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INK MISTING

IN

HIGH SPEED PRINTING PRESSES

by

Robert Adolf Andrew Hentschel

Submitted in Partial Fulfillment

of the

Requirements for the Degree of

Batchelor of Science

from

The Massachusetts Institute of Technology

Signature of author.

Professor in charge. . . . .

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CONCLUSIONS

1) Plateau's spherule is a phenomenon associated with the physical properties of the material.

2) The variation in the rate at which it appears is slight with variations in conditions.

3) Plateau's spherule is not a possible cause of ink misting.

4) News ink is probably plastic in character.

5) To reduce the tendency to mist, both the viscosity and the surface tension should be kept as high as possible.

INTRODUCTION

High speed printing, particularly in the field of newsprinting, occupies a very important place in modern life. Yet for all its importance, it is one of the few industries which has made practically no attempt to apply engineering to its problems, or to conduct any form of research in its particular difficulties. Consequently this industry provides a practically untouched field for the investigator.

One of the problems which has long bothered the printer is that of "ink misting". This term is applied to a breaking up of the ink at the surface of the distributing rollers, particularly in high speed presses, to form a fine mist which is carried, on air currents, to all parts of the pressroom. It is evident that such misting will cause considerable expense, both in wastage of ink, and in painting and other maintainance upkeep in the pressroom, to say nothing of the messy appearance it may give the final product. This problem apparently is one of the standard topics of conversation wherever printers meet, but it is also apparent that no attempt has been made to get at the causes of the trouble

With this in mind, the writer decided to carry out such of this investigation as would be feasible in the laboratory. Much encouragement was received from various members of the printing profession who were consulted.

HISTORICAL

As the first step in the work, a thoro search was conducted thru the available literature. It was discovered that the only publications of a more or less technical nature were the Transactions of the Printing Industries Division of the A.S.M.E. and certain bulletins of the U.S. Government Printing Office. There are other excellent technical publications in allied fields, such as ink manufacture, but the problems they discuss are not the problems of the pressroom.

The earliest reference to the problem is in the September-December 1929 Transactions of the A.S.M.E., p. 96. Here the attitude is taken that misting always has been and always will be, an attitude unfortunately char cteristic of the greater part of this industry.

The only other reference to misting in these Transactions was in a paper by A. S. Thompson, Trans. 1931, p. 78. The following possible causes are listed:

1) Broken or mis-set rollers.

2) Too much air pressure in the fountain mechanism.

3) General bad adjustment of rollers, etc.

4) Ink lacking body or "tack".

The author states that his company has done considerable research in the field, and has set up standards of body and "tack" which will practically eliminate misting. Wheat these standards are, or what the details of the research were was not disclosed.

The next source of information which came under consideration was the progress reports of work done by the U.S. Government Printing Office, in co-operation with the American Newspaper Publishers Association. The first report, issued in June, 1930, outlines the scope of the work, including misting as one of the problems to be investigated. They stated that nothing had been done, but that preliminary work had indicated that the surface tension of the ink was probably very closely involved. They give no reasons for this statement and no indication as to its basis. The great part of this paper was devoted to a study of factors influencing the viscosity of the ink.

The Second Progress Report, Tech. Bul. 13, U.S. Gov't. Printing Office, June 1931, indicates that no further work had been done, but includes a discussion of the effect of various constituents and manufacturing processes on the surface tension, as follows:

1) Grinding increases surface tension.

2) Addition of pigment increases S.T.

3) Addition of gums and resins increases S.T.

4) Addition of dyes and toners increases S.T.

5) The surface tension varies directly with the viscosity of the oil used.

The Third Progress Report, Tech. Bul. 16, June 1932, indicates that the Printing Office has been receiving and is correlating complaints from printers. It points out that many things often given as causes are probably really only contributory, such as improper pressroom ventilation, high speeds, too much ink, etc. The view that the cause may be found in the body or tack of the ink is also put forward. They point out that the trouble may be reduced by increasing the body of the ink, but they also state that it is not yet known whether the cure is effected by the increase in body, or by the alteration of some accompanying characteristic.

The above covers all the references to misting which could be found. The next step lay in obtaining the views of some of those directly concerned in thework.

Mr. E. F. Hulse of the A.S.M.E. gave the following: Nothing is known definitely as to causes or cure, consequently there is no way of dealing with the problem beyond cut and try. The loolwing theories are among those held:

1) That misting is an electrostatic problem. The tiny droplets of ink which float in the region around the distributing rollers are charged. When such a droplet comes near a speck of dust in the air, it is attracted to it and clings. Similarly other droplets attach themselves and soon there is a drp of considerable size, which is carried away by air currents.

A consideration of this theory will show that tho plausible, it gives us no further information, since it simply presupposes the presence of "droplets" of ink without explaining their appearance. The theory concerns itself only with the growth of these droplets, and the problem at hand is the reason for their appearance.

2) That the problem is a purely mechanical question os speeds and centrifugal forces. The ink is thrown off whenever the speed of the roll becomes too great. The cure then lies in increasing the tack of the ink.

If this theory were tenable, the ink mist should be found all around the circumference of the rolls. Even a casual inspection will show that this is not the case, all the misting taking place at the point of separation of the rolls.

3) That there is a tearing action on the film of ink at the point of contact of the rolls, which causes the formation of small drops. These drops are carried away by air currents, thus forming a mist.

This hypothesis is the most plausible of the three, altho it throws no light on the reason for the appearance of the small drops.

Mr. L. G. Morrill of the G. H. Morrill Co., ink manufacturers, was next approached, and he put forth the following view, which he bases on experience solely:

1) Ink has tack, and strings out in long threads when the rollers separate. When these threads break, they split into small droplets which are then picked pu by air currents in the room, and cause misting. The length of these strings depends upon the "length" of the ink.

2) When it occured in news inks, it could

be cured by increasing the body of the ink, which would have the effect of "shortening" the ink.

3) This drawing out into strings is much more noticeable in slow cylinder presses using varnish base inks, which are much more tacky than news inks.

The theory here outlined has some interesting possibilities, as will be brought out later. It was the opinion of some of the more "practical" people later consulted that this was just a "theory" and was just so much silly nonsense.

A number of newspaper men were consulted, but could offer little. Among these were Mr. Burns of the N.Y. Herald Tribune, Mr. Hart of the N.Y. Times, and Mr. Wines of the A.N.P.A. These men have nearly all been brought up in the news game, and do everything by rule-of-thumb. When they have serious difficulty with misting, they turn the problem over to their ink manufacturers. They do not consider misting as serious until it covers the walls of the pressroom with an inch of ink, altho an inspection of their presses will show considerable wastage from this cause, even under the best of conditions.

Mr. Baumrucker of the N.Y. Daily News gave the information that they did not have any trouble with misting regardless of the ink. He suggested that most cases of difficulty came with those types of presses which fed the ink in an uneven manner. That is, that the difficulty came where the ink was fed in streams or jets rather than in a smooth thin sheet. This probably is an important contributory cause of misting. Any accumulation such as would be caused by uneven feeding would leave the ink in a condition much more conducive to being thrown off, particularly where a free edge of ink is formed, which condition would hold at the edge of a stream.

THEORETICAL

It is apparent from the historical work outlined that the problem divided itself into two parts:

1) That concerned with conditons at the point of separation of the various rollers in the ink system.

2) That concerned with the physical condition of the various parts of this system, the rolls themselves, the blanket, plates, etc.

