THE PHASE AND VOLUMETRIC BEHAVIOR OF NATURAL GASES AT LOW TEMPERATURES AND HIGH PRESSURES, INCLUDING THE CRITICAL STATES

by
Philip C. Davis
B. S., University of Kansas, 1948
M. S., University of Kansas, 1949

Submitted to the Department of
Chemical Engineering and the
Faculty of the Graduate School
of the University of Kansas in
partial fulfillment of the re-
quirements for the degree of
Doctor of Philosophy.

Advisory Committee:

Fred Kurata
J. O. Maloney
Max Dresden

December, 1951

ACKNOWLEDGEMENT

The author gratefully acknowledges the sponsorship of the Industrial Fellowship Committee and the University Fund for Research whose financial support made this research possible.

The cooperation of industrial organizations whose donations and services materially aided this project is gratefully acknowledged: The Phillips Petroleum Company donated gas "A" and made four analyses of the gases studied. Mr. W. W. Bodle of J. F. Pritchard and Company donated gas "B", and the Cities Service Gas Company donated gas "C".

The cooperation and assistance of Mr. T. L. Gore and Mr. A. F. Bertuzzi merit special credit. Mr. Gore worked with the author during the construction of the equipment and the collection of the first experimental data. Mr. Bertuzzi worked with the author during the collection and study of the remainder of the experimental results.

The cooperation of others who assisted materially is gratefully acknowledged: Mr. E. E. Williams constructed much of the experimental equipment used. Mr. W. Logan constructed the glass equilibrium cells. Messrs. D. L. Kloepper, R. Sanders, and T. T. Szabo assisted in the determination of the properties of gas "B". Messrs. A. L. Benham and B. T. Papahronis assisted in calculations and in the preparation of charts.

The author also wishes to acknowledge the many constructive comments and criticisms offered by members of the Faculty and Staff of the Chemical Engineering Department of the University of Kansas.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

FIGURES Page

LIST OF TABLES

LIST OF EXHIBITS

TABLE OF NOMENCLATURE

A_{ij}	Defined by equation (1)
$\bar{B}$	Molal average normal boiling point, °R
m_1	Weight fraction of component 1
M	Molal average molecular weight
M*	A correlating variable used instead of the molecular weight for gases containing nitrogen
P_c	True critical pressure, lb./sq. in. abs.
P'_c	Molal average critical pressure, lb./sq. in. abs.
P'_r	Pseudo-reduced pressure, ratio of pressure to molal average critical pressure, dimensionless.
T_c	True critical temperature, °R
T'_c	Molal average critical temperature, °R
T'_r	Pseudo-reduced temperature, ratio of temperature to molal average critical temperature, dimensionless.
X_1	Mole fraction of component 1
W_m	Weight average equivalent molecular weight. The equivalent molecular weight of a non-paraffin is determined by its normal boiling point from the boiling point-molecular weight curve for normal paraffins. An exception is nitrogen which has been assigned an equivalent molecular weight of 16.

SUMMARY

1. Experimental apparatus and procedures have been developed for the determination of the volumetric and phase behavior of very volatile mixtures at low temperatures and high pressures.

2. The apparatus and procedures have been tested and used at temperatures as low as -200°F and pressures as high as 1306 lb./sq. in. abs.

3. The volumetric behavior, phase boundary curves, and critical pressures, temperatures, and densities of ten hydrocarbon mixtures containing up to 24.4 mole percent nitrogen have been determined. The compositions and critical properties of these gases are tabulated in Table I.

4. Existing correlations for estimating the critical temperatures and pressures of hydrocarbon mixtures have been modified and extended so as to apply to the mixtures of this study.

5. A new correlation for estimating critical temperatures of mixtures has been developed. This method has been shown to apply to mixtures containing nitrogen and hydrocarbons from methane through the heptanes as well as small amounts of components heavier than the heptanes. The method predicts the critical temperatures of binary mixtures and reduces to the critical temperature of a single component as the fraction of that component present increases.

Table I PROPERTIES OF GASES STUDIED

Gas	"A"	"A700/770"	"A700/840"	"A700/940"
Carbon Dioxide, Mole %	1.20	1.09	1.00	0.91
Helium	----	----	----	----
Nitrogen	----	8.84	16.11	24.41
Methane	90.89	82.86	76.25	68.70
Ethane	4.40	4.01	3.69	3.33
Propane	1.91	1.74	1.60	1.44
i-Butane	0.33	0.30	0.28	0.30
n-Butane	0.60	0.55	0.51	0.40
i-Pentane	0.21	0.19	0.18	0.16
n-Pentane	0.13	0.12	0.11	0.10
Hexanes	0.15	0.14	0.12	0.11
Heptanes	0.18	0.16	0.15	0.14
Crit. Pressure lb./sq.in.abs.	925	955	968	973
Crit. Temp., °R	381	368	356	340
Crit. Density, g./ml.	0.230	0.242	0.279	0.311
Mol. Av. Crit. Pressure	676	659	646	631
Mol. Av. Crit. Temperature	369	356	346	334
Wt. Av. Crit. Temperature	409	386	368	349
Mol. Av. Mol. Wt.	18.40	19.25	19.94	20.75
Wt. Av. Equiv. Mol. Wt. (W_m)	22.26	21.47	20.80	20.22
Mol. Av. B.P. ($\overline{B}$), °R	218	211	205	199

Table I. CONT. PROPERTIES OF GASES STUDIED

Gas	"AB"	"AB700/800"	"AB700/940"
Carbon Dioxide, Mole %	0.44	0.30	0.20
Helium	----	----	----
Nitrogen	----	11.30	24.00
Methane	96.68	85.80	73.64
Ethane	1.60	1.50	1.20
Propane	0.70	0.60	0.53
i-Butane	0.14	0.12	0.10
n-Butane	0.20	0.18	0.15
i-Pentane	0.07	0.06	0.05
n-Pentane	0.05	0.04	0.04
Hexanes	0.05	0.04	0.04
Heptanes	0.07	0.06	0.05
Crit. Pressure lb./sq.in.abs.	765	790	815
Crit. Temp, °R	359	343	329
Crit. Density, g./ml.	0.183	0.220	0.225
Mol. Av. Crit. Pressure	674	653	630
Mol. Av. Crit. Temperature	353	339	322
Wt. Av. Crit. Temperature	370	344.1	320
Mol. Av. Mol. Wt.	16.90	18.11	19.56
Wt. Av. Equiv. Mol. Wt. (W_m)	18.54	18.00	17.62
Mol. Av. B.P. (B), °R	207	199	191

Table I. CONT. PROPERTIES OF GASES STUDIED

Gas	"B"	"C"	"D"
Carbon Dioxide, Mole %	0.13	0.20	0.25
Helium	1.00	0.60	0.31
Nitrogen	11.46	13.50	7.05
Methane	76.65	75.15	85.42
Ethane	5.51	6.10	4.11
Propane	3.35	3.27	1.98
i-Butane	0.35	0.38	0.37
n-Butane	0.90	0.60	0.39
i-Pentane	0.17	----	----
n-Pentane	0.15	----	----
Pentanes +	----	0.20	0.22
Hexanes +	0.33	----	----
Crit. Pressure, lb./sq.in.abs.	1143	1107	918
Crit. Temp., °R	376	370	364
Crit. Density, g./ml.	0.266	0.270	0.270
Mol. Av. Crit. Pressure	644	644	658
Mol. Av. Crit. Temperature	358	354	354
Wt. Av. Crit. Temperature	397	380	379
Mol. Av. Mol. Wt.	20.02	19.98	18.60
Wt. Av. Equiv. Mol. Wt. (W_m)	22.85	21.25	20.19
Mol. Av. B.P. (B)	213	210	209

INTRODUCTION

Distillation is the most common method of separating hydrocarbon mixtures. Extensive research on the vapor-liquid equilibrium data necessary for the proper design of distillation equipment has resulted in such general correlations as the M. W. Kellogg Equilibrium Constants (31). However, as is discussed in the following section, much work remains to be done to establish the vapor-liquid equilibria at low temperatures.

Knowledge of the critical temperature and pressure of a mixture is important since the critical temperature is the highest at which the mixture can be completely condensed, and the critical pressure is the pressure at which this condensation will take place. The "convergence-pressure" method which utilizes the fact that the compositions of vapor and liquid approach each other as the critical conditions of the mixture are approached has been proposed (25, 82) to correct for the effect of pressure upon vapor-liquid equilibria. The application of this method requires knowledge of the critical conditions of mixtures. Correlations are available (12, 37, 73) for the prediction of critical pressures and temperatures of various types of hydrocarbon systems, but the validity of these has not been tested for very volatile mixtures and for systems containing nitrogen.

