.461845	385.1887	0.496082	0.164082	2.193205
185	100	0.001620	1.108129	172.6012	0.228616	0.373195	2.023012
80	100	0.000705	0.479191	74.58623	0.099469	0.868294	1.840826
1305	19.9	0.048447	39.28043	6111.387	6.834860	0.008879	2.760330
1341	15	0.068518	53.54962	8369.113	9.666458	0.006757	2.837569
1586	15	0.099750	63.33311	9954.128	14.07257	0.007033	2.921585
1870	15.1	0.149475	74.17944	11645.71	21.08766	0.007682	3.008920

Tap DL= 122.2234
79.55358 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.82743	400.6258	39.93032	18.34236	1.237055	0.045784
14.58833	349.1106	38.79457	17.89164	1.226435	0.051249
14.36798	307.5213	37.74790	17.52348	1.219620	0.056982
14.16181	273.1080	36.76863	17.04088	1.203298	0.062396
13.91188	236.5112	35.58146	16.53337	1.188434	0.069905
13.57923	195.2943	34.00138	15.64277	1.151962	0.080098
13.20404	157.3590	32.21922	14.75452	1.117424	0.093763
12.77058	122.6099	30.16026	13.95293	1.092584	0.113799
12.20219	88.39537	27.46044	12.44160	1.019619	0.140749
13.14206	151.8438	31.92482	14.48567	1.102237	0.095398
12.86332	129.3339	30.60081	14.17235	1.101764	0.109579
12.32730	94.99620	28.05469	12.86343	1.043491	0.135410
12.01925	79.55971	26.59145	12.28740	1.022310	0.154442
12.00056	78.70850	26.50269	12.15103	1.012338	0.154380
11.66496	64.88161	24.90859	11.60607	0.994951	0.178880
11.39144	55.42963	23.60937	11.46483	1.006442	0.206835
10.81587	39.79686	20.87540	11.88897	1.099215	0.298741
10.63427	35.84662	20.01279	10.93263	1.028056	0.304983
10.37418	30.86217	18.77738	9.407588	0.906826	0.304825
10.39914	31.30885	18.89595	9.237294	0.888274	0.295037
10.18980	27.75430	17.90155	8.196853	0.804417	0.295336
10.07542	25.98581	17.35827	7.378854	0.732361	0.283957
9.918852	23.74614	16.61454	6.683496	0.673817	0.281456
9.691111	20.82849	15.53277	5.684594	0.586578	0.272923
9.417092	17.78906	14.23119	4.745530	0.503927	0.266766
9.150241	15.25599	12.96364	4.021032	0.439445	0.263570
8.756717	12.16352	11.09440	3.121085	0.356421	0.256593
8.372821	9.751814	9.270902	2.468699	0.294846	0.253152
7.692049	6.590104	6.037233	1.636936	0.212808	0.248393
6.963304	4.332177	2.575697	1.073164	0.154117	0.247719
10.64132	35.99236	20.04627	10.61229	0.997272	0.294848
10.95027	42.99813	21.51382	12.16493	1.110924	0.282917
11.28634	52.17538	23.11012	11.92387	1.056487	0.228534
11.63568	63.79705	24.76949	11.40894	0.980513	0.178831

A3P21406

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
2.908325	88.55209	0.463643	1.947198
2.237548	66.06315	0.349772	1.819959
1.639584	47.20845	0.214733	1.674019
1.205891	34.30518	0.081308	1.535359
0.770045	21.27779	-0.11348	1.327926
0.496082	13.50843	-0.30444	1.130605
0.228616	6.080439	-0.64089	0.783935
0.099469	2.629379	-1.00230	0.419853

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.40432
Std Err of Y Est	0.004638
R Squared	0.999918
No. of Observations	6
Degrees of Freedom	4

X Coefficient(s)	0.969315
Std Err of Coef.	0.004378

Tw = K'(8<U>/D)^n'

K' =	0.039416
n' =	0.969315

Tw* = 27.67825
Res/f* = 1204.434

Regression Output:

Constant	-15.9009
Std Err of Y Est	0.104478
R Squared	0.997557
No. of Observations	9
Degrees of Freedom	7

X Coefficient(s)	9.031505
Std Err of Coef.	0.168910

t = 23.93529 deg C
s.d.)t = 0.601411 deg C

A1P31412 ALCOMER 507 8/13/90 12:46

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14			
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=		
Z =	2.7	Z =	9.05	Z =	6.9	[NaCl]=		

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.9	5.173333	0.0425	0.0425	5.130833
50	1.0118	24.9	3.945	0.0425	0.0425	3.9025
40	0.80944	24.9	2.898333	0.0425	0.0425	2.855833
29	0.586844	24.9	1.814666	0.0425	0.0425	1.772166
25	0.5059	24.9	1.5335	0.0485	0.0485	1.485
18	0.364248	24.9	1.003	0.0485	0.0485	0.9545
15	0.30354	24.9	0.761666	0.0485	0.0485	0.713166
10	0.20236	24.9	0.43325	0.0485	0.0485	0.38475
18	0.364248	24.7	10.953	0.0225	0.0535	10.8995
15	0.30354	24.7	8.681833	0.0225	0.0535	8.628333
10	0.20236	24.7	4.796	0.0225	0.0535	4.7425
7	0.141652	24.7	2.37925	0.0225	0.0535	2.32575
		24.2	2.5172	0.0685	0.062	2.4487
		24.1	2.0208	0.0615	0.0595	1.9593
		24	1.6942	0.0615	0.0595	1.6327
		24	1.274	0.0615	0.0565	1.2125
		24	1.091	0.0575	0.0575	1.0335
		23.9	0.869428	0.0575	0.0575	0.811928
		23.9	5.1468	-0.0025	-0.0085	5.1553
		23.9	4.170222	-0.0135	-0.0105	4.180722
		23.9	3.582625	-0.0135	-0.0125	3.595125
		23.9	3.158818	-0.0145	-0.013	3.173318
		23.85	2.509846	-0.0155	-0.0145	2.524746
		23.8	1.788428	-0.0165	-0.0165	1.804928
		23.7	1.175133	-0.0175	-0.0165	1.191633
		23.6	0.717066	-0.0165	-0.0165	0.733566
		23.3	0.409260	-0.0195	-0.0185	0.427760
		23.2	0.207272	-0.0195	-0.0225	0.229772
		23.1	0.094695	-0.0235	-0.0245	0.119195
		23.3	7.07525	-0.0255	-0.0275	7.10075
		23.55	9.926	-0.0305	-0.0305	9.9565
		23.6	12.49825	-0.0315	-0.0305	12.52975

		density	viscosity			
	co)[NaCl]	1.000088	1.001574		ID(cm) =	1.45796
999.6909	X coeff	-0.00025	-0.02281		K(V/psi)=	1.077888 12.75147
0.000100	constant	0.003419	-4.14933		XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		4.760080	727.2685	118106.5	671.5420	0.002546	3.775220
		3.620506	606.0571	98422.10	510.7733	0.002788	3.715798
		2.649471	484.8457	78737.68	373.7817	0.003188	3.647993
		1.644110	351.5131	57084.82	231.9475	0.003764	3.544379
		1.377694	303.0285	49211.05	194.3621	0.004244	3.505990
		0.885527	218.1805	35431.95	124.9284	0.005263	3.410014
		0.661633	181.8171	29526.63	93.34183	0.005662	3.346722
		0.356948	121.2114	19684.42	50.35747	0.006873	3.212716
		0.854764	218.1805	35272.44	120.5883	0.005079	3.400366
		0.676654	181.8171	29393.70	95.46091	0.005790	3.349626
		0.371917	121.2114	19595.80	52.46938	0.007161	3.219666
		0.182390	84.84800	13717.06	25.73129	0.007167	3.064944
2266	15	0.192032	90.48728	14464.66	27.09157	0.006634	3.071205
1757	15.1	0.153652	69.69694	11116.15	21.67702	0.008947	3.021802
1486	14.9	0.128040	59.73810	9506.323	18.06363	0.010148	2.981220
1143	15.1	0.095087	45.34069	7215.216	13.41468	0.013083	2.916607
1261	19.9	0.081049	37.95604	6040.071	11.43428	0.015913	2.881922
1184	25	0.063673	28.36812	4504.141	8.982898	0.022379	2.828540
1182	25	0.064671	28.32020	4496.532	9.123764	0.022807	2.831919
1130	30	0.052446	22.56192	3582.263	7.398972	0.029142	2.786418
1096	35	0.045099	18.75691	2978.124	6.362592	0.036258	2.753649
1161	39.9	0.039808	17.42923	2767.321	5.616085	0.037066	2.726549
1024	50	0.031667	12.26729	1945.540	4.467545	0.059520	2.676374
713	49.9	0.022642	8.558701	1355.843	3.194332	0.087428	2.603057
561	60.1	0.014948	5.591229	883.7494	2.108932	0.135247	2.511893
337	59.9	0.009202	3.369938	531.4520	1.298254	0.229184	2.405556
285	90	0.005366	1.896798	297.1146	0.757044	0.421808	2.285481
169	99.9	0.002882	1.013304	158.3664	0.406647	0.792897	2.149545
86	100	0.001495	0.515130	80.32682	0.210950	1.593532	2.006041
1242	19.9	0.089076	37.38414	5855.853	12.56678	0.018023	2.895533
1790	19.9	0.124901	53.87891	8487.329	17.62084	0.012168	2.971397
1656	15.1	0.157182	65.69045	10359.63	22.17494	0.010302	3.021807

Tap DL= 122.2234
79.71477 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.70088	372.4782	39.32919	19.81768	1.348061	0.053204
14.46319	324.8466	38.20016	18.93626	1.309272	0.058292
14.19197	277.8902	36.91187	17.70880	1.247804	0.063725
13.77751	218.9067	34.94320	16.29826	1.182961	0.074453
13.62396	200.3872	34.21381	15.34873	1.126598	0.076595
13.24005	160.6552	32.39028	13.78415	1.041094	0.085799
12.98688	138.8680	31.18772	13.28897	1.023260	0.095694
12.45086	101.9990	28.64160	12.06164	0.968739	0.118252
13.20146	157.1254	32.20696	14.03036	1.062788	0.089294
12.99850	139.7998	31.24290	13.14097	1.010960	0.093998
12.47866	103.6446	28.77367	11.81670	0.946952	0.114011
11.85977	72.58130	25.83394	11.81180	0.995955	0.162739
11.88482	73.63512	25.95289	12.27730	1.033024	0.166731
11.68721	65.71772	25.01424	10.57187	0.904568	0.160867
11.52488	59.85494	24.24318	9.926418	0.861303	0.165841
11.26643	51.58075	23.01554	8.742620	0.775988	0.169493
11.12768	47.62139	22.35651	7.927203	0.712385	0.166463
10.91416	42.11342	21.34227	6.684538	0.612464	0.158727
10.92767	42.44234	21.40646	6.621531	0.605941	0.156012
10.74567	38.22064	20.54194	5.857866	0.545137	0.153264
10.61459	35.44291	19.91933	5.251621	0.494754	0.148171
10.50619	33.29884	19.40443	5.194101	0.494384	0.155984
10.30549	29.66567	18.45111	4.098888	0.397738	0.138169
10.01214	25.05631	17.05770	3.381990	0.337788	0.134975
9.647573	20.31296	15.32597	2.719166	0.281849	0.133863
9.222226	15.90144	13.30557	2.088851	0.226501	0.131362
8.741926	12.06040	11.02415	1.539722	0.176130	0.127667
8.198180	8.819119	8.441359	1.122323	0.136899	0.127260
7.624164	6.337544	5.714779	0.792172	0.103902	0.124996
11.18213	49.13752	22.61513	7.448295	0.666088	0.151580
11.48559	58.51639	24.05655	9.065119	0.789260	0.154915
11.68723	65.71855	25.01435	9.852271	0.842994	0.149916

A1P31412

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
6.362592	102.9214	0.803634	2.012505
5.616085	95.63626	0.749433	1.980622
4.467545	67.31211	0.650069	1.828093
3.194332	46.96261	0.504380	1.671752
2.108932	30.67973	0.324062	1.486851
1.298254	18.49125	0.113359	1.266966
0.757044	10.40796	-0.12087	1.017365
0.406647	5.560124	-0.39078	0.745084
0.210950	2.826582	-0.67581	0.451261

Log Tw vs. Log 8<U>/D
Regression Output:

Constant	-1.10736
Std Err of Y Est	0.003694
R Squared	0.999951
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	0.963220
Std Err of Coef.	0.003012

Tw = K'(8<U>/D)^n'

K' = 0.078097
n' = 0.963220

Tw* = 90.01278
Res/f* = 2181.907

Regression Output:

Constant	-39.2712
Std Err of Y Est	0.176747
R Squared	0.995681
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	15.64214
Std Err of Coef.	0.389344

t = 24.15 deg C
s.d.)t = 0.586299 deg C

ASP13110 ALCOMER 507 8/10/90 14:53

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 9 Z = 6.9 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	25.2	8.696333	0.0365	0.0615	8.634833
49	0.991564	25.2	6.047	0.0365	0.0615	5.9855
42	0.849912	25.2	4.571	0.0365	0.0615	4.5095
35	0.70826	25.2	3.354666	0.0365	0.0615	3.293166
30	0.60708	25.2	2.578	0.0405	0.0405	2.5375
24	0.485664	25.2	1.748	0.0405	0.0405	1.7075
17	0.344012	25.2	0.97	0.0405	0.0405	0.9295
13	0.263068	25.2	0.621	0.0405	0.0405	0.5805
9	0.182124	25.2	0.346571	0.0405	0.0405	0.306071
20	0.40472	24.1	1.2845	0.0375	0.0355	1.249
15	0.30354	24.1	0.786285	0.0375	0.0355	0.750785
10	0.20236	24.1	0.405375	0.0375	0.0355	0.369875
8	0.161888	24.1	0.282	0.0375	0.0355	0.2465
18	0.364248	25.1	12.07875	0.0485	0.0745	12.00425
13	0.263068	25.1	6.978363	0.0485	0.0745	6.903863
10	0.20236	25.1	4.341363	0.0485	0.0745	4.266863
7	0.141652	25.1	2.54	0.0485	0.0745	2.4655
		25	2.158166	0.0685	0.0725	2.085666
		24.9	1.5336	0.0695	0.0665	1.4671
		24.9	1.171285	0.0635	0.0615	1.109785
		24.8	0.7346	0.0605	0.0585	0.6761
		24.28	0.5595	0.0585	0.0565	0.503
		24.7	3.211142	-0.0045	-0.0055	3.215642
		26.7	2.434833	-0.0075	-0.009	2.442333
		24.65	1.87275	-0.0115	-0.0115	1.88425
		23.6	1.186111	-0.014	-0.017	1.200111
		24.5	0.802333	-0.017	-0.0185	0.819333
		24.5	0.438642	-0.0205	-0.0225	0.459142
		24.45	0.291187	-0.0235	-0.025	0.314687
		24.4	0.204733	-0.0255	-0.025	0.230233
		24.3	0.1285	-0.027	-0.028	0.1555
		24.2	0.083	-0.0285	-0.0285	0.1115
		24.15	0.043857	-0.03	-0.031	0.074857
		23.6	0.004785	-0.0315	-0.0325	0.037285
		23.5	-0.014	-0.0325	-0.034	0.02
		23.6	4.2265	-0.035	-0.037	4.2635
		23.8	6.986	-0.039	-0.039	7.025
		23.8	9.15575	-0.039	-0.039	9.19475
		23.8	12.91075	-0.0415	-0.0415	12.95225

		density	viscosity			
co)	[NaCl]	1.01234	1.029478		ID(ca) =	1.45796
29.97317	X coeff	-0.00025	-0.02281		K(V/psi)=	1.077888 12.75206
0.300084	constant	0.003419	-4.14933		XS(cm2)=	1.669479
						1.085095

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		8.010881	727.2685	117102.8	1130.158	0.004233	3.881919
		5.552988	593.9360	95633.97	783.4038	0.004400	3.802342
		4.183644	509.0880	81971.97	590.2196	0.004512	3.740856
		3.055203	424.2400	68309.97	431.0215	0.004744	3.672599
		2.354140	363.6342	58551.41	332.1171	0.004976	3.615995
		1.584116	290.9074	46841.12	223.4837	0.005232	3.529972
		0.862334	206.0594	33179.13	121.6563	0.005676	3.397917
		0.538553	157.5748	25372.27	75.97793	0.006062	3.295693
		0.283954	109.0902	17565.42	40.05973	0.006669	3.156703
		1.158747	242.4228	38077.51	163.4736	0.005509	3.451236
		0.696534	181.8171	28558.13	98.26554	0.005887	3.340713
		0.343147	121.2114	19038.75	48.41057	0.006526	3.186982
		0.228687	96.96914	15231.00	32.26281	0.006796	3.098863
		0.941357	218.1805	35051.68	132.8047	0.005527	3.415971
		0.541392	157.5748	25315.10	76.37843	0.006094	3.295850
		0.334601	121.2114	19473.15	47.20492	0.006365	3.191358
		0.193341	84.84800	13631.20	27.27618	0.007506	3.072256
1990	14.9	0.163555	79.99921	12823.26	23.07403	0.007143	3.034941
1620	14.9	0.115048	65.12498	10415.51	16.23073	0.007581	2.957563
1865	20	0.087027	55.85573	8933.074	12.27771	0.007796	2.896953
1393	20	0.053018	41.71958	6657.228	7.479791	0.008513	2.788353
1455	25	0.039444	34.86116	5497.947	5.564761	0.009070	2.719009
1455	25	0.039730	34.86116	5550.288	5.605159	0.009137	2.724717
1253	24.9	0.030176	30.14189	4798.928	4.257209	0.009282	2.664986
1296	30	0.023280	25.87632	4115.157	3.284419	0.009717	2.608160
1186	35	0.014828	20.29717	3152.330	2.091903	0.010056	2.499857
1278	45	0.010123	17.01128	2696.195	1.428172	0.009776	2.425843
1166	50	0.005672	13.96842	2213.918	0.800327	0.008125	2.300087
1045	59.9	0.003888	10.44980	1654.369	0.548529	0.009950	2.217560
780	60	0.002844	7.786857	1231.392	0.401317	0.010110	2.149212
660	75	0.001921	5.271103	831.6798	0.271050	0.010324	2.063008
569	90.1	0.001377	3.782738	595.4992	0.194354	0.026904	1.989795
380	90.1	0.000924	2.526258	397.2488	0.130482	0.040498	1.902782
210	99.9	0.000460	1.259136	195.5550	0.064992	0.081189	1.746018
111	99.9	0.000247	0.665543	103.1318	0.034861	0.155871	1.609776
1026	15	0.052677	40.97085	6363.136	7.431669	0.008768	2.775129
1375	15	0.086797	54.90733	8566.158	12.24521	0.008044	2.895540
1601	15	0.113605	63.93210	9974.123	16.02728	0.007766	2.943987
1961	15	0.160031	78.30783	12216.89	22.57695	0.007292	3.018389

Tap DL= 122.2234
80.93545 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f'	1//f/Slv	1//f/L
15.12767	476.2111	41.35647	15.36907	1.015957	0.032273
14.80937	396.4813	39.84451	15.07541	1.017964	0.038023
14.56342	344.1412	38.67627	14.88704	1.022221	0.043258
14.29039	294.0894	37.37938	14.51726	1.015875	0.049363
14.06398	258.1520	36.30391	14.17561	1.007937	0.054911
13.71989	211.7643	34.66948	13.82465	1.007636	0.065283
13.19166	156.2418	32.16042	13.27234	1.006115	0.084947
12.78277	123.4734	30.21818	12.84297	1.004709	0.104014
12.22681	89.65695	27.57737	12.24488	1.001477	0.136574
13.40494	176.6512	33.17349	13.47199	1.005002	0.076263
12.96285	136.9598	31.07355	13.03216	1.005346	0.095153
12.34793	96.13087	28.15267	12.37815	1.002467	0.128763
11.99545	78.47727	26.47841	12.13011	1.011225	0.154568
13.26388	162.8739	32.50345	13.45046	1.014066	0.082582
12.78340	123.5179	30.22115	12.80942	1.002035	0.103704
12.36543	97.10429	28.23580	12.53366	1.013604	0.129074
11.88902	73.81362	25.97287	11.54191	0.970804	0.156365
11.73976	67.73627	25.26388	11.83198	1.007854	0.174677
11.43025	56.68178	23.79370	11.48464	1.004758	0.202616
11.18781	49.29844	22.64211	11.32524	1.012284	0.229728
10.75341	38.39139	20.57872	10.83776	1.007843	0.282296
10.47603	32.72573	19.26117	10.50004	1.002291	0.320849
10.49887	33.15873	19.36964	10.46158	0.996448	0.315500
10.25994	28.89791	18.23474	10.37905	1.011609	0.359162
10.03264	25.35366	17.15505	10.14438	1.011137	0.400115
9.599430	19.75775	15.09729	9.971814	1.038792	0.504703
9.303375	16.66187	13.69103	10.11363	1.087093	0.606992
8.800350	12.47290	11.30166	11.09363	1.260590	0.889419
8.470243	10.31432	9.733654	10.02471	1.183521	0.971921
8.196850	8.812366	8.435038	8.733415	1.065459	0.991040
7.852033	7.225841	6.797160	7.193624	0.916147	0.995541
7.559181	6.104856	5.406113	6.096572	0.806512	0.998643
7.211128	4.996456	3.752859	4.969132	0.689092	0.994531
6.584072	3.482555	0.774343	3.509545	0.533035	1.007749
6.039106	2.544817	-1.81424	2.532889	0.419414	0.995312
10.70051	37.24062	20.32746	10.67926	0.998013	0.286768
11.14216	48.01980	22.42526	11.14925	1.000436	0.232180
11.37594	54.93728	23.53575	11.34716	0.997470	0.206547
11.67355	65.20334	24.94940	11.71038	1.003154	0.179597

ACP13110

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.800327	76.64641	-0.09673	1.884491
0.548529	57.33934	-0.26080	1.758452
0.401317	42.72741	-0.39651	1.630706
0.271050	28.92317	-0.56694	1.461245
0.194354	20.75633	-0.71140	1.317150
0.130482	13.86187	-0.88444	1.141822
0.064992	6.909030	-1.18713	0.839417
0.034861	3.651915	-1.45764	0.562520

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-2.02432
Std Err of Y Est	0.004281
R Squared	0.999916
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	0.999178
Std Err of Coef.	0.004072

Tw = K'(8<U>/D)^n'

K' = 0.009455
n' = 0.999178

Tw8 = 45.23642
Res/f8 = 1524.382

Regression Output:

Constant	-1.78092
Std Err of Y Est	0.051532
R Squared	0.997740
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	4.433831
Std Err of Coef.	0.086132

t = 24.55717 deg C
s.d.)t = 0.562466 deg C

A1P23104 ALCOMER 507 8/4/90 15:34

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
S =	2.7	S =	7.25	S =	9.9	<C>(ppa)=	
Z =	2.7	Z =	9	Z =	6.95	[NaCl]=	

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	24.8	8.128	0.0285	0.0385	8.0895
52	1.052272	24.8	6.343	0.0285	0.0385	6.3045
45	0.91062	24.8	4.954666	0.0285	0.0385	4.916166
38	0.768968	24.8	3.699	0.0285	0.0385	3.6605
31	0.627316	24.8	2.6138	0.0285	0.0385	2.5853
26	0.526136	24.8	1.946	0.0285	0.0385	1.9075
19	0.384484	24.8	1.15	0.0285	0.0385	1.1115
15	0.30354	24.8	0.7732	0.0285	0.0385	0.7347
10	0.20236	24.8	0.41275	0.0285	0.0385	0.37425
8	0.161888	24.8	0.2905	0.0285	0.0385	0.252
20	0.40472	23.5	1.259	0.0345	0.0415	1.2175
15	0.30354	23.5	0.8034	0.0345	0.0415	0.7619
10	0.20236	23.5	0.409333	0.0345	0.0415	0.367833
25	0.5059	23.5	1.8135	0.0345	0.0415	1.772
18	0.364248	24.7	11.763	0.0445	0.0675	11.6955
13	0.263068	24.7	6.7406	0.0445	0.0675	6.6731
10	0.20236	24.7	4.311384	0.0445	0.0675	4.243884
EXT OL 7	0.141652	24.7	2.3095	0.0445	0.0675	2.242
		24.4	2.1664	0.0375	0.0315	2.1349
		24.2	1.465	0.0285	0.0235	1.4415
		24.1	1.1138	0.0215	0.0185	1.0953
		24.1	0.6826	0.0185	0.0155	0.6671
		24	0.5016	0.0155	0.0145	0.4871
		23.9	3.095833	-0.0155	-0.0165	3.111333
		23.9	1.816571	-0.0205	-0.025	1.837071
		23.8	1.133777	-0.0295	-0.0325	1.163277
		23.8	0.766	-0.0355	-0.036	0.8015
		23.7	0.408928	-0.0405	-0.043	0.449428
		23.6	0.274066	-0.0455	-0.0475	0.319566
		23.55	0.1715	-0.0495	-0.05	0.221
		23.4	0.106266	-0.0515	-0.0565	0.157766
		23.2	0.0235	-0.0535	-0.0535	0.077
		23.2	-0.0226	-0.0545	-0.0555	0.0319
		23.3	4.0994	-0.0565	-0.0575	4.1559
		23.5	6.76975	-0.0595	-0.06	6.82925
		23.5	8.88075	-0.0615	-0.061	8.94225
		23.6	12.7438	-0.0625	-0.0645	12.8063

		density	viscosity			
co)[NaCl]		1.01234	1.029478	ID(cm) =	1.45795	
99.94837	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08859	12.79437
0.300004	constant	0.003419	-4.14933	XS(cm2)=	1.669479	
					1.085095	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		7.431172	727.2685	116050.8	1048.374	0.003926	3.861667
		5.791436	630.2994	100577.3	817.0435	0.004074	3.807531
		4.516086	545.4514	87038.12	637.1199	0.004242	3.753519
		3.362606	460.6034	73498.86	474.3894	0.004429	3.689476
		2.374906	375.7554	59959.60	335.0468	0.004701	3.613961
		1.752266	315.1497	50288.69	247.2060	0.004931	3.547938
		1.021045	230.3017	36749.43	144.0469	0.005380	3.430661
		0.674909	181.8171	29012.70	95.21483	0.005706	3.340761
		0.343793	121.2114	19341.80	48.50163	0.006540	3.194287
		0.231492	96.96914	15473.44	32.65841	0.006880	3.108406
		1.118419	242.4228	37565.57	157.7842	0.005317	3.437633
		0.699896	181.8171	28174.18	98.73987	0.005915	3.335847
		0.337898	121.2114	18782.78	47.67005	0.006425	3.177724
		1.627793	303.0285	46956.96	229.6456	0.004952	3.519130
		0.914113	218.1805	34736.79	128.9611	0.005366	3.405655
		0.521565	157.5748	25087.68	73.58133	0.005870	3.283807
		0.331699	121.2114	19298.22	46.79544	0.006309	3.185525
		0.175233	84.84800	13508.75	24.72154	0.006802	3.046961
2000	14.9	0.166862	80.40121	12714.43	23.54060	0.007213	3.033577
1635	15.1	0.112666	64.85742	10210.20	15.89478	0.007484	2.946125
1380	14.9	0.085607	55.47684	8713.784	12.07739	0.007772	2.885499
1385	20	0.052140	41.47999	6515.290	7.355817	0.008468	2.777828
1436	24.9	0.038071	34.54410	5413.639	5.371036	0.008915	2.708556
1435	24.9	0.039109	34.52005	5397.678	5.517543	0.009170	2.713415
1280	30	0.023092	25.55686	3996.162	3.257806	0.009879	2.599004
1330	40.1	0.014622	19.86671	3099.430	2.062921	0.010352	2.498798
1260	44.9	0.010074	16.80904	2622.399	1.421355	0.009963	2.417908
1151	50	0.005649	12.78872	2146.348	0.797002	0.008302	2.291301
1034	59.9	0.004016	10.33981	1605.864	0.566709	0.010498	2.216267
912	75	0.002778	7.283707	1129.948	0.391914	0.014630	2.135689
790	90.1	0.001983	5.251957	812.0035	0.279778	0.020087	2.061023
518	120	0.000967	2.585636	397.9647	0.136549	0.040447	1.903290
181	99.9	0.000400	1.085255	167.0356	0.056570	0.095118	1.711940
1352	19.9	0.052240	40.69513	6277.684	7.369945	0.008813	2.770363
1367	15	0.085844	54.58787	8458.875	12.11078	0.008049	2.880187
1595	15	0.112405	63.69250	9869.719	15.85791	0.007741	2.938724
1954	14.9	0.160977	78.55198	12199.82	22.71029	0.007289	3.017698

Tap DL= 122.2234
79.55358 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.04666	454.5140	40.97167	15.95809	1.060573	0.035110
14.83012	401.2469	39.94310	15.66637	1.056388	0.039044
14.61407	354.3233	38.91667	15.35287	1.050553	0.043330
14.35790	305.7430	37.70005	15.02463	1.046436	0.049141
14.05584	256.9460	36.26527	14.58467	1.037623	0.056761
13.79175	220.7083	35.01083	14.24071	1.032552	0.064522
13.32264	168.4772	32.78256	13.63293	1.023290	0.080918
12.96304	136.9750	31.07446	13.23813	1.021221	0.096646
12.37714	97.76138	28.29145	12.36544	0.999054	0.126485
12.03362	80.22075	26.65972	12.05536	1.001806	0.150277
13.35053	171.2037	32.91503	13.71376	1.027207	0.080101
12.94339	135.4340	30.98110	13.00179	1.004512	0.096000
12.31089	94.10320	27.97676	12.47485	1.013318	0.132565
13.67652	206.5431	34.46348	14.20918	1.038947	0.068795
13.22261	159.0498	32.30741	13.65011	1.032331	0.085822
12.73523	120.1400	29.99234	13.05127	1.024816	0.108633
12.34210	95.80887	28.12498	12.58900	1.020005	0.131397
11.78784	69.63727	25.49227	12.12421	1.028534	0.174105
11.73350	67.49275	25.23416	11.77388	1.003441	0.174446
11.38450	55.20841	23.57638	11.55870	1.015302	0.209364
11.14199	48.01526	22.42448	11.34246	1.017992	0.236226
10.71131	37.47211	20.37873	10.86689	1.014525	0.289999
10.43422	31.94748	19.06257	10.59089	1.015014	0.331509
10.45366	32.30689	19.15488	10.44219	0.998903	0.323218
9.996019	24.82475	16.98109	10.06093	1.006493	0.405278
9.595193	19.70963	15.07717	9.828414	1.024305	0.498660
9.271634	16.36019	13.54026	10.01821	1.080523	0.612352
8.765207	12.22311	11.13473	10.97484	1.252091	0.897876
8.465068	10.28364	9.709075	9.759818	1.152952	0.949062
8.142759	8.542203	8.178108	8.267399	1.015306	0.967829
7.844094	7.192893	6.759448	7.055605	0.899479	0.980913
7.213163	5.002314	3.762528	4.972257	0.689331	0.993991
6.447763	3.219741	0.126877	3.242412	0.502873	1.007041
10.68145	36.83353	20.23690	10.65212	0.997253	0.289196
11.12075	47.43159	22.32356	11.14615	1.002284	0.234994
11.35489	54.27559	23.43576	11.36528	1.000914	0.209399
11.67079	65.09958	24.93626	11.71265	1.003586	0.179918

A1F23104

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.797002	75.66039	-0.09854	1.878868
0.566709	56.73577	-0.24663	1.753856
0.391914	39.96656	-0.40680	1.601696
0.279778	28.81811	-0.55318	1.459665
0.136549	14.18769	-0.86471	1.151911
0.056570	5.954925	-1.24741	0.774876

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-2.03285
Std Err of Y Est	0.000382
R Squared	0.999999
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	1.013824
Std Err of Coef.	0.000789

Tw = K'(8<U>/D)^n'

K' = 0.009271
n' = 1.013824

Tw* = 46.87517
Res/f* = 1537.731

Regression Output:

Constant	-4.61408
Std Err of Y Est	0.034967
R Squared	0.999252
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	5.322323
Std Err of Coef.	0.055037

t = 24.09594 deg C
s.d.)t = 0.583139 deg C

A3P23107 ALCOMER 507 8/6/90 14:50

10 PSID Tap. 14	1.0 PSID Taps 14	0.1 PSID Taps 14	
S = 2.7	S = 7.25	S = 9.9	<C>(ppm)=
Z = 2.7	Z = 9	Z = 6.9	[NaCl]=

Freq. (Hz)	D)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	24.9	7.254666	0.0465	0.0435	7.211166
52	1.052272	24.9	5.677666	0.0465	0.0435	5.634166
45	0.91062	24.9	4.4855	0.0465	0.0435	4.442
39	0.789204	24.9	3.539333	0.0465	0.0435	3.495833
32	0.647552	24.9	2.550333	0.0465	0.0445	2.505833
26	0.526136	24.9	1.819	0.0445	0.0445	1.7745
19	0.384484	24.9	1.1046	0.0445	0.0445	1.0601
15	0.30354	24.9	0.757	0.0445	0.0445	0.7125
10	0.20236	24.9	0.400625	0.0445	0.0445	0.356125
8	0.161888	24.9	0.28625	0.0445	0.0445	0.24175
24	0.485664	23.5	1.597666	0.0255	0.0235	1.574166
17	0.344012	23.5	0.912333	0.0255	0.0235	0.888833
12	0.242832	23.5	0.5544	0.0275	0.0225	0.5269
20	0.40472	24.9	13.195	0.0515	0.0825	13.1125
15	0.30354	24.9	8.379	0.0515	0.0825	8.2965
18	0.364248	24.9	11.2722	0.0515	0.0825	11.1897
13	0.263068	24.9	6.1652	0.0515	0.0825	6.0827
10	0.20236	24.9	4.244	0.0515	0.0825	4.1615
8	0.161888	24.9	3.053333	0.0515	0.0825	2.970833
		24.6	2.177142	0.0695	0.0585	2.118642
		24.5	1.521333	0.0565	0.0535	1.467833
		24.4	1.234	0.0535	0.0495	1.1845
		24.3	0.789	0.0505	0.0485	0.7405
		24.25	0.6276	0.0485	0.0485	0.5791
		24.1	3.72625	0.0455	-0.0045	3.68075
		24	2.433666	-0.0045	-0.0035	2.438166
		24	1.818857	-0.0055	-0.0065	1.824357
		24	1.4685	-0.0085	-0.0085	1.477
		24	1.130875	-0.0095	-0.0105	1.140375
		24	0.661916	-0.0115	-0.0115	0.673416
		23.9	0.447461	-0.0135	-0.0145	0.460961
		23.9	0.36175	-0.0145	-0.0155	0.37625
		23.9	0.262133	-0.0155	-0.0155	0.277633
		23.8	0.189	-0.0165	-0.0165	0.2055
		23.8	0.119166	-0.0165	-0.0165	0.135666
		23.6	0.04384	-0.0175	-0.0185	0.06134
		23.5	0.007478	-0.0185	-0.0195	0.026978
		23.6	4.13775	-0.0205	-0.0195	4.15725
		23.8	6.792	-0.0195	-0.0195	6.8115
		23.8	8.930666	-0.0165	-0.0145	8.947166

23.8	12.78875	-0.0135	-0.0095	12.80225		

		density	viscosity			
	co)[NaCl]	1.01234	1.029478	ID(cm) =	1.45796	
299.7163	X coeff	-0.00025	-0.02281	K(V/psi)=	1.08859	12.79437
0.300062	constant	0.003419	-4.14933	XS(cm2)=	1.669479	
					1.085095	

Batch	Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		0						
			6.624318	727.2685	116312.9	934.5447	0.003500	3.837694
			5.175655	630.2994	100804.5	730.1704	0.003641	3.784106
			4.080507	545.4514	87234.70	575.6693	0.003833	3.732480
			3.211340	472.7245	75603.41	453.0491	0.004016	3.680466
			2.301907	387.8765	62033.57	324.7482	0.004276	3.608167
			1.630090	315.1497	50402.27	229.9696	0.004587	3.533229
			0.973828	230.3017	36832.43	137.3856	0.005131	3.421365
			0.654516	181.8171	29078.23	92.33778	0.005533	3.335084
			0.327143	121.2114	19385.49	46.15269	0.006223	3.184492
			0.222076	96.96914	15508.39	31.33004	0.006601	3.100374
			1.446060	290.9074	45078.69	204.0071	0.004774	3.493424
			0.816499	206.0594	31930.73	115.1900	0.005372	3.369309
			0.484020	145.4537	22539.34	68.28460	0.006392	3.255762
			1.024864	242.4228	38770.98	144.5857	0.004874	3.432457
			0.648449	181.8171	29078.23	91.48184	0.005482	3.333061
			0.874579	218.1805	34893.88	123.3838	0.005135	3.398023
			0.475420	157.5748	25201.13	67.07125	0.005351	3.265662
			0.325260	121.2114	19385.49	45.88702	0.006187	3.183239
			0.232198	96.96914	15508.39	32.75806	0.006901	3.110053
2020		15.1	0.165591	80.12966	12728.79	23.36134	0.007207	3.033687
1619		15	0.114724	64.65088	10246.80	16.18515	0.007670	2.953011
1410		14.8	0.092579	57.06585	9024.241	13.06095	0.007944	2.905455
1450		19.9	0.057877	43.64493	6886.339	8.165167	0.008490	2.802465
1271		20.1	0.045262	37.87637	5969.433	6.385480	0.008816	2.748587
1258		20	0.046267	37.67641	5917.859	6.527329	0.009108	2.751880
1241		25	0.030648	29.73331	4659.786	4.323769	0.009686	2.661458
1265		29.9	0.022932	25.34134	3971.490	3.235258	0.009978	2.598482
1123		30	0.018566	22.42215	3513.926	2.619266	0.010319	2.552617
1160		35.1	0.014334	19.79565	3102.309	2.022306	0.010221	2.496451
1115		39.9	0.008464	16.73866	2623.228	1.194216	0.008442	2.382069
1140		50	0.005794	13.65695	2135.449	0.817455	0.008681	2.298774
1135		59.9	0.004729	11.34979	1774.694	0.667230	0.010259	2.254680
850		59.9	0.003489	8.499844	1329.066	0.492346	0.013497	2.188677
685		60.1	0.002583	6.827080	1065.160	0.364427	0.015486	2.122362
705		100	0.001705	4.222872	658.8154	0.240587	0.026721	2.032193
322		100	0.000771	1.928744	299.5511	0.108778	0.057912	1.857858
140		100.1	0.000339	0.837746	129.8163	0.047842	0.135007	1.678508
1345		20	0.052257	40.28201	6256.154	7.372339	0.008998	2.773389
1338		14.9	0.085621	53.78841	8391.595	12.07930	0.008269	2.882578
1580		15	0.112467	63.09351	9843.295	15.86663	0.007894	2.941799

1966		15.1	0.160926	77.98758	12166.93	22.70311	0.007393	3.019599

Tap DL= 122.2234
40.77743

79.55358
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.95077	430.1049	40.51619	16.90182	1.130498	0.039296
14.73642	380.1775	39.49802	16.57195	1.124557	0.043590
14.52992	337.5677	38.51713	16.15133	1.111591	0.047846
14.32186	299.4656	37.52887	15.77881	1.101728	0.052689
14.03267	253.5407	36.15518	15.29181	1.089729	0.060313
13.73291	213.3583	34.73136	14.76456	1.075121	0.069200
13.28546	164.9092	32.60593	13.95935	1.050724	0.084648
12.94033	135.1960	30.96659	13.44262	1.038815	0.099430
12.33797	95.58128	28.10536	12.67604	1.027401	0.132620
12.00149	78.75078	26.50712	12.30812	1.025548	0.156292
13.57369	194.6723	33.97506	14.47261	1.066225	0.074343
13.07723	146.2813	31.61687	13.64268	1.043239	0.093263
12.62305	112.6271	29.45949	12.50772	0.990863	0.111054
13.32982	169.1753	32.81668	14.32351	1.074546	0.084666
12.93224	134.5680	30.92817	13.50536	1.044316	0.100360
13.19209	156.2800	32.16244	13.95486	1.057820	0.089293
12.66265	115.2238	29.64758	13.66965	1.079525	0.118635
12.33295	95.30579	28.08154	12.71269	1.030790	0.133388
12.04021	80.52551	26.69101	12.03686	0.999721	0.149478
11.73475	67.54102	25.24006	11.77876	1.003750	0.174394
11.41204	56.09084	23.70722	11.41764	1.000490	0.203556
11.22182	50.27312	22.80366	11.21901	0.999749	0.223161
10.80986	39.65936	20.84684	10.85232	1.003927	0.273638
10.59434	35.03219	19.82315	10.64990	1.005243	0.304003
10.60752	35.29884	19.88572	10.47813	0.987802	0.296840
10.24583	28.66413	18.16771	10.16031	0.991653	0.354460
9.993928	24.79488	16.97115	10.01086	1.001694	0.403747
9.810469	22.30989	16.09973	9.844083	1.003426	0.441243
9.585804	19.60338	15.03256	9.890860	1.031823	0.504548
9.128276	15.06430	12.85931	10.88346	1.192280	0.722466
8.795097	12.43524	11.27671	10.73284	1.220321	0.863099
8.618720	11.23466	10.43892	9.872866	1.145514	0.878785
8.354711	9.650677	9.184877	8.607336	1.030237	0.891889
8.089450	8.284049	7.924891	8.035781	0.993365	0.970030
7.728773	6.730903	6.211673	6.117450	0.791516	0.908860
7.031433	4.505451	2.899307	4.155399	0.590974	0.922304
6.314032	2.981179	-0.50834	2.721580	0.431036	0.912920
10.69355	37.09107	20.29439	10.54187	0.985815	0.284215
11.13031	47.69338	22.36898	10.99680	0.988004	0.230572
11.36719	54.66124	23.49419	11.25488	0.990119	0.205902

11.67839 65.38527 24.97239 11.63004 0.995859 0.177869

A3P23107

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.194216	91.84705	0.077083	1.963065
0.817455	74.93731	-0.08753	1.874698
0.667230	62.27766	-0.17572	1.794332
0.492346	46.63966	-0.30772	1.668755
0.364427	37.46100	-0.43838	1.573579
0.240587	23.17140	-0.61872	1.364952
0.108778	10.58325	-0.96345	1.024619
0.047842	4.596817	-1.32018	0.662457

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.99959
Std Err of Y Est	0.015996
R Squared	0.998900
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 1.006351
Std Err of Coef. 0.019273

Tw = K'(8<U>/D)^n'

K' = 0.010009
n' = 1.006351

Tw* = 45.63800
Res/f* = 1520.749

Regression Output:

Constant	-9.85783
Std Err of Y Est	0.033642
R Squared	0.999362
No. of Observations	8
Degrees of Freedom	6

X Coefficient(s) 6.972239
Std Err of Coef. 0.071915

t = 24.30365 deg C
s.d.)t = 0.533327 deg C

Page 1 Alcomer 507

A1P33113 ALCOMER 507 8/13/90 15:25

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 9 Z = 6.95 [NaCl]=

Freq. (Hz)	Q)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.05	6.062	0.0585	0.0405	6.0215
50	1.0118	25.05	4.536333	0.0585	0.0405	4.495833
40	0.80944	25.05	3.216	0.0585	0.0405	3.1755
30	0.60708	25.05	2.084666	0.0585	0.0405	2.044166
25	0.5059	25	1.539333	0.0475	0.0445	1.491833
19	0.384484	25	1.0242	0.0475	0.0445	0.9797
14	0.283304	25	0.625666	0.0475	0,0445	0.581166
10	0.20236	25	0.414875	0.0475	0.0445	0.370375
8	0.161888	25	0.295285	0.0475	0.0445	0.250785
23	0.465428	23.9	1.384	0.0535	0.0425	1.3415
33	0.667788	23.9	2.39075	0.0535	0.0425	2.34825
44	0.890384	23.9	3.72	0.0535	0.0425	3.6775
10	0.20236	24	0.415	0.0425	0.0395	0.3755
18	0.364248	24.9	10.70225	0.0515	0.0555	10.64675
15	0.30354	24.9	8.19525	0.0515	0.0555	8.13975
10	0.20236	24.9	4.3953	0.0515	0.0555	4.3398
8	0.161888	24.9	2.954285	0.0515	0.0555	2.898785
		24.7	2.3235	0.0565	0.0525	2.267
		24.7	1.646333	0.0475	0.0435	1.598833
		24.6	1.206833	0.0395	0.0385	1.167333
		24.5	0.7348	0.0365	0.0345	0.6983
		24.5	0.543	0.0335	0.0325	0.5095
		24.4	0.3308	0.0315	0.0315	0.2993
		24.3	1.918857	0	-0.0005	1.918857
		24.3	1.001888	-0.0045	-0.0065	1.006388
		24.2	0.7066	-0.0115	-0.0145	0.7181
		24.2	0.566307	-0.0175	-0.0205	0.583907
		24.15	0.3984	-0.022	-0.024	0.4204
		24.1	0.28175	-0.0265	-0.0285	0.30825
		24	0.192526	-0.0295	-0.0305	0.222026
		23.9	0.102454	-0.0325	-0.0345	0.134954
		23.8	0.04024	-0.0345	-0.0355	0.07474
		23.7	0.013708	-0.0365	-0.0375	0.050208
		23.55	-0.01883	-0.0395	-0.0415	0.021662
		23.7	3.081428	-0.0425	-0.0435	3.123928
		23.8	4.182	-0.045	-0.044	4.227
		23.9	6.987	-0.046	-0.0475	7.033
		24	9.074	-0.0485	-0.0465	9.1225
		24	13.4824	-0.049	-0.045	13.5314

Page 2 Alcomer 507

		density	viscosity			
	cp)[NaCl]	1.01234	1.029478	ID(cm) =	1.45796	
999.6909	X coeff	-0.00025	-0.02201	K(V/psi)=	1.077888	12.75147
0.300123	constant	0.003419	-4.14933	XS(cm2)=	1.669479	

Batch Vol (ml)	t)samp (sec)	0 DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		5.586387	727.2685	116707.2	788.1156	0.002952	3.802167
		4.170965	606.0571	97256.01	588.4309	0.003173	3.738719
		2.946038	484.8457	77804.80	415.6209	0.003502	3.663220
		1.896455	363.6342	58353.60	267.5479	0.004008	3.567572
		1.384033	303.0285	48573.18	195.2565	0.004212	3.498682
		0.908907	230.3017	36915.62	128.2266	0.004789	3.407368
		0.539171	169.6960	27200.98	76.06519	0.005233	3.293972
		0.343611	121.2114	19429.27	48.47601	0.006536	3.196143
		0.232663	96.96914	15543.41	32.82374	0.006915	3.111473
		1.244563	278.7862	43592.01	175.5803	0.004474	3.464780
		2.178565	399.9977	62545.06	307.3474	0.003804	3.586357
		3.411764	533.3302	83393.42	481.3244	0.003351	3.683761
		0.348366	121.2114	18995.85	49.14679	0.006625	3.189275
		0.834942	218.1805	34893.88	117.7919	0.004902	3.387952
		0.638338	181.8171	29078.23	90.05539	0.005397	3.329649
		0.340337	121.2114	19385.49	48.01405	0.006474	3.193078
		0.227329	96.96914	15508.39	32.07116	0.006757	3.105451
2036	15	0.177783	81.30278	12944.31	25.08130	0.007516	3.050099
1643	15	0.125384	65.60926	10445.73	17.68894	0.008140	2.974274
1860	20	0.091545	55.70598	8849.032	12.91497	0.008244	2.904985
1386	19.9	0.054762	41.71853	6612.157	7.725751	0.008795	2.792423
1451	25	0.039956	34.76532	5510.112	5.636932	0.009239	2.723974
1073	25	0.023471	25.70861	4065.490	3.311352	0.009924	2.607471
1083	25.3	0.024071	25.64052	4045.586	3.395961	0.010232	2.611964
1181	34.9	0.012624	20.26951	3198.143	1.781090	0.008587	2.471826
1125	40	0.009008	16.84656	2652.077	1.270881	0.008870	2.397550
1181	50.1	0.007223	14.11988	2222.828	1.033213	0.010265	2.352592
1037	60	0.005273	10.35252	1627.913	0.744016	0.013750	2.280796
769	59.9	0.003866	7.689859	1207.851	0.545535	0.018273	2.212924
696	75	0.002785	5.558618	871.1284	0.392938	0.025189	2.140689
513	90	0.001692	3.414237	533.8623	0.238840	0.040582	2.031596
316	99.9	0.000937	1.894700	295.5944	0.132273	0.072978	1.902293
213	100	0.000629	1.275846	198.5978	0.088857	0.108116	1.814919
139	150.1	0.000271	0.554693	86.05168	0.038337	0.246769	1.630905
1153	20	0.039188	34.53172	5375.194	5.528676	0.009182	2.711882
1367	19.9	0.053026	41.14663	6419.336	7.480874	0.008751	2.778533
1376	15.1	0.088227	54.58337	8534.850	12.44688	0.008274	2.890072
1608	15	0.114439	64.21162	10063.03	16.14484	0.007755	2.967544
1986	15	0.169747	79.30615	12428.59	23.94764	0.007541	3.033158

Tap DL= 122.2234
79.71477 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.80866	396.3210	39.84117	18.40477	1.242838	0.046439
14.55487	342.4521	38.63567	17.74992	1.219517	0.051831
14.25288	287.8066	37.20119	16.89606	1.185448	0.058706
13.87029	230.9154	35.38388	15.79409	1.138699	0.068397
13.59472	197.0436	34.07496	15.40686	1.133296	0.078190
13.22947	159.6793	32.34000	14.44912	1.092191	0.090488
12.77589	122.9851	30.18547	13.82331	1.081984	0.112398
12.38457	98.18000	28.32671	12.36840	0.998694	0.125976
12.04589	80.78925	26.71799	12.02466	0.998237	0.148839
13.45912	182.2469	33.43082	14.94949	1.110733	0.082028
13.94542	241.1222	35.74078	16.21197	1.162529	0.067235
14.33504	301.7458	37.59146	17.27310	1.204956	0.057243
12.35710	96.63961	28.19622	12.28524	0.994184	0.127124
13.15180	152.6976	31.97109	14.28226	1.085954	0.093533
12.91859	133.5147	30.86333	13.61190	1.053667	0.101950
12.37231	97.48965	28.26849	12.42791	1.004493	0.127479
12.02180	79.67677	26.60358	12.16508	1.011917	0.152680
11.80039	70.14214	25.55188	11.53400	0.977425	0.164437
11.49709	58.90537	24.11122	11.08317	0.963997	0.188152
11.21994	50.21870	22.79472	11.01311	0.981566	0.219303
10.76969	38.75287	20.65605	10.66397	0.990183	0.275179
10.49589	33.10205	19.35552	10.40364	0.991210	0.314289
10.02988	25.31343	17.14194	10.03787	1.000797	0.396543
10.04785	25.57670	17.22732	9.885915	0.983882	0.386520
9.487304	18.52277	14.56469	10.79125	1.137441	0.582593
9.190201	15.61099	13.15345	10.61783	1.155342	0.680150
9.010371	14.07579	12.29926	9.869905	1.095393	0.701196
8.723187	11.93099	10.93513	8.527752	0.977595	0.714755
8.451697	10.20479	9.645563	7.397570	0.875276	0.724911
8.162759	8.641116	8.273107	6.300751	0.771889	0.729159
7.726384	6.721654	6.200327	4.964015	0.642475	0.738510
7.209175	4.990841	3.743581	3.701710	0.513472	0.741700
6.859679	4.081313	2.083478	3.041267	0.443354	0.745168
6.123620	2.671684	-1.41280	2.013048	0.328734	0.753475
10.44753	32.19308	19.12576	10.43546	0.998844	0.324152
10.71413	37.53300	20.39213	10.68948	0.997699	0.284802
11.16029	48.52357	22.51138	10.99317	0.985025	0.226553
11.39017	55.38913	23.60334	11.35492	0.996905	0.205002
11.73263	67.45886	25.23002	11.51498	0.981448	0.170696

A1P33113

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.744016	56.80555	-0.12841	1.754390
0.545535	42.19517	-0.26317	1.625262
0.392938	30.50080	-0.40567	1.484311
0.238840	18.73432	-0.62189	1.272638
0.132273	10.39644	-0.87852	1.016884
0.088857	7.000722	-1.05130	0.845142
0.038337	3.043668	-1.41637	0.483397

