CORRELATION OF DATA FOR ADSORPTION OF BINARY GAS MIXTURES ON SOLID ADSORBENTS

by

Charles E. Speer
B. S., University of Texas
1949

Submitted in Partial Fulfillment of the Requirements for the

Degree of Master of Science

from

Massachusetts Institute of Technology
1949

Signature redacted

Signature redacted
Supervisor

Head of Department

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Dept. of Chemical Engineering
Mass. Institute of Technology
Cambridge 39, Mass.
September 1, 1949

Professor Joseph S. Newell
Secretary of the Faculty
M.I.T.
Cambridge 39, Mass.

Dear Sir:

The thesis entitled, "Correlation of Data for Adsorption of Binary Gas Mixtures on Solid Adsorbents," is hereby submitted in partial fulfillment of the requirements for the degree of Master of Science in Chemical Engineering.

Respectfully submitted,

Signature redacted

Charles E. Speer

TABLE OF CONTENTS

		Page
I.	Tables	iv
II.	Figures	vi
III.	Summary	viii
IV.	Introduction	1
V.	Literature Survey	3
VI.	Thermodynamic Test of Data	5
VII.	Solid Fugacity Functions	25
VIII.	Precision	53
IX.	Results	54
X.	Appendix	55
	A. Original Data	56
	B. γ Functions	66
	C. Solid Fugacity Functions	71
	D. Sample Calculations	76
	E. Nomenclature	77
	F. Literature Citations	78

TABLES

Page

I. Hydrocarbon Systems Analyzed - - - - - - - - 4

II. Broughton's Test of Data - - - - - - - - - - - 23

Original Data

AI. Ethylene-Propane-PCC - - - - - - - - - - - - - 56
AII. Ethane-Propane-PCC - - - - - - - - - - - - - 56
AIII. Isobutane-Butene-1 - - - - - - - - - - - - - 57
AIV. Acetylene-Ethylene-PCC - - - - - - - - - - - 57
AV. Ethylene-Propane-PCC - - - - - - - - - - - - 58
AVI. Methane-Ethylene-CG - - - - - - - - - - - - - 58
AVII. Ethylene-Ethane-CG - - - - - - - - - - - - - 59
AVIII. Ethylene-Propylene-CG - - - - - - - - - - - 59
AIX. Ethylene-Propane-CG - - - - - - - - - - - - - 60
AX. Propane-Propylene-CG - - - - - - - - - - - - 60
AXI. Propane-Propylene-GLC - - - - - - - - - - - 61
AXII. Methane-Ethylene-SG - - - - - - - - - - - - 61
AXIII. Ethane-Ethylene-SG- - - - - - - - - - - - - 62
AXIV. Ethane-Propane-SG - - - - - - - - - - - - - 62
AXV. Isobutane-Butene-1 - - - - - - - - - - - - - 63
AXVI. Acetylene-Ethylene-SG - - - - - - - - - - - 63
AXVII. Propane-Ethylene-SG - - - - - - - - - - - - 64
AXVIII. Ethylene-Propylene-SG - - - - - - - - - - - 64
AXIX. Propane-Propylene-SG - - - - - - - - - - - - 65
AXX. Ethylene-Ethane-SG - - - - - - - - - - - - - 65

γ Functions

AXXI. Ethylene-Propane-PCC - - - - - - - - - - - - 66
AXXII. Ethane-Propane-PCC - - - - - - - - - - - - - 66
AXXIII. Isobutane-Butene-1-PCC - - - - - - - - - - - 66
AXXIV. Acetylene-Ethylene-PCC - - - - - - - - - - - 66
AXXV. Ethylene-Propane-PCC - - - - - - - - - - - - 67
AXXVI. Methane-Ethylene-CG - - - - - - - - - - - - 67
AXXVII. Ethylene-Ethane-CG - - - - - - - - - - - - 67
AXXVIII. Ethylene-Propylene-CG - - - - - - - - - - - 67
AXXIX. Ethylene-Propane-CG - - - - - - - - - - - - 68
AXXX. Propane-Propylene-CG - - - - - - - - - - - - 68
AXXXI. Propane-Propylene-GLC - - - - - - - - - - - 68
AXXXII. Methane-Ethylene-SG - - - - - - - - - - - - 68
AXXXIII. Ethane-Ethylene-SG - - - - - - - - - - - - 69
AXXXIV. Ethane-Propane-SG - - - - - - - - - - - - - 69
AXXXV. Isobutane-Butene-1-SG - - - - - - - - - - - 69
AXXXVI. Acetylene-Ethylene-SG - - - - - - - - - - - 69
AXXXVII. Propane-Ethylene-SG - - - - - - - - - - - - 70
AXXXVIII. Ethylene-Propylene-SG - - - - - - - - - - - 70
AXXXIX. Propane-Propylene-SG - - - - - - - - - - - - 70
AXL. Ethylene-Ethane-SG - - - - - - - - - - - - - 70

Solid Fugacities

AXLI. Ethane-Propane-PCC - - - - - - - - - - - - - - 71
AXLII. Isobutane-Butene-1-PCC - - - - - - - - - - - - 71
AXLIII. Acetylene-Ethylene-PCC - - - - - - - - - - - - 72
AXLIV. Methane-Ethylene-CG - - - - - - - - - - - - - - 72
AXLV. Ethylene-Ethane-CG - - - - - - - - - - - - - - 73
AXLVI. Propane-Propylene-GLC - - - - - - - - - - - - - 73
AXLVII. Isobutane-Butene-1-SG - - - - - - - - - - - - - 74
AXLVIII. Propane-Ethylene-SG - - - - - - - - - - - - - - 74
AXLIX. Ethylene-Propylene-SG - - - - - - - - - - - - - 75
AL. Propane-Propylene-SG - - - - - - - - - - - - - - 75

FIGURES

γ Functions

		Page
1.	Ethane-Propane-PCC	7
2.	Isobutane-Butene-1-PCC	8
3.	Acetylene-Ethylene-PCC	9
4.	Ethylene-Propane-PCC	10
5.	Methane-Ethylene-CG	11
6.	Ethylene-Ethane-CG	12
7.	Ethylene-Propylene-CG	13
8.	Propane-Propylene-GLC	14
9;	Ethane-Ethylene-SG	15
10.	Ethane-Propane-SG	16
11.	Isobutane-Butene-1-SG	17
12.	Acetylene-Ethylene-SG	18
13.	Propane-Ethylene-SG	19
14.	Ethylene-Propylene-SG	20
15.	Propane-Propylene-SG	21
16.	Ethylene-Ethane-SG	22

Solid Fugacities vs. Pressure

17.	Ethane-Propane-PCC	28
18.	Acetylene-Ethylene-PCC	29
19.	Methane-Ethylene-CG	30
20.	Ethylene-Ethane-CG	31
21.	Isobutane-Butene-1-SG	32
22.	Ethylene-Propylene-SG	33
23.	Propane-Propylene-SG	34

Solid Fugacities vs. N

24.	Ethane-Propane-PCC	35
25.	Acetylene-Ethylene-PCC	36
26.	Methane- Ethylene-CG	37
27.	Ethylene-Ethane-CG	38
28.	Isobutane-Butene-1-SG	39
29.	Ethylene-Propylene-SG	40
30.	Propane-Propylene-SG	41

Solid Fugacities vs. N for Mixture Adsorption Only

Page

31. Ethane-Propane-PCC - - - - - - - - - - - - - - - - - - 42
32. Acetylene-Ethylene-PCC - - - - - - - - - - - - - - - - 43
33. Methane-Ethylene-CG - - - - - - - - - - - - - - - - - 44
34. Ethylene-Ethane-CG - - - - - - - - - - - - - - - - - - 45
35. Isobutane-Butene-1-SG - - - - - - - - - - - - - - - - 46
36. Ethylene-Propylene-SG - - - - - - - - - - - - - - - - 47
37. Propane-Propylene-SG - - - - - - - - - - - - - - - - - 48

Solid Fugacities vs. P for Mixture Adsorption Only

38. Adsorption on Carbon - - - - - - - - - - - - - - - - - 49
39. Adsorption on Silica Gel - - - - - - - - - - - - - - - 50

SUMMARY

The object of this work was to find correlations based on sound thermodynamic principles which would permit prediction of the adsorption of binary gaseous mixtures on a solid from the adsorption isotherms of the pure gases only. Data concerning the adsorption of twenty hydrocarbon mixtures were examined first by utilizing the thermodynamic requirements proposed by Broughton and then by considering the solid as a component of the system and calculating the variation in its fugacity. Neither of these methods of analysis yielded a general correlation of the data. This was primarily due to the fact that both require extremely accurate data as the pressure of the gas being adsorbed approaches zero, and such data were not available.

It was concluded that the Langmuir and the Magnus equations as extended to gaseous mixtures are not generally applicable, that the Broughton criterion cannot be used for testing data or as a possible means of general correlation unless the data are extremely accurate at very low pressures, that there is no general correlation for the variation in the fugacity of the solid adsorbent, and that the Van Laar type of equation cannot be applied in the form proposed by Cadogan and Chertow since the fugacity of the solid varies with the composition of the gaseous mixture.

INTRODUCTION

For many years there has been much interest in the nature of the adsorption of gases on solids. Not only is adsorption of primary concern in many catalytic reaction processes, but also it may prove to be of considerable importance in the separation of petroleum refinery gases. It is the latter consideration that prompted this work.

The normal method of separating the hydrocarbons of petroleum is the distillation and rectification of the crude petroleum. Naturally this method depends on differences in the boiling points of the various components present. However, when the molecular weights of the compounds are nearly equal, these differences become too small to afford a practical separation in this manner. In addition, the very low molecular weight compounds are gases at normal temperatures and pressures, and special high pressure or low temperature equipment would be required to use the distillation procedure at all. A reliable method of predicting the characteristics of selective adsorption would be of great value in judging whether or not the distillation process could be replaced by an adsorption process.

The purpose of this work then was to analyze and correlate previously published data in such a manner that the adsorption of binary gaseous mixtures on a

solid could be predicted from data on the separate adsorption of the pure gases on the solid. In addition, it was proposed to derive these correlations from sound thermodynamic bases rather than from purely empirical considerations.

Most of the previous work done has been concerned with the adsorption of a single pure gas on a solid. Various empirical and semi-theoretical correlations have been presented for predicting the adsorption isotherms of specific systems, but no entirely general correlation has been found. Attempts to extend these theories to gaseous mixtures have not met with much success. One of the main difficulties encountered in these extensions has been the lack of experimental data for mixture adsorption. Such data are now available and show the lack of general applicability of these extensions, the most important of which are the Langmuir (2), the Magnus (2), and the Hill (5) equations. Broughton (1) has also provided a thermodynamic means of testing such equations and he has shown that the Langmuir equation is correct only in a very special instance. Likewise, the Magnus equation proved to be generally inapplicable by this test. The Hill equation is at present in such an impractical form that it could not be tested either by the Broughton criterion or by actual data.

LITERATURE SURVEY

Since the main interest in mixed adsorption lies in the possibilities of separation of hydrocarbons, it was thought desirable to confine the examination to hydrocarbon mixtures. A search of the literature revealed that the only signifigant data were to be found in work recently done at the Massachusetts Institute of Technology. Most of this work was done by Cadogan (3) and Chertow (4) and their coworkers, and all of the data were summarized and presented by one or the other of these men. These two references were the only sources of data used for this analysis. Since the majority of the investigations were carried out at a temperature of 25°C and a pressure of one atmosphere, it was decided to further restrict the examination to data obtained under these conditions. All the data used in this work as original data were obtained from the smoothed curves presented in the references. Table I presents the systems considered and Tables AI through AXX give the original data for them.

Table I

Hydrocarbon Systems Analyzed

Hydrocarbons	Adsorbent	Reference
Ethylene-Propane	PCC+	(3)
Ethane-Propane	"	"
Isobutane-Butene-1	"	"
Acetylene-Ethylene	"	(4)
Ethylene-Propane	"	"
Methane-Ethylene	CG++	(3)
Ethylene-Ethane	"	"
Ethylene-Propylene	"	"
Ethylene-Propane	"	"
Propane-Propylene	"	"
Propane-Propylene	GLC+++	(4)
Methane-Ethylene	SG++++	(3)
Ethane-Ethylene	"	"
Ethane-Propane	"	"
Isobutane-Butene-1	"	"
Acetylene-Ethylene	"	(4)
Propane-Ethylene	"	"
Ethylene-Propylene	"	"
Propane-Propylene	"	"
Ethylene-Ethane	"	"

+ Pittsburgh Coke and Chemical Co. Activated Carbon, 28/60 mesh.

++ Columbia G Activated Carbon, 8/14 mesh.

+++ Godfrey L. Cabot Carbon Black.

++++ Davison Silica Gel, Refrigeration Grade, 14/20 mesh.

THERMODYNAMIC TEST OF DATA

Broughton (1) presented a thermodynamic basis for the examination of binary mixture data but at the time of presentation, not enough data were available to test it adequately. The initial step in the analysis then was the testing of the data for thermodynamic validity. Broughton showed that for a binary gas mixture maintained at constant temperature and at equilibrium at all times

$$\int_0^{N_A} \ln \frac{P_A}{P_A^\circ} \cdot dN_A = \int_0^{N_B} \ln \frac{P_B}{P_B^\circ} \cdot dN_B$$

where: N = the number of moles of gas adsorbed per unit weight of solid.

P° = the pressure of pure gas over the solid.

P = the partial pressure of the gas in the binary mixture over the solid.

This equation can be further simplified to

$$N_A^\circ \int_0^1 \ln \gamma_A \cdot dr_A = N_B^\circ \int_0^1 \ln \gamma_B \cdot dr_B$$

where: N° = the number of moles of pure gas adsorbed per unit weight of solid under a total pressure equal to the mixture pressure.

γ = the ratio P/P°.

r = the ratio N/N°.

Thus, the graphical integration of $\ln \gamma = \phi(r)$ for the two gases in a binary mixture should provide a means of determining the validity of the reported data, i. e., the ratio of the areas under the curves should be equal to the reciprocal of the ratio of the N°'s.

Figures 1 through 16 show these "γ" functions for sixteen of the systems. Four of the systems so obviously violated this condition that the γ funtions were not plotted. Tables AXXI through AXL give the calculated values of γ and r for all twenty systems.

Figure 1.

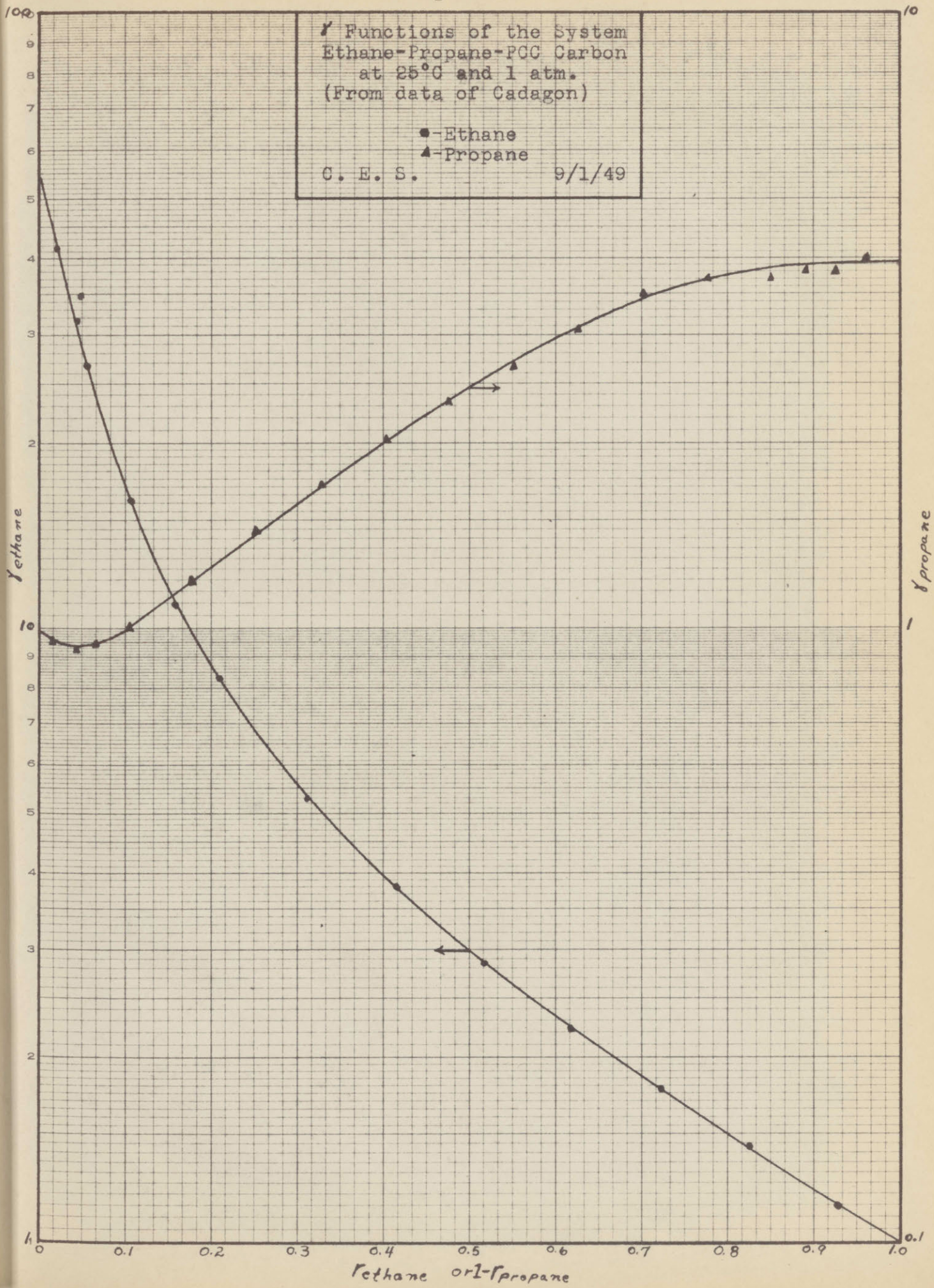

γ Functions of the System
Ethane-Propane-PCC Carbon
at 25°C and 1 atm.
(From data of Cadagon)
●-Ethane
▲-Propane
C. E. S. 9/1/49
γ ethane
γ propane
r ethane or 1-r propane
100
10
1
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Figure 2.

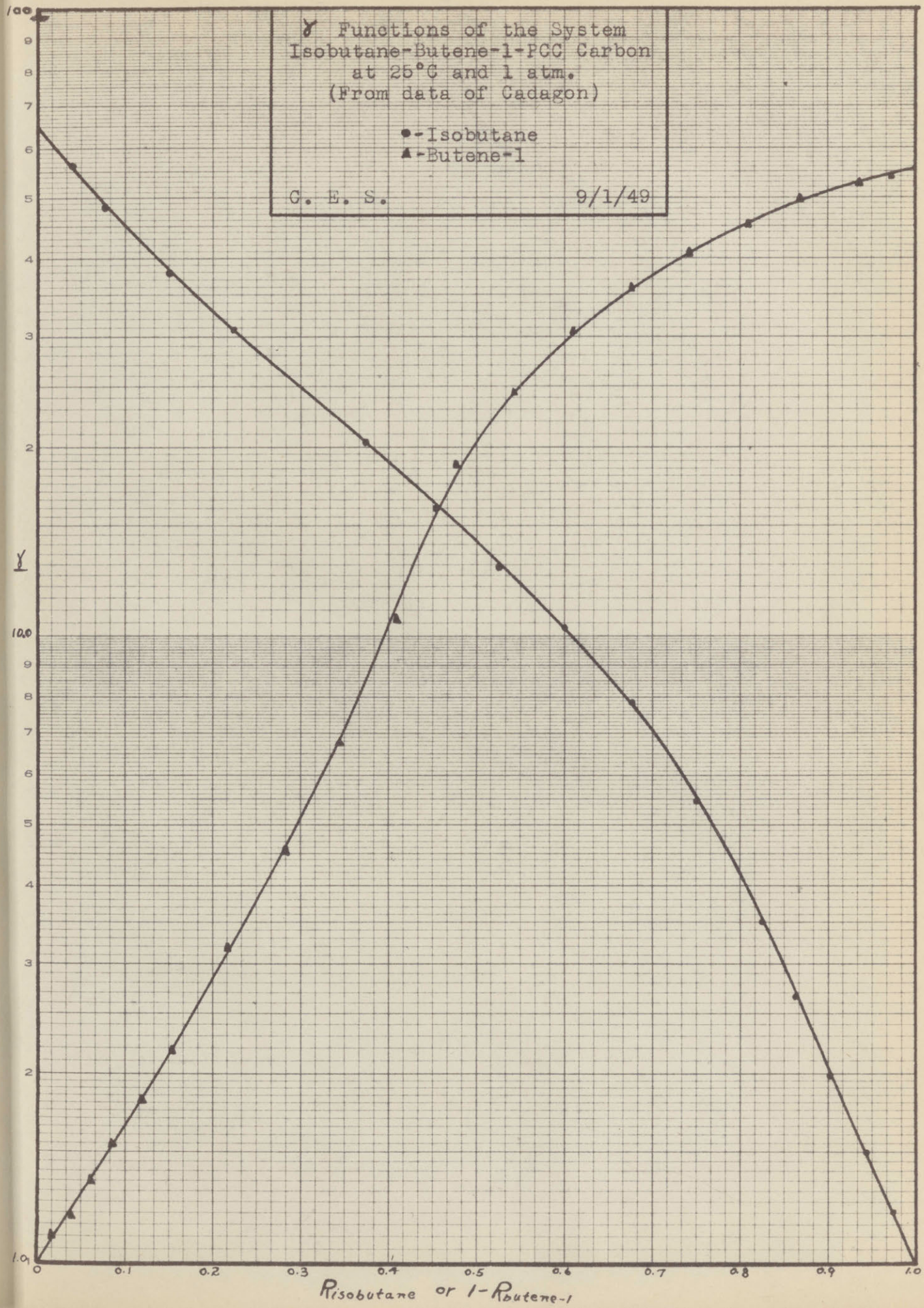

γ Functions of the System
Isobutane-Butene-1-PCC Carbon
at 25°C and 1 atm.
(From data of Cadagon)
●-Isobutane
▲-Butene-1
C. E. S.
9/1/49
γ
100
10.0
1.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Risobutane or 1-Rbutene-1

Figure 3.

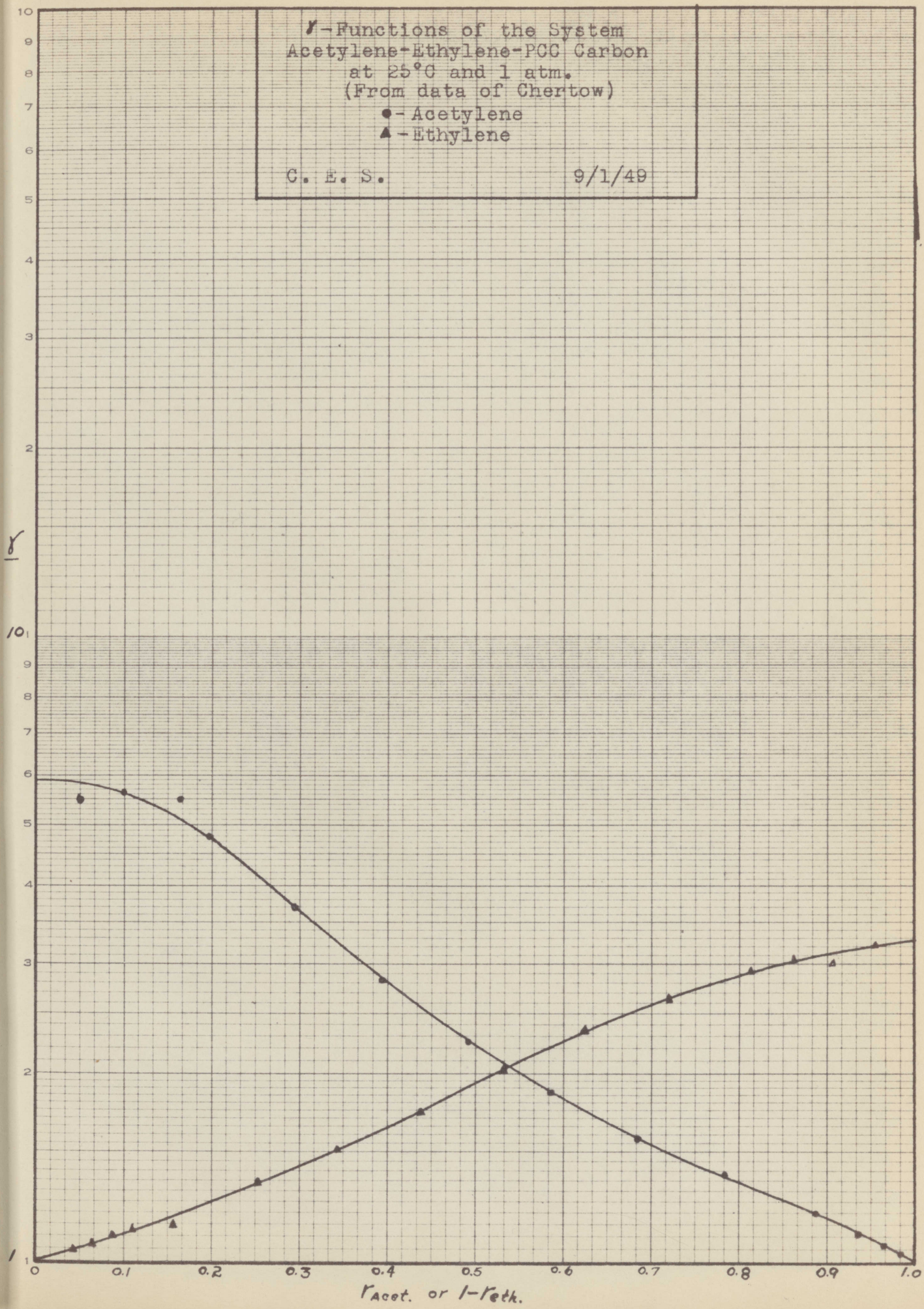

γ-Functions of the System
Acetylene-Ethylene-PCC Carbon
at 25°C and 1 atm.
(From data of Chertow)
●-Acetylene
▲-Ethylene
C. E. S.
9/1/49
γ
10
9
8
7
6
5
4
3
2
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
r Acet. or 1-r Eth.

Figure 4.

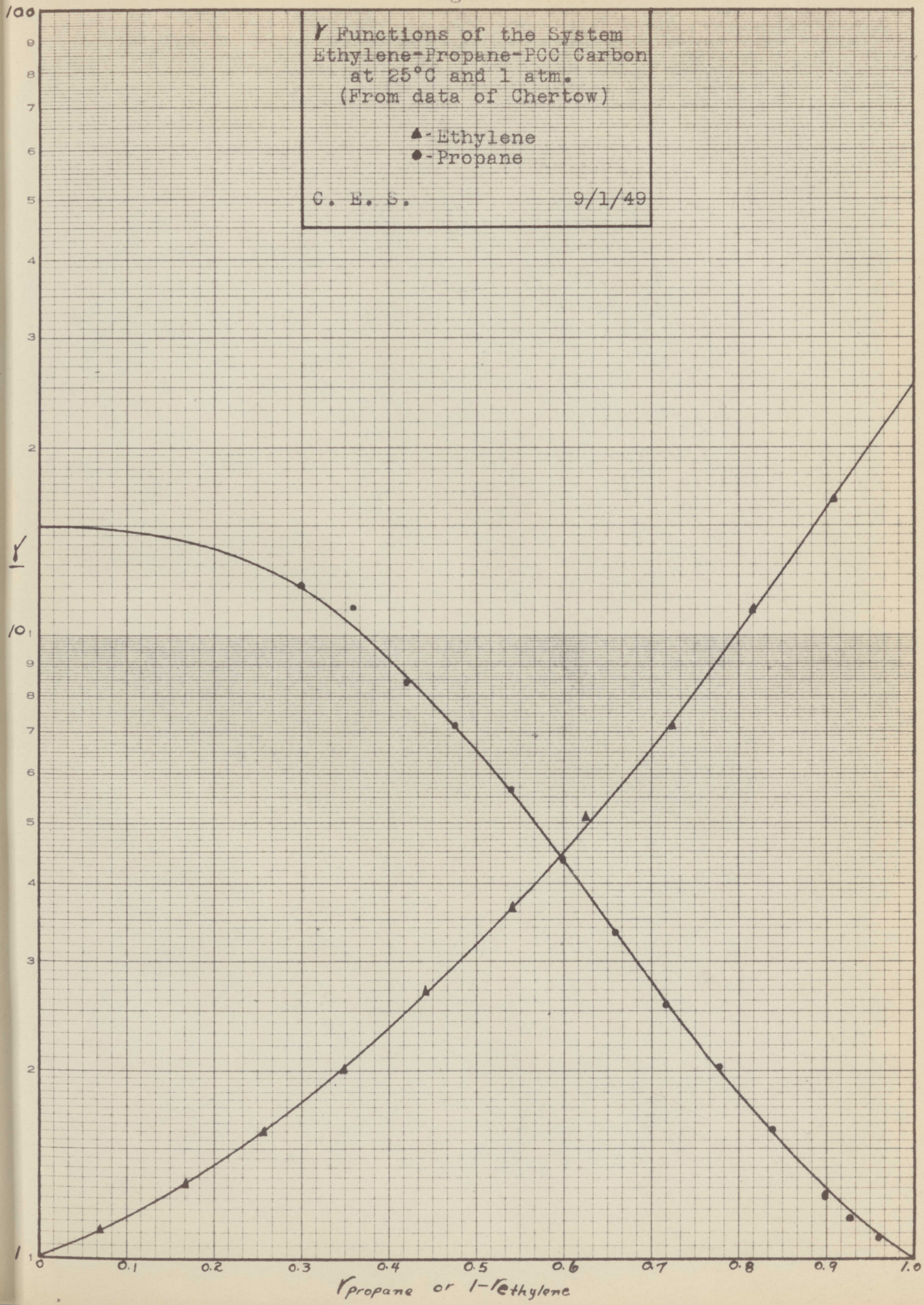

γ Functions of the System
Ethylene-Propane-PCC Carbon
at 25°C and 1 atm.
(From data of Chertow)
▲-Ethylene
●-Propane
C. E. S. 9/1/49
γ
100
10
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
γpropane or 1-γethylene

Figure 5.