Knowledge of critical temperatures and pressures is of particular importance in low-temperature processes because of the necessity of refrigeration and high pressures for the condensation of vapors.

Various correlations such as that of Standing and Katz (74) have been presented for the estimation of densities of hydrocarbon mixtures, but again, these have not been shown to apply to very volatile systems at low temperatures.

The removal of nitrogen from natural gases by low-temperature distillation has recently been proposed (11,44) as a means of improving the quality of some nitrogen-rich natural gases and of increasing the capacity of existing pipelines. This treatment is especially attractive to Kansas producers, because the gas from the Hugoton Field, the largest in the state and one of the largest in the country, contains an unusually large amount of nitrogen, averaging about sixteen percent. The safe design of plants for this treatment will require knowledge of the behavior of natural gases at low temperatures.

In view of the interest in low-temperature processes and the scarcity of the data required for their design it is apparent that experimental study of the phase and pressure volume-temperature behavior of hydrocarbon systems at low temperatures is needed. Such a study has been made possible by grants to the University of Kansas from the Kansas Industrial Fellowship Fund. Gore (19) has described the construction and testing of the apparatus used in this study. This thesis describes the apparatus and experimental procedures. Phase and pressure-volume-temperature data for ten very volatile mixtures (including the one described by Gore) are presented. Correlations for estimating the critical pressures and temperatures of such mixtures are described.

PREVIOUS EXPERIMENTAL WORK

The existing low-temperature vapor-liquid equilibrium data for hydrocarbon systems and for mixtures of hydrocarbons with helium and nitrogen are summarized in Table II. Most of these data are for simple systems, and the data of Stutzman and Brown (~~77~~ 76) at 100 lb./sq. in. are the only data on a natural gas. Brown and Stutzman (8) developed a correlation for the equilibrium constants of nitrogen, methane, and ethane down to -300°F. However, the correlation was developed from data on widely varying types of mixtures and has no parameter to allow for the composition of the system. Large differences between experimental values and those predicted from the correlation indicate that it leaves much to be desired.

The existing critical data for systems containing hydrocarbons are given in Table III. Most of these data are for binary systems at temperatures above the ice-point. The only data for complex systems at low temperatures are those of Eilerts _et_ _al_. Further, only Ruhemann's data for methane-ethane give information about the critical locus of binary systems containing large amounts of methane.

Table II EXISTING PHASE DATA ON HYDROCARBON-NITROGEN-HELIUM SYSTEMS AT LOW TEMPERATURES

System	Temperature, °R		Pressure, lb./sq.in.abs.		
	Min.	Max	Min.	Max.	Reference
He-N_2	140.4	196.2	16	4340	17
	122.5	201.5	4.79	3675	33
	126	198	58.8	220.5	15
He-CH_4	162	191	-----	2350	13
	162	229	2645	3380	14
N_2-CH_4	152.3	193.7	14.7	14.7	41
	162.0	239.4	14.7	147	77
CH_4-C_2H_4	228.5	455.6	9.0	640	80
	304	492	7.3	588	32
	304	492	73.5	735	21
CH_4-C_2H_6	320.5	336.4	441	588	38
CH_4-C_2H_4-C_2H_6	304.5	491.7	73.5	735	22
C_2H_4-C_3H_8	438.0	582.0	25	794	2
Natural Gas	221.7	330.2	100	100	76
Gas-Condensate	395	736	14.4	5000	13

Table III EXISTING CRITICAL DATA FOR SYSTEMS CONTAINING HYDROCARBONS

System	Temperature, °R		Pressure, lb./sq.in.abs.		Reference
	Min.	Max.	Min.	Max.	
$CH_4-C_2H_6$	351	492	550	1205	21,60
$CH_4-C_3H_8$	528	656	622	1456	56,65
$CH_4-nC_4H_{10}$	520	726	550	1924	46,62,63
$CH_4-iC_4H_{10}$	560	680	1035	1679	50
$CH_4-nC_5H_{12}$	566	792	490	2445	68
$CH_4-nC_{10}H_{22}$	560	920	313	5310	55,66
$CH_4-C_2H_4-C_2H_6$	304	492	673	735	22
$CH_4-C_5H_{12}-N_2$	537	645	2380	2570	5
$CH_4-C_6H_{14}-N_2$	537	645	2950	3140	4
$CH_4-C_7H_{16}-N_2$	537	645	3560	3730	6
$C_2H_4-C_2H_6$	510	550	712	745	35
$C_2H_4-C_7H_{16}$	509	973	428	1516	30
$C_2H_4-C_2H_6-C_2H_2$	500	520	464	822	39
$C_2H_6-C_2H_2$	505	535	500	826	35
$C_2H_6-CO_2$	508	534	672	977	35
$C_2H_6-C_4H_{10}$	550	766	551	1924	28
$C_2H_6-C_7H_{16}$	550	973	396	1263	27
$C_2H_6-N_2O$	497	550	403	1058	34
$C_3H_6-C_2H_2$	564	656	667	925	40
C_3H_6-HCl	632	699	---	1690	24
$C_3H_6-iC_4H_{10}$	724	724	600	600	47
$C_3H_8-C_2H_2$	564	666	617	935	40
$C_3H_8-CO_2$	548	666	617	1073	54,57
$C_3H_8-iC_4H_8$	742	742	600	600	70
$C_3H_8-nC_4H_{10}$	666	765	551	638	47
$C_3H_8-nC_5H_{12}$	530	680	622	671	59
$C_3H_8-iC_5H_{12}$	666	830	483	663	79
$nC_4H_{10}-CO_2$	548	766	551	1181	48,54

Tablo III Continued

System	Temperature, °R		Pressure, lb./sq.in.abs.		Referenc
	min.	max.	min.	max.	
nC_4H_{10}-nC_7H_{16}	766	973	396	596	29
nC_5H_{12}-CO_2	548	847	485	1441	54
nC_5H_{12}-nC_7H_{16}	846	972	397	492	9
nC_6H_{14}-Water	680	695	460	754	71
Naphtha	1063	1063	540	540	3
Gasoline	1743	1143	598	598	3
Naphtha-H_2	589	884	432	1198	26
Natural Hydrocarbon	652	652	3470	3470	81
12 Volatile Hydrocarbons	514	649	1706	2900	36,37
2 Volatile Hydrocarbons	555	559	1987	1994	23
50 Refinery Mixtures	1010	1260	325	680	54

APPARATUS

A flow diagram of the apparatus used in this study is given in Fig. 1 and photographs are shown in Figures 2 and 3. Referring to Fig. 2 the low-temperature bath is mounted in a triangular frame at the left behind a steel plate with a safety slit. The gas reservoir is contained in the box in the center behind the control panel. The oil pump and the mercury reservoir are located at the lower right of the control panel. The liquid-nitrogen container and its accessories are shown in Fig. 3 at the left of the low temperature bath.

Low-Temperature Bath

Fig. 4 is a photograph of the low-temperature bath with the steel safety plate removed and with the Dewar flask which contains the bath liquid lowered from its normal position in order to make the other portions of the bath visible. Fig. 5, a horizontal cross-section through the bath, shows the relative positions of the various items which are suspended in the bath.