For the purposes of this investigation, 2) may be excluded. The importance of keeping the various parts of the press clean and in good condition is in most cases, realized, so that difficulties arising from this cause are few. Furthermore, the equipment necessary for such an investigation would not be available. This work, then will be restricted to the problem as outlined in 1), which, as will be shown, may be made to yeild to laboratory methods.

Let us consider what happens at the ink rolls of a press. There are two rolls, separated by a small distance, and both covered with a film of ink, as in Fig. a. These rolls are not polished, but are left as they come from the

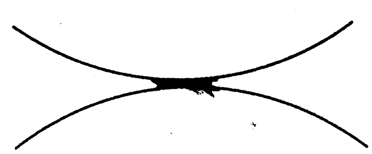


Fig. a

lathe. Therefore they are covered with minute irregularities. When these rolls start to rotate, the ink film necessarily is split between them. In the process of separation, the ink will be drawn out into threads, as in Fig. b, these threads probably forming on the irregularities of the rolls. That such

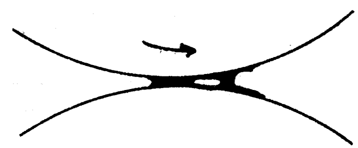


Fig. b

threads do form has been adequately shown by experience with slow-moving cylinder presses, as was brought out previously. As these rolls continue to rotate, there are two things which can happen:

1) The strings may break by the simple process of being drawn out beyond their capacity to elongate, just as a rod or wire will in a testing machine. This process would presume that the ink is in a plastic, as contrasted to a fluid, condition.

2) The strings may be broken by the surface tension forces acting to reduce the surface area of the string to a minimum. This process would occur more readily in fluid media.

Let us examine both of these possibilities. Previous work tends to indicate that printing ink falls just about on the borderline. But such work has been done on varnish base inks rather than the mineral oil base news inks. News inks are considerably more fluid in character than varnish inks. Therefore it may be concluded that surface tension forces will play an important part in the breaking of the string, and the breaking will probably fall into class 2). In either case, there is no reason to believe that the string will break into more than two parts, i.e. that the string will break into droplets directly. Here again there are two possibilities:

1) The droplets causing the misting are due to some phenomenon accompanying the breaking of the string, a possibility which may be decided by analogy to drop formations, as will be shown later.

2) The misting may be caused by the throwing off of the two parts of the string thru cetrifugal force. This drawing out and breaking has left the strings in a condition appropriate to such action. However the centrifugal forces acting on such a projucting bit of ink are very small, and if the surface tension is high enough, as it will be if the ink is a fluid, to play an improtant part in the breakage, it will probably be large enough to draw in the projection, rather than to permit its being thrown off.

This breaking of the string will evidently be analogous to the separation of a drop from the end of a tube, so far as the conditions at the point of separation are concerned. Therefore an examination of work on such conditions would throw light on the problem of misting. These conditions have not been investigated with any great degree of thoroness, but there is one phenomenon which is known, that of Plateau's spherule.[1] Under certain conditions, when a drop separates, a very small secondary droplet will form. This secondary droplet is known as Plateau's spherule. Its formation is illustrated by the three steps of Fig. c. The exact conditions surrounding its appearance are not discussed, but evidently for a given liquid, the rate of separation is a determining factor. This spherule is

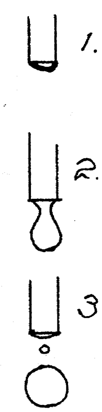


Fig. c

evidently a very possible cause of misting. The number of strings breaking along the length of a roller are very large, and should the conditions be such as to produce this droplet, the effect would be that found in misting.

[1] Darling "Liquid Drops and Globules", London, 1914

Time and the available facilities would not permit an investigation of all phases of the problem as outlined, therefore the experimental work was confined to an investigation of Plateau's spherule as a possible cause of misting. The determination of this factor would reduce the possibilities, and help throw light on the character of news ink.

This work is necessarily based on a study of the conditions surrounding the appearance of Plateau's spherule. These conditions would include the rate of separation at which such a spherule would appear, and its change with variations in viscosity. Could these variations be studied in any liquid, the results could be applied to ink. To investigate these conditions, it is necessary that some means be devised for slowing down the process. In air, the formation would be so rapid that it would be impossible to follow it without elaborate photographic methods. The work of Darling indicates a method for thus slowing down drop formation. He suggests allowing the drop to form in a more dense medium, such as a drop of aniline forming in water. By selecting the materials so that their density is very close to the density of the medium, the process can be slowed down as much as desired.

Aniline and Orthotoluidine are two such liquids. By determining their characteristics, such as viscosity, surface tension, and desity, and then studying the drops which they form in water, the conditions surrounding the formation of Plateau's spherule can be determined, and these conditions correlated with those in the printing press, thus showing the possibility of this phenomenon as a cause of misting.

EXPERIMENTAL

The scope of the experimental work may be outlined as follows:

1) Determination of theviscosity-temperature, and surface tension-temperature relations of O-toluidine and aniline.

2) Set up of apparatus to permit observation of drop formations in water and control of conditions

3) Correlation of observed conditions of drop formation.

4) Application of 3) to news ink, with determination of necessary information, as derived from 3).

The viscosities of aniline and O-toluidine were determined with the Ostwald pipette. The set-up of the apparatus is indicated in Fig. 1[1]. All the equipment was immersed in water in a four liter beaker. The temperature of this water was kept constant by the heater, which was controlled thru a thermostat[2]. The flow thru the pipette was timed to 1/4 second by an Eastman timer. The Ostwald pipette measures viscosity by the time required by a definite volume of liquid to flow thru a capillary. This time is

[1] See Appendix A for this and all following figures.

[2] See Appendix B for connections of thermostat.

connected with the viscosity by the relation:

$$n = kdt$$

Where n = viscosity
d = density
t = time of flow
k = constant

The instrument was calibrated with water, which gave a value of k = 12.84 x 10 -[1]

The densities were determined by equations from the International Critical Tables, and are plotted in Fig. 3.

The results of the viscosity determinations are given in table 1, and the resulting viscosities plotted in Fig. 4. Both viscosity curves stop at approximately the temperature at which the density of the substance is the same as that of water.

The surface tensions, plotted in Fig. 5, were measured with a De Nouy instrument, and indicate that the variations in surface tension with temperature are slight. The surface tension of both liquids is nearly the same.

These curves provide all the necessary physical information on which to proceed to a study of the drop formations. The apparatus used was designed so that the volume and the time of formation of the drop could be measured while the drop was being

[1] See Appendix C

observed. The temperature of the water bath could be raised or lowered. In its final form, this set-up is shown in Fig. 2.

The liquid fills the system and changes in volume may be measured by the burette. This burette was refilled to an arbitrarily selected height after each drop to insure a constant head. The needle valve refulated the flow to any desired rate, and the stop-cock provided a means for stopping or starting it at will. In order to insure the liquid being at the same temperature as the water, the temperature being used as a means of controling the viscosity, a coil of glass tubing with a capacity of about 14 cc. was provided. The temperature of the bath was varied by means of steam, which proved quicker than the electrical methods used in the viscosity measurements, since the volume of the water bath was so much greater. In this case, as previously, air was used to agitate the bath and insure uniformity of temperature while the temperature was being raised.

On starting work with this apparatus, it immediately became evident that, at a given temperature, the rate of formation of the drop was the deciding factor in the appearance of Plateau's spherule. When the rate was increased above a certain value, the spherule disappeared. Consequently the rate at which it appeared was measured. Since the process is, of necessity, cut and try, two rates must be measured. One at which there is a droplet, and one at which there is none. These rates were measured over the available range of temperatures for each liquid, and are reported in Table 2. Fig. 6 shows the variation of this rate with temperature, and Fig. 7 that with viscosity. This rate is calculated as the velocity of flow of the liquid from the tube in cc./sec. according to the formula:

$$r = t/v$$

where r = rate
t = time in sec.
v = volume in cc.