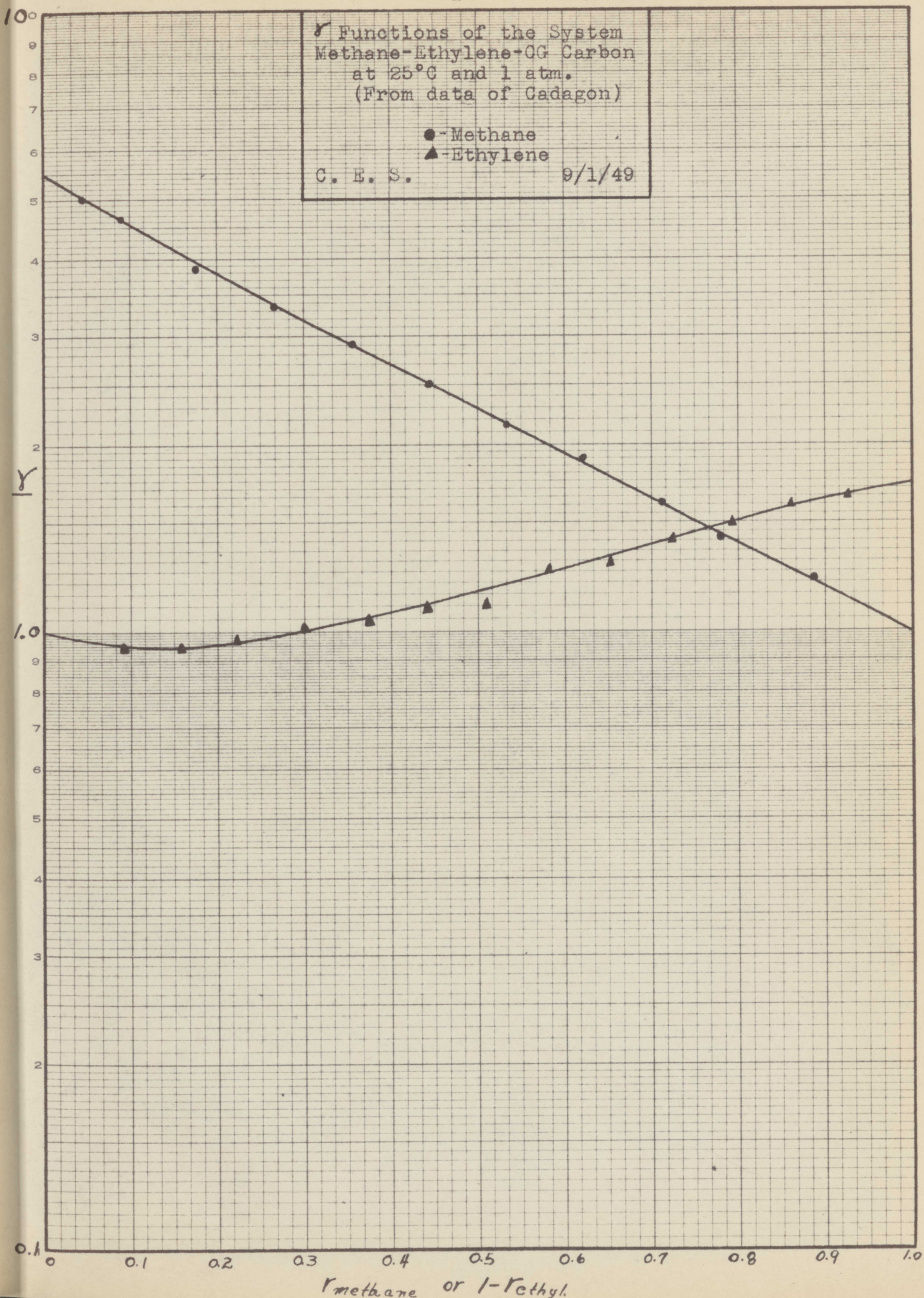

γ Functions of the System
Methane-Ethylene-OG Carbon
at 25°C and 1 atm.
(From data of Cadagon)
●-Methane
▲-Ethylene
C. E. S.
9/1/49
γ
10
1.0
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
γmethane or 1-γethyl.

Figure 6.

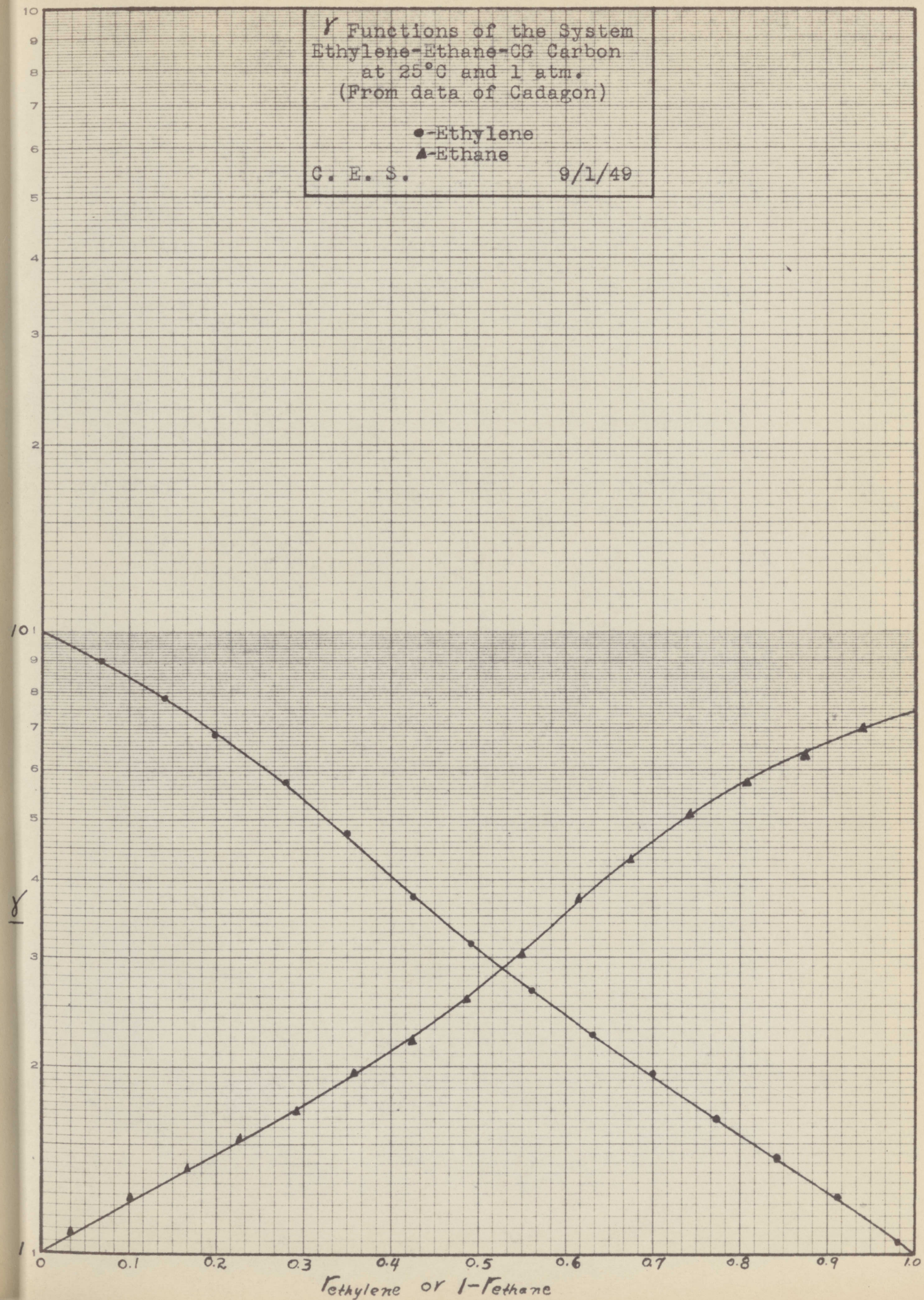

γ Functions of the System
Ethylene-Ethane-CG Carbon
at 25°C and 1 atm.
(From data of Cadagon)
●-Ethylene
▲-Ethane
C. E. S. 9/1/49
γ
$r_{ethylene}$ or $1-r_{ethane}$
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1
2
3
4
5
6
7
8
9
10

Figure 7.

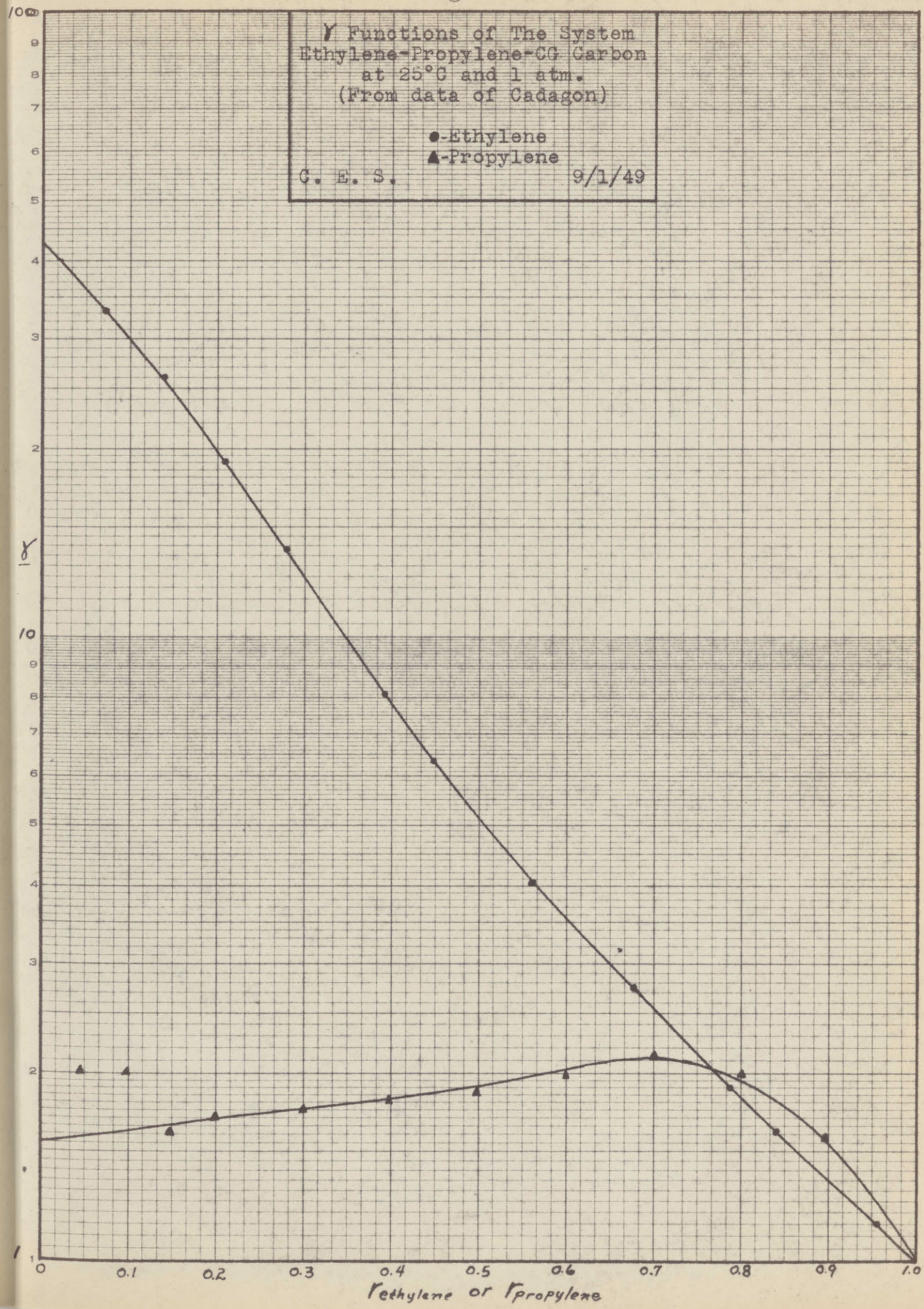

γ Functions of The System
Ethylene-Propylene-CG Carbon
at 25°C and 1 atm.
(From data of Cadagon)
●-Ethylene
▲-Propylene
C. E. S.
9/1/49
γ
r ethylene or r propylene
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1
2
3
4
5
6
7
8
9
10

Figure 8.

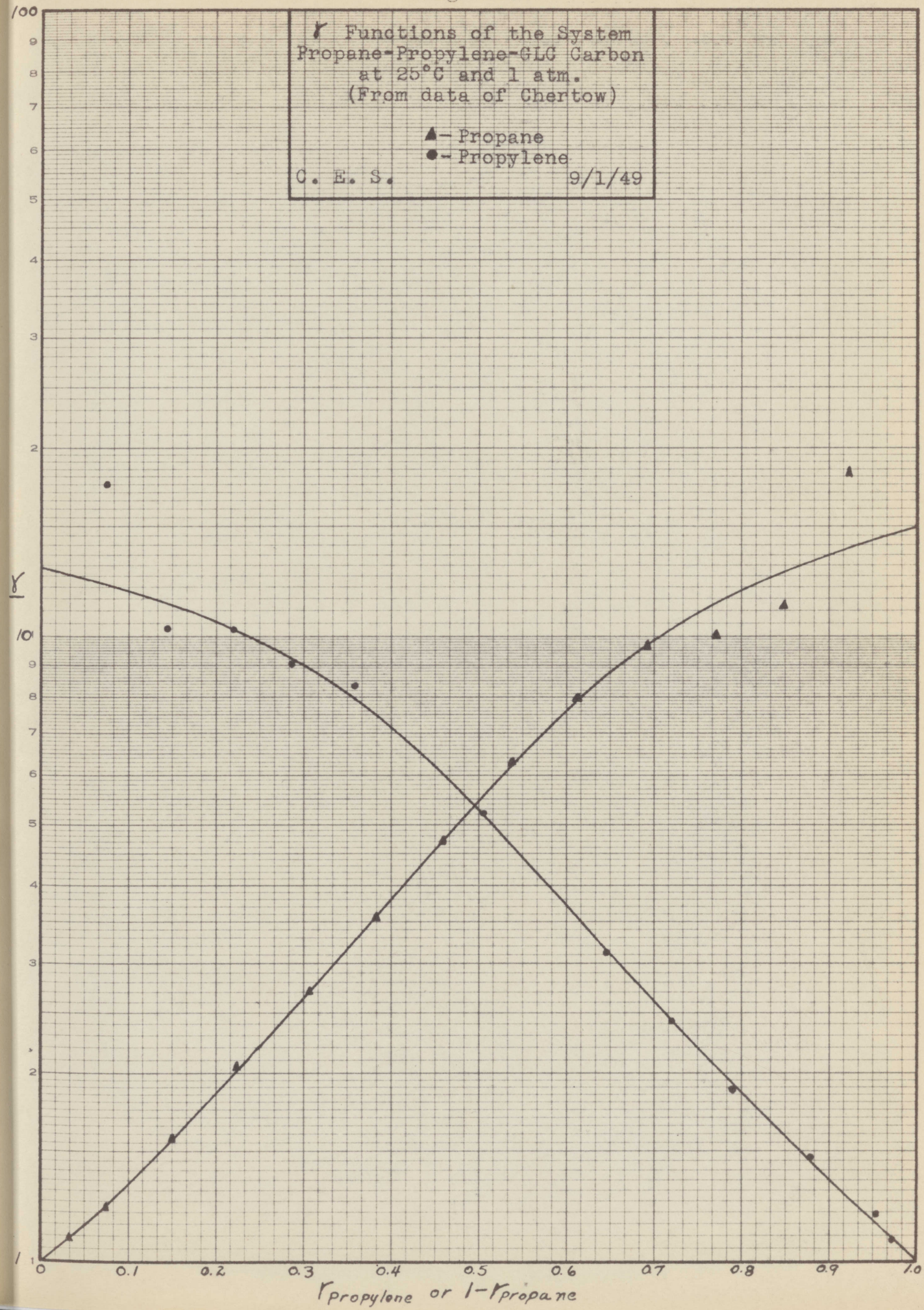

γ Functions of the System
Propane-Propylene-GLC Carbon
at 25°C and 1 atm.
(From data of Chertow)
▲- Propane
●- Propylene
C. E. S.
9/1/49
γ
100
10
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
γpropylene or 1-γpropane

Figure 9.

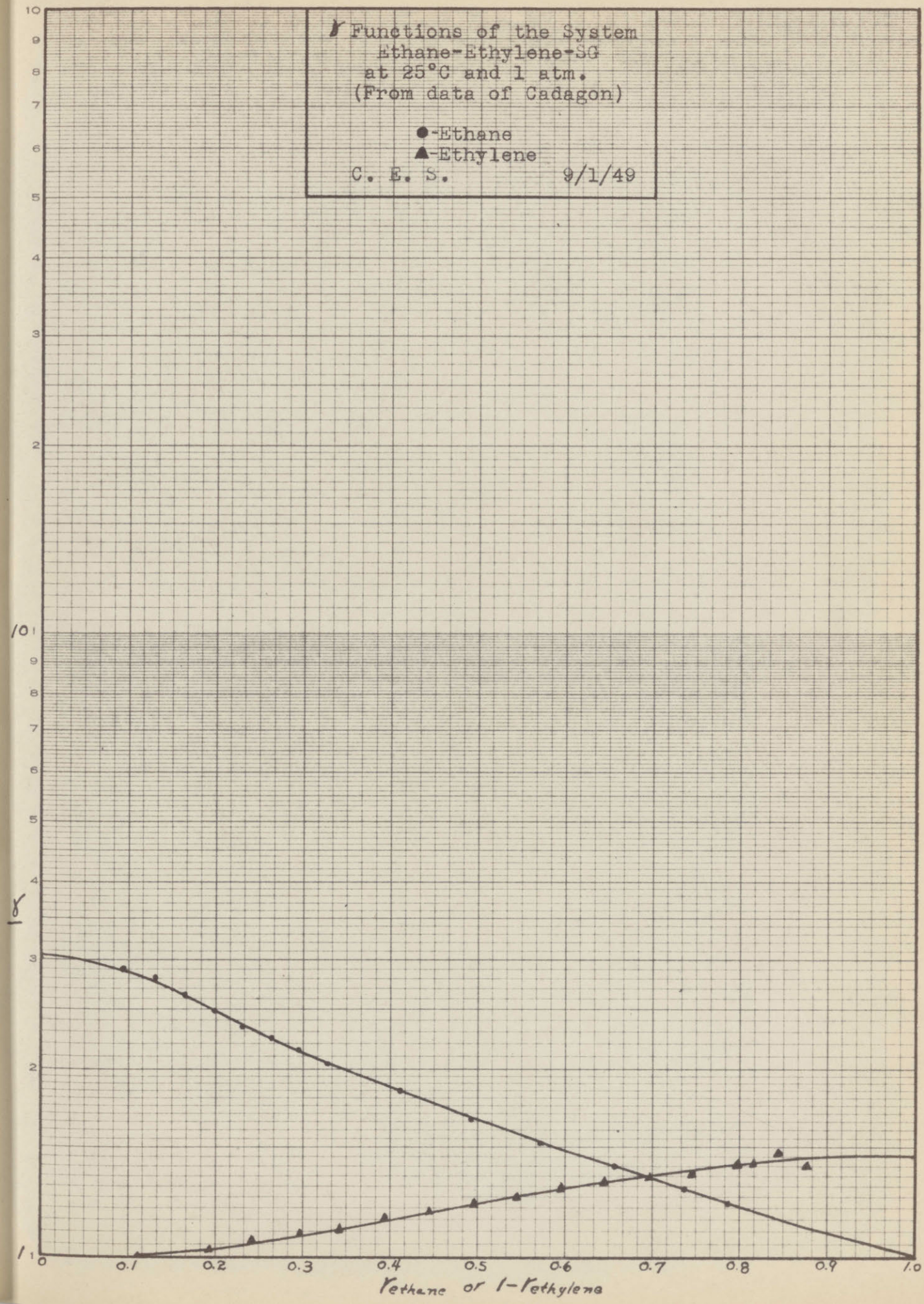

γ Functions of the System
Ethane-Ethylene-SG
at 25°C and 1 atm.
(From data of Cadagon)
●-Ethane
▲-Ethylene
C. E. S. 9/1/49
γ
γethane or 1-γethylene
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1
2
3
4
5
6
7
8
9
10

Figure 10.

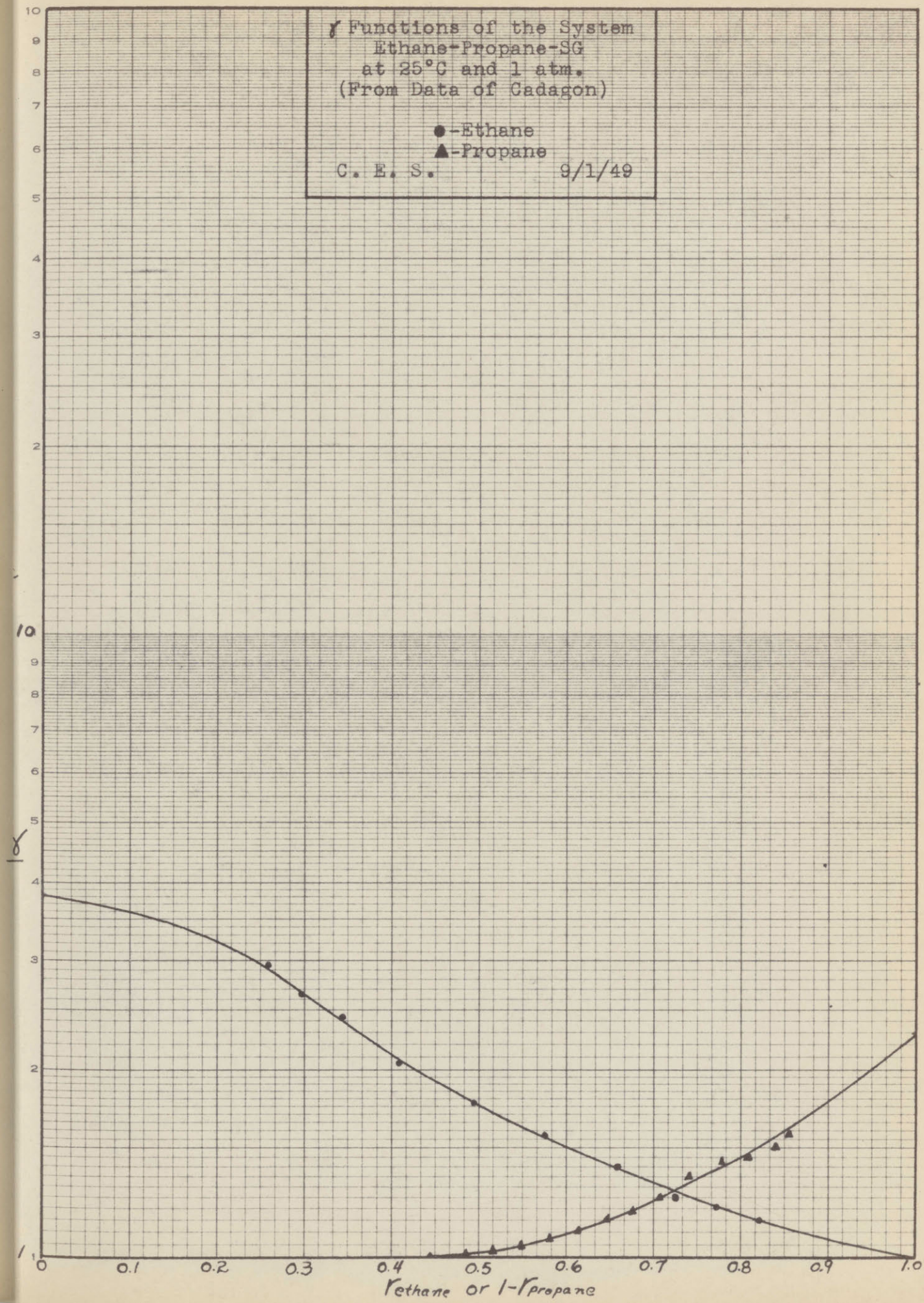

γ Functions of the System
Ethane-Propane-SG
at 25°C and 1 atm.
(From Data of Cadagon)
●-Ethane
▲-Propane
C. E. S. 9/1/49
γ
10
9
8
7
6
5
4
3
2
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
r ethane or 1-r propane

Figure 11.

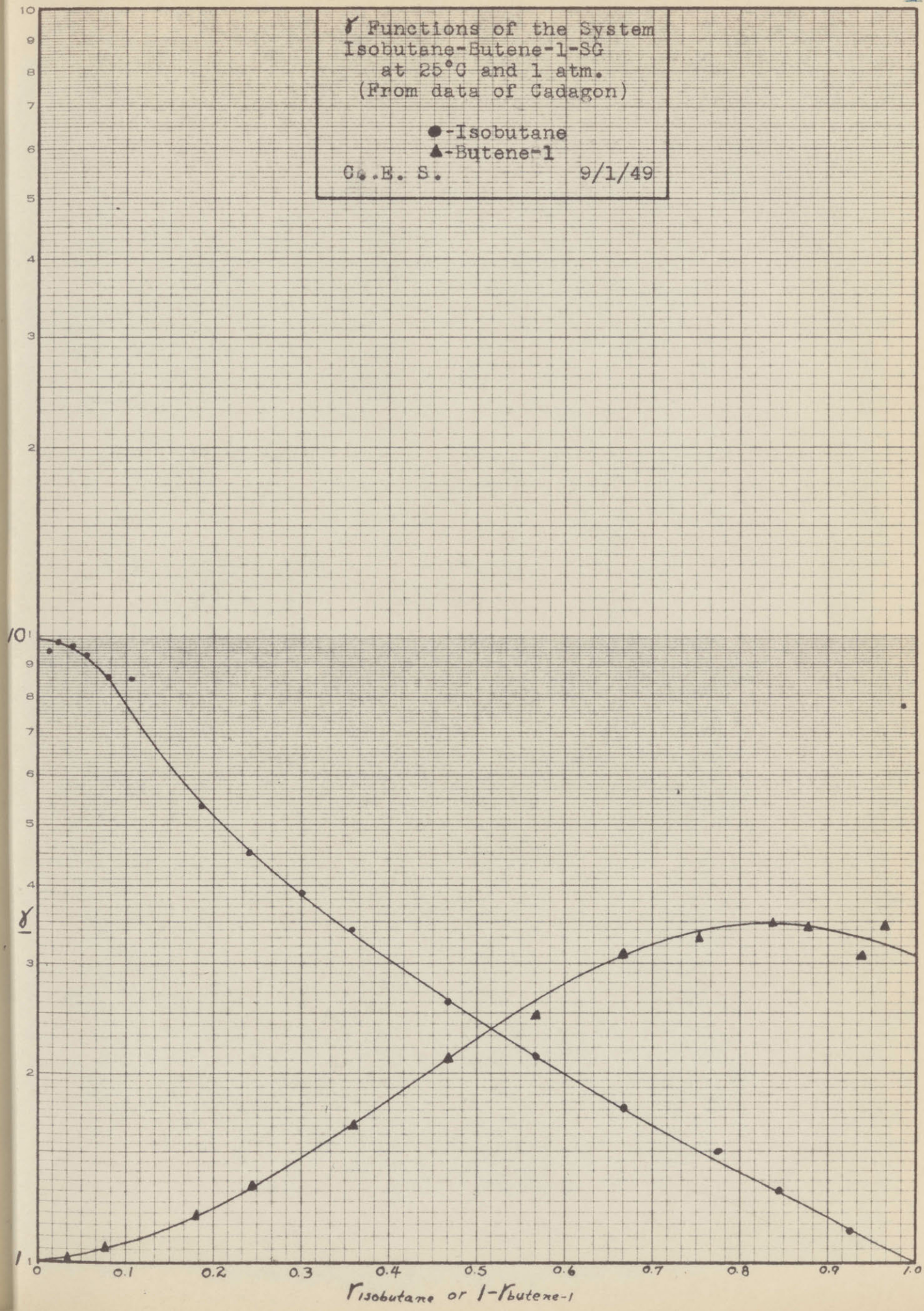

γ Functions of the System
Isobutane-Butene-1-SG
at 25°C and 1 atm.
(From data of Cadagon)
●-Isobutane
▲-Butene-1
C.E.S. 9/1/49
γ
$r_{isobutane}$ or $1-r_{butene-1}$
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1
2
3
4
5
6
7
8
9
10

Figure 12.