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.90421
Std Err of Y Est	0.001128
R Squared	0.999993
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	1.008803
Std Err of Coef.	0.001459

Tw = K'(8<U>/D)^n'

K' = 0.012467
n' = 1.008803

Tw* = 46.76978
Res/f* = 1544.737

Regression Output:

Constant	-18.6712
Std Err of Y Est	0.162296
R Squared	0.993377
No. of Observations	14
Degrees of Freedom	12
X Coefficient(s)	9.729725
Std Err of Coef.	0.229325

t = 24.39743 deg C
s.d.)t = 0.488187 deg C

D3P11418 DSR1438 8/22/90 12:38

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C> (ppm)=

Z = 2.7 Z = 9.05 Z = 6.85 [NaCl]=

Freq. (Hz)	Q)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	24.7	7.62675	0.0515	0.0895	7.53725
50	1.0118	24.7	5.532666	0.0515	0.0895	5.443166
39	0.789204	24.7	3.663	0.0515	0.0895	3.5725
30	0.60708	24.7	2.3845	0.0515	0.0895	2.295
25	0.5059	24.6	1.7545	0.0545	0.0575	1.697
19	0.384484	24.6	1.11275	0.0545	0.0575	1.05525
15	0.30354	24.6	0.750428	0.0545	0.0575	0.692928
9	0.182124	24.6	0.35525	0.0545	0.0575	0.29775
7	0.141652	24.6	0.258714	0.0545	0.0575	0.201214
18	0.364248	25	11.329	0.0405	0.0625	11.2665
14	0.283304	25	7.3915	0.0405	0.0625	7.329
10	0.20236	25	4.2304	0.0405	0.0625	4.1679
8	0.161888	25	2.9545	0.0405	0.0625	2.892
		24.3	2.7035	0.043	0.0435	2.6605
		24.3	1.892	0.0425	0.0425	1.8495
		24.3	1.4662	0.0425	0.0425	1.4237
		24.2	0.91925	0.0425	0.0425	0.87675
		24.2	0.6836	0.0425	0.0425	0.6411
		24	4.184	0.031	0.022	4.153
		24	2.503	0.0215	0.0235	2.4795
		24	1.661333	0.024	0.027	1.634333
		24	1.18275	0.027	0.028	1.15475
		23.95	0.649538	0.0275	0.0275	0.622038
		23.9	0.443933	0.027	0.027	0.416933
		23.9	0.312615	0.0265	0.0265	0.286115
		23.8	0.231722	0.026	0.026	0.205722
		23.65	0.1625	0.0255	0.025	0.13725
		23.5	0.1062	0.0245	0.0245	0.0817
		23.4	0.070625	0.0245	0.023	0.046875
		23.2	0.039882	0.023	0.023	0.016882
		23.3	5.5615	0.0215	0.0175	5.54
		23.6	8.9745	0.0175	0.017	8.957
		23.7	11.5718	0.0155	0.0165	11.5553

		density	viscosity			
co)[NaCl]		1.000038	1.001574		ID(cm) =	1.45796
29.99008	X coeff	-0.00025	-0.02281		K(V/psi)=	1.077888 12.72683
0.000100	constant	0.003419	-4.14933		XS(cm2)=	1.669479

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	U (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		6.992609	727.2685	117574.8	986.5025	0.003740	3.856762
		5.049844	606.0571	97979.02	712.4213	0.003889	3.786082
		3.315279	472.7245	76423.64	467.7125	0.004197	3.694703
		2.129163	383.6342	58787.41	300.3778	0.004555	3.598547
		1.574375	303.0285	48879.11	222.1094	0.004850	3.532012
		0.978997	230.3017	37148.12	138.1149	0.005221	3.428849
		0.642857	181.8171	29327.47	90.69299	0.005501	3.337515
		0.276234	109.0902	17596.48	38.97059	0.006566	3.154097
		0.186674	84.84800	13686.15	26.33565	0.007335	3.069000
		0.885255	218.1805	35511.98	124.8900	0.005261	3.410933
		0.575870	169.6960	27620.43	81.24252	0.005657	3.317561
		0.327489	121.2114	19728.87	46.20148	0.006306	3.194997
		0.227236	96.96914	15783.10	32.05803	0.006837	3.115637
2300	14.9	0.209046	92.46140	14813.61	29.49184	0.006917	3.090624
1884	15	0.145322	75.23302	12053.38	20.50184	0.007263	3.011669
1611	15	0.111866	64.33142	10306.79	15.78182	0.007646	2.954851
1226	15.1	0.068889	48.63315	7774.153	9.718840	0.008039	2.848595
1349	20	0.050373	40.40181	6458.349	7.196642	0.008729	2.780620
1346	20	0.051692	40.31196	6414.977	7.292711	0.008997	2.784262
1001	20	0.030862	29.97940	4770.722	4.354027	0.009713	2.672263
1181	29.9	0.020342	23.65906	3764.946	2.869906	0.010279	2.581751
1311	39.9	0.014373	19.68106	3131.914	2.027753	0.010496	2.506325
1221	45	0.007742	16.25257	2583.409	1.092706	0.008291	2.371497
1160	55.1	0.005189	12.61029	2002.196	0.732139	0.009230	2.284129
909	60	0.003561	9.074684	1440.830	0.502421	0.012232	2.202366
870	80.1	0.002560	6.505873	1030.640	0.361250	0.017111	2.129751
735	100	0.001708	4.402569	695.0854	0.241012	0.024928	2.040389
431	100	0.001016	2.581642	406.2173	0.143466	0.043153	1.926266
250	100.1	0.000583	1.495976	234.8590	0.082312	0.073733	1.804640
93	100	0.000210	0.557059	87.06124	0.029645	0.191505	1.580915
1200	15	0.068956	47.91912	7506.053	9.728297	0.008492	2.839939
1595	15	0.111488	63.69250	10044.54	15.72858	0.007772	2.947221
1843	14.9	0.143829	74.08972	11710.61	20.29122	0.007410	3.003516

Tap DL= 122.2234
80.34 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.02705	449.4102	40.87849	16.35126	1.088121	0.036383
14.74432	381.9111	39.53556	16.03432	1.087491	0.041984
14.37881	309.4449	37.79936	15.43562	1.073498	0.049881
13.99419	247.9864	35.97240	14.81618	1.058738	0.059745
13.72804	212.7611	34.70823	14.35856	1.045929	0.067486
13.31539	167.7756	32.74813	13.83846	1.039283	0.082481
12.95006	135.9551	31.01279	13.48214	1.041087	0.099166
12.21638	89.12042	27.52784	12.34038	1.010149	0.138468
11.87600	73.26233	25.91101	11.67563	0.983128	0.159367
13.24373	160.9953	32.40773	13.78610	1.040953	0.085630
12.87024	129.8497	30.63366	13.29441	1.032957	0.102383
12.37998	97.92136	28.30495	12.59229	1.017149	0.128596
12.06255	81.56765	26.79712	12.09356	1.002571	0.148264
11.96249	77.00236	26.32185	12.02366	1.005113	0.156146
11.64667	64.20215	24.82172	11.73381	1.007482	0.182763
11.41940	56.32895	23.74218	11.43594	1.001448	0.203020
10.99438	44.10371	21.72330	11.01686	1.002045	0.249794
10.72248	37.71378	20.43178	10.70289	0.998173	0.283792
10.73704	38.03137	20.50097	10.54224	0.981856	0.277198
10.28905	29.38617	18.37299	10.14661	0.986156	0.345285
9.927005	23.85785	16.65327	9.862962	0.993548	0.413405
9.625300	20.05418	15.22017	9.760786	1.014076	0.486720
9.085988	14.70202	12.65844	10.98237	1.208715	0.746997
8.736516	12.02289	10.99845	10.40824	1.191349	0.865701
8.409465	9.959705	9.444962	9.041624	1.075172	0.907820
8.119005	8.426190	8.065274	7.644621	0.941571	0.907245
7.761556	6.859130	6.367391	6.333578	0.816019	0.923379
7.305064	5.274072	4.199055	4.813848	0.658974	0.912738
6.818562	3.985846	1.888169	3.682704	0.540099	0.923945
5.923663	2.381200	-2.36259	2.285119	0.385761	0.959650
10.95975	43.23341	21.55885	10.85105	0.990081	0.250987
11.38888	55.34795	23.59720	11.34250	0.995927	0.204930
11.61406	63.00805	24.66680	11.61619	1.000183	0.184360

D3P11418

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.092306	89.17978	0.038344	1.950266
0.732139	69.19419	-0.13540	1.840069
0.502421	49.79387	-0.29893	1.697175
0.361250	35.69850	-0.44219	1.552650
0.241012	24.15742	-0.61796	1.383050
0.143466	14.16578	-0.84325	1.151240
0.082312	8.208602	-1.08453	0.914269
0.029645	3.056653	-1.52803	0.485246

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-2.00012
Std Err of Y Est	0.003109
R Squared	0.999926
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s)	1.002293
Std Err of Coef.	0.004969

Tw = K'(8<U>/D)^n'

K' = 0.009997
n' = 1.002293

Tw* = 29.39713
Res/f* = 1241.270

Regression Output:

Constant	-5.76053
Std Err of Y Est	0.085168
R Squared	0.996615
No. of Observations	8
Degrees of Freedom	6

X Coefficient(s)	5.732631
Std Err of Coef.	0.136377

t = 24.072 deg C
s.d.)t = 0.519823 deg C

D1P21415 DSR1438 8/18/90 13:33

10 PSID Taps 14	1.0 PSID Taps 14	0.1 PSID Taps 14	
S = 2.7	S = 7.25	S = 9.9	[C.(ppm)=
Z = 2.7	Z = 9.05	Z = 6.85	[NaCl]=

Freq. (Hz)	D)est (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	24.8	6.065666	0.0485	0.0245	6.041166
50	1.0118	24.8	4.476666	0.0485	0.0245	4.452166
39	0.789204	24.8	2.979	0.0485	0.0245	2.9545
29	0.586844	24.8	1.871333	0.0485	0.0245	1.846833
25	0.5059	24.7	1.4785	0.0435	0.0355	1.443
19	0.384484	24.7	0.955	0.0435	0.0355	0.9195
15	0.30354	24.7	0.647875	0.0435	0.0355	0.612375
10	0.20236	24.7	0.349666	0.0435	0.0355	0.314166
18	0.364248	24.9	9.9176	0.0645	0.0935	9.8241
14	0.283304	24.9	6.643285	0.0645	0.0935	6.549785
10	0.20236	24.9	3.945818	0.0645	0.0935	3.852318
7	0.141652	24.9	2.274142	0.0645	0.0935	2.180642
		24.6	2.7052	0.0775	0.0625	2.6277
		24.5	1.86975	0.0605	0.0605	1.80925
		24.5	1.4572	0.0605	0.0605	1.3967
		24.4	0.934666	0.0615	0.0615	0.873166
		24.3	0.6845	0.0625	0.0625	0.622
		24.3	0.411714	0.0625	0.0625	0.349214
		24.2	2.338	-0.0045	0.0005	2.3375
		24.2	1.272222	0.0025	0.0025	1.269722
		24.2	1.0356	0.0045	0.0045	1.0311
		24.1	0.846363	0.0055	0.0055	0.840863
		24.1	0.636	0.0055	0.0055	0.6305
		24	0.504875	0.0055	0.0055	0.499375
		24	0.394277	0.0055	0.006	0.388277
		23.9	0.28376	0.006	0.007	0.27676
		23.9	0.20516	0.0065	0.0065	0.19866
		23.75	0.11752	0.0065	0.0065	0.11102
		23.65	0.071	0.0065	0.0055	0.0655
		23.6	0.028409	0.0055	0.0055	0.022909
		23.7	3.884333	0.0045	0.0015	3.879833
		23.8	5.524666	0.0015	0.0015	5.523166
		23.95	8.9806	0.0005	-0.0015	8.9821
		24	11.2918	-0.001	0	11.2918

		density	viscosity		
	co)[NaCl]	1.000088	1.001574	ID(cm) =	1.45795
99.83178	X coeff	-0.00025	-0.02281	K(V/psi)=	1.077888 12.72583
0.000100	constant	0.000419	-4.14933	XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		5.604633	727.2685	117840.3	790.6897	0.002997	3.309702
		4.170453	606.0571	98200.31	582.7156	0.003181	3.743427
		2.741008	472.7245	76596.24	386.6956	0.003470	3.654383
		1.713381	351.5121	56956.18	241.7202	0.003923	3.552255
		1.338729	303.0285	48989.51	189.8650	0.004124	3.497789
		0.853057	230.3017	37232.02	120.3474	0.004550	3.399932
		0.568124	181.8171	29393.70	80.14985	0.004862	3.311665
		0.291465	121.2114	19595.80	41.11926	0.005612	3.166736
		0.771920	218.1805	35431.95	108.9008	0.004587	3.380200
		0.514643	169.6960	27558.18	72.60487	0.005056	3.292167
		0.302692	121.2114	19684.42	42.70323	0.005828	3.176914
		0.171342	84.84800	13779.09	24.17259	0.006733	3.053345
2368	14.9	0.206469	95.19504	15355.15	29.12825	0.006445	3.090885
1901	14.9	0.142160	76.42135	12299.14	20.05567	0.006886	3.008862
1636	15.1	0.109744	64.89709	10444.44	15.48252	0.007371	2.952664
1601	19.9	0.068608	48.19002	7738.154	9.679118	0.008357	2.849676
1350	20	0.048873	40.43176	6477.734	6.894917	0.008457	2.775037
1252	25	0.027439	29.99737	4805.999	3.871066	0.008626	2.649688
1251	25	0.029160	29.97341	4791.339	4.113906	0.009181	2.661915
1186	30	0.015839	23.68003	3785.323	2.234660	0.007990	2.529393
1168	35	0.012863	19.98912	3195.320	1.814694	0.009106	2.484189
1096	39.9	0.010489	16.45343	2624.203	1.479886	0.010960	2.428916
1020	49.9	0.007865	12.24386	1952.807	1.109654	0.014841	2.576396
951	59.5	0.006229	9.573758	1523.504	0.878880	0.019225	2.524782
927	74.9	0.004843	7.413389	1179.717	0.683353	0.024930	2.270140
881	99.9	0.003452	5.282376	838.7078	0.487086	0.034998	2.195625
625	100	0.002478	3.743681	594.4020	0.349633	0.050016	2.123638
351	100	0.001384	2.102451	332.6884	0.195390	0.088621	1.995806
205	99.9	0.000817	1.229156	194.0614	0.115277	0.152969	1.880241
73	100.1	0.000295	0.436825	68.88898	0.040319	0.423608	1.651632
1327	20	0.048401	29.74292	4281.765	5.828552	0.008667	2.767019
1204	15	0.068902	48.07835	7616.505	9.720553	0.008430	2.844692
1605	15	0.112052	64.09183	10187.64	15.80813	0.007715	2.951765
1866	14.9	0.140866	75.01433	11937.28	19.87311	0.007080	3.001950

Tap DL= 122.2234
80.1597 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.83880	403.2572	39.98434	18.26383	1.230815	0.045290
14.57370	346.1843	38.72512	17.72904	1.216509	0.051212
14.21753	282.0095	37.03329	16.97554	1.193986	0.060194
13.80942	222.9644	35.09475	15.96560	1.156138	0.071606
13.59115	196.6390	34.05800	15.57088	1.145663	0.079185
13.19972	156.9684	32.19871	14.82464	1.123102	0.094443
12.84666	128.0988	30.52163	14.34131	1.116346	0.111955
12.26694	91.75222	27.76799	13.34831	1.088153	0.145482
13.12080	149.9961	31.82380	14.76369	1.125213	0.098427
12.76866	122.4749	30.15117	14.06317	1.101381	0.114824
12.30765	93.92792	27.96137	13.09808	1.064222	0.139448
11.81338	70.66850	25.61357	12.18638	1.031574	0.172444
11.96354	77.04881	26.32683	12.45570	1.041138	0.161659
11.63544	63.78846	24.76838	12.05070	1.035689	0.188916
11.41065	56.04597	23.70062	11.64718	1.020728	0.207814
10.99870	44.21363	21.74384	10.93858	0.994534	0.247402
10.70015	37.23210	20.32571	10.87390	1.016238	0.292057
10.19875	27.89770	17.94408	10.76701	1.055718	0.385946
10.24766	28.69426	18.17638	10.43618	1.018396	0.363702
9.717574	21.14821	15.65847	11.18688	1.151201	0.528975
9.536758	19.05766	14.79960	10.47911	1.098813	0.549863
9.355667	17.17105	13.93942	9.551697	1.020953	0.556267
9.105586	14.86882	12.75153	8.208680	0.901477	0.552059
8.899129	13.20268	11.77086	7.212092	0.810426	0.546259
8.680560	11.64180	10.77266	6.333412	0.729608	0.544023
8.382541	9.806531	9.317072	5.345339	0.637675	0.545079
8.094555	8.308429	7.949139	4.471377	0.552393	0.538173
7.583226	6.189941	5.520324	3.359164	0.442972	0.542681
7.120965	4.743745	3.324586	2.556806	0.359053	0.538984
6.206528	2.802203	-1.01899	1.536447	0.247553	0.548284
10.66807	36.55105	20.17337	10.74142	1.006875	0.293874
10.97877	43.70917	21.64915	10.89088	0.991994	0.249166
11.40706	55.93006	23.68354	11.38436	0.998010	0.203546
11.60780	62.78133	24.63705	11.88378	1.023775	0.189288

D1P21415

Tw dyne/cm2	B<U>/D (1/sec)	Log Tw	Log B<U>/D
1.109654	67.18354	0.045187	1.827262
0.878880	52.53235	-0.05607	1.720426
0.683353	40.67815	-0.16535	1.609361
0.487086	28.98502	-0.31239	1.462173
0.349633	20.54202	-0.45638	1.312643
0.195390	11.53640	-0.70909	1.062070
0.115277	6.744529	-0.93825	0.828951
0.040319	2.396911	-1.39448	0.379652

Log Tw vs. Log B<U>/D

Regression Output:

Constant	-1.77159
Std Err of Y Est	0.003676
R Squared	0.999944
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 1.000366
Std Err of Coef. 0.004305

Tw = K'(B<U>/D)^n'

K' = 0.016920
n' = 1.000366

Tw* = 18.27988
Res/f* = 981.0379

Regression Output:

Constant	-12.7263
Std Err of Y Est	0.123504
R Squared	0.994126
No. of Observations	7
Degrees of Freedom	5

X Coefficient(s) 8.120185
Std Err of Coef. 0.279125

t = 24.33088
s.d.)t = 0.415687 deg C

D3P21421 DSR1438 8/25/90 13:09

	10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14	
S =	2.7	S =	7.25	S =	9.9	C)(ppm)=	
Z =	2.7	Z =	9.05	Z =	6.85	[NaCl]=	

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25	4.76425	0.0395	0.0175	4.74675
50	1.0118	25	3.62075	0.0395	0.0175	3.60325
40	0.80944	25	2.57575	0.0395	0.0175	2.55825
30	0.60708	25	1.697666	0.0395	0.0175	1.680166
25	0.5059	25.1	1.28975	0.0225	0.026	1.26375
20	0.40472	25.1	0.9198	0.0225	0.026	0.8938
15	0.30354	25.1	0.626444	0.0225	0.026	0.600444
10	0.20236	25.1	0.360333	0.0225	0.026	0.334333
18	0.364248	24.8	9.1165	-0.0295	0.0945	9.146
24	0.485664	24.8	13.41933	-0.0295	0.0945	13.44883
15	0.30354	24.8	7.065125	-0.0295	0.0945	6.970625
10	0.20236	24.8	4.002428	-0.0295	0.0945	3.907928
8	0.161888	24.8	3.032875	-0.0295	0.0945	2.938375
		24.3	2.713	0.0265	0.0235	2.6895
		24.2	1.905333	0.0155	0.0135	1.889833
		24.2	1.4445	0.0095	0.0085	1.435
		24.1	0.7112	0.0065	0.0035	0.7047
		24.1	0.532833	0.0025	0	0.530333
		24	3.465833	0.0245	0.0255	3.441333
		24	2.577428	0.0255	0.027	2.551928
		23.9	2.08275	0.0255	0.0265	2.05725
		23.9	1.7959	0.0255	0.0265	1.7694
		23.9	1.497769	0.0245	0.0245	1.473269
		23.8	1.15775	0.0215	0.0215	1.13625
		23.7	0.872928	0.0195	0.0195	0.853428
		23.6	0.603684	0.0185	0.0185	0.585184
		23.5	0.476772	0.0175	0.0165	0.460272
		23.3	0.33648	0.0155	0.0155	0.32098
		23.2	0.23052	0.0135	0.0125	0.21702
		23.1	0.1554	0.0125	0.0115	0.1429
		23	0.099793	0.0115	0.0095	0.088293
		22.8	0.05964	0.0095	0.0075	0.05214
		23.1	4.498833	0.0065	0.0025	4.492333
		23.3	9.033666	0	0.0045	9.029166
		23.5	11.65075	0.0015	0.006	11.64475

		density	viscosity			
	co)[NaCl]	1.000088	1.001574		ID(cm) =	1.45796
299.6776	X coeff	-0.00025	-0.02281		K(V/psi)=	1.077888 12.72683
0.000100	constant	0.003419	-4.14933		XS(cm2)=	1.669479

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		4.403750	727.2685	118373.2	621.2718	0.002355	3.759310
		3.342879	606.0571	98644.39	471.6063	0.002574	3.699459
		2.373391	484.8457	78915.51	334.8330	0.002856	3.625083
		1.558758	363.6342	59186.63	219.9062	0.003335	3.553788
		1.172431	303.0285	49333.59	165.4041	0.003612	3.472927
		0.829214	242.4228	39546.87	116.9837	0.003992	3.397717
		0.557056	181.8171	29660.15	78.58833	0.004767	3.311333
		0.310174	121.2114	19773.43	43.75875	0.005973	3.184187
		0.718639	218.1805	35352.11	101.3841	0.004271	3.367684
		1.056730	290.9074	47136.15	149.0813	0.003532	3.447410
		0.547711	181.8171	29460.09	77.26990	0.004687	3.304704
		0.307062	121.2114	19640.06	43.31968	0.005912	3.179041
		0.230880	96.96914	15712.05	32.57211	0.006946	3.117122
2377	14.9	0.211325	95.55684	15309.54	29.81331	0.006546	3.092978
1888	15	0.148492	75.39275	12051.75	20.94894	0.007389	3.015368
1611	15	0.112753	64.33142	10283.56	15.90708	0.007706	2.955583
1607	20	0.055371	48.12877	7676.189	7.811653	0.006761	2.800174
1341	20.1	0.041670	39.96240	6373.713	5.878785	0.007380	2.738446
1340	20	0.043182	40.13226	6386.381	6.092154	0.007583	2.745202
1225	24.9	0.032022	29.46833	4689.394	4.517651	0.010430	2.680273
1171	30.1	0.025815	23.30286	3699.906	3.641927	0.013446	2.632497
1151	35	0.022202	19.69818	3127.573	3.132549	0.016185	2.599767
1220	45	0.018487	16.23925	2578.384	2.608112	0.019828	2.559995
1211	59.9	0.014258	12.10977	1918.394	2.011490	0.027500	2.502606
920	60	0.010709	9.184499	1451.701	1.510815	0.035907	2.439467
777	75.1	0.007343	6.197263	977.3318	1.035945	0.054076	2.356545
728	90	0.005775	4.845156	762.3775	0.814815	0.069582	2.303421
561	99.9	0.004027	3.363692	526.8889	0.568227	0.100676	2.222182
376	100	0.002723	2.252198	351.9895	0.384188	0.151829	2.137207
295	120	0.001793	1.472514	229.6164	0.252974	0.233868	2.045488
184	119.9	0.001107	0.919215	143.0148	0.156304	0.370800	1.939951
107	120.1	0.000654	0.533653	82.65395	0.093702	0.649648	1.823602
1585	20	0.056371	47.46988	7402.210	7.952728	0.007074	2.794208
1587	15	0.113300	63.37304	9926.756	15.98423	0.007978	2.947767
1861	15.1	0.146121	73.82242	11615.84	20.61457	0.007583	3.004978

Tap DL= 122.2234
79.692 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.63724	359.0792	39.02689	20.60361	1.407615	0.057379
14.39783	312.8522	37.88972	19.70666	1.368723	0.062990
14.10033	265.6110	36.47658	18.71021	1.326934	0.070976
13.73515	213.6329	34.74197	17.31551	1.260671	0.081052
13.49171	185.6982	33.58563	16.63773	1.233182	0.089595
13.19086	156.1699	32.15663	15.82685	1.199834	0.101343
12.84533	128.0011	30.51534	14.48237	1.127442	0.113142
12.33674	95.51403	28.09955	12.93883	1.048803	0.135465
13.05473	144.3989	31.50999	15.30140	1.172096	0.105966
13.38964	175.1018	33.10080	16.82454	1.256534	0.096084
12.81881	126.0620	30.38938	14.60595	1.139414	0.115863
12.31616	94.38907	28.00179	13.00472	1.055906	0.137777
12.06848	81.84686	26.82531	11.99805	0.994163	0.146591
11.97191	77.42090	26.36658	12.35902	1.032334	0.159634
11.66147	64.75137	24.89201	11.63272	0.997534	0.179652
11.42233	56.42391	23.75608	11.39096	0.997254	0.201881
10.80069	39.45065	20.80330	12.16106	1.125951	0.308260
10.55378	34.22366	19.63048	11.63981	1.102904	0.340110
10.58081	34.76025	19.75885	11.48290	1.085257	0.330345
10.32109	29.93325	18.52520	9.791358	0.948674	0.327106
10.12999	26.81500	17.61746	8.623682	0.851302	0.321599
9.999069	24.86837	16.99558	7.860318	0.786105	0.316076
9.839981	22.69214	16.23991	7.101533	0.721701	0.312951
9.610424	19.88319	15.14951	6.030199	0.627464	0.303281
9.357870	17.19283	13.94988	5.277275	0.563939	0.306946
9.026180	14.20447	12.37435	4.300282	0.476423	0.302741
8.813684	12.56901	11.36500	3.790956	0.430121	0.301611
8.492728	10.44869	9.840462	3.151641	0.371098	0.301630
8.148831	8.572113	8.206950	2.566385	0.314939	0.299387
7.781955	6.940151	6.464289	2.067825	0.265720	0.297951
7.359804	5.442908	4.459069	1.642214	0.223132	0.301716
6.894411	4.163732	2.248452	1.240683	0.179954	0.297973
10.77683	38.91247	20.68996	11.88919	1.103218	0.305536
11.39106	55.41751	23.60757	11.19541	0.982824	0.202019
11.61991	63.22061	24.69459	11.48343	0.988254	0.181640

D3P21421

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
2.011490	66.44779	0.303518	1.822480
1.510815	50.39643	0.179211	1.702399
1.035945	34.00512	0.015336	1.531544
0.814815	26.58594	-0.08894	1.424652
0.568227	18.45698	-0.24547	1.266160
0.384188	12.35808	-0.41545	1.091951
0.252974	8.079863	-0.59692	0.907404
0.156304	5.043847	-0.80602	0.702761
0.092302	2.928222	-1.03478	0.466604

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.49457
Std Err of Y Est	0.002906
R Squared	0.999963
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	0.985859
Std Err of Coef.	0.002238

Tw = K'(8<U>/D)^n'

K' = 0.032020
n' = 0.985859

Tw* = 33.82628
Res/f* = 1340.592

Regression Output:

Constant	-29.3868
Std Err of Y Est	0.113496
R Squared	0.998378
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	13.26898
Std Err of Coef.	0.218298

t = 24.14 deg C
s.d.)t = 0.718013 deg C

D1P31424 DSR1438 8/29/90 12:37

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 9.05 Z = 6.85 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.7	4.055666	0.0545	0.0575	3.998166
50	1.0118	24.7	3.166333	0.0545	0.0575	3.108833
39	0.789204	24.7	2.268666	0.0545	0.0575	2.211166
29	0.586844	24.7	1.543	0.0545	0.0575	1.4855
19	0.384484	24.7	0.918666	0.0545	0.0575	0.861166
14	0.283304	24.7	0.63725	0.0545	0.0575	0.57975
9	0.182124	24.7	0.371	0.0545	0.0575	0.3135
18	0.364248	24.9	9.4716	0.0675	0.085	9.3866
14	0.283304	24.9	6.5951	0.0675	0.085	6.5101
10	0.20236	24.8	4.43025	0.0875	0.0905	4.33975
8	0.161888	24.8	3.05	0.0875	0.0905	2.9595
		24.4	2.804666	0.1035	0.106	2.698666
		24.3	1.6448	0.0995	0.0995	1.5453
		24.3	1.2452	0.0995	0.0995	1.1457
		24.2	7.45675	0.0445	-0.1425	7.59925
		24.2	5.5362	0.0205	0.0085	5.5277
		24.2	4.596666	0.0095	0.014	4.582666
		24.1	3.503714	0.0135	0.0145	3.489214
		24.1	2.784375	0.0145	0.0145	2.769875
		24.1	2.446333	0.0135	0.0135	2.432833
		24	2.057666	0.0105	0.0075	2.050166
		23.95	1.562181	0.0075	0.0045	1.557681
		23.8	1.206818	0.0025	0	1.206818
		23.7	0.793388	0	0	0.793388
		23.6	0.571045	-0.0005	-0.0015	0.572545
		23.6	0.382833	-0.0035	-0.0035	0.386333
		23.5	0.213578	-0.0045	-0.0065	0.218078
		23.4	0.136	-0.0085	-0.0095	0.1445
		23.3	0.065909	-0.0105	-0.0125	0.076409
		23.6	9.50175	-0.0145	-0.0165	9.51825

		density	viscosity			
	co)[NaCl]	1.000088	1.001574		ID(cm) = 1.45796	12.72683
996.8529	X coeff	-0.00025	-0.02281		K(V/psi)=	1.077088 12.8687
0.000099	constant	0.003419	-4.14933		XS(cm2)= 1.669479	

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		3.709259	727.2685	117574.8	523.2945	0.001984	3.719086
		2.884189	606.0571	97979.02	406.8953	0.002221	3.664455
		2.051388	472.7245	76423.64	289.4054	0.002597	3.590467
		1.378158	351.5131	56827.83	194.4276	0.003155	3.504092
		0.798938	230.3017	37232.02	112.7126	0.004261	3.385700
		0.537857	169.6960	27434.12	75.87977	0.005284	3.299776
		0.290846	109.0902	17636.22	41.03201	0.006914	3.166275
		0.729413	218.1805	35431.95	102.9040	0.004335	3.367900
		0.505886	169.6960	27558.18	71.36937	0.004970	3.288440
		0.337232	121.2114	19640.06	47.57611	0.006493	3.199393
		0.229976	96.96914	15712.05	32.44461	0.006919	3.116270
2222	15	0.209707	88.73024	14247.93	29.58513	0.007535	3.092295
1745	14.9	0.120082	70.15006	11239.02	16.94092	0.006902	2.970241
1485	14.9	0.089029	59.69790	9564.440	12.56015	0.007066	2.905270
1481	14.9	0.095231	59.53710	9517.182	13.43503	0.007599	2.918907
1111	14.8	0.069271	44.96465	7187.733	9.772656	0.009691	2.849794
1242	19.9	0.057428	37.38414	5975.966	8.101891	0.011623	2.809081
1160	24.8	0.043725	28.01723	4468.545	6.168730	0.015756	2.748900
1083	29.9	0.034711	21.69582	3460.326	4.896980	0.020859	2.698766
940	30	0.030487	18.76832	2993.411	4.301109	0.024482	2.670592
908	35.1	0.025692	15.49521	2465.805	3.624577	0.030267	2.632446
781	40	0.019520	11.69526	1859.007	2.753892	0.040367	2.572298
604	40.1	0.015123	9.022179	1429.266	2.133585	0.052550	2.515402
735	74.9	0.009942	5.877930	929.0653	1.402666	0.081392	2.423339
634	90	0.007174	4.219545	665.4382	1.012227	0.113976	2.351515
431	90	0.004841	2.868492	452.3720	0.683015	0.166414	2.266091
306	120	0.002732	1.527422	240.3374	0.385551	0.331300	2.140932
201	119.9	0.001810	1.004143	157.6443	0.255467	0.507916	2.050574
107	120	0.000957	0.534098	83.66122	0.135086	0.949307	1.911227
1731	15	0.119279	69.12333	10901.01	16.82771	0.007060	2.961889

79.692 Tap DL= 122.2234
79.79777 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.47634	327.3158	38.26265	22.45057	1.550844	0.068589
14.25782	288.6258	37.22464	21.21670	1.488074	0.073509
13.96186	243.4149	35.81887	19.62277	1.405454	0.080614
13.61637	199.5137	34.17776	17.80197	1.307395	0.089226
13.14280	151.9078	31.92830	15.31851	1.165543	0.100840
12.79910	124.6398	30.29576	13.75669	1.074817	0.110371
12.26510	91.65482	27.75923	12.02625	0.980526	0.131212
13.07160	145.8077	31.59011	15.18779	1.161892	0.104163
12.75376	121.4283	30.08036	14.18438	1.112172	0.116812
12.39757	98.91760	28.38847	12.40935	1.000950	0.125451
12.06508	81.68652	26.80913	12.02160	0.996396	0.147167
11.96918	77.29921	26.35360	11.52011	0.962481	0.149032
11.48096	58.36085	24.03459	12.03613	1.048355	0.206236
11.22108	50.25169	22.80014	11.89566	1.060117	0.236721
11.27562	51.85460	23.05923	11.47099	1.017326	0.221214
10.99917	44.22565	21.74609	10.15775	0.923501	0.229680
10.83632	40.26809	20.97254	9.275279	0.855943	0.230338
10.59560	35.05747	19.82911	7.966462	0.751865	0.227240
10.39506	31.23538	18.87657	6.923891	0.666074	0.221668
10.28237	29.27338	18.34126	6.391068	0.621555	0.218323
10.12978	26.81181	17.61647	5.747945	0.567430	0.214381
9.889193	23.34416	16.47366	4.977174	0.503394	0.213208
9.661608	20.47774	15.39264	4.362254	0.451303	0.213024
9.293356	16.56605	13.64344	3.505154	0.377167	0.211586
9.006063	14.04092	12.27879	2.962047	0.328894	0.210958
8.664367	11.53378	10.65574	2.451341	0.282922	0.212535
8.163729	8.645945	8.277717	1.737356	0.212814	0.200944
7.802297	7.021895	6.560912	1.403149	0.179838	0.199824
7.244910	5.094572	3.913326	1.026352	0.141665	0.201459
11.44755	57.24919	23.87589	11.90083	1.039596	0.207877

D1P31424

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
2.753892	64.17329	0.439946	1.807354
2.133585	49.50577	0.329110	1.694655
1.402666	32.25290	0.146954	1.508568
1.012227	23.15314	0.005278	1.364610
0.683015	15.73975	-0.16556	1.196998
0.385551	8.381147	-0.41391	0.923303
0.255467	5.509854	-0.59266	0.741140
0.135086	2.930662	-0.86938	0.466965

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.31874
Std Err of Y Est	0.006098
R Squared	0.999848
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	0.971772
Std Err of Coef.	0.004884

Tw = K'(8<U>/D)^n'

K' = 0.048001
n' = 0.971772

Tw* = 60.52745
Res/f* = 1781.107

Regression Output:

Constant	-55.0788
Std Err of Y Est	0.105409
R Squared	0.999223
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	20.82069
Std Err of Coef.	0.290197

t = 24.22166 deg C
s.d.)t = 0.485057 deg C

DSP13119 DSR1438 8/22/90 15:40

10 PSID Taps 14	1.0 PSID Taps 14	0.1 PSID Taps 14	
S = 2.7	S = 7.25	S = 9.9	<C>(ppm)=
Z = 2.7	Z = 9.1	Z = 6.85	[NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>corr (volts)
60	1.21416	24.9	8.171	0.0555	0.0785	8.0925
50	1.0118	24.9	5.98225	0.0555	0.0785	5.90375
40	0.80944	24.9	4.1225	0.0555	0.0785	4.067
30	0.60708	24.9	2.5235	0.0555	0.0785	2.445
25	0.5059	24.9	1.861666	0.058	0.0585	1.803166
20	0.40472	24.9	1.2725	0.058	0.0585	1.214
15	0.30354	24.9	0.801428	0.058	0.0585	0.742928
10	0.20236	24.9	0.428125	0.058	0.0585	0.369625
8	0.161888	24.9	0.306	0.058	0.0585	0.2475
23	0.465428	23.5	1.633666	0.0645	0.0705	1.563166
34	0.688024	23.5	3.1185	0.0645	0.0705	3.048
12	0.242832	23.4	0.582	0.0615	0.0625	0.5195
18	0.364248	24.9	12.34033	0.0535	0.0825	12.25783
14	0.283304	24.9	7.790125	0.0535	0.0825	7.707625
10	0.20236	24.9	4.42225	0.0535	0.0825	4.33975
8	0.161888	24.9	3.059833	0.0535	0.0825	2.977333
		24.5	2.073	0.0555	0.056	2.017
		24.4	1.48475	0.0555	0.0545	1.43025
		24.4	1.15075	0.0545	0.0535	1.09725
		24.3	0.7158	0.0535	0.0535	0.6623
		24.25	0.542166	0.0535	0.0535	0.488666
		24.1	3.1132	0.029	0.0295	3.0837
		24.1	1.8408	0.0385	0.041	1.8023
		24.05	1.215142	0.0455	0.0435	1.171642
		24	0.879416	0.0475	0.0475	0.831916
		24	0.496812	0.0495	0.05	0.446812
		24	0.354705	0.0495	0.0495	0.305205
		23.9	0.273409	0.0505	0.0505	0.222909
		23.8	0.20325	0.0505	0.05	0.15325
		23.6	0.1454	0.05	0.05	0.0954
		23.5	0.104454	0.05	0.05	0.054454
		23.4	0.077083	0.05	0.049	0.028083
		23.6	4.1612	0.048	0.0475	4.1137
		23.7	6.89225	0.0475	0.05	6.84225
		23.8	8.77325	0.0495	0.0505	8.72275
		23.7	12.43	0.0495	0.05	12.38

		density	viscosity			
	co)[NaCl]	1.01234	1.029478	ID(cm) =	1.45796	
29.99008	X coeff	-0.00025	-0.02281	K(V/psi)=	1.077888	12.72683
0.300133	constant	0.003419	-4.14933	XS(cm2)=	1.669479	
					1.085095	

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		7.507737	727.2685	116312.9	1059.175	0.003967	3.864878
		5.477146	606.0571	96927.45	772.7041	0.004167	3.796400
		3.773119	484.8457	77541.96	532.3036	0.004486	3.715474
		2.268324	363.6342	58156.47	320.0104	0.004794	3.604976
		1.672870	303.0285	48463.72	236.0049	0.005091	3.533854
		1.126276	242.4228	38770.98	158.8927	0.005356	3.452946
		0.689244	181.8171	29078.23	97.23717	0.005827	3.346310
		0.342915	121.2114	19385.49	48.37785	0.006523	3.194717
		0.229615	96.96914	15508.39	32.39369	0.006825	3.107624
		1.450212	278.7862	43200.41	204.5929	0.005213	3.494046
		2.827752	412.1188	63861.47	398.9332	0.004651	3.639051
		0.481961	145.4537	22488.55	67.99403	0.006364	3.253851
		0.963148	218.1805	34893.88	135.8790	0.005655	3.418970
		0.605620	169.6960	27139.68	85.43960	0.005878	3.318223
		0.340992	121.2114	19385.49	48.10645	0.006486	3.193496
		0.233941	96.96914	15508.39	33.00396	0.006953	3.111677
1963	15	0.158484	78.38770	12424.01	22.35859	0.007208	3.023175
1594	15	0.112380	63.65257	10065.84	15.85442	0.007751	2.947543
1380	15	0.086215	55.10699	8714.472	12.16309	0.007934	2.889990
1367	20	0.052039	40.94090	6459.695	7.341645	0.008676	2.779379
1146	19.9	0.038396	34.49454	5436.447	5.416907	0.009017	2.712866
1147	20	0.038469	34.35202	5395.695	5.427189	0.009109	2.711800
1056	25	0.032483	25.30129	3974.091	3.171976	0.009814	2.595177
1157	35	0.014616	19.80086	3106.629	2.062044	0.010417	2.501169
1264	45.1	0.010378	16.78763	2630.902	1.464140	0.010290	2.426318
1376	60	0.005574	13.73681	2152.788	0.786372	0.008254	2.291341
1254	75	0.003807	10.01509	1569.533	0.537150	0.010607	2.208575
1120	90	0.002780	7.454086	1165.547	0.392311	0.013984	2.139357
862	100	0.001911	5.163285	805.5304	0.269713	0.020037	2.057008
647	120	0.001190	3.229549	501.5776	0.167900	0.031882	1.952112
310	100	0.000679	1.856866	287.7378	0.095837	0.055048	1.829370
158	100	0.000350	0.946402	146.3230	0.049425	0.109284	1.684592
1346	20	0.051318	40.31196	6260.805	7.239948	0.008823	2.769454
1348	15	0.085257	53.82915	8379.026	12.04208	0.008231	2.830922
1571	15	0.108817	62.73412	9787.225	15.35169	0.007725	2.934635
1912	15	0.154441	76.35114	11884.79	21.78830	0.007402	3.009683

Tap DL= 122.2234
80.1597 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
15.05951	457.8870	41.03268	15.87631	1.054238	0.034672
14.78560	391.0938	39.73161	15.48980	1.047627	0.039606
14.46189	324.6041	38.19400	14.93010	1.032374	0.045994
14.01990	251.6844	36.09455	14.44181	1.030093	0.057380
13.75541	216.1398	34.83824	14.01399	1.018797	0.064837
13.41178	177.3480	33.20598	13.66345	1.018764	0.077043
12.98524	138.7364	31.17989	13.09958	1.008805	0.094420
12.37887	97.85830	28.29963	12.38109	1.000179	0.126520
12.03049	80.07641	26.64486	12.10437	1.006140	0.151160
13.57618	194.9516	33.98689	13.84972	1.020148	0.071041
14.15620	272.2273	36.74198	14.66179	1.035715	0.053858
12.61540	112.1325	29.42318	12.53457	0.993592	0.111783
13.27588	164.0025	32.56044	13.29776	1.001648	0.081082
12.87289	130.0480	30.64625	13.04310	1.013221	0.100294
12.37398	97.58342	28.27642	12.41597	1.003393	0.127234
12.04670	80.82718	26.72187	11.99193	0.995453	0.148365
11.69270	65.92586	25.04034	11.77839	1.007328	0.178661
11.39017	55.38902	23.60332	11.35812	0.997186	0.205060
11.15996	48.51438	22.50981	11.22666	1.005976	0.231408
10.71751	37.60623	20.40821	10.73574	1.001700	0.285477
10.45146	32.26608	19.14445	10.53049	1.007561	0.326364
10.44720	32.18698	19.12420	10.47724	1.002875	0.325511
9.980710	24.60694	16.90837	10.09392	1.011343	0.410206
9.604676	19.81751	15.12221	9.797611	1.020087	0.494391
9.305275	16.68011	13.70005	9.857932	1.059391	0.590999
8.765366	12.22423	11.13549	11.00676	1.255710	0.900405
8.434301	10.10311	9.562933	9.709459	1.151187	0.961035
8.157430	8.614651	8.247795	8.456142	1.036618	0.981600
7.828035	7.126706	6.683167	7.064364	0.902444	0.991252
7.408449	5.597478	4.690135	5.600486	0.755959	1.000537
6.917480	4.219394	2.358031	4.262132	0.616139	1.010129
6.338568	3.023236	-0.39274	3.024966	0.477246	1.000572
10.67781	36.75653	20.21963	10.64573	0.996995	0.289628
11.12369	47.51195	22.33753	11.02226	0.990881	0.231989
11.33854	53.76694	23.35807	11.37690	1.003383	0.211596
11.63873	63.90925	24.78399	11.62272	0.998624	0.181862

DSP13119

Tw dyne/cm2	8*U*/D (1/sec)	Log Tw	Log 8*U*/D
0.786372	75.37554	-0.10437	1.877230
0.537150	54.95403	-0.26990	1.739999
0.392311	40.90145	-0.40636	1.611738
0.269713	28.33156	-0.56909	1.452270
0.167900	17.72092	-0.77494	1.248486
0.095837	10.18884	-1.01846	1.008124
0.049425	5.193024	-1.30604	0.715420

Log Tw vs. Log 8*U*/D

Regression Output:

Constant	-2.02501
Std Err of Y Est	0.003767
R Squared	0.999906
No. of Observations	4
Degrees of Freedom	2

X Coefficient(s)	1.001306
Std Err of Coef.	0.006852

Tw = K'(8*U*/D)^n'

K' =	0.009440
n' =	1.001306

Tw* = 77.28853
Res/f* = 1979.027

Regression Output:

Constant	-4.88857
Std Err of Y Est	0.054415
R Squared	0.997551
No. of Observations	10
Degrees of Freedom	8

X Coefficient(s)	5.361639
Std Err of Coef.	0.093905

t = 24.04074 deg C
s.d.)t = 0.471411 deg C

D1P23116 DSR1438 8/18/90 13:33

10 PSID	Taps 14	1.0 PSID	Taps 14	0.1 PSID	Taps 14		
S =	2.7	S =	7.25	S =	9.9	<C>(ppm)=	
Z =	2.7	Z =	9.1	Z =	6.85	[NaCl]=	

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	24.9	6.866333	0.0465	0.0155	6.850833
50	1.0118	24.9	5.157	0.0465	0.0155	5.1415
42	0.849912	24.9	3.934	0.0465	0.0155	3.8875
34	0.688024	24.9	2.818	0.0465	0.0155	2.8025
30	0.60708	24.8	2.300333	0.0515	0.0525	2.247833
23	0.465428	24.8	1.50125	0.0515	0.0525	1.44875
17	0.344012	24.8	0.9292	0.0515	0.0525	0.8767
13	0.263068	24.8	0.6226	0.0515	0.0525	0.5701
10	0.20236	24.8	0.41575	0.0515	0.0525	0.36325
25	0.5059	24.3	1.73325	0.0475	0.0415	1.69175
35	0.70826	24.3	2.916	0.0475	0.0415	2.8745
10	0.20236	24.3	0.3945	0.0615	0.03	0.3645
18	0.364248	25.7	11.51775	0.0405	0.0655	11.45225
15	0.30354	25.7	8.44525	0.0405	0.0655	8.37975
10	0.20236	25.7	4.34875	0.0405	0.0655	4.28325
8	0.161888	25.7	2.927857	0.0405	0.0655	2.862357
		25.4	2.0902	0.0205	0.019	2.0712
		25.3	1.43325	0.0125	0.0125	1.42075
		25.3	1.1062	0.0105	0.0095	1.0967
		25.3	0.6754	0.0085	0.0075	0.6679
		25.2	0.490833	0.0065	0.0065	0.484333
		25.1	3.145666	0.0045	0.0285	3.117166
		25.1	1.887833	0.0295	0.034	1.853833
		25	1.267428	0.0385	0.0385	1.228928
		25	0.890125	0.0415	0.0415	0.848625
		24.95	0.492384	0.0425	0.0425	0.449884
		24.8	0.368	0.0425	0.0425	0.3255
		24.75	0.273823	0.0425	0.0425	0.231323
		24.6	0.193894	0.0425	0.0425	0.151394
		24.5	0.129055	0.0425	0.0425	0.086555
		24.4	0.086571	0.0425	0.0425	0.044071
		24.25	0.064388	0.0425	0.0425	0.021888
		24.4	4.2258	0.0415	0.0395	4.1863
		24.6	6.8386	0.0395	0.0395	6.7991
		24.6	8.988666	0.0395	0.0385	8.950166
		24.6	12.59825	0.0385	0.0385	12.55975

		density	viscosity		
	CO)[NaCl]	1.012234	1.029478	ID(cm) =	1.45796
99.83178	X coeff	-0.00025	-0.02281	K(V/psi)=	1.077888 12.72683
0.300128	constant	0.003419	-4.14933	XS(cm2)=	1.669479
					1.085095

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		6.355793	727.2685	116312.9	896.6618	0.003358	3.828708
		4.769976	606.0571	96927.45	672.9381	0.003629	3.766381
		3.606589	509.0880	81419.06	508.8100	0.003889	3.705672
		2.599991	412.1188	65910.86	366.8013	0.004278	3.634669
		2.085405	363.6342	58025.41	294.2045	0.004407	3.585733
		1.344063	278.7862	44586.15	189.6176	0.004833	3.490348
		0.813349	206.0594	32881.07	114.7456	0.005353	3.381277
		0.528904	157.5748	25144.34	74.61674	0.005955	3.297827
		0.337001	121.2114	19341.80	47.54367	0.006410	3.189954
		1.569504	303.0285	47812.14	221.4223	0.004776	3.519093
		2.666789	424.2400	66936.99	376.2249	0.004140	3.634206
		0.338161	121.2114	19124.85	47.70707	0.006432	3.185774
		0.899850	218.1805	35529.36	126.9490	0.005284	3.412090
		0.658431	181.8171	29607.80	92.89016	0.005568	3.344260
		0.336552	121.2114	19738.53	47.48015	0.006403	3.198531
		0.224907	96.96914	15790.82	31.72944	0.006686	3.111007
1967	14.9	0.162742	79.07459	12789.95	22.95940	0.007275	3.037800
1592	14.9	0.111634	63.99936	10328.27	15.74912	0.007618	2.954963
1366	14.9	0.086172	54.91403	8862.079	12.15700	0.007987	2.898748
1372	20	0.052479	41.09065	6631.248	7.403722	0.008688	2.791060
1431	25	0.038056	34.28613	5520.660	5.368871	0.009049	2.720291
1429	25	0.038886	34.23821	5500.521	5.486089	0.009272	2.723996
1062	25	0.023126	25.44505	4087.861	3.262672	0.007984	2.611151
1180	35	0.015331	20.19448	3237.023	2.162865	0.010507	2.520894
1130	39.9	0.010586	16.96385	2719.176	1.493546	0.010282	2.440488
1158	50	0.005612	13.87258	2221.163	0.791778	0.008151	2.302188
1057	59.9	0.004060	10.56980	1686.632	0.572867	0.010158	2.230436
954	74.9	0.002885	7.629313	1216.043	0.407120	0.013856	2.155777
625	75	0.001889	4.991575	792.9240	0.266448	0.021184	2.062245
380	80	0.001079	2.845198	450.9482	0.152334	0.037277	1.939852
220	90	0.000549	1.464195	231.5439	0.077563	0.071668	1.792298
110	90	0.000273	0.732097	115.3808	0.038523	0.142377	1.638853
1348	19.9	0.052224	40.57473	6416.380	7.367721	0.008865	2.781134
1350	15	0.084819	53.90901	8563.579	11.96614	0.008156	2.888415
1582	15	0.111654	63.17338	10035.24	15.75193	0.007819	2.948105
1944	15.1	0.156684	77.11488	12249.88	22.10465	0.007363	3.021680