Since the same tube opening was used in all cases, this rate will correspond to the velocity in cm./sec. which would strictly be the factor to be used if the results are to be correlated with the separation of two rolls.

The rate of formation and separation of the drop is thus established as being the controlling factor in the production of Plateau's spherule. The variation in this rate with either temperature or viscosity, over a very considerable range, is slight. Therefore it was decided that a determination of the rate for news ink at room temperature would be adequate to indicate whether such a rate was approached in the operation of a press. This rate would have to be determined in air in order to avoid discrepancies due to the density of the medium. This requirement was met by allowing the drop to form in air and fall, as soon as possible after separation, into alcohol, in which the ink is insoluble. The apparatus for accomplishing this is sketched in Fig. 9.

This system was permissible, since it was not necessary to follow the actual formation of the drop. Should Plateau's spherule form, it would be preserved, and its rate of fall sufficiently slowed by the alcohol to make it visible. As before, a needle valve was used to regulate the flow, and a stop-cock to control it.

In order to indicate the effect of the size of the opening, corresponding to the size of the string formed between the rolls, on the formation of the spherule, a series of three nozzles was prepared with openings as follows:

1) 2.28 mm.

2) 1.40 mm.

3) 1.02 mm.

Due to the opacity of the ink, it was impossible to read the burette, so the volume of the drop was calculated from its weight, using a value of .930 gms./cc. for the density of the ink, a value obtained as representative from the U.S. Gov't Printing office Progress Reports. The formula used for calculating the velocity of flow was:

$$v = 4 \times r/\pi D^2 = 4w/\pi D^2 dt$$

where v = velocity
r = rate, cc/sec.
D = dia. opening
d = density
t = time, sec.

Table 3 gives the results of this test. The tendency for the formation of Plateau's spherule was not very strong. Its formation was observed in about four out of five drops at the rates reported.

At higher velocities, a rather strong tendency was noticed for the drops to string out, with long tails. This tendency was reduced as the size of the opening was reduced.

In order to observe the effect of reducing the surface tension of the ink, an attempt was made to form the drops in alcohol, the interfacial tension for alcohol-ink being much smaller than for air-ink. It was found to be very difficult to make the drops form at all. The tendency was rather for the ink to form long unbroken strings.

DISCUSSION

The first problem to be attacked in this investigation was that of the conditions surrounding the formation of Plateau's spherule, and the effect of changes in these conditions. Such variations would be changes in temperature, viscosity and surface tension.

It is apparent that the variations in rate withchanges in these variables is comparatively slight, When the rate is plotted against temperature, as in Fig. 6, a straight line will represent the variation. The individual points show considerable spread, due probably to experimental errors, so that there is no justification for assuming a more complicated type of curve. The orthotoluidine, due to the comparatively steep lope of its density curve with respect to water, Fig. 3, did not give a very great number of points from which to plot a rate curve, so these points were plotted together with those for aniline, They fall in very well with the aniline values, and indicate that the appearance of Plateau's spherule depends on the physical, and not the chemical, properties of the material. Thus any general conclusions which may be drawn from these results will be applicable to ink, provided that the ink acts as a fluid, and not as a plastic material.

The total variation in rate with temperature may be seen to be very small over a considerable range of temperature. In general, however, it tends to fall off with increases in temperature. Now if this rate is plotted against viscosity, as in plot 7a, the variation does not show as a straight line, but rather as a curve of the general nature indicated. Since the viscosity varies in a logarithmic manner with the temperature, this is to be expected, and suggests that a plot of rate against log n will be of more use. Such a plot has been made in Fig. 7b, and very clearly indicates a straight line relationship here. Finally, the rate may be plotted against the surface tension, as in Fig. 8. Here again the variations are not large, but the tendency is for the rate to rise slightly more rapidly than the surface tension.

From all these relationships, it may be seen that altho the rate at which the spherule developes varies with temperature, viscosity, and surface tension, this variation, for very considerable changes in the factors, is very slight. Therefore the conclusion may be drawn that if the rate for ink be determined under one set of conditions, this rate will approach very closely the rate under almost any conditions which would be practically encountered. This conclusion greatly simplifies matters.

Now let us examine the results of such a determination on a news ink, as given in table 3. Itwas deiscovered that the critical rate for ink was extremely low, so low that it was difficult to reach stable conditions. Since the strings demanded by the hypothesis previously outlined will vary, the effect of reducing the size of the opening at which the drop was allowed to form was investigated. As might be expected no evidence of appreciable change was noticed. Thus we have established, at least the order of magnitude of the rate. In order to correlate this with press operation, and determine the possibility of the spherule forming under these conditions, the following calculations as to the rate of separation of two points on the surfaces of the rolls may be made:

$$l = 2(r-a)$$

$$a = r\cos\theta = r\cos\omega t$$

$$l = 2r(1-\cos\omega t)$$

$$v = dl/dt = 2\omega r\sin\omega t$$

$$= 2\omega r\sin\theta$$

where l = length string
r = radius roll
θ = angle of r with centre line rolls
ω = angular vel. roll
v = vel. separation

With $r = 3$ inches and $\omega = 1000$ r.p.m., which approximate the values used in commercial practice:

$$v = 2 \times 0.1047 \times 1000 \times 3 \sin \theta \quad \text{where } v = \text{ins/sec.}$$
$$= 628 \sin \theta$$
and $$l = 2r(1-\cos \theta)$$

Now if $\theta = 1°$
$v = 10.9$ ins./sec.
and l = negligible.

Since v will continue to increase as the rolls rotate, it is perfectly apparent that the rate of separation of the rolls will exceed enormously the rate at which the spherule is produced.

From the results of aniline, it would be expected that the rate for ink would be very high, as it would have to be to cause misting, since the main physical property in which ink differs from aniline is in its viscosity, the surface tension and the density being about the same. There is therfore a very evident discrepancy somewhere. One of the basic assumprions, it has been pointed out, is that ink is a fluid. Should this not be true, i.e. should ink act as a plastic rather than a fluid, the above conclusions would not apply. In a plastic material under deformation, it takes the various molecules a certain amount of time to adjust themselves, which is not the fact in a fluid substance. This is illustrated by tensile tests on metals, where the rate of application of the load has considerable effect on the strength obtained. Similarly in the ink, a certain amount of time is necessary for the ink particles to adjust themselves, hence Plateau's spherule appears at a rate far below that which we might expect, were the particles perfectly free to move about. Thus the conclusion may be drawn that the ink acts as a plastic rather than a fluid.

In the light of this conclusion, the probable cause of misting is shifted to number 1 on page 14, ie. that the strings break by the process of being drawn out beyond their capacity to elongate, and the two parts thus left are thrown off by centrifugal forces. The breaking of the string is then analogous to the breaking of a tensile specimen of a ductile metal. Increasing the hardness of such a metal results in reducing the elongation. Since viscosity may be likened to hardness, increasing the viscosity will reduce the capacity for elongation of the ink, and cause the parts of the string to be shorter. This in turn lessens the tendency for them to be thrown off. Surface tension forces will aid this process, and should therefore be kept as high as possible. This fact is born out by the great difficulty with which drops form in alcohol.