The cylindrical glass Dewar flask, 5-1/2 inches O.D. by 4-1/4 inches I.D. and 15-3/4 inches deep is wrapped with adhesive tape to prevent flying glass in case of rupture of the equilibrium cell. Unsilvered strips on opposite sides of the flask allow visual inspection of the interior of the

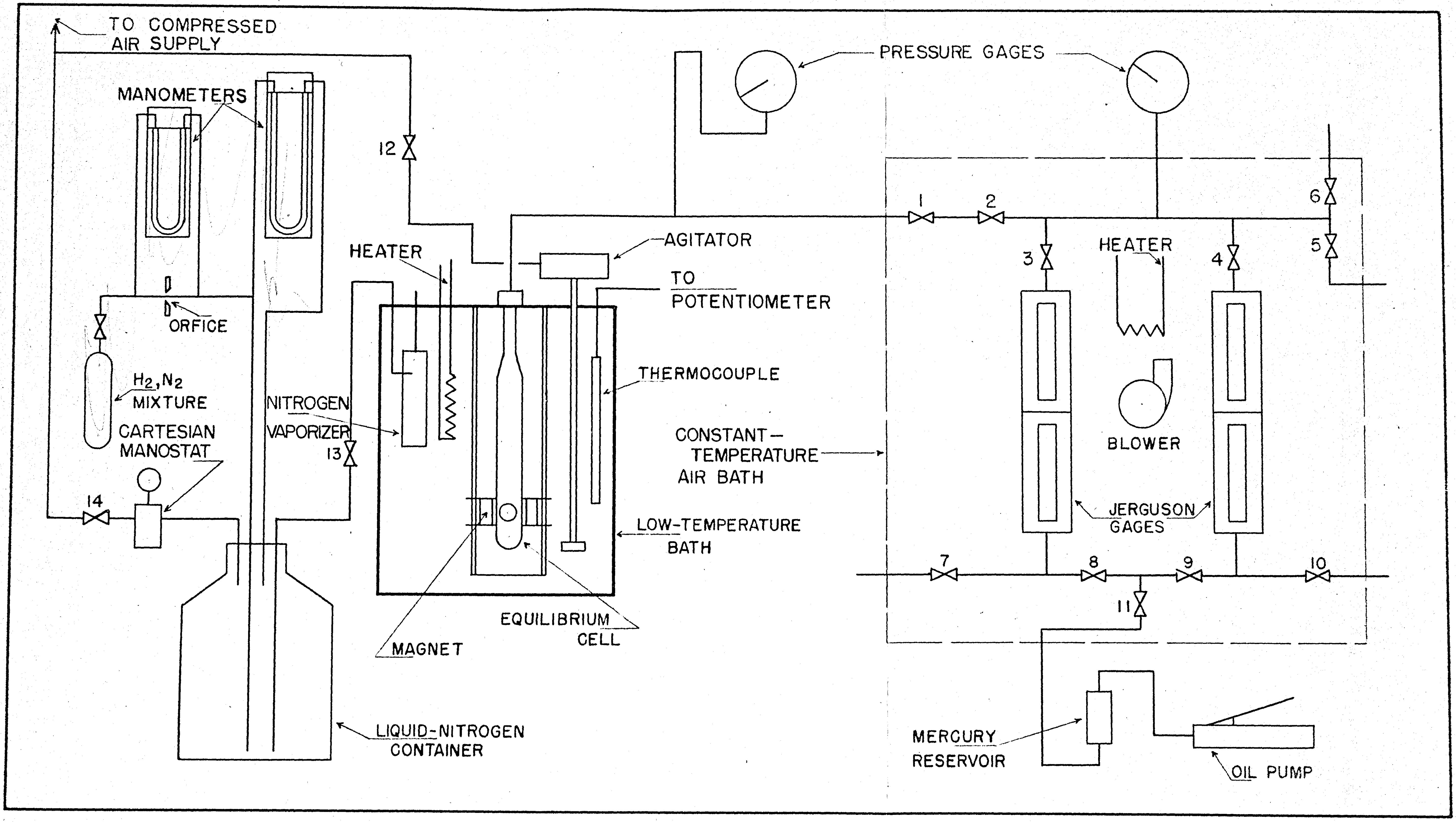


FIG. 1 FLOW DIAGRAM OF APPARATUS

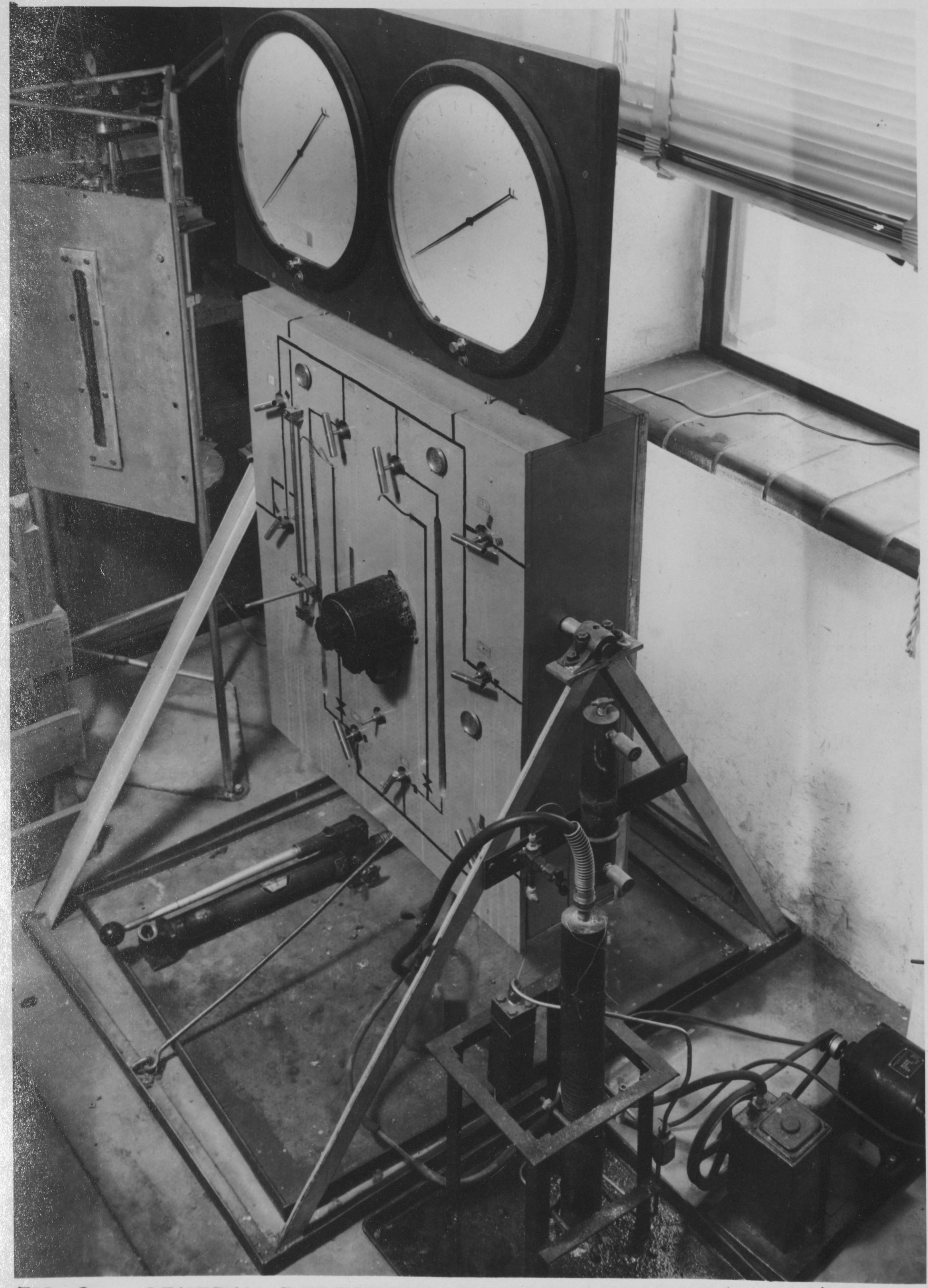


FIG. 2 GENERAL PHOTOGRAPH OF APPARATUS (RIGHT)