Tap DL= 122.2234
80.1597 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.91483	421.2973	40.34546	17.25517	1.156913	0.040957
14.66552	364.9739	39.16125	16.59834	1.131793	0.045478
14.42268	317.3600	38.00777	16.03444	1.111751	0.050524
14.13843	269.4572	36.65758	15.28783	1.081295	0.056735
13.94293	240.7763	35.72894	15.06206	1.080264	0.062556
13.56139	193.2985	33.91662	14.38389	1.060649	0.074412
13.12510	150.3686	31.84426	13.66685	1.041275	0.090889
12.75130	121.2571	30.06871	12.96024	1.016385	0.106882
12.35981	96.79092	28.20913	12.48942	1.010486	0.129035
13.67637	206.5256	34.46278	14.46919	1.057969	0.070060
14.13682	269.2073	36.64993	15.54029	1.099277	0.057726
12.34309	95.86378	28.12971	12.46877	1.010181	0.130067
13.24836	161.4249	32.42972	13.75614	1.038328	0.085216
12.97704	138.0831	31.14095	13.40125	1.032689	0.097052
12.39412	98.72155	28.37210	12.49634	1.008247	0.126581
12.04402	80.70253	26.70913	12.22919	1.015373	0.151534
11.75120	68.18372	25.31821	11.72379	0.997668	0.171944
11.41985	56.34343	23.74430	11.45683	1.003238	0.203339
11.19499	49.50264	22.67621	11.18889	0.999455	0.226026
10.76424	38.63137	20.65014	10.72840	0.996670	0.277712
10.48116	32.82248	19.28553	10.51234	1.002974	0.320278
10.49598	33.10367	19.35592	10.38502	0.989428	0.313712
10.04460	25.52886	17.21187	10.00793	0.996349	0.392024
9.683577	20.73835	15.49699	9.755546	1.007432	0.470410
9.361955	17.23331	13.96928	9.861627	1.053372	0.572241
8.808755	12.53340	11.34158	11.07622	1.257410	0.883736
8.521744	10.62468	9.978285	9.921662	1.164276	0.933831
8.223111	8.946597	8.559779	8.495152	1.033082	0.949540
7.848982	7.213160	6.782665	6.870463	0.875331	0.952490
7.359409	5.441673	4.457196	5.179337	0.703770	0.951791
6.769193	3.874167	1.653668	3.735382	0.551820	0.964176
6.155415	2.721033	-1.26177	2.650208	0.430549	0.973971
10.72453	37.75852	20.44156	10.62074	0.990322	0.281280
11.15366	48.33880	22.47990	11.07234	0.992708	0.229056
11.39242	55.46075	23.61400	11.30895	0.992673	0.203909
11.68672	65.69929	25.01193	11.65336	0.997145	0.177374

D1P23116

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.791778	76.12053	-0.10139	1.881501
0.572867	57.99778	-0.24194	1.763411
0.407120	41.86295	-0.39027	1.621829
0.266448	27.38936	-0.57438	1.437582
0.152334	15.61194	-0.81720	1.193456
0.077563	8.034215	-1.11034	0.904943
0.038523	4.017107	-1.41427	0.603913

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-2.02309
Std Err of Y Est	0.002328
R Squared	0.999978
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	1.008639
Std Err of Coef.	0.002356

Tw = K'(8<U>/D)^n'

K' = 0.009482
n' = 1.008639

Tw* = 40.89822
Res/f* = 1439.615

Regression Output:

Constant	-7.89313
Std Err of Y Est	0.072396
R Squared	0.994515
No. of Observations	10
Degrees of Freedom	8
X Coefficient(s)	6.372561
Std Err of Coef.	0.167318

t = 24.90138 deg C
s.d.)t = 0.411211 deg C

D3P23122 DSR1438 8/25/90 15:49

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14 <C> (ppm) =
S = 2.7 S = 7.25 S = 9.9
Z = 2.7 Z = 9.05 Z = 6.85 [NaCl] =

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.5	5.7435	0.049	0.0475	5.696
50	1.0118	25.5	4.323	0.049	0.0475	4.2755
40	0.80944	25.5	3.081333	0.049	0.0475	3.033833
30	0.60708	25.5	2.012666	0.049	0.0475	1.965166
25	0.5059	25.5	1.536	0.049	0.0475	1.4885
19	0.384484	25.5	0.991	0.049	0.0475	0.9435
15	0.30354	25.5	0.691	0.049	0.0475	0.6435
10	0.20236	25.5	0.388375	0.049	0.0475	0.340875
35	0.70826	24.2	2.512	0.0525	0.0535	2.4585
26	0.526136	24.2	1.62575	0.0525	0.0535	1.57225
10	0.20236	24	0.393833	0.0525	0.0555	0.338333
20	0.40472	25.5	12.46666	0.0135	0.0405	12.42616
15	0.30354	25.5	7.730444	0.0135	0.0405	7.689944
10	0.20236	25.5	4.165222	0.0135	0.0405	4.124722
8	0.161868	25.5	2.925833	0.0135	0.0405	2.885333
		25.1	2.121	0.0065	0.0035	2.1175
		25	1.445	0.0005	-0.0025	1.4475
		24.9	1.10325	-0.0035	-0.0065	1.10975
		24.8	0.6688	-0.0065	-0.0075	0.6763
		24.7	4.27425	0.047	-0.0585	4.22725
		24.6	3.1502	0.0455	-0.0425	3.1047
		24.5	1.866833	0.0085	-0.002	1.858333
		24.5	1.1829	-0.0065	-0.0065	1.1894
		24.4	0.677	-0.0065	-0.0065	0.6835
		24.4	0.464333	-0.0045	-0.004	0.468333
		24.3	0.345142	-0.0025	-0.0025	0.347642
		24.2	0.263263	-0.0025	-0.0025	0.265763
		24.15	0.205363	-0.0015	-0.0015	0.206863
		24	0.162363	-0.0005	0	0.162863
		23.9	0.105941	0	0.001	0.105941
		23.75	0.069863	0.0015	0.0025	0.068363
		23.6	0.032833	0.0025	0.003	0.030333
		24	6.779	0.0035	-0.0045	6.7835
		24.1	8.985	-0.0055	-0.0095	8.9905
		24.2	12.76275	-0.0105	-0.0155	12.77825

		density	viscosity			
	co)[NaCl]	1.01234	1.029478	ID(cm) =	1.45796	
299.6776	X coeff	-0.00025	-0.02281	K(V/psi)=	1.077888	12.72683
0.300065	constant	0.003419	-4.14933	XS(cm2)=	1.669479	
					1.085095	

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		5.284408	727.2685	117898.0	745.5130	0.002792	3.794533
		3.966553	606.0571	98248.38	559.5928	0.003018	3.732241
		2.814609	484.8457	78598.70	397.0790	0.003347	3.657744
		1.823164	363.6342	58949.03	257.2081	0.003854	3.563447
		1.380941	303.0285	49124.19	194.8202	0.004203	3.503122
		0.875322	230.3017	37334.38	123.4886	0.004613	3.404119
		0.597000	181.8171	29474.51	84.22360	0.005048	3.321022
		0.316243	121.2114	19649.67	44.61495	0.006017	3.183045
		2.280849	424.2400	66786.15	321.7773	0.003541	3.599275
		1.458639	315.1497	49612.57	205.7817	0.004106	3.502201
		0.313885	121.2114	18995.85	44.28228	0.005969	3.166642
		0.976375	242.4228	39299.35	137.7450	0.004644	3.427843
		0.604230	181.8171	29474.51	85.24361	0.005109	3.323636
		0.324096	121.2114	19649.67	45.72285	0.006166	3.188372
		0.226712	96.96914	15719.74	31.98413	0.006739	3.110772
1994	15	0.166380	79.62561	12792.20	23.47264	0.007335	3.039645
1607	15	0.113736	64.17169	10286.23	16.04564	0.007719	2.956058
1376	15	0.087197	54.94726	8787.782	12.30166	0.008072	2.897376
1368	19.9	0.053139	41.17673	6570.605	7.496836	0.008759	2.788848
1374	20	0.053044	41.15054	6551.629	7.483454	0.008754	2.787475
1431	25.1	0.038958	34.14953	5424.737	5.496216	0.009336	2.719470
1275	30	0.023318	25.45703	4034.799	3.289787	0.010056	2.607037
1339	40	0.014924	20.05115	3177.998	2.105581	0.010374	2.510139
1411	49.9	0.008576	16.93734	2678.426	1.209992	0.008355	2.388859
1265	54.9	0.005876	13.80184	2182.586	0.829085	0.008621	2.306767
1050	59.9	0.004362	10.49980	1656.669	0.615428	0.011057	2.241071
1005	75	0.003334	8.026453	1263.567	0.470477	0.014465	2.181767
947	90	0.002595	6.302696	991.0659	0.366208	0.018260	2.126869
746	90.1	0.002043	4.959443	777.2276	0.288315	0.023218	2.073461
485	90.1	0.001329	3.224303	504.1634	0.187546	0.035731	1.979096
383	110	0.000857	2.085571	325.0056	0.121023	0.055108	1.882499
154	100.1	0.000380	0.921521	143.1204	0.053698	0.125237	1.704568
1346	14.9	0.085121	54.11001	8479.944	12.00875	0.008123	2.883276
1573	14.9	0.112815	63.23555	9932.451	15.91578	0.007883	2.945426
1941	14.9	0.160345	78.02938	12283.80	22.62119	0.007359	3.022755

Tap DL= 122.2234
79.692 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.77813	389.4154	39.69613	18.92228	1.280424	0.048591
14.52896	337.3817	38.51259	18.20051	1.252705	0.053946
14.23097	284.1999	37.09713	17.28507	1.214609	0.060820
13.85379	228.7325	35.30550	16.10752	1.162679	0.070420
13.61249	199.0685	34.15932	15.42314	1.133013	0.077476
13.21647	158.4890	32.27826	14.72278	1.113971	0.092894
12.88408	130.8887	30.69942	14.07421	1.092371	0.107528
12.33218	95.26333	28.07786	12.89168	1.045369	0.135326
13.99710	248.4023	35.98623	16.80392	1.200528	0.067648
13.60880	198.6467	34.14182	15.60954	1.147018	0.078579
12.26657	91.73237	27.76620	12.94244	1.055098	0.141089
13.31137	167.3876	32.72902	14.67377	1.102348	0.087665
12.89454	131.6789	30.74909	13.98975	1.084936	0.106241
12.35348	96.43889	28.17907	12.73453	1.030845	0.132047
12.04309	80.65900	26.70468	12.18070	1.011427	0.151014
11.75858	68.47401	25.35326	11.67615	0.992989	0.170519
11.42423	56.48565	23.76510	11.38146	0.996256	0.201493
11.18950	49.34649	22.65014	11.13020	0.994700	0.225552
10.75539	38.43511	20.58811	10.68457	0.993415	0.277989
10.74990	38.31378	20.56202	10.68745	0.994191	0.278945
10.47788	32.76051	19.26994	10.34923	0.987721	0.315905
10.02814	25.28817	17.13371	9.972051	0.994405	0.394336
9.640558	20.23110	15.29265	9.817796	1.018384	0.485282
9.155438	15.30170	12.98833	10.94006	1.194925	0.714957
8.827071	12.66624	11.42859	10.76969	1.220075	0.850267
8.564287	10.88809	10.18036	9.509640	1.110383	0.873397
8.327069	9.498334	9.053581	8.314403	0.998478	0.875353
8.107478	8.370464	8.010521	7.400171	0.912758	0.884081
7.893846	7.401875	6.995772	6.562759	0.831376	0.886634
7.516387	5.956304	5.202840	5.290229	0.703826	0.888173
7.129997	4.768472	3.367485	4.259823	0.597450	0.893330
6.418275	3.165548	-0.01318	2.825744	0.440265	0.892655
11.13310	47.77014	22.38225	11.09472	0.996552	0.232252
11.38170	55.11969	23.56310	11.26236	0.989514	0.204325
11.69102	65.86212	25.03235	11.65674	0.997067	0.176987

D3P23122

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
0.829085	75.73235	-0.08140	1.879281
0.615428	57.61369	-0.21082	1.760525
0.470477	44.04210	-0.32746	1.643868
0.366208	34.58364	-0.43627	1.539870
0.288315	27.21305	-0.54013	1.434777
0.187546	17.69213	-0.72689	1.247780
0.121023	11.44377	-0.91713	1.058569

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.98270
Std Err of Y Est	0.001314
R Squared	0.999979
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	1.006118
Std Err of Coef.	0.002267

Tw = K'(8<U>/D)^n'

K' = 0.010406
n' = 1.006118

Tw* = 27.69786
Res/f* = 1200.960

Regression Output:

Constant	-15.2927
Std Err of Y Est	0.190557
R Squared	0.988963
No. of Observations	14
Degrees of Freedom	12
X Coefficient(s)	8.836043
Std Err of Coef.	0.269457

t = 24.72857 deg C
s.d.)t = 0.638445 deg C

Page 1 DSR 1438

DIP33125 DSR1438 8/29/90 15:32

10 PSID Taps 14 1.0 PSID Taps 14 0.1 PSID Taps 14

S = 2.7 S = 7.25 S = 9.9 <C>(ppm)=

Z = 2.7 Z = 9.1 Z = 6.85 [NaCl]=

Freq. (Hz)	Q)est (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>f (volts)	<V>)corr (volts)
60	1.21416	25.1	4.5645	0.0565	0.0785	4.486
51	1.032036	25.1	3.618333	0.0565	0.0785	3.539833
43	0.870148	25.1	2.828666	0.0565	0.0785	2.750166
35	0.70826	25.2	2.063	0.0545	0.0545	2.0085
26	0.526136	25.2	1.388666	0.0545	0.0545	1.334166
20	0.40472	25.2	0.97175	0.0545	0.0545	0.91725
15	0.30354	25.2	0.65375	0.0545	0.0545	0.59925
10	0.20236	25.2	0.402333	0.0545	0.0545	0.347833
30	0.60708	23.4	1.718	0.0575	0.0715	1.6465
18	0.364248	25.15	9.1385	0.0795	0.0875	9.051
13	0.263068	25.15	5.790857	0.0795	0.0875	5.703357
10	0.20236	25.15	4.1516	0.0795	0.0875	4.0641
8	0.161888	25.15	2.9868	0.0795	0.0875	2.8993
6	0.121416	25.15	1.99575	0.0795	0.0875	1.90825
		24.9	2.15925	0.0435	0.0365	2.11575
		24.8	1.4705	0.034	0.034	1.4365
		24.7	1.0966	0.0325	0.0325	1.0641
		24.5	0.689	0.0295	0.0295	0.6595
		24.5	0.503166	0.0285	0.0285	0.474666
		24.35	3.0905	0.0615	-0.0105	3.029
		24.3	1.732625	-0.009	-0.0415	1.774125
		24.2	0.8531	-0.0405	-0.063	0.9161
		24.2	0.648363	-0.0615	-0.071	0.719363
		24.1	0.4995	-0.072	-0.0715	0.571
		24	0.347	-0.0745	-0.075	0.4215
		24	0.225478	-0.0745	-0.0745	0.299978
		23.9	0.16568	-0.0745	-0.0745	0.24018
		23.8	0.103125	-0.0745	-0.0745	0.177625
		23.8	0.052166	-0.0755	-0.0755	0.127666
		23.7	-0.00368	-0.0755	-0.0755	0.071818
		23.5	-0.03914	-0.074	-0.074	0.034851
		23.6	3.880428	-0.0745	-0.135	4.015428
		23.7	6.2684	-0.0295	-0.0305	6.2989
		23.7	8.2954	0.0245	0.0245	8.2709
		23.5	12.581	0.0695	0.0595	12.5215

Page 2 DSR 1438

		density	viscosity			12.3687
	co)[NaCl]	1.01234	1.029478	ID(cm) =	1.45796	12.72683
996.8529	X coeff	-0.00025	-0.02281	K(V/psi)=	1.077888	12.72683
0.300028	constant	0.003419	-4.14933	XS(cm2)=	1.669479	
					1.085095	

0

Batch Vol (ml)	t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)
		4.161842	727.2685	116838.9	587.1438	0.002199	3.728737
		3.284045	618.1782	99313.09	463.3061	0.002402	3.687298
		2.551440	521.2091	83734.57	359.9517	0.002625	3.632486
		1.363366	424.2400	68309.97	262.8797	0.002893	3.565228
		.237760	315.1497	50744.55	174.6205	0.003483	3.476397
		0.850969	242.4228	39034.27	120.0529	0.004047	3.395036
		0.555948	181.8171	29275.70	78.43200	0.004700	3.302596
		0.322698	121.2114	19517.13	45.52568	0.006139	3.184478
		1.527524	363.6342	56221.38	215.4998	0.003227	3.504339
		0.711174	218.1805	35091.24	100.3310	0.004175	3.355574
		0.448136	157.5748	25343.67	63.22214	0.005044	3.255291
		0.319333	121.2114	19495.13	45.05085	0.006075	3.181708
		0.227810	96.96914	15596.10	32.13896	0.006771	3.108373
		0.149939	72.72685	11697.08	21.15309	0.007923	3.017544
1995	15	0.166243	79.66554	12741.00	23.45324	0.007321	3.037495
1575	14.8	0.112871	63.74376	10171.64	15.92371	0.007763	2.952431
1345	14.9	0.083610	54.06981	8608.522	11.79562	0.007993	2.886284
1350	19.9	0.051819	40.63493	6440.413	7.310607	0.008770	2.780430
1121	19.9	0.037296	33.74204	5347.928	5.261716	0.009155	2.709017
1121	19.9	0.038008	33.74204	5329.861	5.362205	0.009329	2.711647
1038	24.9	0.022262	24.96990	3939.775	3.140714	0.009978	2.594997
1125	35	0.011495	19.25322	3030.946	1.621761	0.008666	2.450491
1090	40	0.009026	16.32245	2569.568	1.273481	0.009468	2.397994
1112	50	0.007165	13.32151	2092.419	1.010835	0.011282	2.346852
1002	60	0.005289	10.00311	1567.655	0.746176	0.014770	2.279948
1070	89.9	0.003764	7.129235	1117.270	0.531048	0.020695	2.206094
956	99.9	0.003013	5.732067	896.2864	0.425188	0.025631	2.156832
710	100	0.002228	4.252822	663.4879	0.314447	0.034434	2.090331
507	99.9	0.001602	3.039914	474.2607	0.226006	0.048439	2.018618
311	110.1	0.000901	1.691967	263.3710	0.127138	0.087960	1.892711
211	150.1	0.000437	0.842016	130.4779	0.061697	0.172345	1.733736
1321	19.8	0.050386	39.96285	6206.585	7.108469	0.008815	2.765474
1325	15	0.079040	52.91070	8236.060	11.15087	0.007888	2.864226
1560	15.1	0.100785	61.88231	9632.578	14.64188	0.007572	2.920370
1916	15	0.157123	76.51087	11856.03	22.16667	0.007499	3.011451

79.79777
79.692 Tap DL= 122.2234
79.692 40.77743
4
0.4

Solvent 1//f	L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
14.55494	342.4656	38.63600	21.32311	1.465007	0.062263
14.34919	306.2137	37.65867	20.40364	1.421936	0.067070
14.12994	268.1432	36.61725	19.51721	1.381266	0.072786
13.86091	229.6722	35.33934	18.58898	1.341108	0.080937
13.50559	187.1878	33.65155	16.94305	1.254521	0.090513
13.18914	155.2088	32.10569	15.71844	1.192585	0.101272
12.81038	125.4517	30.34933	14.58514	1.138540	0.116261
12.33791	95.57805	28.10508	12.76256	1.034418	0.133530
13.61735	199.6272	34.18245	17.60198	1.292613	0.088174
13.02229	141.7277	31.35592	15.47475	1.188327	0.109186
12.62116	112.5050	29.45054	14.07918	1.115521	0.125142
12.32683	94.97053	28.05246	12.82972	1.040796	0.135091
12.03349	80.21457	26.65909	12.15186	1.009836	0.151491
11.67017	65.07652	24.93334	11.23396	0.962621	0.172627
11.74998	68.13588	25.31242	11.68713	0.994650	0.171526
11.40972	56.01590	23.69619	11.34906	0.994683	0.202604
11.14513	48.10215	22.43940	11.18520	1.003595	0.232530
10.72172	37.69730	20.42817	10.67784	0.995907	0.283252
10.43606	31.98138	19.07132	10.45125	1.001454	0.326791
10.44658	32.17566	19.12130	10.35305	0.991046	0.321766
9.979989	24.59673	16.90494	10.01092	1.003099	0.407002
9.401966	17.63483	14.15933	10.74203	1.142531	0.609137
9.191977	15.62695	13.16189	10.27699	1.118039	0.657645
8.987411	13.89098	12.19020	9.414469	1.047517	0.677739
8.719793	11.90771	10.91902	8.228150	0.943617	0.690993
8.424378	10.04556	9.515796	6.951263	0.825136	0.691973
8.227331	8.968357	8.579824	6.246172	0.759197	0.696467
7.961325	7.695048	7.316295	5.388919	0.676887	0.700310
7.674472	6.523761	5.953742	4.543589	0.592039	0.696467
7.170845	4.881927	3.561514	3.37[illegible]760	0.470204	0.690651
6.534946	3.385451	0.540995	2.4[illegible]8798	0.368602	0.711514
10.66189	36.42125	20.14402	10.65069	0.998949	0.292430
11.05690	45.72002	22.02030	11.25882	1.018261	0.246255
11.29348	52.39025	23.14403	11.49137	1.017523	0.219341
11.64580	64.16997	24.81758	11.54749	0.991558	0.179951

D1P33125

Tw dyne/cm2	8<U>/D (1/sec)	Log Tw	Log 8<U>/D
1.010835	73.09674	0.004680	1.863898
0.746176	54.88829	-0.12715	1.739479
0.531048	39.11896	-0.27486	1.592387
0.425188	31.45253	-0.37141	1.497655
0.314447	22.33574	-0.50245	1.368021
0.226006	16.68037	-0.64587	1.222205
0.127138	9.284026	-0.89572	0.967736
0.061697	4.620245	-1.20972	0.664665

Log Tw vs. Log 8<U>/D

Regression Output:

Constant	-1.87652
Std Err of Y Est	0.003946
R Squared	0.999918
No. of Observations	8
Degrees of Freedom	6

X Coefficient(s)	1.006742
Std Err of Coef.	0.003717

Tw = K'(8<U>/D)^n'

K' =	0.013288
n' =	1.006742

Tw* = 40.19588
Res/f* = 1433.690

Regression Output:

Constant	-36.3965
Std Err of Y Est	0.132760
R Squared	0.998033
No. of Observations	9
Degrees of Freedom	7

X Coefficient(s)	15.40092
Std Err of Coef.	0.258394

t = 24.46285 deg C
s.d.)t = 0.633960 deg C

Page 1 Cyanamid 837A

P1P03478 2/3/89 12:11

1.0 PSID Taps 14 0.1 PSID Taps 14 co)NaCl
S = 8 S = 10.05 <C>(ppm)= 1.3203 X coeff
Z = 4.9 Z = 7.27 [NaCl]= 0.000309 constant

MMD-40 Q)l (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.19	0.192	21.9	3.072857	-0.0715	3.147857	
0.18	0.181	21.9	2.748833	-0.0785	2.826833	
0.167	0.168	21.9	2.402875	-0.0775	2.524125	
0.156	0.157	21.9	2.143833	-0.165	2.257083	
0.156	0.157	21.9	2.24	-0.0615	2.303	
0.14	0.141	21.9	1.775857	-0.0645	1.840857	
0.118	0.119	21.9	1.320142	-0.0655	1.385642	
0.1	0.101	21.9	0.965625	-0.0655	1.032125	
0.073	0.074	21.9	0.540857	-0.0675	0.607857	
				-0.0665		
0.093	0.094	22	7.8935	-0.094	7.99725	1150
0.054	0.055	22	3.101125	-0.1135	3.215125	1087
0.037	0.038	22	1.571428	-0.1145	1.685928	1177
0.029	0.03	22	0.9589	-0.1145	1.0734	1127
0.025	0.026	22	0.552	-0.1145	0.666	1094
0.017	0.018	22	0.2495	-0.1135	0.3615	1081
0.012	0.013	22	0.148357	-0.1105	0.257857	1070
		22.05	0.080571	-0.1085	0.188571	1020
		22.05	0.028916	-0.1075	0.136416	554
		22	-0.032	-0.1075	0.0755	570
		22	-0.07507	-0.1075	0.032423	245
				-0.1075		

Page 2 Cyanamid 837A

density	viscosity					
1.000096	1.001592	IP(cm) = 1.45796				
-0.00025	-0.02281	K(V/psi)= 9.48	85.14			
0.003419	-4.14933	XS(cm2)= 1.669479				2.97533
						-1.99543
						Solvent
0						
t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.332052	115.0059	17454.27	46.84525	0.007097	3.167455	11.41965
	0.298189	108.4170	16454.29	42.06789	0.007171	3.141697	11.35015
	0.266257	100.6301	15272.49	37.56310	0.007433	3.119503	11.27698
	0.238088	94.04128	14272.50	33.58908	0.007611	3.095221	11.20473
	0.242932	94.04128	14272.50	34.27240	0.007765	3.099594	11.21774
	0.194183	84.45745	12817.98	27.39495	0.007696	3.050957	11.07303
	0.146164	71.27969	10818.01	20.62062	0.008133	2.989273	10.88950
	0.108873	60.49789	9181.676	15.35970	0.008409	2.925313	10.69920
	0.064119	44.32519	6727.168	9.045906	0.009226	2.810348	10.35714
12.2	0.093930	56.46208	8568.520	13.25152	0.008329	2.894240	10.60675
19.6	0.037762	33.21964	5053.052	5.327496	0.009674	2.696369	10.01801
30.7	0.019801	22.96449	3493.159	2.793601	0.010615	2.556189	9.600937
37.2	0.012607	18.14679	2760.332	1.778635	0.010923	2.458150	9.309240
41.9	0.007822	15.63947	2378.940	1.103569	0.009041	2.354507	9.000856
59.9	0.004245	10.80980	1644.293	0.599009	0.010272	2.221824	8.606090
82.3	0.003028	7.787585	1184.579	0.427272	0.014118	2.148459	8.387806
107.3	0.002214	5.694024	867.1030	0.312464	0.019313	2.081000	8.187093
80.3	0.001602	4.132502	629.3097	0.226043	0.026525	2.010696	7.977915
150	0.000886	2.276158	346.2294	0.125104	0.048390	1.881743	7.594238
149.9	0.000380	0.979001	148.9171	0.053725	0.112332	1.698197	7.048127

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
91.90414	27.78164	11.86989	1.039426	0.129155
87.09188	27.33785	11.80813	1.040350	0.135582
82.29681	26.87055	11.59863	1.028523	0.140936
77.82182	26.40920	11.46248	1.023003	0.147291
78.60941	26.49229	11.34764	1.011579	0.144354
70.28095	25.56819	11.39887	1.029426	0.162190
60.97520	24.39619	11.08853	1.018277	0.181853
52.62520	23.18096	10.90456	1.019193	0.207211
40.38577	20.99661	10.41079	1.005180	0.257783
48.99147	22.59056	10.95665	1.032988	0.223644
31.06340	18.83101	10.16681	1.014852	0.327292
22.49415	16.16760	9.705741	1.010915	0.431478
17.94861	14.30486	9.611925	1.032514	0.535524
14.13797	12.33563	10.51662	1.168401	0.743856
10.41607	9.814661	9.866314	1.146433	0.947219
8.797104	8.420734	8.415977	1.003358	0.956675
7.531486	7.139012	7.195649	0.878901	0.955408
6.405845	5.803232	6.139994	0.769623	0.958498
4.760182	3.383128	4.545904	0.598599	0.954985
3.119444	-0.13425	2.983647	0.423324	0.956467

P1P03478

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
0.427272	42.73140	-0.36929	1.630747
0.312464	31.24379	-0.50519	1.494763
0.226043	22.67553	-0.64580	1.355557
0.125104	12.48955	-0.90272	1.096546
0.053725	5.371897	-1.26982	0.730127

Regression Output:

Constant	-1.99941
Std Err of Y Est	0.000850
R Squared	0.999995
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s)	0.999445
Std Err of Coef.	0.001191

K' =	0.010013
n' =	0.999445

Tw# = 0.061357
Res/f# = 53.21779

Regression Output:

Constant	1.607649
Std Err of Y Est	0.109634
R Squared	0.981722
No. of Observations	12
Degrees of Freedom	10

X Coefficient(s)	3.199992
Std Err of Coef.	0.138072

t = 21.96 deg C
s.d.)t = 0.056124 deg C

P2P03497 2/17/89 11:51

1.0 PSID Taps 14 co)NaCl
S = 10.05 <C>(ppm)= 2.08962 X coeff
Z = 4.9 [NaCl]= 0.000309 constant

MMD-40 Q)l (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vo (ml)
0.187	0.188	20.45	3.897	0.0015	3.8965	
0.17	0.171	20.5	3.358333	-0.0005	3.359333	
0.163	0.164	20.5	3.190083	-0.0015	3.192083	
0.145	0.146	20.5	2.600666	-0.0025	2.603666	
0.116	0.117	20.5	1.803	-0.0035	1.807	
0.133	0.134	20.5	2.263125	-0.0045	2.267625	
0.087	0.088	20.5	1.13525	-0.0045	1.13975	
0.07	0.072	20.6	0.802454	-0.0045	0.807454	1440
0.055	0.056	20.55	0.520428	-0.0055	0.525928	1130
0.039	0.04	20.65	0.286625	-0.0055	0.292125	1196
0.03	0.031	20.65	0.1801	-0.0055	0.1851	1259
0.024	0.025	20.65	0.080916	-0.0045	0.085416	1114
0.018	0.019	20.65	0.062285	-0.0045	0.066785	1137
0.012	0.013	20.65	0.042173	-0.0045	0.046173	1075
		20.65	0.02188	-0.0035	0.02488	756
				-0.0025		

density viscosity
1.000096 1.001592 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.25
0.003419 -4.14933 XS(cm2)= 1.669479 3.539999
-0.79424
0 Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.273438	112.6 79	16540.62	38.57613	0.006093	3.110996	11.80717
	0.235742	102.4271	15061.90	33.25807	0.006350	3.079278	11.69488
	0.224005	98.23420	14445.33	31.60226	0.006560	3.068188	11.65563
	0.182713	87.45240	12859.87	25.77682	0.006751	3.023944	11.49900
	0.126807	70.08172	10305.51	17.88966	0.007296	2.944630	11.21823
	0.159131	80.26453	11802.89	22.44994	0.006980	2.993937	11.39278
	0.079982	52.71103	7751.156	11.28375	0.008135	2.844556	10.86397
20.1	0.056663	42.91265	6324.556	7.993963	0.008696	2.770695	10.60250
20.2	0.036907	33.50780	4932.882	5.206799	0.009289	2.677107	10.27120
30	0.0205	23.87969	3523.411	2.892096	0.010160	2.550413	9.822710
40.2	0.012989	18.75938	2767.917	1.832527	0.010431	2.451332	9.471962
45.2	0.009994	14.76269	2178.212	0.845642	0.007773	2.283400	8.877484
60.1	0.004686	11.33195	1672.012	0.661192	0.010314	2.229971	8.688343
80	0.003240	8.048915	1187.604	0.457131	0.014135	2.149827	8.404635
102	0.001745	4.439566	655.0510	0.246317	0.025035	2.015554	7.929309

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
80.70051	26.70892	12.81018	1.084949	0.158737
75.01673	26.10628	12.54878	1.073014	0.167279
73.12547	25.89558	12.34636	1.059261	0.168838
66.04261	25.05494	12.17005	1.058356	0.184275
55.01874	23.54798	11.70682	1.043552	0.212778
61.63355	24.48480	11.96882	1.050561	0.194193
43.69546	21.64657	11.08690	1.020519	0.253731
36.86173	20.24322	10.72344	1.011406	0.290909
29.71580	18.46504	10.37512	1.010117	0.349144
22.19697	16.05786	9.920868	1.009992	0.446946
17.66902	14.17531	9.790854	1.033666	0.554125
12.00274	10.98461	11.34225	1.277643	0.944971
10.61331	9.969451	9.846192	1.133264	0.927720
8.824858	8.446726	8.410934	1.000749	0.953095
6.477904	5.895536	6.320050	0.797049	0.975631

P2P03497

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
0.845642	81.00466	-0.07281	1.908510
0.661192	62.17979	-0.17967	1.793649
0.457131	44.16535	-0.33995	1.645081
0.246317	24.36042	-0.60850	1.386684

Regression Output:

Constant	-2.01057
Std Err of Y Est	0.007835
R Squared	0.998302
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	1.017211
Std Err of Coef.	0.041950

K' = 0.009759
n' = 1.017211

Tw* = 7.026210
Res/f* = 551.7101

Regression Output:

Constant	-5.87387
Std Err of Y Est	0.067940
R Squared	0.992318
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	5.972103
Std Err of Coef.	0.214504

t = 20.56666 deg C
s.d.)t = 0.074535 deg C

P5P03486 2/8/89 11:49

1.0 PSID Taps 14 co)NaCl
S = 10.05 <C>(ppm)=5.156122 X coeff
Z = 4.9 [NaCl]= 0.000309 constant

MMD-40 Q)l (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.231	0.232	21.2	4.3495	-0.1165	4.4695	
0.205	0.206	21.2	3.649111	-0.1235	3.774111	
0.191	0.192	21.2	3.175416	-0.1265	3.301916	
0.162	0.163	21.2	2.494857	-0.1265	2.622357	
0.123	0.125	21.2	1.587916	-0.1285	1.716416	
0.102	0.103	21.2	1.16375	-0.1285	1.29175	
0.07	0.071	21.35	0.5694	-0.1275	0.6974	1250
0.084	0.085	21.35	0.821666	-0.1285	0.949666	1250
0.053	0.055	21.3	0.342	-0.1275	0.4695	1239
0.042	0.042	21.33	0.178857	-0.1275	0.306357	1250
0.033	0.034	21.35	0.0813	-0.1275	0.2088	1123
0.027	0.028	21.4	-0.0112	-0.1275	0.1158	1122
0.019	0.02	21.4	-0.04726	-0.1265	0.079233	1230
0.012	0.013	21.4	-0.07415	-0.1265	0.05235	1150
				-0.1265		

density viscosity
1.000096 1.001592 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.24
0.003419 -4.14933 XS(cm2)= 1.669479 2.97533
-1.99543
Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.313869	138.9654	20760.13	44.28002	0.004594	3.148329	11.36275
	0.265035	123.3917	18433.56	37.39070	0.004920	3.111607	11.25348
	0.231876	115.0059	17180.80	32.71259	0.004955	3.082583	11.16713
	0.184154	97.63521	14585.78	25.98009	0.005460	3.032546	11.01825
	0.120534	74.87363	11185.41	17.00480	0.006077	2.940511	10.74442
	0.090712	61.69587	9216.784	12.79756	0.006736	2.878789	10.56077
17.6	0.048974	42.54183	6376.894	6.909249	0.007649	2.746419	10.16693
14.7	0.066690	50.93444	7634.921	9.408494	0.007266	2.813463	10.36641
22.6	0.032970	32.83838	4916.826	4.651408	0.008642	2.660003	9.909817
29.3	0.021513	25.55414	3828.761	3.035127	0.009312	2.567595	9.634872
32.5	0.014662	20.69737	3102.474	2.068613	0.009675	2.484543	9.387766
40.3	0.008132	16.67656	2502.589	1.147248	0.008265	2.357025	9.008357
59.9	0.005564	12.29977	1845.780	0.784976	0.010396	2.274624	8.767189
85.4	0.003676	8.066012	1210.435	0.518639	0.015972	2.184629	8.495422

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
87.94474	27.41826	14.75367	1.298425	0.167760
80.81421	26.72054	14.25613	1.266818	0.176406
75.58984	26.16908	14.20561	1.272091	0.187930
67.36376	25.21837	13.53267	1.228204	0.200889
54.49940	23.46972	12.82745	1.193870	0.235368
47.27914	22.29700	12.18399	1.153702	0.257703
34.85773	19.78196	11.43378	1.124605	0.328012
40.67652	21.05581	11.73115	1.131650	0.288401
28.56823	18.14006	10.75675	1.085464	0.376528
23.09272	16.38430	10.36246	1.075516	0.448732
19.07319	14.80632	10.16634	1.082935	0.533017
14.22017	12.38347	10.99928	1.221009	0.773498
11.76263	10.81787	9.807431	1.119162	0.833778
9.561128	9.107953	7.912479	0.931381	0.827567

P5P03486

Tw# = 3.529210
Res/f# = 397.2507

Regression Output:

Constant	-13.7201
Std Err of Y Est	0.098389
R Squared	0.993802
No. of Observations	7
Degrees of Freedom	5

X Coefficient(s) 9.021940
Std Err of Coef. 0.318622

t = 21.29142 deg C
s.d.)t = 0.083397 deg C

P1P13490 2/12/89 12:37

1.0 PSID Taps 14

S = 10.05

Z = 4.9

<C>(ppm)= 10.325 co)NaCl X coeff

[NaCl]= 0.000309 constant

MMD-40 Q)1 (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.225	0.226	20.75	3.243571	-0.0005	3.246571	
0.193	0.194	20.7	2.6	-0.0055	2.6065	
0.186	0.187	20.7	2.404333	-0.0075	2.412333	
0.16	0.161	20.7	2.0569	-0.0085	2.0654	
0.124	0.125	20.7	1.394888	-0.0085	1.403888	
0.104	0.105	20.7	1.0864	-0.0095	1.0969	
0.085	0.086	20.7	0.821666	-0.0115	0.833666	1132
0.065	0.066	20.75	0.561375	-0.0125	0.574375	1316
0.048	0.049	20.8	0.345875	-0.0135	0.359375	1258
0.038	0.039	20.8	0.238125	-0.0135	0.251625	1176
0.03	0.031	20.8	0.122	-0.0135	0.135	1255
0.025	0.026	20.8	0.084	-0.0125	0.0965	1053
0.02	0.021	20.85	0.0646	-0.0125	0.0771	1197
0.013	0.014	20.85	0.041941	-0.0125	0.053441	1092
0.172	0.173	20.75	2.1996	-0.0115	2.2131	
0.187	0.188	20.65	2.4825	-0.0155	2.498	
				-0.0155		

density viscosity

1.000096 1.001592 ID(cm) = 1.45796

-0.00025 -0.02281 K(V/psi)= 14.25

0.003419 -4.14933 XS(cm2)= 1.669479

3.539999

-0.79424

Solvent

0

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.227829	135.3715	20018.96	32.14171	0.003513	3.074327	11.67736
	0.182912	116.2038	17185.05	25.80487	0.003828	3.026150	11.50681
	0.169286	112.0109	16565.69	23.88258	0.003813	3.009740	11.44731
	0.144940	96.43724	14265.22	20.44787	0.004404	2.975624	11.32795
	0.098518	74.87363	11059.95	13.89878	0.004966	2.891798	11.03117
	0.076975	62.89385	9290.362	10.85953	0.005499	2.838205	10.84149
13	0.058502	52.15812	7704.535	8.253468	0.006077	2.778618	10.63055
19.9	0.040307	39.61153	5857.820	5.686428	0.007260	2.698212	10.34591
25.4	0.025219	29.66646	4392.078	3.557885	0.008098	2.596881	9.987204
30	0.017657	23.48037	3476.235	2.491138	0.009052	2.519484	9.713219
40	0.009473	18.79328	2782.318	1.336527	0.007581	2.584274	9.234575
40.4	0.006771	15.61226	2311.373	0.955369	0.007852	2.311370	8.976498
57.1	0.005410	12.55674	1861.105	0.763305	0.009698	2.263126	8.805715
75.4	0.003750	8.675014	1285.773	0.529078	0.014084	2.183557	8.523969
	0.155305	103.6251	15324.25	21.91013	0.004087	2.991115	11.38279
	0.175298	112.6099	16615.42	24.73070	0.003906	3.016425	11.47239

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
74.16637	26.01221	16.86998	1.444674	0.227461
66.37902	25.09686	16.16196	1.404555	0.243480
63.85878	24.77747	16.19363	1.414623	0.253585
59.08865	24.13685	15.06763	1.330128	0.255000
48.71563	22.54397	14.18943	1.286302	0.291270
43.06113	21.52590	13.48426	1.243764	0.313142
37.54034	20.39374	12.82709	1.206625	0.341688
31.19552	18.86603	11.73609	1.134370	0.376210
24.70364	16.94074	11.11191	1.112615	0.449808
20.67112	15.47019	10.51054	1.082086	0.508465
15.14098	12.90120	11.48504	1.243700	0.758540
12.80120	11.51604	11.28494	1.257165	0.881553
11.45531	10.59941	10.15416	1.153133	0.886415
9.537131	9.087217	8.426098	0.988518	0.883504
61.23434	24.43118	15.64099	1.374090	0.255428
64.90910	24.91208	15.99873	1.394542	0.246479

P1P13490

Tw# = 3.140475
Res/f# = 370.9285

Regression Output:

Constant	-25.2099
Std Err of Y Est	0.181332
R Squared	0.989756
No. of Observations	10
Degrees of Freedom	8
X Coefficient(s)	13.66116
Std Err of Coef.	0.491372

t = 20.75 deg C
s.d.)t = 0.058630 deg C

Page 1 Cyanamid 837A

P2P13494 2/15/89 12:26

1.0 PSID Taps 14 co)NaCl
S = 10.05 <C>(ppm)= 20.9137 X coeff
Z = 4.9 [NaCl]= 0.000312 constant

MMD-40 Q)l (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.218	0.219	21.8	2.027333	-0.033	2.068583	
0.178	0.179	21.8	1.5534	-0.0495	1.6049	
0.152	0.153	21.8	1.270428	-0.0535	1.324928	
0.118	0.119	21.8	0.927888	-0.0555	0.984888	
0.087	0.088	21.8	0.614	-0.0585	0.672	
0.069	0.07	21.85	0.430666	-0.0575	0.488666	1162
0.054	0.055	21.9	0.2615	-0.0585	0.32	1157
0.045	0.046	21.9	0.156111	-0.0585	0.214611	1166
0.036	0.037	21.9	0.113222	-0.0585	0.171222	1055
0.027	0.028	21.9	0.072076	-0.0575	0.129076	1121
0.022	0.023	21.9	0.045181	-0.0565	0.101181	1160
0.018	0.019	22	0.031562	-0.0555	0.087062	1115
0.012	0.013	22	0.004869	-0.0555	0.059869	1213
		22	-0.02703	-0.0545	0.027461	1065
				-0.0545		

Page 2 Cyanamid 837A

density	viscosity							
1.000096	1.001592		ID(cm) =	1.45796				
-0.00025	-0.02281		K(V/psi)=	14.25				
0.003419	-4.14933		XS(cm2)=	1.669479				3.529999
								-0.79424
0								Solvent
t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f	
	0.145163	131.1786	19863.91	20.47939	0.002384	2.986795	11.36750	
	0.112624	107.2190	16235.80	15.88883	0.002769	2.921685	11.17240	
	0.092977	91.64532	13877.53	13.11706	0.003129	2.890055	11.02504	
	0.069115	71.27969	10793.63	9.750598	0.003845	2.825652	10.79705	
	0.047157	52.71103	7981.848	6.652935	0.004798	2.742643	10.50320	
16.5	0.034292	42.18335	6394.887	4.837898	0.005448	2.673958	10.26005	
20.9	0.022456	33.15934	5032.545	3.168064	0.005773	2.582519	9.936362	
25.1	0.015060	27.82554	4223.042	2.124693	0.005499	2.495770	9.629272	
28.4	0.012015	22.25117	3377.028	1.695134	0.006860	2.446724	9.455649	
40.1	0.009058	16.74480	2541.334	1.277887	0.009133	2.385168	9.238450	
50	0.007100	13.89654	2109.058	1.001720	0.010394	2.332495	9.051279	
59.9	0.006109	11.14979	1696.010	0.861936	0.013894	2.300845	8.939237	
90.1	0.004201	8.064081	1226.637	0.592720	0.018265	2.219522	8.651391	
180.1	0.001927	3.535399	537.7741	0.271874	0.043589	2.050291	8.052279	

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
60.62833	24.34911	20.47713	1.801375	0.337748
53.40269	23.30197	19.00162	1.709764	0.355817
48.52163	22.51105	17.87544	1.621349	0.368401
41.83432	21.28740	16.12556	1.493515	0.385462
34.55602	19.71023	14.43642	1.374478	0.417768
29.50109	18.40520	13.54798	1.320459	0.459236
23.90007	16.66786	13.16037	1.324466	0.550641
19.57268	15.01963	13.48512	1.400430	0.688976
17.48253	14.08776	12.07286	1.276788	0.690567
15.17919	12.92200	10.46389	1.132645	0.689357
13.43926	11.91741	9.808283	1.083634	0.729822
12.49467	11.31605	8.483661	0.949036	0.678981
10.36126	9.771119	7.399183	0.855259	0.714120
7.017331	6.555547	4.789696	0.594824	0.682552

P2P13494

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
2.124693	152.6820	0.327296	2.183788
1.695134	122.0948	0.229204	2.086697
1.277887	91.88074	0.106492	1.963224
0.861936	61.18026	-0.06452	1.786611
0.592720	44.24857	-0.22714	1.645899
0.271874	19.39915	-0.56563	1.287782

Regression Output:

Constant	-1.86082
Std Err of Y Est	0.008624
R Squared	0.999449
No. of Observations	6
Degrees of Freedom	4

X Coefficient(s)	1.001517
Std Err of Coef.	0.011752

K' = 0.013777
n' = 1.001517

Tw# = 2.964849
Res/f# = 369.0952

Regression Output:

Constant	-54.2601
Std Err of Y Est	0.175983
R Squared	0.995870
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s)	24.98583
Std Err of Coef.	0.928925

t = 21.88214 deg C
s.d.)t = 0.074659 deg C

Page 1 Cyanamid 837A

P5P13401 2/21/89 13:01

1.0 PSID		1.0 PSID			co)NaCl
S =	10.05	S =	10.05	[Ca++](ppm)=52.04769	X coeff
Z =	4.77	Z =	4.82	[NaCl]= 0.000312	constant

MMD-40 Q)l (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.211	0.212	23.95	1.676285	0.003	1.665035	
0.186	0.188	23.8	1.42325	0.0195	1.40525	
0.18	0.181	23.8	1.3195	0.0165	1.3005	
0.155	0.156	23.8	1.113285	0.0215	1.089785	
0.121	0.122	23.8	0.789444	0.0255	0.762944	
				0.0275		
0.106	0.107	23.85	3.430571	0.0065	3.475071	1139
0.078	0.079	23.9	2.408714	-0.0445	2.448714	1136
0.058	0.059	23.9	1.8785	-0.0355	1.914	1150
0.04	0.041	23.9	1.355	-0.0355	1.3885	1228
0.032	0.033	23.95	1.059181	-0.0315	1.089681	1170
0.025	0.026	23.95	0.862384	-0.0295	0.890384	1128
0.018	0.019	24	0.693733	-0.0265	0.719733	1166
0.013	0.014	24	0.506947	-0.0255	0.531447	1080
		24	0.342565	-0.0255	0.366065	753
		24.05	0.204291	-0.0235	0.228291	485
		24.1	0.10732	-0.0245	0.13232	337
		24.1	0.037478	-0.0255	0.062478	223
				-0.0245		

Page 2 Cyanamid 837A

density	viscosity				
1.000096	1.001592	ID(cm) = 1.45796			
-0.00025	-0.02281	K(V/psi)= 14.29	75.06		
0.003419	-4.14933	XS(cm2)= 1.669479			3.539999
					-0.79424
0					Solvent

t)samp (sec)	DP (psid)	U (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.116517	126.9856	20184.67	16.43804	0.002043	2.960243	11.27350
	0.098337	112.6099	17839.14	13.87331	0.002193	2.921931	11.15789
	0.091007	108.4170	17174.92	12.83917	0.002189	2.905109	11.07833
	0.076262	93.44229	14802.69	10.75889	0.002470	2.886724	10.94245
	0.053390	73.07666	11576.46	7.532161	0.002827	2.789300	10.66837
10.5	0.046297	64.97605	10304.82	6.531517	0.003101	2.758840	10.56054
14.1	0.032623	48.25897	7642.229	4.602443	0.003962	2.683320	10.29719
19.3	0.025499	35.69105	5666.781	3.597429	0.005662	2.629822	10.10381
29.9	0.018498	24.60062	3905.918	2.609733	0.008645	2.560124	9.857085
34.9	0.014517	20.08072	3191.877	2.048094	0.010183	2.507993	9.672545
43.7	0.011862	15.46131	2457.613	1.673508	0.014035	2.464132	9.517275
60	0.009588	11.64035	1852.349	1.352763	0.020016	2.418422	9.355460
79.9	0.007080	8.096473	1288.405	0.998873	0.030551	2.352566	9.122331
90	0.004876	5.011541	797.4954	0.688032	0.054925	2.271615	8.835765
100.1	0.003041	2.902194	462.3525	0.429082	0.102141	2.169574	8.474538
99.8	0.001762	1.422449	226.8680	0.248700	0.246446	2.051634	8.057032
239.9	0.000832	0.556792	88.80350	0.117430	0.759472	1.888686	7.480195

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
57.03270	23.84463	22.11962	1.962088	0.387841
52.21691	23.11669	21.35221	1.917080	0.408913
50.23305	22.79708	21.36904	1.928904	0.425398
45.98381	22.06777	20.11943	1.838659	0.437533
38.47519	20.59671	18.80507	1.762694	0.488758
35.86911	20.01797	17.95559	1.700253	0.500586
30.14397	18.58308	15.88673	1.543420	0.527028
26.65031	17.56662	13.28966	1.315311	0.498668
22.69887	16.24236	10.75471	1.091064	0.473799
20.13139	15.25188	9.909515	1.024499	0.492241
18.19754	14.41852	8.440742	0.886886	0.463839
16.37956	13.55002	7.068066	0.755501	0.431517
14.07494	12.29876	5.721184	0.627162	0.406480
11.68142	10.76070	4.266898	0.482912	0.365272
9.235369	8.821910	3.128952	0.329218	0.338801
7.039058	6.581056	2.014367	0.250013	0.286170
4.836891	3.485039	1.147476	0.153401	0.237234

P5P13401

Tw dyne/cm2	8*U*/D (1/s)	Log Tw	Log 8*U*/D
1.352763	63.87200	0.131221	1.805310
0.998873	44.42631	-0.00048	1.647640
0.688032	27.49892	-0.16239	1.439315
0.429082	15.92468	-0.36745	1.202070
0.248700	7.805146	-0.60432	0.892381
0.117430	3.055187	-0.93022	0.485037

Regression Output:

Constant	-1.32270
Std Err of Y Est	0.006137
R Squared	0.999808
No. of Observations	6
Degrees of Freedom	4

X Coefficient(s) 0.803368
Std Err of Coef. 0.005562

K' = 0.047565
n' = 0.803368

Regression Output:

Constant	-36.7177
Std Err of Y Est	0.208443
R Squared	0.980837
No. of Observations	5
Degrees of Freedom	3

X Coefficient(s) 19.89530
Std Err of Coef. 1.605540

t = 23.93235 deg C
s.d.)t = 0.098430 deg C

P1P01379 2/3/89 14:51

1.0 PSID Taps 14	0.1 PSID Taps 14				ca)NaCl
S = 8	S = 10.05	<C>(ppm)=	1.3203	X coeff	
Z = 4.9	Z = 7.27	[NaCl]=	0.001035	constant	

MMD-40 Q)1 (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.184	0.185	21.7	2.983125	-0.077	3.059375	
0.169	0.17	21.7	2.5695	-0.0755	2.64525	
0.161	0.162	21.7	2.352571	-0.076	2.428821	
0.148	0.149	21.7	1.990428	-0.0765	2.066928	
0.127	0.128	21.7	1.522	-0.0765	1.599	
0.097	0.099	21.7	0.930777	-0.0775	1.008277	
0.071	0.072	21.7	0.491	-0.0775	0.569	
				-0.0785		
0.09	0.091	21.8	7.7242	-0.0845	7.8232	1246
0.067	0.068	21.8	4.5915	-0.1135	4.7075	1170
0.036	0.037	21.8	1.4641	-0.1185	1.58335	1204
0.052	0.053	21.8	2.906375	-0.12	3.026375	1182
0.029	0.03	21.8	0.9343	-0.12	1.05255	1335
0.022	0.023	21.8	0.37075	-0.1165	0.48675	1076
0.017	0.018	21.8	0.240058	-0.1155	0.356058	1077
		21.8	0.122944	-0.1165	0.236944	1077
		21.85	0.0386	-0.1115	0.1491	664
		21.85	-0.0347	-0.1095	0.0753	350
		21.85	-0.07311	-0.1105	0.037388	280
				-0.1105		

density	viscosity				
1.000125	1.001657	ID(cm) =	1.45796		
-0.00025	-0.02281	K(V/psi)=	9.48	85.14	
0.003419	-4.14933	XS(cm2)=	1.669479		
					2.97533
					-1.99543
0					Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.322718	110.8129	16741.60	45.52849	0.007429	3.159271	11.39530
	0.279034	101.8281	15384.18	39.36563	0.007607	[illegible]588	11.30133
	0.256204	97.03622	14660.21	36.14482	0.00768	[illegible]153	11.24618
	0.218030	89.24937	13483.78	30.75927	0.0077	[illegible]4118	11.14194
	0.168670	76.67060	11583.38	23.79573	0.008[illegible]	3.018379	10.97610
	0.106358	59.29991	8959.023	15.00481	0.0[illegible]50	2.918245	10.67817
	0.060021	43.12721	6515.653	8.467649	0.[illegible]09122	2.794011	10.30853
13.6	0.091886	54.87796	8309.681	12.96312	0.008625	2.887470	10.58660
17	0.055291	41.22454	6242.264	7.800377	0.009197	2.777173	10.25843
32.4	0.018597	22.25872	3370.440	2.623627	0.010611	2.540566	9.554453
22.2	0.035545	31.89212	4829.139	5.014735	0.009879	2.681239	9.973001
44.1	0.012362	18.13266	2745.667	1.744086	0.010629	2.451899	9.290639
47	0.005717	13.71302	2076.441	0.806549	0.008594	2.284430	8.792365
60.2	0.004182	10.71613	1622.648	0.589993	0.010295	2.216538	8.590364
89.9	0.002782	7.175875	1086.578	0.392619	0.015278	2.128101	8.327233
90	0.001751	4.419208	669.9165	0.247060	0.025349	2.028009	8.029426
90.1	0.000884	2.326816	352.7267	0.124772	0.046180	1.879667	7.588062
149.9	0.000439	1.118858	169.6100	0.061953	0.099170	1.727641	7.135734