APPENDIX A

TABLE 1 Viscosity Determinations

Aniline	Temp. °C	t secs.	d gm/cc.	n poises
	9	505	1.031	.067
	11	467	1.029	.063
	13	435	1.027	.057
	15	397	1.026	.052
	17	369	1.024	.048
	19	344	1.022	.044
	21	325	1.021	.042
	24	292	1.018	.038
	30	243	1.013	.032
	35	211	1.009	.027
	40	185	1.004	.023
	45	166	1.000	.021
	50	149	.996	.019
	55	133	.991	.016
	60	123	.987	.015
	65	115	.984	.014
	66	110	.982	.013
	69	104	.979	.012
	72	98	.976	.011
O-toluidine	9	507	1.010	.066
	11	476	1.008	.062
	13	430	1.007	.055
	15	404	1.005	.052
	17	371	1.003	.048
	19	348	1.002	.046
	21	330	1.000	.042
	24	291	.997	.038

TABLE 2 Drop formation data

Aniline

Temp. °C	Volume	t secs.	Rate	r aver.
15	.37	1.5	.250	.219
	.37	2.0	.188	
20	.36	2.5	.147	.140
	.36	2.7	.134	
25	.43	2.5	.174	.172
	.47	2.7	.170	
30	.53	3.0	.178	.156
	.47	3.5	.134	
35	.63	3.2	.195	.179
	.57	3.5	.163	
40	.67	4.0	.167	.157
	.67	4.5	.149	
45	.80	4.2	.188	.183
	.80	4.5	.178	
50	.94	6.5	.144	.142
	.94	6.7	.139	
55	1.35	9.2	.146	.142
	1.30	9.5	.138	
60	1.70	12.0	.142	.139
	1.70	12.5	.136	
65	2.80	19.5	.144	.142
	2.80	20.0	.140	

O-toluidine

Temp. °C	Volume	t secs.	Rate	r aver.
10	1.7	7.5	.226	.213
	1.7	8.5	.200	
13	2.6	15.0	.173	.168
	2.6	16.0	.162	
16	4.8	25.0	.192	.188
	4.8	26.0	.185	

TABLE 3 Drop formation in news ink.

Opening	Size D.	w gms.	t secs.	v cm/sec
1	2.28	.590	62	.00025
2	1.40	.100	23	.00030
3	1.02	.120	60	.00026

The weights and times given do not necessarily represent single drops. In order to make the work more accurate, several drops were timed and weighed. since $r = w/t$ regardless of the number, the number weighed was not recorded.

Fig. 1

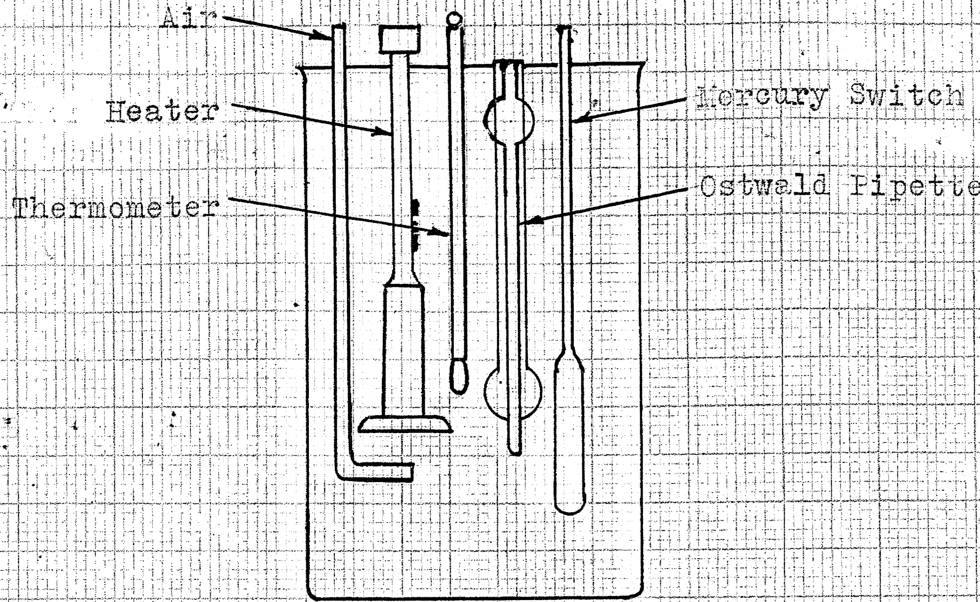
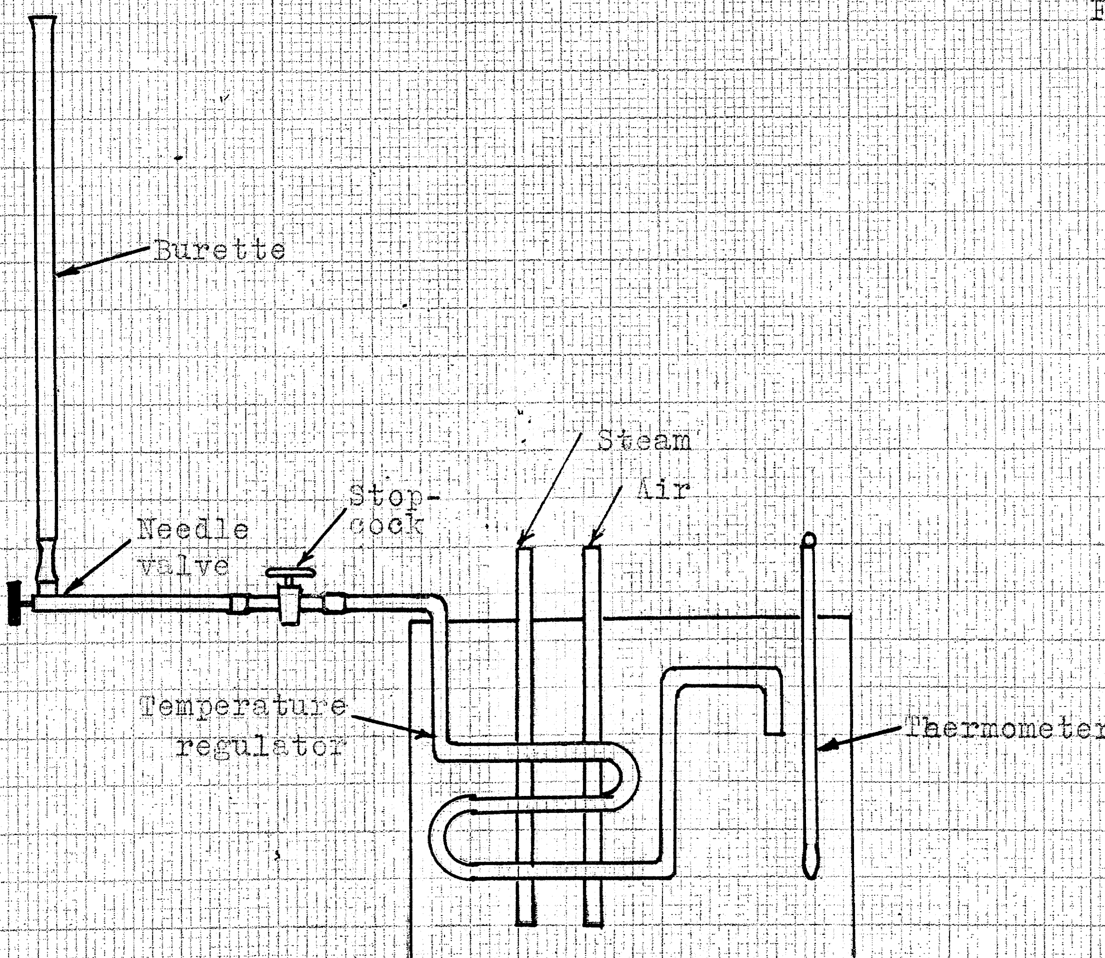
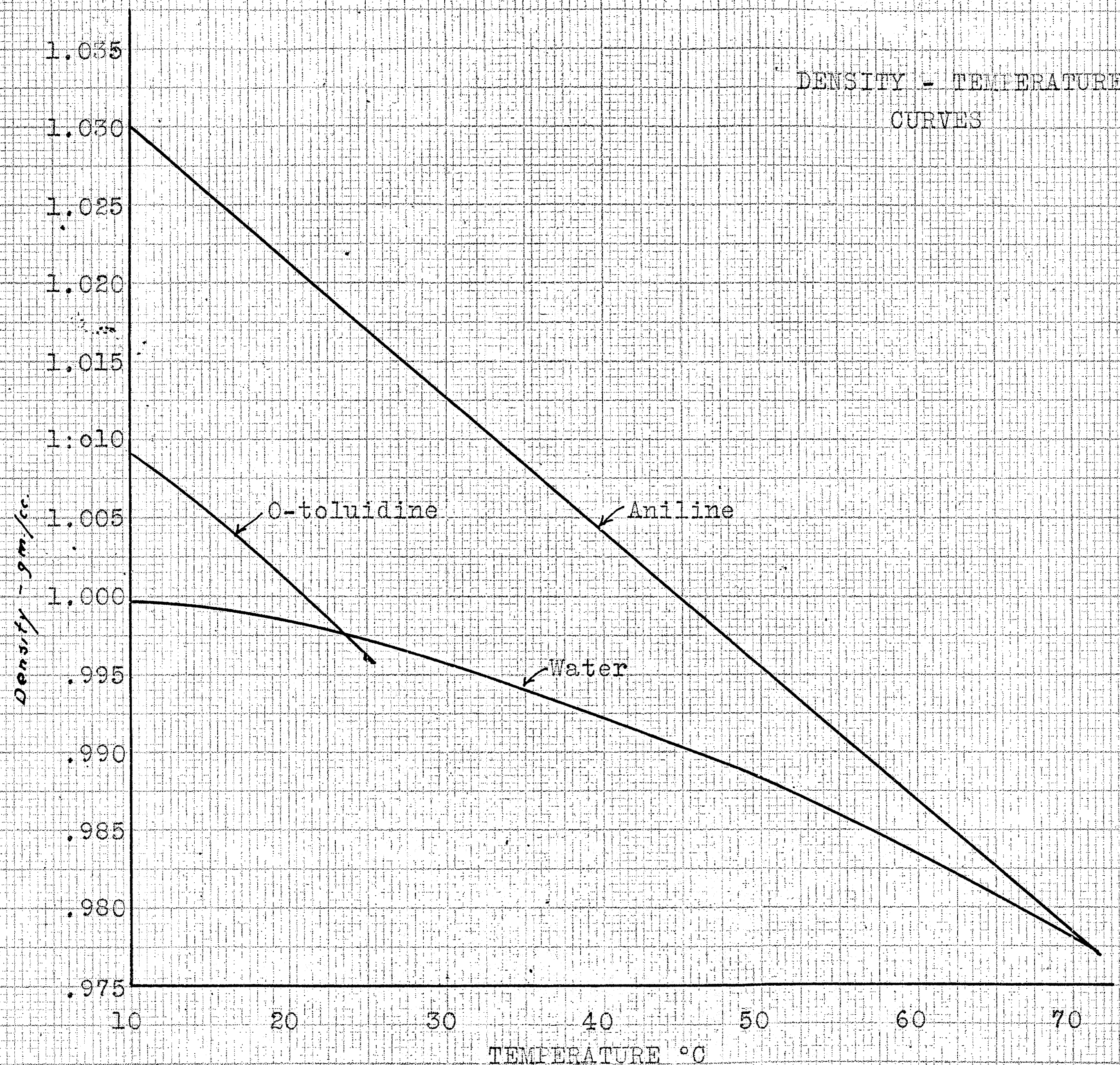