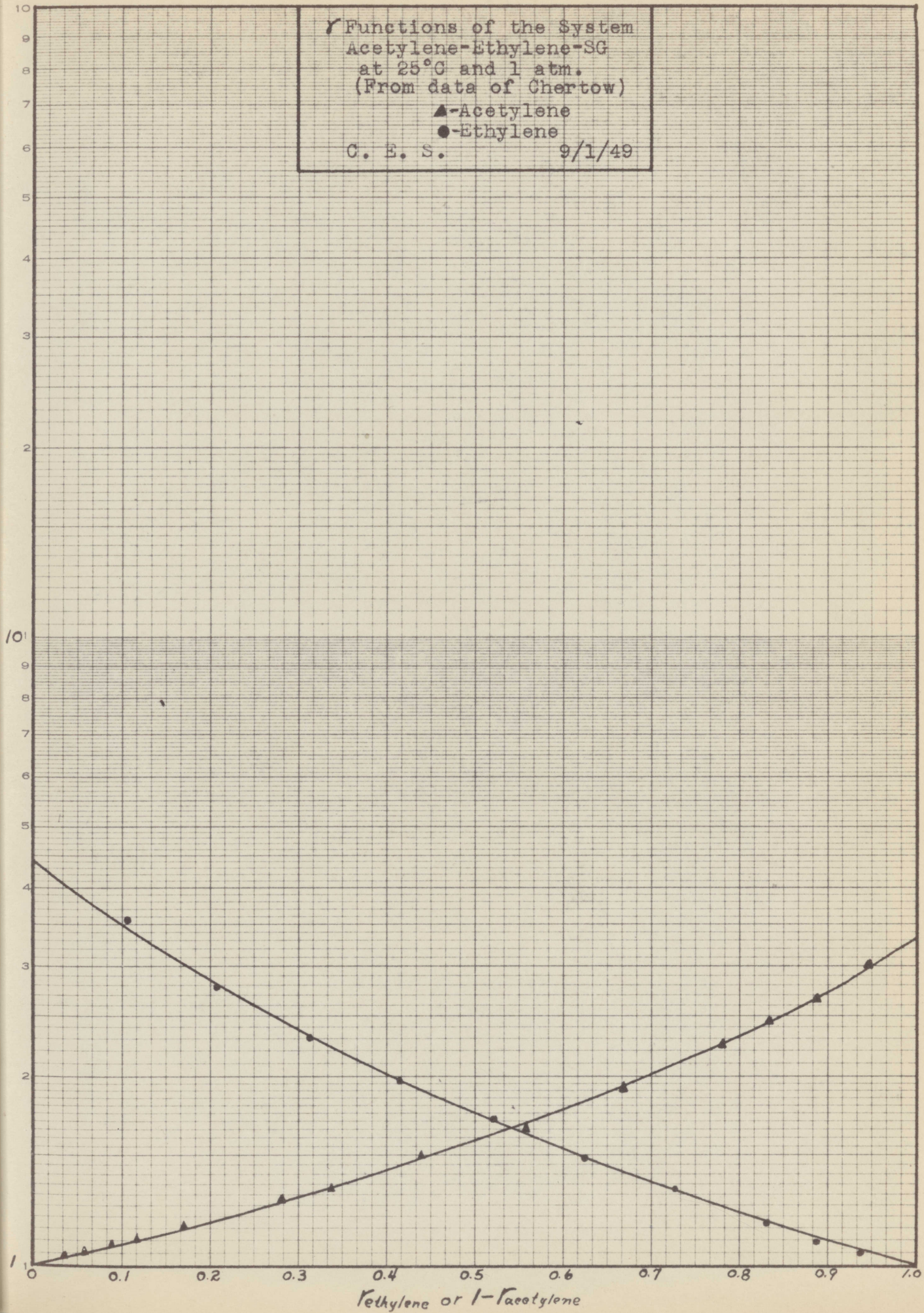

γ Functions of the System
Acetylene-Ethylene-SG
at 25°C and 1 atm.
(From data of Chertow)
▲-Acetylene
●-Ethylene
C. E. S. 9/1/49
10
9
8
7
6
5
4
3
2
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
γethylene or 1-γacetylene

Figure 13.

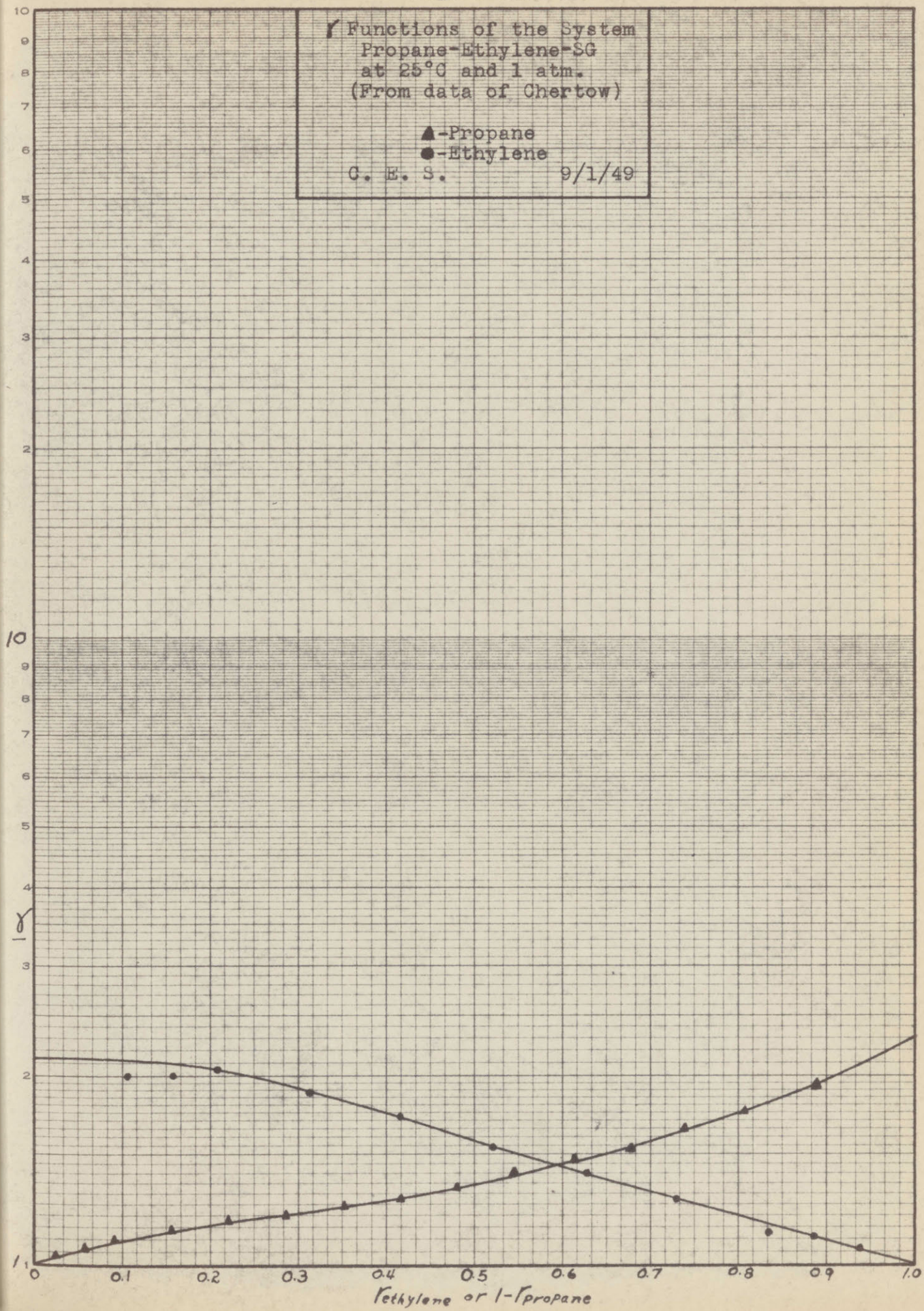

γ Functions of the System
Propane-Ethylene-SG
at 25°C and 1 atm.
(From data of Chertow)
▲-Propane
●-Ethylene
C. E. S. 9/1/49
10
9
8
7
6
5
4
3
2
1
γ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
γethylene or 1-γpropane

Figure 14.

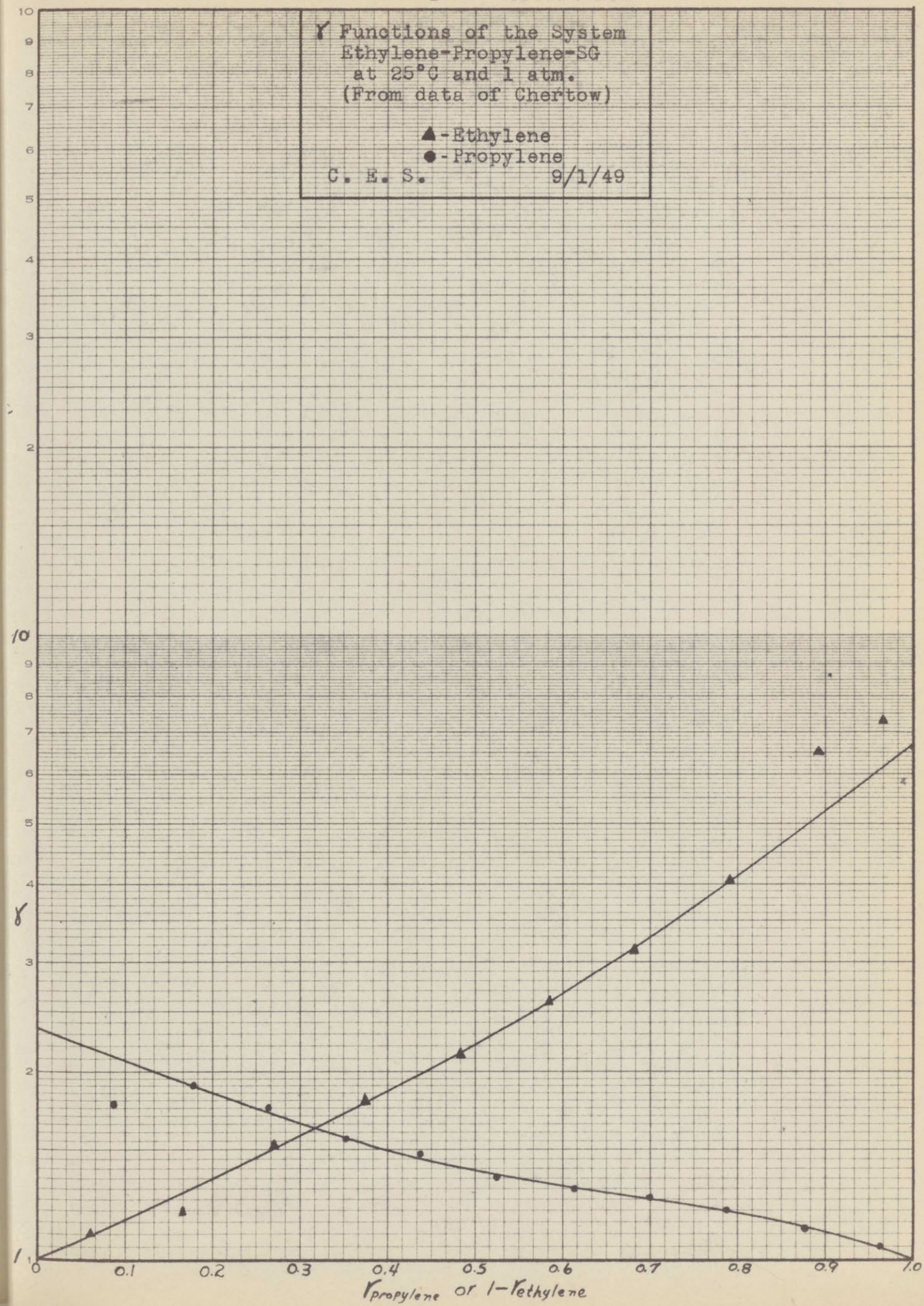

γ Functions of the System
Ethylene-Propylene-SG
at 25°C and 1 atm.
(From data of Chertow)
▲-Ethylene
●-Propylene
C. E. S. 9/1/49
γ
γpropylene or 1-γethylene
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1
2
3
4
5
6
7
8
9
10

Figure 15.

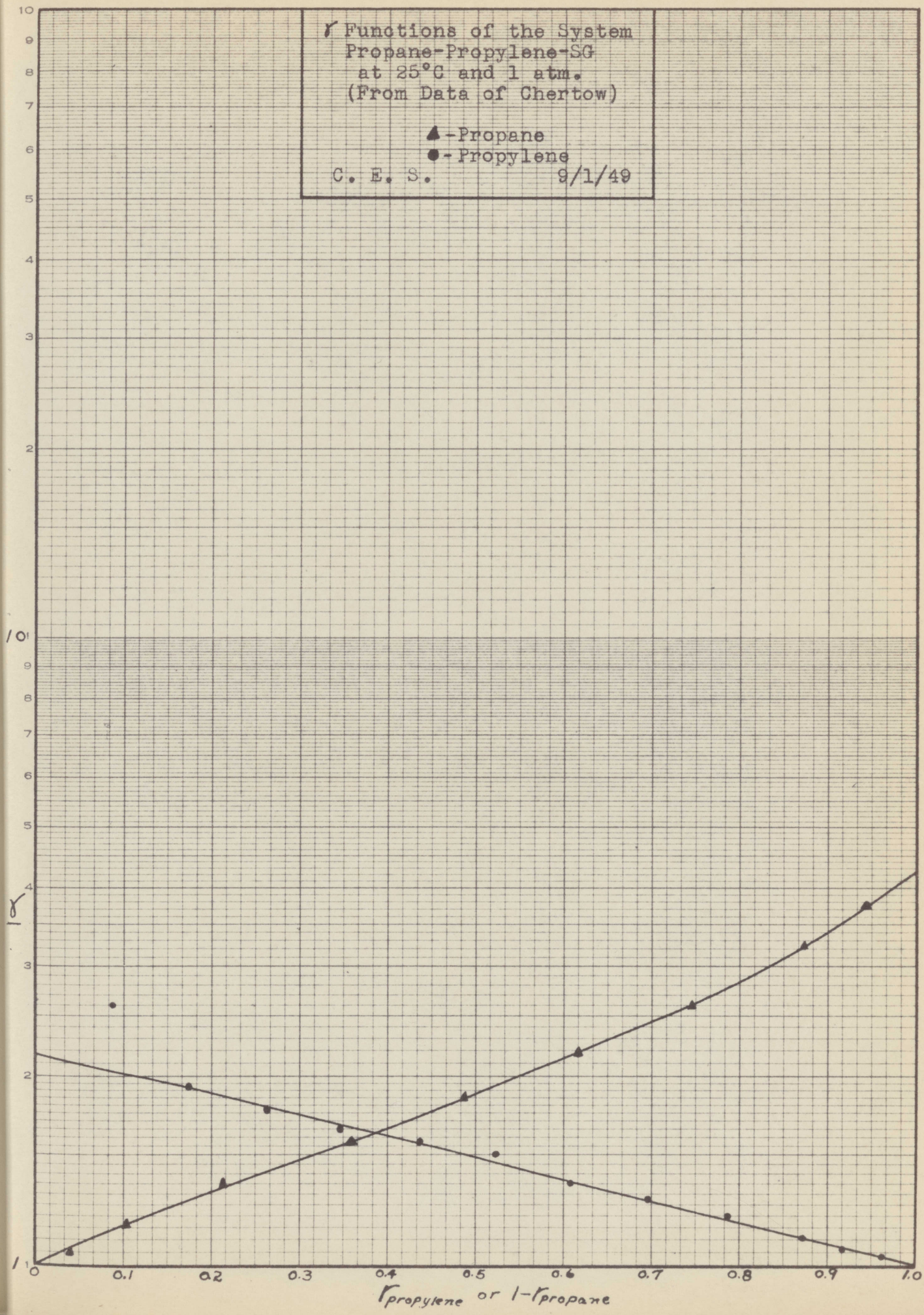

γ Functions of the System
Propane-Propylene-SG
at 25°C and 1 atm.
(From Data of Chertow)
▲-Propane
●-Propylene
C. E. S. 9/1/49
γ
γpropylene or 1-γpropane
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1
2
3
4
5
6
7
8
9
10

Figure 16.

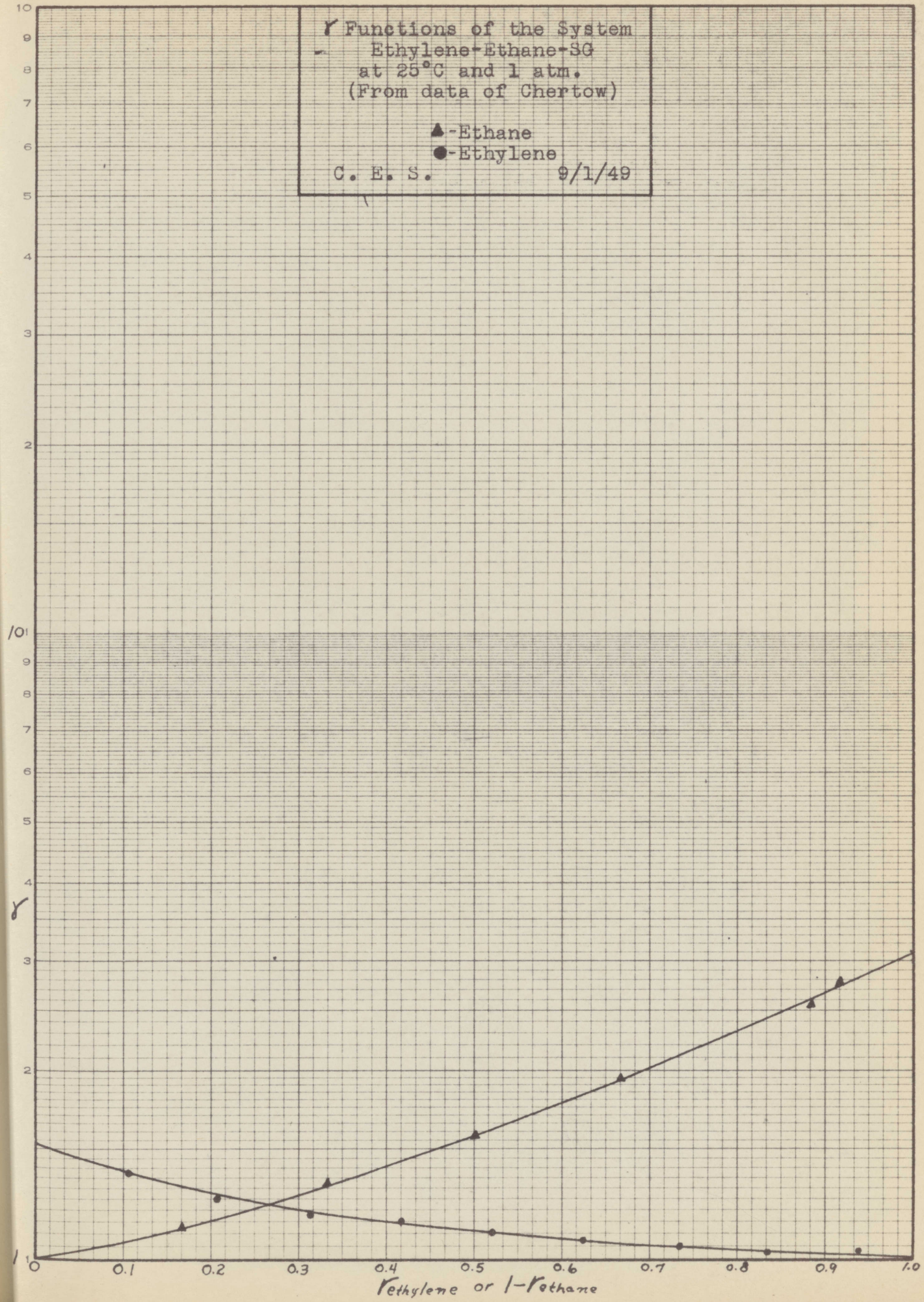

γ Functions of the System
Ethylene-Ethane-SG
at 25°C and 1 atm.
(From data of Chertow)
▲-Ethane
●-Ethylene
C. E. S. 9/1/49
γ
γethylene or 1-γethane
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1
2
3
4
5
6
7
8
9
10

Table II presents the results of the graphical integration of the γ functions.

Table II

Broughton's Test of Data

System					% Diff.
Component A	Component B	Ads.	$N_A^0\int_0^1 \ln\gamma_A \cdot dr_A$	$N_B^0\int_0^1 \ln\gamma_B \cdot dr_B$	$=\left(\frac{B-A}{A}\right)100$
Ethylene	Propane	PCC	------	------	»100
Ethane	Propane	"	1.375	1.151	-16.3
Isobutane	Butene-1	"	3.56	4.20	18.0
Acetylene	Ethylene	"	0.786	0.593	-24.6
Ethylene	Propane	"	1.235	2.39	-93.5
Methane	Ethylene	CG	0.413	0.276	-33.2
Ethylene	Ethane	"	1.81	1.74	- 3.90
Ethylene	Propylene	"	2.75	1.24	-55.0
Ethylene	Propane	"	------	------	»100
Propane	Propylene	"	Insufficient data.		
Propane	Propylene	GLC	1.759	1.823	- 3.6
Methane	Ethylene	SG	Unreliable data.		
Ethane	Ethylene	"	0.1445	0.0814	-42.4
Ethane	Propane	"	0.170	0.106	-37.6
Isobutane	Butene-1	"	1.012	1.043	3.06
Acetylene	Ethylene	"	0.389	0.267	-31.4
Propane	Ethylene	"	0.230	0.1825	-20.6
Ethylene	Propylene	"	0.358	0.3875	9.08
Propane	Propylene	"	0.445	0.402	- 9.67
Ethylene	Ethane	"	0.0566	0.1315	132

It can be seen that, according to this test, few of the data seem to be consistent with the thermodynamic requirements. This is due to the fact that the test requires high precision of the data in regions where this is usually not obtainable. Most of the area under each curve is to be found at the end at which r approaches zero. At this end, the pressure is also approaching zero and as this happens, the precision of the original data becomes very poor. In order to obtain values of γ

at low r's, it was necessary to extrapolate the original data to such low values of pressure that errors of 50% or more could easily be made. Even with careful extrapolation of the original data as far as possible, it was still necessary to extrapolate the γ functions to zero r. With these extrapolations, which occur at such critical regions, it is not surprising that the correct area ratios are not obtained. It seems unlikely therefore, that this test can be used for more than a qualitative check unless extremely precise data for the critical regions are available. It can be used for this however, and on this basis the following systems seemed doubtful enough to be neglected in subsequent examinations.

Ethylene-Propane-PCC (3)
Ethylene-Propane-PCC (4)
Ethylene-Propylene-CG
Ethylene-Propane-CG
Propane-Propylene-CG
Methane-Ethylene-SG
Ethane-Ethylene-SG (3)
Ethane-Propane-SG
Acetylene-Ethylene-SG
Ethylene-Ethane-SG (4)

In spite of the difficulties involved in using this test, attempts were made to find simple empirical equations for the γ functions, and in doing so, impose the condition of correct area ratios. It was thought that these functions might possibly be correlated by such means. Such investigations showed that the wide diversity of the shapes of the curves prevented the use of the γ functions as a means of general correlation.

SOLID FUGACITY FUNCTIONS

In a further attempt to find a sound thermodynamic correlation, the possibility of a relation between the fugacity of the solid adsorbent when the pure gases are separately adsorbed and the fugacity of the solid adsorbent when the gaseous mixture is adsorbed was investigated.

Consider the system of pure gas and solid as a binary one, i. e., include the normally neglected solid as a component. If

$$\bar{F}_s \equiv \left[\frac{\partial F_s}{\partial N_s}\right]_{P,T,N_g}$$

$$\bar{F}_g \equiv \left[\frac{\partial F_g}{\partial N_g}\right]_{P,T,N_s}$$

where: N is the number of moles adsorbed.

F is the molal free energy.

$\bar{F}$ is the partial molal free energy.

s refers to the solid.

g refers to the gas.

then, from basic thermodynamic relations

$$N_s d\bar{F}_s + N_g d\bar{F}_g = 0\Big]_{P,T} \text{ - - - - - - - - - } (1)$$

If, during the adsorption process, the total pressure is assumed to be held constant by a non-adsorbable gas that has a negligible effect on $\bar{F}_s$ and $\bar{F}_g$, then the restriction of constant pressure may be neglected. Since $d\bar{F}_s \equiv RTd\ln f_s$, where f is the fugacity, equation (1) becomes $N_s d\ln f_s + N_g d\ln f_g = 0\Big]_T$. Since the moles of

solid remain constant,

$$d\ln f_s^{N_s} = -N_g d\ln f_g \Big]_T \text{ - - - - - - - - - - } (2)$$

For the gas mixtures, i. e., ternary systems, similar reasoning shows that

$$d\ln f_s^{N_s} = -N_A d\ln f_A - N_B d\ln f_B \Big]_{P,T} \text{ - - - - } (3)$$

Here one does not require the hypothetical non-adsorbable gas to maintain constant pressure. Since the pressures in question are all atmospheric or less, partial pressures may be substituted for the fugacities of the gases. Also, $d\ln P = \frac{dP}{P}$ and $dP_A = -dP_B$. Upon substitution in equations (2) and (3), one obtains the final equations

$$d\ln f_s^{N_s} = -\frac{N_g}{P_g} dP_g \Big]_T \text{ - - - - - - - - - - - - - - - } (4)$$

$$d\ln f_s^{N_s} = -\left(\frac{N_A}{P_A} - \frac{N_B}{P_B}\right) dP_A \Big]_T \text{ - - - - - - - - - - - - } (5)$$

Equation (4) applies to the binary system and equation (5) applies to the ternary system.

Graphical integration should then reveal $\ln f_s^{N_s}$ or $f_s^{N_s}$ as a function of P_g for the binary systems and as a function of P_A for the ternary systems. If the fugacity functions of the solid in the ternary systems could be related to the fugacity functions of the solid in the binary systems and if the empirical relation that N_A is linear in N_B be assumed (4), then the characteristics of mixture adsorption could be predicted from data on pure gas adsorption alone.

Figures 17 through 23 show $f_s^{N_s} = \phi(P_g)$ for pure gases and $f_s^{N_s} = \phi'(P_A)$ for the mixtures. Figures 24 through 30 show the fugacities of the solid as functions of N. Figures 31 through 37 show the fugacities of the solid in the mixtures as functions of N on a larger scale and Figures 38 and 39 show $\ln f_s^{N_s} = \phi''(P_A)$. The numerical values from which these curves were plotted may be found in Tables AXL through AL. The basis for all calculations was the assumption that the fugacity of the pure solid is 1.0. In three cases the functions $\frac{N_g}{P_g}$ for the pure gases were so lacking in precision at low pressures that the fugacity of the solid for pure gas adsorption could not be calculated. For these cases the fugacities of the solid in the ternary systems were calculated by arbitrarily assigning a fugacity of 1.0 to the solid when one of the pure gases is adsorbed under a pressure of one atmosphere. Since the basis of calculation in now different from the original one, the numerical values of the fugacity of the solid are incorrect. However, the shapes of the curves are correct and are shown in Figures 38 and 39.

Figure 17.