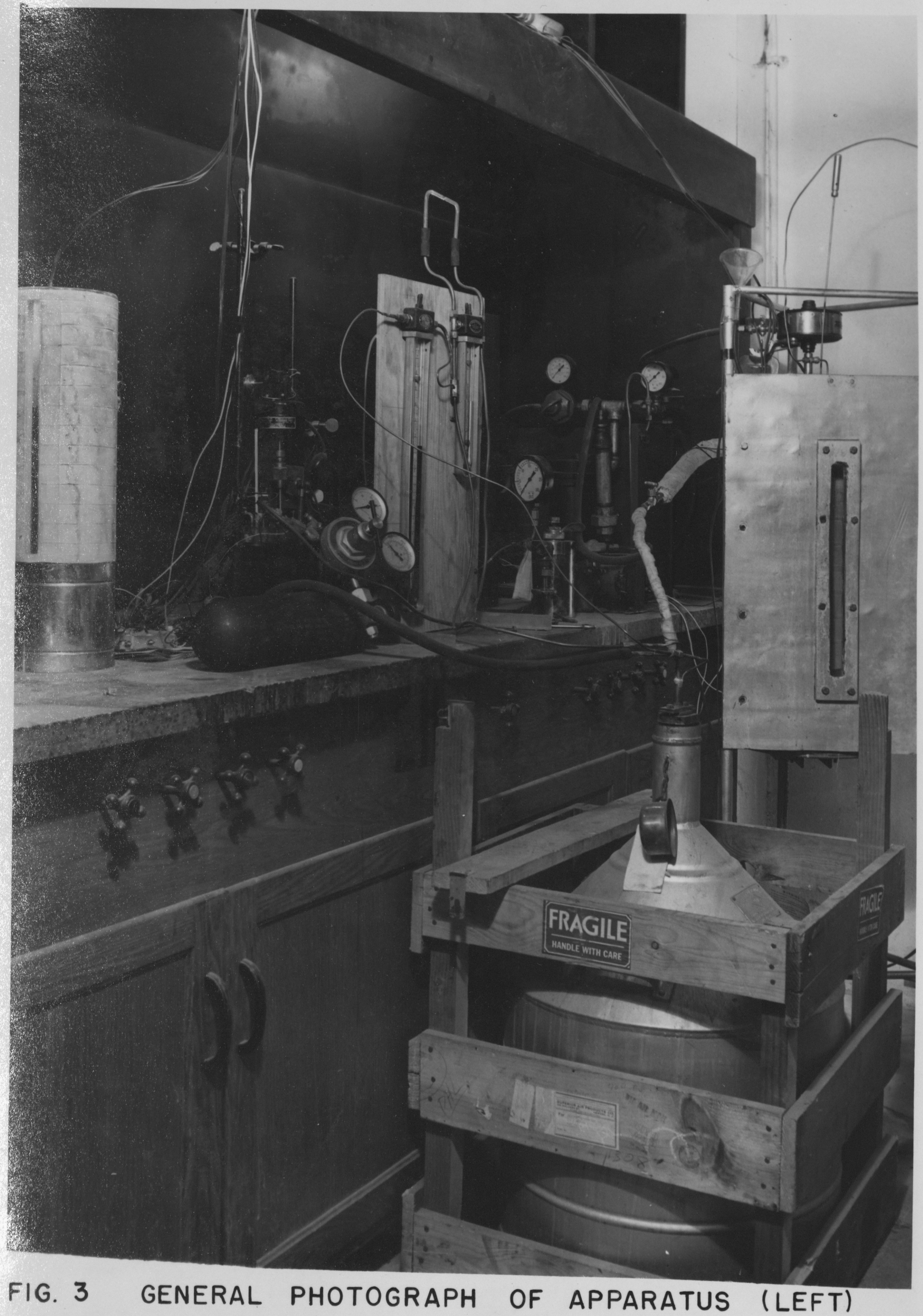


FIG. 3 GENERAL PHOTOGRAPH OF APPARATUS (LEFT)