Air
Heater
Thermometer
Mercury Switch
Ostwald Pipette

Fig. 2


Burette
Needle valve
Stop-cock
Steam
Air
Temperature regulator
Thermometer



EQUATIONS, International Critical Tables

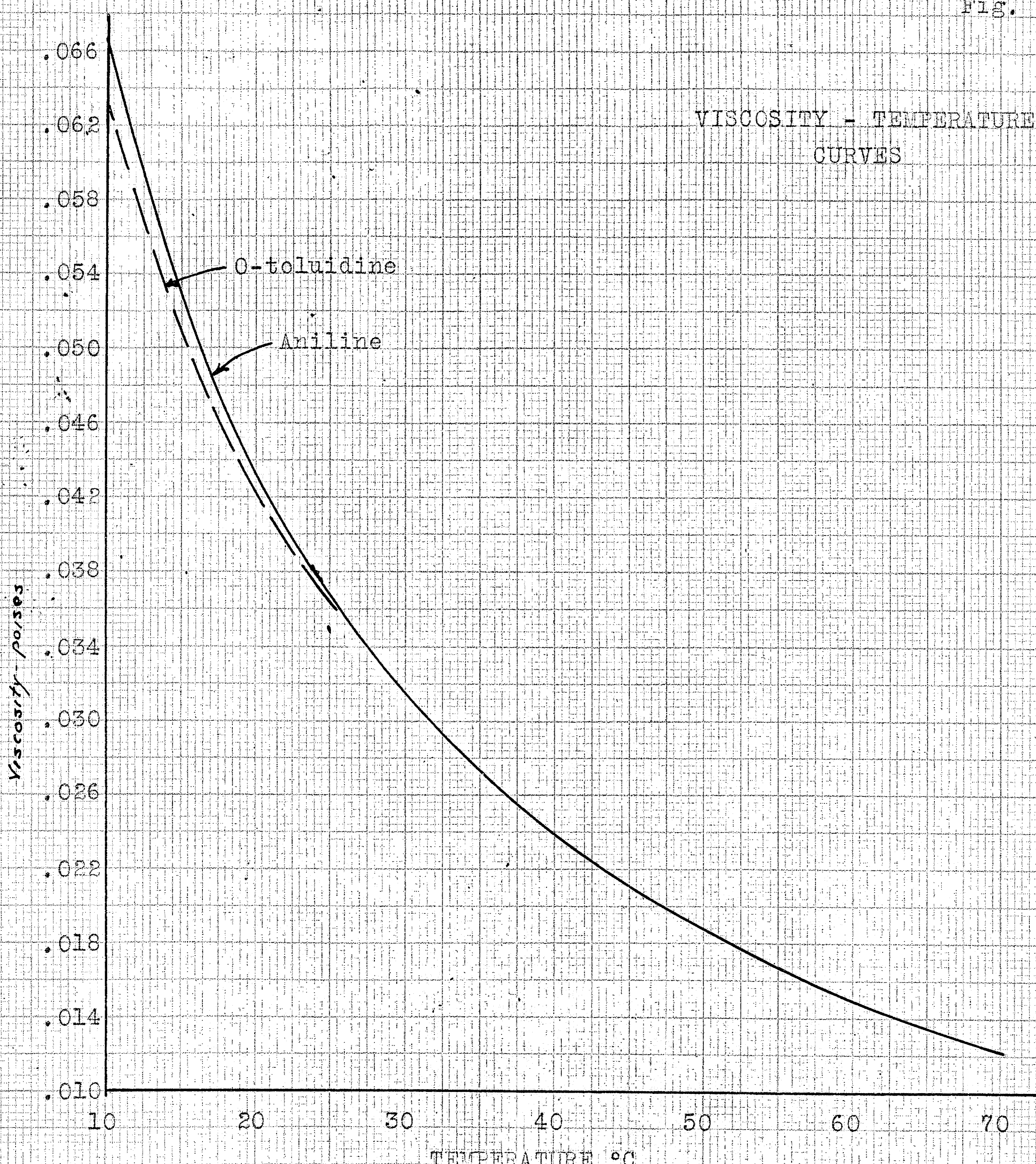
Aniline:

$d = 1.0389 - .8653 \times 10^{-3}t + .0929 \times 10^{-6}t^2 - 1.90 \times 10^{-9}t^3$

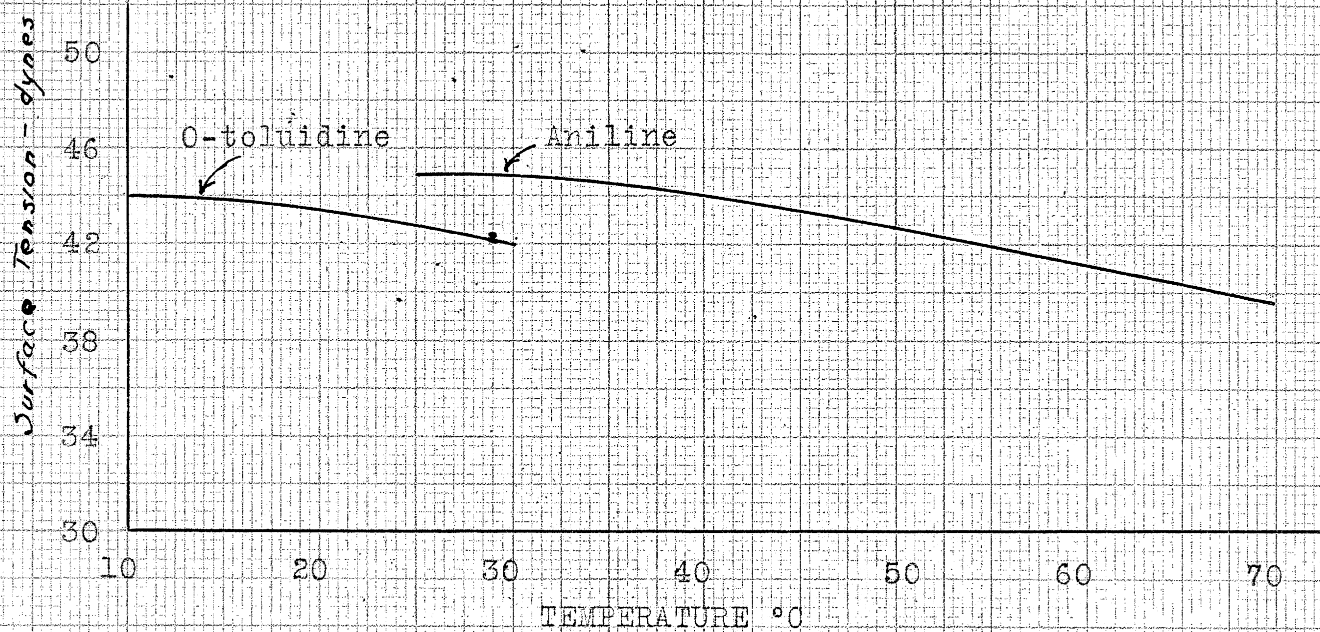
O-toluidine

$d = 1.0149 - .833 \times 10^{-3}t - .04 \times 10^{-6}t^2$

Fig. 4


VISCOSITY - TEMPERATURE CURVES
O-toluidine
Aniline
Viscosity poises
.066
.062
.058
.054
.050
.046
.042
.038
.034
.030
.026
.022
.018
.014
.010
10
20
30
40
50
60
70
TEMPERATURE °C

VARIATION OF SURFACE TENSION WITH TEMPERATURE



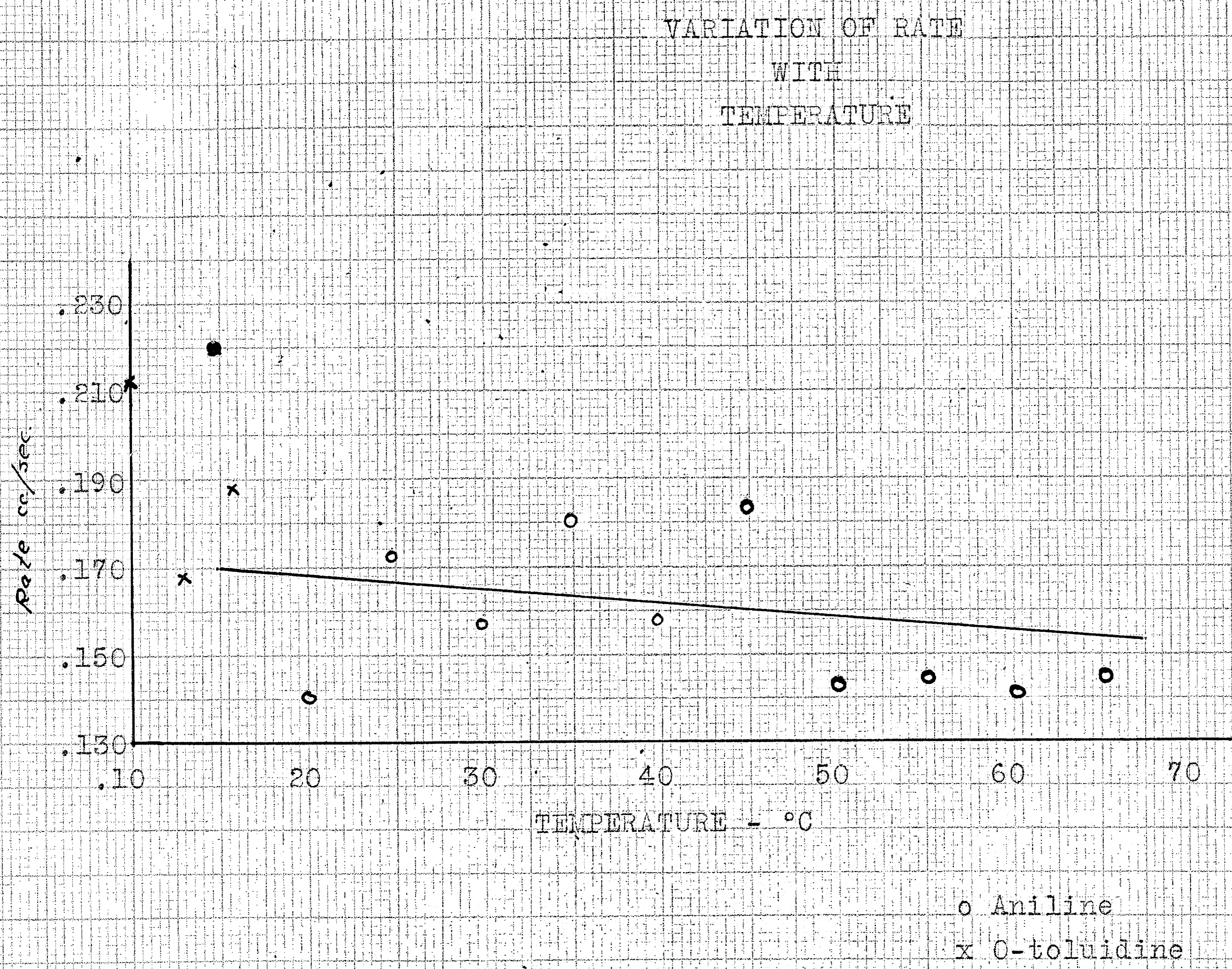
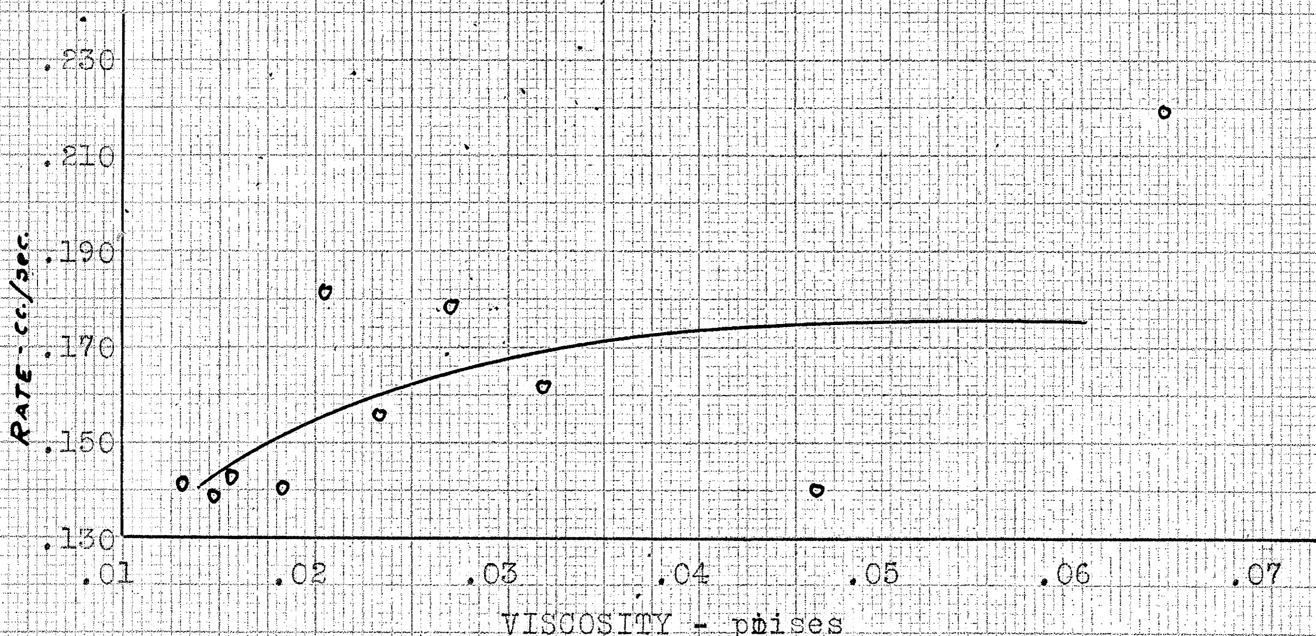