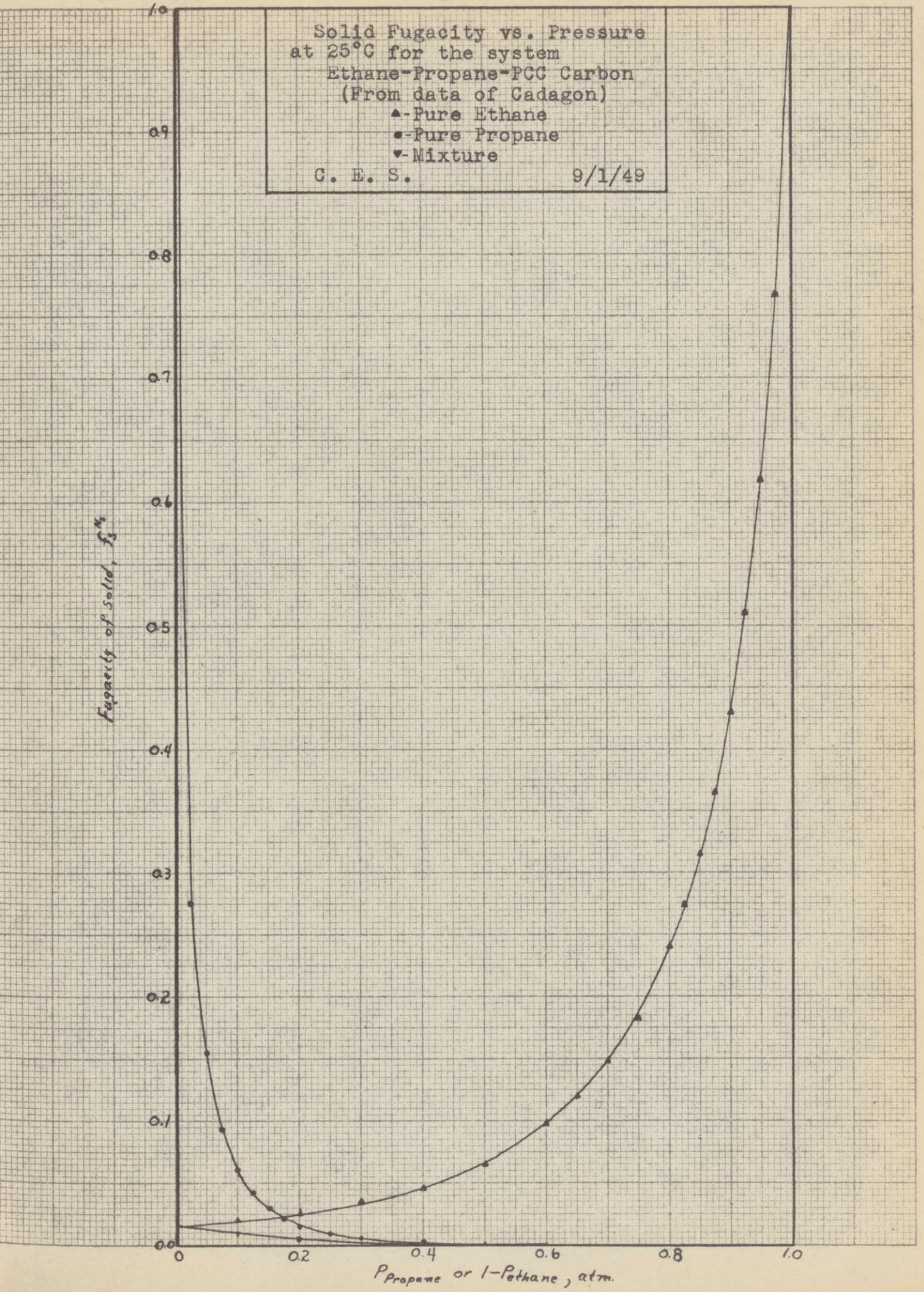

Solid Fugacity vs. Pressure
at 25°C for the system
Ethane-Propane-PCC Carbon
(From data of Cadagon)
▲-Pure Ethane
●-Pure Propane
▼-Mixture
C. E. S.
9/1/49
Fugacity of solid, $f_s^{N_s}$
$P_{Propane}$ or $1-P_{ethane}$, atm.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
0.2
0.4
0.6
0.8
1.0

Figure 18.

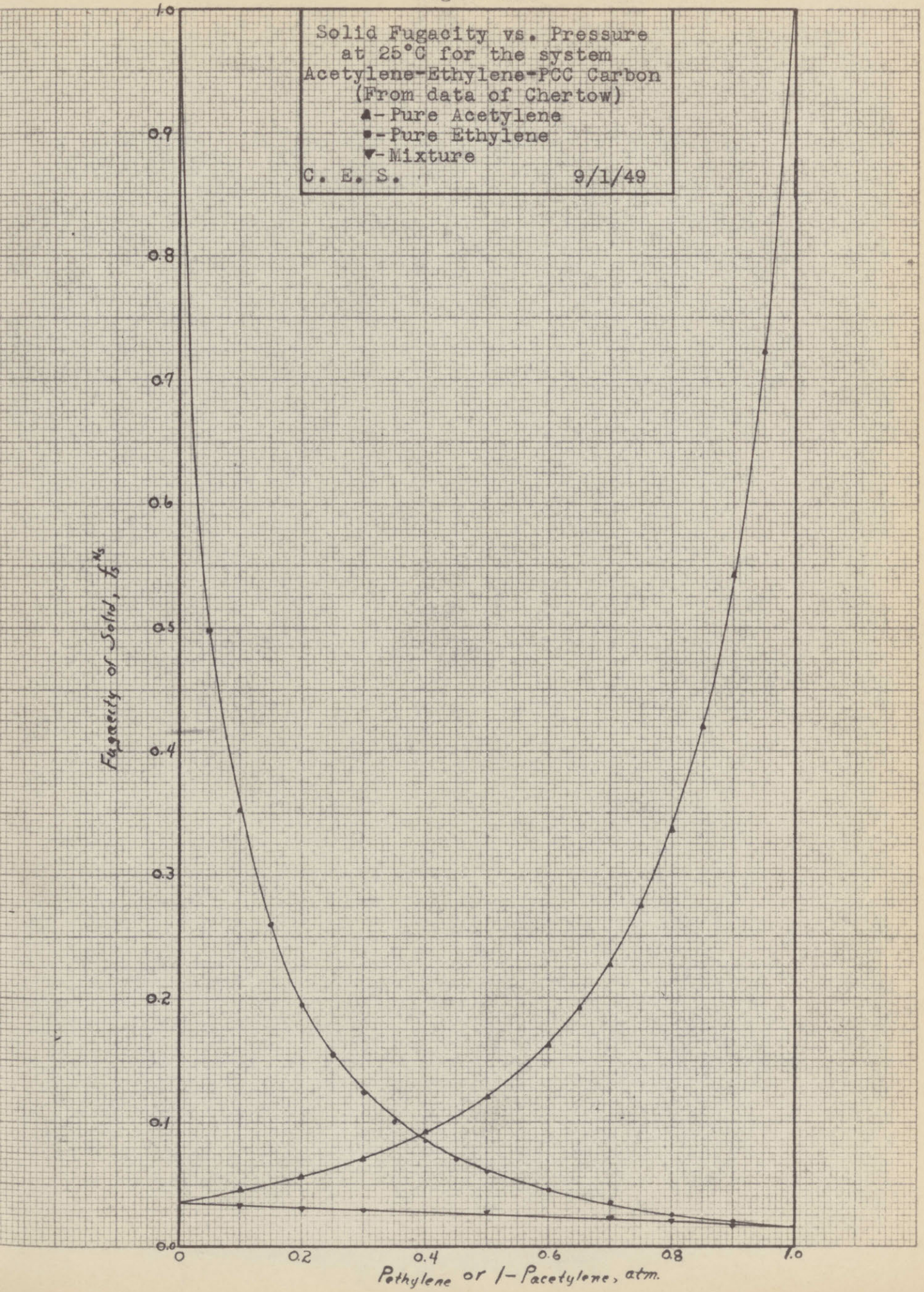

Solid Fugacity vs. Pressure
at 25°C for the system
Acetylene-Ethylene-PCC Carbon
(From data of Chertow)
▲- Pure Acetylene
●- Pure Ethylene
▼- Mixture
C. E. S.
9/1/49
Fugacity of Solid, $f_s^{N_s}$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.2
0.4
0.6
0.8
1.0
$P_{ethylene}$ or $1-P_{acetylene}$, atm.

Figure 19.

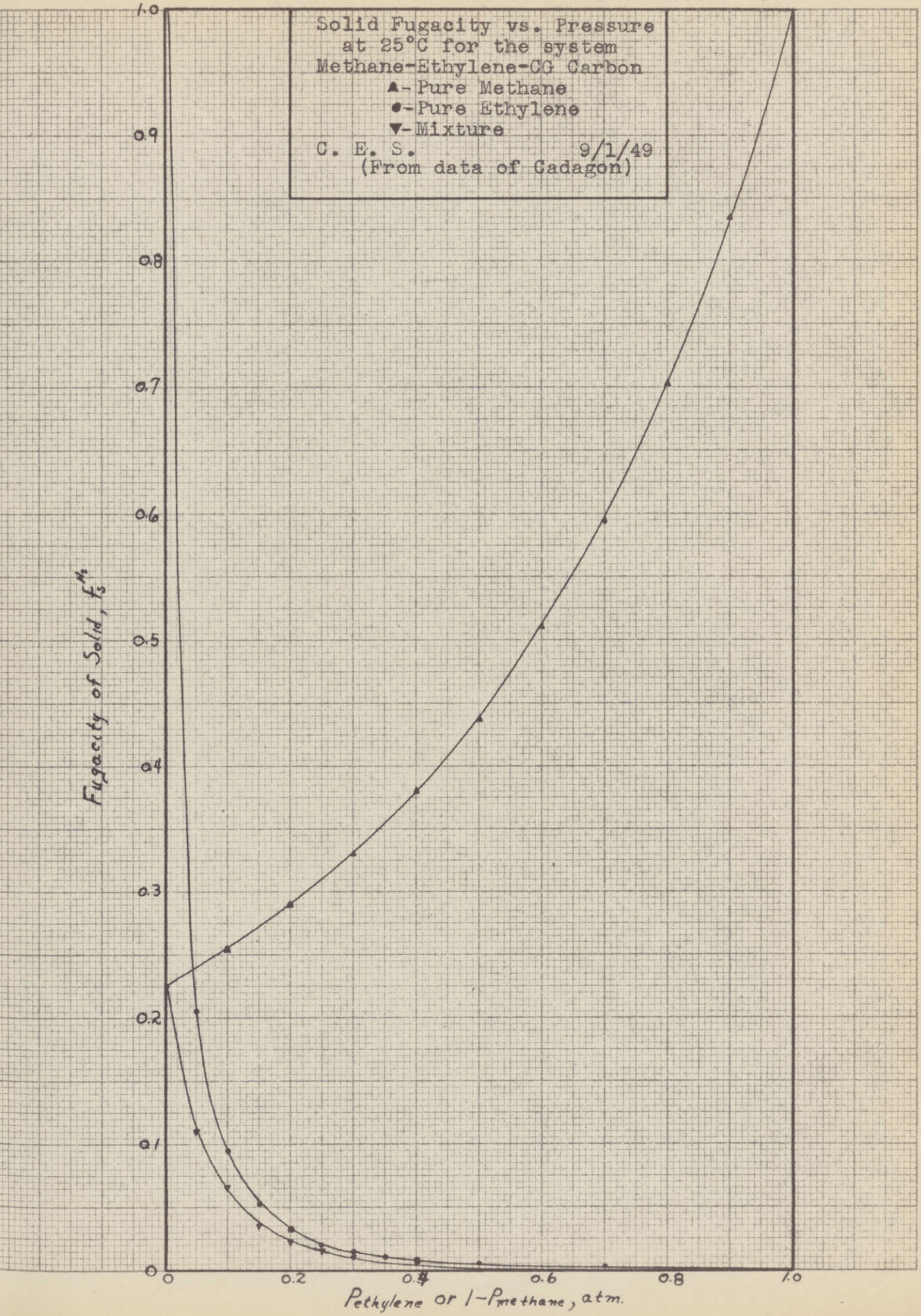

Solid Fugacity vs. Pressure
at 25°C for the system
Methane-Ethylene-CG Carbon
▲- Pure Methane
●- Pure Ethylene
▼- Mixture
C. E. S. 9/1/49
(From data of Cadagon)
Fugacity of Solid, $f_s^{M_1}$
$P_{ethylene}$ or $1-P_{methane}$, atm.
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
0.2
0.4
0.6
0.8
1.0

Figure 20.

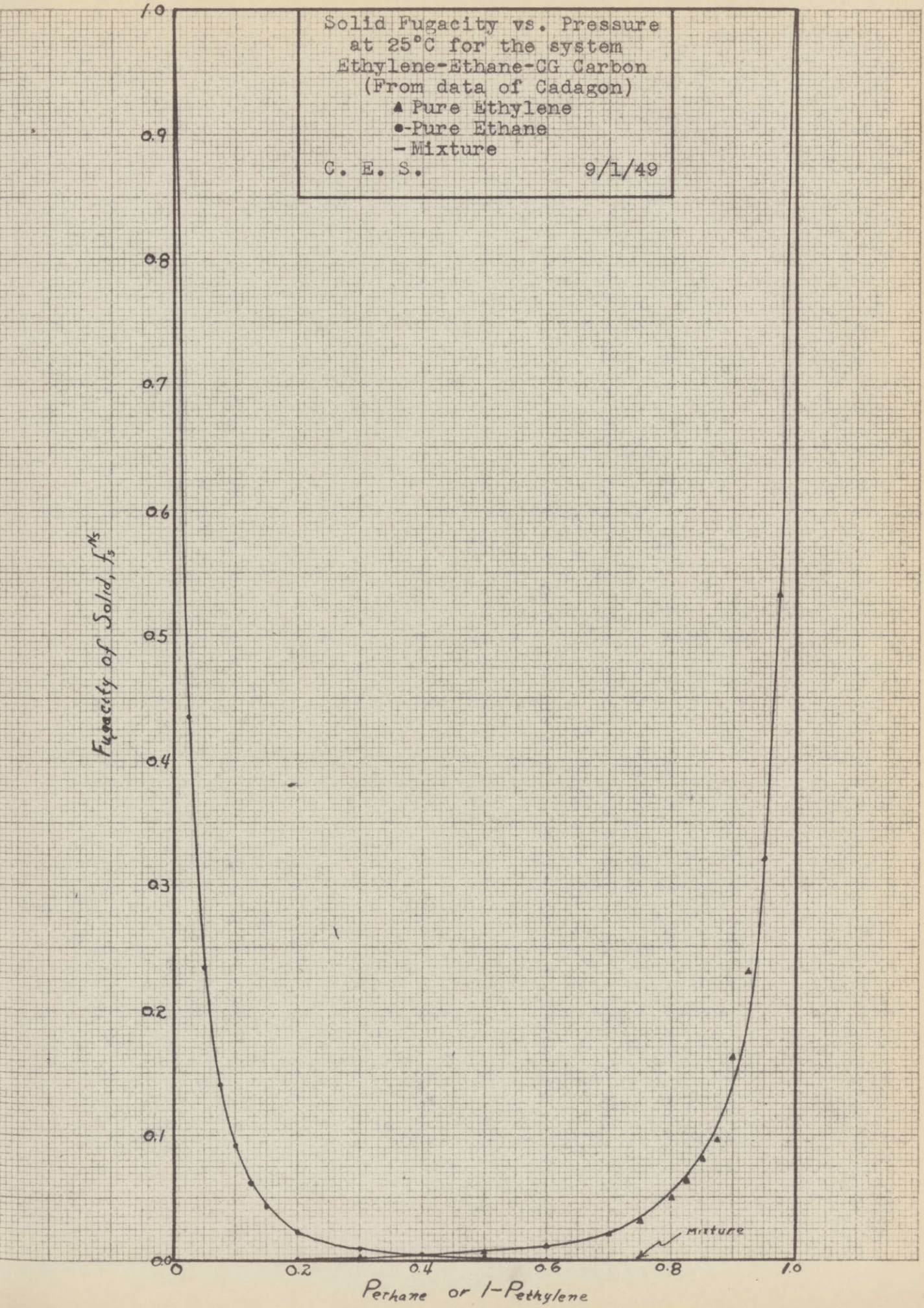

Solid Fugacity vs. Pressure
at 25°C for the system
Ethylene-Ethane-CG Carbon
(From data of Cadagon)
▲ Pure Ethylene
•-Pure Ethane
- Mixture
C. E. S. 9/1/49
Fugacity of Solid, $f_s^{1/2}$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.2
0.4
0.6
0.8
1.0
Mixture
P_{ethane} or $1-P_{ethylene}$

Figure 21.

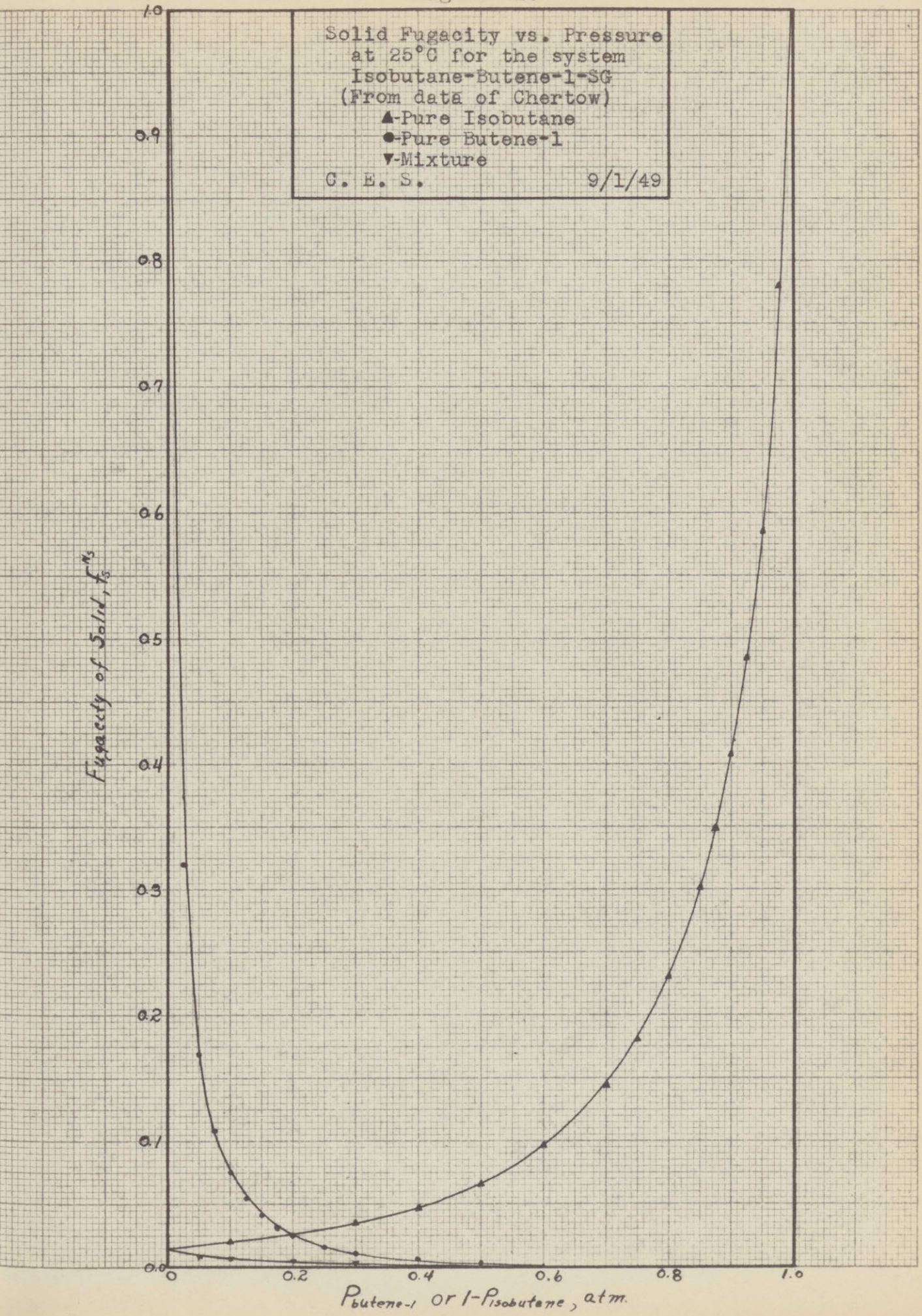

Solid Fugacity vs. Pressure
at 25°C for the system
Isobutane-Butene-1-SG
(From data of Chertow)
▲-Pure Isobutane
●-Pure Butene-1
▼-Mixture
C. E. S. 9/1/49
Fugacity of Solid, f_s^{ns}
$P_{butene-1}$ or $1-P_{isobutane}$, atm.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
0.2
0.4
0.6
0.8
1.0

Figure 22.

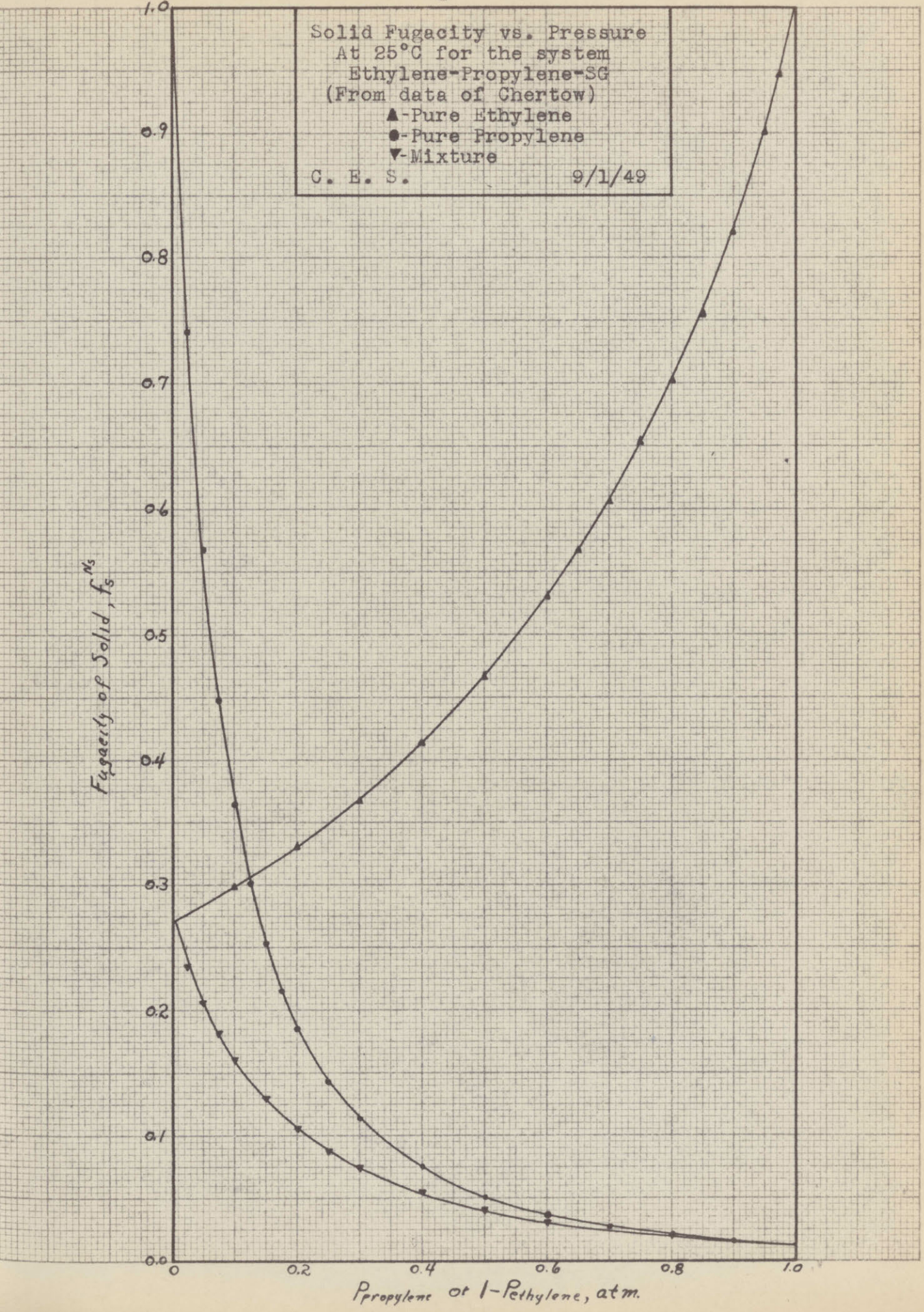

Solid Fugacity vs. Pressure
At 25°C for the system
Ethylene-Propylene-SG
(From data of Chertow)
▲-Pure Ethylene
●-Pure Propylene
▼-Mixture
C. E. S. 9/1/49
Fugacity of Solid, $f_s^{N_s}$
$P_{propylene}$ or $1-P_{ethylene}$, atm.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
0.2
0.4
0.6
0.8
1.0

Figure 23.

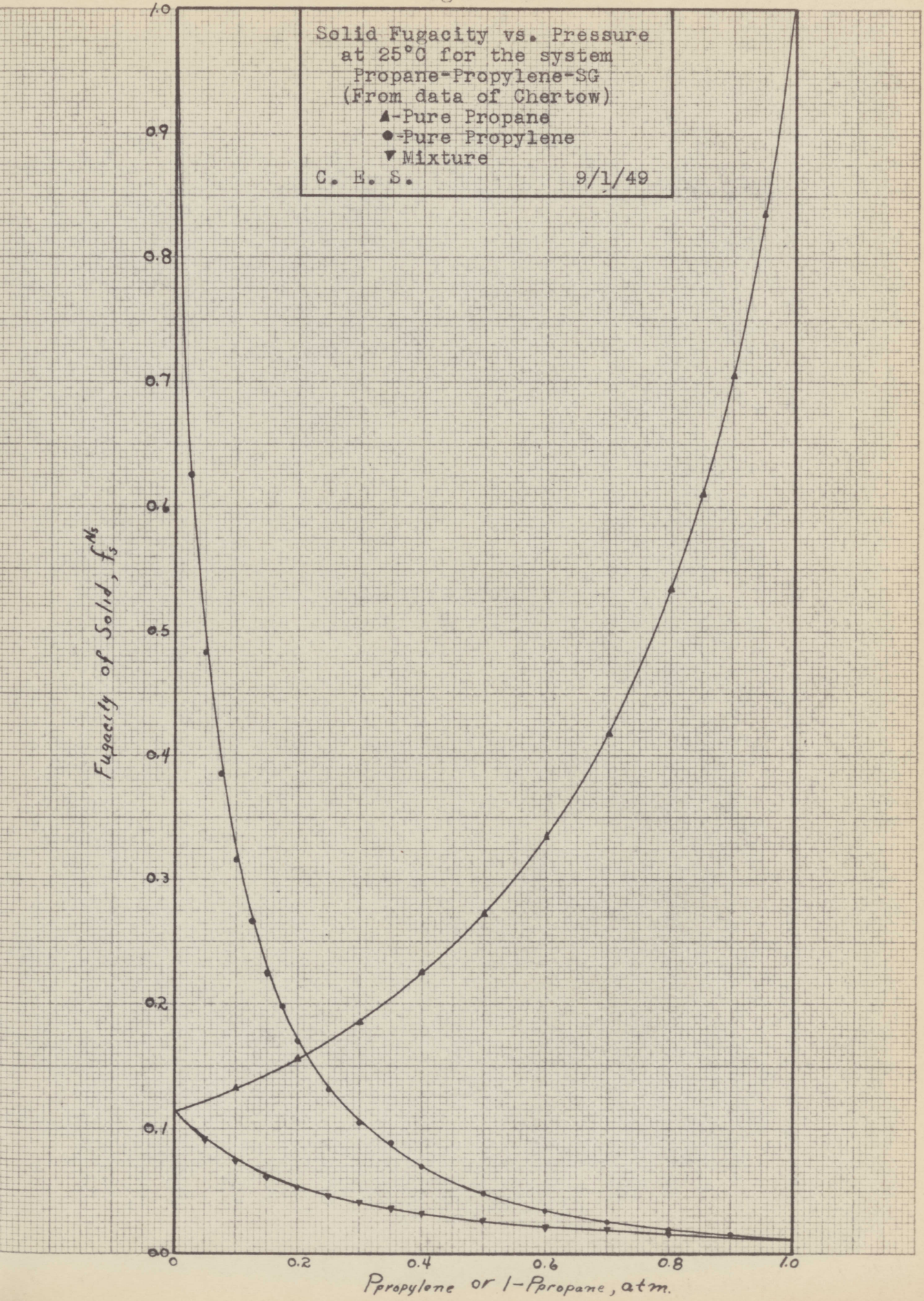

Solid Fugacity vs. Pressure
at 25°C for the system
Propane-Propylene-SG
(From data of Chertow)
▲-Pure Propane
●-Pure Propylene
▼Mixture
C. E. S. 9/1/49
Fugacity of Solid, $f_s^{N_s}$
$P_{propylene}$ or $1-P_{propane}$, atm.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
0.2
0.4
0.6
0.8
1.0

Figure 24.