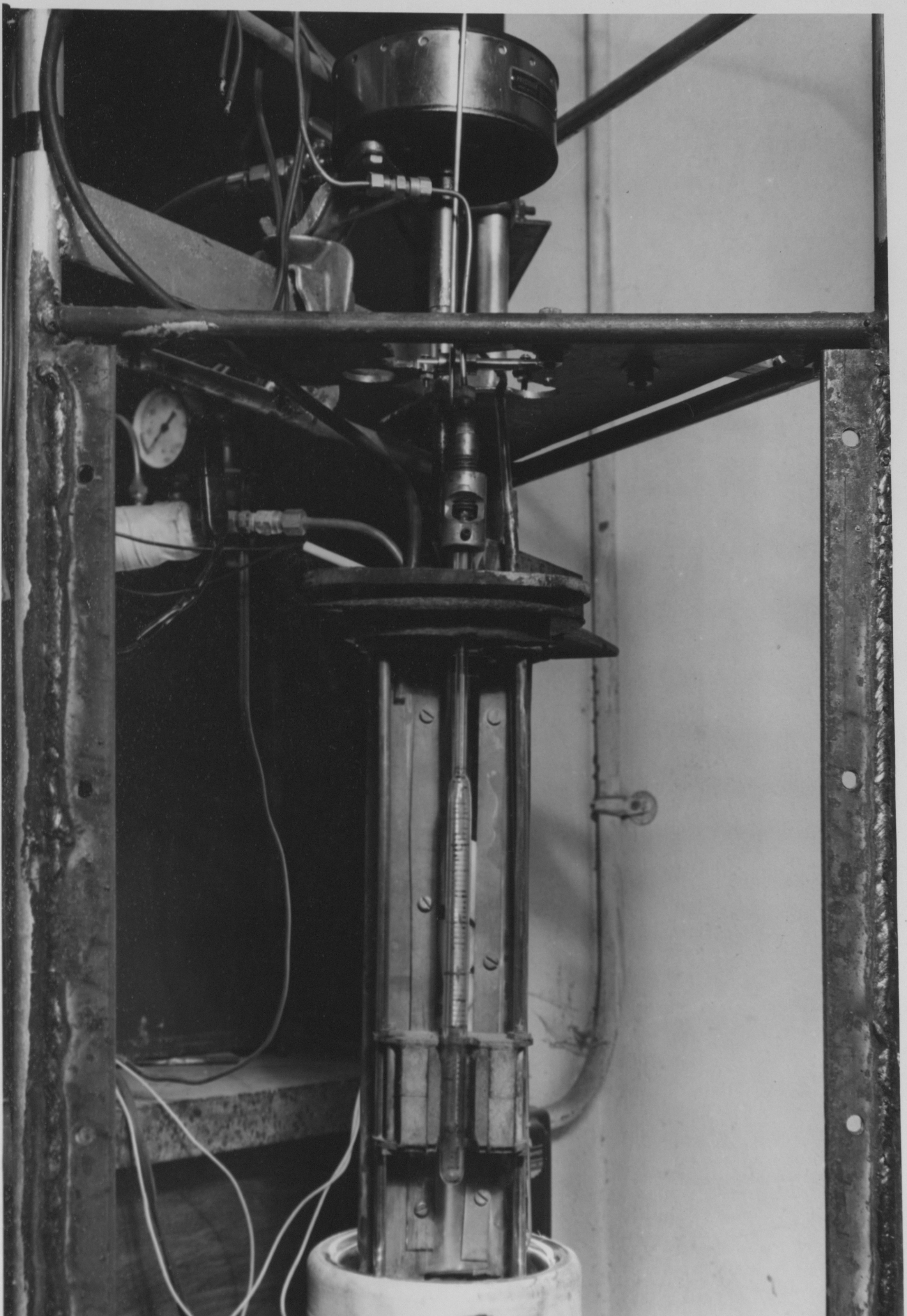


FIG. 4 PHOTOGRAPH OF LOW-TEMPERATURE BATH

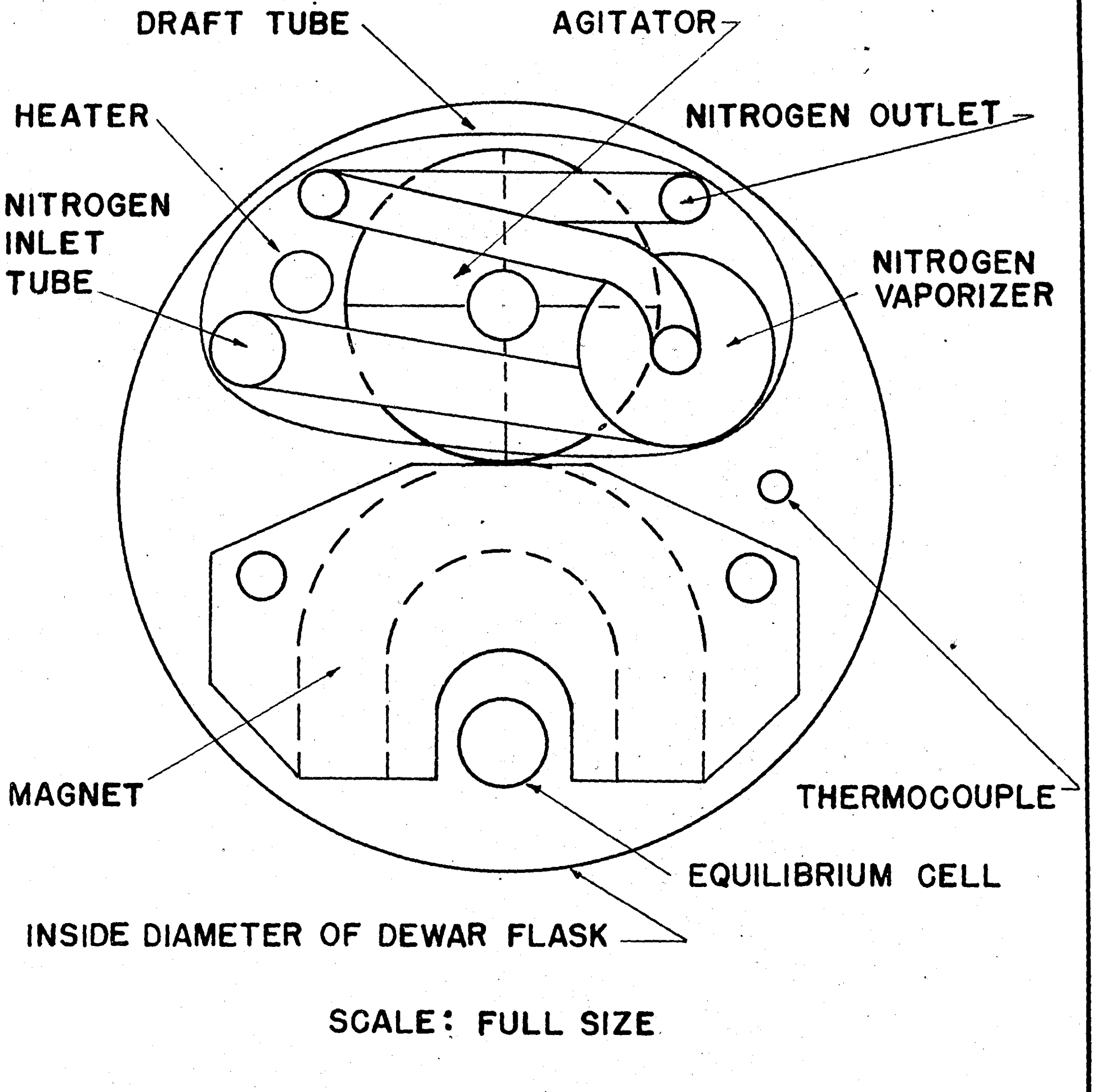


FIG. 5 HORIZONTAL CROSS-SECTION OF LOW-TEMPERATURE BATH

bath when the flask is in its normal position. The bath is illuminated by a fluorescent tube mounted behind the rear slit. A wooden cover anchored to the frame closes the bath when the flask is raised to its normal position.

The equilibrium cell is anchored near the front of the bath by a vise which clamps the 1/8 inch O.D. by 0.025 inch I.D. steel tubing connecting the cell to the gas reservoir. A horseshoe magnet suspended from the bath cover by two vertical rods may be moved along the length of the cell by a 1/8 inch bronze rod, in order to move a steel ball which agitates the contents of the equilibrium cell.

The nitrogen vaporizer is a copper cylinder 1 inch in diameter and 4 inches high. A copper inlet tube leading from the nitrogen container enters the cylinder tangentially near the top, and a vapor outlet tube leads from the top of the cylinder, down one side of the bath, up the other side and exhausts at the top of the bath. This separator arrangement prevents liquid nitrogen from passing through the bath without vaporizing, as occurred when a simple coil vaporizer was used.

The heater consists of two ten-foot coils of 30 gage constantan wire wrapped around ceramic insulators, connected in parallel and enclosed in a Plexiglas tube. The power input to the heater is controlled by a 0-130 volt variable transformer which controls the primary voltage of a 25 volt output transformer.

Agitation of the liquid bath is accomplished by an air-operated Precision Aero-Mix Stirrer, senior model. Circulatic of the bath liquid is encouraged by a draft tube mounted coaxially with the agitator. The draft tube is made of thin copper sheet with windows of transparent acetate plastic along the lengths of its front and rear surfaces to permit illumination of the cell from the rear.

The liquid-nitrogen is contained in 25 and 50 liter metal Dewar flasks manufactured by the Superior Air Products Company. The liquid nitrogen is caused to flow out of the flask, through an eductor tube by means of gas pressure exerted over the liquid. The pressure is brought to the desired level by admitting compressed air to the flask, and is controlled at that level by a Cartesian Manostat which allows gas to escape from the flask as nitrogen evaporates as a result of the heat leak into the Dewar flask. The amount of liquid in the flask is determined by slowly bubbling a nitrogen-helium mixture into the bottom of the liquid through a 1/8 inch O.D. copper tube. The differential pressure required to produce this flow is measured with a carbon tetrachloride manometer, and the flow is indicated by a glass capillary flow meter and a mercury manometer.

Equilibrium Cells

Cross-sections of the various equilibrium cells used are shown in Figures 6, 7, and 8. Photographs of these cells are shown in Fig. 9. All of these cells were made of High Pressure Pyrex gage-glass tubing of 3/8 inch or 1/2 inch O. D. Agitation is effected by moving the steel ball in the cell with a horseshoe Alnico magnet. The neck of cell G, which was used in studying the first gas, was constructed of 2-1/2 mm.I.D. by 10 mm O.D. tubing, and the volume of the neck was reduced with a steel insert. All later cells had necks made of 6 mm.O.D. by 1/2 mm. I.D. tubing. Connection was made to the 1/8 inch O.D. tubing by means of a fitting developed during this work and previously reported (10).

The 1/2 inch O.D. by 0.314 inch I.D. cells burst within thirty minutes when exposed to a pressure of 1500 lbs./sq. in. gage but would withstand a pressure of 1300 lbs./sq. in. at least as long as 24 hours. Cell No. 25 was used over a period of four months at temperatures as low as -200°F and pressures as high as 1296 lb./sq. in. gage without failure, however, cell G burst at 800 lb./sq. in. after being tested to 1250 lb./sq. in. and used successfully at pressures as high as 1000 lb./sq. in. Such behavior made it impossible to assign reasonable factors of safety to the glass cells, and made it necessary to heavily armor the low temperature bath. Some attempt was made to use cells having greater wall thicknesses with little or no success. Small bore tubing was found to be able to resist considerably higher pressures; test cells made of 2-1/2 mm. I.D. by 10

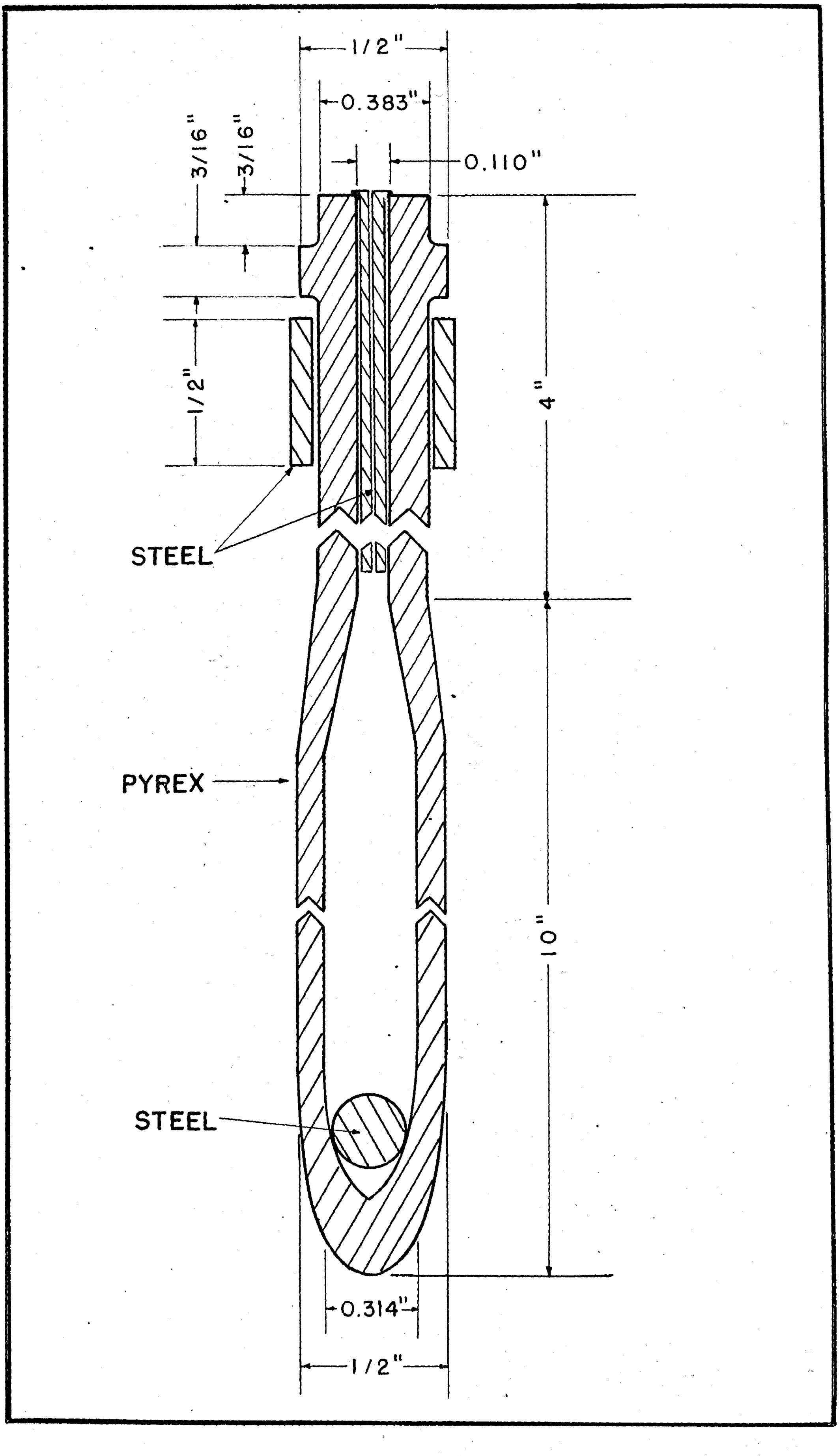


FIG. 6 CROSS SECTION OF EQUILIBRIUM CELL "G"