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/PK	1//f/L
90.18860	27.62616	11.60180	1.018121	0.128639
83.86267	27.02608	11.46530	1.014509	0.136715
80.35874	26.67390	11.40216	1.013869	0.141890
74.13069	26.00824	11.36825	1.020311	0.153354
65.20179	24.94921	11.10339	1.011597	0.170292
51.77563	23.04666	10.81471	1.012787	0.208876
38.89479	20.68621	10.46999	1.015662	0.269187
48.23364	22.46193	10.76748	1.017085	0.223235
37.41562	20.36628	10.42723	1.016454	0.278686
21.69933	15.87076	9.707790	1.016048	0.447377
29.99986	18.54354	10.06075	1.008798	0.335360
17.69209	14.18608	9.699485	1.044006	0.548238
12.03125	11.00418	10.78670	1.226826	0.896557
10.29007	9.714235	9.855660	1.147292	0.957782
8.394235	8.033921	8.090216	0.971537	0.963782
6.666368	6.132176	6.280748	0.782216	0.942154
4.737486	3.313690	4.653400	0.613252	0.982250
3.338272	0.425192	3.175482	0.445011	0.951235

P1P01379

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
0.589993	58.80069	-0.22915	1.769382
0.392619	39.37488	-0.40602	1.595219
0.247060	24.24872	-0.60719	1.384688
0.124772	12.76751	-0.90387	1.106106
0.061953	6.139311	-1.20793	0.788119

Regression Output:

Constant	-2.00140
Std Err of Y Est	0.007801
R Squared	0.999701
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	1.001402
Std Err of Coef.	0.009987

K' = 0.009967
n' = 1.001402

Tw* = 0.000002
Res/f* = 0.321111

Regression Output:

Constant	2.019581
Std Err of Y Est	0.030170
R Squared	0.997708
No. of Observations	10
Degrees of Freedom	8
X Coefficient(s)	3.024284
Std Err of Coef.	0.051243

t = 21.76944 deg C
s.d.)t = 0.058068 deg C

Cyanamid 837A

P2P01398 2/17/89 13:51

1.0 PSID Taps 14 co)NaCl

S = 10.05 <C>(ppm)= 2.08962 X coeff

Z = 4.9 [NaCl]= 0.001034 constant

MMD-40 Q)l (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.174	0.175	20.35	3.655545	0.006	3.653295	
0.168	0.169	20.4	3.422428	-0.0015	3.424928	
0.157	0.158	20.4	3.103833	-0.0035	3.107833	
0.14	0.141	20.4	2.56775	-0.0045	2.57225	
0.129	0.13	20.4	2.236125	-0.0045	2.241125	
0.112	0.113	20.4	1.776714	-0.0055	1.782214	
0.09	0.091	20.5	1.211666	-0.0055	1.218666	1161
0.068	0.07	20.55	0.780428	-0.0085	0.788928	1172
0.053	0.054	20.55	0.49525	-0.0085	0.50375	1242
0.038	0.039	20.55	0.275625	-0.0085	0.284125	1169
0.03	0.031	20.6	0.167666	-0.0085	0.176166	1196
0.024	0.025	20.65	0.083363	-0.0085	0.091863	1127
0.016	0.018	20.65	0.04975	-0.0085	0.05825	1134
0.013	0.014	20.65	0.039307	-0.0085	0.047307	1134
		20.6	0.016714	-0.0075	0.024714	1118
				-0.0085		

Cyanamid 837A

density viscosity

1.000125 1.001657 ID(cm) = 1.45796

-0.00025 -0.02281 K(V/psi)= 14.25

0.003419 -4.14933 XS(cm2)= 1.669479 3.539999

-0.79424

Solvent

0

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.256371	104.8230	15361.60	36.16836	0.006593	3.095994	11.75406
	0.240345	101.2291	14851.66	33.90748	0.006628	3.082470	11.70618
	0.218093	94.64027	13884.98	30.76817	0.006881	3.061373	11.63150
	0.180508	84.45745	12391.03	25.46579	0.007151	3.020301	11.48611
	0.157271	77.86857	11424.35	22.18759	0.007329	2.990377	11.38018
	0.125067	67.68576	9930.404	17.64428	0.007714	2.940624	11.20405
12.7	0.085520	54.50800	8015.112	12.06504	0.008134	2.859072	10.91536
16.8	0.055363	41.78661	6151.435	7.810552	0.008960	2.765141	10.58284
23	0.035350	32.34540	4761.588	4.987226	0.009548	2.667729	10.23800
29.9	0.019938	23.41866	3447.477	2.812894	0.010274	2.543377	9.797800
39	0.012362	18.36899	2707.164	1.744085	0.010354	2.440076	9.432117
44.9	0.006446	15.03475	2218.275	0.909468	0.008059	2.299179	8.933340
64.9	0.004087	10.46615	1544.209	0.576686	0.010546	2.200255	8.582150
79.9	0.003319	8.501296	1254.307	0.468355	0.012981	2.155073	8.423205
150.5	0.001734	4.449633	655.7726	0.244676	0.024755	2.013588	7.922350

Tap DL= 123.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
77.96044	26.42389	12.31522	1.047741	0.157967
75.57014	26.16693	12.28301	1.049275	0.162537
71.98688	25.76609	12.05513	1.036421	0.167462
65.49092	24.98572	11.82514	1.029516	0.180561
61.13044	24.41717	11.68030	1.026372	0.191071
54.51355	23.47186	11.38524	1.016171	0.208851
45.18061	21.92237	11.08759	1.015779	0.245406
36.39327	20.13768	10.56416	0.998235	0.290278
29.08103	18.28686	10.23345	0.999554	0.351894
21.84022	15.92416	9.865621	1.006922	0.451718
17.21397	13.96145	9.827382	1.041906	0.570796
12.44684	11.28440	11.13874	1.246873	0.894904
9.911410	9.404853	9.737574	1.134498	0.982461
8.932095	8.546393	8.776691	1.041965	0.982601
6.448651	5.858180	6.355714	0.802251	0.985588

P2P01398

Tw dyne/cm2	B<U>/D (1/s)	Log Tw	Log B<U>/D
0.909468	82.49751	-0.04121	1.916440
0.576686	57.42905	-0.23906	1.759131
0.468355	46.64762	-0.32942	1.668829
0.244676	24.41566	-0.61140	1.387668

Regression Output:

Constant	-2.00253
Std Err of Y Est	0.000119
R Squared	0.999999
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	1.002511
Std Err of Coef.	0.000437

K' = 0.009941
n' = 1.002511

Tw* = 8.766974
K <U>/f* = 614.8575

Regression Output:

Constant	-3.90361
Std Err of Y Est	0.061878
R Squared	0.991178
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	5.224561
Std Err of Coef.	0.201216

t = 20.51 deg C
s.d.)t = 0.105198 deg C

Page 1 Cyanamid 837A

P5P01387 2/8/89 13:19

1.0 PSID Taps 14 co)NaCl
S = 10.05 <C>(ppm)=5.156122 X coeff
Z = 4.9 [NaCl]= 0.001035 constant

MMD-40 Q)1 (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.221	0.222	21.25	4.3766	-0.125	4.50535	
0.198	0.199	21.2	3.686625	-0.1325	3.820125	
0.183	0.1845	21.2	3.272375	-0.1345	3.406875	
0.157	0.158	21.2	2.572857	-0.1345	2.707357	
0.12	0.121	21.2	1.632333	-0.1345	1.766833	
0.1	0.101	21.2	1.184375	-0.1345	1.318875	
0.068	0.068	21.25	0.593428	-0.1345	0.728928	1124
0.08	0.081	21.25	0.824	-0.1365	0.961	1173
0.042	0.043	21.3	0.1954	-0.1375	0.3329	1189
0.054	0.055	21.3	0.3715	-0.1375	0.509	1116
0.035	0.036	21.3	0.103625	-0.1375	0.240625	1065
0.028	0.029	21.3	0.003727	-0.1365	0.140227	1154
0.02	0.021	21.4	-0.06287	-0.1365	0.073625	1096
0.012	0.013	21.4	-0.09078	-0.1365	0.045214	1180
				-0.1355		

Page 2 Cyanamid 837A

density viscosity
1.000125 1.001657 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.24
0.003419 -4.14933 XS(cm2)= 1.669479 2.97533
-1.99543
0 Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.316386	132.9755	19887.00	44.63519	0.005057	3.150535	11.36931
	0.268267	119.1988	17806.54	37.84656	0.005336	3.114217	11.26125
	0.239246	110.5134	16509.08	33.75243	0.005536	3.089356	11.18728
	0.190123	94.64027	14137.86	26.82220	0.005999	3.039451	11.03880
	0.124075	72.47767	10827.09	17.50429	0.006676	2.946776	10.76306
	0.092617	60.49789	9037.493	13.06629	0.007152	2.883280	10.57414
16.4	0.051188	41.05266	6139.584	7.221607	0.008505	2.755013	10.19250
14.5	0.067485	48.45615	7246.804	9.520775	0.008124	2.815032	10.37108
27.5	0.023377	25.89810	3877.533	3.298091	0.009852	2.585320	9.687611
20.3	0.035744	32.92964	4930.313	5.042741	0.009317	2.677522	9.961943
29.9	0.016897	21.33522	3194.367	2.383909	0.010492	2.514834	9.477891
40.1	0.009847	17.23774	2580.880	1.389253	0.009367	2.397579	9.129021
52.6	0.005170	12.48083	1872.884	0.729414	0.009382	2.258661	8.715693
92.6	0.003175	7.632906	1145.400	0.447944	0.015404	2.152786	8.400680

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
88.39249	27.46017	14.06157	1.236801	0.159091
81.30126	26.77012	13.68870	1.215557	0.168370
76.77796	26.29777	13.43898	1.201272	0.175036
68.44335	25.34957	12.91018	1.169527	0.188625
55.29123	23.58874	12.23871	1.137103	0.221349
47.77056	22.38232	11.82408	1.118208	0.247518
35.55442	19.94525	10.79258	1.058874	0.303551
40.82374	21.08562	11.09465	1.069768	0.271769
24.05473	16.72109	10.07476	1.039963	0.418826
29.74422	18.47292	10.35981	1.039939	0.348296
20.45097	15.38184	9.762268	1.030004	0.477349
15.61205	13.15401	10.33208	1.131784	0.661801
11.33813	10.51456	10.32403	1.184533	0.910558
8.885190	8.502947	8.056945	0.959082	0.906783

P5P01387

Tw* = 4.651262
Res/f* = 456.5433

Regression Output:

Constant	-12.0445
Std Err of Y Est	0.095029
R Squared	0.994747
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	8.254546
Std Err of Coef.	0.244865

t = 21.26785 deg C
s.d.)t = 0.067101 deg C

P1P11391 2/12/89 14:55

1.0 PSID Taps 14 co)NaCl
S = 10.05 <C>(ppm)= 10.325 X coeff
Z = 4.9 [NaCl]= 0.001037 constant

MMD-40 Q)1 (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.214	0.215	20.55	3.360666	-0.0115	3.374666	
0.177	0.178	20.5	2.630333	-0.0165	2.647833	
0.154	0.155	20.45	2.08925	-0.0185	2.10825	
0.119	0.12	20.45	1.472125	-0.0195	1.492125	
0.1	0.101	20.45	1.140571	-0.0205	1.161071	
0.083	0.084	20.5	0.857142	-0.0205	0.878642	1157
0.068	0.069	20.5	0.647166	-0.0225	0.669666	1187
0.052	0.053	20.55	0.4247	-0.0225	0.4472	1220
0.038	0.039	20.55	0.250666	-0.0225	0.272666	1180
0.031	0.032	20.6	0.1436	-0.0215	0.1651	1122
0.025	0.026	20.6	0.075545	-0.0215	0.096045	1134
0.018	0.019	20.65	0.0522	-0.0205	0.0727	1255
0.012	0.013	20.65	0.027157	-0.0205	0.047657	1041
0.194	0.195	20.5	2.938571	-0.0205	2.960571	
0.136	0.137	20.45	1.75975	-0.0235	1.78375	
				-0.0245		

density	viscosity			
1.000125	1.001657	ID(cm) = 1.45796		
-0.00025	-0.02281	K(V/psi)= 14.25		
0.003419	-4.14933	XS(cm2)= 1.669479		3.539999
				-0.79424
				Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.236818	128.7826	18958.17	33.40988	0.004035	3.080737	11.70005
	0.185812	106.6200	15677.91	26.21408	0.004619	3.027575	11.51186
	0.147947	92.84330	13636.72	20.87210	0.004850	2.977598	11.33494
	0.104710	71.87868	10557.46	14.77233	0.005727	2.902539	11.06923
	0.081478	60.49789	8885.865	11.49484	0.006291	2.848066	10.87640
13.7	0.061659	50.31508	7398.565	8.698741	0.006882	2.788035	10.66389
17	0.046994	41.82353	6149.928	6.629835	0.007592	2.729059	10.45511
23	0.031382	31.77246	4677.245	4.427370	0.008785	2.641873	10.14647
30.1	0.019134	23.48196	3456.795	2.699455	0.009806	2.574438	9.766157
34.9	0.011585	19.25689	2838.019	1.634523	0.008829	2.425988	9.382244
42.9	0.006740	15.83341	2333.478	0.950869	0.007597	2.308353	8.965816
64.7	0.005101	11.61872	1714.262	0.719744	0.010680	2.248374	8.753492
80.1	0.003344	7.784614	1148.566	0.471822	0.015596	2.156674	8.428875
	0.207759	116.8028	17175.24	29.31025	0.004303	3.051817	11.59767
	0.125175	82.06150	12053.10	17.65948	0.005253	2.941304	11.20646

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
75.26927	26.13401	15.74196	1.345460	0.209141
66.59705	25.12392	14.71340	1.278108	0.220931
59.35784	24.17436	14.35859	1.266754	0.241898
49.93668	22.74825	13.21356	1.193719	0.264606
44.05006	21.71326	12.60762	1.159172	0.286211
38.36329	20.57268	12.05345	1.130305	0.314192
33.49184	19.45212	11.47654	1.097696	0.342666
27.40016	17.79559	10.66883	1.051481	0.389371
21.39529	15.75432	10.09799	1.033978	0.471972
16.66742	13.69377	10.64209	1.134280	0.638496
12.71256	11.45871	11.47229	1.279559	0.902437
11.07272	10.31911	9.676151	1.105404	0.873872
8.965095	8.576823	8.007209	0.949973	0.893153
70.42023	25.58453	15.24352	1.314359	0.216465
54.59892	23.48477	13.79732	1.231193	0.252703

P1P11391

fw# = 4.162903
Res/f# = 425.1071

Regression Output:

Constant	-21.4729
Std Err of Y Est	0.154078
R Squared	0.990285
No. of Observations	9
Degrees of Freedom	7

X Coefficient(s)	12.01146
Std Err of Coef.	0.449657

t = 20.53 deg C
s.d.)t = 0.067823 deg C

P1P01180 2/3/89 16:38

1.0 PSID Taps 14 0.1 PSID Taps 14 co)NaCl
S = 8 S = 10.05 <C>(ppm)= 1.3203 X coeff
Z = 4.9 Z = 7.27 [NaCl]= 0.104494 constant

MMD-40 Q)l (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.18	0.181	21.55	2.931285	-0.0795	3.011285	
0.157	0.159	21.5	2.267875	-0.0805	2.348375	
0.148	0.149	21.45	2.08675	-0.0805	2.16725	
0.129	0.13	21.4	1.600714	-0.0805	1.681214	
0.113	0.114	21.4	1.2411	-0.0805	1.3221	
0.096	0.097	21.45	0.894444	-0.0815	0.976444	
0.069	0.071	21.5	0.4821	-0.0825	0.5646	
				-0.0825		
0.088	0.089	21.6	7.311333	-0.3365	7.658333	1085
0.067	0.068	21.55	4.34275	-0.3575	4.70025	1216
0.044	0.045	21.6	1.9237	-0.3575	2.2822	1245
0.035	0.036	21.6	1.166444	-0.3595	1.526944	1091
0.029	0.03	21.6	0.706636	-0.3615	1.068136	1094
0.023	0.024	21.6	0.2008	-0.3615	0.5623	1076
0.016	0.017	21.6	-0.02333	-0.3615	0.337666	1086
		21.65	-0.13384	-0.3605	0.227153	1045
		21.65	-0.19975	-0.3615	0.16225	748
		21.65	-0.26028	-0.3625	0.102214	650
		21.65	-0.30757	-0.3625	0.055428	592
				-0.3635		

density viscosity
1.00417 1.010869 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 9.48 85.14
0.003419 -4.14933 XS(cm2)= 1.669479 2.97533
-1.99543
0 Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.317646	108.4170	16349.29	44.81284	0.007639	3.155045	11.38273
	0.247718	95.23926	14345.90	34.94765	0.007720	3.100560	11.22062
	0.228612	89.24937	13428.48	32.25221	0.008113	3.082638	11.16729
	0.177343	77.86857	11702.92	25.01921	0.008268	3.027003	11.00176
	0.139462	68.28475	10262.56	19.67500	0.008455	2.974823	10.84651
	0.103000	58.10194	8742.034	14.53108	0.008625	2.909507	10.65217
	0.059556	42.52822	6406.030	8.402169	0.009309	2.791047	10.29971
12	0.089949	54.15859	8176.339	12.68993	0.008669	2.881566	10.56904
17.8	0.055206	40.91970	6170.695	7.788363	0.009321	2.775067	10.25217
27.4	0.026805	27.21683	4108.934	3.781629	0.010230	2.618676	9.786855
30.1	0.017934	21.71086	3277.696	2.530163	0.010756	2.531410	9.527213
36.5	0.012545	17.95326	2710.409	1.769913	0.011004	2.453812	9.296332
44.5	0.006604	14.48342	2186.566	0.931737	0.008901	2.314483	8.881781
64.8	0.003966	10.03861	1515.532	0.559517	0.011126	2.203743	8.552293
90.2	0.002668	6.939507	1048.842	0.376396	0.015663	2.118151	8.297631
89.9	0.001905	4.983802	753.2553	0.268849	0.021691	2.045084	8.080230
123	0.001200	3.165389	478.4191	0.169370	0.033874	1.944747	7.781696
210	0.000651	1.688578	255.2129	0.091845	0.064552	1.811858	7.386307

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/PK	1//f/L
89.31520	27.54586	11.44073	1.005095	0.128093
78.78445	26.51065	11.38063	1.014262	0.144453
75.59946	26.17013	11.10167	0.994123	0.146848
66.50942	25.11305	10.99742	0.999605	0.165351
58.97986	24.12165	10.87506	1.002632	0.184386
50.74438	22.88065	10.76724	1.010802	0.212185
38.63022	20.62989	10.36434	1.006274	0.268296
47.58241	22.34976	10.73970	1.016147	0.225707
37.23464	20.32627	10.35778	1.010391	0.278175
25.97503	17.35484	9.886738	1.010205	0.380624
21.24667	15.69680	9.641791	1.012026	0.453802
17.77021	14.22244	9.532837	1.025440	0.536450
12.89327	11.57518	10.59935	1.193381	0.822083
9.991333	9.471125	9.480294	1.108508	0.948851
8.204120	7.844887	7.990208	0.962950	0.973926
6.933688	6.456601	6.789814	0.840299	0.979250
5.503358	4.550207	5.433264	0.698210	0.987263
4.052647	2.025317	3.935899	0.532864	0.971192

P1P01180

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
0.559517	55.08306	-0.25218	1.741018
0.376390	38.07790	-0.42435	1.580673
0.268849	27.34671	-0.57049	1.436905
0.169370	17.36886	-0.77116	1.239771
0.091845	9.265432	-1.03694	0.966865

Regression Output:

Constant	-2.00474
Std Err of Y Est	0.003809
R Squared	0.999862
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	0.998431
Std Err of Coef.	0.008274

K' = 0.009891
n' = 0.998431

Tw* = 74.89090
Res/f* = 1831.333

Regression Output:

Constant	2.661654
Std Err of Y Est	0.068100
R Squared	0.990732
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	2.771139
Std Err of Coef.	0.089340

t = 21.55555 deg C
s.d.)t = 0.083147 deg C

P2P01199 2/17/89 15:22

1.0 PSID Taps 14 co)NaCl
S = 10.05 <C>(ppm)= 2.08962 X coeff
Z = 4.9 [NaCl]= 0.104687 constant

MMD-40 Q)1 (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vc (ml)
0.173	0.174	20.2	3.873	-0.0035	3.8795	
0.161	0.162	20.2	3.389333	-0.0095	3.400333	
0.152	0.153	20.2	3.133142	-0.0125	3.145142	
0.136	0.137	20.2	2.557375	-0.0115	2.569875	
0.126	0.127	20.2	2.227	-0.0135	2.2415	
0.11	0.111	20.2	1.764125	-0.0155	1.779625	
0.084	0.085	20.25	1.1025	-0.0155	1.1205	
0.068	0.069	20.35	0.755428	-0.0205	0.775178	1100
0.053	0.054	20.35	0.489125	-0.019	0.508125	1250
0.037	0.038	20.45	0.252555	-0.019	0.271555	1171
0.03	0.031	20.45	0.1666	-0.019	0.18435	1086
0.024	0.025	20.5	0.070928	-0.0165	0.088928	1122
0.016	0.017	20.5	0.037466	-0.0195	0.055966	1094
0.011	0.012	20.55	0.0235	-0.0185	0.0415	1113
		20.55	0.010312	-0.018	0.027812	1089
				-0.0175		

density viscosity
1.00417 1.010869 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.25
0.003419 -4.14933 XS(cm2)= 1.669479 3.539999
-0.79424
Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.272245	104.2240	15144.51	38.40783	0.007053	3.104462	11.78404
	0.238619	97.03622	14100.06	33.66398	0.007132	3.075835	11.68270
	0.220711	91.64532	13316.72	31.13754	0.007395	3.058894	11.62273
	0.180342	82.06150	11924.12	25.44228	0.007537	3.015030	11.46745
	0.157298	76.07161	11053.75	22.19130	0.007650	2.985344	11.36236
	0.124885	66.48778	9661.154	17.61864	0.007950	2.935238	11.18499
	0.078631	50.91407	7406.531	11.09317	0.008537	2.835273	10.83111
16	0.054398	41.18049	6004.106	7.674424	0.009028	2.756253	10.55138
23.4	0.035657	31.99727	4665.195	5.030540	0.009802	2.664537	10.22670
30.9	0.019056	22.69955	3317.064	2.688454	0.010409	2.529467	9.748558
34.9	0.012936	18.63902	2723.703	1.825102	0.010480	2.445359	9.450817
44.9	0.006240	14.96805	2189.736	0.880410	0.007840	2.287550	8.892176
65	0.003927	10.08144	1474.855	0.554081	0.010876	2.186995	8.536208
89.8	0.002912	7.423995	1087.311	0.410858	0.014872	2.122546	8.308062
130	0.001951	5.017685	734.8856	0.275349	0.021819	2.035642	8.000421

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
79.49551	26.58478	11.90673	1.010411	0.149778
74.42442	26.04087	11.84092	1.013543	0.159099
71.57723	25.71900	11.62793	1.000447	0.162452
64.70096	24.88558	11.51849	1.004451	0.178026
60.42603	24.32153	11.43314	1.006229	0.189208
53.84172	23.36954	11.21476	1.002661	0.208291
42.77138	21.47019	10.82284	0.999237	0.253039
35.65606	19.96881	10.52434	0.997437	0.295162
28.86807	18.22621	10.10024	0.987634	0.349876
21.15178	15.65987	9.801370	1.005417	0.463382
17.42766	14.06182	9.767886	1.033549	0.560481
12.11800	11.06346	11.29382	1.270085	0.931987
9.613356	9.152905	9.588579	1.123283	0.997422
8.287565	7.928392	8.199872	0.986977	0.989418
6.784579	6.277215	6.769815	0.846182	0.997823

P2P01199

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
1.825102	102.2745	0.261287	2.009767
0.880410	82.13150	-0.05531	1.914509
0.554081	55.31809	-0.25642	1.742867
0.410858	40.73634	-0.38630	1.609982

Regression Output:

Constant	-2.14813
Std Err of Y Est	0.011850
R Squared	0.997475
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	1.090939
Std Err of Coef.	0.054883

K' = 0.007109
n' = 1.090939

Tw* = 13.19078
Res/f* = 746.9501

Regression Output:

Constant	-0.59374
Std Err of Y Est	0.043275
R Squared	0.995706
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	4.023065
Std Err of Coef.	0.099845

t = 20.34333 deg C
s.d.)t = 0.138884 deg C

Page 1 Cyanamid 837A

P5P01188 2/8/89 15:59

1.0 PSID Taps 14 co)NaCl
S = 10.05 <C>(ppm)=5.156122 X coeff
Z = 4.9 [NaCl]= 0.10444 constant

MMD-40 Q)l (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.211	0.212	21.3	4.977285	-0.133	5.113785	
0.188	0.189	21.2	4.143285	-0.14	4.283785	
0.176	0.177	21.2	3.7395	-0.141	3.8805	
0.152	0.153	21.2	3.019428	-0.141	3.161428	
0.116	0.117	21.3	1.922373	-0.143	2.066125	
0.137	0.138	21.3	2.515142	-0.1445	2.659142	
0.098	0.099	21.3	1.401666	-0.1435	1.545916	
0.078	0.079	21.4	0.903285	-0.145	1.048785	1182
0.067	0.068	21.4	0.627	-0.146	0.77275	1127
0.052	0.053	21.45	0.365125	-0.1455	0.511125	1173
0.04	0.0415	21.5	0.177222	-0.1465	0.323222	1195
0.033	0.034	21.5	0.085777	-0.1455	0.231277	1040
0.027	0.028	21.5	0.0095	-0.1455	0.1545	1130
0.021	0.022	21.5	-0.06486	-0.1445	0.079633	1210
0.017	0.018	21.5	-0.08507	-0.1445	0.059428	1093
0.012	0.012	21.6	-0.10395	-0.1445	0.040547	1104
0.098	0.099	21.6	1.401	-0.1445	1.547	
				-0.1475		

Page 2 Cyanamid 837A

density viscosity
1.00417 1.010869 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.24
0.003419 -4.14933 XS(cm2)= 1.669479 3.97533
-1.99543
Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.359114	124.9856	18915.56	50.66306	0.006269	3.175435	11.46339
	0.300827	113.2089	16825.40	42.44012	0.006607	3.135995	11.32604
	0.272507	106.0210	15757.12	38.44471	0.006824	3.114522	11.26216
	0.222010	91.64532	13620.56	31.32076	0.007441	3.070020	11.12975
	0.145093	70.08172	10439.25	20.46941	0.008316	2.978642	10.85787
	0.186737	82.66049	12312.96	26.34453	0.007693	3.033435	11.02090
	0.108561	59.29991	8833.212	15.31563	0.008691	2.915657	10.67047
14.9	0.073650	47.51711	7094.053	10.39048	0.009183	2.832392	10.42273
16.6	0.054266	40.66630	6071.263	7.655753	0.009258	2.766069	10.22539
22.3	0.035893	31.50736	4709.191	5.063794	0.010179	2.676805	9.959810
28.9	0.022698	24.76788	3706.065	3.202212	0.010417	2.577785	9.665192
30.2	0.016241	20.62743	3086.522	2.291304	0.010746	2.505101	9.448934
40	0.010849	16.92144	2531.987	1.530655	0.010667	2.417498	9.188287
54	0.005592	13.42179	2008.328	0.788939	0.008739	2.273582	8.760087
60.2	0.004173	10.87533	1627.296	0.588768	0.009934	2.210032	8.571005
90	0.002847	7.347599	1101.918	0.401711	0.014849	2.128002	8.326939
	0.108637	59.29991	8893.198	15.32636	0.008697	2.918765	10.67971

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
93.60857	27.93327	12.62943	1.103643	0.134917
85.48167	27.18386	12.30190	1.086161	0.143912
81.35851	26.77593	12.10469	1.074811	0.148782
73.43461	25.93039	11.59242	1.041570	0.157860
59.50077	24.19420	10.96545	1.009908	0.184290
67.50177	25.23526	11.40059	1.034451	0.168893
51.46801	22.99749	10.72658	1.005258	0.208412
42.48864	21.41546	10.43521	1.001197	0.245600
36.47111	20.15531	10.40423	1.017489	0.285273
29.69516	18.45930	9.911528	0.995152	0.333775
23.64097	16.57792	9.797782	1.013718	0.414440
19.99777	15.19693	9.646455	1.020904	0.482376
16.34477	13.53248	9.681943	1.053726	0.592357
11.73443	10.79806	10.69676	1.221079	0.911570
10.13706	9.590615	10.03308	1.170583	0.989741
8.392331	8.032049	8.206288	0.985510	0.977831
51.83762	23.05653	10.72242	1.003998	0.206846

P5P01188

Tw# = 19.43554
Res/f# = 927.6587

Regression Output:

Constant	-14.6790
Std Err of Y Est	0.064012
R Squared	0.991487
No. of Observations	6
Degrees of Freedom	4

X Coefficient(s) 8.594574
Std Err of Coef. 0.398174

t = 21.39705 deg C
s.d.)t = 0.131138 deg C

Page 1 Cyanamid 837A

P1P11192 2/12/89 16:34

1.0 PSID Taps 14 co)NaCl
S = 10.05 <C>(ppm)= 10.325 X coeff
Z = 4.9 [NaCl]= 0.103322 constant

MMD-40 Q)1 (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vc (ml)
0.2	0.201	20.25	4.2875	-0.0215	4.312	
0.188	0.189	20.2	3.908	-0.0275	3.9355	
0.168	0.169	20.2	3.434	-0.0275	3.4615	
0.147	0.148	20.2	2.802444	-0.0275	2.830444	
0.115	0.116	20.2	1.863666	-0.0285	1.892666	
0.097	0.098	20.2	1.420166	-0.0295	1.449666	115
0.08	0.081	20.3	1.012166	-0.0295	1.042166	109
0.066	0.067	20.3	0.724	-0.0305	0.755	112
0.046	0.047	20.35	0.367571	-0.0315	0.399071	112
0.034	0.035	20.4	0.205	-0.0315	0.2365	104
0.029	0.03	20.45	0.118898	-0.0315	0.149888	110
0.023	0.024	20.45	0.051375	-0.0305	0.081875	109
0.016	0.017	20.5	0.027307	-0.0305	0.057807	108
0.012	0.012	20.55	0.009923	-0.0325	0.040923	109
				-0.0295		

Page 2 Cyanamid 837A

density viscosity
1.00417 1.010869 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.25
0.003419 -4.14933 XS(cm2)= 1.669479 3.539999
-0.79424
0 Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.302596	120.3968	17514.26	42.68967	0.005875	3.127906	11.86703
	0.276175	113.2089	16450.07	38.96224	0.006064	3.107574	11.79505
	0.242912	101.2291	14709.32	34.26954	0.006671	3.079706	11.69640
	0.198627	88.65038	12881.53	28.02197	0.007113	3.036002	11.54169
	0.132818	69.48273	10096.34	18.73778	0.007742	2.948611	11.22233
13.7	0.101730	58.70092	8529.668	14.35199	0.008309	2.890708	11.02735
13.5	0.073134	48.54029	7069.185	10.31766	0.008736	2.820628	10.77714
16.8	0.052982	40.14652	5846.755	7.474652	0.009252	2.756033	10.52936
24	0.028005	27.95282	4075.514	3.950887	0.010087	2.612077	10.04100
30.2	0.016596	20.78611	3034.030	2.341397	0.010811	2.498960	9.640586
36.9	0.010518	17.95343	2623.519	1.483930	0.009184	2.400422	9.291741
45	0.005745	14.50884	2120.164	0.810579	0.007682	2.269113	8.826907
64.5	0.004056	10.06673	1472.702	0.572307	0.011267	2.194023	8.561087
91.2	0.002871	7.187868	1052.728	0.405146	0.015645	2.119507	8.297300

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
83.90478	27.03022	13.04623	1.099367	0.155488
80.06721	26.64391	12.84083	1.088661	0.160375
75.09083	26.11443	12.24294	1.046726	0.163041
67.90192	25.28403	11.85675	1.027297	0.174615
55.52541	23.62362	11.36455	1.011771	0.204672
48.59469	22.52346	10.97042	0.994837	0.225753
41.29605	21.18054	10.69894	0.992743	0.259079
35.14903	19.85063	10.39636	0.987368	0.295779
25.58337	17.22947	9.956453	0.991579	0.389176
19.71699	15.08025	9.617434	0.997600	0.487773
15.71456	13.20802	10.43426	1.122961	0.663986
11.61430	10.71315	11.40922	1.292550	0.982341
9.770193	9.286439	9.420886	1.100431	0.964247
8.229758	7.870634	7.994833	0.963546	0.971454

P1P11192

Tw& = 24.83040
Res/f& = 1023.851

Regression Output:

Constant	-29.1543
Std Err of Y Est	0.123329
R Squared	0.965986
No. of Observations	4
Degrees of Freedom	2

X Coefficient(s)	13.48892
Std Err of Coef.	1.789802

t = 20.325 deg C
s.d.)t = 0.120638 deg C

P2P11195 2/15/89 17:03

1.0 PSID Taps 14 co)NaCl
S = 10.05 <C>(ppm)= 20.8137 X coeff
Z = 4.9 [NaCl]= 0.105488 constant

MMD-40 Q)l (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.212	0.213	21.9	3.073666	-0.0485	3.127416	
0.175	0.176	21.8	2.411	-0.059	2.47125	
0.191	0.192	21.8	2.705625	-0.0615	2.769125	
0.15	0.151	21.8	2.007125	-0.0655	2.072625	
0.117	0.118	21.8	1.44	-0.0655	1.506	
0.135	0.136	21.8	1.7537	-0.0665	1.8202	
0.085	0.086	21.8	0.9435	-0.0665	1.01	
0.069	0.07	21.9	0.691714	-0.0665	0.758214	1127
0.053	0.054	21.9	0.4325	-0.0665	0.499	1150
0.045	0.046	21.95	0.312142	-0.0665	0.378642	1147
0.036	0.037	22	0.198666	-0.0665	0.265166	1108
0.028	0.029	22	0.081636	-0.0665	0.148136	1170
0.018	0.022	22	0.002375	-0.0665	0.067875	1090
				-0.0645		

density	viscosity						
1.00417	1.010869	ID(cm) = 1.45796					
-0.00025	-0.02281	K(V/psi)= 14.25					
0.003419	-4.14933	XS(cm2)= 1.669479					3.539999
							-0.79424
0							Solvent
t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.219467	127.5846	19263.78	30.96205	0.003796	3.074415	11.67767
	0.173421	105.4220	15881.62	24.46587	0.004393	3.022296	11.49317
	0.194324	115.0059	17325.41	27.41489	0.004136	3.047009	11.58065
	0.145447	90.44735	13625.71	20.51940	0.005005	2.984098	11.35795
	0.105684	70.68071	10647.90	14.90970	0.005956	2.914750	11.11246
	0.127733	81.46251	12272.16	18.02034	0.005419	2.955897	11.25812
	0.070877	51.51306	7760.340	9.999204	0.007520	2.827998	10.80536
16.1	0.053208	41.92923	6330.822	7.506474	0.008521	2.766719	10.58843
21.3	0.035017	32.33978	4882.928	4.940200	0.009427	2.675873	10.26683
25.1	0.026571	27.37213	4137.535	3.748640	0.009985	2.616430	10.05640
29.8	0.018608	22.27113	3370.275	2.625203	0.010563	2.539567	9.784315
40.1	0.010395	17.47673	2644.742	1.466579	0.009583	2.413139	9.336758
53.7	0.004763	12.15825	1839.899	0.671976	0.009072	2.243663	8.736813

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
74.18156	26.01390	16.23027	1.389854	0.218791
65.79247	25.02362	15.08685	1.312679	0.229309
69.64487	25.49317	15.54799	1.342583	0.223246
60.25294	24.29786	14.13386	1.244402	0.234575
51.36063	22.98025	12.95728	1.166013	0.252280
56.46475	23.76205	13.58387	1.206584	0.240572
42.06090	21.33197	11.53140	1.067193	0.274159
36.52574	20.16766	10.83280	1.023079	0.296580
29.63148	18.44159	10.29928	1.003160	0.347579
25.84107	17.31218	10.00716	0.995103	0.387258
21.64949	15.85178	9.729659	0.994413	0.449417
16.18151	13.44964	10.21513	1.094077	0.631284
10.95325	10.22960	10.49858	1.201649	0.958490

P2P11195

Tw# = 9.241803
Res/f# = 640.4543

Regression Output:

Constant	-47.0544
Std Err of Y Est	0.097967
R Squared	0.994951
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	20.55662
Std Err of Coef.	0.732123

t = 21.88076 deg C
s.d.)t = 0.082131 deg C

P5P11102 2/21/89 15:28

1.0 PSID		1.0 PSID			co)NaCl
S =	10.05	S =	10.05	<C>(ppa)=52.04769	X coeff
Z =	4.77	Z =	4.82	[NaCl]= 0.106855	constant

MMD-40 Q)l (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.223	0.224	23.85	2.443428	0.0455	2.398928	
0.181	0.182	23.8	2.061833	0.0435	2.017333	
0.156	0.157	23.8	1.744142	0.0455	1.699142	
0.122	0.123	23.75	1.3665	0.0445	1.321	
0.089	0.09	23.8	0.924125	0.0465	0.876125	
				0.0495		
0.028	0.029	23.85	0.71075	0.034	0.6765	1057
0.021	0.022	23.9	0.456230	0.0305	0.426230	1086
0.015	0.016	23.9	0.319562	0.0295	0.290062	1046
		24	0.185071	0.0295	0.156571	534
		24	0.068875	0.0305	0.038375	125
0.06	0.0615	24	2.970666	0.0295	2.944666	1064
0.045	0.046	23.95	1.942666	0.0225	1.920666	1090
0.072	0.075	23.9	3.729166	0.0215	3.707166	1128
				0.0225		

density	viscosity					
1.00417	1.010869	ID(cm) = 1.45796				
-0.00025	-0.02281	K(V/psi)= 14.29	75.06			
0.003419	-4.14933	XS(cm2)= 1.669479				3.539999
						-0.79424
						Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.167874	134.1735	21169.74	23.68339	0.002626	3.035434	11.53968
	0.141170	109.0160	17181.02	19.91610	0.003346	2.997321	11.40476
	0.118904	94.04128	14820.99	16.77477	0.003787	2.960048	11.27281
	0.092442	73.67565	11598.26	13.04155	0.004797	2.904891	11.07756
	0.061310	53.90991	8496.111	8.649535	0.005942	2.816216	10.76365
36.7	0.009039	17.25153	2721.927	1.275264	0.008556	2.401012	9.293829
50	0.005678	13.01004	2055.025	0.801115	0.009450	2.300552	8.938201
65.1	0.003864	9.624309	1520.226	0.545182	0.011752	2.216975	8.642340
59.9	0.002059	5.339902	845.3794	0.290522	0.020344	2.081279	8.161977
59.9	0.000511	1.249977	197.8884	0.072127	0.092180	1.778739	7.090984
17.1	0.039230	37.27043	5900.417	5.534603	0.007956	2.721233	10.42741
23.6	0.025588	27.66517	4374.836	3.609959	0.009418	2.627948	10.09718
15.2	0.049389	44.45129	7021.388	6.967748	0.007041	2.770251	10.60093

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
67.81322	25.27325	19.51107	1.690780	0.287717
62.11578	24.54911	17.28729	1.515796	0.278307
57.00698	23.84091	16.24909	1.441441	0.285036
50.20788	22.79294	14.43779	1.303337	0.287560
40.93513	21.10810	12.97191	1.205159	0.316889
15.73593	13.21923	10.81095	1.163239	0.687023
12.48626	11.31049	10.28643	1.150839	0.823819
10.30044	9.722543	9.224274	1.067335	0.895521
7.536331	7.144319	7.010866	0.858966	0.930275
3.755083	1.396051	3.293676	0.464487	0.877124
32.89375	19.30343	11.21112	1.075159	0.340828
26.53559	17.53102	10.30417	1.020499	0.388315
36.82402	20.23477	11.91713	1.124158	0.323623

P5P11102

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
0.800175	71.38765	-0.09681	1.853623
0.554597	52.80973	-0.25602	1.722713
0.294382	29.30068	-0.53108	1.466877
0.072127	6.858773	-1.14190	0.836246

Regression Output:

Constant	-1.97624
Std Err of Y Est	0.015387
R Squared	0.999424
No. of Observations	3
Degrees of Freedom	1

X Coefficient(s)	0.993514
Std Err of Coef.	0.023848

K' = 0.010562
n' = 0.993514

Tw* = 4.396551
Res/f* = 467.4658

Regression Output:

Constant	-37.5790
Std Err of Y Est	0.121213
R Squared	0.995024
No. of Observations	4
Degrees of Freedom	2

X Coefficient(s)	17.91327
Std Err of Coef.	0.895670

t = 23.88461 deg C
s.d.)t = 0.081770 deg C

P1P03404 5/2/89 12:22

1.0 PSID Taps 14 0.1 PSID Taps 14 co)NaCl
S = 10.05 S = 10.05 <C>(ppm)=1.031289 X coeff
Z = 4.9 Z = 4.92 [NaCl]= 0.000309 constant

NMD 40 θ)1 (1/s)	NMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.187	0.188	21.3	4.102111	0.0225	4.087111	
0.17	0.171	21.2	3.5036	0.0075	3.4971	
0.166	0.165	21.2	3.309714	0.0055	3.304714	
0.147	0.148	21.2	2.759666	0.0045	2.754666	
0.117	0.118	21.2	1.907428	0.0035	1.904928	
0.134	0.135	21.2	2.372666	0.0015	2.371666	
0.1	0.101	21.2	1.452166	0.0005	1.430166	
				0		
0.092	0.093	21.4	6.601833	0.0435	6.558333	1096
0.07	0.071	21.45	4.158714	0.0265	4.053214	1134
0.055	0.056	21.4	2.875666	0.1055	2.772666	1092
0.047	0.048	21.4	2.201428	0.1005	2.103428	1106
0.037	0.038	21.4	1.547	0.0955	1.4565	1094
0.031	0.032	21.5	1.091818	0.0855	1.011318	1106
0.025	0.026	21.5	0.587769	0.0755	0.517269	1078
0.018	0.019	21.5	0.391071	0.0655	0.330071	1128
0.013	0.013	21.5	0.28925	0.0565	0.23675	1087
		21.55	0.21725	0.0465	0.17225	1183
		21.55	0.14075	0.0435	0.09925	692
		21.6	0.084305	0.0395	0.044805	313
		21.65	0.053535	0.0365	0.019535	204
				0.0315		

density viscosity
1.000096 1.001592 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.29 73.56
0.003419 -4.14933 XS(cm2)= 1.669479 5.539999
0.79424
0
Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/(cm2)	f	Log(Re/f)	1/√f
	0.286011	112.6099	16860.86	40.34096	0.006375	3.129132	11.87137
	0.244723	102.4271	15301.65	34.52508	0.006595	3.094293	11.74804
	0.231260	98.83319	14764.75	32.62575	0.006692	3.082006	11.70454
	0.192768	88.65038	13243.53	27.17941	0.006933	3.042473	11.56460
	0.133305	70.68071	10559.07	18.80638	0.007542	2.962378	11.28106
	0.165966	80.86352	12080.25	23.41425	0.007174	3.009966	11.44952
	0.100081	60.49789	9037.818	14.11930	0.007729	2.900132	11.06071
11.8	0.089156	55.63491	8348.920	12.52797	0.008142	2.877001	10.97883
16	0.055100	42.45335	6378.002	7.777502	0.008642	2.772997	10.61065
19.4	0.037692	33.71629	5059.675	5.317590	0.009729	2.690053	10.31707
22.9	0.028594	28.92934	4341.316	4.034084	0.009658	2.630068	10.10468
28.2	0.019800	23.23737	3487.144	2.793365	0.010365	2.550360	9.822166
34.9	0.013748	18.98228	2855.033	1.939568	0.010785	2.472034	9.545245
42	0.007031	15.57405	2312.336	0.992050	0.008409	2.326448	9.029877
60	0.004487	11.26099	1693.711	0.633031	0.010002	2.228894	8.684530
79.9	0.003218	8.148950	1225.643	0.454053	0.013700	2.156735	8.429088
119.9	0.002341	5.909958	889.8913	0.330351	0.018951	2.068162	8.106340
119.9	0.001349	3.457051	520.5450	0.190247	0.031913	1.768447	7.762551
120.4	0.000609	1.557172	234.7356	0.085930	0.071010	1.796241	7.152940
179.8	0.000265	0.679609	102.5632	0.037466	0.162548	1.616482	6.516594

Tap DL= 122.2236

L 1/f	MDR 1/f	1/f	1/f/Blv	1/f/L
84.14197	27.05352	12.52411	1.054984	0.148845
77.65569	26.39157	12.31530	1.048285	0.158588
75.48944	26.15811	12.22418	1.044396	0.161932
68.92135	25.40700	12.00964	1.038483	0.174251
57.31372	23.88519	11.51451	1.020693	0.200903
63.95081	24.78935	11.80619	1.031151	0.184613
49.66067	22.70251	11.37446	1.028366	0.229043
47.08490	22.26303	11.08226	1.009621	0.235367
37.05760	20.28694	10.75690	1.013783	0.290275
30.61496	18.71102	10.32925	1.001184	0.337392
26.66544	17.57130	10.17542	1.007000	0.381595
22.18912	16.05494	9.822223	1.000005	0.442659
18.57164	14.56864	9.628911	1.008765	0.519592
13.25343	11.80252	10.90441	1.207593	0.822761
10.58702	9.948987	9.998740	1.151327	0.944433
8.966338	8.577967	8.543369	1.013557	0.952826
7.656712	7.275084	7.263960	0.887329	0.948707
5.812031	5.000511	5.597709	0.721117	0.963124
3.909500	1.728583	3.752648	0.524630	0.959879
2.584416	-1.68683	2.480327	0.380617	0.959724

P1P03404

Tw dyne/cm2	B(U)/D (1/s)	Log Tw	Log B(U)/D
0.633031	61.79041	-0.19857	1.790921
0.454053	44.71425	-0.34289	1.650446
0.330351	32.42864	-0.48102	1.510928
0.190347	18.96925	-0.72045	1.278050
0.085930	8.544391	-1.06585	0.931681
0.037466	3.729097	-1.42635	0.571603

Regression Output:

Constant	2.00187
Std Err of Y Est	0.002308
R Squared	0.999979
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	1.005066
Std Err of Coef.	0.002627

K' = 0.009956
n' = 1.005066

Tw8 = 12.06977
Res/f8 = 736.3099

Regression Output:

Constant	-6.32231
Std Err of Y Est	0.008874
R Squared	0.999531
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	6.022181
Std Err of Coef.	0.065215

t = 21.395 deg C
s.d.)t = 0.148239 deg C

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
84.14197	27.05352	12.52411	1.054984	0.148845
77.65569	26.39157	12.31530	1.048285	0.158588
75.48944	26.15811	12.22418	1.044376	0.161932
69.92135	25.40700	12.00964	1.038483	0.174251
57.31372	23.88519	11.51451	1.020695	0.200903
63.95081	24.78935	11.80619	1.031151	0.184613
49.66067	22.70251	11.37446	1.028366	0.229043
47.08490	22.26303	11.09226	1.009421	0.235367
37.05760	20.28694	10.75690	1.013783	0.290275
30.61496	18.71102	10.32925	1.001184	0.337392
26.66544	17.57130	10.17542	1.007060	0.381595
22.18912	16.05494	9.822223	1.000005	0.442659
18.53164	14.56864	9.628911	1.008765	0.519592
13.25343	11.80252	10.90441	1.207593	0.822761
10.58702	9.948987	9.998740	1.151327	0.944433
8.966338	8.577967	8.543369	1.013557	0.952826
7.656712	7.275084	7.263980	0.887329	0.948707
5.812031	5.000511	5.597709	0.721117	0.963124
3.909500	1.728583	3.752648	0.524630	0.959879
2.584416	-1.68683	2.480327	0.380617	0.959724

P1P03404

Tw dyne/cm2	8*U*/D (1/s)	Log Tw	Log 8*U*/D
0.633031	61.79041	-0.19857	1.790921
0.454053	44.71425	-0.34289	1.650446
0.330351	32.42864	-0.48102	1.510928
0.190347	18.96925	-0.72045	1.278050
0.085930	8.544391	-1.06585	0.931681
0.037466	3.729097	-1.42635	0.571603

Regression Output:

Constant	-2.00187
Std Err of Y Est	0.002308
R Squared	0.999979
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	1.005066
Std Err of Coef.	0.002627

K' = 0.009956
n' = 1.005066

Tw* = 12.06977
Res/f* = 736.3099

Regression Output:

Constant	-6.32231
Std Err of Y Est	0.008874
R Squared	0.999531
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	6.022181
Std Err of Coef.	0.065215

t = 21.395 deg C
s.d.)t = 0.148239 deg C

Page 1 Cyanamid 836

P2P03407 3/4/89 13:22

1.0 PSID Taps 14	0.1 PSID Taps 14				co)NaCl
S = 10.05	S = 10.05	<C>(ppm)=	2.065943		X coeff
Z = 4.86	Z = 4.92	[NaCl]=	0.000309		constant

MMD-40 Θ)l (1/s)	MMD-40 Θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.196	0.197	20.95	4.296166	0.003	4.295416	
0.178	0.18	20.9	3.694	-0.0015	3.6965	
0.17	0.171	20.8	3.438571	-0.0035	3.441071	
0.151	0.152	20.8	2.855142	-0.0015	2.855642	
0.132	0.133	20.9	2.2555	0.0005	2.2545	
0.101	0.102	20.85	1.48675	0.0015	1.486	
				0		
0.093	0.094	21.05	6.765714	0.0225	6.743214	1196
0.07	0.072	21	4.2084	0.004	4.2071	1228
0.055	0.056	21	2.749714	0.0015	2.744714	1133
0.038	0.039	21.3	1.522285	0.0085	1.513285	1174
0.031	0.032	21.4	0.997333	0.0095	0.986833	1099
0.023	0.024	21.35	0.451461	0.0115	0.439961	1099
0.017	0.018	21.4	0.335333	0.0115	0.323333	1094
0.012	0.013	21.35	0.239136	0.0125	0.226636	1116
		21.25	0.192538	0.0125	0.181038	1076
		21.3	0.127384	0.0105	0.116384	1203
		21.3	0.077	0.0115	0.0655	1150
		21.3	0.028454	0.0115	0.016954	292
				0.0105		