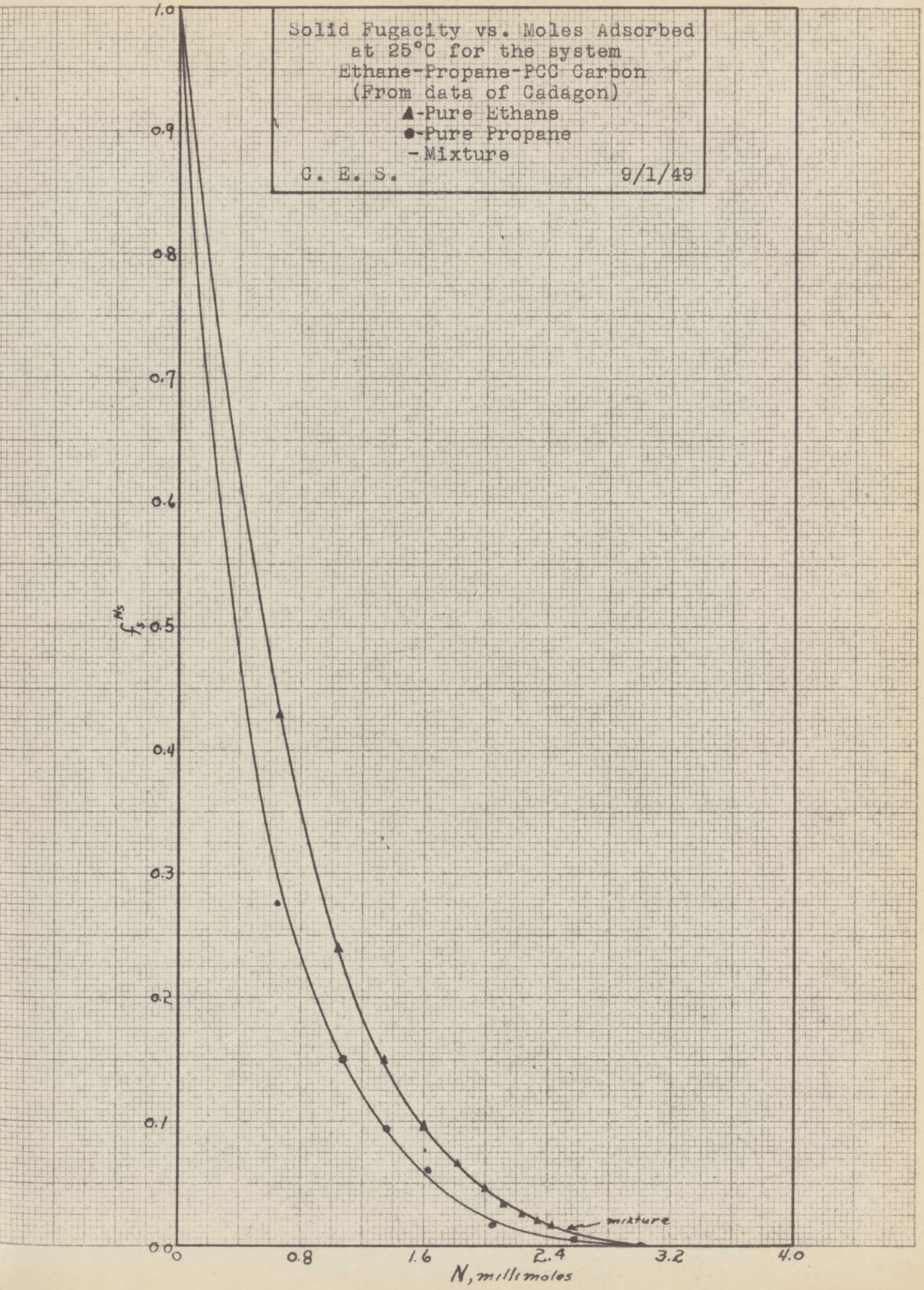

Solid Fugacity vs. Moles Adsorbed
at 25°C for the system
Ethane-Propane-PCC Carbon
(From data of Cadagon)
▲-Pure Ethane
●-Pure Propane
-Mixture
C. E. S.
9/1/49
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
f_s^{Ms}
0
0.8
1.6
2.4
3.2
4.0
N, millimoles
mixture

Figure 25.

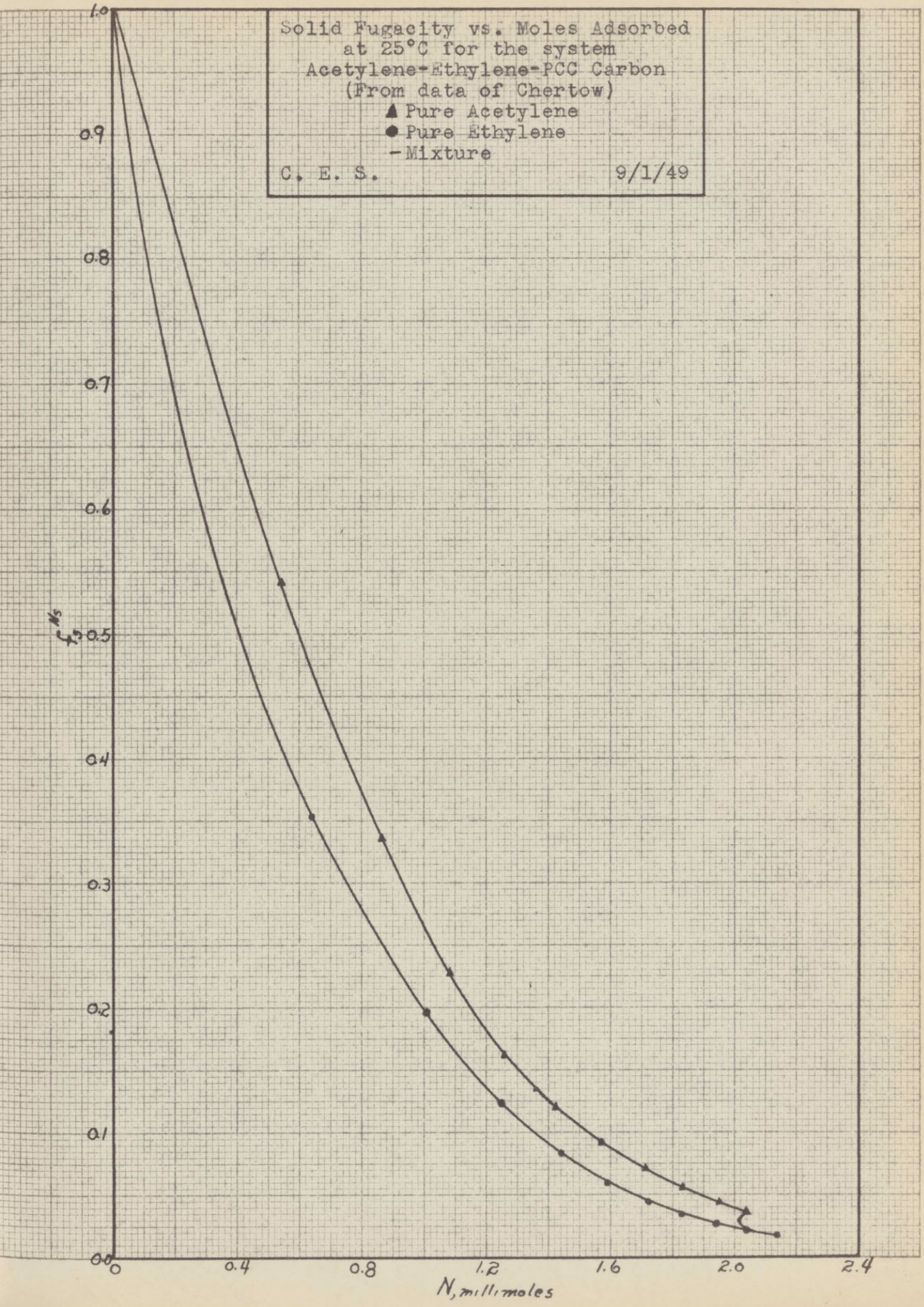

Solid Fugacity vs. Moles Adsorbed
at 25°C for the system
Acetylene-Ethylene-PCC Carbon
(From data of Chertow)
▲ Pure Acetylene
● Pure Ethylene
- Mixture
C. E. S.
9/1/49
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.4
0.8
1.2
1.6
2.0
2.4
N, millimoles

Figure 26.

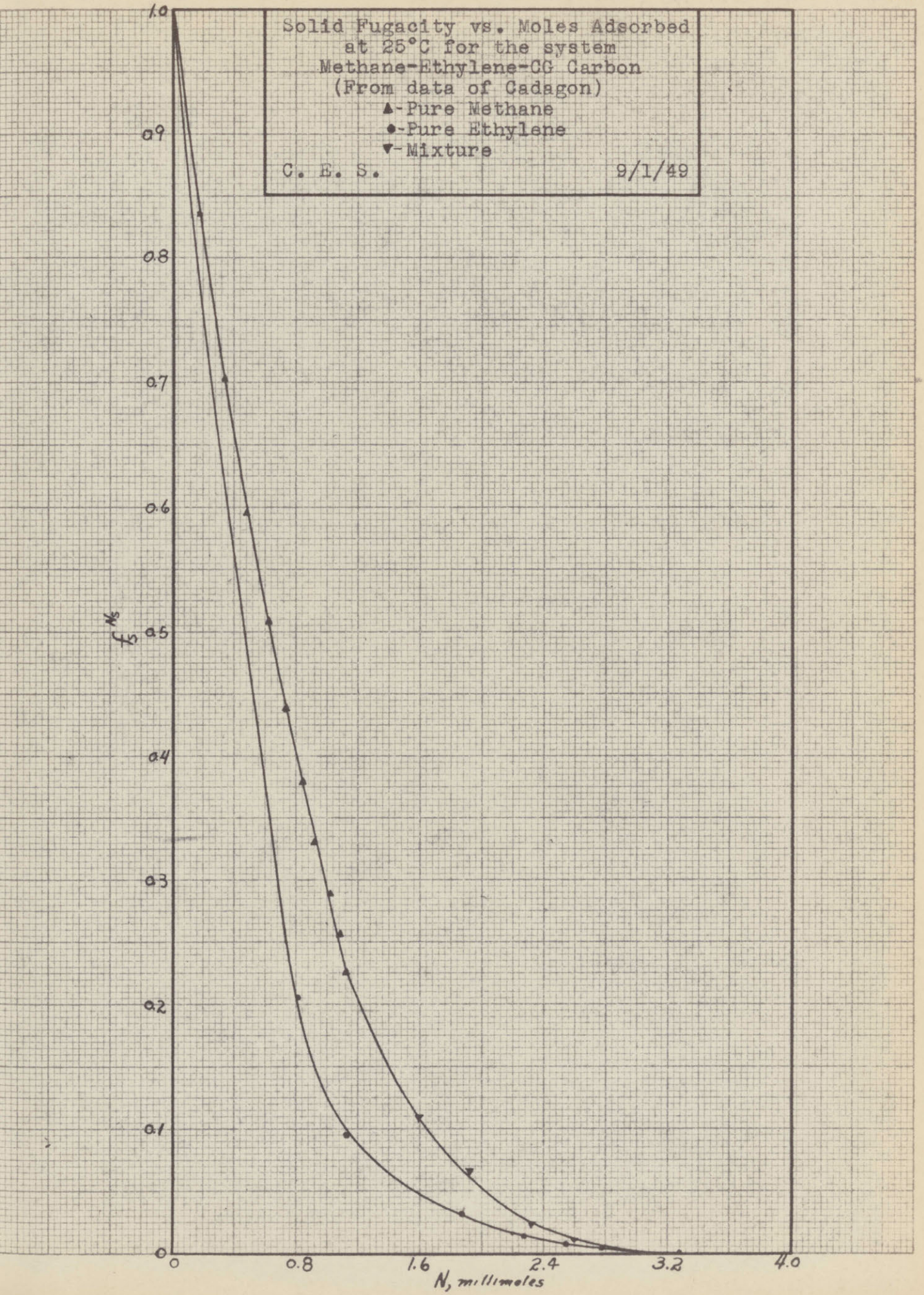

Solid Fugacity vs. Moles Adsorbed
at 25°C for the system
Methane-Ethylene-CG Carbon
(From data of Cadagon)
▲-Pure Methane
●-Pure Ethylene
▼-Mixture
C. E. S.
9/1/49
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
f_s
0
0.8
1.6
2.4
3.2
4.0
N, millimoles

Figure 27.

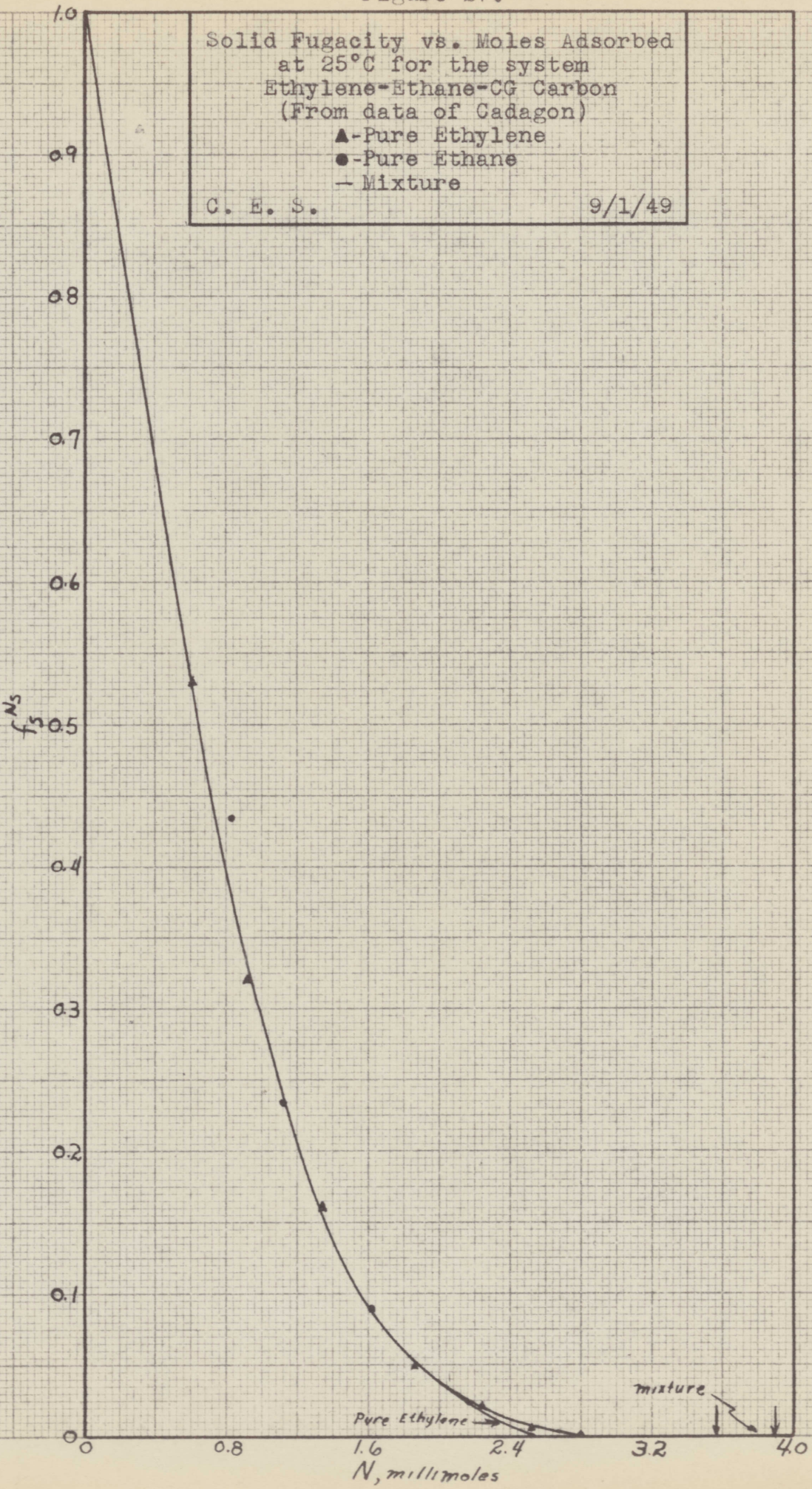

Solid Fugacity vs. Moles Adsorbed
at 25°C for the system
Ethylene-Ethane-CG Carbon
(From data of Cadagon)
▲-Pure Ethylene
●-Pure Ethane
— Mixture
C. E. S.
9/1/49
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$f_s^{N_s}$
0
0.8
1.6
2.4
3.2
4.0
N, millimoles
Pure Ethylene
mixture

Figure 28.

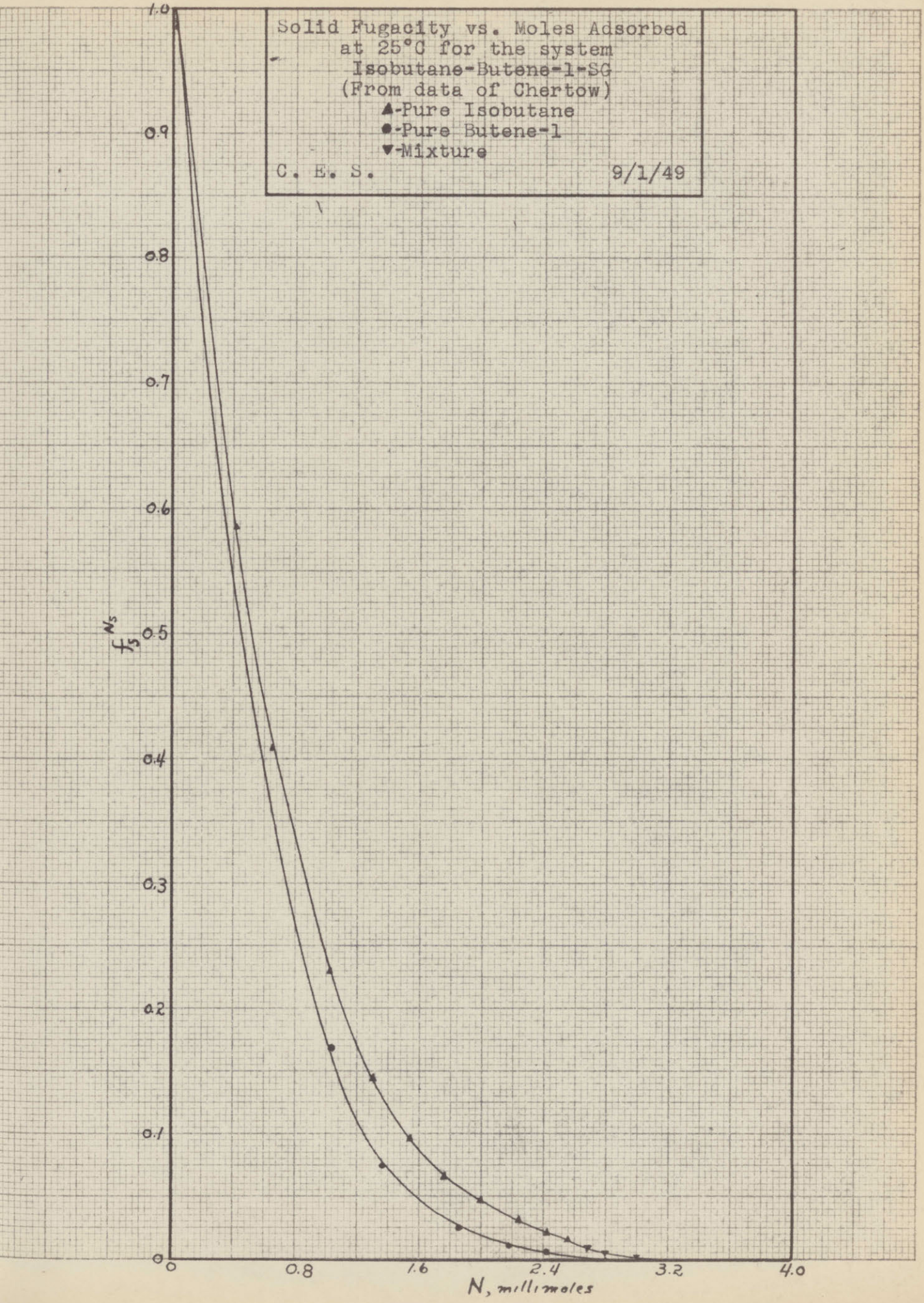

Solid Fugacity vs. Moles Adsorbed
at 25°C for the system
Isobutane-Butene-1-SG
(From data of Chertow)
▲-Pure Isobutane
●-Pure Butene-1
▼-Mixture
C. E. S.
9/1/49
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$f_s^{N_s}$
0
0.8
1.6
2.4
3.2
4.0
N, millimoles

Figure 29.

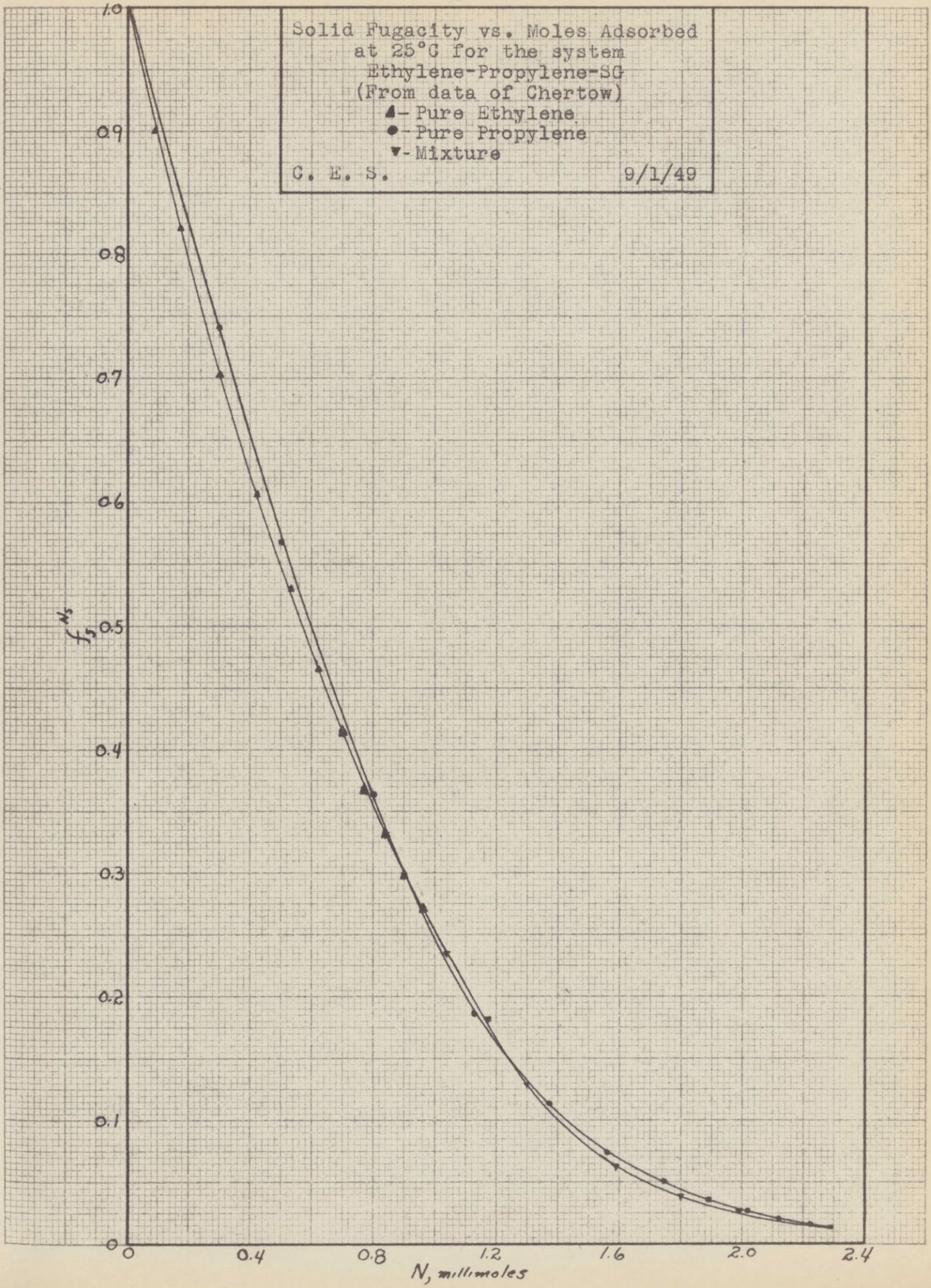

Solid Fugacity vs. Moles Adsorbed
at 25°C for the system
Ethylene-Propylene-SG
(From data of Chertow)
▲- Pure Ethylene
●- Pure Propylene
▼- Mixture
C. E. S.
9/1/49
f_s
N, millimoles
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.4
0.8
1.2
1.6
2.0
2.4

Figure 30.

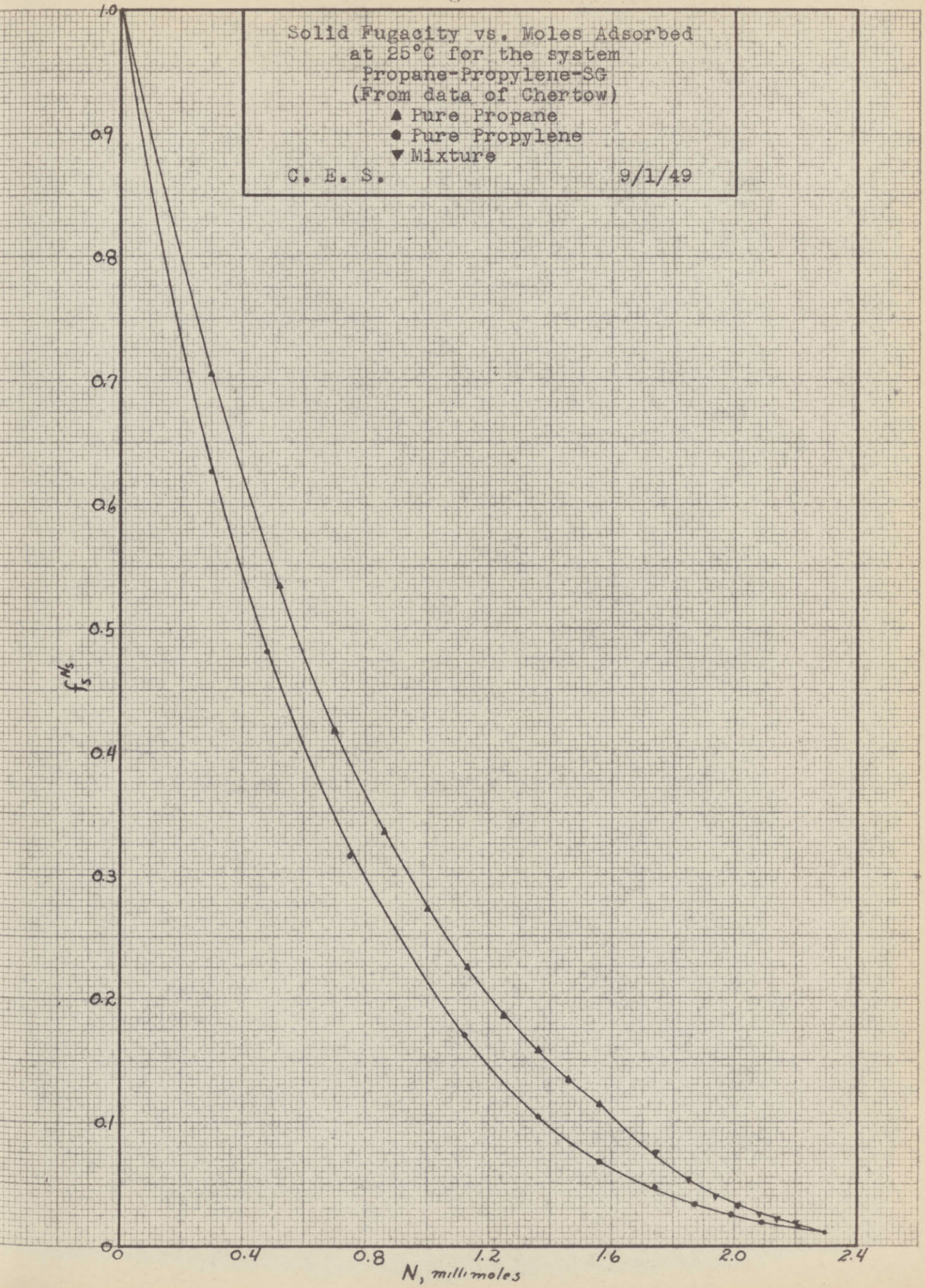

Solid Fugacity vs. Moles Adsorbed
at 25°C for the system
Propane-Propylene-SG
(From data of Chertow)
▲ Pure Propane
● Pure Propylene
▼ Mixture
C. E. S.
9/1/49
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$f_s^{N_s}$
0
0.4
0.8
1.2
1.6
2.0
2.4
N, millimoles

Figure 31.