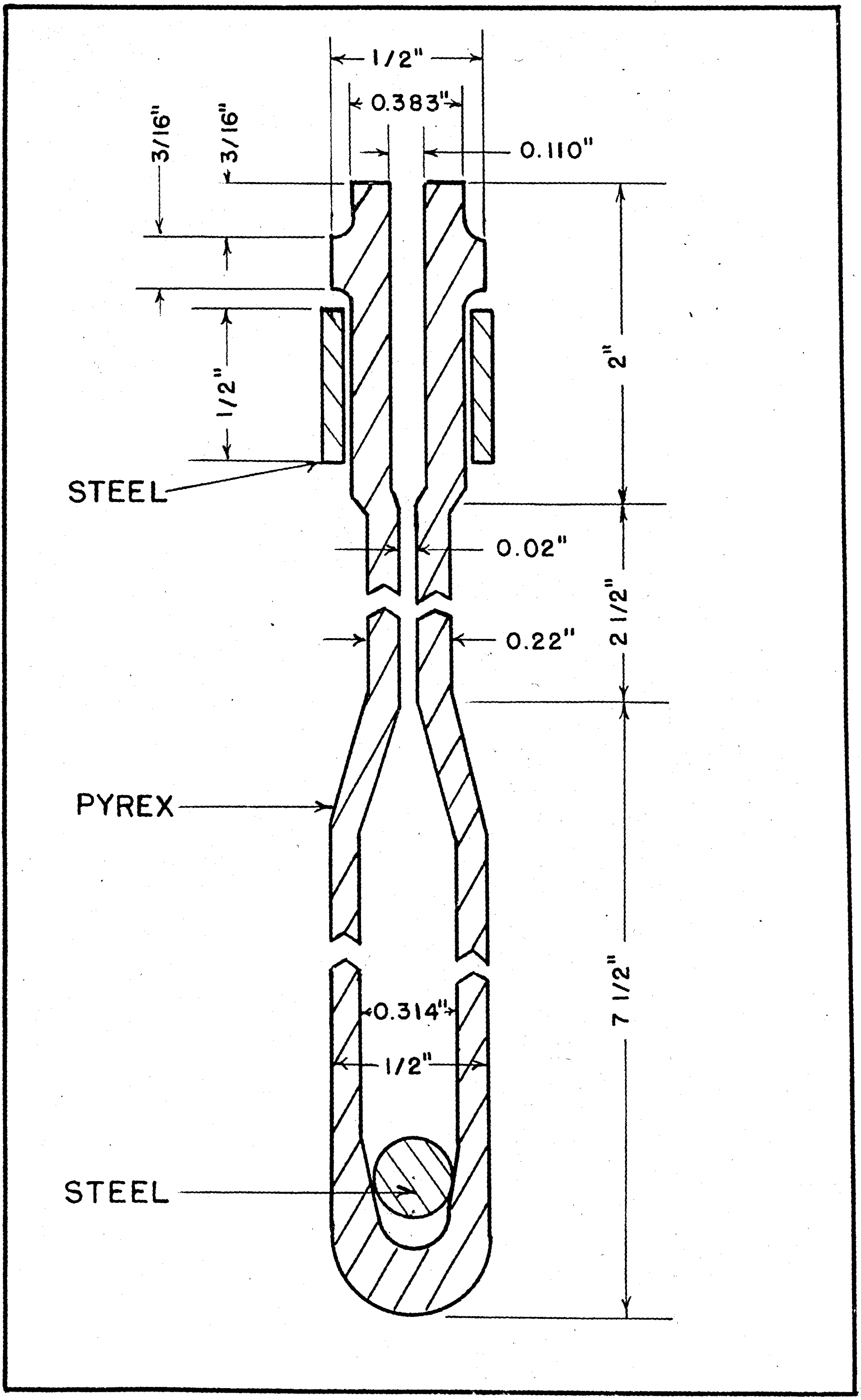


FIG. 7 CROSS-SECTION OF CELL NO. 25

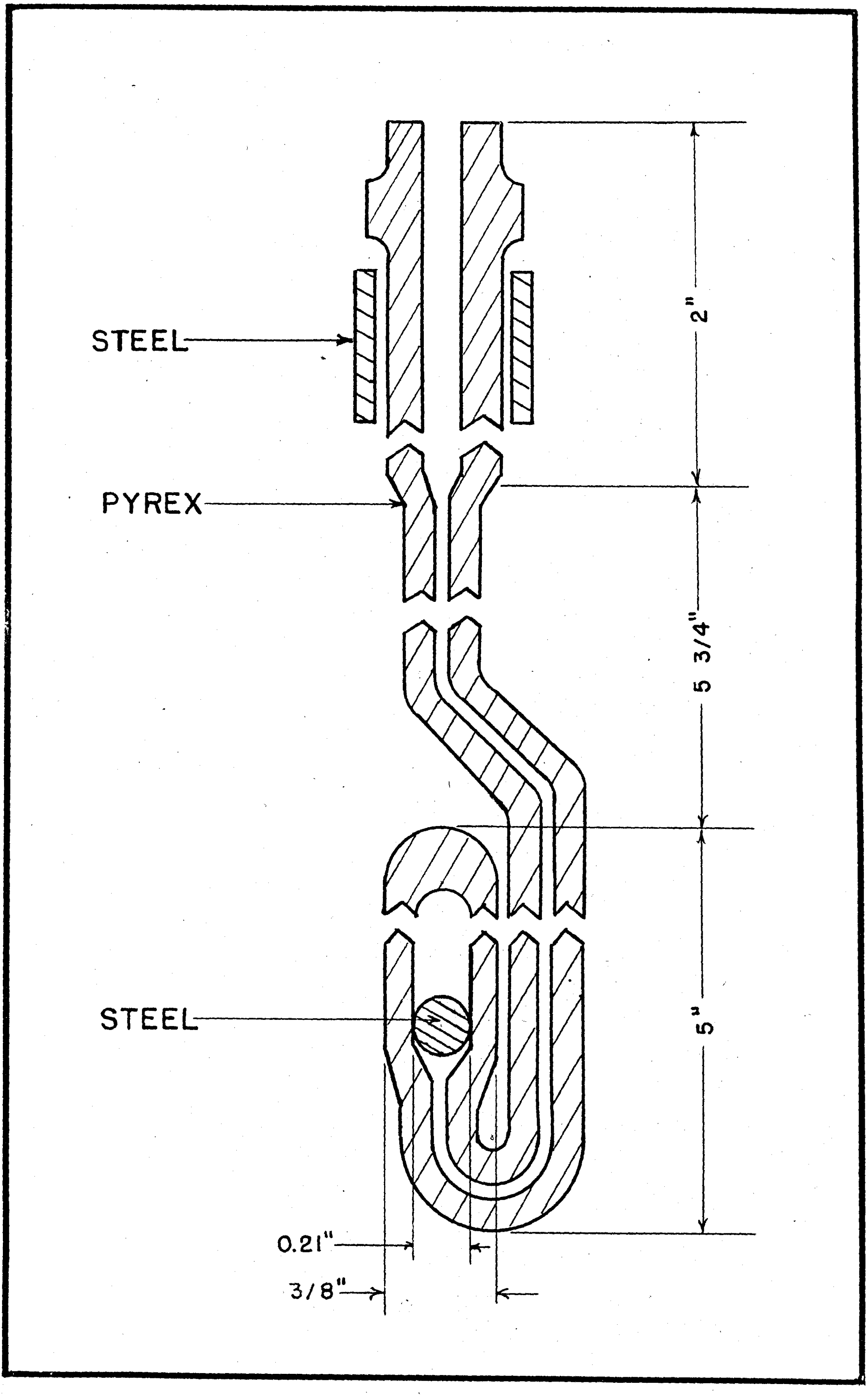


FIG. 8 CROSS-SECTION OF CELL NO. 51

Fig 9

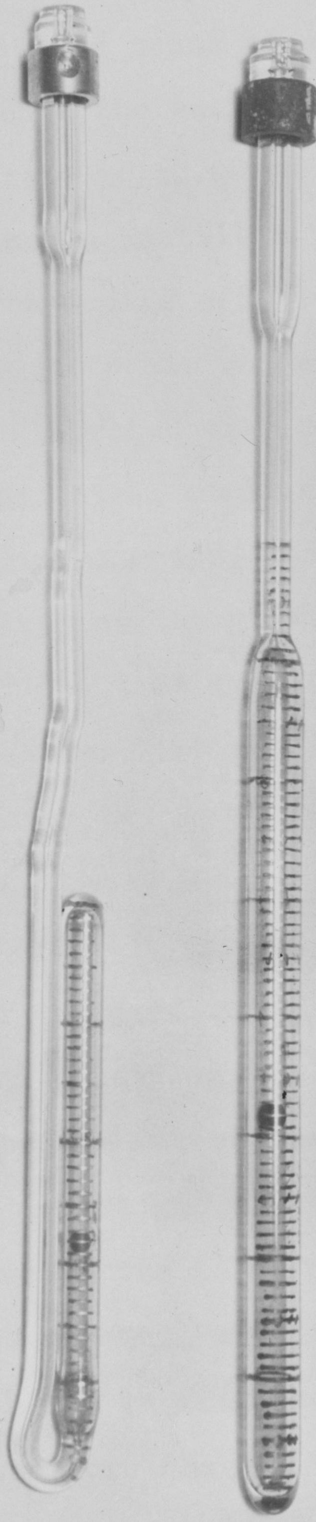


FIG. 9 PHOTOGRAPH OF EQUILIBRIUM CELLS

mm. O. D. tubing burst at 3100-3300 lb./sq. in.

The cells were calibrated by adding water from a calibrated 10 ml. burette by means of a capillary tube small enough to pass through the neck of the cell. These calibrations were accurate to ±0.02 ml; calibrations for all cells used are shown in Exhibit A. The amounts of liquid were determined from scales affixed to the cells. In the case of cell G a paper scale was attached to the cell, but later cells were calibrated with a platinum ink (Liquid Platinum Bright No. 05-X, obtained from the Hanovia Chemical and Manufacturing Company, Newark, New Jersey) which was permanently fired on the glass.

The volume of the line from the neck of the cell to valve 1 was made as small as possible in order to minimize errors in calculation of amount of gas metered to the cell. This volume amounted to 3.7 to 4.0 ml., however, which was too large to neglect. It was determined by filling the cell with mercury into the neck, then metering methane from the Jerguson gages and observing the increase of pressure. The details of this method and the data obtained are given in Exhibit B. This method was precise to ±0.1 ml. and the increase of volume of the lines due to expansion of the Bourdon tube with pressure was less than 0.1 ml. Failure to observe any change in the mercury level in the 1/2 mm. I.D. neck with pressure changes of 1000 lb./sq. in. assured that the expansion of the cell due to pressure was less than 0.02 ml.

The change of volume of the cell with temperature was not experimentally determined. The Corning Glass Works recommended a value of 0.00037 for the fractional decrease in length of this glass (No. 7740) on cooling from 25°C to -100°C. This represents a fractional decrease in volume of 0.0011 and was neglected in all calculations.

Gas Reservoir

The gas reservoir consists of two identical liquid-level gages which serve as high pressure burettes. Manifolds and valves connect these gages to the rest of the apparatus, and an air bath serves to maintain the gages at a constant known temperature.

The liquid-level gages, manufactured by the Jerguson Gage and Valve Company are of the two-section transparent type, Model 25-T-40. They have an internal volume of approximately 75 ml. each, and have been tested to 8000 lb./sq. in. by the manufacturer.

The manifolds were constructed from 1/4 inch O.D. by 3/32 inch I.D. stainless-steel tubing, American Instrument Company catalog No. 406-110A. The stainless-steel union-type high-pressure fittings and series 30,000 lb./sq. in. stainless-steel valves were manufactured by Autoclave Engineers, Inc.

The Jerguson gages and manifolds are enclosed in a box

37 inches high, 32 inches wide, and nine inches deep. The front, sides, top and bottom of the box are insulated by a layer of fiberglass covered by a sheathing of 1/4 inch plywood, and the back of the box is covered by a removable sandwich of two layers of plywood and one layer of fiberglas

Two vertical slits, 3/4 inch wide by 21 inches high cut in the front and back plates permit visual observation of the sight glasses of the Jerguson gages. These slits are covered with 1/4 inch sheets of Plexiglass, and two fluorescent tubes mounted over the rear slits illuminate the interior of the box.

Each of the Jerguson gages is supported by two lengths of angle-iron welded to the top and bottom of the box. All valves are bolted to the front plate, and the stems of the valves extend through holes drilled in the plate.