Page 2 Cyanamid 836

density	viscosity				
1.000096	1.001592	ID(cm) =	1.45796		
-0.00025	-0.02281	K(V/psi)=	14.29	75.56	
0.003419	-4.14933	XS(cm2)=	1.669479		3.539999
					-0.79424
0					Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.300588	118.0008	17529.07	42.40645	0.006101	3.176478	11.89738
	0.258677	107.8180	15998.35	36.49365	0.006289	3.103379	11.78020
	0.240802	102.4271	15164.19	33.97194	0.006487	3.066845	11.72167
	0.199835	91.04633	13479.28	28.19250	0.006811	3.046350	11.57852
	0.157767	79.66554	11821.00	22.25752	0.007026	2.996008	11.40011
	0.103988	61.09688	9055.515	14.67051	0.007873	2.905000	11.07794
12.7	0.091669	56.40873	8398.467	12.93254	0.008142	2.879590	10.98799
17.1	0.057192	43.01512	6397.126	8.068634	0.008736	2.776655	10.62360
20.3	0.037312	33.43126	4971.833	5.263981	0.009436	2.683912	10.29529
29.7	0.020572	23.67721	3545.141	2.902272	0.010372	2.557580	9.848079
34.8	0.013415	18.91635	2838.704	1.892609	0.010697	2.465726	9.522918
44.9	0.005980	14.66122	2197.673	0.843785	0.007065	2.287819	8.900207
60	0.004398	10.92156	1638.958	0.620492	0.010423	2.203564	8.665667
85.4	0.003080	7.827538	1173.724	0.434657	0.014214	2.145777	8.390296
103.9	0.002461	6.203197	927.7454	0.347206	0.018078	2.096012	8.214130
180.2	0.001582	3.998800	598.7324	0.223209	0.027968	2.000567	7.876254
299.9	0.000890	2.296890	343.9088	0.125619	0.047708	1.875740	7.434367
299.9	0.000230	0.583210	87.32294	0.032516	0.171544	1.582362	6.395456

Tap DL= 122.2234

L 1/f	MBR 1/f	1/f	1/f/Blv	1/f/L
85.57737	27.19309	12.80206	1.076040	0.149596
79.29741	26.56420	12.60945	1.070393	0.159014
76.33528	26.25006	12.41577	1.059215	0.162647
69.53932	25.48065	12.11680	1.046336	0.174215
61.92825	24.52414	11.95014	1.046493	0.192646
50.22043	22.79500	11.26970	1.017310	0.224604
47.36638	22.31221	11.08178	1.008535	0.233958
37.37107	20.35645	10.69866	1.007064	0.266281
30.18510	18.59434	10.29446	0.999919	0.341044
22.56629	16.19402	9.818687	0.997015	0.435104
18.26446	14.44880	9.713896	1.020054	0.531866
12.18146	11.10657	11.27570	1.266903	0.925643
10.45789	9.867724	9.794976	1.130320	0.936610
8.742932	8.369765	8.387665	0.999686	0.959365
7.796372	7.424238	7.437316	0.905429	0.953945
6.258172	5.610782	5.979506	0.759181	0.955471
4.694835	3.239067	4.578286	0.615827	0.975175
2.388596	-2.33700	2.204891	0.357267	0.956583

P2P03407

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
0.620492	59.92794	-0.20726	1.777629
0.434657	42.95063	-0.36185	1.632969
0.347206	34.03768	-0.45941	1.531960
0.125619	12.60331	-0.90094	1.100484
0.032516	3.200145	-1.48789	0.505169
0.223209	21.94189	-0.65128	1.341274

Regression Output:

Constant	-1.99603
Std Err of Y Est	0.005371
R Squared	0.999927
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	1.000723
Std Err of Coef.	0.006042

K' = 0.010091
n' = 1.000723

Tw8 = 10.77046
Res/f8 = 690.7054

Regression Output:

Constant	-7.64699
Std Err of Y Est	0.060259
R Squared	0.990454
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	6.513269
Std Err of Coef.	0.319704

t = 21.12222 deg C
s.d.)t = 0.216809 deg C

Page 1 Cyanamid 836

P5P03410 3/7/89 12:15

1.0 PSID Taps 14	0.1 PSID Taps 14			co)NaCl	
S = 10.05	S = 10.05	<C>(ppm)=	5.158589	X coeff	
Z = 4.95	Z = 4.95	[NaCl]=	0.000309	constant	

MMD-40 @)1 (1/s)	MMD-40 @)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.226	0.227	20.1	3.797	0.0025	3.808	
0.203	0.204	20.1	3.22575	-0.0245	3.25025	
0.189	0.19	20.1	2.797	-0.0315	2.8285	
0.164	0.165	20.1	2.2994	-0.0365	2.3376	
0.141	0.142	20.1	1.84375	-0.0395	1.88325	
0.106	0.107	20.1	1.170555	-0.0425	1.213555	
0.126	0.127	20.1	1.573625	-0.0435	1.617125	
				-0.0435		
0.097	0.098	20.2	5.559833	0.0605	5.515333	1132
0.073	0.074	20.2	3.617166	0.0445	3.571666	1158
0.057	0.058	20.2	2.4675	0.0465	2.4195	1163
0.039	0.04	20.2	1.154555	0.0495	1.105055	1198
0.03	0.032	20.25	0.715166	0.0495	0.665166	1254
0.024	0.025	20.25	0.561909	0.0505	0.509409	1141
0.018	0.019	20.25	0.435928	0.0545	0.380928	1142
0.013	0.014	20.25	0.331157	0.0555	0.275657	1089
		20.25	0.255130	0.0555	0.200130	860
		20.3	0.205812	0.0545	0.151312	1144
		20.3	0.134833	0.0545	0.080333	664
		20.35	0.0858	0.0515	0.0348	358
				0.0505		

Page 2 Cyanamid 836

density	viscosity						
1.000096	1.001592	ID(cm) = 1.45796					
-0.00025	-0.02281	K(V/psi)= 14.24		77.95			
0.003419	-4.14933	XS(cm2)= 1.669479					3.539999
							-0.79424
0							Solvent
t)samp (sec)	DP (psid)	<U> (cm/s)	Re	fw dyne/cm2	f	log(Re/f)	1/√f
	0.267415	135.9705	19814.84	37.72644	0.004087	3.102711	11.77784
	0.228247	122.1937	17807.17	32.20072	0.004319	3.068321	11.65610
	0.198630	113.8079	16585.11	28.02238	0.004533	3.038141	11.54926
	0.164157	98.83319	14402.85	23.15896	0.004748	2.996748	11.40277
	0.132250	85.05644	12395.18	18.65764	0.005165	2.949817	11.23659
	0.085221	64.09183	9340.035	12.02288	0.005862	2.854393	10.89879
	0.113562	76.07161	11085.83	16.02110	0.005545	2.916735	11.11948
11.4	0.074581	59.47856	8687.325	10.52185	0.005957	2.886420	10.79977
15.5	0.048298	44.75028	6536.140	6.813835	0.006815	2.732069	10.46577
19.8	0.032718	35.18304	5138.768	4.615793	0.007469	2.664497	10.16638
29.9	0.014943	23.99962	3505.340	2.108166	0.007531	2.477326	9.563980
39.6	0.008994	18.96798	2773.554	1.268969	0.007064	2.367592	9.175521
45.2	0.006888	15.12049	2210.963	0.971823	0.008514	2.309660	8.970443
59.9	0.005151	11.41979	1669.835	0.726715	0.011162	2.246540	8.747028
80.1	0.003727	8.143559	1190.775	0.525885	0.015804	2.176312	8.498590
89.9	0.002706	5.730040	837.8633	0.381798	0.023092	2.106783	8.252259
159.9	0.002046	4.285450	627.3383	0.288665	0.031485	2.046556	8.039057
180.1	0.001086	2.208377	323.2798	0.153255	0.062947	1.909067	7.502344
239.9	0.000470	0.893864	130.9986	0.066389	0.166444	1.727901	6.911018

Tap DL= 122.2234

L 1/f	MDR 1/f	1/f	1/f/Blv	1/f/L
79.17566	26.55152	15.64151	1.320046	0.197554
73.14785	25.89811	15.21504	1.305328	0.208004
68.23722	25.32468	15.19067	1.315293	0.222615
62.03379	24.53821	14.51119	1.272398	0.233922
55.67974	23.64652	13.91348	1.238229	0.249884
44.69645	21.83346	13.06037	1.198331	0.292201
51.59588	23.01796	13.42868	1.207671	0.260266
41.90831	21.30198	12.95584	1.199640	0.309147
33.72483	19.50932	12.11299	1.157391	0.359171
27.75729	17.90244	11.57076	1.138139	0.416854
18.75885	14.46920	11.67894	1.221138	0.622583
14.57042	12.58425	11.89719	1.296623	0.816530
12.75088	11.48354	10.83730	1.208112	0.849925
11.02627	10.28442	9.465095	1.082092	0.858413
9.379769	8.949930	7.934464	0.933643	0.845912
7.992147	7.628086	6.552238	0.793993	0.819836
6.957239	6.484581	5.635662	0.701035	0.810042
5.069293	3.872280	3.985761	0.527751	0.786255
3.340271	0.430133	2.451123	0.354668	0.733809

P5P03410

Tw dyne/cm2	8*U*/D (1/s)	Log Tw	Log 8*U*/D
0.726715	62.66175	-0.13867	1.797002
0.525885	44.68467	-0.27910	1.650158
0.381798	31.44141	-0.41816	1.497502
0.268665	23.51477	-0.57960	1.371740
0.153255	12.11762	-0.81458	1.083417
0.066389	4.904740	-1.17790	0.690616

Regression Output:

Constant	-1.82947
Std Err of Y Est	0.002843
R Squared	0.999955
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.940523
Std Err of Coef.	0.003147

K' = 0.014808
n' = 0.940523

Tw@ = 3.460799
Res/f@ = 384.1301

Regression Output:

Constant	-18.6782
Std Err of Y Est	0.153981
R Squared	0.979610
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	11.05892
Std Err of Coef.	0.717521

t = 20.19473 deg C
s.d.)t = 0.080939 deg C

P1P13413 3/9/89 12:07

1.0 PSID Taps 14 0.1 PSID Taps 14 co)NaCl
S = 10.05 S = 10.05 <C>(ppm)=10.31423 X coeff
Z = 4.9 Z = 4.9 [NaCl]= 0.000309 constant

MMD-40 G)1 (1/s)	MMD-40 G)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.236	0.237	21.1	3.359142	0.0115	3.348142	
0.21	0.211	21.1	2.807333	-0.0295	2.842833	
0.193	0.194	21	2.4844	-0.0415	2.5279	
0.166	0.167	21	1.929571	-0.0455	1.980071	
0.143	0.144	21	1.561333	-0.0555	1.619833	
0.117	0.118	21	1.178375	-0.0615	1.240375	
0.093	0.094	21.05	0.8255	-0.0625	0.8885	
				-0.0635		
0.097	0.098	21.2	4.934	0.0465	4.897	1196
0.073	0.074	21.2	3.378625	0.0315	3.345625	1134
0.055	0.056	21.2	2.290888	0.0345	2.255888	1168
0.038	0.039	21.2	1.0847	0.0355	1.0492	1142
0.029	0.03	21.3	0.663625	0.0375	0.626125	1114
0.024	0.024	21.3	0.550909	0.0375	0.512909	1076
0.016	0.017	21.3	0.396647	0.0385	0.359147	1142
0.012	0.013	21.3	0.310285	0.0365	0.274785	1080
		21.4	0.21155	0.0345	0.17805	1074
		21.4	0.12	0.0325	0.0835	1057
		21.45	0.080666	0.0365	0.044166	352
				0.0365		

density viscosity
1.000096 1.091592 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.24 73.95
0.003419 -4.14933 X8(cm2)= 1.669479 -1.539999
0.79424
Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1/f
	0.236526	141.9604	21159.76	33.36871	0.003317	3.085910	11.71836
	0.199637	126.3866	18838.43	28.16438	0.003372	3.049090	11.58802
	0.177521	116.2038	17281.61	25.04429	0.003715	3.022609	11.49428
	0.139049	99.73168	14831.90	19.61687	0.003951	2.969570	11.30652
	0.113752	86.25442	12827.59	16.04795	0.004321	2.925965	11.15216
	0.087104	70.68071	10511.49	12.28858	0.004928	2.868006	10.94698
	0.062394	56.30497	8383.018	8.802506	0.005562	2.796051	10.69226
12	0.066220	58.70092	8769.367	9.342236	0.005432	2.810451	10.74324
15.2	0.045241	44.68773	6675.928	6.382605	0.006403	2.727724	10.45039
20.5	0.030505	34.12776	5098.368	4.303664	0.007407	2.642145	10.14743
29.3	0.014174	23.34626	3487.712	1.999700	0.007350	2.475708	9.558253
37.4	0.009466	17.84154	2671.379	1.194487	0.007518	2.364802	9.165644
43.7	0.006935	14.74856	2208.273	0.978500	0.009013	2.321491	9.012326
66.7	0.004856	10.25555	1535.543	0.685161	0.013052	2.264107	8.738386
83.2	0.003715	7.775338	1164.186	0.524221	0.017373	2.185968	8.432574
128.9	0.002407	4.990801	748.9505	0.339674	0.027324	2.092727	8.079501
270	0.001129	2.344931	351.8949	0.159296	0.058046	1.928299	7.620427
180	0.000597	1.171356	175.9793	0.084258	0.123046	1.790496	7.130604

Tap DL= 122.2234

L 1/f	MDR 1/f	1/f	1/f/Slv	1/f/L
76.17114	26.23229	17.36202	1.481607	0.227934
69.97951	25.53272	16.82495	1.451926	0.240426
65.84002	25.02958	16.40493	1.427225	0.249163
58.27072	24.02183	15.90839	1.407010	0.273008
52.70419	23.19333	15.21177	1.364020	0.288635
46.11970	22.09212	14.24486	1.301258	0.308867
39.07790	20.72497	13.40754	1.253947	0.343097
40.39534	20.99857	13.56803	1.262936	0.335881
33.38911	19.42677	12.49645	1.195788	0.374267
27.41733	17.80075	11.62213	1.145327	0.423897
18.68910	14.63845	11.66359	1.220264	0.624035
14.47711	12.53123	11.53274	1.258260	0.796620
13.10302	11.70834	10.53321	1.168757	0.803876
10.96447	10.23804	8.752953	1.001666	0.798301
9.590661	9.133402	7.586716	0.889147	0.791052
7.737625	7.361825	6.049583	0.737529	0.781839
5.298829	4.237698	4.150620	0.544670	0.783308
3.858127	1.619435	2.850789	0.399694	0.738904

P1P13413

Tw dyne/cm2	BKUS/D (1/s)	Log Tw	Log BKUS/D
1.194487	97.89868	0.077181	1.990776
0.978500	80.92712	-0.00943	1.908094
0.685161	56.27345	-0.16420	1.750503
0.524221	42.66420	-0.28048	1.630063
0.339674	27.38511	-0.46893	1.437514
0.159296	12.86691	-0.79779	1.109474
0.084258	6.427372	-1.07438	0.808033

Regression Outputs:

Constant	-1.89320
Std Err of Y Est	0.002591
R Squared	0.999948
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.988739
Std Err of Coef.	0.003560

K' = 0.012787
n' = 0.988739

Tw$ = 2.562397
Res/f$ = 337.7256

Regression Outputs:

Constant	-24.7470
Std Err of Y Est	0.084282
R Squared	0.997852
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	15.64109
Std Err of Coef.	0.239170

t = 21.19444 deg C
s.d.)t = 0.146143 deg C

P2P13426 4/12/89 13:00

1.0 PSID Taps 14		0.1 PSID Taps 14			co)NaCl
S =	10.05	B =	10.05	<C>(ppm)= 20.58907	X coeff
Z =	4.62	Z =	4.72	[NaCl]= 0.000309	constant

MMD-40 Q)l (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.271	0.272	21.5	2.590166	0	2.587916	
0.21	0.211	21.5	1.8102	0.0045	1.8063	
0.242	0.243	21.5	2.176166	0.0045	2.171666	
0.175	0.176	21.5	1.367428	0.0045	1.363928	
0.149	0.15	21.5	1.058142	0.0025	1.056642	
0.131	0.132	21.5	0.870426	0.0005	0.870178	
0.109	0.11	21.5	0.616166	0	0.616916	
0.268	0.269	21.5	2.633166	-0.0015	2.632166	
				0.0035		
0.099	0.1	21.6	3.3084	0.0485	3.2674	1180
0.074	0.074	21.6	2.335666	0.0335	2.300666	1244
0.057	0.058	21.6	1.843	0.0365	1.8045	1273
0.039	0.04	21.6	1.314444	0.0405	1.271944	1080
0.028	0.029	21.6	0.985230	0.0445	0.939730	1175
0.02	0.021	21.6	0.7762	0.0465	0.7282	1283
0.013	0.014	21.6	0.545333	0.0495	0.494833	810
		21.6	0.341444	0.0515	0.289944	620
		21.6	0.423714	0.0525	0.371214	570
		21.6	0.251	0.0525	0.1985	514
		21.6	0.173	0.0515	0.1215	275
		21.6	0.105166	0.0515	0.053666	151
				0.0495		

density	viscosity				
1.000096	1.001592	ID(cm) =	1.45796		
-0.00025	-0.02281	K(V/psi)=	13.975	86.66	
0.003419	-4.14933	XS(cm2)=	1.669479		
					0.539999
					0.79424
0					Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1/√f
	0.185181	162.9250	24504.75	26.12506	0.001972	3.036710	11.54419
	0.129252	126.3866	19009.20	18.23463	0.002087	2.958630	11.26779
	0.155396	145.5543	21892.11	21.92301	0.002073	2.998631	11.40940
	0.097597	105.1225	15810.97	13.76888	0.002496	2.897630	11.05185
	0.075609	89.84836	13513.65	10.66682	0.002647	2.842199	10.85563
	0.062266	79.06655	11892.01	8.784468	0.002815	2.800039	10.70638
	0.044144	65.88879	9910.012	6.227784	0.002874	2.735348	10.44197
	0.188348	161.1280	24234.48	26.57177	0.002050	3.040391	11.55725
11.7	0.038594	59.89890	9029.449	5.444812	0.003040	2.677158	10.74218
16.6	0.027175	44.88809	6766.647	3.833843	0.003812	2.620981	10.07252
21.9	0.021314	34.81794	5248.625	3.007028	0.004970	2.568375	9.885799
26.7	0.015024	24.22877	3652.361	2.119575	0.007254	2.492091	9.616956
40	0.011100	17.59530	2652.400	1.565972	0.010135	2.426558	9.384261
59.9	0.008601	12.82976	1934.020	1.213476	0.014772	2.371182	9.188231
60	0.005844	8.086352	1218.975	0.824592	0.025268	2.287286	8.891239
90	0.003624	4.126369	622.0287	0.483164	0.056860	2.171214	8.480344
60	0.004384	5.690396	857.7977	0.610593	0.038279	2.224869	8.670283
120	0.002344	2.565669	386.7614	0.330781	0.100690	2.088957	8.187083
120.2	0.001435	1.370399	206.5805	0.202468	0.216020	1.982345	7.811747
179.8	0.000633	0.503044	75.83130	0.089430	0.708144	1.804909	7.183625

Tap DL= 122.2234

L 1/f	MDR 1/f	1/f	1/f/Blv	1/f/L
68.01273	25.29749	22.51853	1.950636	0.331092
56.82115	23.81397	20.90903	1.855465	0.367979
62.30338	24.57400	21.96120	1.924834	0.352488
49.37543	22.65498	20.01371	1.810891	0.405337
43.45894	21.60178	19.43451	1.790270	0.447192
39.43839	20.80074	18.84507	1.760246	0.477855
33.20690	19.38161	18.65202	1.784253	0.561691
68.59173	25.36744	22.68218	1.910481	0.321936
31.11990	18.84600	18.13439	1.753439	0.582726
26.11342	17.39869	16.19532	1.607870	0.620191
23.12679	16.39647	14.18437	1.434822	0.613330
19.41650	14.95353	11.75662	1.222489	0.605496
16.68932	13.70461	9.932999	1.050474	0.595170
14.69137	12.65266	8.227705	0.895461	0.560036
12.11062	11.05844	6.290838	0.707332	0.519447
9.270314	8.853074	4.193687	0.494518	0.452378
10.48936	9.872518	5.111113	0.589497	0.487264
7.670387	7.289808	3.151416	0.386831	0.410854
6.001021	5.264558	2.151514	0.275420	0.358524
3.988314	1.893277	1.188335	0.165422	0.297954

P2P13426

Tw dyne/cm2	8(U)/D (1/s)	Log Tw	Log 8(U)/D
1.565972	96.54752	0.194784	1.984741
1.213476	70.39845	0.084031	1.847563
0.824592	44.37077	-0.08376	1.647097
0.483164	22.64187	-0.31590	1.354912
0.618593	31.22388	-0.20959	1.494486
0.330781	14.07813	-0.48045	1.148545
0.202468	7.519543	-0.69364	0.876191
0.089430	2.760263	-1.04851	0.440950

Regression Output:

Constant	-1.40199
Std Err of Y Est	0.004159
R Squared	0.999912
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	0.802618
Std Err of Coef.	0.003057

K' = 0.039628
n' = 0.802618

Tw@ = 0.774560
Res/f@ = 187.3739

Regression Output:

Constant	31.9668
Std Err of Y Est	0.080108
R Squared	0.996289
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	17.95500
Std Err of Coef.	0.774818

t = 21.56 deg C
s.d.)t = 0.048989 deg C

P1P01305 3/2/89 15:09

1.0 PSID Taps 14	0.1 PSID Taps 14			co)NaCl	
S = 10.05	S = 10.05	<C>(ppm)=	1.031289	X coeff	
Z = 4.9	Z = 4.92	[NaCl]=	0.001035	constant	

MMD-40 @)l (1/c)	MMD-40 @)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.181	0.182	21.35	4.019142	0.0105	4.032642	
0.167	0.168	21.2	3.567833	-0.0145	3.534333	
0.159	0.16	21.2	3.2225	-0.0185	3.242	
0.143	0.144	21.1	2.664454	-0.0205	2.687954	
0.126	0.127	21.15	2.16425	-0.0225	2.18775	
0.098	0.099	21.15	1.425688	-0.0245	1.450888	
0.115	0.116	21.2	1.8598	-0.0255	1.8853	
				-0.0255		
0.09	0.091	21.3	6.532714	0.0305	6.458214	1190
0.068	0.069	21.3	4.143857	0.1185	4.023357	1190
0.038	0.039	21.3	1.604375	0.1225	1.483375	1172
0.054	0.055	21.4	2.824285	0.1195	2.705285	1150
0.03	0.031	21.4	1.123	0.1225	1.002	1095
0.023	0.025	21.4	0.5799	0.1195	0.4614	1149
0.018	0.019	21.35	0.4489	0.1175	0.3313	1144
0.012	0.013	21.4	0.340631	0.1175	0.223131	1053
		21.45	0.233428	0.1135	0.121928	712
		21.45	0.168666	0.1095	0.059166	416
		21.5	0.1338	0.1055	-0.0283	412
				0.0975		

density	viscosity						
1.000125	1.001657	ID(cm) =	1.45796				
-0.00025	-0.02281	K(V/psi)=	14.29	73.56			
0.003419	-4.14933	XS(cm2)=	1.669479				3.539999
							0.79424
0							Solvent
t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.282200	109.0160	16340.58	39.81222	0.006711	3.126690	11.86272
	0.267329	100.6301	15032.66	34.89266	0.006903	3.096571	11.75610
	0.226871	95.83825	14316.82	32.00661	0.006981	3.077823	11.68974
	0.188100	86.25442	12856.10	26.53680	0.007146	3.036145	11.54219
	0.153096	76.07161	11351.16	21.59853	0.007477	2.991923	11.38565
	0.101531	59.29991	8848.546	14.32388	0.008160	2.902741	11.06995
	0.131931	69.48273	10379.69	18.61760	0.007724	2.960107	11.27302
12.9	0.087795	55.25558	8273.011	12.38595	0.008127	2.872654	10.96744
17.2	0.054694	41.44168	6204.750	7.716741	0.009001	2.769092	10.59966
29.9	0.020165	25.47876	3515.303	2.844707	0.010140	2.557223	9.812655
20.9	0.036749	32.95872	4945.813	5.184527	0.009362	2.684529	10.29747
34.9	0.013621	18.79349	2820.187	1.921697	0.010901	2.469016	9.534065
47	0.006272	14.64357	2197.396	0.884901	0.008268	2.500621	8.938446
60	0.004503	11.42072	1711.871	0.635387	0.009760	2.228701	8.682077
80.1	0.003060	7.874350	1181.631	0.431771	0.013952	2.144801	8.386842
100.3	0.001657	4.252046	638.7855	0.233842	0.025914	2.012128	7.917180
120.1	0.000804	2.074766	311.6925	0.113473	0.052817	1.855114	7.361350
240	0.000384	1.028264	154.6507	0.054275	0.102853	1.695461	6.796179

Tap DL= 122.2234

L 1/f	MDR 1/f	1/f	1/f/Slv	1/f/L
83.67005	27.00711	12.20611	1.028947	0.145883
78.66406	26.43485	12.03551	1.023767	0.154174
74.76595	26.07865	11.96803	1.023006	0.160073
67.92398	25.28671	11.82949	1.024891	0.174157
61.34845	24.44654	11.56423	1.015684	0.188500
49.95993	22.75209	11.06955	0.999964	0.221568
57.01480	23.84204	11.37829	1.009337	0.199547
46.61590	22.18042	11.09199	1.011725	0.237944
36.79358	20.22795	10.53981	0.994353	0.286457
22.34103	16.11124	9.834210	1.000158	0.440185
30.22797	18.60605	10.22606	0.993065	0.338298
18.40335	14.51132	9.577628	1.004516	0.520428
12.48825	11.31181	10.99731	1.230338	0.880612
10.57015	9.935821	10.12208	1.163859	0.957610
8.723309	8.351223	8.466049	1.009444	0.970508
6.427001	5.830439	6.211932	0.784614	0.966536
4.477073	2.847169	4.351231	0.591091	0.971891
3.099855	-0.18623	3.118103	0.458802	1.005886

P1P0[illegible]05	dyne/cm2	(1/s)	Tw	B·U /D
	0.635387	62.66687	-0.19696	1.797038
	0.431771	43.20749	-0.36474	1.635559
	0.233842	23.33148	-0.63107	1.367942
	0.113473	11.38449	-0.94510	1.056313
	0.054275	5.642210	-1.26539	0.751449

Regression Output:

Constant	-2.00995
Std Err of Y Est	0.002596
R Squared	0.999957
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	1.007693
Std Err of Coef.	0.004619

K' = 0.009773
n' = 1.007693

Tw8 = 13.10746
Res/f8 = 765.5319

Regression Output:

Constant	-3.45248
Std Err of Y Est	0.076295
R Squared	0.993237
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	5.005598
Std Err of Coef.	0.184766

t = 21.31111 deg C
s.d.)t = 0.116136 deg C

P2P01308 3/4/89 15:50

1.0 PSID Taps 14 0.1 PSID Taps 16 co)NaCl
S = 10.05 S = 10.05 <C>(ppm)=2.065943 X coeff
Z = 4.86 Z = 4.92 [NaCl]= 0.001035 constant

MMD-40 θ)l (1/s)	MMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.19	0.191	21.05	4.246571	-0.0015	4.241071	
0.177	0.178	20.95	3.794111	0.0125	3.778111	
0.165	0.166	20.9	3.44225	0.0195	3.42125	
0.147	0.148	20.9	2.832	0.0225	2.8105	
0.13	0.131	20.9	2.303428	0.0205	2.282428	
0.1	0.102	20.9	1.513111	0.0215	1.497611	
0.117	0.118	20.95	1.926875	0.0095	1.916875	
				0.0105		
0.091	0.092	21.1	6.6568	0.0415	6.6153	1114
0.069	0.07	21.1	4.126	0.0185	4.106	1164
0.054	0.055	21.1	2.782714	0.0215	2.760714	1213
0.038	0.039	21.15	1.520333	0.0225	1.497333	1178
0.03	0.031	21.2	0.9998	0.0235	0.9748	1250
0.023	0.024	21.2	0.453636	0.0265	0.426136	1069
0.016	0.017	21.2	0.3318	0.0295	0.3018	1065
0.012	0.013	21.3	0.26	0.0305	0.229	1184
		21.3	0.191916	0.0315	0.160916	1130
		21.35	0.122571	0.0305	0.092571	642
		21.4	0.085142	0.0295	0.055642	383
		21.45	0.047	0.0295	0.0185	260
				0.0275		

density viscosity
1.000125 1.001657 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.29 75.56
0.003419 -4.14933 XS(cm2)= 1.669479 3.539999
-0.79424

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	fw dyne/cm2	f	Log(Re/f)	1/√f Solvent
	0.296785	114.4069	17032.96	41.86993	0.006408	3.134677	11.89100
	0.266388	106.6200	15837.88	37.29936	0.006577	3.108591	11.79865
	0.239415	99.43218	14753.51	33.77625	0.006844	3.086554	11.72064
	0.196675	88.65038	13153.73	27.74663	0.007077	3.043853	11.56948
	0.159722	78.46756	11642.85	22.53525	0.007751	2.990660	11.40950
	0.104f01	61.09688	9065.410	14.78515	0.007935	2.907161	11.08559
12	0.089930	55.60615	8288.020	12.68722	0.008[illegible]0	2.875901	10.97493
16.5	0.055818	42.25595	6298.192	7.874730	0.008835	2.772356	10.60031
21.9	0.037530	33.17688	4944.968	5.294667	0.009677	2.686158	10.30317
29.9	0.020355	23.59896	3521.363	2.871677	0.010330	2.553779	9.814624
40.1	0.013251	18.67172	2789.281	1.869551	0.010745	2.461070	9.506434
65	0.005765	14.22931	2125.650	0.813454	0.008049	2.280365	8.866739
60.9	0.004102	10.47493	1564.800	0.578810	0.010568	2.206472	8.605157
90.1	0.003113	7.871288	1178.510	0.439190	0.014202	2.147515	8.396456
120.1	0.002187	5.635783	843.8044	0.308615	0.019467	2.070898	8.125336
120.1	0.001258	3.201923	479.7414	0.177539	0.034696	1.751328	7.701950
120	0.000756	1.911773	286.8822	0.106715	0.058501	1.841287	7.312404
240	0.000251	0.648904	97.48508	0.035480	0.160878	1.602661	6.467668

Tap DL= 122.2234

L 1/f	MDR 1/f	1/f	1/f/Slv	1/f/L
85.22311	27.15887	12.49145	1.050496	0.146573
80.25493	26.66324	12.33404	1.045376	0.153685
76.28413	26.24452	12.08763	1.031310	0.158455
69.14067	25.43321	11.89037	1.027735	0.171973
61.30751	24.57454	11.67880	1.023602	0.187438
50.47093	22.83606	11.22602	1.012668	0.222425
46.96585	22.24214	11.02931	1.004954	0.234836
37.00129	20.27440	10.63846	1.002841	0.287516
30.34018	18.63662	10.18650	0.988476	0.335743
22.36965	16.12180	9.838560	1.000400	0.439817
18.06967	14.36033	9.647657	1.014855	0.533914
11.91915	10.92694	11.14618	1.257078	0.935149
10.05431	9.522972	9.727174	1.130388	0.967463
8.778000	8.402795	8.391077	0.999360	0.955921
7.358314	6.947068	7.167100	0.882080	0.974013
5.587389	4.675249	5.368579	0.697041	0.960638
4.336783	2.584467	4.134432	0.565399	0.953340
2.503464	-1.94943	2.433753	0.376295	0.972154

P2P01308

Tw dyne/cm2	B*U*/D (1/s)	Log Tw	Log B U*/D
0.578810	57.47719	-0.23746	1.759495
0.439190	43.19069	-0.35734	1.635390
0.308615	30.92421	-0.51058	1.490298
0.177539	17.56933	-0.75070	1.244755
0.106715	10.49012	-0.97177	1.020780
0.035480	3.560618	-1.45001	0.551525

Regression Output:

Constant	2.00029
Std Err of Y Est	0.004106
R Squared	0.999932
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	1.002810
Std Err of Coef.	0.004107

K' = 0.009993
n' = 1.002810

Tw@ = 11.30084
Res/f@ = 708.4050

Regression Output:

Constant	-4.62435
Std Err of Y Est	0.056128
R Squared	0.991197
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	5.441076
Std Err of Coef.	0.229303

t = 21.12631 deg C
s.d.)t = 0.174995 deg C

Page 1 Cyanamid 836

P5P01311 3/7/89 14:55

1.0 PSID Tape 14 0.1 PSID Tape 14 co)NaCl
S = 10.05 B = 10.05 <C>(ppm)=5.158589 X coeff
Z = 4.95 Z = 4.95 [NaCl]= 0.001035 constant

MMD-40 θ)1 (1/s)	MMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.215	0.216	20	4.0381	-0.0445	4.0841	
0.192	0.193	20	3.3416	-0.0475	3.3916	
0.181	0.182	20	3.033333	-0.0525	3.086333	
0.158	0.159	20	2.520142	-0.0535	2.576142	
0.137	0.138	20	1.967142	-0.0585	2.026642	
0.114	0.115	20	1.451111	-0.0605	1.514111	
0.09	0.091	20	1.000125	-0.0655	1.066125	
				-0.0665		
0.094	0.095	20.15	5.84	0.0545	5.7935	1146
0.071	0.072	20.1	3.866714	0.0385	3.827714	1122
0.055	0.056	20.15	2.560714	0.0395	2.520214	1115
0.038	0.039	20.2	1.439666	0.0415	1.395666	1169
0.03	0.031	20.2	0.782454	0.0465	0.735954	1160
0.023	0.024	20.2	0.520076	0.0465	0.474076	1356
0.017	0.018	20.25	0.387142	0.0455	0.341642	1071
0.013	0.014	20.25	0.314266	0.0455	0.268266	1108
		20.25	0.2475	0.0465	0.2015	783
		20.25	0.178	0.0455	0.1325	1032
		20.3	0.121375	0.0455	0.074875	767
		20.25	0.083666	0.0465	0.037166	573
				0.0465		

Page 2 Cyanamid 836

density	viscosity					
1.000125	1.001657	ID(cm) = 1.45796				
-0.00025	-0.02281	K(V/psi)= 14.24	73.95			
0.003419	-4.14933	XS(cm2)= 1.669479				3.539999
						-0.79424
0						Solvent

t)sam. (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1/√f
	0.286804	129.3816	18811.48	40.46180	0.004841	3.116904	11.82808
	0.238174	115.6048	16808.41	33.60110	0.005035	3.076558	11.68526
	0.216736	109.0160	15850.42	30.57678	0.005153	3.056077	11.61275
	0.180908	95.23926	13847.34	25.52224	0.005635	3.016841	11.47386
	0.142320	82.66049	12018.45	20.07826	0.005885	2.964744	11.28944
	0.106328	68.88374	10015.37	15.00053	0.006331	2.901435	11.06532
	0.074868	54.50800	7925.210	10.56226	0.007120	2.825260	10.79566
12	0.078343	57.20345	8345.309	11.05253	0.006765	2.836590	10.83577
15.5	0.051760	43.35908	6318.446	7.302309	0.007779	2.746096	10.51542
20	0.034079	33.39364	4871.730	4.807930	0.008635	2.656038	10.19591
29.9	0.018873	23.41866	3420.365	2.662578	0.009724	2.538003	9.743777
37.4	0.009952	18.57827	2713.409	1.404014	0.008147	2.589037	9.951439
55.6	0.006410	14.60843	2133.604	0.904418	0.008488	2.573536	9.913366
59.9	0.004619	10.70980	1565.962	0.651768	0.011582	2.222871	8.663280
80.1	0.003627	8.285641	1211.507	0.511784	0.014933	2.170388	8.477420
75.1	0.002724	6.245119	913.1469	0.384410	0.019742	2.108242	8.257424
150.2	0.001791	4.115557	601.7673	0.252776	0.029892	2.017212	7.935179
199.9	0.001012	2.298272	336.4273	0.142842	0.054168	1.893768	7.490177
299.8	0.000502	1.144832	167.3947	0.070904	0.108362	1.741181	6.958029

Tap DL= 122.2234

L 1/f	MDR 1/f	1/f	1/f/Blv	1/f/L
81.80584	26.82118	14.37205	1.215078	0.175684
74.54842	26.05461	14.09185	1.295951	0.189029
71.11440	25.66547	13.93038	1.199576	0.195887
64.97123	24.91998	13.32065	1.160956	0.205023
57.62683	23.93015	13.03478	1.154599	0.226192
49.80982	22.72726	12.56701	1.135711	0.252299
41.79652	21.27994	11.85087	1.097744	0.283537
42.90129	21.49521	12.15771	1.121998	0.283388
34.03188	19.77584	11.33739	1.078167	0.325489
28.29557	18.06093	10.76081	1.055405	0.380300
21.08061	15.63206	10.14072	1.040781	0.481044
15.30798	12.99172	11.07840	1.197479	0.723701
12.26617	11.17720	10.85367	1.217685	0.883405
10.44170	9.834932	9.373251	1.081951	0.897674
9.252698	8.837379	8.183673	0.965325	0.884441
8.019043	7.656608	7.117010	0.861893	0.887514
6.502689	5.927046	5.783831	0.729894	0.889452
4.893798	3.581555	4.296603	0.573019	0.877968
3.443989	0.682455	3.037602	0.436589	0.892059

PSP01311

Tw dyne/cm2	B<U>/D (1/s)	Log Tw	Log B<U>/D
0.904418	80.15824	-0.04363	1.903948
0.511784	45.46430	-0.29091	1.657670
0.384410	34.26771	-0.41520	1.534885
0.252776	22.58255	-0.59726	1.353773
0.070904	6.281831	-1.14932	0.798086
0.142842	12.61089	-0.84514	1.100745
0.651768	58.76597	-0.18590	1.769125

Regression Output:

Constant	-1.94852
Std Err of Y Est	0.001823
R Squared	0.999985
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.999710
Std Err of Coef.	0.002194

K' = 0.011258
n' = 0.999710

Tw8 = 3.406163
Res/f8 = 379.7645

Regression Output:

Constant	-11.2784
Std Err of Y Est	0.108984
R Squared	0.990775
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	8.220211
Std Err of Coef.	0.299791

t = 20.13421 deg C
s.d.)t = 0.111275 deg C

P1P11314 3/9/89 14:02

1.0 PSID Taps 14		0.1 PSID Taps 14						co)NaCl	
S =	10.05	S =	10.05	<C>(ppm)=	10.31423	X coeff			
Z =	4.85	Z =	4.9	[NaCl]=	0.001037	constant			
MMD-40 Q)1 (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)			
0.229	0.23	21.1	3.47875	-0.0015	3.48725				
0.199	0.2	21.1	2.838333	-0.0155	2.851833				
0.188	0.189	21	2.662375	-0.0115	2.674875				
0.167	0.168	21	2.2616	-0.0135	2.2741				
0.139	0.14	21	1.693222	-0.0155	1.709222				
0.104	0.105	21	1.099625	-0.0165	1.116125				
				-0.0165					
0.094	0.095	21.15	5.117833	0.04	5.085083	1084			
0.071	0.071	21.1	3.433125	0.0255	3.406125	1365			
0.054	0.055	21.2	2.290265	0.0285	2.260035	1218			
0.039	0.04	21.3	1.42325	0.032	1.3905	1102			
0.029	0.029	21.25	0.6594	0.0335	0.6254	1180			
0.022	0.023	21.25	0.501333	0.0345	0.466333	1085			
0.017	0.018	21.25	0.3904	0.0355	0.3619	1086			
0.011	0.012	21.3	0.266875	0.0375	0.248375	1157			
		21.35	0.202923	0.0395	0.162423	990			
		21.35	0.125875	0.0415	0.084375	485			
		21.45	0.088	0.0415	0.0465	393			
				0.0415					

density	viscosity								
1.000125	1.001657		ID(cm) =	1.45796					
-0.00025	-0.02281		K(V/psi)=	14.24	73.95				
0.003419	-4.14933		XS(cm2)=	1.669479					3.539999
									-0.79424
									Solvent
0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1/f		
	0.244891	137.7674	20534.05	34.54872	0.003646	3.093434	11.74500		
	0.200269	119.7978	17855.69	28.25355	0.003944	3.049755	11.59037		
	0.187842	113.2089	16835.61	26.50039	0.004142	3.034859	11.53764		
	0.159838	100.6301	14964.98	22.54967	0.004461	2.999803	11.41355		
	0.120029	83.85847	12470.82	16.93352	0.004824	2.937607	11.19337		
	0.078379	62.89385	9353.117	11.05762	0.005600	2.845064	10.86577		
11.3	0.068763	56.90396	8491.029	9.701051	0.006002	2.810120	10.77039		
19	0.046059	43.03263	6413.955	6.498024	0.007030	2.730609	10.46060		
22	0.030561	33.16221	4953.945	4.311575	0.007854	2.642522	10.14877		
27.7	0.018803	23.82981	3567.863	2.652721	0.009359	2.530035	9.770889		
39.4	0.008457	17.93926	2682.886	1.193104	0.007427	2.564035	9.162932		
47.1	0.006306	13.79836	2063.599	0.889645	0.009361	2.500505	8.957326		
59.8	0.004893	10.87796	1626.841	0.690413	0.011689	2.245251	8.742435		
93.9	0.003358	7.390515	1105.030	0.473836	0.017428	2.164003	8.454818		
123.3	0.002196	4.809401	720.8890	0.309862	0.026840	2.072266	8.130067		
120	0.001140	2.420914	362.8747	0.160966	0.055020	1.930049	7.626619		
180.3	0.000628	1.305616	196.1430	0.088710	0.104270	1.801653	7.172100		

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
77.50234	26.37524	16.55921	1.409894	0.213660
70.08666	25.54535	15.92287	1.373801	0.227189
67.72357	25.26233	15.53706	1.346640	0.229418
62.47176	24.59627	14.97175	1.311752	0.239656
54.13615	23.41454	14.39752	1.286253	0.265950
47.74662	21.65622	13.36262	1.229790	0.305455
41.11505	21.14429	12.90742	1.198416	0.313934
33.61162	19.48158	11.92659	1.140143	0.354835
27.44113	17.80791	11.28311	1.111771	0.411175
21.57322	15.82266	10.33649	1.057020	0.479135
14.45160	12.51668	11.60289	1.266286	0.802879
12.47915	11.30579	10.33522	1.156411	0.828199
10.99338	10.25977	9.248980	1.057940	0.841322
9.117665	8.716067	7.574790	0.895914	0.830781
7.381524	6.973055	6.103828	0.750772	0.826906
5.520214	4.270932	4.262924	0.556953	0.801269
3.958529	1.831423	3.096841	0.431790	0.782321

P1P11314

Tw dyne/cm2	B<U>/D (1/s)	Log Tw	Log B<U>/D
1.193104	98.43489	0.076678	1.993149
0.889645	75.71328	-0.05078	1.879172
0.690413	59.68867	-0.16089	1.775891
0.473836	40.49776	-0.32437	1.607431
0.309862	26.38975	-0.50883	1.421435
0.160966	13.28384	-0.79326	1.123323
0.080710	7.164074	-1.05202	0.855160

Regression Output:

Constant	1.08031
Std Err of Y Est	0.002504
R Squared	0.999966
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.967414
Std Err of Coef.	0.003218

K' = 0.013172
n' = 0.967414

Tw# = 3.139418
Res/f# = 373.8035

Regression Output:

Constant	-22.0567
Std Err of Y Est	0.144099
R Squared	0.997080
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	12.42230
Std Err of Coef.	0.423333

t = 21.18529 deg C
s.d.)t = 0.138016 deg C

Cyanamid 836

P2P11327 4/13/89 15:16

1.0 PSID Taps 14 0.1 PSID Taps 14 co)NaCl

S = 10.05 S = 10.05 <C>(ppm)=20.58907 X coeff

Z = 4.62 Z = 4.72 [NaCl]= 0.001037 constant

MMD-40 G)1 (1/s)	MMD-40 G)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.264	0.265	21.4	2.708166	-0.0065	2.713666	
0.222	0.223	21.4	2.115	-0.0045	2.119	
0.204	0.206	21.4	1.9232	-0.0035	1.9267	
0.171	0.172	21.4	1.4985	-0.0035	1.502	
0.146	0.148	21.4	1.1914	-0.0035	1.1949	
0.129	0.13	21.4	1.0356	-0.0035	1.0391	
0.108	0.109	21.4	0.7562	-0.0045	0.7607	
				-0.0045		
0.096	0.098	21.4	4.14025	0.0825	4.05775	
0.072	0.074	21.4	2.370833	0.0735	2.295833	1243
0.039	0.04	21.4	1.189090	0.0745	1.111590	1188
0.057	0.058	21.4	1.716428	0.0785	1.637928	1218
0.029	0.03	21.4	0.9605	0.0785	0.8805	1075
0.021	0.022	21.4	0.71	0.0815	0.6285	1083
0.015	0.016	21.4	0.568066	0.0845	0.483066	949
		21.4	0.375153	0.0855	0.289653	845
		21.4	0.259375	0.0855	0.173875	468
		21.4	0.166666	0.0855	0.081166	268
				0.0835		

Cyanamid 836

density	viscosity		
1.000125	1.001657	ID(cm) =	1.45796
-0.00025	-0.02281	K(V/psi)=	13.975
0.003419	-4.14933	XS(cm2)=	1.6694?9

84.66

0.539999

0.79424

Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Iw dyne/cm2	f	Log(Re*f)	1/√f
	0.194180	158.7321	23819.46	27.39451	0.002178	1.946006	11.57710
	0.151627	133.5745	20044.30	21.39134	0.002402	2.772293	11.58696
	0.137867	123.3917	18516.26	19.45007	0.002569	2.971635	11.51303
	0.107477	102.7266	15415.23	15.16271	0.002878	2.941562	11.12241
	0.085502	88.65038	13302.94	12.06253	0.003075	2.867893	10.94658
	0.074354	77.86857	11685.02	10.48973	0.003466	2.834556	10.83919
	0.054432	65.28980	9797.441	7.679280	0.003609	2.749834	10.59946
	0.047929	58.70092	8808.708	6.761856	0.003931	2.712407	10.50165
16.7	0.027118	44.58343	6690.326	5.025780	0.003856	2.610574	10.06305
29.9	0.013130	23.79929	3571.741	1.852361	0.006552	2.461037	9.506317
21	0.019347	34.74136	5213.317	2.729452	0.004571	2.545013	9.804296
35.2	0.010400	18.29299	2745.060	1.467269	0.008708	2.414049	9.527165
50	0.007423	12.97410	1946.904	1.047335	0.012466	2.292317	9.067995
60	0.005705	9.474010	1421.677	0.804984	0.017969	2.280068	8.865687
90.1	0.003421	5.617600	842.9815	0.482680	0.030641	2.169004	8.472521
89.8	0.002053	3.121680	468.4418	0.289746	0.059571	2.050187	8.080214
119.9	0.000958	1.338857	200.9101	0.135256	0.151183	1.802755	7.424593

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
69.48423	25.47411	21.42524	1.850656	0.308346
61.40072	24.45357	20.40316	1.791800	0.332295
58.54840	24.06106	19.78598	1.747063	0.337600
51.69433	23.03369	18.63748	1.675468	0.360532
46.10773	22.08998	18.03242	1.647309	0.391093
42.99685	21.51357	16.98528	1.567024	0.395035
36.78872	20.22685	16.64477	1.570341	0.452442
34.52132	19.70194	15.94794	1.518612	0.461973
25.96659	17.35216	16.10296	1.600078	0.620141
18.06829	14.55970	12.35361	1.299516	0.683717
21.93270	15.95903	14.65600	1.515254	0.677344
16.08086	13.39815	10.66897	1.143859	0.663457
13.58618	12.00713	8.956270	0.987679	0.659219
11.91100	10.92129	7.459897	0.841434	0.626303
9.223259	8.811083	5.712335	0.674219	0.619340
7.146005	6.705483	4.097060	0.507048	0.573335
4.882403	3.562318	2.571864	0.345162	0.526762

P2P11327

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
1.852361	130.5895	0.267725	2.115958
2.729452	190.6300	0.436075	2.280.91
1.467269	100.3758	0.166510	2.001629
1.047335	71.19044	0.020085	1.852421
0.804984	51.98502	-0.09421	1.715878
0.482680	30.82444	-0.31634	1.488895
0.289746	17.12903	-0.53798	1.233732
0.135256	7.346473	-0.86884	0.866078

Regression Output:

Constant	-1.66085
Std Err of Y Est	0.007195
R Squared	0.999719
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.910001
Std Err of Coef.	0.007622

K' = 0.021834
n' = 0.910001

Tw8 = 1.645860
Res/f8 = 272.5027

Regression Output:

Constant	-38.8728
Std Err of Y Est	0.246519
R Squared	0.981003
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	19.82792
Std Err of Coef.	1.379600

t = 21.4 deg C
s.d.)t = 0.000000 deg C

P2P11229 4/15/89 13:08

1.0 PSID	Taps 14	0.1 PSID	Taps 14		co)NaCl
S =	10.05	S =	10.05	<C>(ppm)=20.55048	X coeff
Z =	4.62	Z =	4.84	[NaCl]= 0.010334	constant

NMD-40 θ)1 (1/s)	NMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>α (volts)	<V>)corr (volts)	Batch Vol (ml)
0.266	0.267	21.2	3.742375	-0.0075	3.748375	
0.242	0.243	21.2	3.233	-0.0045	3.2365	
0.207	0.208	21.2	2.711333	-0.0025	2.714333	
0.213	0.214	21.2	2.804	-0.0035	2.8075	
0.235	0.236	21.2	3.1846	-0.0035	3.1881	
0.174	0.175	21.2	2.174125	-0.0035	2.178125	
0.148	0.149	21.2	1.755875	-0.0045	1.760875	
0.131	0.132	21.2	1.491888	-0.0055	1.498388	
0.109	0.11	21.2	1.149	-0.0075	1.1565	
				-0.0075		
0.098	0.098	21.2	7.430833	1.188	6.242833	1160
0.073	0.074	21.2	4.1154	-0.0045	4.1324	1118
0.057	0.058	21.2	2.894	-0.0275	2.9125	1224
0.039	0.04	21.2	1.6698	-0.0295	1.6993	1203
0.03	0.031	21.2	0.7883	-0.0295	0.8173	1219
0.022	0.023	21.2	0.546	-0.0285	0.5745	1165
0.015	0.016	21.2	0.326666	-0.0285	0.353166	959
		21.2	0.2372	-0.0265	0.2637	932
		21.2	0.159318	-0.0265	0.185818	759
		21.2	0.071833	-0.0275	0.099333	530
		21.2	0.015	-0.0295	0.0445	349
		21.2	0.111545	-0.0315	0.143045	579
				-0.0335		

density	viscosity				
1.000493	1.002495	ID(cm) =	1.49796		
-0.00025	-0.02281	K(V/psi)=	13.975	84.66	
0.003619	-4.14933	XS(cm2)=	1.669479		
					5.979999
					-0.79424
					Solvent

θ)samp (sec)	DP (psid)	U (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1/√f
	0.268220	159.9300	23880.00	37.83991	0.002967	3.113895	11.81743
	0.231592	145.5543	21733.49	32.67252	0.003088	3.082012	11.70456
	0.194227	124.5897	18603.15	27.40124	0.003535	3.041805	11.56971
	0.200894	128.1836	19139.78	28.34176	0.003454	3.051174	11.59525
	0.228128	141.3614	21107.42	32.18392	0.003225	3.078740	11.69290
	0.155858	104.8230	15651.69	21.98821	0.004007	2.996015	11.40014
	0.126001	89.24937	13326.29	17.77606	0.004469	2.949038	11.27667
	0.107219	79.06655	11805.84	15.12626	0.004845	2.914786	11.11258
	0.082754	65.88879	9838.205	11.67488	0.005305	2.868547	10.91350
11.7	0.073740	58.70092	8764.946	10.40309	0.006046	2.813501	10.82484
15	0.048811	44.64465	6666.129	6.886253	0.006919	2.741912	10.50769
21.1	0.034402	34.74704	5188.265	4.853405	0.008050	2.667944	10.27876
29.8	0.020072	24.18066	3610.543	2.831722	0.009699	2.569946	9.804594
39.9	0.009653	18.29994	2732.461	1.361953	0.008145	2.592001	9.261952
49.8	0.006785	14.01249	2092.279	0.957349	0.009765	2.515456	8.990960
60.3	0.004171	9.526210	1422.409	0.588518	0.012988	2.209800	8.616941
80.2	0.003114	6.960820	1039.357	0.439471	0.018163	2.146366	8.292381
89.8	0.002194	5.062725	755.9423	0.309448	0.024195	2.070355	8.127507
120	0.001173	2.645535	395.0188	0.165529	0.047367	1.924358	7.641875
180.1	0.000525	1.160728	173.3145	0.074155	0.110233	1.799791	7.024614
90	0.001689	3.853496	575.3859	0.238471	0.032149	2.017548	7.932206