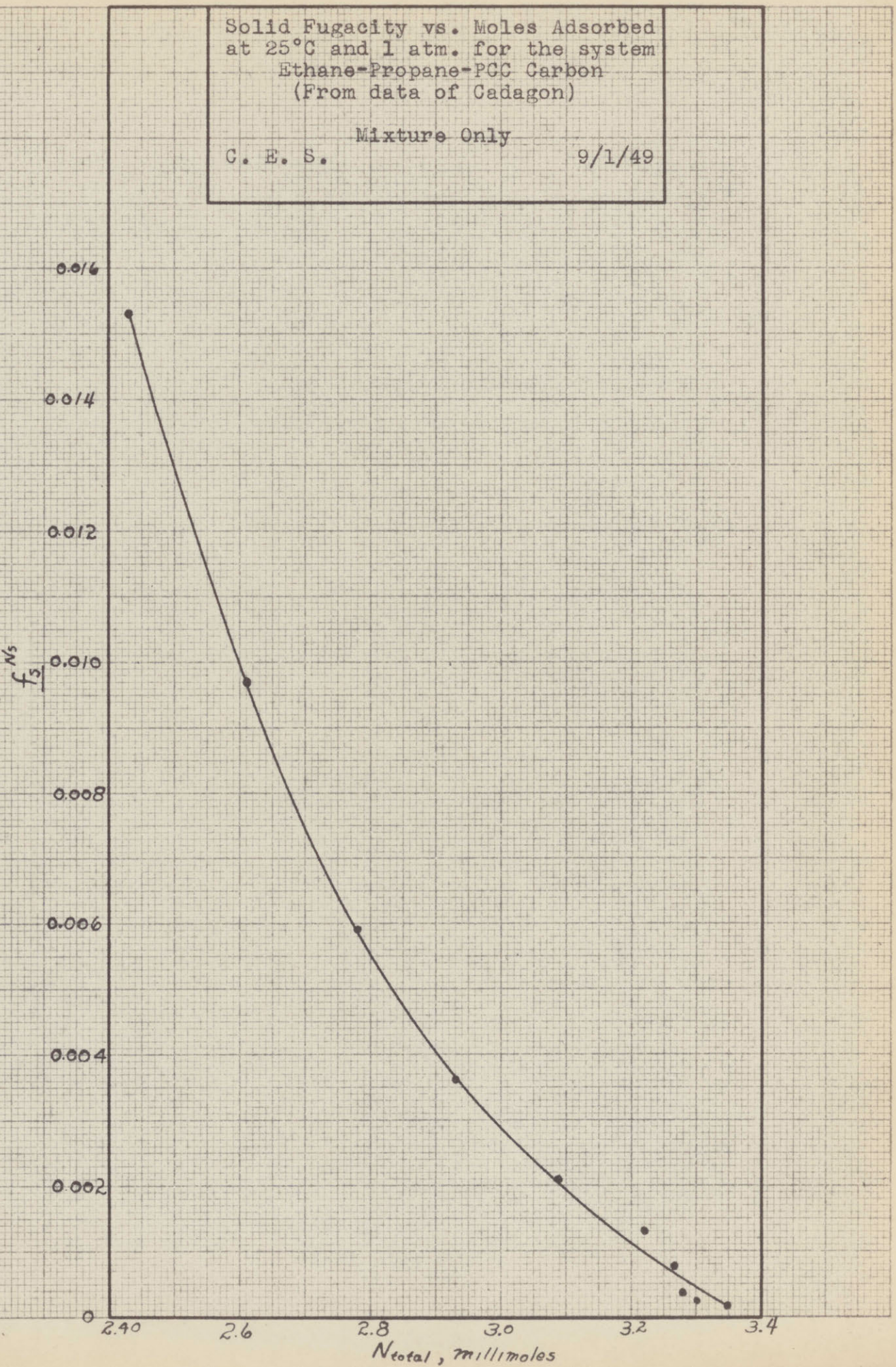

Solid Fugacity vs. Moles Adsorbed
at 25°C and 1 atm. for the system
Ethane-Propane-PCC Carbon
(From data of Cadagon)
Mixture Only
C. E. S.
9/1/49
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0
$f_s^{N_s}$
2.40
2.6
2.8
3.0
3.2
3.4
N_{total}, millimoles

Figure 32.

Solid Fugacity vs. Moles Adsorbed
at 25°C and 1 atm. for the system
Acetylene-Ethylene-PCC Carbon
(From data of Chertow)

Mixture Only

C. E. S. 9/1/49

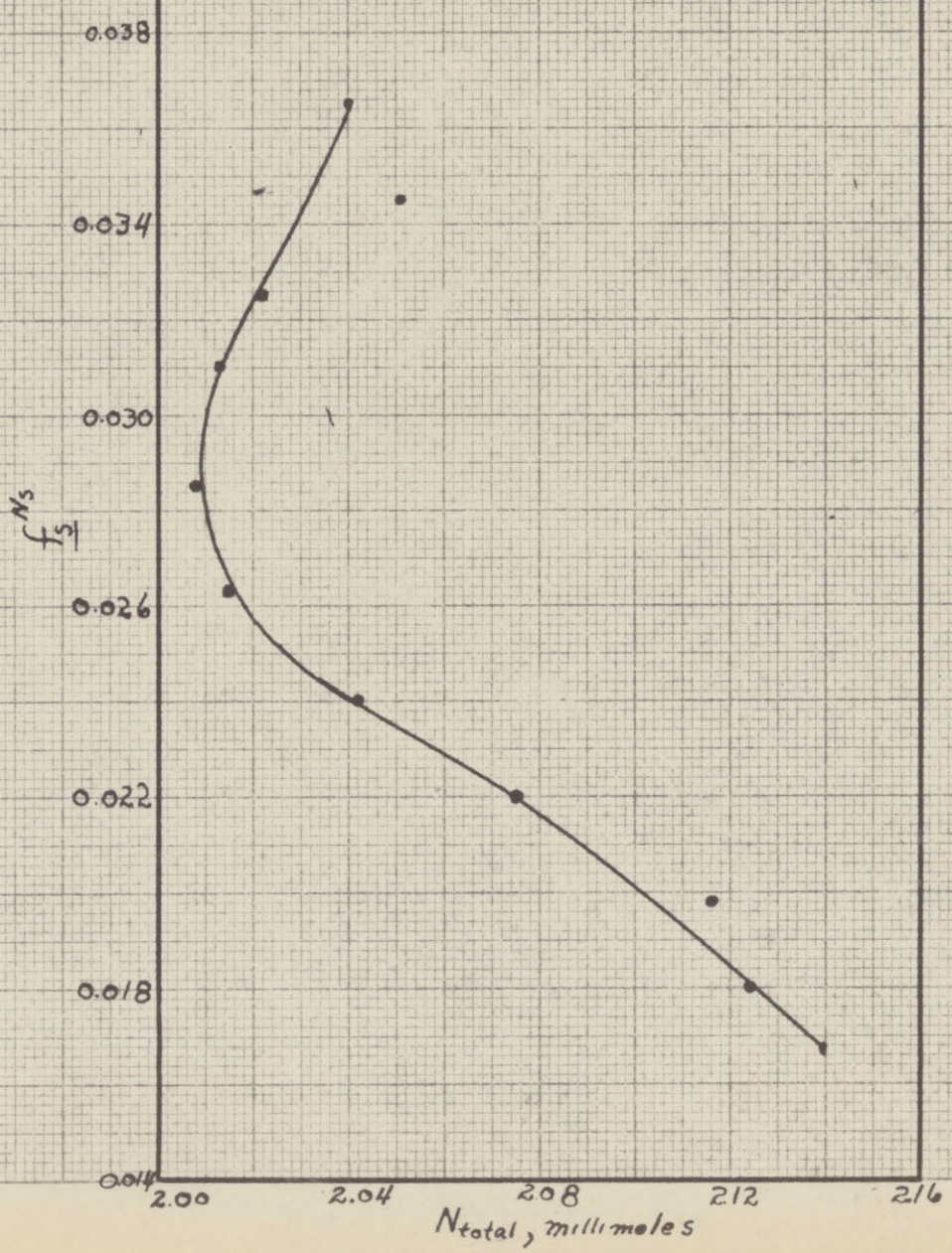


Figure 33.

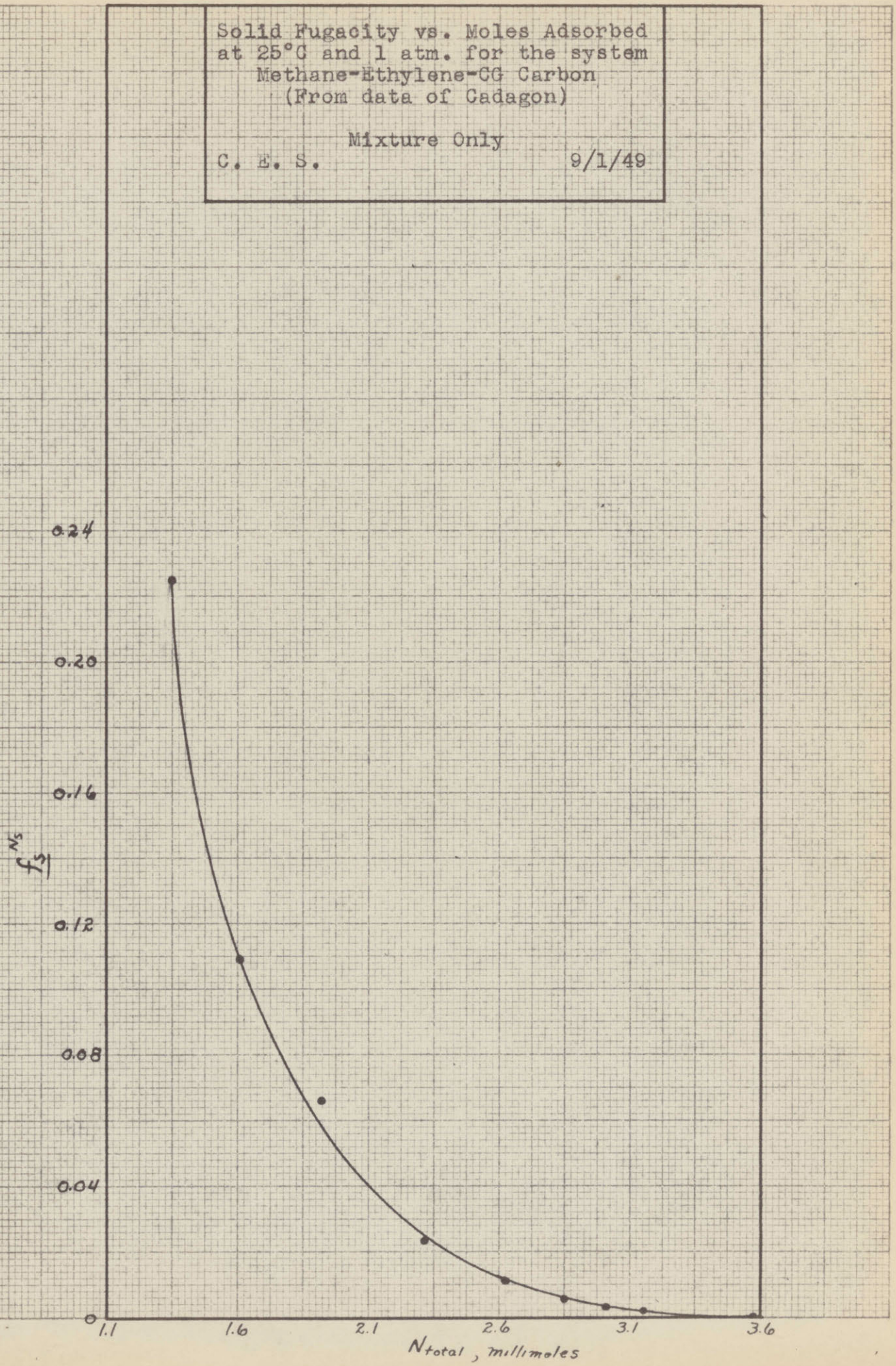

Solid Fugacity vs. Moles Adsorbed
at 25°C and 1 atm. for the system
Methane-Ethylene-CG Carbon
(From data of Cadagon)
Mixture Only
C. E. S.
9/1/49
0.24
0.20
0.16
0.12
0.08
0.04
0
f_{N_s}
1.1
1.6
2.1
2.6
3.1
3.6
N_{total}, millimoles

Figure 34.

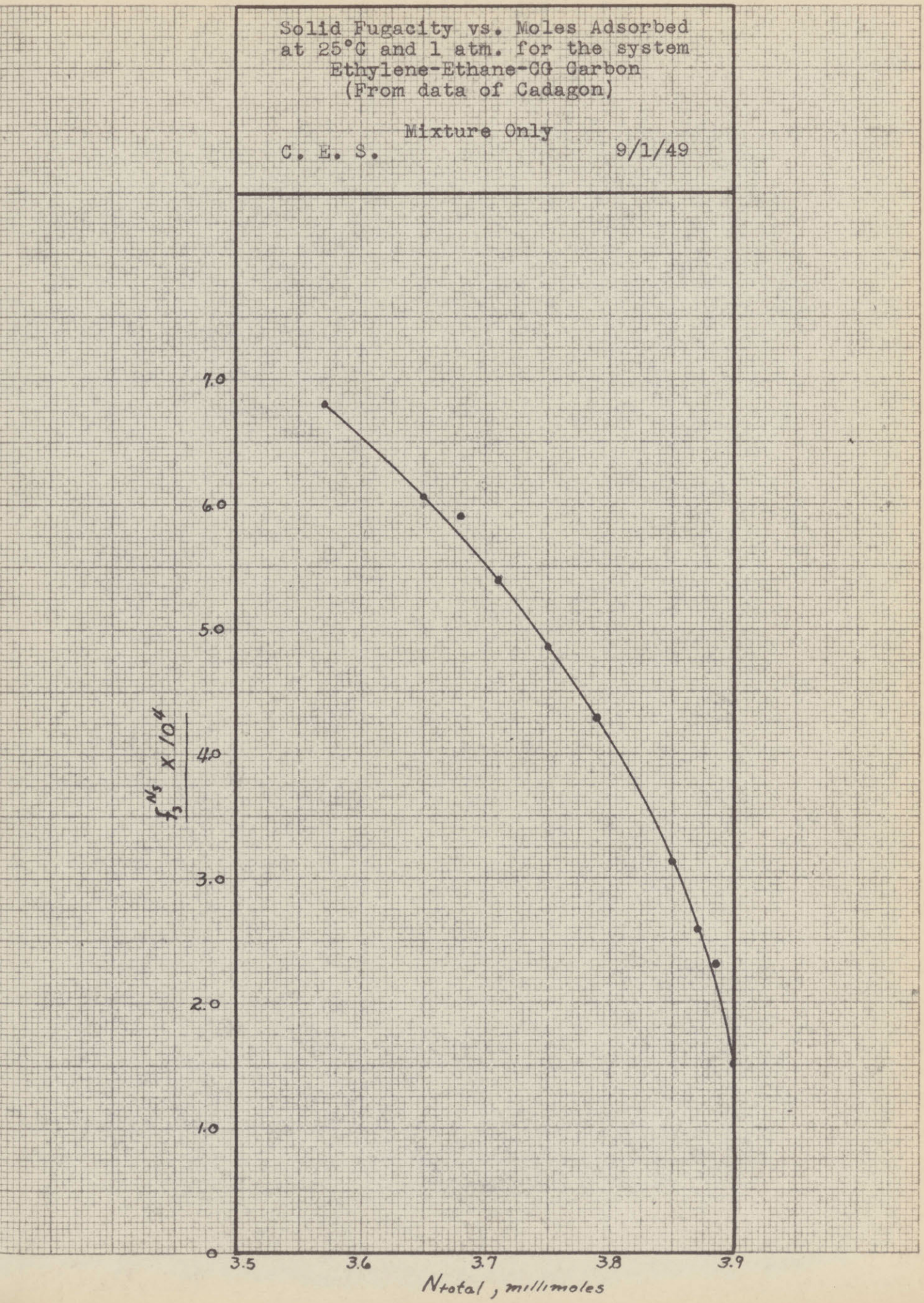

Solid Fugacity vs. Moles Adsorbed
at 25°C and 1 atm. for the system
Ethylene-Ethane-CG Carbon
(From data of Cadagon)
Mixture Only
C. E. S.
9/1/49
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
3.5
3.6
3.7
3.8
3.9
$f_s^{N_s} \times 10^4$
N_{total}, millimoles

Figure 35.

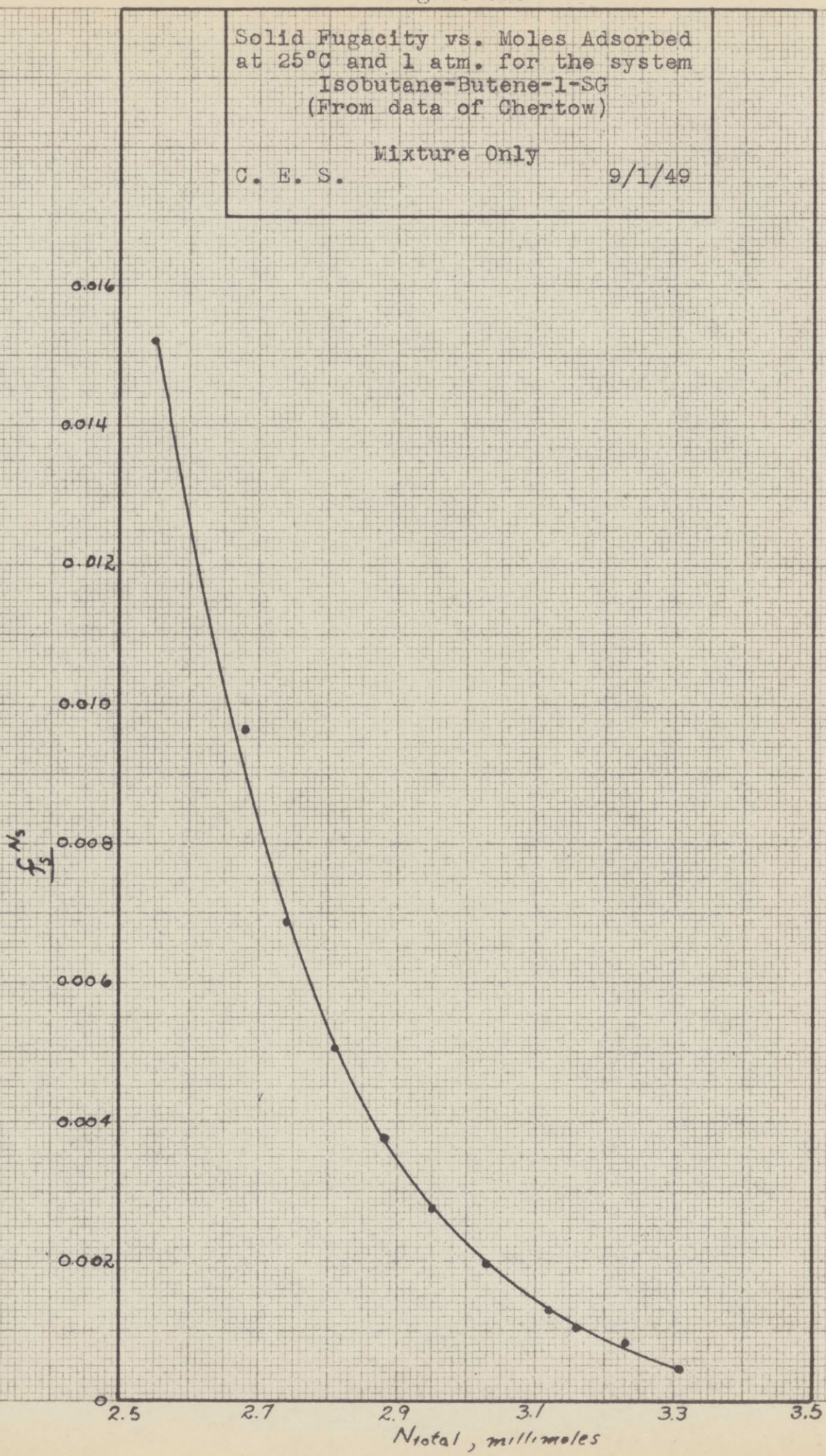

Solid Fugacity vs. Moles Adsorbed
at 25°C and 1 atm. for the system
Isobutane-Butene-1-SG
(From data of Chertow)
Mixture Only
C. E. S.
9/1/49
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0
$f_s^{N_s}$
2.5
2.7
2.9
3.1
3.3
3.5
N_{total}, millimoles

Figure 36.

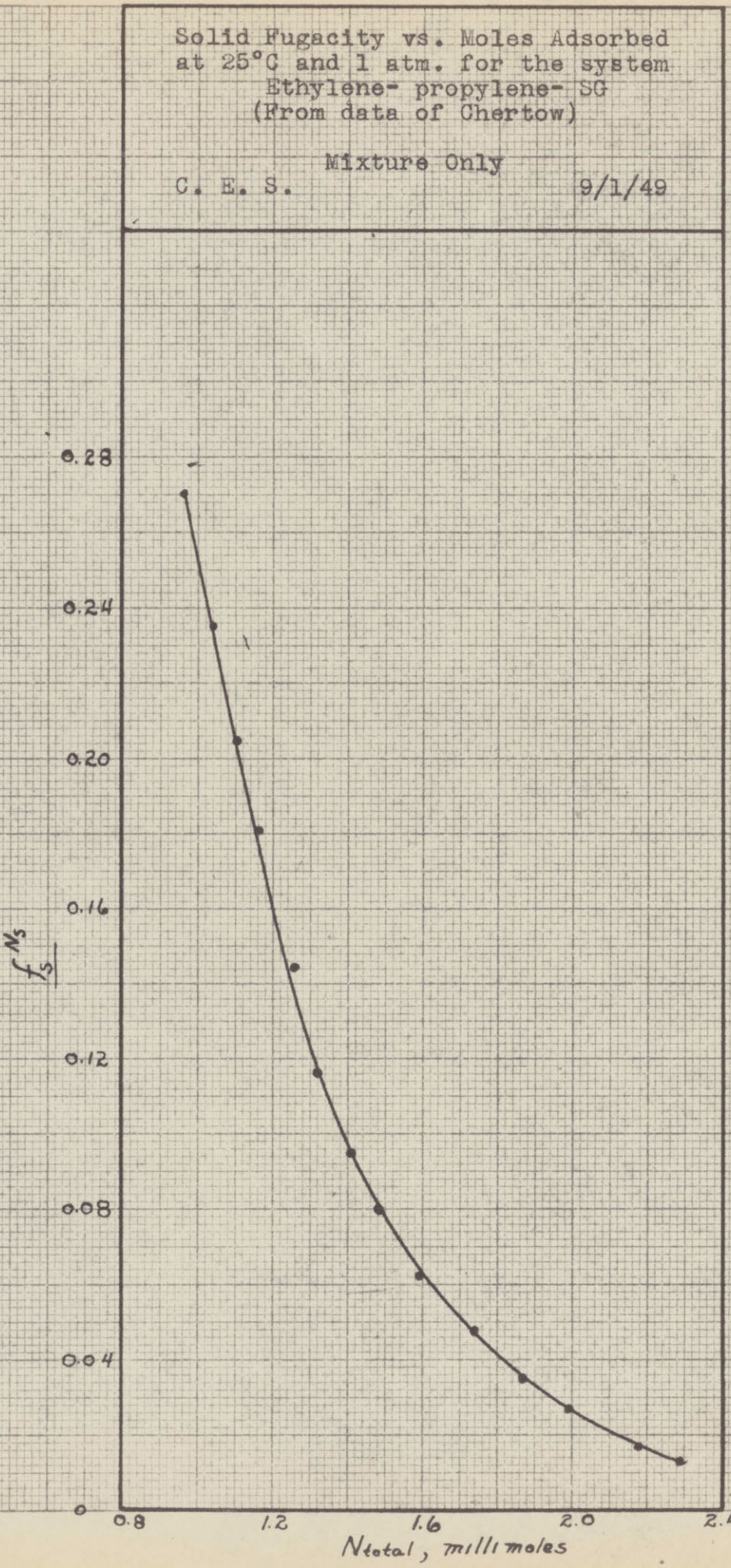

Solid Fugacity vs. Moles Adsorbed
at 25°C and 1 atm. for the system
Ethylene- propylene- SG
(From data of Chertow)
Mixture Only
C. E. S.
9/1/49
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0
$f_s N_s$
0.8
1.2
1.6
2.0
2.4
N_{total}, millimoles

Figure 37.