The box is pivoted on two 7/8 inch steel shafts which bear on a pair of pillow blocks supported by a welded frame of angle-iron. This arrangement allows the box to be rotated to a horizontal position when it is necessary to remove the Jerguson gages. It also permits agitation of the contents of the Jerguson gages, should it be desired to obtain phase equilibrium data at room temperatures and above.

A 1/30 horsepower centrifugal blower mounted between the Jerguson gages circulates a stream of air through the box to maintain a uniform temperature. A 200 watt heater mounted in the discharge stream of this blower and controlled by a Variac serves to regulate the temperature which is indicated by three Weston dial-type thermometers which extend through holes drilled in the front plate. These thermometers agreed to 1°F with a Bureau of Standards thermometer. When the box is allowed several hours to reach a steady state the three thermometers indicate a temperature uniform to within 1°F.

One of the Jerguson gages was calibrated for internal volume by delivering mercury from the gage into a calibrated burette through valve 7, and observing the change in mercury level on a paper scale cemented to the front glass of the gage. Viewing the mercury level through a movable sight tube mounted over the front slit effectively reduced parallax It was necessary to calibrate only one gage since the other gage served only as a reservoir of high pressure gas.

The calibrations of the gage are given in Exhibit C. Check calibrations at pressures from 100 to 2500 lb./sq. in. and over intervals of several months showed that the calibration was essentially linear and did not vary with pressure or with time, although slightly different calibrations resulted when the gages glasses were removed and the gaskets replaced. A calibration constant of 0.891 ml./cm. was used for Gas "A" and 0.888 for all later work. This constant was known to less than 0.002 and readings of the mercury level could be duplicated to ±0.1 cm., so that the uncertainty of the volume measurements is ±0.2 percent or 0.1 ml., whichever is larger.

Pressure Generator

The pressure required to force the gas from the reservoir into the equilibrium cell is developed by a manually-operated hydraulic jack, Blackhawk Model P-76. Oil delivere from the jack displaces mercury from a reservoir into the Jerguson gages, thus compressing the gas contained in the gages. The mercury reservoir consists of a vertical steel cylinder, 3-1/2 inches O.D. by 1-1/16 inches I.D. by 24 inches long, to the top of which is attached the oil inlet line from the jack, and to the bottom of which is attached the mercury delivery line leading to the Jerguson gages. Pressures as high as 5000 lb./sq. in. have been produced with this equipment.

Pressure Measurements

The pressure in the equilibrium cell is measured by a 16-inch dial Bourdon tube gage having a range of 0 to 2000 lb./sq. in. gage and graduated at intervals of 5 lb./sq. in. The pressure in the gas reservoir is measured by a similar gage having a range of 0 to 5000 lb./sq. in. gage and graduated in 10 lb./sq. in. increments. These gages, manufactured by the Heise Bourdon Tube Company, were certified to be accurate to one-half a scale division when new. They were compared with an Ashcroft dead-weight tester at intervals of several months and the results are shown in Exhibit D. It is believed that the uncertainty in pressure measurements is ±3 lb./sq. in. above 800 lb./sq. in. and ±2 lb./sq. in. at lower pressures. No corrections were applied to the readings of the pressure gages, and absolute pressures were computed by adding 14 lb./sq. in. to the gage readings.