VARIATION OF RATE
WITH
TEMPERATURE
.230
.210
.190
.170
.150
.130
Rate cc/sec
.10
20
30
40
50
60
70
TEMPERATURE - °C
o Aniline
x O-toluidine

Fig. 7a

VARIATION IN RATE
WITH
VISCOSITY



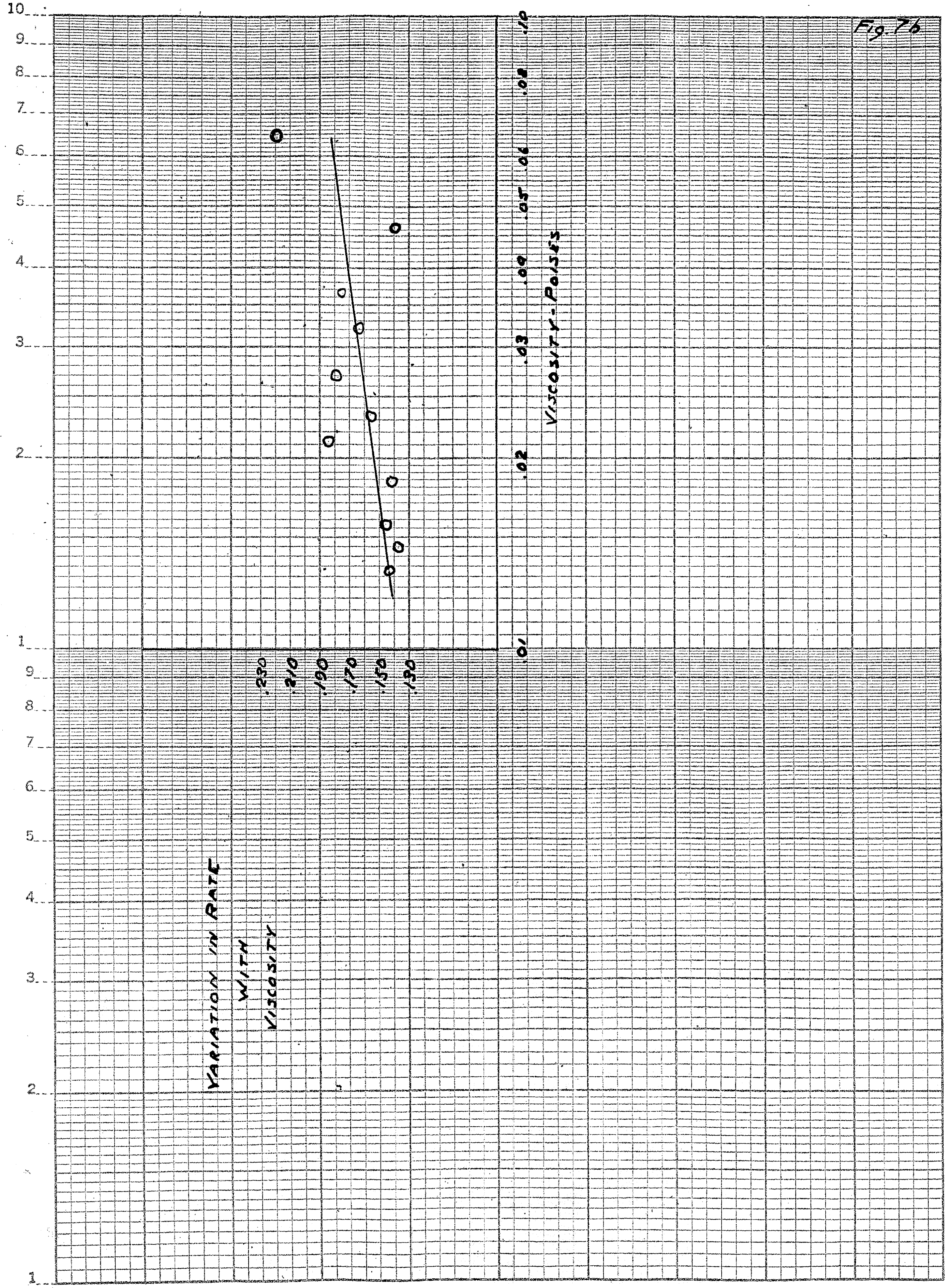

VISCOSITY - POISES
.01
.02
.03
.04
.05
.06
.08
.10
.230
.210
.190
.170
.150
.130
VARIATION IN RATE
WITH
VISCOSITY
Fig. 7b