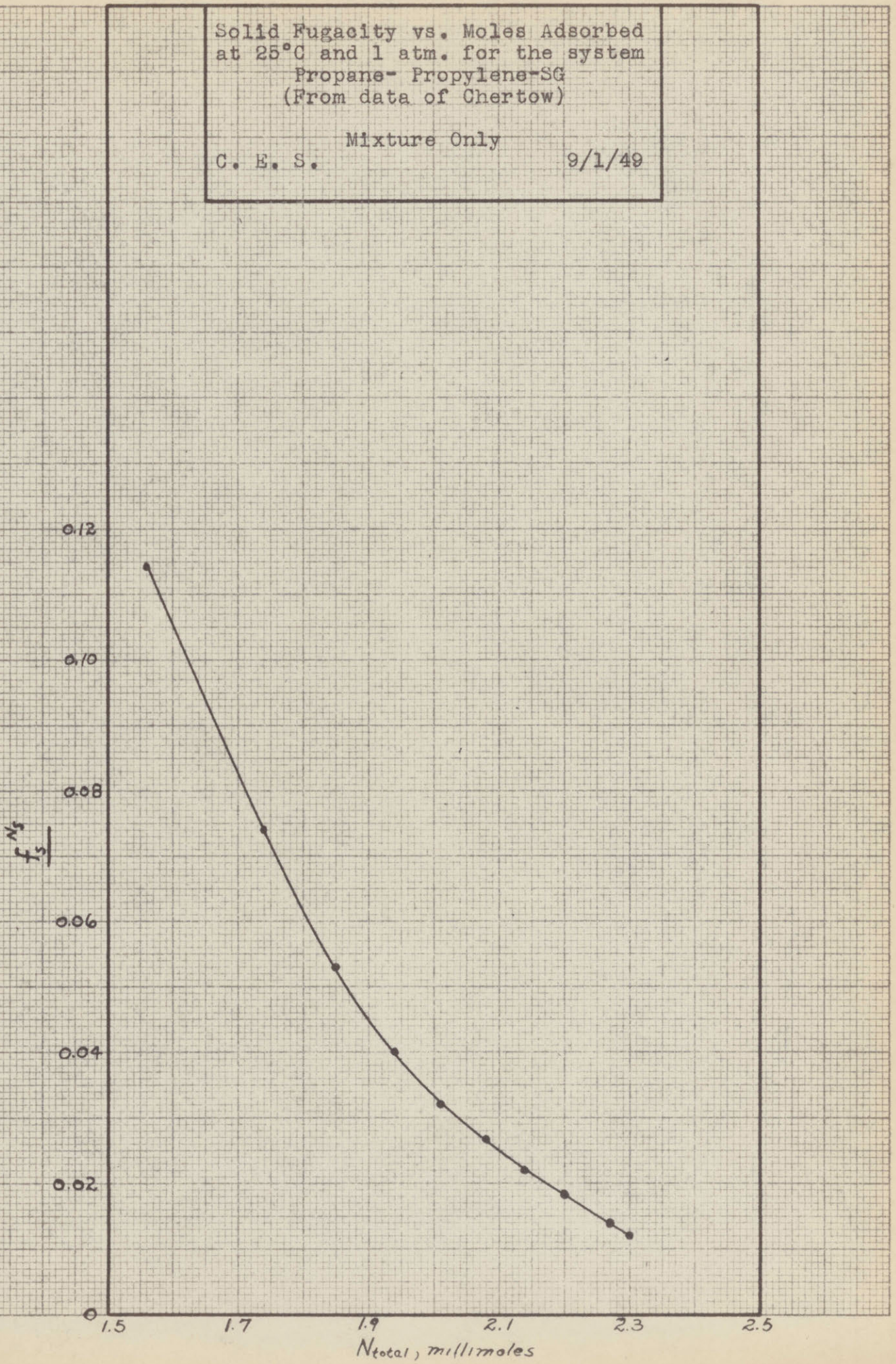
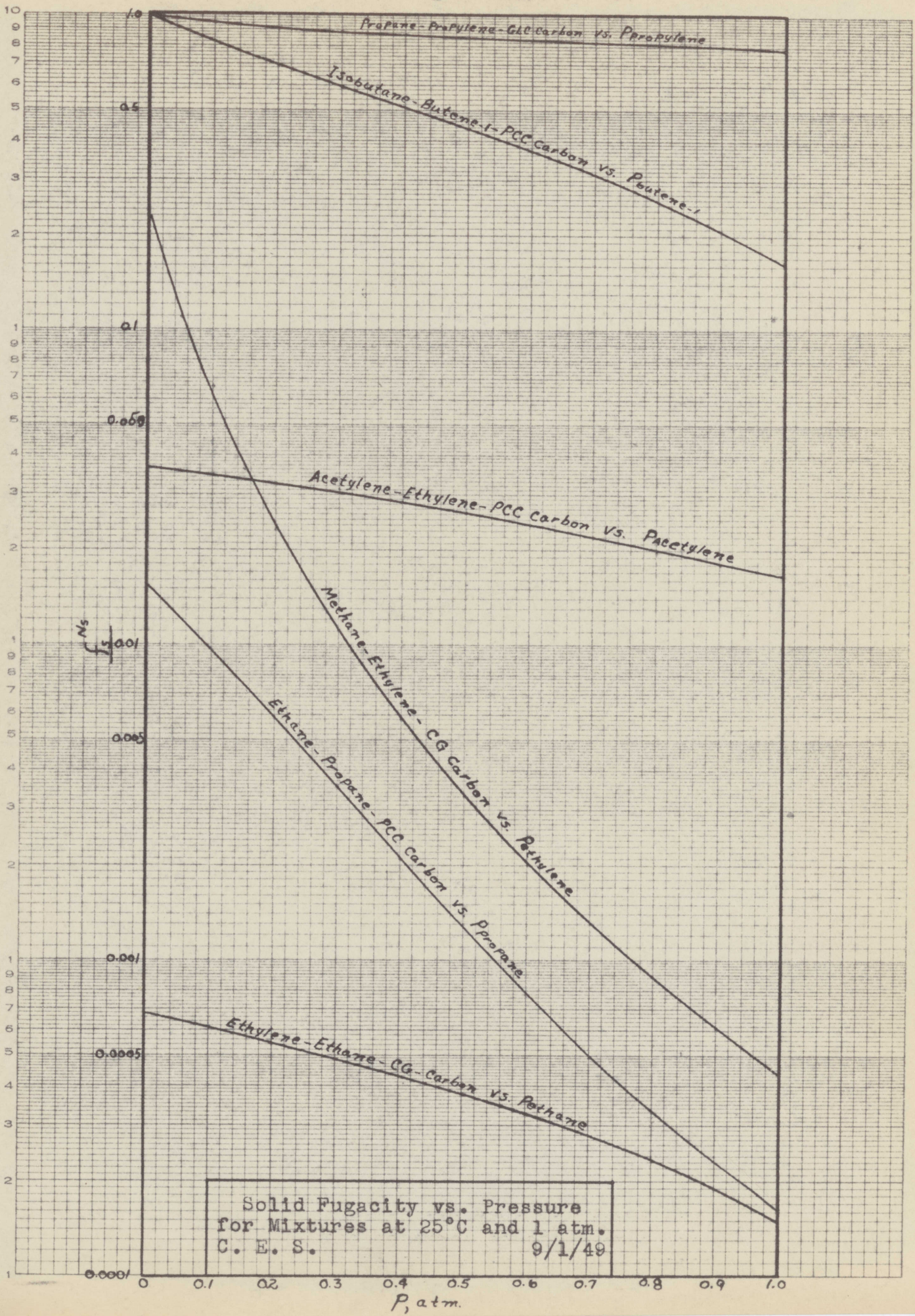
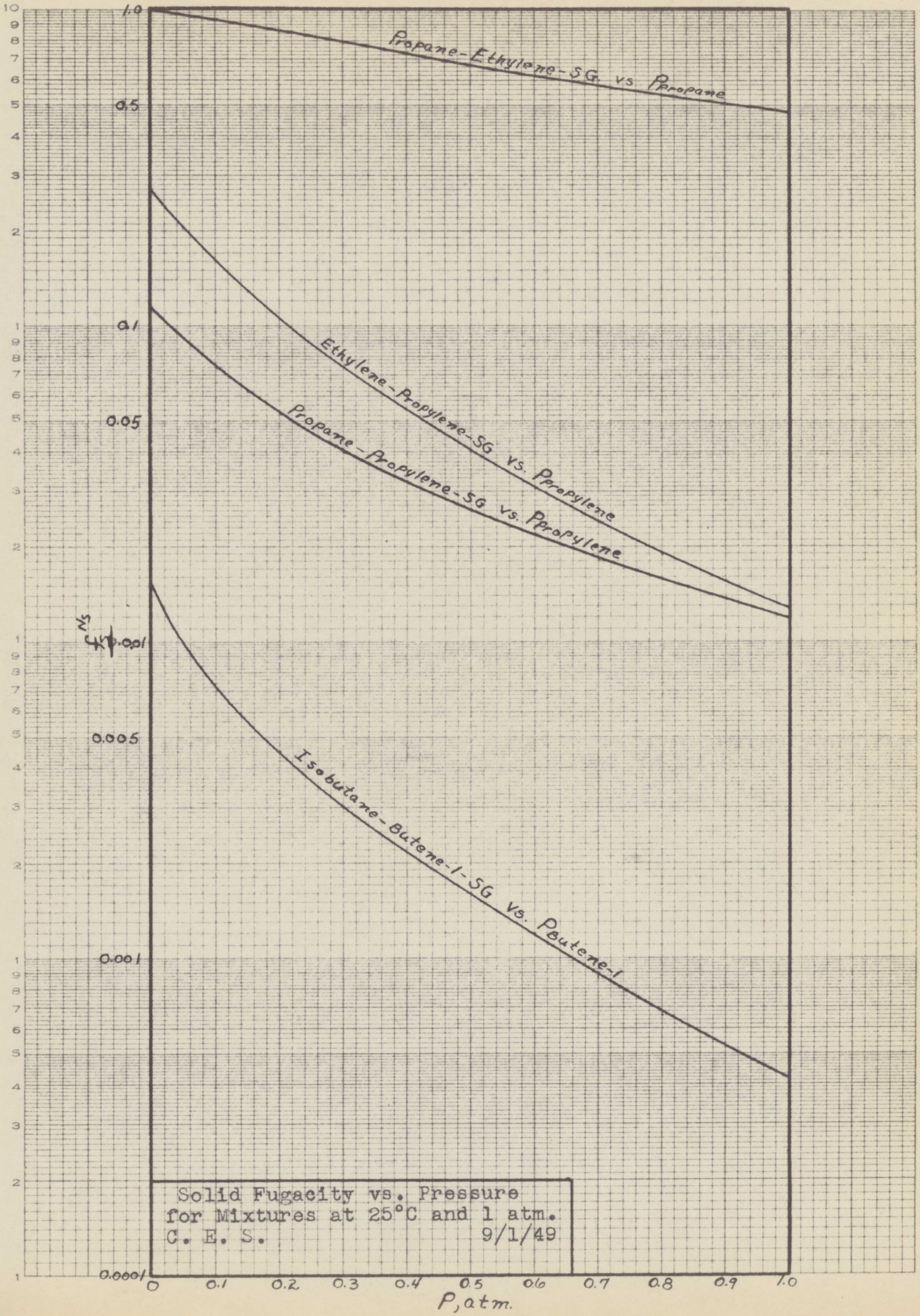

Solid Fugacity vs. Moles Adsorbed
at 25°C and 1 atm. for the system
Propane- Propylene-SG
(From data of Chertow)
Mixture Only
C. E. S.
9/1/49
0.12
0.10
0.08
0.06
0.04
0.02
0
1.5
1.7
1.9
2.1
2.3
2.5
N_{total}, millimoles

Figure 38.



Solid Fugacity vs. Pressure
for Mixtures at 25°C and 1 atm.
C. E. S. 9/1/49

Figure 39.



Solid Fugacity vs. Pressure
for Mixtures at 25°C and 1 atm.
C. E. S. 9/1/49

Unfortunately, no correlation could be found for predicting the fugacity of the solid in ternary systems from pure gas isotherms only. This may be due to the enormous difference in the range of values for the solid fugacity when under the pure gases and when under the mixture. This can be easily seen in Figures 24 through 30. If, for example, the fugacity of the solid when N_A moles of A and N_B moles of B were adsorbed at one time (ternary system) were some function of the fugacities of the solid when N_A moles of A and N_B moles of B were adsorbed separately (binary systems), the fugacities in the binary systems would have to be extremely accurate as they would be so much larger than those in the ternary system. It may be possible to find a correlation similar to this but involving only those portions of the curves for the binary systems which lie in the same range of fugacity values as those for the ternary system. For example, the fugacity of the solid in the ternary system may be a function of the fugacities of the solid in the binary systems at points where the moles adsorbed in the binary systems are equal to the total moles adsorbed in the ternary system. This would require that the data for one of the binary systems extend to pressures higher than one atmosphere.

Lacking a correlation between the adsorption of the pure gases and the adsorption of the mixtures,

considerable aid could still be obtained if the shapes of the solid fugacity functions for various ternary systems could be related to one another. If the shapes of these functions could be accurately predicted, then the slopes of these curves at various points could be used to find $N_A = \phi'''(P_A)$ if the empirical relation that N_A is linear in N_B could still be assumed. Chertow has shown that this relation is within engineering accuracy in most cases. Here again, no such relation could be found. These solid fugacity functions are not of the types generally found in engineering work since all attempts to rectify the curves failed completely.

It might be well to mention here that the Van Laar type of relation proposed by both Chertow and Cadogan should not be correct, if the solid is to be considered as a component of the system as it certainly should be. The tacit assumption which must be made in order to apply their equation correctly is that the fugacity of the solid in ternary systems at constant pressure is not affected by changes in the composition of the gaseous mixtures. This is clearly not the case. An attempt was made to apply a similar type of equation to the adsorption of the pure gas with the intention of extending it to the ternary system by analogy to the original Van Laar extension. However, no satisfactory equation could be found, the difficulty lying in the fact that ln P approaches $-\infty$ as P approaches zero. No means could be found to make this an indeterminate ratio as the original Van Laar equation does.

PRECISION

Basically, the investigations carried out in this work were done in the light of the thermodynamic equilibria requirements of the systems. Both the original Broughton proposal and the idea of solid fugacity are seriously hampered by the lack of precision of the data in the most critical regions, viz. when the pressure approaches zero. This is probably the primary reason for the failure of the two methods of attack. As mentioned before, at pressures lower than 50 or 60 millimeters of mercury, an error of five millimeters would be magnified enormously when the γ or $\frac{N}{P}$ functions are integrated. The last type of curve is not quite so bad as the first in this respect, since the total area under the curve is distributed more evenly over the entire curve.

RESULTS

The results of the work done are mainly negative and may be summed up as follows:

1. It was found that the extension of Langmuir's formula is sound only when the moles of pure materials adsorbed in a complete monomolecular layer are equal.
2. The Magnus mixture equation is generally inapplicable.
3. The Hill equation is not in a usable form.
4. Logically, the Van Laar type equation applied in the form proposed by Chertow and Cadogan is incorrect since the fugacity of the solid changes with mixture composition.
5. It is unlikely that the Broughton equation can be used to test data, though it is of great value in testing proposed correlation formulae.
6. It is unlikely that a relation can be found between the fugacity of the solid under the pure gases and the fugacity of the solid under the gaseous mixtures.
7. It may be possible to relate the variation in the fugacity of the solid under mixtures to various types of systems.

APPENDIX

Table AI.

Original Data for the System
Ethylene-Propane-PCC Carbon at 25°C
(Cadagon)

Pure Ethylene		Pure Propane		Mixture (P= 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	Xe	Ye
0.187	13	0.301	4	3.15	0.067	0.409
0.639	60	0.667	19.5	3.03	0.110	0.553
0.82	100	1.25	50	2.79	0.239	0.782
1.198	203	1.90	100	2.79	0.239	0.786
1.42	300	2.275	150	2.52	0.439	0.914
1.555	356	2.48	200	2.37	0.601	0.949
1.79	500	2.67	250			
2.004	645	2.79	300			
2.14	760	2.88	350			
		2.96	400			
		3.08	500			
		3.20	600			
		3.30	700			
		3.38	800			

Table AII.

Original Data for the System
Ethane-Propane-PCC Carbon at 25°C
(Cadagon)

Pure Ethane		Pure Propane		Mixture (P= 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, Et.	Y, Et.
0.167	12.5	0.301	4	3.23	0.050	0.385
0.381	37.0	0.667	19.5	3.19	0.100	0.505
0.625	69.5	1.25	50	3.12	0.150	0.570
0.925	128	1.90	100	3.06	0.200	0.615
1.16	180	2.275	150	3.00	0.250	0.653
1.35	230	2.48	200	2.95	0.300	0.683
1.62	312	2.67	250	2.85	0.400	0.735
1.82	399.5	2.79	300	2.77	0.500	0.785
2.06	512	2.88	350	2.71	0.600	0.840
2.21	597.5	2.96	400	2.64	0.700	0.883
2.41	751.5	3.08	500	2.57	0.800	0.938
		3.20	600	2.49	0.900	0.967
		3.30	700	2.45	0.950	0.984
		3.38	800			

Table AIII.

Original Data for the System
Isobutane-Butene-1-PCC Carbon at 25°C
(Cadagon)

Pure Isobutane		Pure Butene-1		Mixture (P= 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, Iso.	Y, Iso.
0.312	2.5	2.08	21	3.82	0.070	0.140
1.46	23.5	2.40	50	3.80	0.100	0.174
2.27	70.5	2.73	100	3.75	0.200	0.305
2.46	100	2.95	150	3.70	0.300	0.408
2.67	150	3.10	200	3.66	0.400	0.505
2.79	200	3.22	250	3.60	0.500	0.600
2.87	250	3.30	300	3.55	0.600	0.693
2.93	300	3.47	400	3.50	0.700	0.773
3.05	400	3.59	500	3.45	0.800	0.862
3.14	500	3.69	600			
3.23	600	3,78	700			
3.31	700	3.83	748.5			
3.33	747					

Table AIV.

Original Data for the System
Acetylene-Ethylene-PCC Carbon
at 25°C (Chertow)

Acetylene			Ethylene		
N, mmols.	Pressure, mm. Hg. Pure	Mixture	N, mmols.	Pressure, mm. Hg. Pure	Mixture
2.04	760	760	2.14	760	760
2.00	723	744	2.05	682	715
1.96	690	734	2.00	645	693
1.90	645	717	1.95	605	670
1.80	580	688	1.90	570	645
1.60	458	632	1.80	505	578
1.40	363	572	1.60	385	518
1.20	274	513	1.40	290	440
1.00	200	453	1.20	213	372
0.80	135	383	1.00	150	305
0.60	83	308	0.80	103	243
0.40	45	218	0.60	69	183
0.30	30	165	0.40	41	120
0.20	20	113	0.30	29	89
0.10	10	55	0.20	20	60
			0.10	10	32

Table AV.
Original Data for the System
Ethylene-Propane-PC Carbon at 25°C
(Chertow)

Propane			Ethylene		
N, mmols.	Pressure, mm. Hg. Pure	Pressure, mm. Hg. Mixture	N, mmols.	Pressure, mm. Hg. Pure	Pressure, mm. Hg. Mixture
3.35	760	760	2.15	760	760
3.20	608	655	2.00	633	700
3.10	508	595	1.80	493	648
3.00	425	538	1.60	378	610
2.80	280	450	1.40	285	575
2.60	190	388	1.20	203	548
2.40	133	343	1.00	143	523
2.20	93	308	0.80	95	485
2.00	64	280	0.60	60	430
1.80	45	255	0.40	33	362
1.60	33	236	0.20	15	246
1.40	25	210	0.10		160
1.20	18	200			
1.00	15	180			
0.80		155			
0.60		128			
0.40		93			
0.20		53			
0.10		33			

Table AVI.

Original Data for the System
Methane-Ethylene-CG Carbon at 25°C
(Cadagon)

Pure Methane		Pure Ethylene		Mixture (P = 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, Me.	Y, Me.
0.066	30.5	1.04	46	3.20	0.050	0.375
0.180	72	1.53	100	2.88	0.100	0.585
0.230	100	2.13	200	2.60	0.150	0.700
0.435	200	2.52	300	2,38	0.200	0.775
0.600	300	2.83	400	2.23	0.250	0.823
0.750	400	3.07	500	2.10	0.300	0.860
0.880	500	3.29	600	1.98	0.350	0.880
0.990	600	3.47	700	1.85	0.400	0.910
1.10	700	3.57	757	1.70	0.500	0.938
1.13	755			1.53	0.600	0.960
				1.42	0.700	0.970
				1.35	0.800	0.983

Table AVII.

Original Data for the System
Ethylene-Ethane-CG Carbon at 25°C
(Cadagon)

Pure Ethylene		Pure Ethane		Mixture (P= 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, Ethy.	Y, Ethy.
1.04	46	0.888	23.5	3.88	0.150	0.195
1.53	100	1.32	50	3.87	0.200	0.255
2.13	200	1.83	100	3.85	0.300	0.375
2.52	300	2.43	200	3.79	0.500	0.600
2.83	400	2.83	300	3.75	0.600	0.700
3.07	500	3.15	400	3.71	0.700	0.785
3.29	600	3.42	500	3.67	0.800	0.865
3.47	700	3.63	600	3.65	0.835	0.893
3.57	757	3.80	700			
		3.90	761.5			

Table AVIII.

Original Data for the System
Ethylene-Propylene-CG Carbon at 25°C
(Cadagon)

Pure Ethylene		Pure Propylene		Mixture (P = 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, Et.	Y, Et.
1.04	46	2.56	53.5	4.80	0.050	0.345
1.53	100	3.28	100	4.62	0.100	0.550
2.13	200	3.99	200	4.46	0.150	0.670
2.52	300	4.35	300	4.34	0.200	0.743
2.83	400	4.56	400	4.24	0.250	0.800
3.07	500	4.72	500	4.15	0.300	0.838
3.29	600	4.86	600	4.07	0.350	0.870
3.47	700	4.96	700	4.00	0.400	0.890
3.57	757	5.03	761.5	3.88	0.500	0.923
				3.80	0.600	0.944
				3.72	0.700	0.960
				3.67	0.800	0.972
				3.64	0.833	0.975

Table AIX.

Original Data for the System
Ethylene-Propane-CG Carbon at 25°C
(Cadagon)

Pure Ethylene		Pure Propane		Mixture (P = 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, Et.	Y, Et.
1.04	46	2.46	53	4.45	0.070	0.380
1.53	100	3.10	100	4.35	0.100	0.501
2.13	200	3.76	200	4.22	0.150	0.635
2.52	300	4.00	300	4.12	0.200	0.724
2.83	400	4.16	400	4.04	0.250	0.787
3.07	500	4.28	500	3.96	0.300	0.833
3.29	600	4.37	600	3.89	0.350	0.873
3.47	700	4.45	700	3.83	0.400	0.900
3.57	757	4.50	800	3.78	0.450	0.918
				3.74	0.500	0.931
				3.66	0.600	0.953
				3.62	0.714	0.970

Table AX.

Original Data for the System
Propane-Propylene-CG Carbon at 25°C
(Cadogan)

Pure Propane		Pure Propylene		Mixture (P = 1 Atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, C_3H_8	Y, C_3H_8
2.46	53	2.56	53.5	4.79	0.264	0.260
3.10	100	3.28	100	4.70	0.501	0.511
3.76	200	3.99	200	4.70	0.502	0.507
4.00	300	4.35	300	4.60	0.742	0.749
4.16	400	4.56	400			
4.28	500	4.72	500			
4.37	600	4.86	600			
4.45	700	4.96	700			
4.50	800	5.03	761.5			

Table AXI.

Original Data for the System
Propane- Propylene-GLC Carbon at 25°C
(Chertow)

Propylene			Propane		
N, mmols.	Pressure, mm. Hg. Pure	Mixture	N, mmols.	Pressure, mm. Hg. Pure	Mixture
2.79	760	760	2.59	760	760
2.70	675	723	2.50	650	708
2.60	575	685	2.40	550	672
2.40	425	625	2.20	390	613
2.20	305	573	2.00	273	555
2.00	215	520	1.80	185	500
1.80	150	468	1.60	125	443
1.40	70	363	1.40	83	388
1.00	32	258	1.20	53	333
0.80	23	208	1.00	35	278
0.60	15	155	0.80	23	222
0.40	10	103	0.60	15	165
0.20	3	52	0.40	10	112
			0.20	3	55

Table AXII.

Original Data for the System
Methane-Ethylene-SG at 25°C
(Cadogan)

Pure Methane		Pure Ethylene		Mixture (P = 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, Me.	Y, Me.
0.0130	72.5	0.150	55.5	0.77	0.050	0.581
0.0295	180.5	0.259	107	0.62	0.100	0.682
0.0469	285.5	0.425	211.5	0.51	0.150	0.750
0.0619	369	0.592	336	0.44	0.200	0.800
0.0629	404.5	0.766	503.5	0.38	0.250	0.842
0.0844	529.5	0.993	758	0.34	0.300	0.878
0.108	678			0.32	0.350	0.911
0.122	766			0.28	0.400	0.920
				0.24	0.500	0.948
				0.20	0.600	0.970
				0.17	0.700	0.980
				0.16	0.750	0.985

Table AXIII.

Original Data for the System
Ethane-Ethylene-SG at 25°C
(Cadogan)

Pure Ethane		Pure Ethylene		Mixture (P = 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, C_2H_6	Y, C_2H_6
0.070	50	0.150	55.5	0.94	0.060	0.175
0.120	100	0.259	107	0.90	0.100	0.253
0.220	200	0.425	211.5	0.87	0.150	0.340
0.300	300	0.592	336	0.84	0.200	0.412
0.370	400	0.766	503.5	0.80	0.250	0.475
0.435	500	o.993	758	0.78	0.300	0.537
0.500	600			0.73	0.400	0.640
0.610	760			0.69	0.500	0.730
				0.65	0.600	0.803
				0.63	0.700	0.870
				0.60	0.800	0.921

Table AXIV.

Original Data for the System
Ethane-Propane-SG at 25°C
(Cadogan)

Pure Ethane		Pure Propane		Mixture (P = 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, Et.	Y, Et.
0.070	50	0.225	50	1.14	0.139	0.503
0.120	100	0.390	100	1.08	0.200	0.600
0.220	200	0.640	200	1.03	0.250	0.655
0.300	300	0.850	300	0.97	0.300	0.700
0.370	400	1.025	400	0.88	0.400	0.770
0.435	500	1.180	500	0.80	0.500	0.823
0.500	600	1.330	600	0.73	0.600	0.863
0.610	760	1.55	760	0.724	0.671	0.896

Table AXV.

Original Data for the System
Isobutane-Butene-1-SG at 25°C
(Cadogan)

Pure Isobutane		Pure Butene-1		Mixture (P = 1 atm.)		
N, mmols.	P, mm. Hg.	N, mmols.	P, mm. Hg.	N, mmols.	X, Iso.	Y, Iso.
0.217	15.5	1.09	40	3.23	0.080	0.215
0.574	62.5	1.625	100	3.16	0.150	0.352
1.04	155.5	2.11	200	3.12	0.200	0.435
1.43	264	2.43	300	3.03	0.300	0.565
1.84	414	2.67	400	2.95	0.400	0.663
2.25	605	2.86	500	2.88	0.500	0.753
2.53	757.5	3.05	600	2.81	0.600	0.828
		3.21	700	2.74	0.700	0.890
		3.28	749	2.68	0.800	0.939
				2.56	0.843	0.958

Table AXVI.

Original Data for the System
Acetylene-Ethylene-SG at 25°C
(Chertow)

Acetylene			Ethylene		
N, mmols.	Pressure, mm. Hg. Pure	Pressure, mm. Hg. Mixture	N, mmols.	Pressure, mm. Hg. Pure	Pressure, mm. Hg. Mixture
1.81	760	760	0.96	760	760
1,75	700	725	0.90	685	720
1.70	663	698	0.85	625	693
1.65	620	670	0.80	565	667
1.60	582	642	0.70	465	615
1.50	505	585	0.60	373	555
1.40	440	553	0.50	290	495
1.30	380	483	0.40	215	425
1.20	325	433	0.30	153	353
1.00	230	343	0.20	95	265
0.80	155	257	0.10	44	160
0.60	95	183			
0.40	53	120			
0.30	36	88			
0.20	22	58			
0.10	9	27			

Table AXVII.

Original Data for the System
Propane-Ethylene-SG at 25°C
(Chertow)

Pure Ethylene			Pure Propane		
N, mmols.	Pressure, mm. Hg. Pure	Mixture	N, mmols.	Pressure, mm. Hg. Pure	Mixture
0.96	760	760	1.54	760	760
0.90	685	725	1.50	725	748
0.85	623	692	1.45	685	730
0.80	569	645	1.40	650	710
0.70	465	590	1.30	575	655
0.60	370	518	1.20	510	595
0.50	285	438	1.10	445	535
0.40	212	357	1.00	388	480
0.30	145	272	0.90	333	425
0.20	90	185	0.80	282	375
0.10	45	90	0.70	232	325
			0.60	187	275
			0.50	148	225
			0.40	110	180
			0.30	76	133
			0.20	48	92
			0.10	22	49

Table AXVIII.

Original Data for the System
Ethylene-Propylene-SG at 25°C
(Chertow)

Propylene			Ethylene		
N, mmols.	Pressure, mm. Hg. Pure	Mixture	N, mmols.	Pressure, mm. Hg. Pure	Mixture
2.29	760	760	0.96	760	760
2.20	675	710	0.90	685	753
2.00	520	590	0.80	563	725
1.80	400	485	0.70	458	695
1.60	310	390	0.60	365	655
1.40	235	305	0.50	285	605
1.20	173	235	0.40	210	545
1.00	118	175	0.30	146	466
0.80	80	125	0.20	90	365
0.60	50	88	0.10	40	260
0.40	28	53	0.05	18	130
0.20	13	23			

Table AXIX.

Original Data for the System
Propane-Propylene-SG at 25°C
(Chertow)

Propylene			Propane		
N, mmols.	Pressure, mm. Hg. Pure	Mixture	N, mmols.	Pressure, mm. Hg. Pure	Mixture
2.30	760	760	1.56	760	760
2.20	678	698	1.50	715	746
2.10	605	648	1.40	635	728
2.00	535	595	1.20	500	675
1.80	418	498	1.00	383	603
1.60	320	405	0.80	280	515
1.40	242	330	0.60	185	405
1.20	173	260	0.40	108	280
1.00	123	200	0.20	46	148
0.80	85	140	0.10	20	75
0.60	53	94			
0.40	29	56			
0.20	10	26			

Table AXX.

Original Data for the System
Ethane-Ethylene-SG
at 25°C (Chertow)

Ethylene			Ethane		
N, mmols.	Pressure, mm. Hg. Pure	Mixture	N, mmols.	Pressure, mm. Hg. Pure	Mixture
0.96	760	760	0.60	760	760
0.90	675	695	0.50	600	680
0.80	563	580	0.40	450	593
0.70	455	476	0.30	313	495
0.60	360	385	0.20	193	375
0.50	275	305	0.10	85	218
0.40	203	233	0.05	43	120
0.30	137	162			
0.20	80	100			
0.10	35	48			

Table AXXI.

γ Functions for the System Propane-Ethylene-PCC Carbon at 25°C (Cadogan)

C_3H_8 r	C_3H_8 γ	C_2H_4 r	C_2H_4 γ
0.075	1.25	0.116	17.5
0.149	1.309	0.232	10.8
0.224	1.23	0.349	7.06
0.298	1.21	0.465	4.70
0.373	1.22	0.582	3.19
0.448	1.22	0.698	2.175
0.522	1.22	0.814	1.57
0.597	1.275	0.930	1.173
0.671	1.292	1.00	1.00
0.746	1.308	0.058	26.0
0.820	1.275	0.035	28.9
0.895	1.142	0.024	34.0
0.971	1.038		
1.00	1.00		

Table AXXII.