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
81.24110	26.76402	18.37124	1.554588	0.226132
75.49046	26.15822	17.99357	1.537313	0.238355
69.13307	25.43231	16.81824	1.453693	0.243273
70.30952	25.57154	17.01385	1.467311	0.241985
74.92388	26.09606	17.60738	1.505807	0.235003
61.92923	24.52429	15.79594	1.385592	0.255064
55.68248	23.64693	14.95791	1.331168	0.268628
51.36491	22.98094	14.36516	1.292692	0.279668
45.17602	21.91239	13.62601	1.240946	0.301954
42.59728	21.43653	12.86018	1.188025	0.301901
34.65710	19.73433	12.02157	1.144073	0.346872
29.09538	18.29093	11.14495	1.038505	0.383048
22.72419	16.06797	10.15375	1.033503	0.454878
15.41281	13.04803	11.08031	1.196328	0.718903
12.92218	11.59366	10.11960	1.125531	0.783118
10.13166	9.586217	8.774524	1.018287	0.866049
8.754798	8.380956	7.419909	0.884124	0.847524
7.349117	6.936748	6.428052	0.791408	0.874778
5.373269	4.352812	4.594722	0.601255	0.855107
3.596425	1.039830	3.011922	0.428767	0.837476
6.448045	5.857413	5.577135	0.703987	0.864934

P2P11229

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
0.588518	52.27145	-0.23023	1.718264
0.439431	38.19485	-0.35710	1.582004
0.309648	27.77977	-0.50913	1.443728
0.165529	14.51636	-0.78112	1.161857
0.074155	6.369054	-1.12985	0.804074
0.238371	21.14459	-0.62274	1.325199

Regression Output:

Constant	-1.91025
Std Err of Y Est	0.001014
R Squared	0.999990
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	0.971126
Std Err of Coef.	0.002106

K' = 0.012295
n' = 0.971126

Tw8 = 5.756257
Res/f8 = 506.9800

Regression Output:

Constant	-42.0941
Std Err of Y Est	0.186487
R Squared	0.991604
No. of Observations	10
Degrees of Freedom	8
X Coefficient(s)	19.39527
Std Err of Coef.	0.630976

t = 21.2 deg C
s.d.)t = ERR deg C

Page 1 Cyanamid 836

P1P01106 3/2/89 16:54

1.0 PSID Taps 14	0.1 PSID Taps 14			co)NaCl	
S = 10.05	S = 10.05	<C>(ppm)=	1.031289	X coeff	
Z = 4.9	Z = 4.92	[NaCl]=	0.105538	constant	

MMD-40 θ)l (1/s)	MMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.178	0.18	21.1	4.040888	-0.027	4.097388	
0.16	0.161	21	3.447833	-0.0365	3.484333	
0.156	0.158	21	3.221111	-0.0365	3.258111	
0.14	0.142	21	2.6749	-0.0375	2.7129	
0.124	0.125	21	2.153555	-0.0385	2.192055	
0.096	0.098	21	1.398	-0.0385	1.437	
0.113	0.114	21	1.841444	-0.0395	1.880944	
				-0.0395		
0.087	0.089	21.15	6.3085	0.0295	6.166	1156
0.067	0.068	21.15	4.073571	0.1425	3.929571	1095
0.053	0.054	21.2	2.7808	0.1455	2.6358	1123
0.037	0.038	21.2	1.556875	0.1445	1.414875	1102
0.03	0.031	21.2	1.091	0.1395	0.9525	1251
0.022	0.023	21.2	0.566076	0.1375	0.428576	1184
0.018	0.018	21.3	0.450666	0.1355	0.315166	1119
0.012	0.013	21.3	0.349	0.1305	0.2185	1158
		21.35	0.241833	0.1275	0.115333	1041
		21.35	0.275428	0.1255	0.154428	1038
		21.45	0.1936	0.1165	0.0771	554
		21.5	0.170277	0.1145	0.047277	234
		21.5	0.155428	0.1315	0.016428	288
				0.1465		

Page 2 Cyanamid 836

density	viscosity					
1.00417	1.010869	ID(cm) =	1.45796			
-0.00025	-0.02281	K(V/psi)=	14.29	77.56		
0.003419	-4.14933	XS(cm2)=	1.669479			7.539999
						-0.79424
						Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Iw dyne/cm2	f	Log(Re/f)	1/√f
	0.286731	107.8180	15988.08	40.45142	0.006941	3.124586	11.85528
	0.243830	96.43724	14268.22	34.39904	0.007380	3.088407	11.72720
	0.227999	94.64027	14002.36	32.16566	0.007165	3.073850	11.67560
	0.189846	85.05644	12584.40	26.78307	0.007386	3.034064	11.53483
	0.153397	74.87363	11077.81	21.64104	0.007702	2.987773	11.37096
	0.100559	58.70092	8685.009	14.18676	0.008215	2.896076	11.04635
	0.131626	68.28475	10102.96	18.56960	0.007946	2.954535	11.25730
13.1	0.083822	52.85735	7846.941	11.82553	0.008441	2.858022	10.91164
16.2	0.053419	40.48722	6010.532	7.536373	0.009174	2.760197	10.56572
20.8	0.035831	32.33965	4806.402	5.055098	0.009644	2.677969	10.26009
29	0.019234	22.76158	3382.885	2.713534	0.010451	2.538072	9.781053
40	0.012948	18.43388	2739.692	1.826762	0.010727	2.452945	9.477673
50.2	0.005826	14.12755	2099.673	0.821951	0.008217	2.279527	8.863773
60.1	0.004284	11.15255	1661.265	0.604445	0.009697	2.213768	8.630986
89.8	0.002970	7.724157	1150.577	0.419052	0.014015	2.134024	8.349399
150.1	0.001567	4.154214	619.5030	0.221193	0.025577	1.995968	7.859974
113.1	0.002099	5.497353	819.8004	0.296172	0.019556	2.059754	8.084362
120.6	0.001048	2.751575	411.2591	0.14786/	0.038974	1.909503	7.553888
89.8	0.000642	1.560840	233.5514	0.090672	0.074272	1.803797	7.179688
250.1	0.000223	0.689759	103.2100	0.031507	0.132158	1.574268	6.367157

Tap DL= 122.2234

L 1/f	MDR 1/f	1/f	1/f/Slv	1/f/L
83.26575	26.96714	12.00079	1.012274	0.144126
74.61035	26.27974	11.64025	0.992585	0.151941
74.08163	26.00278	11.81328	1.011792	0.159463
67.59966	25.24722	11.63504	1.000697	0.172116
60.76498	24.36769	11.39612	1.002036	0.187511
49.19897	22.62544	11.03301	0.998792	0.224252
54.28797	23.73617	11.21794	0.996858	0.199295
45.07154	21.90242	10.88122	0.997212	0.241421
35.98100	20.04367	10.44046	0.988181	0.290165
29.50186	18.40542	10.18241	0.992428	0.345144
21.61485	15.83857	9.781715	0.999985	0.452545
17.73477	14.20596	9.655083	1.018718	0.544415
11.89618	10.91102	11.03123	1.244530	0.927291
10.22465	9.661603	10.15477	1.176549	0.993166
8.513422	8.150259	8.446787	1.011664	0.992172
6.192250	5.523401	6.252005	0.795524	1.009779
7.165309	6.727742	7.150777	0.884519	0.997971
5.074385	3.880565	5.065381	0.670566	0.998225
3.978115	1.872150	3.669316	0.511049	0.922375
2.345032	-2.48807	2.750742	0.432023	1.173016

P1P01106

Tw dyne/cm2	BKU>/D (1/s)	Log Tw	Log BKU>/D
0.604445	61.19541	-0.21864	1.786718
0.419052	42.38337	-0.37773	1.627195
0.221193	22.79467	-0.65522	1.357833
0.296172	30.16463	-0.52845	1.479498
0.147867	15.09821	-0.83012	1.178925

Regression Output:

Constant	-2.02285
Std Err of Y Est	0.002660
R Squared	0.999905
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	1.009946
Std Err of Coef.	0.005657

K' = 0.009487
n' = 1.009946

Tw@ = 23.50472
Res/f@ = 1013.238

Regression Output:

Constant	-0.40152
Std Err of Y Est	0.044246
R Squared	0.994949
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	3.937832
Std Err of Coef.	0.106041

t = 21.1975 deg C
s.d.)t = 0.167686 deg C

P2P01109 3/4/89 15:50

1.0 PSID Tape 14	0.1 PSID Tape 14				co)NaCl
S = 10.05	S = 10.05	<C>(ppa)=	2.065943		X coeff
Z = 4.86	Z = 4.92	[NaCl]=	0.104712		constant

NMD-40 θ)1 (1/s)	NMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.185	0.186	21	4.3316	-0.0015	4.3241	
0.171	0.172	20.9	3.8025	0.0165	3.786	
0.161	0.162	20.9	3.484714	0.0165	3.464714	
0.144	0.145	20.9	2.875625	0.0235	2.852125	
0.127	0.128	20.9	2.303	0.0235	2.2795	
0.115	0.116	20.9	1.96575	0.0235	1.94225	
0.098	0.099	20.9	1.5051	0.0235	1.4811	
				0.0245		
0.088	0.09	21.1	6.4435	0.0495	6.394	1192
0.068	0.069	21.1	4.138428	0.0365	4.100428	1257
0.054	0.055	21.1	2.72325	0.0395	2.68375	1204
0.037	0.038	21.15	1.454666	0.0395	1.414666	1146
0.029	0.03	21.2	0.969090	0.0405	0.927590	1209
0.023	0.024	21.2	0.4917	0.0425	0.4382	1102
0.017	0.018	21.2	0.361	0.0445	0.3165	1077
0.012	0.013	21.3	0.2754	0.0445	0.2309	1094
		21.35	0.212333	0.0445	0.167333	1186
		21.4	0.16115	0.0455	0.11665	832
		21.4	0.10025	0.0435	0.05625	1100
				0.0445		

density	viscosity					
1.00417	1.010869	ID(cm) =	1.45796			
-0.00025	-0.02281	K(V/psi)=	14.29	73.56		
0.003419	-4.14933	XS(cm2)=	1.669479			3.539999
						0.79424
						Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1/√f
	0.302596	111.4119	16483.79	62.68963	0.006869	3.135295	11.89319
	0.264940	103.0261	15208.72	57.37724	0.007026	3.105452	11.78754
	0.242457	97.03622	14324.49	54.20535	0.007248	3.086196	11.71937
	0.199588	86.85341	12821.31	48.15757	0.007447	3.049946	11.58981
	0.159517	76.67060	11318.12	42.50434	0.007638	2.995282	11.39754
	0.135916	69.48273	10257.04	39.17484	0.007924	2.960514	11.27446
	0.103645	59.29991	8753.860	34.62214	0.008296	2.901654	11.06610
13.3	0.086922	53.68383	7960.651	32.26280	0.008490	2.865414	10.93781
18.1	0.055742	41.59830	6168.515	27.864053	0.009068	2.768942	10.59670
22.1	0.036483	32.68691	4847.066	25.147060	0.009612	2.676892	10.27046
30.2	0.019231	22.72985	3374.360	22.713134	0.010478	2.528547	9.779996
39.8	0.012609	18.19542	2704.250	21.778990	0.010722	2.443191	9.457503
45.7	0.005957	14.44389	2146.689	20.840406	0.008053	2.284349	8.880842
60	0.004302	10.75185	1597.968	20.607003	0.010477	2.213700	8.630744
80.7	0.003138	8.045900	1198.503	20.442834	0.013650	2.146210	8.391830
119.9	0.002274	5.924946	883.5658	20.320922	0.018242	2.076782	8.146055
120	0.001585	4.152990	620.0195	20.225718	0.025084	1.998926	7.870444
329.8	0.000764	1.997841	298.2670	20.107879	0.053936	1.840544	7.309775

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Slv	1//f/L
85.34449	27.17041	12.07151	1.014995	0.141444
79.67695	26.60340	11.92999	1.012084	0.149729
76.22126	26.23772	11.74581	1.002256	0.154101
69.15549	25.43498	11.58739	1.001519	0.167555
61.82473	24.51036	11.44174	1.003877	0.185067
57.04830	23.84978	11.23330	0.996348	0.196839
49.83501	22.73143	10.97855	0.992088	0.220297
45.84525	22.04287	10.85261	0.992210	0.236722
36.71324	20.20991	10.50117	0.991022	0.286032
29.70155	18.46108	10.19952	0.993092	0.343400
21.58876	15.82860	9.763858	0.998861	0.452497
17.50134	14.09665	9.657294	1.021146	0.551802
12.02899	11.00265	11.15371	1.255930	0.927235
10.22304	9.660302	9.769403	1.131930	0.955625
8.751660	8.377998	8.559114	1.019934	0.977998
7.458685	7.058863	7.403832	0.908985	0.992645
6.234563	5.579594	6.215546	0.789732	0.996949
4.329372	2.570353	4.305864	0.589035	0.994570

P2P01109

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
0.840406	79.25536	-0.07551	1.899023
0.607003	58.99670	-0.21680	1.770827
0.442934	44.14881	-0.35375	1.644919
0.320922	32.51086	-0.49360	1.512028
0.223718	22.78795	-0.65029	1.357705
0.107879	10.96239	-0.96706	1.039905

Regression Output:

Constant	-2.00936
Std Err of Y Est	0.001551
R Squared	0.999979
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	1.001919
Std Err of Coef.	0.004556

K' = 0.009786
n' = 1.001919

Tw@ = 17.26828
Res/f@ = 868.4781

Regression Output:

Constant	-0.78062
Std Err of Y Est	0.058708
R Squared	0.992964
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	4.078619
Std Err of Coef.	0.129764

t = 21.10535 deg C
s.d.)t = 0.177081 deg C

PSP01112 3/7/89 16:30

1.0 PSID Tape 14 0.1 PSID Tape 14 co)NaCl
S = 10.05 S = 10.05 <C>(ppm)=5.158589 X coeff
Z = 4.95 Z = 4.95 [NaCl]= 0.105623 constant

NMB-40 0)1 (1/s)	NMB-40 0)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.205	0.206	19.9	4.6154	-0.0755	4.6909	
0.188	0.189	19.9	4.042833	-0.0755	4.119333	
0.174	0.175	19.9	3.625833	-0.0775	3.706333	
0.152	0.153	19.9	2.8355	-0.0835	2.919	
0.132	0.133	19.9	2.3189	-0.0835	2.4025	
0.111	0.112	19.9	1.712428	-0.087	1.799178	
0.089	0.089	19.9	1.133166	-0.0845	1.217166	
				-0.0835		
0.09	0.091	20.05	6.707	0.0555	6.6575	1152
0.068	0.069	20.05	4.155666	0.0435	4.112166	1121
0.054	0.055	20.05	2.736833	0.0435	2.693833	1168
0.037	0.038	20.1	1.466	0.0425	1.4025	1132
0.029	0.03	20.15	0.917555	0.0445	0.872055	1196
0.022	0.023	20.15	0.466181	0.0465	0.419631	1150
0.013	0.014	20.2	0.296615	0.0465	0.250115	1133
		20.2	0.22	0.0465	0.17225	1196
		20.15	0.170181	0.049	0.121181	838
		20.2	0.112	0.0465	0.0655	567
		20.25	0.078555	0.043	0.035555	796
				0.044		

density viscosity
1.00417 1.010869 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.24 73.95
0.003419 -4.14933 XB(cm2)= 1.669479 ?.539999
-0.79424
Solvent

0 t)samp (sec)	DP (psid)	<μ> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.329417	123.3917	17808.77	46.47347	0.006088	3.142899	11.92010
	0.289279	112.6099	16252.66	40.81087	0.006419	3.114685	11.82022
	0.260276	104.8230	15128.81	36.71921	0.006666	3.091743	11.73901
	0.204985	91.04633	13140.45	28.91898	0.006959	3.039888	11.55545
	0.168700	79.66554	11497.89	23.79995	0.007480	2.997585	11.40569
	0.126276	67.08677	9682.439	17.81483	0.007895	2.934687	11.18304
	0.085475	53.31002	7694.081	12.05865	0.008464	2.849946	10.88305
12.6	0.090027	54.76471	7930.824	12.70082	0.008447	2.862690	10.92817
16.1	0.055607	41.70400	6039.710	7.844972	0.008997	2.758070	10.55781
21.3	0.036427	32.84597	4756.632	5.139152	0.009502	2.666220	10.23266
29.8	0.018965	22.75354	3298.803	2.675614	0.010709	2.524979	9.732673
40	0.011792	17.90977	2599.485	1.663661	0.010946	2.422292	9.369161
50	0.005675	13.77674	1999.604	0.800646	0.008415	2.263480	8.806966
79.9	0.003382	8.493800	1234.210	0.477156	0.013194	2.151583	8.410850
120.3	0.002329	5.955036	865.3097	0.328609	0.018485	2.070592	8.124144
120	0.001638	4.182940	607.1261	0.231184	0.026358	1.993739	7.852082
150	0.000885	2.264178	329.0014	0.124957	0.048626	1.860633	7.380889
389.9	0.000480	1.219793	177.4447	0.067830	0.090947	1.728459	6.912992

Tap DL= 122.2234

L 1/f	MDR 1/f	1/f	1/f/Slv	1/f/L
86.85197	27.31509	12.81546	1.075112	0.147555
81.38887	26.77901	12.48071	1.055877	0.153346
77.20116	26.34313	12.24788	1.043348	0.158648
68.51231	25.35788	11.90738	1.057372	0.174965
62.15344	24.55411	11.56200	1.013704	0.186023
55.77346	23.35907	11.25373	1.006321	0.209280
44.24117	21.74898	10.86951	0.998755	0.245687
45.55865	21.99112	10.87996	0.995588	0.238812
35.80557	20.00334	10.54254	0.998553	0.294438
28.98015	18.25819	10.25838	1.002513	0.353979
20.93434	15.57460	9.848639	1.011917	0.470454
16.52618	13.62355	9.830934	1.049286	0.594870
11.46464	10.60613	10.90092	1.237761	0.950830
8.860603	8.480082	8.705744	1.035061	0.982522
7.353137	6.941261	7.354936	0.903318	1.000244
6.160546	5.481044	6.159418	0.784431	0.999817
4.534336	2.952040	4.534862	0.614605	1.000116
3.344563	0.440728	3.315918	0.479644	0.991435

P5P01112

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
1.663661	98.27305	0.221064	1.992434
0.900646	75.59465	-0.09655	1.878491
0.477156	46.60649	-0.32133	1.668446
0.328609	32.67599	-0.48332	1.514228
0.231184	22.95229	-0.63604	1.360826
0.124957	12.42381	-0.90323	1.094255
0.067030	6.693149	-1.16857	0.825630

Regression Output:

Constant	-1.99916
Std Err of Y Est	0.003633
R Squared	0.999913
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	1.003071
Std Err of Coef.	0.005401

K' = 0.010019
n' = 1.003071

Tw# = 20.05719
Res/f# = 912.9188

Regression Output:

Constant	-12.6390
Std Err of Y Est	0.079570
R Squared	0.979241
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	8.077606
Std Err of Coef.	0.679013

t = 20.04722 deg C
s.d.)t = 0.128530 deg C

P1P11115 3/9/89 16:08

1.0 PSID Taps 14 0.1 PSID Taps 14 co)NaCl
S = 10.05 S = 10.05 <C>(ppm)=10.31423 X coeff
Z = 4.82 Z = 4.9 [NaCl]= 0.105428 constant

NMD-40 θ)1 (1/s)	NMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.216	0.217	20.85	4.64375	0.0045	4.616	
0.198	0.199	20.7	4.188285	0.051	4.138535	
0.18	0.181	20.7	3.578285	0.0485	3.529285	
0.162	0.163	20.7	3.130571	0.0695	3.081571	
0.135	0.136	20.7	2.416222	0.0485	2.368222	
0.112	0.113	20.7	1.839428	0.0475	1.792428	
				0.0465		
0.092	0.093	20.85	6.821666	0.1935	6.707166	1319
0.069	0.071	20.9	4.297833	0.0335	4.253833	1304
0.054	0.055	20.9	2.80025	0.0525	2.74325	1374
0.037	0.038	20.9	1.492333	0.0615	1.430833	1307
0.028	0.029	20.9	0.839666	0.0615	0.778166	1170
0.02	0.021	20.95	0.438722	0.0615	0.377222	1245
0.014	0.015	21	0.320727	0.0615	0.259227	1166
		21	0.2282	0.0615	0.1667	1129
		21.05	0.159375	0.0605	0.098875	676
		21.05	0.1035	0.0595	0.044	464
		21.1	0.087166	0.0575	0.029666	746
				0.0575		

density viscosity
1.00417 1.010869 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 14.24 23.95
0.003419 -4.14933 XS(cm2)= 1.669479 3.539999
-0.79424
Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1/√f
	0.324157	129.9806	19166.12	45.73142	0.005400	3.148763	11.94086
	0.290627	119.1988	17516.93	41.00111	0.005757	3.103576	11.85170
	0.247843	108.4170	15932.48	34.96517	0.005775	3.060996	11.72929
	0.216402	97.63521	14348.03	30.52960	0.006389	3.059539	11.62501
	0.166307	81.46251	11971.36	23.46234	0.007054	3.002364	11.42261
	0.125872	67.68576	9946.798	17.75786	0.007733	2.941874	11.20847
14.2	0.090698	55.70598	8214.052	12.79557	0.008227	2.871186	10.96178
18.5	0.057523	42.22063	6232.614	8.115237	0.009085	2.777799	10.61349
25	0.037096	32.92043	4859.719	5.233426	0.009635	2.678542	10.27628
34.3	0.019348	22.82445	3369.348	2.729667	0.010454	2.553203	9.775947
40	0.010522	17.52043	2586.367	1.484544	0.009649	2.404945	9.707753
59.9	0.005101	12.44977	1839.911	0.719644	0.009264	2.248200	8.752876
79.9	0.003505	8.741192	1293.290	0.494540	0.012914	2.167234	8.466257
119.9	0.002254	5.640189	834.4858	0.318021	0.019947	2.071362	8.126868
119.7	0.001337	3.377119	500.2206	0.188628	0.037001	1.958830	7.727089
180.1	0.000594	1.543203	228.5800	0.083940	0.070331	1.708613	7.104698
419.9	0.000401	1.064172	157.8036	0.056596	0.099722	1.597514	6.803446

Tap BL= 122.2234

L 1/f	MDR 1/f	1/f	1/f/Slv	1/f/L
88.03266	27.42651	13.60725	1.139552	0.154570
83.07235	26.94795	13.17897	1.111989	0.158644
76.71434	26.29093	12.98036	1.106662	0.169203
71.68351	25.73124	12.50988	1.076117	0.174515
62.84118	24.64492	11.90637	1.042350	0.189467
54.67063	23.49560	11.37127	1.014524	0.207996
46.56573	22.17154	11.02480	1.005749	0.236758
37.12613	20.30219	10.49229	0.988580	0.282612
29.81413	18.49230	10.18753	0.991363	0.341701
21.53198	15.80687	9.780069	1.000421	0.454211
15.87909	13.29396	10.17992	1.093703	0.641089
11.06829	10.31581	10.38953	1.186985	0.938675
9.185758	8.777464	8.799560	1.039368	0.957956
7.366182	6.955886	7.080379	0.871250	0.961200
5.679505	4.810179	5.504667	0.712385	0.969216
3.788729	1.469658	3.770724	0.530736	0.995247
3.114542	-0.14722	3.166669	0.465450	1.016736

P1P11115

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
1.484544	96.17658	0.171593	1.982889
0.719644	68.31338	-0.14288	1.834505
0.494560	47.96396	-0.30579	1.680915
0.318021	30.94838	-0.49754	1.490638
0.188628	18.53065	-0.72439	1.267890
0.083940	8.487740	-1.07602	0.927767
0.056596	5.839238	-1.24721	0.766356

Regression Output:

Constant	2.03261
Std Err of Y Est	0.003459
R Squared	0.999941
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	1.029106
Std Err of Coef.	0.004546

K' = 0.009276
n' = 1.029106

Tw# = 16.47566
Res/f# = 845.4306

Regression Output:

Constant	-20.2700
Std Err of Y Est	0.088272
R Squared	0.991077
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	10.73637
Std Err of Coef.	0.509361

t = 20.87941 deg C
s.d.)t = 0.134009 deg C

P2P11128 4/13/89 17:00

1.0 PSID	Taps 14	0.1 PSID	Taps 14				co)NaCl	
S =	10.05	S =	10.05	<C>(ppm)=	20.58907		X coeff	
Z =	4.62	Z =	4.75	[NaCl]=	0.105631		constant	

MHD-40 G)l (1/s)	MHD-40 G)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.252	0.253	21	4.5495	-0.0015	4.549	
0.216	0.217	20.9	3.646333	0.0025	3.643333	
0.199	0.2	20.9	3.3735	0.0035	3.3695	
0.169	0.17	20.9	2.647333	0.0045	2.642333	
0.144	0.145	20.9	2.2755	0.0055	2.27	
0.129	0.129	20.9	1.922857	0.0053	1.916357	
0.107	0.108	20.9	1.456166	0.0075	1.449666	
				0.0055		
0.095	0.096	20.95	7.628	0.0395	7.5885	1180
0.071	0.072	21	4.9098	0.0295	4.8753	1154
0.038	0.039	21	1.721285	0.0395	1.685285	1177
0.055	0.056	21	3.2348	0.0325	3.2018	1205
0.029	0.03	21	0.902583	0.0335	0.867583	1200
0.022	0.023	21	0.52	0.0365	0.4795	922
0.013	0.014	21	0.3246	0.0405	0.2824	827
		21	0.2332	0.0435	0.1897	560
		21	0.138833	0.0445	0.094333	413
		21	0.089666	0.0465	0.044166	330
0.055	0.056	21	3.180571	0.0455	3.138071	1020
0.083	0.084	21	6.2624	0.0395	6.2234	952
0.101	0.102	21	8.0225	0.0385	7.984	
				0.0385		

density	viscosity						
1.00417	1.010869	ID(cm) =	1.45796				
-0.00025	-0.02281	K(V/psi)=	13.975	84.66			
0.003419	-4.14933	XS(cm2)=	1.669479				5.539999
							-0.79424
0							Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	log(Re/f)	1/√f
	0.325509	151.5442	22421.50	45.92223	0.003989	3.151145	11.94970
	0.260703	129.9806	19187.75	36.77951	0.004143	3.101952	11.77515
	0.241109	119.7978	17684.56	34.01516	0.004229	3.084985	11.71509
	0.189075	101.8281	15031.88	26.67440	0.005130	3.032196	11.52822
	0.162432	86.85341	12821.31	22.91569	0.006061	2.999315	11.41146
	0.137127	77.26959	11406.54	19.34566	0.006465	2.967440	11.28128
	0.103732	64.69081	9549.666	14.63441	0.006977	2.901836	11.06674
12.3	0.089635	57.46399	8492.415	12.64551	0.007641	2.870609	10.95620
15.9	0.057586	43.47379	6432.101	8.124226	0.008577	2.775025	10.61783
29.9	0.019906	23.57893	3488.586	2.808369	0.010079	2.544361	9.801284
21.3	0.037819	33.88647	5013.622	5.335496	0.009271	2.683721	10.29462
40.2	0.010247	17.88027	2645.449	1.445745	0.009023	2.400180	9.290883
39.9	0.005663	13.84130	2047.869	0.799041	0.008529	2.271418	8.835068
60	0.003335	8.256066	1221.514	0.470592	0.013775	2.156456	8.420103
59.9	0.002240	5.599897	828.5245	0.316117	0.020114	2.070058	8.122252
89.8	0.001114	2.756816	407.5847	0.157197	0.041331	1.918757	7.585270
149.9	0.000521	1.318655	195.0996	0.073599	0.084456	1.757571	7.001890
18.3	0.037066	33.38627	4939.617	5.229299	0.009361	2.679756	10.27916
11.1	0.073510	51.37275	7600.780	10.37070	0.007840	2.828078	10.80550
	0.094306	61.09688	9039.499	13.30458	0.007111	2.882174	10.99700

Tap DL= 122.2234

L 1/f	MDR 1/f	1/f	1/f/Slv	1/f/L
88.51682	27.47177	15.83139	1.324879	0.178851
79.03730	24.53708	15.17302	1.288542	0.191972
76.00906	26.21472	14.54149	1.241261	0.191312
67.30951	25.21173	13.95779	1.210730	0.207367
62.38721	24.58509	12.84449	1.125577	0.205985
57.32193	23.88637	12.43693	1.102439	0.216966
49.85591	22.73489	11.97158	1.081761	0.240123
46.39700	22.14158	11.43987	1.044145	0.246564
37.23105	20.32548	10.79760	1.016931	0.290016
21.88977	15.94284	9.960659	1.016260	0.455037
30.17183	18.59071	10.38556	1.008853	0.344213
15.70580	13.20342	10.52735	1.133084	0.670284
11.67613	10.75695	10.96183	1.240718	0.938824
8.960597	8.572682	8.520037	1.010908	0.950833
7.344094	6.931107	7.050961	0.868101	0.960085
5.178896	4.048784	4.918817	0.648473	0.949781
3.543659	0.917866	3.460999	0.491438	0.971030
29.87005	18.50776	10.33563	1.005493	0.346020
42.06476	21.33273	11.29327	1.045140	0.268473
47.64473	22.36056	11.85796	1.078289	0.248882

P2P11128

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
0.799041	75.94886	-0.09743	1.880521
0.470592	45.30201	-0.32735	1.656117
0.316117	30.72730	-0.50015	1.487524
0.157197	15.11600	-0.80355	1.179436
0.073599	7.235617	-1.13312	0.859475

Regression Output:

Constant	-1.99759
Std Err of Y Est	0.004104
R Squared	0.999910
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	1.008417
Std Err of Coef.	0.006742

K' = 0.010055
n' = 1.008417

Tw8 = 13.68447
Res/f8 = 773.1224

Regression Output:

Constant	-42.7827
Std Err of Y Est	0.214078
R Squared	0.978930
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	18.62769
Std Err of Coef.	1.366414

t = 20.9675 deg C
s.d.)t = 0.045683 deg C

Page 1 Cyanamid 836

F2P11130 4/15/89 15:52

1.0 PSID Tape 14	0.1 PSID Tape 14			co)NaCl	
S = 10.05	S = 10.05	<C>(ppa)=	20.55048	X coeff	
Z = 4.55	Z = 4.82	[NaCl]=	0.104479	constant	

MMD-40 Q)l (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.256	0.257	21	4.216285	-0.0245	4.227285	
0.232	0.233	21	3.808164	0.0025	3.812664	
0.2	0.202	21	3.1605	-0.0115	3.1755	
0.17	0.171	20.95	2.564833	-0.0185	2.585333	
0.145	0.146	20.95	2.087428	-0.0255	2.113928	
0.129	0.13	21	1.780875	-0.0275	1.808375	
0.109	0.11	21	1.430285	-0.0275	1.458285	
				-0.0285		
0.096	0.098	21	7.330166	-0.0165	7.346666	1108
0.071	0.072	21	4.734	-0.039	4.77725	1184
0.056	0.057	21	3.209125	-0.0435	3.251625	1214
0.039	0.04	21	1.6558	-0.0415	1.6973	1275
0.03	0.031	21	0.9702	-0.0415	1.0107	1242
0.024	0.025	21	0.515636	-0.0395	0.554636	1126
0.015	0.016	21	0.294637	-0.0385	0.332637	1135
		21.05	0.194117	-0.0375	0.231617	790
		21.05	0.13125	-0.0365	0.16775	489
		21.1	0.0404	-0.0365	0.0969	404
		21.1	0.017125	-0.0375	0.055125	830
0.095	0.096	21.1	7.2354	-0.0385	7.2759	
0.104	0.105	21.1	8.16925	-0.0425	8.21225	
0.071	0.072	21	4.71475	-0.0435	4.75875	
0.047	0.048	21	2.3492	-0.0445	2.3942	
0.028	0.029	21	0.728716	-0.0455	0.774214	
0.019	0.02	21	0.381444	-0.0455	0.426944	
				-0.0455		

Page 2 Cyanamid 836

density	viscosity				
1.00417	1.010869	ID(cm) =	1.45796		
-0.00025	-0.02281	K(V/psi)=	13.975	84.66	
0.003419	-4.14933	XS(cm2)=	1.669479		
					5.539999
					0.79424
0					Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	log(Re*f)	1/√f
	0.302489	153.9401	22775.99	42.67452	0.003593	3.135218	11.89291
	0.272820	139.5444	20649.05	38.48893	0.003942	3.112802	11.81356
	0.227227	120.9957	17901.75	32.05673	0.004369	3.073093	11.67299
	0.184997	102.1276	15093.10	26.09898	0.004992	3.027953	11.51320
	0.151245	87.45240	12924.30	21.34014	0.005567	2.984240	11.35845
	0.129400	77.86857	11520.93	18.25557	0.006007	2.950832	11.24017
	0.104349	65.88879	9748.479	14.72142	0.006766	2.904109	11.07479
11.3	0.086778	58.73273	8689.714	12.24252	0.007081	2.864069	10.93305
16.3	0.056428	43.50939	6437.367	7.960835	0.008390	2.770613	10.60221
21.4	0.038408	33.98003	5027.465	5.418525	0.009363	2.687074	10.30649
31.9	0.020048	23.94078	3542.123	2.828589	0.009846	2.545903	9.806745
39.8	0.011938	18.69207	2765.557	1.684235	0.009618	2.433335	9.408254
44.9	0.006551	15.02141	2222.471	0.924249	0.008173	2.303028	8.946967
70	0.003926	9.712179	1436.951	0.553975	0.011718	2.191879	8.553499
70	0.002735	6.760019	1001.297	0.385968	0.016853	2.113903	8.277462
60.4	0.001981	4.849431	718.3002	0.279539	0.023718	2.043048	8.029469
89.9	0.001144	2.691786	399.1587	0.161474	0.044468	1.925171	7.609353
310.2	0.000651	1.602710	237.6622	0.091860	0.071358	1.802684	7.175747
	0.005942	57.50295	8526.979	12.12459	0.007316	2.862953	10.92909
	0.097002	62.59435	9281.972	13.68493	0.006969	2.889240	11.02215
	0.056210	43.12721	6380.823	7.930006	0.008507	2.769771	10.59933
	0.028280	28.75147	4253.882	3.989707	0.009630	2.620604	10.07118
	0.009144	17.37068	2570.053	1.290154	0.008531	2.375455	9.203357
	0.005043	11.97978	1772.450	0.711462	0.009891	2.246210	8.745830

Tap DL= 122.2234

L 1//f	MDR 1//f	1//f	1//f/Blv	1//f/L
85.32939	27.16915	16.68240	1.402717	0.195505
81.03679	26.74324	15.92567	1.348083	0.196524
73.95608	25.98878	15.12870	1.296042	0.204563
66.65512	25.13111	14.15224	1.229218	0.212320
60.27266	24.30056	13.40191	1.179906	0.222354
55.81000	23.66580	12.90195	1.147841	0.231176
50.11747	22.77807	12.15703	1.097721	0.242570
45.70353	22.01732	11.88326	1.086911	0.260007
36.85476	20.24165	10.91678	1.029669	0.296210
30.40568	18.65442	10.33413	1.002682	0.339875
21.96766	15.97217	10.07766	1.027625	0.458749
16.95179	13.83337	10.19640	1.083772	0.601493
12.35766	11.35754	11.04133	1.236322	0.880843
9.722089	9.245712	9.237669	1.079987	0.950173
8.124245	7.764157	7.703003	0.930599	0.948150
6.913985	6.453120	6.493181	0.808668	0.939137
5.260798	4.178262	4.742135	0.625198	0.901409
3.967931	1.850997	3.743685	0.521685	0.943435
45.58617	21.99611	11.69074	1.069689	0.256453
48.43071	22.49557	11.97841	1.086757	0.247330
36.78333	20.22564	10.84190	1.022895	0.294750
26.09064	17.39149	10.19015	1.011812	0.390567
14.83662	12.73366	10.82647	1.176361	0.729712
11.01768	10.27799	10.05457	1.149642	0.912585

P2P11130

Tw dyne/cm2	B<U>/D (1/s)	Log Tw	Log B<U>/D
0.924249	82.42431	-0.03421	1.916055
0.533975	53.29188	-0.25650	1.726661
0.385968	37.09303	-0.41344	1.569292
0.279539	26.60940	-0.55355	1.425035
0.091860	8.794265	-1.03687	0.944199
0.161474	14.77015	-0.79189	1.169384

Regression Output:

Constant	-1.97773
Std Err of Y Est	0.002305
R Squared	0.999968
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	0.997415
Std Err of Coef.	0.003939

K' = 0.010526
n' = 0.997415

Tw8 = 10.85401
Res/f8 = 688.5404

Regression Output:

Constant	-42.0416
Std Err of Y Est	0.192790
R Squared	0.989497
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	18.63405
Std Err of Coef.	0.783738

t = 21.91666 deg C
s.d.)t = 0.042491 deg C

P1P01536 1/6/89 16:27 density viscosity
1.0 PSID Taps 14 co)NaCl 1.000085 1.001565
S = 0 <C>(ppm)= 1.0009 X coeff -0.00025 -0.02281
Z = 5.05 [NaCl]= 0.000010 constant 0.003419 -4.16933

MMD-40 @)1 (1/s)	MMD-40 @)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.189	0.19	20.8	2.9853	-0.0855	3.0718	
0.176	0.177	20.8	2.631428	-0.0875	2.719428	
0.165	0.166	20.8	2.301714	-0.0885	2.390214	
0.155	0.156	20.8	2.055625	-0.0885	2.144125	
0.139	0.14	20.8	1.691625	-0.0865	1.780125	
0.117	0.118	20.8	1.224111	-0.0885	1.312611	
0.099	0.1	20.8	0.8859	-0.0885	0.9744	
0.074	0.075	20.8	0.493111	-0.0885	0.581611	
0.054	0.055	20.8	0.245222	-0.0885	0.333222	
0.045	0.046	20.8	0.157714	-0.0915	0.249714	
0.036	0.037	20.8	0.0735	-0.0885	0.163	
0.029	0.03	20.8	-0.0136	-0.0905	0.0754	
0.021	0.021	20.8	-0.03977	-0.0875	0.047722	
0.013	0.014	20.8	-0.05633	-0.0875	0.031166	
				-0.0875		

ID(cm) = 1.45796 Tap BL=
K(V/psi)= 9.4 2.97533
XB(cm2)= 1.669479 -1.99543
Solvent

t)samp (sec)	BP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.326787	113.5084	16805.02	46.10244	0.007168	3.153156	11.37711	
0.289300	103.7215	15452.17	40.81395	0.007315	3.126478	11.29839	
0.234278	99.13269	14676.68	35.87301	0.007313	3.098678	11.21502	
0.220098	93.14280	13789.87	32.17963	0.007431	3.075085	11.14482	
0.189375	83.55897	12370.98	26.71662	0.007665	3.034685	11.02462	
0.139639	70.38121	10420.00	19.70004	0.007967	2.968528	10.82778	
0.103659	59.59941	8823.769	14.62407	0.008248	2.903828	10.63527	
0.061873	44.62468	6606.726	8.728985	0.008781	2.791776	10.30188	
0.033661	32.64490	4833.108	5.031110	0.009458	2.672126	9.945887	
0.026352	27.25400	4034.980	3.717766	0.010027	2.606435	9.750435	
0.017340	21.84310	3236.852	2.446350	0.010253	2.515553	9.480032	
0.008021	17.67017	2616.086	1.131624	0.007260	2.348145	8.981938	
0.003076	12.57877	1862.298	0.716228	0.009068	2.268820	8.684412	
0.003315	8.086352	1197.192	0.467758	0.014331	2.156305	8.411149	

122.2234

L 1/f	MBR 1/f	1/f	1/f/PK	1/f/L
88.92758	27.50997	11.81089	1.038127	0.132814
83.67174	27.00727	11.69165	1.034807	0.139732
78.44376	26.47468	11.69363	1.042674	0.149070
74.29593	26.02661	11.60046	1.040883	0.156138
67.69635	25.25901	11.42139	1.035989	0.168715
58.13103	24.00203	11.20314	1.034666	0.192722
50.08511	22.77274	11.01694	1.035322	0.219844
38.69513	20.64375	10.67112	1.035841	0.275774
29.37692	18.37049	10.28293	1.033847	0.350020
25.25314	17.12227	9.986331	1.024193	0.395448
20.49489	15.39552	9.875728	1.041739	0.482098
13.93239	12.21476	11.73563	1.306581	0.842327
11.08409	10.32758	10.50096	1.208895	0.947389
8.957466	8.569798	8.353311	0.993123	0.932552

P1P01554

Tms = 0.004401
Res/f8 = 13.90323

Regression Outputs

Constant	1.745537
Std Err of Y Est	0.030220
R Squared	0.997076
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	3.193936
Std Err of Coef.	0.065362

t = 20.8 deg C
s.d.)t = 0.000000 deg C

Page 1 Cyanamid 832A

P2P01570 1/22/89 12:02 density
1.0 PSID G.1 PSID Taps 14 co)NaCl 1.000085
S = 8 10.05 <C>(ppm)=2.086688 X coeff -0.00025
Z = 4.9 7.27 [NaCl]= 0.000010 constant 0.003419

MMD-40 θ)1 (1/s)	MMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.176	0.177	19.9	2.175181	-0.0405	2.213681	2634
0.154	0.155	19.9	1.7308	-0.0365	1.7688	2486
0.137	0.138	19.9	1.4045	-0.0395	1.444	2534
0.11	0.111	19.9	0.946	-0.0395	0.986	2503
0.082	0.083	19.95	0.5678	-0.0405	0.6083	1864
0.093	0.094	19.95	0.7078	-0.0405	0.7478	1745
				-0.0395		
0.093	0.094	20.05	6.754571	0.245	6.523821	1077
0.082	0.083	20.05	5.463285	0.2165	5.249785	1082
0.062	0.063	19.9	3.50425	0.2105	3.29425	1019
0.045	0.046	20	2.104222	0.2095	1.894722	567
0.036	0.037	20	1.3254	0.2095	1.1159	456
0.028	0.029	20	0.8886	0.2095	0.6786	542
0.02	0.021	20	0.681363	0.2105	0.470113	646
0.012	0.013	20.15	0.520076	0.212	0.306826	536
		20.2	0.36125	0.2145	0.14625	362
		20.25	0.303375	0.2155	0.087875	308
		20.25	0.230714	0.2155	0.015214	75
				0.2155		
0.176	0.177	19.9	2.175181	-0.0405	2.213681	2634
0.154	0.155	19.9	1.7308	-0.0365	1.7688	2486
0.137	0.138	19.9	1.4045	-0.0395	1.444	2534
0.11	0.111	19.9	0.946	-0.0395	0.986	2503
0.082	0.083	19.95	0.5678	-0.0405	0.6083	1864
0.093	0.094	19.95	0.7078	-0.0405	0.7478	1745
				-0.0395		
0.093	0.094	20.05	6.754571	0.245	6.523821	1077
0.082	0.083	20.05	5.463285	0.2165	5.249785	1082
0.062	0.063	19.9	3.50425	0.2105	3.29425	1019
0.045	0.046	20	2.104222	0.2095	1.894722	567
0.036	0.037	20	1.3254	0.2095	1.1159	456
0.028	0.029	20	0.8886	0.2095	0.6786	542
0.02	0.021	20	0.681363	0.2105	0.470113	646
0.012	0.013	20.15	0.520076	0.212	0.306826	536
		20.2	0.36125	0.2145	0.14625	362
		20.25	0.303375	0.2155	0.087875	308
		20.25	0.230714	0.2155	0.015214	75
				0.2155		

Page 2 Cyanamid 832A

viscosity
1.001569 ID(cm) = 1.45796 Tap DL=
-0.02281 K(V/psi)= 9.39 82.21
-4.14933 XB(ca2)= 1.669479 2.97533
-1.99543

t)samp (sec)	BP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
14.9	0.235748	105.8884	15361.78	33.25894	0.005941	3.073381	11.13975
15.9	0.188370	93.65326	13584.76	26.57492	0.006068	3.026663	10.99480
18.2	0.153780	83.39770	12098.94	21.69504	0.006247	2.980607	10.86372
22.5	0.105005	66.63420	9666.972	14.81392	0.006682	2.897762	10.61723
22.4	0.066781	49.84444	7239.356	9.139262	0.007368	2.793375	10.30664
18.5	0.079637	54.49923	8205.891	11.23514	0.007049	2.838209	10.44004
11.4	0.079355	54.58870	8237.447	11.19531	0.007002	2.838423	10.44067
13.1	0.063858	49.47375	7201.745	9.008984	0.007372	2.791243	10.30030
16.1	0.040071	37.91117	5499.971	5.653154	0.007879	2.688573	9.994822
12.3	0.023047	27.61193	4014.855	3.251470	0.008542	2.569452	9.640399
12.2	0.013573	22.38844	3255.344	1.914959	0.007652	2.454492	9.298355
18.4	0.008254	17.64413	2565.508	1.164523	0.007492	2.366486	8.977002
30.6	0.005718	12.64532	1838.666	0.806746	0.010105	2.266781	8.739852
40.1	0.003732	8.006437	1168.105	0.526535	0.016452	2.175604	8.468571
60.1	0.001778	3.607887	526.9696	0.250974	0.038621	2.015198	7.991310
89.9	0.001068	2.052153	300.0767	0.150799	0.071727	1.905075	7.663658
180.2	0.000185	0.249301	36.45422	0.026108	0.841476	1.524268	6.530632
14.9	0.235748	106.0210	15403.79	33.25894	0.005926	3.074042	11.89617
15.9	0.188370	92.84330	13489.19	26.57492	0.006175	3.025324	11.70129
18.2	0.153780	82.66049	12009.73	21.69504	0.006360	2.981268	11.52507
22.5	0.105005	66.48778	9660.005	14.81392	0.006712	2.898623	11.19369
22.4	0.066781	49.71609	7231.399	9.139262	0.007406	2.794036	10.77614
18.5	0.079637	54.30497	8189.777	11.23514	0.007098	2.838870	10.95548
11.4	0.079355	54.30497	8208.274	11.19531	0.007073	2.839084	10.95633
13.1	0.063858	49.71609	7267.732	9.008984	0.007301	2.791904	10.76761
16.1	0.040071	37.73631	5482.705	5.653154	0.007952	2.689233	10.35693
12.3	0.023047	27.55349	4012.284	3.251470	0.008579	2.570113	9.880453
12.2	0.013573	22.16259	3227.274	1.914959	0.007809	2.455153	9.420613
18.4	0.008254	17.37068	2529.485	1.164523	0.007730	2.347147	8.988590
30.6	0.005718	12.57877	1831.696	0.806746	0.010213	2.267442	8.669768
40.1	0.003732	7.786857	1137.750	0.526535	0.017395	2.176265	8.305060
60.1	0.001778	3.607887	527.7494	0.250974	0.038624	2.015859	7.663436
89.9	0.001068	2.052153	300.5208	0.150799	0.071733	1.905736	7.322945
180.2	0.000185	0.249301	36.50816	0.026108	0.841547	1.524929	5.699717

122.2234

L 1/f	MDR 1/f	1/f	1/f/PK	1/f/L
74.00515	25.99425	12.97357	1.166619	0.175306
66.15211	25.06861	12.83667	1.167521	0.194047
59.77064	24.23155	12.65142	1.166557	0.211666
49.39043	22.65749	12.23285	1.152169	0.247676
38.83791	20.67414	11.64993	1.130333	0.299963
43.06155	21.52598	11.91011	1.140811	0.276583
43.08277	21.53004	11.95003	1.144564	0.277373
38.64767	20.63362	11.64647	1.130692	0.301349
30.51076	18.68288	11.26665	1.127229	0.369261
23.19171	16.41960	10.81974	1.122333	0.466535
17.79804	14.23536	11.43152	1.229413	0.642290
13.87928	12.18325	11.55277	1.286930	0.832375
11.55211	10.66884	9.947674	1.138197	0.861112
9.344499	8.936486	7.796100	0.920592	0.832516
6.472593	5.888769	5.088469	0.636750	0.786156
5.022913	3.796437	5.733848	0.487214	0.743363
2.090012	-3.43889	1.090131	0.166925	0.521591
74.11782	26.00680	12.98927	1.091887	0.175251
66.25282	25.08116	12.72511	1.087495	0.192069
59.86164	24.24410	12.53905	1.087980	0.209467
49.44562	22.67004	12.20545	1.090386	0.246746
38.89703	20.68669	11.61945	1.078257	0.298723
43.12711	21.53853	11.84866	1.083353	0.275201
43.14836	21.34260	11.88960	1.085180	0.275551
38.70651	20.64617	11.70302	1.086872	0.302352
30.55721	18.69544	11.21401	1.082754	0.366984
23.22701	16.43215	10.79638	1.092701	0.464820
17.82515	14.24791	11.31572	1.201166	0.634817
13.90041	12.19580	11.37324	1.265298	0.818195
11.56970	10.68149	9.894898	1.141310	0.855242
9.378756	8.949039	7.581967	0.912933	0.808419
6.482449	5.901321	5.088253	0.663965	0.784727
5.030560	3.808990	3.733689	0.516920	0.742201
2.093194	-3.42633	1.090085	0.191252	0.520776

P2P01570

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
1.164523	96.81546	0.066148	1.985944
0.806746	69.38640	-0.09326	1.841274
0.526535	43.93227	-0.27857	1.642783
0.250116	19.79690	-0.60185	1.296597
0.150799	11.26041	-0.82160	1.051554
0.026108	1.367948	-1.58321	0.136069

Regression Output:

Constant	-1.70902
Std Err of Y Est	0.019193
R Squared	0.999201
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	0.860391
Std Err of Coef.	0.017193

K' = 0.019542
n' = 0.860391

Tw3 = 0.222873
Res/f8 = 96.92975

Regression Output:

Constant	-1.46490
Std Err of Y Est	0.051761
R Squared	0.993263
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	4.717294
Std Err of Coef.	0.146839

t = 20.02058 deg C
s.d.)t = 0.118890 deg C

Cyanamid 832A

PSP01573 1/25/89 12:25

1.0 PSID Taps 14 PSID Taps 14 co)NaCl

S = 8 S = 10.05 <C>(ppm)=5.630432 X coeff

Z = 4.9 Z = 7.27 [NaCl] = 0.000010 constant

MMD-40 θ)1 (1/s)	MMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.233	0.234	20.5	2.476636	-0.044	2.520386	
0.212	0.213	20.5	2.198875	-0.0435	2.152125	
0.191	0.192	20.4	1.764272	-0.043	1.807022	
0.169	0.17	20.5	1.390818	-0.0425	1.433318	
0.139	0.14	20.5	1.054666	-0.0425	1.097666	
0.1	0.101	20.5	0.606222	-0.0435	0.649722	
0.123	0.124	20.45	0.845230	-0.0435	0.888730	
				-0.0435		
0.111	0.112	20.5	6.8025	0.0375	6.7745	1135
0.093	0.094	20.55	5.203625	0.0185	5.186125	1100
0.068	0.069	20.55	3.240125	0.0165	3.225125	1051
0.053	0.054	20.6	2.14375	0.0135	2.131	1080
0.044	0.045	20.6	1.3833	0.012	1.37205	1114
0.036	0.037	20.6	0.914083	0.0105	0.905083	1088
0.028	0.029	20.6	0.71	0.0075	0.7015	1096
0.022	0.023	20.6	0.552928	0.0095	0.542428	1056
0.017	0.018	20.65	0.438	0.0115	0.426	1128
0.012	0.013	20.65	0.334083	0.0125	0.320583	1053
		20.65	0.288125	0.0145	0.273125	1053
		20.75	0.139166	0.0155	0.123166	730
		20.8	0.078714	0.0165	0.061714	415
		20.8	0.0472	0.0175	0.0307	251
		20.9	0.2283	0.0155	0.2128	1039
				0.0155		