Fig. 8

VARIATION IN RATE
WITH
SURFACE TENSION

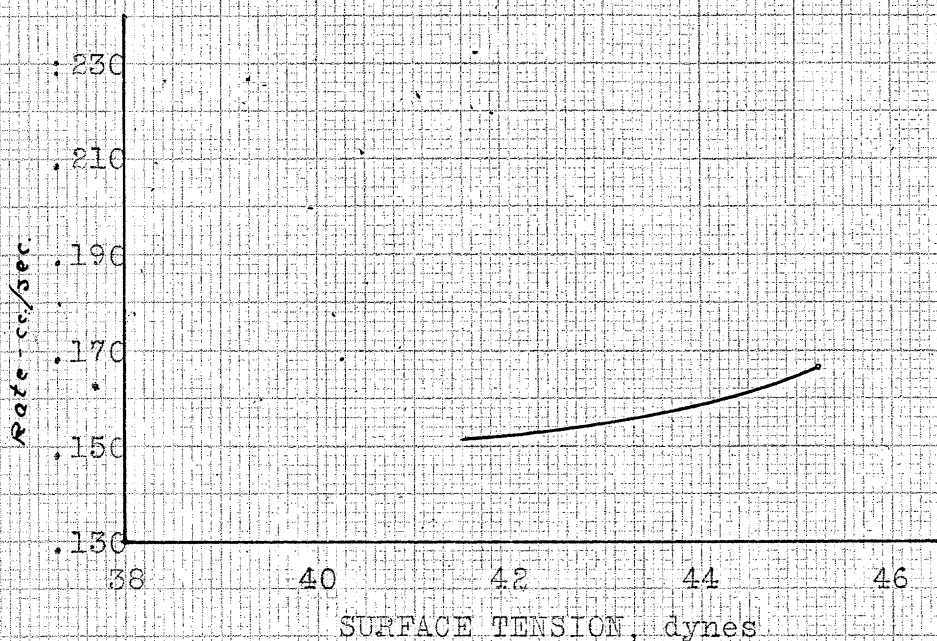
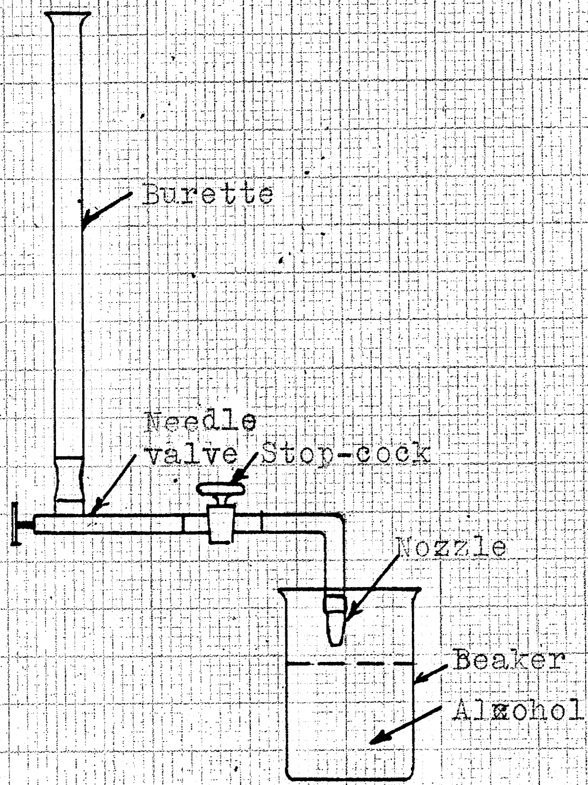
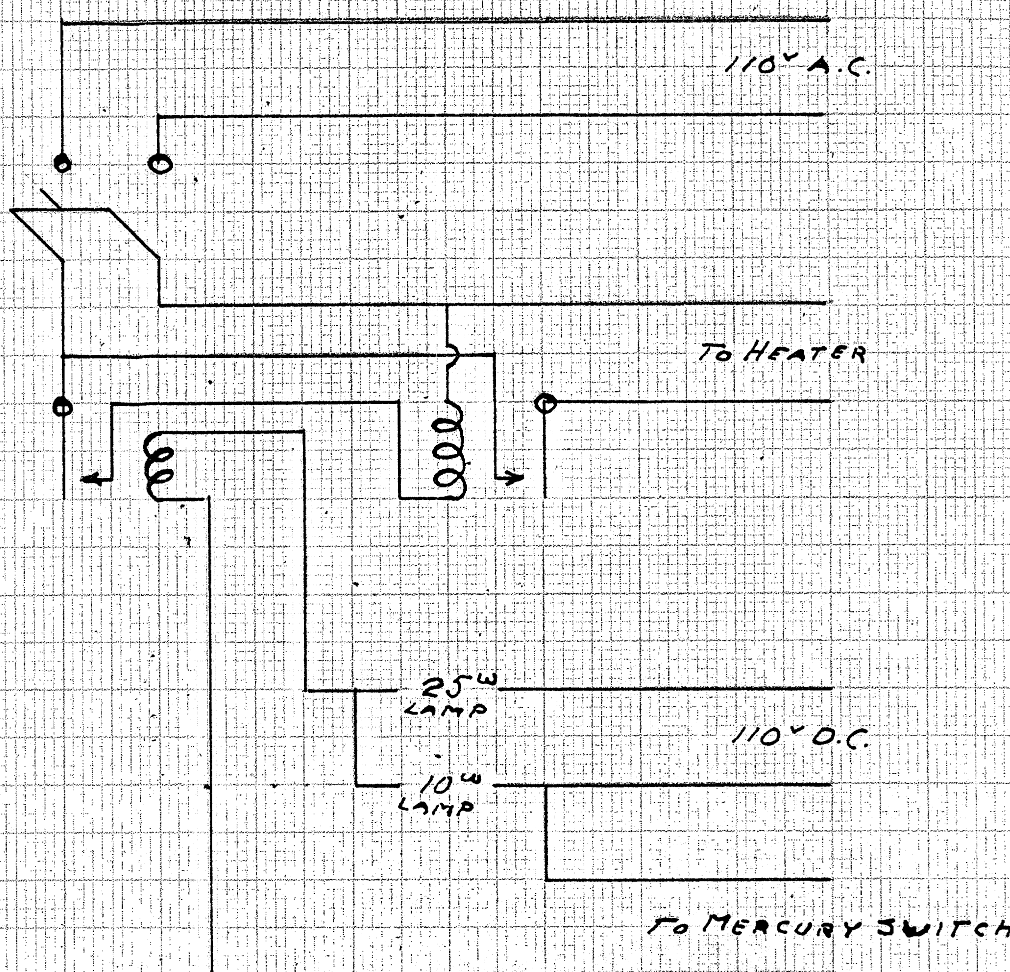


Fig. 9



APPENDIX B


110ᵛ A.C.
To Heater
25ʷ Lamp
110ᵛ D.C.
10ʷ Lamp
To Mercury Switch

APPENDIX C

In the determination of viscosity by means of the Ostwald pipette, an equation of the form

$$n = kdt$$

is assumed. This equation is not strictly accurate for all times of efflux, and to determine the variation of the constant k, a series of runs were made with H_2O from which k was calmulated. A relation expressed by the accompanying curve was found. It may be seen that for times of efflux above 80 sec., with the pipette used, the value of k is constant at 12.84x10 but for times below this, it falls of considerably In using such a pipette, a value of k appropriate to the time of efflux must be used. This value of k may be read directly from a curve similar to that shown.


$K \times 10^5$
13.1
13.0
12.9
12.8
12.7
12.6
12.5
12.4
12.3
12.2
12.1
12.0
11.9
20
30
40
50
60
70
80
90
100
TIME OF EFFLUX-SEC.