γ Functions for the System Ethane-Propane-PCC Carbon at 25°C (Cadogan)

C_2H_6 r	C_2H_6 γ	C_3H_8 r	C_3H_8 γ
0.021	41.7	0.037	4.0
0.031	34.8	0.075	3.85
0.041	31.6	0.112	3.80
0.052	26.4	0.149	3.72
0.103	16.05	0.224	3.71
0.206	8.36	0.373	3.04
0.309	5.29	0.523	2.32
0.412	3.79	0.597	2.04
0.515	2.845	0.672	1.71
0.618	2.23	0.748	1.45
0.721	1.792	0.821	1.21
0.824	1.45	0.934	0.95
0.927	1.142	0.956	0.925
1.00	1.00	0.986	0.951
		1.00	1.00

Table AXXIII.

γ Functions for the System Isobutane-Butene-1-PCC Carbon at 25°C (Cadogan)

Isobutane r	Isobutane γ	Butene-1 r	Butene-1 γ
0.037	56.5	0.033	53.8
0.075	48.0	0.065	53.0
0.150	37.8	0.130	49.7
0.224	30.9	0.260	40.6
0.300	25.1	0.391	30.5
0.450	15.8	0.456	24.8
0.524	12.79	0.521	18.7
0.600	10.39	0.651	6.69
0.674	7.86	0.716	4.55
0.749	5.46	0.781	3.18
0.824	3.50	0.847	2.16
0.861	2.675	0.879	1.819
0.899	1.983	0.912	1.541
0.944	1.510	0.936	1.36
0.974	1.201	0.961	1.183
1.00	1.00	0.985	1.062
		1.00	1.00

Table AXXIV.

γ Functions for the System Acetylene-Ethylene-PCC Carbon at 25°C (Chertow)

Acetylene r	Acetylene γ	Ethylene r	Ethylene γ
0.049	5.5	0.047	3.2
0.098	5.65	0.094	3.0
0.162	5.50	0.140	3.07
0.196	4.8	0.187	2.93
0.294	3.7	0.280	2.64
0.392	2.84	0.374	2.36
0.491	2.26	0.467	2.03
0.588	1.87	0.560	1.75
0.686	1.58	0.655	1.52
0.784	1.38	0.748	1.34
0.883	1.19	0.842	1.14
0.932	1.11	0.888	1.13
0.962	1.063	0.912	1.11
0.982	1.015	0.935	1.07
1.00	1.00	0.958	1.05
		1.00	1.00

Table AXXV.

γ Functions for the System Ethylene-Propane-PCC Carbon at 25°C (Chertow)

Propane		Ethylene	
r	γ	r	γ
0.299	12.0	0.093	16.4
0.358	11.10	0.186	11.0
0.418	8.40	0.278	7.16
0.477	7.15	0.372	5.10
0.537	5.66	0.465	3.66
0.597	4.37	0.559	2.70
0.657	3.31	0.651	2.02
0.717	2.58	0.744	1.61
0.776	2.04	0.838	1.32
0.836	1.61	0.931	1.11
0.895	1.26	1.00	1.00
0.927	1.17		
0.956	1.08		
1.00	1.00		

Table AXXVI.

γ Functions for the System Methane-Ethylene-CG Carbon at 25°C (Cadogan)

Methane		Ethylene	
r	γ	r	γ
0.044	5.0	0.070	1.65
0.089	4.67	0.140	1.60
0.178	3.89	0.210	1.47
0.267	3.39	0.279	1.39
0.356	2.91	0.349	1.289
0.444	2.515	0.419	1.263
0.534	2.14	0.489	1.112
0.622	1.796	0.559	1.074
0.711	1.625	0.629	1.040
0.800	1.411	0.699	1.00
0.889	1.23	0.769	0.969
1.00	1.00	0.838	0.942
		0.909	0.942
		1.00	1.00

Table AXXVII.

γ Functions for the System Ethylene-Ethane-CG Carbon at 25°C (Cadogan)

Ethylene		Ethane	
r	γ	r	γ
0.070	8.92	0.064	6.96
0.140	7.85	0.128	6.31
0.196	6.84	0.192	5.70
0.280	5.75	0.256	5.06
0.350	4.75	0.320	4.25
0.420	3.74	0.385	3.73
0.491	3.16	0.449	3.05
0.561	2.66	0.514	2.58
0.631	2.27	0.577	2.20
0.701	1.94	0.641	1.96
0.771	1.65	0.706	1.71
0.842	1.42	0.770	1.545
0.912	1.24	0.834	1.38
0.981	1.05	0.899	1.24
1.00	1.00	0.967	1.09
		1.00	1.00

Table AXXVIII.

γ Functions for the System Ethylene-Propylene-CG Carbon at 25°C (Cadogan)

Ethylene		Propylene	
r	γ	r	γ
0.035	18.65	0.050	2.01
0.070	33.4	0.099	2.01
0.140	25.9	0.149	1.61
0.210	19.0	0.199	1.70
0.279	13.85	0.298	2.23
0.392	8.10	0.398	1.80
0.449	6.33	0.497	1.87
0.560	4.06	0.596	1.98
0.673	2.75	0.696	2.07
0.785	1.90	0.796	1.98
0.840	1.61	0.895	1.58
0.897	1.36	1.00	1.00
0.953	1.15		
1.00	1.00		

Table AXXIX.

γ Functions for the System Ethylene-Propane-CG Carbon at 25°C (Cadogan)

Ethylene		Propane	
r	γ	r	γ
0.013	38.3	0.040	1.13
0.025	37.6	0.080	1.62
0.038	36.9	0.163	1.81
0.050	34.4	0.232	1.78
0.061	33.1	0.325	1.77
0.074	32.6	0.416	1.71
0.086	30.9	0.464	1.68
0.121	28.0	0.512	1.67
0.177	21.8	0.564	1.70
0.230	17.2	0.617	1.79
0.282	13.7	0.675	1.73
0.332	10.84	0.800	1.70
0.427	6.84	0.867	1.55
0.475	5.46	0.905	1.41
0.615	3.29	0.919	1.36
0.721	2.38	0.934	1.32
0.799	1.81	0.947	1.26
0.900	1.33	0.964	1.16
0.950	1.14	0.975	1.16
0.978	1.05	0.989	1.05
1.00	1.00	1.00	1.00

Table AXXX.

γ Functions for the System Propane-Propylene-CG Carbon at 25°C (Cadogan)

Propane		Propylene	
r	γ	r	γ
0.282	11.78	0.702	4.46
0.525	5.94	0.466	8.40
0.762	3.37	0.235	12.50

Table AXXXI.

γ Functions for the System Propane-Propylene-GLC Carbon at 25°C (Chertow)

Propylene		Propane	
r	γ	r	γ
0.072	17.30	0.077	18.30
0.143	10.30	0.155	11.20
0.215	10.30	0.232	11.00
0.287	9.04	0.309	9.65
0.359	8.38	0.387	7.95
0.501	5.19	0.464	6.28
0.645	3.12	0.541	4.67
0.716	2.42	0.619	3.54
0.789	1.88	0.695	2.70
0.861	1.47	0.774	2.03
0.932	1.19	0.850	1.57
0.968	1.07	0.928	1.22
1.00	1.00	0.967	1.09
		1.00	1.00

Table AXXXII.

γ Functions for the System Methane-Ethylene-SG at 25°C (Cadogan)

Data too unreliable to warrant calculation.

Table AXXXIII.

γ Functions for the System Ethylene-Ethane-SG at 25°C (Cadogan)

Ethane		Ethylene	
r	γ	r	γ
0.093	2.89	0.121	1.41
0.131	2.80	0.151	1.47
0.164	2.63	0.182	1.40
0.197	2.49	0.202	1.40
0.230	2.37	0.252	1.36
0.262	2.25	0.302	1.34
0.295	2.16	0.403	1.28
0.328	2.06	0.454	1.24
0.410	1.85	0.504	1.21
0.492	1.67	0.554	1.18
0.574	1.53	0.605	1.16
0.655	1.40	0.655	1.12
0.738	1.29	0.706	1.09
0.787	1.23	0.756	1.06
1.00	1.00	0.807	1.03
		0.888	1.00
		1.00	1.00

Table AXXXIV.

γ Functions for the System Ethane-Propane-SG at 25°C (Cadogan)

Ethane		Propane	
r	γ	r	γ
0.260	2.96	0.146	1.58
0.295	2.66	0.161	1.50
0.328	2.44	0.194	1.45
0.410	2.06	0.226	1.38
0.492	1.78	0.258	1.31
0.574	1.58	0.323	1.18
0.656	1.40	0.355	1.14
0.728	1.26	0.387	1.10
0.770	1.21	0.420	1.07
0.820	1.15	0.451	1.04
1.00	1.00	0.485	1.02
		0.516	1.01
		0.550	1.00
		1.00	1.00

Table AXXXV.

γ Functions for the System Isobutane-Butene-1-SG at 25°C (Cadogan)

Isobutane		Butene-1	
r	γ	r	γ
0.013	9.50	0.024	3.33
0.026	9.83	0.030	3.78
0.039	9.65	0.040	3.44
0.051	9.31	0.064	3.08
0.077	8.66	0.079	2.96
0.101	8.51	0.121	3.44
0.186	5.36	0.162	3.49
0.244	4.50	0.248	3.30
0.356	3.40	0.338	3.11
0.464	2.61	0.435	2.48
0.565	2.14	0.532	2.12
0.661	1.76	0.641	1.65
0.752	1.50	0.756	1.32
0.841	1.30	0.813	1.19
0.846	1.30	0.897	1.06
0.926	1.12	0.921	1.05
0.941	1.09	0.949	1.02
0.965	1.045	0.961	1.01
0.973	1.023	0.973	1.01
0.977	1.018	0.991	1.00
1.00	1.00	1.00	1.00

Table AXXXVI.

γ Functions for the System Acetylene-Ethylene-SG at 25°C (Chertow)

Ethylene		Acetylene	
r	γ	r	γ
0.104	3.56	0.055	3.00
0.208	2.79	0.111	2.64
0.312	2.30	0.166	2.44
0.416	1.97	0.221	2.26
0.520	1.71	0.332	1.93
0.625	1.49	0.442	1.66
0.729	1.32	0.563	1.49
0.833	1.18	0.664	1.33
0.885	1.09	0.719	1.27
0.937	1.05	0.724	1.21
1.00	1.00	0.830	1.16
		0.885	1.10
		0.912	1.08
		0.940	1.05
		0.968	1.04
		1.00	1.00

Table AXXXVII.

γ Functions for the System Propane-Ethylene-SG at 25°C (Chertow)

Ethylene		Propane	
r	γ	r	γ
0.104	2.00	0.065	2.22
0.156	2.00	0.130	1.92
0.208	2.06	0.195	1.75
0.312	1.88	0.260	1.64
0.416	1.73	0.324	1.52
0.520	1.54	0.390	1.47
0.625	1.40	0.455	1.40
0.729	1.27	0.520	1.33
0.833	1.13	0.584	1.275
0.885	1.11	0.650	1.24
0.937	1.06	0.715	1.20
1.00	1.00	0.780	1.17
		0.845	1.14
		0.910	1.09
		0.943	1.07
		0.974	1.03
		1.00	1.00

Table AXXXVIII.

γ Functions for the System Ethylene-Propylene-SG at 25°C (Chertow)

Propylene		Ethylene	
r	γ	r	γ
0.087	1.78	0.052	7.22
0.175	1.89	0.104	6.50
0.262	1.76	0.208	4.06
0.350	1.56	0.313	3.19
0.437	1.48	0.416	2.60
0.524	1.36	0.520	2.12
0.611	1.30	0.625	1.80
0.699	1.26	0.730	1.52
0.786	1.21	0.834	1.29
0.874	1.13	0.939	1.10
0.961	1.05	1.00	1.00
1.00	1.00		

Table AXXXIX.

γ Functions for the System Propane-Propylene-SG at 25°C (Chertow)

Propylene		Propane	
r	γ	r	γ
0.087	2.60	0.064	3.75
0.174	1.93	0.128	3.22
0.261	1.77	0.256	2.60
0.348	1.65	0.385	2.18
0.435	1.63	0.513	1.84
0.521	1.50	0.642	1.57
0.609	1.36	0.770	1.35
0.695	1.27	0.899	1.15
0.784	1.19	0.962	1.04
0.870	1.11	1.00	1.00
0.914	1.07		
0.958	1.03		
1.00	1.00		

Table AXL.

γ Functions for the System Ethylene-Ethane-SG at 25°C (Chertow)

Ethylene		Ethane	
r	γ	r	γ
0.104	1.37	0.083	2.79
0.208	1.25	0.167	2.56
0.313	1.18	0.333	1.94
0.416	1.15	0.500	1.58
0.520	1.11	0.667	1.32
0.625	1.07	0.834	1.13
0.730	1.04	1.00	1.00
0.834	1.03		
0.939	1.03		
1.00	1.00		

Table AXLI.

Solid Fugacities for the System
Ethane-Propane-PCC Carbon at 25°C
(From data of Cadogan)

Pure Propane			Pure Ethane			Mixture		
P, atm.	$f_s^{N_s}$	N, mmol.	P, atm.	$f_s^{N_s}$	N, mmol.	P_p, atm.	$f_s^{N_s}$	N, mmol.
0.000	1.0	0.000	0.000	1.0	0.000	0.000	0.01530	2.43
0.025	0.275	0.650	0.025	0.767				
0.050	0.154	1.070	0.050	0.617				
0.075	0.094	1.380	0.075	0.510				
0.100	0.061	1.630	0.100	0.429	0.666	0.100	0.0097	2.609
0.125	0.042		0.125	0.366				
0.150	0.0295		0.150	0.315				
0.175	0.0215		0.175	0.273				
0.200	0.0160	2.250	0.200	0.240	1.036	0.200	0.0059	2.780
0.250	0.0095		0.250	0.1825		0.250	0.0046	
0.300	0.0059	2.580	0.300	0.1490	1.344	0.300	0.0036	2.931
0.350			0.350	0.1200		0.350	0.0028	
0.400	0.00275	2.800	0.400	0.0970	1.600	0.400	0.0021	3.088
0.500	0.00145	2.950	0.500	0.0660	1.825	0.500	0.0013	3.220
0.600	0.00085	3.060	0.600	0.0470	1.988	0.600	0.00078	3.266
0.700	0.00052	3.15	0.700	0.034	2.114	0.700	0.00049	3.274
0.800	0.00035	3.20	0.800	0.0255	2.240	0.800	0.00033	3.280
0.900	0.00024	3.33	0.900	0.0197	2.340	0.900	0.00024	3.300
1.000	0.00016	3.35	1.000	0.0153	2.43	1.000	0.00016	3.350

Table AXLII.

Solid Fugacities for the System
Isobutane-Butene-1-PCC Carbon at 25°C
(From data of Cadogan)

Mixture Only		
P_b, atm.	$f_s^{N_s}$	N, mmol.
0.000	1.000	3.34
0.100	0.822	3.413
0.200	0.691	3.478
0.300	0.589	3.529
0.400	0.505	3.600
0.500	0.434	3.665
0.600	0.370	3.720
0.700	0.311	3.756
0.800	0.256	3.788
0.900	0.208	3.814
1.000	0.165	3.840

Table AXLIII.

Solid Fugacities for the System
Acetylene-Ethylene-PCC Carbon at 25°C
(From data of Chertow)

Pure Acetylene			Pure Ethylene			Mixture		
P, atm.	$f_s^{N_s}$	N, mmol.	P, atm.	$f_s^{N_s}$	N, mmol.	Pe, atm.	$f_s^{N_s}$	N, mmol.
0.000	1.00	0.000	0.000	1.00	0.000	0.000	0.0365	2.04
0.050	0.724		0.050	0.499				
0.100	0.542	0.543	0.100	0.354	0.640	0.100	0.0345	2.051
0.150	0.420		0.150	0.261				
0.200	0.337	0.864	0.200	0.196	1.008	0.200	0.0325	2.022
0.250	0.275		0.250	0.154				
0.300	0.228	1.086	0.300	0.124	1.254	0.300	0.0310	2.013
0.400	0.162	1.264	0.400	0.084	1.444	0.400	0.0285	2.008
0.500	0.121	1.425	0.500	0.059	1.590	0.500	0.0263	2.015
0.600	0.092	1.571	0.600	0.044	1.722	0.600	0.0240	2.042
0.700	0.071	1.708	0.700	0.034	1.834	0.700	0.0220	2.075
0.800	0.056	1.832	0.800	0.0262	1.944	0.800	0.0198	2.116
0.900	0.045	1.953	0.900	0.021	2.043	0.900	0.0180	2.124
1.000	0.0365	2.04	1.000	0.0167	2.14	1.000	0.0167	2.14

Table AXLIV.

Solid Fugacities for the System
Methane-Ethylene- CG Carbon at 25°C
(From data of Cadogan)

Pure Methane			Pure Ethylene			Mixture		
P, atm.	$f_s^{N_s}$	N, mmol.	P, atm.	$f_s^{N_s}$	N, mmol.	P_e, atm.	$f_s^{N_s}$	N, mmol.
0.000	1.000	0.000	0.000	1.000	0.000	0.000	0.225	1.125
0.050			0.050	0.205	0.810	0.050	0.109	1.601
0.100	0.8355	0.178	0.100	0.095	1.315	0.100	0.066	1.928
0.150			0.150	0.053		0.150	0.036	
0.200	0.703	0.340	0.200	0.032	1.874	0.200	0.023	2.320
0.250			0.250	0.021		0.250	0.0158	
0.300	0.595	0.486	0.300	0.014	2.265	0.300	0.0110	2.603
0.350			0.350	0.0097		0.350	0.0079	
0.400	0.509	0.616	0.400	0.0070	2.552	0.400	0.0058	2.850
0.500	0.438	0.740	0.500	0.0039	2.775	0.500	0.0033	3.010
0.600	0.379	0.840	0.600	0.0023	2.958	0.600	0.0020	3.16
0.700	0.330	0.924	0.700	0.0014	3.115	0.700	0.0013	3.302
0.800	0.290	1.024	0.800	0.00093	3.280	0.800	0.00089	3.414
0.900	0.256	1.08	0.900	0.00063	3.429	0.900	0.00061	3.504
1.000	0.225	1.125	1.000	0.00044	3.575	1.000	0.00044	3.575

Table AXLV.

Solid Fugacities for the System
Ethylene-Ethane-CG Carbon at 25°C
(From data of Cadogan)

Pure Ethylene			Pure Ethane			Mixture		
P, atm.	$f_s^{N_s}$	N, mmol.	P, atm.	$f_s^{N_s}$	N, mmol.	$P_{C_2H_6}$ atm.	$f_s^{N_s}$	N, mmol.
0.000	1.000	0.000	0.000	1.000	0.000	0.000	0.00067	3.57
0.025	0.532	0.625	0.025	0.435	0.831	0.100	0.00061	
0.050	0.321	0.918	0.050	0.234	1.125	0.107	0.00061	3.65
0.075	0.230		0.075	0.140		0.135	0.00059	3.67
0.100	0.162	1.34	0.100	0.0910	1.620	0.200	0.00054	
0.125	0.096		0.125	0.0630		0.215	0.00054	3.71
0.150	0.080		0.150	0.0440		0.300	0.00049	3.75
0.175	0.0625		0.175	0.0325		0.400	0.00043	3.79
0.200	0.0490	1.86	0.200	0.0245	2.170	0.500	0.00038	
0.250	0.0315		0.250	0.0150		0.600	0.00033	
0.300	0.0215	2.25	0.300	0.0095	2.520	0.625	0.00031	3.85
0.350	0.0150		0.350	0.0064		0.700	0.00028	
0.400	0.0110	2.52	0.400	0.0044	2.840	0.745	0.00026	3.87
0.450	0.0079		0.450	0.00315		0.800	0.00024	
0.500	0.0059	2.80	0.500	0.00235	3.100	0.805	0.00023	3.88
0.600	0.0035	3.00	0.600	0.00130	3.300	0.900	0.00019	
0.700	0.0022	3.15	0.700	0.00075	3.430	0.950	0.00017	
0.800	0.00145	3.320	0.800	0.00047	3.600	1.000	0.00015	3.90
0.900	0.00095	3.42	0.900	0.00031	3.780			
1.000	0.00067	3.57	1.000	0.00015	3.900			

Table AXLVI.

Solid Fugacities for the System
Propane-Propylene-GLC Carbon at 25°C
(From data of Chertow)

Mixture Only		
$P_{C_3H_6}$ atm.	$f_s^{N_s}$	N, mmol.
0.000	1.000	2.59
0.050	0.969	
0.100	0.944	2.729
0.150	0.923	
0.200	0.904	2.780
0.300	0.887	2.802
0.400	0.870	2.821
0.500	0.854	2.840
0.600	0.838	2.856
0.700	0.822	2.871
0.800	0.808	2.886
0.900	0.796	2.867
0.950	0.785	2.837
1.000	0.780	2.790

Table AXLVII.

Solid Fugacities for the System
Isobutane-Butene-1-SG at 25°C
(From data of Cadogan)

Pure Isobutane			Pure Butene-1			Mixture		
P, atm.	$f_s^{N_s}$	N, mmol.	P, atm.	$f_s^{N_s}$	N, mmol.	P_b, atm.	$f_s^{N_s}$	N, mmol.
0.000	1.000	0.000	0.000	1.000	0.000	0.000	0.0152	2.550
0.025	0.780		0.025	0.320		0.025	0.0121	
0.050	0.585	0.409	0.050	0.169	1.035	0.061	0.00965	2.680
0.075	0.484		0.075	0.108		0.075	0.0084	
0.100	0.408	0.655	0.100	0.0745	1.360	0.110	0.00685	2.740
0.125	0.349		0.125	0.0540		0.150	0.0056	
0.150	0.301		0.150	0.0410		0.172	0.00505	2.810
0.175	0.262		0.175	0.0315		0.200	0.00455	
0.200	0.230	1.018	0.200	0.0250	1.850	0.247	0.00378	2.88
0.250	0.181		0.250	0.0160		0.300	0.0030	
0.300	0.144	1.296	0.300	0.0110	2.175	0.337	0.00275	2.95
0.350	0.116		0.350	0.0077		0.400	0.00215	
0.400	0.096	1.540	0.400	0.0056	2.420	0.435	0.00197	3.03
0.450	0.080		0.450	0.00425		0.500	0.00160	
0.500	0.066	1.755	0.500	0.00320	2.650	0.565	0.00130	3.12
0.600	0.0474	1.950	0.600	0.00195	2.820	0.600	0.00120	
0.700	0.0350	2.100	0.700	0.00130	2.940	0.648	0.00101	3.16
0.800	0.0260	2.240	0.800	0.00085	3.040	0.718	0.00083	3.23
0.900	0.0200	2.421	0.900	0.00058	3.204	0.894	0.00055	3.27
1.000	0.0152	2.550	1.000	0.00042	3.310	1.000	0.00042	3.31

Table AXLVIII.

Solid Fugacities for the System
Propane-Ethylene-SG at 25°C
(From data of Chertow)

Mixture Only		
Pp, atm.	$f_s^{N_s}$	N, mmol.
0.000	1.000	0.960
0.100	0.926	1.007
0.200	0.856	1.062
0.300	0.790	1.124
0.400	0.729	1.181
0.500	0.670	1.240
0.600	0.624	1.296
0.700	0.579	1.341
0.800	0.538	1.381
0.900	0.505	1.437
1.000	0.470	1.54

Table AXLIX.

Solid Fugacities for the System
Ethylene-Propylene-SG At 25°C
(From data of Chertow)

Pure Propylene			Pure Ethylene			Mixture		
P, atm.	$f_s^{N_s}$	N, mmol.	P, atm.	$f_s^{N_s}$	N, mmol.	P_p, atm.	$f_s^{N_s}$	N, mmol.
0.000	1.000	0.000	0.000	1.000	0.000	0.000	0.270	0.960
0.025	0.741	0.300	0.025	0.947		0.025	0.235	1.039
0.050	0.568	0.500	0.050	0.900	0.098	0.050	0.205	1.103
0.100	0.364	0.800	0.100	0.821	0.174	0.100	0.160	1.221
0.150	0.253		0.150	0.755		0.150	0.129	1.293
0.200	0.186	1.130	0.200	0.702	0.304	0.200	0.105	1.369
0.250	0.1425		0.250	0.652		0.250	0.0875	1.442
0.300	0.114	1.356	0.300	0.606	0.420	0.300	0.0740	1.516
0.400	0.0745	1.564	0.400	0.530	0.528	0.400	0.0540	1.667
0.500	0.051	1.744	0.500	0.466	0.620	0.500	0.0400	1.810
0.600	0.037	1.890	0.600	0.414	0.696	0.600	0.0305	1.934
0.700	0.0275	2.023	0.700	0.368	0.770	0.700	0.0240	2.044
0.800	0.0208	2.120	0.800	0.331	0.840	0.800	0.0190	2.145
0.900	0.0160	2.232	0.900	0.298	0.900	0.900	0.0155	2.219
1.000	0.0128	2.290	1.000	0.270	0.960	1.000	0.0128	2.290

Table AL.

Solid Fugacities for the System
Propane-Propylene-SG at 25°C
(From data of Chertow)

Pure Propane			Pure Propylene			Mixture		
P, atm.	$f_s^{N_s}$	N, mmol.	P, atm.	$f_s^{N_s}$	N, mmol.	$P_{C_3H_6}$ atm.	$f_s^{N_s}$	N, mmol.
0.000	1.000	0.000	0.000	1.000	0.000	0.000	0.114	1.56
0.025			0.025	0.627	0.300	0.025		
0.050	0.835		0.050	0.483	0.482	0.050	0.091	
0.100	0.705	0.304	0.100	0.316	0.753	0.100	0.074	1.737
0.150	0.610		0.150	0.224		0.150	0.062	
0.200	0.534	0.518	0.200	0.170	1.116	0.200	0.053	1.848
0.250	0.470		0.250	0.131		0.250	0.046	
0.300	0.417	0.696	0.300	0.104	1.359	0.300	0.040	1.938
0.400	0.335	0.856	0.400	0.068	1.560	0.400	0.032	2.012
0.500	0.2725	1.000	0.500	0.0475	1.735	0.500	0.026	2.080
0.600	0.225	1.128	0.600	0.0340	1.872	0.600	0.022	2.142
0.700	0.186	1.253	0.700	0.0253	1.988	0.700	0.0182	2.198
0.800	0.157	1.360	0.800	0.0195	2.088	0.800	0.0158	2.238
0.900	0.133	1.458	0.900	0.0150	2.214	0.900	0.0138	2.269
1.000	0.114	1.560	1.000	0.0118	2.300	1.000	0.0118	2.300

SAMPLE CALCULATIONS

The following examples are for the system Ethane-Propane-PCC Carbon at 25°C.

1. Calculation of γ for propane:

   First plot N vs. P from original data for both pure adsorption and for mixture adsorption. Then, at N = 0.125 mmols./gm. read P_{pure} = 3 mm. Hg. and P_{mix} = 12 mm. Hg.

   $$= \frac{12}{3} = 4.0$$

2. Calculation of $f_s^{N_s}$ for pure adsorption of propane:

   First plot $\frac{N}{P}$ vs. P from the original data. Graphical integration from 0 to P = 0.025 atm. gives an area of 1.2872 = $-\Delta \ln f_s^{N_s}$. Assume the fugacity of the solid is 1.0 for pure solid.

   $$-\ln f_s^{N_s} = 1.2872$$

   $$f_s^{N_s} = 0.275$$

3. Calculation of $f_s^{N_s}$ for mixture adsorption:

   First plot $\frac{N}{P}$ vs. $P_{propane}$ for both ethane and propane from the original data. Then, read $(\frac{N}{P})_{propane} - (\frac{N}{P})_{eth.}$ at constant $P_{propane}$ from these curves and plot vs. $P_{propane}$. Graphical integration from 0 to P = 0.10 atm. gives an area of 0.4500 = $-\Delta \ln f_s^{N_s}$. Calculation of the adsorption of ethane shows that $-\ln f_s^{N_s}$ = 4.1882 at $P_{propane}$ = 0.0 atm.

   $$-\ln f_s^{N_s} = 4.1882 + 0.4500$$

   $$= 4.6382$$

   $$f_s^{N_s} = 0.0097$$

NOMENCLATURE

$\underline{F}$ - Molal free energy, cal./g.mol.
$\overline{F}$ - Partial molal free energy, cal./g.mol.
f - Fugacity
N - Millimols of gas adsorbed from mixture or millimols of solid.
N°- Millimols of gas adsorbed from pure gas at $P = \pi$.
P-- Partial pressure of gas in mixture in mm. Hg. or atm.
P°- Pressure of pure gas in mm. Hg. or atm.
r - The ratio $\frac{N}{N^{\circ}}$.

Greek Letters

γ - The ratio $\frac{P}{P^{\circ}}$.
ϕ - Any mathematical function.
π - Total pressure in mm. Hg. or atm.

Subscripts

A - First component in a binary gaseous mixture.
B - Second component in a binary gaseous mixture.
g - Gas.
s - Solid.

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