Cyanamid 832A

density viscosity

1.000085 1.000154 ID(ca) = 1.45796

-0.00025 -0.02281 K(V/psi)= 9.46 83.22

0.003419 -4.16933 X8(ca2)= 1.669479 2.97533

t)error= -1.99543

0

t)samp (sec)	DP (psid)	<U> (ca/s)	Re	Te dyne/ca2	f	Log(Re/f)	1//f
	0.266425	140.1634	20640.38	37.58676	0.003832	3.106467	11.23819
	0.227497	127.3646	18788.04	32.09484	0.003949	3.072167	11.13614
	0.191017	115.0059	16897.53	26.94839	0.004081	3.033230	11.02029
	0.151513	101.8201	14995.15	21.37521	0.004129	2.983905	10.87353
	0.116032	83.65847	12348.94	16.36960	0.004663	2.923969	10.70115
	0.068480	60.49789	8908.884	9.689369	0.005303	2.812097	10.36234
	0.093946	74.27464	10925.30	13.25372	0.004812	2.879626	10.56326
10.1	0.081404	67.31213	9912.345	11.48440	0.005077	2.849004	10.47215
11.7	0.062318	56.31521	8302.304	8.791726	0.005553	2.791479	10.30100
15.1	0.038754	41.49122	6146.354	5.467341	0.006301	2.688331	9.994103
19.9	0.025406	32.50794	4797.913	3.612556	0.006848	2.598842	9.727844
24.5	0.016487	27.23564	4019.766	2.323956	0.006281	2.503235	9.443382
29.6	0.010875	22.01689	3249.317	1.534333	0.006360	2.412895	9.174589
37.2	0.008429	17.44763	2604.649	1.189210	0.007449	2.357564	9.009962
46.6	0.006518	13.63216	2011.998	0.919546	0.009912	2.301722	8.843812
62.3	0.005118	10.84525	1602.480	0.722172	0.012300	2.249748	8.689173
79.8	0.003852	7.903953	1167.876	0.543465	0.017427	2.188013	8.505493
94.8	0.003281	6.653328	983.0862	0.463012	0.020953	2.153224	8.401982
149.9	0.001480	2.917024	431.9889	0.208797	0.049159	1.961275	7.890377
180	0.000741	1.381002	204.7466	0.104620	0.109899	1.831714	7.445383
240.1	0.000368	0.626181	92.83736	0.052043	0.265910	1.680090	6.994253
120.2	0.002557	5.177617	769.3644	0.360747	0.026960	2.101492	8.248062

Tap BL= 122.2234

L 1/f	R 1/f	1/f	1/f/Pi	1/f/L
79.86334	24.62288	16.15289	1.437320	0.202254
73.79852	25.97118	15.91160	1.428825	0.215609
67.46997	25.25138	15.65282	1.420364	0.231996
60.22617	24.29419	15.56129	1.431116	0.258380
52.70440	23.19341	14.64403	1.368654	0.277850
46.54878	21.02985	13.73173	1.325156	0.338647
47.37033	22.31290	14.41475	1.344611	0.304299
44.14528	21.73108	14.03369	1.340096	0.317898
38.66871	20.63811	13.41896	1.302604	0.347023
30.49379	18.67829	12.59754	1.260498	0.413118
24.81547	16.97800	12.08397	1.242204	0.486953
19.91204	15.16148	12.61725	1.336095	0.633649
16.17242	13.66500	12.55869	1.348791	0.776512
14.23785	12.39372	11.43364	1.269900	0.803045
12.51993	11.33272	10.04397	1.135706	0.802238
11.10780	10.34521	9.016633	1.037685	0.811738
9.635936	9.172264	7.575069	0.890601	0.786128
8.894144	8.511259	6.908240	0.822215	0.776717
5.986255	5.244229	4.510216	0.571609	0.753428
4.242228	2.402567	3.016496	0.405149	0.711063
2.992060	-0.47828	1.939263	0.277262	0.648129
7.895365	7.528352	6.090316	0.738393	0.771378

P3P01373

Tw dyne/cm2	B<U>/B (1/s)	Log Tw	Log B<U>/B
0.722172	59.50925	-0.14135	1.774584
0.543465	43.36993	-0.26482	1.637186
0.463012	36.50760	-0.33440	1.562383
0.360747	28.41020	-0.44279	1.453474
0.288797	18.00606	-0.68027	1.204284
0.184620	7.377725	-0.98038	0.879538
0.092043	3.435934	-1.28363	0.536044

Regression Output:

Constant	-1.82198
Std Err of Y Est	0.003936
R Squared	0.999720
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.949467
Std Err of Coef.	0.009171

K' = 0.015066
n' = 0.949467

Tw8 = 0.569327
Rw/f8 = 157.2646

Regression Output:

Constant	-10.1246
Std Err of Y Est	0.151312
R Squared	0.988854
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	8.492920
Std Err of Coef.	0.300553

t = 20.59772 deg C
s.d.)t = 0.121988 deg C

Page 1:Cyanamid 832A

P1P11574 1/26/89 13:00

1.0 PSID Taps 14		0.1 PSID Taps 14				co)NaCl	
S =	8	S =	10.05	<C>(ppm)=	10.17577	X coeff	
Z =	4.9	Z =	7.27	[NaCl] =	0.000010	constant	

MMD-40 Θ)l (1/s)	MMD-40 Θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.244	0.245	21.1	1.634857	-0.0515	1.683357	
0.224	0.226	21.1	1.368142	-0.0455	1.414142	
0.194	0.196	21.1	1.086714	-0.0465	1.133714	
0.169	0.171	21.1	0.846	-0.0475	0.89375	
0.139	0.14	21.1	0.559444	-0.048	0.608194	
0.116	0.12	21.1	0.404444	-0.0495	0.453444	
0.099	0.103	21.1	0.322818	-0.0495	0.371818	
				-0.0495		
0.124	0.125	21.15	3.991571	-0.0565	4.055071	1154
0.11	0.112	21.1	3.522	-0.0705	3.596	1154
0.093	0.094	21.15	2.840166	-0.0775	2.928666	1140
0.068	0.069	21.15	2.023571	-0.0995	2.114071	1208
0.052	0.053	21.2	1.527	-0.0815	1.6085	1174
0.035	0.036	21.2	1.03575	-0.0815	1.11725	1101
0.03	0.031	21.25	0.886727	-0.0815	0.968227	1057
0.025	0.026	21.3	0.746692	-0.0815	0.826692	1161
0.02	0.021	21.3	0.610470	-0.0785	0.687470	1220
0.013	0.014	21.3	0.450416	-0.0755	0.504416	1122
		21.3	0.29025	-0.0725	0.36125	490
		21.3	0.194571	-0.0695	0.264571	255
		21.3	0.0282	-0.0705	0.0982	228
				-0.0693		

Page 2:Cyanamid 832A

density	viscosity				
1.000085	1.000154	ID(cm) =	1.45796		
-0.00025	-0.02201	K(V/psi)=	9.44	83.22	
0.003419	-4.14933	XB(ca2)=	1.669479		2.97533
t)error=					-1.99543
0					

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.177944	146.7523	21905.17	25.10406	0.002335	3.024733	10.99300
	0.149486	135.3715	20206.40	21.08924	0.002305	2.926891	10.88241
	0.119842	117.4018	17524.13	16.90718	0.002457	2.938896	10.73961
	0.094476	102.4271	15288.91	13.32857	0.002545	2.887253	10.58596
	0.064291	83.85847	12517.24	9.070061	0.002584	2.803644	10.33726
	0.047932	71.87848	10729.06	6.762260	0.002622	2.739907	10.14755
	0.039304	61.69587	9209.112	5.544959	0.002918	2.696810	10.01933
9.2	0.048727	75.13406	11227.63	6.874319	0.002439	2.743968	10.15964
10.3	0.043210	67.22634	10034.62	6.096083	0.002702	2.717386	10.08053
12.1	0.035191	54.43568	8433.151	4.964793	0.003123	2.673304	9.949392
17.4	0.025403	41.58498	6214.241	3.583858	0.004152	2.602529	9.738813
22.2	0.019329	31.67626	4738.877	2.726793	0.005444	2.543672	9.563695
29.9	0.013425	22.05642	3299.715	1.894006	0.007800	2.464537	9.328241
33.9	0.011634	18.67644	2797.212	1.641377	0.009428	2.433943	9.237214
44.4	0.009933	15.66275	2348.493	1.401641	0.011446	2.400119	9.136574
59.3	0.008260	12.32321	1847.758	1.165427	0.015376	2.360074	9.017429
79.5	0.006041	8.453657	1267.552	0.855107	0.023974	2.292841	8.817391
51.1	0.004340	5.743730	861.2223	0.612405	0.037193	2.220351	8.601707
60.2	0.003179	3.799357	569.7104	0.448512	0.062248	2.152718	8.400478
161.4	0.001180	0.846155	126.8736	0.166472	0.465868	1.937502	7.760140

Tap BL= 122.2234

L 1/f	M 1/f	1/f	1/f/PK	1/f/L
44.16270	25.06993	20.49252	1.881992	0.312752
40.44175	24.35094	20.82538	1.913690	0.343419
34.29713	23.43904	20.17157	1.878239	0.371503
48.20955	22.45780	19.82090	1.872376	0.411140
39.76915	20.86966	19.67171	1.902990	0.494647
34.35896	19.65823	19.52785	1.924390	0.568679
31.09499	18.83939	18.51003	1.847432	0.595273
34.66160	19.73540	20.24509	1.992697	0.584078
32.60368	19.23036	19.23598	1.908227	0.589994
29.45872	18.39278	17.89309	1.798410	0.607436
25.02702	17.04805	15.51882	1.593502	0.620082
21.85508	15.92977	13.55198	1.417023	0.620083
18.21449	14.42620	11.32241	1.213778	0.621615
16.97552	13.84492	10.29867	1.114913	0.606678
15.70359	13.20224	9.346955	1.023026	0.595211
14.32037	12.44141	8.064379	0.896310	0.563140
12.26653	11.16399	6.458384	0.732459	0.526506
10.38080	9.786671	5.185183	0.602808	0.499497
8.883798	8.501655	4.009072	0.477124	0.451166
5.412313	4.412556	1.465103	0.189798	0.270498

P1P11574

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
1.401461	85.94339	0.146575	1.934212
1.165427	67.61894	0.066465	1.830048
0.855107	46.38622	-0.06797	1.666389
0.612405	31.51633	-0.21296	1.498538
0.448312	20.84842	-0.34822	1.319077
0.166472	6.442956	-0.77865	0.666794

Regression Output:

Constant	-1.28701
Std Err of Y Est	0.023232
R Squared	0.996182
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.732169
Std Err of Coef.	0.022662

K' = 0.051639
n' = 0.732169

Tw)Retro=6.206063
Ram/f)R= 526.3435

Regression Output:

Constant	6.687405
Std Err of Y Est	0.216454
R Squared	0.872450
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	4.636333
Std Err of Coef.	0.086366

t = 21.185 deg C
s.d.)t = 0.085293 deg C

P2P11375 1/29/89 14:10

1.0 PSID Tape 14 0.1 PSID Tape 14 co)NaCl

B = 8 B = 10.05 <C>(ppa)= 20.859 X coeff

Z = 4.9 Z = 7.27 [NaCl] = 0.000010 constant

MMD-40 θ)1 (1/s)	MMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.252	0.253	21.35	1.316	-0.0445	1.3615	
0.223	0.224	21.3	1.0975	-0.0465	1.145	
0.194	0.196	21.3	0.898714	-0.0485	0.947714	
0.175	0.176	21.2	0.764375	-0.0495	0.814375	
0.151	0.152	21.2	0.64175	-0.0505	0.69275	
0.122	0.123	21.3	0.492666	-0.0515	0.544166	
0.085	0.086	21.3	0.316090	-0.0515	0.367590	
				-0.0515		
0.132	0.133	21.25	5.1513	-0.0965	5.2618	1076
0.11	0.111	21.25	4.154000	-0.1265	4.284388	1196
0.081	0.082	21.3	2.93575	-0.1305	3.06625	1270
0.052	0.053	21.3	1.911000	-0.1305	2.043380	1178
0.043	0.044	21.3	1.616	-0.1325	1.749	1090
0.034	0.035	21.3	1.330538	-0.1335	1.463538	1232
0.029	0.03	21.3	1.155272	-0.1325	1.287772	1148
0.023	0.024	21.3	0.977928	-0.1325	1.109928	1108
0.016	0.018	21.35	0.730333	-0.1315	0.860333	1135
0.012	0.013	21.4	0.581818	-0.1285	0.709818	797
		21.4	0.347071	-0.1275	0.474071	642
		21.4	0.179687	-0.1265	0.306687	425
		21.45	0.069846	-0.1255	0.195346	282
		21.45	-0.026	-0.1255	0.0975	178
		21.35	3.743	-0.1215	3.8725	1337
				-0.1375		

density viscosity

1.000085 1.001565 ID(ca) = 1.45796

-0.00025 -0.02281 K(V/psi)= 9.4 84.18

0.003419 -4.14983 XS(ca2)= 1.669479 2.97533

t)error= -1.99543

0 Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.144840	151.5442	22716.39	20.43377	0.001782	2.981887	10.86752
	0.121000	134.1735	20089.84	17.10440	0.001912	2.943788	10.75417
	0.106820	117.4018	17578.62	14.22356	0.002067	2.902724	10.63199
	0.086435	105.4220	15749.32	12.22237	0.002203	2.868812	10.53109
	0.073496	91.04633	13601.68	10.39698	0.002513	2.833689	10.42659
	0.057870	73.67545	11031.48	8.167008	0.003014	2.782251	10.27354
	0.039105	51.51306	7713.071	5.516909	0.004165	2.697068	10.02009
8	0.062506	80.56403	12049.28	8.818289	0.002722	2.798438	10.32170
10.8	0.050895	66.33249	9920.794	7.180238	0.003249	2.753815	10.18894
15.3	0.036424	49.72000	7444.597	5.138750	0.004165	2.681667	9.974276
22.2	0.024274	31.78419	4759.060	3.424530	0.006792	2.593539	9.712065
24.6	0.020776	26.54057	3973.930	2.931161	0.008338	2.559758	9.611357
33.4	0.017385	20.84617	3121.306	2.452754	0.011309	2.521065	9.496433
38.4	0.015297	17.90727	2681.264	2.158187	0.013486	2.493283	9.413771
45.2	0.013185	14.68318	2198.519	1.840137	0.017288	2.461011	9.317751
64.9	0.010220	10.47538	1570.254	1.441838	0.026329	2.406189	9.154638
80.1	0.008432	7.965332	1192.044	1.189589	0.037779	2.364922	9.031855
89.9	0.005631	4.277541	641.9246	0.794499	0.087010	2.277270	8.771062
119.9	0.003619	2.123188	318.6239	0.510628	0.226984	2.181276	8.485647
179.9	0.002320	0.938937	141.0441	0.327382	0.744140	2.085244	8.199719
480.1	0.001158	0.222078	33.34467	0.163400	6.639177	1.934344	7.750741
13	0.046002	61.60372	9234.561	6.489951	0.003426	2.732852	10.12656

Tap BL= 122.2234

L 1/f	M 1/f	1/f	1/f/PK	1/f/L
59.94699	24.25584	23.68382	2.179320	0.395079
54.91218	23.53198	22.86589	2.126254	0.416408
49.95796	22.75176	21.99177	2.068452	0.440205
46.20542	22.10744	21.30339	2.022904	0.461058
42.61564	21.44009	19.94819	1.913204	0.468095
37.85375	20.46278	18.21302	1.772807	0.481116
31.11346	18.84429	15.49383	1.546276	0.497978
39.29329	20.77033	19.16561	1.956826	0.487757
35.45649	19.92249	17.48762	1.716333	0.493213
30.02947	18.55168	15.49435	1.553431	0.515971
24.51429	16.87724	12.13338	1.249309	0.494951
22.67977	16.23561	10.95119	1.139377	0.482861
20.74655	15.50025	9.603085	0.990170	0.453236
19.46092	14.97238	8.611049	0.914728	0.442478
18.06722	14.35921	7.605343	0.816220	0.420946
15.92444	13.31760	6.162828	0.673191	0.386999
14.48113	12.53353	5.144814	0.569630	0.355277
11.83452	10.86814	3.390104	0.386510	0.284458
9.487601	9.044251	2.098949	0.247358	0.221230
7.605434	7.219638	1.159257	0.141375	0.152422
5.373089	4.352335	0.380099	0.050072	0.072230
33.78564	19.52419	17.08262	1.686911	0.505617

P3P11378

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
1.860137	80.36837	0.269545	1.904164
1.441838	57.47969	0.158916	1.759514
1.189589	43.58401	0.075397	1.639347
0.794499	23.47137	-0.09990	1.370538
0.510628	11.63019	-0.29189	1.066333
0.327382	5.152043	-0.48494	0.711981
0.163600	1.218573	-0.78674	0.085851

Regression Output:

Constant	-0.93631
Std Err of Y Est	0.012980
R Squared	0.998186
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.616874
Std Err of Coef.	0.015180

K' = 0.115794
n' = 0.616874

Regression Output:

Constant	-40.0500
Std Err of Y Est	0.002937
R Squared	0.999993
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	21.37324
Std Err of Coef.	0.052461

t = 21.32045 deg C
s.d.)t = 0.066842 deg C

Page 1 Cyanamid 832A

P1P03443 12/25/88 13:08 Tape 14 co)NaCl
1.0 PSID Tape 14 <C>(ppa)= 1.03135 X coeff
S = 8 [NaCl] = 0.000308 constant
I = 5.05

NMD-40 G)l (1/s)	NMD-40 G)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.227	0.228	22.1	4.1655	0.0415	4.124	
0.236	0.235	22.1	4.058	0.0415	4.0165	
0.238	0.239	22.1	4.226666	0.0415	4.191666	
0.215	0.216	22.1	3.561714	0.0283	3.514714	
0.194	0.195	22.1	3.0255	0.0255	3.0005	
0.184	0.184	22.1	2.7	0.0245	2.67625	
0.169	0.17	22.1	2.4004	0.023	2.37815	
0.151	0.152	22.1	1.932714	0.0215	1.911464	
0.129	0.13	22.1	1.4914	0.021	1.47115	
0.094	0.095	22.1	0.8706	0.0195	0.85135	
				0.019		

P1P03443 12/25/88 12:36 Note: 0.1 PSID transducer has mal

0.095	0.095	20.7	0.952625	0.045	0.909125
0.06	0.061	20.35	0.454628	0.042	0.412678
0.081	0.082	20.25	0.7342	0.0415	0.6932
0.05	0.052	20.25	0.351666	0.0405	0.311166
0.042	0.043	20.2	0.264666	0.0405	0.224166
0.033	0.034	20.2	0.182375	0.0405	0.140875
0.025	0.026	20.2	0.099444	0.0425	0.056944
0.017	0.018	20.2	0.081375	0.0425	0.038875
0.012	0.013	20.2	0.070571	0.0425	0.028071
				0.0425	

Page 2 Cyanamid 832A

density viscosity
1.000096 1.001592 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 9.6176 70.31
0.003619 -4.14933 XS(cm2)= 1.669479 4
t)error= 0.4
0 Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.428797	136.5695	20820.68	60.49379	0.006499	3.224948	12.49979
	0.417619	140.7624	21459.91	58.91691	0.005958	3.219212	12.47685
	0.435832	143.1583	21825.19	61.48638	0.006012	3.228482	12.51392
	0.363446	129.3816	19724.85	51.55635	0.006172	3.190233	12.36093
	0.311980	116.8028	17807.16	44.01349	0.006465	3.155885	12.22354
	0.278245	111.4119	16985.29	39.25716	0.006338	3.131052	12.12420
	0.247270	101.8281	15524.19	34.88441	0.006742	3.105408	12.02163
	0.198746	91.04633	13880.45	28.03873	0.006778	3.057971	11.83188
	0.152964	77.86857	11871.44	21.57988	0.007132	3.001117	11.60446
	0.088520	56.90396	8675.284	12.48821	0.007728	2.882342	11.12937

functioned. It does not bleed.

	0.094527	56.90396	8405.566	13.33569	0.008250	2.882807	11.13123
	0.042908	36.23883	5310.917	6.053466	0.009233	2.707853	10.43141
	0.072076	48.81760	7138.254	10.16835	0.008546	2.819491	10.87796
	0.032333	30.56844	4466.883	4.564416	0.009797	2.645559	10.18223
	0.023307	25.45703	3718.206	3.288237	0.010163	2.573855	9.895422
	0.014647	20.06613	2930.821	2.066455	0.010280	2.472987	9.491948
	0.005920	15.27422	2230.923	0.835302	0.007171	2.276295	8.705182
	0.004042	10.40230	1531.026	0.570266	0.010395	2.193405	8.373621
	0.002918	7.487363	1093.590	0.411771	0.014712	2.122702	8.090809

Tap BL=

L 1/f	HDR 1/f	1/f	1/f/PK	1/f/L
104.9127	28.87401	12.40357	0.992302	0.118227
103.5363	28.76504	12.95434	1.038270	0.125118
105.7699	28.94116	12.89661	1.036981	0.121930
96.85316	28.21444	12.72858	1.021742	0.131421
89.48817	27.56182	12.43481	1.017647	0.138977
84.51448	27.08999	12.56090	1.036018	0.148623
79.64883	26.60276	12.17869	1.013064	0.152866
71.42527	25.70146	12.14593	1.026544	0.170051
62.66099	24.62132	11.84694	1.020377	0.188968
47.66755	22.36451	11.37472	1.022045	0.238626
47.71861	22.37334	11.00928	0.989044	0.230712
31.89582	19.04922	10.40676	0.997636	0.326273
41.24506	21.17034	10.81693	0.996379	0.262257
27.63371	17.84562	10.10288	0.992206	0.365600
23.62802	16.50325	9.919220	1.002405	0.423391
18.57235	14.58675	9.862847	1.039075	0.531049
11.80778	10.84961	11.80834	1.356472	1.000050
9.756302	9.274899	9.807929	1.171288	1.005291
8.290530	7.931344	8.244270	1.018947	0.994420

P1P03443

Tw dyne/cm2	B<U>/D (1/s)	Log Tw	Log B<U>/D
0.835302	83.81147	-0.07815	1.923503
0.570246	57.51767	-0.24393	1.759801
0.411771	41.08405	-0.38534	1.613673

Regression Output:

Constant	-1.98023
Std Err of Y Est	0.002919
R Squared	0.999820
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	0.992539
Std Err of Coef.	0.013296

K' = 0.010274
n' = 0.992539

Tw@ = 6.185549
Res/f@ = 536.7620

Regression Output:

Constant	-2.57487
Std Err of Y Est	0.123749
R Squared	0.989110
No. of Observations	12
Degrees of Freedom	10
X Coefficient(s)	4.782067
Std Err of Coef.	0.158671

t = 21.23947 deg C
s.d.)t = 0.913290 deg C

Cyanamid 832A

P2P03443 12/29/88 13:54

1.0 PSID Taps 14

S = 8

Z = 5.05

					density	viscosity
				co)NaCl	1.000096	1.001592
		<C>(ppm)=	2.0633	X coeff	-0.00025	-0.02201
		[NaCl]=	0.000308	constant	0.003419	-4.14933

MMD-40 Q)l (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.255	0.256	22	3.796142	-0.018	3.817142	
0.235	0.236	22	3.322714	-0.024	3.348714	
0.205	0.206	22	2.5365	-0.028	2.56525	
0.189	0.189	22	2.2695	-0.0255	2.2955	
0.162	0.163	22	1.758777	-0.0265	1.785527	
0.132	0.133	22	1.264857	-0.027	1.292107	
0.111	0.112	22	0.94125	-0.0275	0.96875	
0.082	0.083	22	0.557285	-0.0275	0.585285	
0.052	0.053	21.95	0.25	-0.0285	0.2785	
0.043	0.044	21.95	0.173444	-0.0285	0.201444	
0.034	0.035	21.95	0.104833	-0.0275	0.132083	
0.026	0.026	21.95	0.0354	-0.027	0.0619	
0.017	0.018	21.9	0.016333	-0.026	0.040333	
0.012	0.013	21.9	0.004181	-0.026	0.029681	
				-0.025		

Cyanamid 832A

ID(cm) = 1.45796

K(V/psi)= 9.6176

XS(cm2)= 1.669479

Tap DL=

4

0.4

Solvent

0

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.396891	153.0417	23279.37	55.99259	0.004790	3.207172	12.42869	
0.348186	141.0619	21457.11	49.12135	0.004947	3.178742	12.31497	
0.266516	123.0922	18723.72	37.59959	0.004972	3.120699	12.08279	
0.238677	112.9094	17174.80	33.67204	0.005292	3.096742	11.98696	
0.185652	97.33572	14805.86	26.19140	0.005539	3.042186	11.76874	
0.134348	79.36605	12072.47	18.95355	0.006029	2.971952	11.48781	
0.100726	66.78728	10159.09	14.21032	0.006384	2.909409	11.23763	
0.060855	49.41659	7516.822	8.585392	0.007045	2.799987	10.79995	
0.028957	31.44692	4778.040	4.085238	0.008278	2.638223	10.15289	
0.020945	26.05602	3958.967	2.954932	0.008722	2.567888	9.871554	
0.013733	20.66512	3139.854	1.937493	0.009091	2.476235	9.504940	
0.006436	15.57371	2366.267	0.907993	0.007502	2.311656	8.846625	
0.004193	10.48230	1590.884	0.591638	0.010790	2.218150	8.472601	
0.003086	7.487363	1136.346	0.435394	0.015563	2.151563	8.206254	

122.2234

L 1/f	MDR 1/f	1/f	1/f/PM	1/f/L
100.7054	28.53628	14.44769	1.162446	0.143464
94.32410	27.99611	14.21767	1.154503	0.150732
82.52377	26.89328	14.18035	1.173614	0.171835
78.09482	26.43810	13.74514	1.166574	0.176005
68.87584	25.40155	13.43328	1.161404	0.195065
58.59126	24.06710	12.87785	1.121001	0.219791
50.73287	22.87877	12.51342	1.113706	0.246692
39.43370	20.79976	11.91370	1.103125	0.302119
27.17087	17.72626	10.99072	1.082520	0.404503
23.10833	16.38988	10.70757	1.084689	0.463364
18.71177	14.64846	10.48756	1.103380	0.560479
12.80962	11.52147	11.54536	1.305058	0.901303
10.32833	9.744858	9.626938	1.136243	0.932089
8.860203	8.479709	8.015801	0.976791	0.904697

P2P03445

Tw dyne/cm2	8*U*/D (1/s)	Log Tw	Log 8*U*/D
0.907993	85.45483	0.04191	1.931736
0.591638	57.51767	-0.22794	1.759801
0.435394	41.08405	-0.36111	1.613677

Regression Output:

Constant	-1.980909
Std Err of Y Est	0.010991
R Squared	0.997649
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	1.005861
Std Err of Coef.	0.048818

K' = 0.010254
n' = 1.005861

Tw@ = 0.596175
Res/f@ = 166.2426

Regression Output:

Constant	4.917227
Std Err of Y Est	0.127250
R Squared	0.992077
No. of Observations	10
Degrees of Freedom	8
X Coefficient(s)	6.034059
Std Err of Coef.	0.190689

t = 21.97142 deg C
s.d.)t = 0.036421 deg C

Page 1 Cyanamid 832A

P5P03448 12/30/89 12:38 density viscosity

1.0 PBID Taps 14 co)NaCl 1.000096 1.001592

S = 0 <C>(ppm)=5.577168 X coeff -0.00025 -0.02281

Z = 5.05 [NaCl]= 9.000308 constant 0.003419 -4.14933

MMD-40 Q)l (l/s)	MMD-40 Q)h (l/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.235	0.236	21.45	2.469444	-0.0335	2.506444	
0.218	0.219	21.5	2.187428	-0.0405	2.228428	
0.193	0.194	21.5	1.803333	-0.0415	1.844833	
0.177	0.177	21.5	1.546666	-0.0415	1.588166	
0.153	0.153	21.5	1.226142	-0.0415	1.268642	
0.125	0.126	21.4	0.8934	-0.0435	0.9369	
0.104	0.105	21.4	0.667888	-0.0435	0.711388	
0.076	0.077	21.4	0.397444	-0.0435	0.440944	
0.056	0.057	21.4	0.237375	-0.0435	0.280375	
0.038	0.039	21.4	0.083625	-0.0425	0.126125	
0.029	0.03	21.4	0.036571	-0.0425	0.078821	
0.024	0.025	21.4	0.017666	-0.042	0.059666	
0.017	0.018	21.4	0.001727	-0.0415	0.042727	
0.012	0.013	21.4	-0.01	-0.0405	0.0305	
				-0.0405		

Page 2 Cyanamid 832A

ID(cm) = 1.45796 Tap DL=

K(V/psi)= 9.6176 4

XS(cm2)= 1.669479 0.4

0 Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.260610	141.0619	21192.51	36.76633	0.003702	3.110414	12.04165	
0.251703	130.8791	19684.88	32.68819	0.003823	3.085376	11.94150	
0.191818	115.9043	17432.61	27.06134	0.004056	3.044356	11.77742	
0.165131	106.0210	15946.11	23.29637	0.004152	3.011825	11.64730	
0.131908	91.64532	13783.92	18.60936	0.004439	2.963047	11.45218	
0.097415	75.17312	11280.94	13.74312	0.004872	2.896239	11.18495	
0.073967	62.59435	9393.296	10.43516	0.005336	2.836445	10.94578	
0.045867	45.82266	6876.452	6.468090	0.006172	2.732584	10.55033	
0.029152	33.84288	5078.672	4.112742	0.007194	2.634262	10.13704	
0.013113	23.06107	3460.688	1.850092	0.006970	2.460793	9.443172	
0.008195	17.67017	2651.696	1.156209	0.007419	2.358714	9.034858	
0.006203	14.67523	2202.256	0.875233	0.008142	2.298258	8.793033	
0.004442	10.48230	1573.040	0.626756	0.011429	2.725745	8.502980	
0.003171	7.487363	1123.600	0.447395	0.015990	2.152542	8.210169	

122.2234

L 1/f	MDR 1/f	1/f	2/f/PK	1/f/L
80.59239	26.69786	16.43495	1.364841	0.203926
76.07763	26.22216	16.17171	1.354243	0.212548
69.22073	25.44276	15.74005	1.336460	0.227389
64.22523	24.82468	15.51776	1.332305	0.241614
57.40203	23.89789	15.00809	1.310500	0.261455
49.21744	22.62854	14.32538	1.280772	0.291063
42.88703	21.49247	13.66901	1.250619	0.319187
33.76481	19.51910	12.72854	1.208750	0.376976
26.92415	17.65097	11.78930	1.162991	0.437870
18.05814	14.35506	11.97759	1.268386	0.663279
14.27560	12.41557	11.60938	1.284954	0.813232
12.42047	11.26690	11.08178	1.260290	0.892218
10.51053	9.889155	9.353944	1.100078	0.889958
8.890192	8.498304	7.908050	0.963201	0.890526

P5P03448

Tw dyne/cm2	8 U /D (1/s)	Log Tw	Log 8 U /D
0.875233	80.52474	0.05787	1.905929
0.626754	57.51767	0.20290	1.759801
0.447395	41.08405	-0.34930	1.613673

Regression Output:

Constant	1.95820
Std Err of Y Est	0.000562
R Squared	0.999992
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	0.997180
Std Err of Coef.	0.002723

K' = 0.011010
n' = 0.997180

Tw@ = 1.120894
Res/f@ = 225.1496

Regression Output:

Constant	14.0082
Std Err of Y Est	0.076226
R Squared	0.999550
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	9.784681
Std Err of Coef.	0.078794

t = 21.43214 deg C
s.d.)t = 0.044749 deg C

Page 1 Cyanamid 832A

P1P13451 1/2/89 13:59 density viscosity

1.0 PSID Tape 14 co)NaCl 1.000096 1.001592

S = 8 <C>(ppm)= 10.017 X cosff -0.00025 -0.02281

Z = 5.05 [NaCl]= 0.000308 constant 0.003419 -4.14933

MMD-40 Q)l (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.267	0.268	20	2.002571	-0.0275	2.030071	
0.24	0.241	20	1.6194	-0.0375	1.6586	
0.207	0.208	20	1.2475	-0.0405	1.288	
0.187	0.188	20	1.0595	-0.0405	1.1005	
0.161	0.162	20	0.8501	-0.0415	0.8916	
0.13	0.131	20	0.580727	-0.0415	0.622727	
0.108	0.109	20	0.4008	-0.0425	0.4508	
0.08	0.081	20	0.236555	-0.0415	0.278055	
0.061	0.062	20	0.1593	-0.0415	0.2003	
0.04	0.041	20	0.0934	-0.0405	0.1334	
0.033	0.035	20	0.069666	-0.0395	0.109166	
0.03	0.031	20	0.059	-0.0395	0.0985	
0.025	0.026	20	0.0479	-0.0395	0.0869	
0.02	0.021	20	0.026888	-0.0395	0.046888	
0.014	0.015	20	0.012222	-0.0375	0.049722	
				-0.0375		

Page 2 Cyanamid 832A

ID(cm) = 1.45796 Tap DL=

K(V/psi)= 9.6176 ζ

XB(ca2)= 1.669479 0.4

0 Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.211078	160.2295	23297.47	29.77854	0.002323	3.050355	11.80142	
0.172454	144.0568	20945.95	24.32953	0.002348	3.006470	11.62588	
0.133921	124.2902	18071.87	19.89331	0.002449	2.951557	11.40623	
0.114425	112.3104	16330.00	16.14292	0.002563	2.917394	11.26957	
0.092705	96.73673	14065.57	13.07863	0.002799	2.871684	11.08673	
0.064748	78.16807	11365.68	9.134611	0.002994	2.793748	10.77499	
0.046872	64.99031	9449.628	6.612658	0.003135	2.723591	10.49436	
0.028911	40.21862	7011.014	4.078718	0.003513	2.618665	10.07466	
0.020824	36.83782	5356.241	2.938144	0.004336	2.547440	9.789760	
0.013870	24.25905	3527.280	1.956807	0.006660	2.459177	9.436710	
0.011350	20.36562	2961.173	1.601335	0.007733	2.415644	9.262578	
0.010241	18.26916	2656.347	1.444868	0.008670	2.393317	9.173271	
0.009035	15.27422	2220.880	1.274711	0.010943	2.366109	9.064438	
0.006954	12.27927	1785.413	0.981174	0.013033	2.309276	8.837106	
0.005169	8.685341	1262.853	0.729361	0.019366	2.244874	8.579499	

122.2234

L 1//f	MBR 1//f	1//f	1//f/PW	1//f/L
70.18355	25.55675	20.74691	1.758001	0.295609
63.43815	24.72293	20.63619	1.775021	0.325296
55.90332	23.67959	20.20437	1.771345	0.361416
51.67431	23.03049	19.75111	1.752604	0.382223
46.51196	22.16200	18.90047	1.704782	0.406357
38.87124	20.68122	18.27455	1.696015	0.470130
33.07285	19.34824	17.85760	1.701636	0.539947
25.97439	17.35464	16.87001	1.674699	0.649686
22.04551	16.00136	15.18518	1.551128	0.688810
17.99109	14.32437	12.25356	1.298699	0.681090
16.27513	13.49724	11.37153	1.227686	0.698706
15.45958	13.07303	10.73907	1.170692	0.694635
14.52076	12.55408	9.559049	1.054568	0.658303
12.73962	11.47625	8.759154	0.991179	0.687551
10.98385	10.25262	7.185848	0.837569	0.654218

P1P13451

Tw dyne/cs2	B'U'/D (1/s)	Log Tw	Log B'U'/D
1.956807	135.1123	0.291548	2.124218
1.601335	111.7486	0.204482	2.048242
1.444868	100.2450	0.159828	2.001063
1.274711	83.81147	0.105411	1.923305
0.981174	67.37784	-0.00825	1.828517
0.729361	47.65750	-0.13705	1.678131

Regression Output:

Constant	-1.74171
Std Err of Y Est	0.010553
R Squared	0.996758
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.953702
Std Err of Coef.	0.029220

K' = 0.018125
n' = 0.953702

Tw# = 3.098975
Res/f# = 362.2575

Regression Output:

Constant	8.18122
Std Err of Y Est	0.205813
R Squared	0.981753
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	9.535890
Std Err of Coef.	0.530728

t = 20 deg C
s.d.)t = 0 deg C

Cyanamid 832A

P2P13457 1/8/89 13:01

					density	viscosity
1.0 PSID	Taps 14			co)NaCl	1.000096	1.001592
S =	8	<C>(ppm)=	20.6882	X coeff	-0.00025	-0.02281
Z =	5.05	[NaCl]=	0.000309	constant	0.003419	-4.14933

MMD-40 θ)l (1/s)	MMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.249	0.25	20.5	1.3116	-0.1245	1.4361	
0.22	0.221	20.4	1.0484	-0.1245	1.1734	
0.196	0.197	20.4	0.872833	-0.1255	0.999333	
0.177	0.178	20.4	0.753288	-0.1275	0.881285	
0.153	0.154	20.4	0.601875	-0.1285	0.730375	
0.124	0.125	20.4	0.4275	-0.1285	0.556	
0.102	0.104	20.4	0.2999	-0.1285	0.4289	
0.088	0.09	20.4	0.250222	-0.1295	0.379722	
0.071	0.072	20.4	0.168875	-0.1295	0.298375	
0.054	0.055	20.4	0.092	-0.1295	0.221	
0.043	0.045	20.4	0.0527	-0.1285	0.1812	
0.035	0.036	20.45	0.019222	-0.1285	0.147222	
0.027	0.028	20.45	-0.00666	-0.1275	0.120333	
0.021	0.022	20.5	-0.02755	-0.1265	0.098944	
0.016	0.016	20.5	-0.048	-0.1265	0.0785	
0.012	0.013	20.5	-0.06018	-0.1265	0.066318	
				-0.1265		

Cyanamid 832A

ID(co) = 1.45796
K(V/psi)= 9.407
XS(ca2)= 1.669479

Tap DL=
4
0.4
Solvent

0 t)samp (sec)	DP (psid)	<U> (co/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.152662	149.4477	21976.29	21.53735	0.001931	2.984925	11.53970	
0.124736	132.0770	19378.16	17.59761	0.002020	2.940071	11.36028	
0.106232	117.7013	17268.97	14.98711	0.002167	2.905203	11.22081	
0.093684	106.3205	15599.20	13.21674	0.002342	2.877906	11.11162	
0.077641	91.94482	13490.01	10.95351	0.002595	2.837121	10.94848	
0.059104	74.57413	10941.41	8.338396	0.003003	2.777885	10.71154	
0.045593	61.69587	9051.932	6.432263	0.003385	2.721526	10.48610	
0.040365	53.31002	7821.572	5.694738	0.004013	2.695081	10.38032	
0.031718	42.82771	6283.622	4.474764	0.004886	2.642729	10.17091	
0.023493	32.64490	4789.614	3.314362	0.006229	2.577544	9.910177	
0.019262	26.35551	3866.844	2.717477	0.007836	2.534427	9.737709	
0.015650	21.26411	3123.361	2.207908	0.009781	2.489827	9.559510	
0.012791	16.47219	2419.505	1.804653	0.013323	2.446035	9.384135	
0.010518	12.87826	1893.748	1.483881	0.017923	2.404029	9.216116	
0.008344	9.383825	1409.301	1.177273	0.025676	2.353768	9.015073	
0.007049	7.487363	1101.016	0.994581	0.035539	2.317149	8.868598	

122.2234

L 1//f	MDR 1//f	1//f	1//f/PW	1//f/L
60.36786	24.31358	22.75247	1.971668	0.376897
54.44415	23.46135	22.24545	1.958177	0.408592
50.24391	22.79086	21.48143	1.914427	0.427542
47.18311	22.28022	20.66311	1.859594	0.437934
42.95376	21.50530	19.62868	1.792822	0.456972
37.47707	20.37982	18.24684	1.703675	0.486800
32.91594	19.30899	17.10759	1.639082	0.522166
30.97143	18.80654	15.78384	1.520554	0.509625
27.45424	17.81185	14.30476	1.404457	0.521040
23.62786	16.57334	12.66940	1.278423	0.536206
21.39475	15.75411	11.29612	1.160039	0.527985
19.30667	14.90672	10.11101	1.057713	0.523705
17.45475	14.07446	8.663489	0.923205	0.496339
15.84561	13.27655	7.469528	0.810485	0.471393
14.11394	12.32159	6.240732	0.692255	0.442167
12.97269	11.62584	5.304495	0.598121	0.408897

P2P13457

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
2.207908	116.6787	0.343981	2.066991
1.804653	90.38491	0.256393	1.956095
1.483881	70.66457	0.171399	1.849201
1.177273	52.58758	0.070877	1.720883
0.994581	41.08405	-0.00235	1.613673

Regression Output:

Constant	-1.24819
Std Err of Y Est	0.004299
R Squared	0.999282
No. of Observations	5
Degrees of Freedom	3
X Coefficient(s)	0.769132
Std Err of Coef.	0.011902

K' = 0.056467
n' = 0.769132

Regression Output:

Constant	-34.7115
Std Err of Y Est	0.234639
R Squared	0.955974
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	19.30190
Std Err of Coef.	2.930358

t = 20.43125 deg C
s.d.)t = 0.042847 deg C

P1P01346 12/25/88 14:06

1.0 PSID Tape 14 Tape 14 co)NaCl
B = 8 <C>(ppm)= 1.03135 X coeff
Z = 5.05 [NaCl] = 0.001033 constant

NMD-40 θ)l (1/s)	NMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.226	0.227	20.15	4.164571	0.0435	4.126071	
0.202	0.202	20.05	3.396833	0.0335	3.364333	
0.187	0.188	20.05	3.0125	0.0315	2.9815	
0.174	0.175	20	2.633833	0.0305	2.603833	
0.152	0.153	20	2.114571	0.0295	2.085071	
0.127	0.128	20	1.556	0.0295	1.527	
0.106	0.107	20	1.167333	0.0285	1.119333	
0.08	0.08	20	0.6978	0.0275	0.6698	
0.06	0.061	20.1	0.445	0.0285	0.4165	
0.041	0.042	20.05	0.244666	0.0285	0.215666	
0.033	0.034	20.1	0.169375	0.0295	0.139875	
0.024	0.024	20.1	0.083333	0.0295	0.054033	
0.014	0.015	20.1	0.0432	0.0295	0.0337	
0.021	0.022	20.1	0.07925	0.0295	0.04925	
0.028	0.029	20.1	0.116	0.0305	0.086	
				0.0295		

density viscosity
1.000125 1.001657 ID(cm) = 1.45796
-0.00025 -0.02281 K(V/psi)= 9.6176
0.005419 -4.14933 XB(cm2)= 1.669479 4
t)error= 0.4
0 Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.429012	135.9705	19836.49	60.52418	0.006557	3.205823	12.42329
	0.349810	120.9957	17612.08	49.35046	0.006751	3.160519	12.24207
	0.310004	112.6099	16391.44	43.73478	0.006907	3.134287	12.13715
	0.270734	104.8230	15240.78	38.19490	0.006962	3.104384	12.01753
	0.216797	91.64532	13324.80	30.58532	0.007293	3.056138	11.82455
	0.158771	76.67060	11147.54	22.39913	0.007631	2.988497	11.55398
	0.116383	64.09183	9318.653	16.41918	0.008005	2.921057	11.28422
	0.069643	47.91912	6967.217	9.825108	0.008570	2.809550	10.83820
	0.043306	36.53833	5324.502	6.109521	0.009166	2.707370	10.42948
	0.022424	25.15754	3661.917	3.163553	0.010011	2.563961	9.855847
	0.014543	20.36562	2967.755	2.051787	0.009908	2.470433	9.481732
	0.005620	14.37573	2094.886	0.792925	0.007685	2.263983	8.655932
	0.003503	8.984836	1309.303	0.494335	0.012265	2.161377	8.245511
	0.005120	13.17775	1920.312	0.722434	0.008332	2.243766	8.575064
	0.008941	17.37068	2531.320	1.261509	0.008373	2.364812	9.059248

Tap BL=

L 1//f	MDR 1//f	1//f	1//f/PK	1//f/L
100.3931	28.51065	12.34926	0.994040	0.123009
90.64819	27.64987	12.17000	0.994112	0.134552
85.14669	27.15146	12.03176	0.991317	0.141306
79.48119	26.58330	11.98458	0.997258	0.150785
71.12434	25.66662	11.70907	0.990234	0.164628
60.86635	24.38144	11.44674	0.990718	0.188063
52.11197	23.10009	11.17623	0.990429	0.214465
40.31163	20.98145	10.80212	0.996671	0.267965
31.06034	19.04003	10.44500	1.001488	0.327837
22.90033	16.31527	9.994169	1.014034	0.436420
18.46345	14.53822	10.04604	1.039515	0.544104
11.47791	10.61567	11.40715	1.317042	0.993834
9.062707	8.666180	9.029475	1.093077	0.996333
10.95585	10.23155	10.95483	1.277521	0.999907
14.47745	12.53143	10.92785	1.206265	0.754818

P1P01344

Tw dyne/cm2	8 U*/D (1/s)	Log Tw	Log 8 U*/D
0.792925	78.88138	-0.10076	1.896974
0.494335	49.30086	0.30597	1.692854
0.722434	72.30793	-0.14120	1.859105

Regression Output:

Constant	2.00062
Std Err of Y Est	0.001875
R Squared	0.999851
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	1.000902
Std Err of Coef.	0.012209

K' = 0.009985
n' = 1.000902

Tw8 = 0.000020
Res/t8 = 0.925987

Regression Output:

Constant	0.40088
Std Err of Y Est	0.035512
R Squared	0.996173
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	3.977577
Std Err of Coef.	0.100536

t = 20.06 deg C
s.d.)t = 0.048987 deg C

P2P01346 12/29/88 15:26

					density	viscosity
1.0 PSID Tape 14				co)NaCl	1.000125	1.001657
S =	0	<C>(ppm)=	2.0633	X coeff	-0.00025	-0.02281
Z =	5.05	[NaCl] =	0.001034	constant	0.003419	-4.14933

MMD-40 G)l (1/s)	MMD-40 G)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.243	0.244	21.7	3.914333	-0.0245	3.942333	
0.222	0.224	21.7	3.387857	-0.0315	3.419107	
0.196	0.198	21.7	2.727571	-0.031	2.759071	
0.181	0.182	21.7	2.365428	-0.032	2.396928	
0.157	0.158	21.7	1.845428	-0.031	1.877428	
0.129	0.13	21.7	1.329375	-0.033	1.362375	
0.108	0.109	21.7	0.9885	-0.033	1.0215	
0.081	0.082	21.7	0.591285	-0.033	0.624285	
0.061	0.062	21.7	0.362875	-0.033	0.395875	
0.041	0.042	21.7	0.173428	-0.033	0.206178	
0.034	0.034	21.7	0.108425	-0.0325	0.140875	
0.025	0.026	21.7	0.0266	-0.032	0.0576	
0.019	0.019	21.7	0.011923	-0.031	0.042423	
0.012	0.013	21.65	-0.0027	-0.0305	0.0278	
				-0.0305		

ID(cm) = 1.45796
K(V/psi)= 9.6176
XS(cm2)= 1.669479

Tap DL=
4
0.4
Solvent
0

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.409908	145.8538	22035.57	57.82898	0.005446	3.211202	12.44481	
0.355505	133.5745	20180.42	50.15392	0.005632	3.180282	12.32112	
0.286877	118.0008	17827.55	40.47204	0.005824	3.133707	12.13483	
0.249223	108.7165	16424.87	35.15987	0.005960	3.103153	12.01261	
0.195207	94.34077	14252.99	27.53947	0.006200	3.050107	11.80043	
0.141654	77.56908	11719.12	19.98429	0.006655	2.980474	11.52189	
0.106211	64.99031	9818.727	14.98409	0.007108	2.917945	11.27178	
0.064910	48.81760	7375.357	9.157472	0.007699	2.811017	10.84407	
0.041161	36.83782	5565.453	5.806979	0.008574	2.712105	10.44842	
0.021437	24.85804	3755.550	3.024375	0.009807	2.570447	9.881791	
0.014647	20.36562	3076.836	2.066455	0.009983	2.487743	9.550972	
0.005989	15.27422	2307.627	0.844918	0.007256	2.293537	8.774149	
0.004410	11.38079	1719.408	0.622292	0.009627	2.227127	8.508508	
0.002890	7.487363	1129.914	0.407790	0.014575	2.134855	8.139423	

122.2234

L 1//f	MDR 1//f	1//f	1//f/PK	1//f/L
101.6442	28.61285	13.54944	1.088762	0.133302
94.65912	28.02536	13.32440	1.081427	0.140761
85.03302	27.14044	13.10340	1.079817	0.154097
79.25628	26.55991	12.93234	1.078228	0.163423
70.14356	25.55204	12.69783	1.076218	0.181054
59.75227	24.22901	12.25803	1.063890	0.205147
51.73986	23.04095	11.86068	1.052246	0.229236
40.44807	21.00933	11.39633	1.050927	0.281752
32.20958	19.12999	10.79929	1.033581	0.335281
23.24491	16.43850	10.09777	1.021856	0.434407
19.21423	14.86711	10.00832	1.047085	0.520880
12.28619	11.17721	11.73692	1.337898	0.955456
10.54604	9.915416	10.19182	1.197838	0.966595
8.525815	8.162262	8.283038	1.017444	0.971524

P2P01346

Tw dyne/cm2	8 U /D (1/s)	Log Tw	Log 8 U /D
0.844918	83.81147	0.07318	1.923303
0.622292	62.44776	-0.20600	1.795516
0.407790	41.08405	-0.38956	1.613673

Regression Output:

Constant	-2.03766
Std Err of Y Est	0.001827
R Squared	0.999933
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	1.020955
Std Err of Coef.	0.008302

K' = 0.009169
n' = 1.020955

Tw# = 1.646760
Res/f# 274.4286

Regression Output:

Constant	-2.79709
Std Err of Y Est	0.041205
R Squared	0.998852
No. of Observations	10
Degrees of Freedom	8
X Coefficient(s)	1.292519
Std Err of Coef.	0.065049

t = 21.69642 deg C
s.d.)t = 0.012876 deg C

Page 1 Cyanamid 832A

P5P01349 12/30/88 14:17 density viscosity
1.0 PSID Taps 14 co)NaCl 1.000125 1.001657
B = 0 <C>(ppm)=5.577168 X coeff -0.00025 -0.02281
Z = 5.05 [NaCl]= 0.001034 constant 0.003419 -4.14933

HMD-40 0)1 (1/s)	HMD-40 0)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.22	0.221	21.1	2.695857	-0.0355	2.734107	
0.205	0.206	21.1	2.424857	-0.041	2.466107	
0.183	0.185	21.1	2.032333	-0.0415	2.073333	
0.17	0.17	21.1	1.78	-0.0405	1.82075	
0.148	0.149	21.1	1.427	-0.041	1.46775	
0.121	0.122	21.1	1.03775	-0.0405	1.079	
0.102	0.103	21.1	0.788	-0.042	0.82975	
0.075	0.076	21.1	0.44475	-0.0415	0.50625	
0.056	0.057	21.1	0.277	-0.0415	0.318	
0.037	0.038	21.1	0.127	-0.0405	0.1675	
0.028	0.03	21.1	0.039272	-0.0405	0.078522	
0.025	0.026	21.1	0.022875	-0.04	0.062375	
0.017	0.018	21.1	0.005	-0.039	0.0435	
0.012	0.012	21.1	-0.01	-0.0385	0.0285	
				-0.038		

Page 2 Cyanamid 832A

[illegible](cm) = 1.45796
K(V/psi)= 9.6176
XS(cm2)= 1.669479

Tap DL=
4
0.4
Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
	0.284281	132.0770	19685.90	40.10585	0.004606	3.125829	12.10331
	0.254414	123.0922	18346.73	36.17463	0.004783	3.103427	12.01370
	0.215576	110.2139	16427.24	30.41314	0.005016	3.065755	11.86302
	0.189314	101.8281	15177.34	26.70807	0.005160	3.037546	11.75018
	0.152610	88.94987	13257.85	21.53001	0.005451	2.990747	11.56298
	0.112190	72.77717	10847.33	15.82754	0.005987	2.923931	11.29572
	0.086274	61.39638	9151.045	12.17137	0.006469	2.866894	11.06757
	0.052637	45.22367	6740.524	7.426039	0.007274	2.759603	10.63841
	0.033064	33.84288	5044.234	4.664652	0.008159	2.658654	10.23453
	0.017415	22.46209	3347.943	2.457010	0.009756	2.519428	9.677714
	0.008164	17.37068	2589.076	1.151827	0.007648	2.354918	9.019675
	0.006485	15.27422	2276.601	0.914961	0.007857	2.304926	8.819706
	0.004522	10.48230	1562.373	0.638089	0.011634	2.226665	8.506663
	0.002963	7.187848	1071.341	0.418058	0.016211	2.134843	8.139374

122.2234

L 1//f	MDR 1//f	1//f	1//f/PK	1//f/L
83.50433	26.99075	14.73419	1.217368	0.176448
79.30621	26.56511	14.45877	1.203522	0.182315
72.71697	25.84936	14.11916	1.190182	0.194165
68.14381	25.31338	13.92032	1.184689	0.204278
61.18251	24.42419	13.54334	1.171267	0.221359
52.45803	23.15470	12.92382	1.144134	0.246365
46.00180	22.07100	12.43299	1.123570	0.270271
35.93219	20.03247	11.72438	1.102089	0.326291
28.47834	18.11406	11.07032	1.081663	0.388727
20.66848	15.44914	10.12393	1.046108	0.489824
14.15138	12.34345	11.43473	1.267754	0.808029
12.61265	11.39360	11.28133	1.279105	0.894645
10.53284	9.906651	9.270838	1.089832	0.880183
8.525375	8.162029	7.853883	0.964924	0.921214

P5P01349

Tw dyne/cm2	8*U*/D (1/s)	Log Tw	Log 8*U*/D
0.914961	83.81147	-0.03859	1.923303
0.638089	57.51767	-0.19511	1.759801
0.418058	39.44069	-0.37876	1.595944

Regression Output:

Constant	-2.09273
Std Err of Y Est	0.010922
R Squared	0.997942
No. of Observations	3
Degrees of Freedom	1
X Coefficient(s)	1.039150
Std Err of Coef.	0.047185

K' = 0.009273
n' = 1.039150

Tw# = 3.192290
Res/f# = 376.9381

Regression Output:

Constant	-12.5079
Std Err of Y Est	0.040061
R Squared	0.996974
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	8.699813
Std Err of Coef.	0.239636

t = 21.1 deg C
s.d.)t = ERR deg C

P1P11352 1/2/89 15:50

				density	viscosity
1.0 PSID Taps 14			co)NaCl	1.000125	1.001657
S =	0	<C>(ppa)= 10.017	X coeff	-0.00025	-0.02281
Z =	5.65	[NaCl]= 0.001014	constant	0.003419	-4.14953

MMD-40 θ)1 (1/s)	MMD-40 θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>corr (volts)	Batch Vol (ml)
0.257	0.258	19.7	2.3815	-0.0345	2.423	
0.234	0.233	19.7	2.011375	-0.0465	2.058375	
0.201	0.202	19.7	1.568272	-0.0475	1.615772	
0.183	0.184	19.7	1.3908	-0.0475	1.4383	
0.157	0.158	19.7	1.032888	-0.0475	1.080388	
0.128	0.129	19.7	0.762875	-0.0475	0.810425	
0.106	0.107	19.7	0.550142	-0.048	0.597892	
0.078	0.079	19.7	0.333875	-0.0475	0.381375	
0.06	0.061	19.7	0.179555	-0.0475	0.227055	
0.039	0.04	19.7	0.075	-0.0475	0.12	
0.035	0.036	19.7	0.058888	-0.0465	0.105388	
0.029	0.03	19.7	0.040777	-0.0465	0.087277	
0.023	0.024	19.7	0.024545	-0.0465	0.070545	
0.016	0.017	19.7	0.005142	-0.0455	0.050142	
0.012	0.013	19.7	-0.007	-0.0445	0.0375	
				-0.0465		

ID(cm) = 1.45796 Tap DL=
K(V/psi)= 9.6176 4
XS(cm2)= 1.669479 0.4
Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.251933	154.2396	22274.46	35.54230	0.002992	3.085798	11.94319	
0.214021	139.8639	20198.40	30.19372	0.003091	3.050384	11.80153	
0.168001	120.6962	17430.31	23.70131	0.003258	2.997812	11.59124	
0.149548	109.9144	15873.26	21.09801	0.003497	2.972546	11.49018	
0.112334	94.34077	13624.18	15.84792	0.003566	2.910412	11.24164	
0.094285	76.97009	11115.60	11.89083	0.004019	2.848032	10.99212	
0.062166	63.79233	9212.546	8.770322	0.004316	2.781933	10.72773	
0.039653	47.02064	6790.468	5.594282	0.005067	2.684298	10.33719	
0.023608	36.23883	5233.418	3.330614	0.005079	2.571688	9.886753	
0.012477	23.66006	3416.860	1.760246	0.006297	2.433712	9.332851	
0.010957	21.26411	3070.848	1.545920	0.006847	2.405019	9.220078	
0.009074	17.67017	2551.832	1.280253	0.008211	2.364074	9.056296	
0.007335	14.07624	2032.815	1.034811	0.010459	2.317856	8.8/1426	
0.005213	9.883519	1427.295	0.735531	0.015080	2.243726	8.574906	
0.003899	7.487363	1081.284	0.550076	0.019651	2.180637	8.322551	

122.2234

L 1/f	MBR 1/f	1/f	1/f/PK	1/f/L
76.15157	26.23017	18.28135	1.530692	0.240065
70.18825	25.55730	17.90591	1.524031	0.256252
62.18595	24.55843	17.51833	1.511341	0.281708
58.67146	24.07839	16.90905	1.471607	0.288198
50.85015	22.89783	16.74551	1.489395	0.329310
44.04650	21.71241	15.77251	1.434892	0.358087
37.82804	20.45674	15.22109	1.418854	0.402375
30.21191	18.60166	14.04757	1.358935	0.464968
23.31139	16.46207	14.03127	1.419199	0.601906
16.94699	13.83104	12.60127	1.350206	0.743569
15.88179	13.29537	12.08478	1.310702	0.760920
14.45284	12.51740	11.03514	1.218505	0.763526
12.99381	11.63927	9.777802	1.102167	0.752496
10.95485	10.23080	8.143054	0.949637	0.743328
9.473660	9.032118	7.133493	0.857128	0.752981

P1P11352

Tw dyne/cm2	BKU/D (1/s)	Log Tw	Log BKU/D
1.760246	129.8256	0.245573	2.113360
1.545920	116.6787	0.189187	2.066991
1.280253	96.95836	0.107295	1.986585
1.034811	77.23802	0.014861	1.887831
0.735531	54.23095	-0.13339	1.734247
0.550076	41.08405	-0.25957	1.613673

Regression Outputs:

Constant	1.86264
Std Err of Y Est	0.005307
R Squared	0.999402
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	0.994485
Std Err of Coef.	0.012158

K' = 0.013720
n' = 0.994485

Tw@ = 0.380571
Res/f@ = 126.0793

Regression Outputs:

Constant	-14.0339
Std Err of Y Est	0.157973
R Squared	0.989880
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	10.49035
Std Err of Coef.	0.433023

t = 19.7 deg C
s.d.)t = 0.000000 deg C

Page 1 Cyanamid 832A

P2P11358 1/8/89 14:41

					density	viscosity
1.0 PSID	Taps 14			co)NaCl	1.000125	1.001657
S =	0	<C>(ppm)=	20.6882	X coeff	-0.00025	-0.02281
Z =	5.05	[NaCl]=	0.001031	constant	0.003419	-4.14933

NMD-40 0)l (1/s)	NMD-40 0)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.245	0.246	20.4	1.2545	-0.1255	1.383	
0.214	0.215	20.4	0.992375	-0.1315	1.123875	
0.192	0.193	20.4	0.8366	-0.1315	0.9681	
0.167	0.168	20.4	0.669428	-0.1315	0.800928	
0.138	0.14	20.4	0.467777	-0.1315	0.599277	
0.102	0.103	20.4	0.2702	-0.1315	0.4017	
0.073	0.073	20.45	0.144636	-0.1315	0.276636	
0.045	0.046	20.5	0.040090	-0.1325	0.172090	
0.036	0.037	20.5	0.0071	-0.1315	0.1381	
0.029	0.029	20.55	-0.021	-0.1305	0.109	
0.021	0.023	20.55	-0.041	-0.1295	0.0885	
0.016	0.017	20.6	-0.06008	-0.1295	0.068111	
0.011	0.012	20.6	-0.07633	-0.1295	0.052166	
				-0.1285		

Page 2 Cyanamid 832A

ID(cm) = 1.45796 Tap DL=
K(V/psi)= 9.407 4
X8(cm2)= 1.669479 0.4
Solvent
0

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.147018	167.0518	21574.46	20.74101	0.001921	2.975737	11.50294	
0.119472	128.4831	18850.19	16.85488	0.002045	2.930685	11.32274	
0.102912	115.3053	16916.83	14.51870	0.002187	2.898286	11.19314	
0.085141	100.3306	14719.84	12.01161	0.002390	2.857123	11.02849	
0.063705	83.25948	12215.27	8.987438	0.002597	2.794140	10.77656	
0.042702	61.39638	9007.667	6.024341	0.003201	2.707277	10.42910	
0.029407	43.72620	6422.457	4.148747	0.004346	2.626773	10.10709	
0.018293	27.25400	4007.556	2.580867	0.006960	2.524190	9.696762	
0.014690	21.86310	3214.852	2.071101	0.008679	2.476408	9.505633	
0.011587	17.37068	2557.149	1.634685	0.010852	2.425517	9.302069	
0.009407	13.17775	1939.906	1.327244	0.015310	2.380275	9.121103	
0.007240	9.883319	1456.572	1.021470	0.020948	2.323905	8.895622	
0.005545	6.898374	1015.196	0.782349	0.033028	2.265993	8.663973	

122.2234

L 1/s	MDR 1/s	1/s	1/s/PW	1/s/L
59.10407	24.13901	22.81405	1.983322	0.385998
53.28014	23.28302	22.11212	1.952894	0.415016
49.45002	22.66744	21.38123	1.910207	0.432380
44.97832	21.88534	20.45408	1.854658	0.454754
38.90434	20.68966	19.42288	1.820685	0.504362
31.83350	19.03824	17.67400	1.694680	0.554852
26.46388	17.50869	15.16797	1.500725	0.573157
20.39435	15.55961	11.70841	1.236125	0.573612
18.71924	14.65175	10.73378	1.129202	0.573408
16.44935	13.68483	9.599281	1.031951	0.576555
15.00222	12.82523	8.081742	0.886048	0.538702
13.17606	11.75420	6.909175	0.776693	0.524373
11.53116	10.65387	5.502405	0.635090	0.477176

P2P11358

Tw dyne/cm2	8<U>/D (1/s)	Log Tw	Log 8<U>/D
2.071101	119.9654	0.316201	2.079056
1.634685	95.31500	0.213434	1.979161
1.327244	72.30793	0.122951	1.859185
1.021470	54.23095	0.009225	1.734247
0.782349	37.79732	-0.10659	1.577461

Regression Output:

Constant	-1.38145
Std Err of Y Est	0.006945
R Squared	0.998331
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	0.806261
Std Err of Coef.	0.023304

K' = 0.041547
n' = 0.806261

Regression Output:

Constant	-36.7415
Std Err of Y Est	0.115000
R Squared	0.991368
No. of Observations	4
Degrees of Freedom	2
X Coefficient(s)	20.04210
Std Err of Coef.	1.322344

t = 20.47307 deg C
s.d.)t = 0.077497 deg C

Page 1 Cyanamid 832A

P2P01147 12/29/88 16:31 density viscosity
1.0 PSID Taps 14 co)NaCl 1.00417 1.010869
S = 0 <C>(ppm)= 2.0433 X coeff -0.00025 -0.02281
Z = 5.05 [NaCl] = 0.104675 constant 0.003419 -4.14933

MMD-40 Θ)l (1/s)	MMD-40 Θ)h (1/s)	Temp (deg C)	<V> (volts)	<V>c (volts)	<V>)corr (volts)	Batch Vol (ml)
0.208	0.228	21.3	3.819166	-0.0295	3.850416	
0.184	0.189	21.3	2.894	-0.033	2.927	
0.153	0.164	21.3	2.126733	-0.033	2.160483	
0.139	0.143	21.3	1.7788	-0.0345	1.8133	
0.123	0.125	21.3	1.411	-0.0345	1.4465	
0.105	0.106	21.3	1.061857	-0.0365	1.097857	
0.089	0.09	21.3	0.783875	-0.0355	0.819125	
0.067	0.068	21.3	0.465625	-0.035	0.500875	
0.049	0.051	21.3	0.253571	-0.0355	0.289571	
0.033	0.035	21.3	0.112714	-0.0345	0.147214	
0.026	0.028	21.3	0.042375	-0.0345	0.076875	
0.02	0.022	21.3	0.014	-0.0345	0.04775	
0.013	0.014	21.3	-0.00775	-0.033	0.0255	
0.157	0.158	21.2	2.153555	-0.0335	2.188055	
0.148	0.15	21.2	1.967555	-0.0355	2.003055	
0.134	0.137	21.2	1.692833	-0.0355	1.728333	

Page 2 Cyanamid 832A

ID(cm) = 1.45796 Tap DL=
K(V/psi)= 9.6176 4
XS(cm2)= 1.669479 0.4
0 Solvent

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.400351	130.5796	19450.91	56.48068	0.006609	3.199039	12.39615	
0.304337	113.2089	16863.40	42.93534	0.006685	3.139497	12.15798	
0.224638	94.93976	14142.06	31.69152	0.007016	3.073561	11.89424	
0.188539	85.65543	12759.08	26.59878	0.007234	3.035520	11.74208	
0.150401	74.87363	11153.04	21.21830	0.007552	2.986445	11.54578	
0.114150	63.49284	9457.783	16.10415	0.007971	2.926558	11.30623	
0.085169	53.90901	8030.193	12.01551	0.008250	2.862961	11.05184	
0.052079	40.73125	6067.257	7.347194	0.008837	2.756150	10.62460	
0.030004	30.54844	4550.443	4.232973	0.009051	2.636412	10.14565	
0.015306	20.96461	3122.853	2.159445	0.009804	2.490260	9.561043	
0.007993	16.77169	2498.282	1.127657	0.007999	2.349178	8.996714	
0.004964	13.17775	1962.936	0.700431	0.008048	2.245772	8.587090	
0.002651	8.385847	1249.141	0.374052	0.010614	2.109556	8.038224	
0.227505	94.64027	14065.68	32.09597	0.007150	3.075329	11.90131	
0.208269	89.84836	13353.49	29.38226	0.007262	3.056147	11.82458	
0.179705	82.06150	12196.19	25.35243	0.007512	3.024114	11.69645	

122.2234

L 1/f	MDR 1/f	1/f	1/f/PK	1/f/L
98.83706	28.38175	12.29985	0.992231	0.124445
86.17421	27.25044	12.23060	1.005972	0.141928
74.03574	25.99766	11.93854	1.003724	0.161253
67.82672	25.27489	11.75706	1.001275	0.173339
60.57943	24.34245	11.50663	0.996609	0.189942
52.77629	23.20461	11.20032	0.990632	0.212222
45.58700	21.99626	11.00943	0.996162	0.241503
35.64763	19.96686	10.63755	1.001210	0.298408
27.05781	17.69184	10.51092	1.036003	0.388461
19.32595	14.91495	10.09928	1.056295	0.522576
13.96556	12.23439	11.18054	1.242736	0.800579
11.00658	10.26968	11.14637	1.298643	1.012700
8.043333	7.681565	9.706339	1.207522	1.206755
74.33784	26.03126	11.82580	0.993655	0.159081
71.12582	25.66679	11.73404	0.992342	0.164975
66.06851	25.05817	11.53744	0.986405	0.174628

P2P01147

Iw# = 0.001614
Res/f# = 0.455411

Regression Output:

Constant	-0.38124
Std Err of Y Est	0.075275
R Squared	0.979942
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	7.979770
Std Err of Coef.	0.189790

t = 21.28125 deg C
s.d.)t = 0.039031 deg C

Cyanamid 832A

PSP01150 12/30/89 16:10

					density	viscosity
1.0 PSID	Tape 14			co)NaCl	1.00417	1.010869
S =	0	<C>(ppm)=	5.577168	X coeff	-0.00025	-0.02281
Z =	5.05	[NaCl]=	0.104287	constant	0.003419	-4.14933

MMD-40 Q)l (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.16	0.216	20.6	2.926428	-0.0355	2.962928	
0.14	0.15	20.6	1.9215	-0.0375	1.96	
0.123	0.131	20.6	1.504777	-0.0395	1.544277	
0.11	0.115	20.6	1.195	-0.0395	1.2345	
0.099	0.102	20.6	0.958777	-0.0395	0.998277	
0.084	0.088	20.6	0.722090	-0.0395	0.761590	
0.073	0.075	20.6	0.5489	-0.0395	0.5884	
0.058	0.06	20.6	0.356777	-0.0395	0.396277	
0.045	0.047	20.6	0.215285	-0.0395	0.254285	
0.031	0.033	20.6	0.09025	-0.0385	0.12875	
0.038	0.039	20.6	0.147142	-0.0385	0.185642	
0.025	0.027	20.65	0.025181	-0.0385	0.063681	
0.015	0.018	20.7	-0.00127	-0.0385	0.036227	
0.01	0.012	20.7	-0.01433	-0.0365	0.022166	
0.11	0.115	20.6	1.205090	-0.0365	1.243090	
0.103	0.106	20.6	1.0353	-0.0395	1.0948	
0.094	0.098	20.6	0.888181	-0.0395	0.927681	
				-0.0395		

Cyanamid 832A

ID(cm) = 1.45796
K(V/psi)= 9.6176
XB(cm2)= 1.669479

Tap DL=
4
0.4
Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.308073	112.4099	16511.36	43.46236	0.006838	3.135250	12.14100	
0.203793	89.84836	13173.96	28.75069	0.007105	3.045517	11.78207	
0.140567	78.46756	11505.25	22.65257	0.007340	2.993752	11.57500	
0.128358	68.88374	10100.03	18.10853	0.007614	2.945135	11.38054	
0.103796	61.09688	8958.293	14.64345	0.007826	2.899015	11.19606	
0.079187	51.51306	7553.071	11.17156	0.008399	2.840250	10.96100	
0.061179	44.32319	6499.154	8.631074	0.008764	2.784225	10.73690	
0.041203	35.34035	5181.758	5.812887	0.009285	2.698389	10.39355	
0.026439	27.55349	4040.014	3.730045	0.009802	2.602050	10.00820	
0.013386	19.16765	2810.445	1.888597	0.010255	2.454263	9.417052	
0.019302	23.06107	3381.316	2.723143	0.010216	2.533728	9.734914	
0.006621	15.57371	2286.063	0.934130	0.007684	2.301889	8.807559	
0.003766	9.883319	1452.408	0.531407	0.010854	2.179892	8.319570	
0.002304	6.588879	968.2724	0.325156	0.014943	2.073224	7.892899	
0.129251	67.38627	9880.471	18.23455	0.008011	2.946641	11.38656	
0.113832	62.59435	9177.859	16.05931	0.008177	2.919056	11.27622	
0.096456	57.50295	8431.335	13.60790	0.008210	2.883089	11.13235	

122.2234

L I/f	MDR I/f	I/f	I/f/PE	I/f/L
85.33559	27.16975	12.09296	0.996043	0.141710
69.40610	25.46483	11.86311	1.006878	0.170925
61.60732	24.48129	11.67196	1.008574	0.189457
55.08269	23.55756	11.46099	1.004989	0.208052
49.53307	22.68129	11.30342	1.009389	0.228199
43.26438	21.56475	10.91121	0.995457	0.252198
38.02821	20.50029	10.68146	0.994856	0.280862
31.20825	18.86939	10.37737	0.998443	0.332520
24.99945	17.03896	10.10025	1.009197	0.404019
17.78845	14.23100	9.874426	1.040568	0.555096
21.36036	15.74084	9.893663	1.016397	0.463178
12.52477	11.33590	11.40770	1.295217	0.910811
9.457418	9.017959	9.598342	1.153706	1.014900
7.397841	6.991274	9.100363	1.036420	1.105777
55.27402	23.50617	11.17214	0.981169	0.202122
51.87247	23.06208	11.03819	0.980644	0.213180
47.74935	22.37869	11.03588	0.991336	0.231120

P5P01150

Tw8 = 7.720768
Res/f8 = 399.9017

Regression Output:

Constant	-0.21894
Std Err of Y Est	0.121342
R Squared	0.961117
No. of Observations	12
Degrees of Freedom	10
X Coefficient(s)	3.930414
Std Err of Coef.	0.249991

t = 20.61470 deg C
s.d.)t = 0.033275 deg C

Page 1 Cyanamid 832A

P1P11153 1/2/89 17:10

						density	viscosity
1.0 PSID Taps 14					co)NaCl	1.00417	1.010869
S =	8	<C>(ppm)=	10.017	X coeff		-0.00025	-0.02281
Z =	5.05	[NaCl]=	0.104987	constant		0.003419	-4.14933

MMD-40 Q)l (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.238	0.241	19.5	3.245625	-0.0435	3.293125	
0.215	0.218	19.4	2.807333	-0.0515	2.858833	
0.186	0.19	19.4	2.2845	-0.0515	2.3355	
0.168	0.17	19.4	1.92725	-0.0505	1.97775	
0.14	0.144	19.4	1.514644	-0.0505	1.565144	
0.108	0.112	19.45	1.013777	-0.0505	1.064277	
0.084	0.088	19.45	0.685142	-0.0505	0.735642	
0.056	0.058	19.5	0.3225	-0.0505	0.372	
0.036	0.041	19.5	0.122375	-0.0485	0.170375	
0.015	0.021	19.5	-0.01154	-0.0475	0.035454	
0.025	0.029	19.5	0.015	-0.0465	0.062	
0.227	0.228	19.5	3.0255	-0.0475	3.073	
				-0.0475		

Page 2 Cyanamid 832A

ID(cm) = 1.45796
K(V/psi)= 9.6176
XS(cm2)= 1.669479

Tap DL=
4
0.4
Solvent

0 t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.342406	143.4578	20518.85	48.30592	0.004681	3.147356	12.18942	
0.297250	129.6811	18506.56	41.93542	0.004973	3.115661	12.06244	
0.242834	113.2089	16155.84	34.25879	0.005331	3.071757	11.88702	
0.205638	101.2291	14446.23	29.01106	0.005646	3.035652	11.74261	
0.162739	85.05644	12138.25	22.95099	0.006329	2.984847	11.53939	
0.110459	65.88879	9413.485	15.61159	0.007172	2.901587	11.20634	
0.076489	51.51306	7359.634	10.79093	0.008110	2.821393	10.88557	
0.038479	34.14237	4883.402	5.456763	0.009336	2.673823	10.29529	
0.017714	23.04107	3298.438	2.499183	0.009373	2.504255	9.617021	
0.003686	10.78180	1542.127	0.520072	0.008923	2.163388	8.253553	
0.006446	16.17270	2313.190	0.909460	0.006935	2.284748	8.738993	
0.319518	136.2700	19490.77	45.07697	0.004841	3.132333	12.12933	

122.2234

L 1//f	MDR 1//f	1//f	1//f/P%	1//f/L
87.74786	27.39977	14.61492	1.190984	0.166555
81.57210	26.79757	14.17960	1.175497	0.173829
73.72880	25.96338	13.69533	1.152124	0.185752
67.84735	25.27740	13.30765	1.133279	0.196141
60.35698	24.31210	12.56923	1.089245	0.208248
49.82729	22.73015	11.80764	1.053656	0.236971
41.42603	21.20647	11.10357	1.020026	0.268033
29.49197	18.40265	10.34900	1.005216	0.350909
19.95884	15.18085	10.32887	1.074020	0.517508
9.104757	8.704379	10.58599	1.282598	1.162688
12.04004	11.01021	12.00779	1.374047	0.997320
84.76444	27.11434	14.37127	1.184836	0.169543

P1P11153

Tw8 = 10.11657
Res/f8 = 642.4987

Regression Output:

Constant	-19.6917
Std Err of Y Est	0.100778
R Squared	0.994617
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	10.87045
Std Err of Coef.	0.326461

t = 19.45833 deg C
s.d.)t = 0.044876 deg C

Page 1 Cyanamid 832A

P2P11159 1/6/89 16:23

					density	viscosity
1.0 PSID	Taps 14			c0)NaCl	1.004:7	1.010869
B =	B	<C>(ppm)=	20.6882	X coeff	-0.00025	-0.02281
Z =	5.05	[NaCl]=	0.104734	constant	0.003419	-4.14933

MMD-40 Q)l (1/s)	MMD-40 Q)h (1/s)	Temp (deg C)	<V> (volts)	<V>o (volts)	<V>)corr (volts)	Batch Vol (ml)
0.258	0.239	20.65	2.143	-0.1285	2.274	
0.213	0.214	20.55	1.820375	-0.1335	1.953875	
0.189	0.191	20.5	1.6003	-0.1335	1.7333	
0.173	0.174	20.5	1.368	-0.1325	1.5205	
0.149	0.15	20.5	1.126428	-0.1325	1.258928	
0.122	0.123	20.5	0.845	-0.1325	0.9775	
0.101	0.102	20.55	0.644285	-0.1325	0.776785	
0.074	0.075	20.6	0.384888	-0.1325	0.517388	
0.056	0.057	20.6	0.214164	-0.1325	0.346664	
0.043	0.045	20.65	0.099571	-0.1325	0.232071	
0.035	0.036	20.65	0.026363	-0.1325	0.158863	
0.03	0.03	20.7	-0.0324	-0.1325	0.0996	
0.024	0.025	20.7	-0.07263	-0.1315	0.058863	
0.017	0.018	20.75	-0.0888	-0.1315	0.0427	
0.011	0.013	20.75	-0.1022	-0.1315	0.0288	
				-0.1305		

Page 2 Cyanamid 832A

ID(cm) = 1.45796 Tap DL=
K(V/psi)= 9.407 4
X8(cm2)= 1.669479 0.4
Solvent
0

t)samp (sec)	DP (psid)	<U> (cm/s)	Re	Tw dyne/cm2	f	Log(Re/f)	1//f
0.241734	142.8588	20970.23	34.10344	0.003333	3.087085	11.93234	
0.207704	127.8841	18729.79	29.30249	0.003574	3.049153	11.79661	
0.184256	114.4069	16737.04	25.99450	0.003962	3.022649	11.69059	
0.161634	103.9246	15203.54	22.80311	0.004212	2.994205	11.57682	
0.133828	89.54886	13100.46	18.88029	0.004697	2.953212	11.41285	
0.103911	73.37616	10734.49	14.65968	0.005432	2.898270	11.19308	
0.082575	60.79739	8904.330	11.64954	0.006287	2.848855	10.99542	
0.055000	44.62468	6543.067	7.75934[illegible]	0.007774	2.761105	10.64442	
0.036851	33.84288	4962.192	5.199000	0.009056	2.674153	10.29661	
0.024670	26.35551	3868.723	3.480402	0.009996	2.587500	9.950003	
0.016887	21.26411	3121.356	2.382496	0.010512	2.505202	9.620808	
0.010587	17.96967	2640.743	1.493712	0.009229	2.404312	9.217248	
0.006257	14.67523	2156.606	0.882784	0.008178	2.290106	8.760424	
0.004539	10.48230	1542.172	0.640376	0.011628	2.220889	8.483556	
0.003061	7.187868	1057.489	0.431916	0.016679	2.135571	8.141485	

122.2234

L 1//t	MBR 1//t	1//t	1//t/PK	1//t/L
75.67722	26.17861	17.31881	1.451418	0.228851
69.98954	25.53391	16.72553	1.417825	0.238971
65.84594	25.03033	15.88455	1.353917	0.241268
61.67162	24.48990	15.40775	1.330914	0.249835
56.11677	23.71104	14.59062	1.278438	0.260004
49.44821	22.66714	13.56784	1.212163	0.274384
44.13015	21.72825	12.61089	1.146922	0.285765
36.05669	20.06101	11.34163	1.065499	0.314549
29.51436	18.40891	10.50900	1.020529	0.356030
24.17579	16.76251	10.00154	1.005179	0.413700
20.00240	15.19884	9.753065	1.013766	0.487594
15.85594	13.28193	10.40911	1.129308	0.656480
12.18950	11.11201	11.05770	1.262233	0.907149
10.39367	9.796893	9.273500	1.093114	0.892225
8.535941	8.172056	7.742917	0.951044	0.907095

P2P11159

Tw dyne/cm2	8(U)/D (1/s)	Log Tw	Log 8·U /D
2.382496	116.6787	0.377032	2.066991
1.493712	98.60172	0.174267	1.993884
0.882784	80.52474	-0.05414	1.905929
0.640376	57.51767	-0.19356	1.759801
0.431916	39.44069	-0.36459	1.595944

Regression Output:

Constant	1.96214
Std Err of Y Est	0.005655
R Squared	0.999338
No. of Observations	5
Degrees of Freedom	1
X Coefficient(s)	1.002366
Std Err of Coef.	0.025787

K' = 0.010910
n' = 1.002366

Tw0 = 7.435025
Res/f0 = 565.3629

Regression Output:

Constant	44.7502
Std Err of Y Est	0.111520
R Squared	0.996354
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	20.11373
Std Err of Coef.	0.544102

t = 20.61 deg C
s.d.)t = 0.087939 deg C

APPENDIX G

NOMENCLATURE

Latin Symbols

a	Effective backbone chain link length; Mark-Houwink-Kuhn-Surada(MHKS) exponent in equations 2.4-7, 2.4-8, and 2.4-9
A	Dimensionless slope in equations 5.1-1 and 5.2-1; dimensionless constant in equation 2.4-12; dimensionless lin charge density in Appendix A
Å	Angstrom, 10^{-8} cm
b	Polyion effective radius in Appendix A
B	Dimensionless intercept in equations 5.1-1 and 5.2-1; dimensionless constant in equation 2.4-12.
ΔB	Dimensionless upward shift of the mean-velocity profile above Newtonian
C	Constant in equation 3.1-1
c	Polymer concentration in weight parts-per-million(wppm)
c_i	Concentration of species i
C_p	Injected polymer concentration
$<C>$	Average concentration in injection experiment assuming total dissolution
C_{uv}	u-v correlation coefficient, $-<uv>/(u'v')$
d	Additive diameter
D	Pipe inner diameter
D_h	Hydraulic diameter
DR	Drag reduction
e	Standard error
f	Fanning friction factor, $2T_w/(\rho u_\tau^2)$

Latin Symbols(continued)

f_o	Macromolecular friction coefficient
$1/\sqrt{f}$	Prandtl-Karman ordinate, $<\overline{U}>/(\sqrt{2}u_\tau)$
F	Bursting frequency, $1/T_{bb}$
G	Elastic modulus in equation 2.3-20
g	Acceleration of gravity, 980.6 cm^2/s
$<h^2>$	Root-mean-square end-to-end length
h	Fluid height in manometer
I	Solvent ionic strength, $\frac{1}{2}\Sigma z_i c_i^2$
K'	MHKS constant, dimensionless; pseudo-power-law coefficient, cm^3/g(by convention)
k	Boltzman's constant, 1.380667×10^{-23} J/(K·atom)
k'	Huggins constant, 0.35 - 0.40, dimensionless
$k_{s\infty}$	Slope coefficient in equation 2.4-13
L	Length of pipe
L_c	Additive contour length
ℓ	Backbone link distance, C-C
ℓ'	Kuhn statistical segment length, $1/\lambda$
$\mathscr{L}$	Persistence length
M	Molecular weight, g/mole; maximum drag-reduction(MDR) asymptote
M_v	Viscosity-average molecular weight
M_w	Weight-average molecular weight
m	Average molecular weight per backbone link, g/mole

Latin Symbols(continued)

N	Number of backbone links; turbulent Newtonian PK line; number of convolutions in equation 3.1-1
N_A	Avogadro's number, 6.022×10^{23} mole^{-1}
n	Number density, cm^{-3}
n'	Pseudo-power-law exponent, dimensionless
P	Pressure in N/m^2 or psid; polymeric regime
ΔP	Pressure drop, N/m^2 or psid
Q	Flow rate — l/s, cm3/s, or gpm; Bjerrum length
q'	Turbulent kinetic energy, $(u'^2 + v'^2 + w'^2)/(2u_\tau^2)$
R	Pipe inner radius
$<R^2>$	Mean-square radius
R_G	Radius of gyration, $<R^2>^{1/2}$
Re	Reynolds number, $D<\overline{U}>/\nu_s$
$Re_s\sqrt{f}$	Prandtl-Karman abscissa, $\sqrt{2}Du_\tau/\nu_s$
R_o	Reynolds number in equation 3.1-1
r	Radial position
S'	Apparent slip, $1/\sqrt{f_p} - 1/\sqrt{f_n}$ at same u_τ
T	Temperature in K(elvins)
T_{bb}	Time between bursts
t	Temperature, °C
t_p	Polymer relaxation time, s
$\overline{U}$	Mean velocity

Latin Symbols(continued)

$<\overline{U}>$	Average bulk velocity, $4Q/(\pi D^2)$
u	Axial velocity fluctuation
u_τ	Friction velocity, $(T_w/\rho)^{1/2}$
$-\rho<uv>$	Turbulent Reynolds stress
V	Volume; transducer output voltage; bulk velocity in equation 3.1-1
v	Radial velocity fluctuation
W	Wave number, u_τ/ν_s
w	Azimuthal velocity fluctuation
X_v	Additive-pervaded volume fraction
x	Downstream distance
y	Position from wall, R-r
z	Azimuthal spacing
z_i	Charge on species i

Greek Symbols

α	Linear expansion factor, $([\eta]/[\eta]_o)^{1/6}$
$\dot{\gamma}$	Shear rate, s^{-1}
δ	Slope increment, A_p-A_n, dimensionless
ϵ	Excluded volume exponent
ϵ_o	Vacuum permittivity, 8.8542×10^{-12} $C^2/(J\cdot m)$
ϵ_r	Relative permittivity(dielectric constant), dimensionless
η	Viscosity, g/(cm·s)
η_r	Relative viscosity, η/η_s, dimensionless

Greek Symbols(continued)

η_{sp}	Specific viscosity, η_r-1, dimensionless
$[\eta]$	Intrinsic viscosity, cm^3/g
θ	Bond angle between adjacent backbone links
Θ	Theta temperature
κ	Slope modulus; inverse Debye length
λ	Slip modulus; inverse Kuhn statistical length
ξ	Line-charge density ratio, Q/A
ρ	Solvent(solution) density, g/cm^3
σ	Standard deviation
Σ	Intrinsic Slip, $S'/(c/M_w)$
ς	Bead friction coefficient
T_w	Wall shear stress, $(D/4)(-\Delta P/L)$, $dyne/cm^2$
Φ	Kirk-Riseman(KR) constant, $\sim 2\times10^{23}$ $mole^{-1}$
ϕ	Volume fraction, dimensionless
χ	Von-Karman constant; 0.4 and 0.085 for Newtonian and asymptotic maximum drag-reducing flows, respectively
Ω_L	Length-based onset constant, $R_G W^*$
Ω_T	Time-based onset constant, $R_G^3 T_w^*$

Superscripts

+	Normalized by wall units, u_τ/ν_s
*	Onset value
#	Retro-onset value
^	Degradation falloff
'	Root-mean-square(RMS) value

Subscripts

e	Elastic (sublayer)
l	Laminar value
M, m	Maximum Drag Reduction(MDR) value
n	Newtonian(turbulence) value
o	Initial conditions, random-flight value
p	Polymer, polymeric
s	Solvent value
v	Viscous (sublayer)

APPENDIX H

REFERENCES

Achia, B. U.; Thompson, D. W. *J. Fl. Mech.*, **1977**, *81 Part III*, 439-464.

Ait-Kadi, A.; Carreau, P. J.; Chauveteau, G. *J. Rheol.*, **1987**, *31(7)*, 537-561.

American Cyanamid Co., New Product Bulletin No. 34, June 1955; American Cyanamid Co., New York.

Banijamali, S. H.; Merrill, E. W.; Smith, K. A.; Peebles, L. H. *A.I.Ch.E. J.*, **1974**, *20(4)*, 824-826.

Bartels, P. V. In *I.U.T.A.M. Symposium Essen/Germany: The Influence of Polymer Additives on Velocity and Temperature Fields*; Gampert, B., Ed.; Springer-Verlag: Berlin/Heidelberg, 1984; pp. 279-289.

Berman, N. S. *Phys. Fl.*, **1977**, *20(10) Part II*, S168-S174.

Berman, N. S.; Griswold, S. T.; Elihu, S.; Yuen, J. *A.I.Ch.E. J.*, **1978**, *24(1)*, 124-130.

Bewersdorff, H.-W. *Rheol. Acta*, **1984**, *23(5)*, 522-543.

Bewersdorff, H.-W.; Berman, N. S. *Rheol. Acta*, **1988**, *27*, 130-136.

Blackwelder, R. F.; Kaplan, R. E. *J. Fl. Mech.*, **1976**, *76*, 89-112.

Bobkowicz, A. J.; Gauvin, W. H. *Can. J. Chem. Eng.*, **1965**, *43*, 87-91.

Bohdanecký, M.; Kovář, J. *Viscosity of Polymer Solutions*. Jenkins, A. D., Ed.;Elsevier Scientific: New York, 1982.

Brender, C. *J. Chem. Phys.*, **1990**, *7*, 4468-4472.

Burger, E. D.; Chorn, L. G.; Perkins, T. K. *J. Rheol.*, **1980**, *24(5)*, 603-626.

Carnie, S. L.; Christos, G. A.; Creamer, T. *J. Chem. Phys.*, **1988**, *10*, 6484-6496.

Chemical Engineers' Handbook; Perry, Robert H.(Ed.); McGraw-Hill: New York, 1973; p. 3-71.

CRC Handbook of Chemistry and Physics, 67th Edition; Weast, Robert C.(Ed.); CRC Press: Boca Raton, Florida, 1986-1987; pp. D-253, F-37.

Clarke, W. B. Sc.D. Thesis, Massachusetts Institute of Technology, October, 1970.

Cohen, J.; Priel, Z.; Rabin, Y. *J. Chem. Phys.*, **1988**, *11*, 7111-7116.

Collinson, E.; Dainton, F. S.; McNaughton, G. S. *Trans. Far. Soc.*, **1956**, *53*, 489-498.

Debye, P.; Bueche, A. M. *J. Chem. Phys.*, **1948**, *16(6)*, 573-579.

Del Villar, R.; Carreau, P. J.; Patterson, W. I. *Chem. Eng. Comm.*, **1984**, *25*, 321-331.

Donohue, G. L.; Tiederman, W. G.; Reischman, M. M. *J. Fl. Mech.*, **1972**, *56 Part III*, 559-575.

Dunlop, E. H.; Cox, L. R. *Phys. Fl.*, **1977**, *20(10) Part II*, S203-S213.

Eckelman, L. D.; Fortuna, G.; Hanratty, T. J. *Nature*, **1972**, *236*, 94-96.

Einvoll, G.; Hemmer, P. C. *J. Chem. Phys.*, **1988**, *1*, 474-484.

Elson, T. P.; Garside, J. *J. Non-Newt. Fl. Mech.*, **1983**, *12*, 121-133.

Falco, R. E. *Phys. Fl.*, **1977**, *20(10) Part II*, S124-S132.

Fanood, M. H. R.; George, M. H. *Polymer*, **1987**, *28*, 2241-2243.

Farinato, R. S. *Polymer*, **1988**, *29*, 2182-2190.

Fixman, M. *J. Chem. Phys.*, **1964**, *41*, 937-944.

Fixman, M. *Macromolecules*, **1981**, *14*, 1710-1717.

Flory, P. J. *Principles of Polymer Chemistry*; Cornell University: Ithaca, 1953.

Frings, B. In *I.U.T.A.M. Symposium Essen/Germany: The Influence of Polymer Additives on Velocity and Temperature Fields*; Gampert, B., Ed.; Springer-Verlag: Berlin/Heidelberg, 1984; pp. 209-221.

Frings, B. *Rheol. Acta*, **1988**, *27*, 92-110.

Fujita, Hiroshi *Macromolecules*, **1988**, *21*, 179-185.

Fuoss, R. M.; Strauss, U. P. *J. Polym. Sci.*, **1948**, *3*, 245-263.

Garcia de la Torre, J.; Jimenez, A.; Freire, J. J. *Macromolecules*, **1982**, *15*, 148-154.

Gramain, Ph.; Borreill, J. *Rheol. Acta*, **1978**, *17*, 303-311.

Hinze, J. O. *Turbulence*; McGraw-Hill: New York, 1975.

Hoyt, J. W.; *ASME J. Basic Eng.*, **1972**, *94*, 258-285.

Hoyt, J. W.; Sellin, R. H. *Rheol. Acta*, **1988**, *27*, 518-522.

Huggins, M. L. *J. Am. Chem. Soc.*, **1942**, *64*, 2716-2718.

Inge, C.; Johansson, A. V.; Lindgren, E. R, *Phys. Fl.*, **1979**, *22(5)*, 824-829.

Interthal, W.; Wilski, H. *Coll. & Polym. Sci.*, **1985**, *263*, 217-229.

Kagawa, I.; Fuoss, R. M. *J. Polym. Sci.*, **1955**, *18*, 535-542.

Kale, D.; Metzner, A. B. *A.I.Ch.E. J.*, **1976**, *22(4)*, 669-674.

Kirkwood, J. G.; Riseman, J. *J. Chem. Phys.*, **1948**, *16(6)*, 565-573.

Klein, J.; Conrad, K.-D. *Makromol. Chem.*, **1978**, *179*, 1635-1638.

Klein, J.; Conrad, K.-D. *Makromol. Chem.*, **1980**, *181*, 227-240.

Kline, J. S.; Reynolds, W. C.; Schraub, F. A.; Runstadler, P. W. *J. Fl. Mech.*, **1967**, *152*, 455-478.

Kowalik, R. M.; Duvdevani, I.; Peiffer, D. G.; Lundberg, R. D.; Kitano, K.; Schulz, D. N. *J. Non-Newt. Fl. Mech.*, **1987**, *24*, 1-10.

Kraemer, E. O. *Ind. Eng. Chem.*, **1938**, *30*, 1200-1203.

Kratky, O.; Porod, G. *Rec. Trav. Chim. Pays.-Bas.*, **1949**, *68*, 1106-1121.

Kulicke, W.-M.; Kniewske, R.; Klein, J. *Prog. Polym. Sci.*, **1982**, *8*, 373-468.

Kulicke, W.-M.; Kötter, M.; Gräger, H. In *Advances in Polymer Science 89: Polymer Characterization/Polymer Solutions*: Benoit, H., Ed.; Springer-Verlag: Berlin/Heidelberg, 1989; pp. 1-68.

Kwack, E. Y.; Cho, Y. I.; Harnett, J. P. *J. Non-Newt. Fl. Mech.*, **1981**, *9*, 79-90.

Laufer, J. *N.A.C.A*, Report No. 1174, 1954, pp. 1-18.

Lee, P. F. W.; Duffy, G. G. *A.I.Ch.E. J.*, **1976**, *22*, 750-753.

Lee, W. K.; Vaseleski, R. C.; Metzner, A. B. *A.I.Ch.E. J.*, **1974**, *20*, 301-306.

Luchik, T. S.; Tiederman, W. G. *J. Fl. Mech.*, **1987**, *174*, 529-552.

Lumley, J. L. In *Macromolecular Reviews*; Peterlin, A., Ed.; Journal of Polymer Science: Wiley; New York, 1973; Volume 7, pp. 263-290.

Lyons, S. L.; Nikolaides, C.; Hanratty, T. J. *A.I.Ch.E. J.*, **1988**, *34(6)*, 938-945.

Madavan, N. K.; Deutsch, S.; Merkle, C. L. *J. Fl. Mech.*, **1985**, *156*, 237-256.

Manning, G. S. *J. Chem. Phys.*, **1969**, *31(3)*, 924-933.

McComb, W. D.; Rabie. *A.I.Ch.E. J.*, **1982a**, *28(4)*, 547-557.

McComb, W. D.; Rabie. *A.I.Ch.E. J.*, **1982b**, *28(4)*, 558-565.

McComb, W. D.; Chan, K. T. J. *Nature*, **1981**, *292*, 520-522.

McComb, W. D.; Chan, K. T. J. *J. Fl. Mech.*, **1985**, *152*, 455-478.

McCormick, C. L.; Hester, R. D.; Morgan, S. E.; Safieddine, A. M. *Macromolecules*, **1990a**, *23*, 2124-2131.

McCormick, C. L.; Hester, R. D.; Morgan, S. E.; Safieddine, A. M. *Macromolecules*, **1990b**, *23*, 2132-2139.

Merrill, E. W.; Horn A. F. *Polym. Comm.*, **1984**, *25*, 144-146.

Miyaki, Y.; Fujita, H.; Fukuda, M. *Macromolecules*, **1980**, *13*, 588-592.

Mizushina, T.; Usui, H. *Phys. Fl.*, **1977**, *20(10) Part II*, S100-S108.

Monin, A. S.; Yaglom, A. M. *Statistical Fluid Mechanics*; M.I.T.: Cambridge, MA, 1971.

Morawetz, H. *Macromolecules in Solution, 2nd Edition*; Wiley: New York, 1975.

Morgan, S. E.; McCormick, C. L. *Prog. Polym. Sci.*, **1990**, *15*, 507-549.

Muller, G.; Laine, J. P.; Fenyo, J. C. *J. Polym. Sci.: Polym. Chem. Ed.*, **1979**, *17*, 659-672.

Munk, P.; Aminabhavi, T. M.; Williams, P.; Hoffman, D. E.; Chemlir, M. *Macromolecules*, **1980**, *13*, 871-875.

Noda, I.; Tsuge, T.; Nagasawa, M. *J. Phys. Chem.*, **1970**, *74*, 710-719.

Odijk, T.; Houwaart, A. C. *J. Polym. Sci.*, **1978**, *16*, 627-639.

Ogawa, K.; Kuroda, C. *Can. J. Chem. Eng.*, **1986**, *64*, 497-500.

Ohlendorf, D.; Interthal, W.; Hoffmann, H. *Rheol. Acta*, **1986**, *25*, 468-486.

Oldaker, D. K.; Tiederman, W. G. *Phys. Fl.*, **1977**, *20(10) Part II*, S133-S144.

Oliver, D. R.; Bakhtiyarov, S. I. *J. Non-Newt. Fl. Mech*, **1983**, *12*, 113-118.

Oono, Y.; Kohomoto, M. *J. Chem. Phys.*, **1983**, *78*, 520-528.

Oosawa, F. *Polyelectrolytes*; Marcel Dekker: New York, 1970.

Parker, C. A.; Hedley, A. H. *Nature*, **1972**, *236*, 61-62.

Peterlin, A. J. *J. Chem. Phys.*, **1955**, *23*, 2464-2465.

Pinho, F. T.; Whitelaw, J. H. *J. Non-Newt. Fl. Mech.*, **1990**, *34*, 129-144.

Polymers in Solution: Theoretical Considerations and Newer Methods of Characterization; Forsman, W. C., Ed.; Plenum: New York, 1986.

Pyun, C. W.; Fixman, M. *J. Chem. Phys.*, **1966**, *44*, 2107-2115.

Qian, C.; Kholodenko, A. L. *J. Chem. Phys.*, **1988**, *4*, 2301-2311.

Rice, S. A.; Nagasawa, M. *Polyelectrolyte Solutions*; Academic: New York, 1961.

Rochefort, S.; Middleman, S. In *I.U.T.A.M. Symposium Essen/Germany: The Influence of Polymer Additives on Velocity and Temperature Fields*; Gampert, B., Ed.; Springer-Verlag: Berlin/Heidelberg, 1984; pp. 117-127.

Schlichting, H. *Boundary Layer Theory, 7th Edition*; McGraw-Hill: New York, 1979.

Scholtan, W. *Makromol. Chem.*, **1954**, *14*, 169-178.

Sellin, R. H. J.; Ollis, M. *Ind. Eng. Chem. Prod. Res. & Dev.*, **1983**, *22*, 445-452.

Sharma, R. S.; Seshradi, V.; Malhotra, R. C. *Chem. Eng. Sci.*, **1979**, *34*, 703-713.

Stenberg, L.-G.; Lagerstedt, T.; Sehlen, O.; Lindgren, E. R. *Phys. Fl.*, **1977**, *20(5)*, 858-859.

Takahashi, A.; Nagasawa, M. *J. Am. Chem. Soc.*, **1964**, *86*, 543-548.

Tam, K. C.; Tiu, C. *Polym. Comm.*, **1989**, *30*, 114-116.

Tam, K. C.; Tiu, C. *Polym. Comm.*, **1990**, *31*, 102-104.

Tanford, C. *Physical Chemistry of Macromolecules*; Wiley: New York, 1961.

Tiederman, W. G.; Luchik, T. S.; Bogard, D. G. *J. Fl. Mech.*, **1985**, *156*, 419-437.

Ting, R. Y. *Chem. Eng. Comm.*, **1982**, *15*, 331-342.

Toms, B. A. *Proceedings of the First International Congress on Rheology: Volume II*; North Holland: Amsterdam, 1948; pp. 135-141.

Usui, H.; Iwata, N.; Sano, Y. In *I.U.T.A.M. Symposium Essen/Germany: The Influence of Polymer Additives on Velocity and Temperature Fields*; Gampert, B., Ed.; Springer-Verlag: Berlin/Heidelberg, 1984; pp. 223-232.

Usui, H.; Maeguchi, K.; Sano, Y. *Phys. Fl.*, **1988**, *31(9)*, 2518-2523.

Virk, P. S.; Mickley, H. S.; Smith, K. A. *A.S.M.E. J. Appl. Mech.* , **1970**, *37*, 488-493.

Virk, P. S. *J. Fl. Mech.*, **1971a**, *45*, 225-246.

Virk, P. S. *J. Fl. Mech.*, **1971b**, *45*, 417-440.

Virk, P. S. *Nature*, **1975a**, *253*, 109-110.

Virk, P. S. *A.I.Ch.E. J.*, **1975b**, *21(4)*, 625-656.

Wells, C. S.; Spangler, J. G. *Phys. Fl.*, **1967**, *10(9)*, 1890-1894.

White, D. Jr.; Gordon, R. J. *A.I.Ch.E. J.*, **1975**, *21(5)*, 1027-1029.

Willmarth, W. W.; Wei, T.; Lee, C. O. *Phys. Fl.*, **1987**, *30(40)*, 933-935.

Wolff, C. *Eur. Polym. J.*, **1977**, *13*, 739-741.

Yamakawa, H. *Modern Theory of Polymer Solutions*; Harper & Row: New York, 1971.

Zakin, J. L.; Hunston, D. L *J. Macromol. Sci.-Phys.*, **1980**, *B18(4)*, 795-814.

Zimm, B. H. *Macromolecules*, **1980**, *13*, 592-602.

APPENDIX I

BIOGRAPHICAL NOTE

The author was born 7 August 1963 in Baltimore, Maryland and lived in nearby Randallstown for nearly his first five years. His family moved to Palo Alto, California in July 1968, where he attended elementary, middle, and high schools up to mid-1981.

In September 1981, he entered the University of California at Berkeley, starting in the College of Letters and Science with an undeclared major and later pursued chemical engineering, switching to the College of Chemistry. In June 1983, he left UC Berkeley for Gaithersburg, Maryland to do cooperative research at the National Bureau of Standards(now the National Institute for Standards and Technology) in the Center for Fire Research. Returning the following December, he continued the chemical-engineering curriculum. In May 1985, he received a BSChE degree with high honors, earned the Mabel Kittredge Wilson Prize from College of Chemistry, being third in the class, and also was elected Phi Beta Kappa.

In September 1985, he entered MIT's department of chemical engineering with a Hertz Graduate Fellowship and a Gilliland Award, the former of which was chosen. After passing the qualifying exams in January 1986, he decided to work with Professor P. S. Virk in turbulent drag reduction. A thesis proposal was submitted in November 1987, and the last of many experiments was done in late December 1990.

During this period, minor degrees were earned in mechanical engineering and political science. Professor P. S. Virk and he coauthored a paper titled "Aspects of Mechanisms in Type B Drag Reduction," which was presented in Zurich, Switzerland at the IUTAM Symposium on the Structure of Turbulence and Drag Reduction in July 1989.

During the writing of this thesis, this author was chosen to be a 1991-1992 AAAS Science, Engineering, and Diplomacy Fellow working for the United States Agency for International Development(USAID) on development problems pertaining to energy and environment in less-developed countries. The position was accepted before the completion of this thesis and the defense thereof. Currently, the author works for the Office of Energy and Infrastructure in USAID's Bureau of Research & Development in Arlington, VA.