In order to reduce the volume between valve 1 and the neck of the equilibrium cell, the 0 to 2000 lb./sq. in. gage was evacuated and filled with mercury. A U-tube as shown in Fig. 1 was made of 1/8 inch O.D. thin-walled steel tubing to prevent the mercury from running into the manifold when the cell was evacuated.

Temperature Measurement

The temperature of the low-temperature bath is measured by a four-junction thermocouple the E.M.F. of which is measured by a Leeds & Northrup Type K-2, No. 7552 potentiometer and a Type R, No. 2500-a galvanometer. The thermocouple consists of four individual couples of No. 24 B & S gage glass-insulated copper-constantan wire connected in series and inserted in a six mm. I.D. thin walled pyrex tube. The position of the thermocouple in the bath is indicated by the cross-section in Fig. 5. The junction of the couple is immersed approximately 12 inches below the surface of the bath liquid and the reference junction is immersed the same depth in a mixture of ice and water contained in a Dewar flask. Tests indicated that with immersions of this magnitude there is no detectable effect of immersion on indicated temperature.

The thermocouple was calibrated by comparison with a Leeds and Northrup platinum resistance thermometer. The details of this comparison are described in Exhibit E. The deviation of this thermocouple from a standard calibration curve (72) is shown by Fig. 10. The precision of the temperature measurements is judged to be ±0.1°F and the accuracy to be ±0.5°F at -200°F and proportionally more accurate as the ice-point is approached. This increase in accuracy as the ice-point is approached is due to the fact that the deviation of this thermocouple from the standard thermocouple must become zero at the ice-point. The calibration of the thermocouple is such that 15 microvolts represents approximately 1°F.

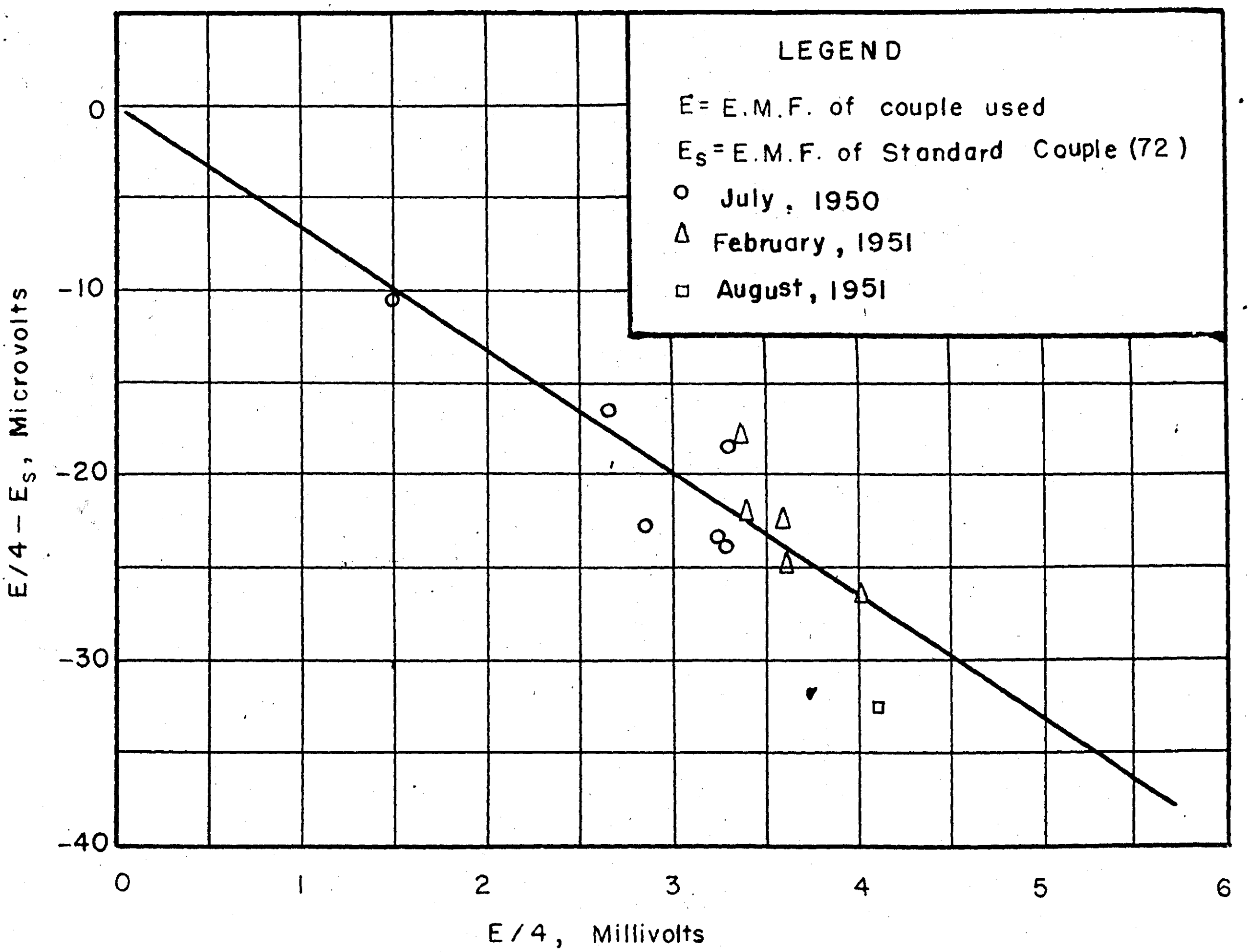


FIG. 10 CALIBRATION CURVE FOR THERMOCOUPLE

EXPERIMENTAL PROCEDURE

General Features of Method

A modification of the dew-point bubble-point method was chosen because of its simplicity and because this method permits accurate determination of the critical point. In the usual method of operation a fluid is confined in a cell, and the volume of the system is changed by the addition or removal of mercury at constant temperature. Since this method cannot be used below the freezing point of mercury a modification was used in which the pressure was varied at constant temperature by injecting fluid into a constant-volume cell.

Procedure for Determination of an Isotherm

Several hours before the isotherm was to be run the heater and blower in the gas reservoir were turned on and the reservoir brought to a constant and uniform temperature somewhat above that of the room, in order to permit the control of temperature by addition of heat. When the reservoir temperature approached the desired level the Dewar flask which encloses the low-temperature bath (Fig. 4) was filled with liquid pentane and raised into position. The cell was evacuated at room temperature to remove traces of heavy hydrocarbons which were found to materially affect the dew-point. The Jerguson gages were then evacuated through valve 5 (Fig.1) and the gas to be studied was admitted through valve 6. The gas was then compressed to the desired pressure by alternately filling the right Jerguson gage with gas and forcing the gas into the left gage by admitting mercury through valve 9. In order to remove the last traces of air the Jerguson gages were flushed from 500 lb./sq. in. to atmospheric pressure several times. Five different mixtures were prepared by mixing nitrogen with other gases in the gages; this procedure is described in the section entitled "Compositions of Mixtures Studied".

The equilibrium cell was filled with gas to 400 lb./sq. in. and flushed to atmospheric pressure six or seven times, then filled to 20 to 25 lb./sq. in. gage, all at room temperature. The cell was then placed in the cold bath with lines attached. The efficiency of this flushing method is shown by the flat character of the isotherms for gases "A" and "AB" at high percentages of liquid.

The temperature was controlled by adjusting the Cartesian Manostat so as to maintain a constant pressure of approximate 7 lb./sq. in. gage in the liquid nitrogen container and regulating the flow of nitrogen with valve 13. Fine adjustments were made by use of the Variac which controls the power input to the electrical heater. The temperature was indicated by a copper-constantan thermocouple and a K-2 potentiometer which would indicate temperature changes of the order of 0.01°F. The control of temperature required the full attention of one man. When no gross heat effects occurred the temperature of the bath could be controlled to

± 0.1°F. The condensation of large amounts of gas produced temperature changes as large as 2°F, but the temperature was always brought to within 0.1°F of the control point before readings were made.

Gas was added to the cell through valves 1 and 2 while maintaining a constant pressure in the manifold by raising the mercury level in the left Jerguson. The mixture was agitated after each addition until the pressure did not change further with time; the pressure in the cell and the new mercury level in the reservoir were then recorded. The pressure at which the first dew appeared on the ball was recorded, this pressure being considerably below that at which measurable liquid formed. When liquid was present the mixture was agitated until neither pressure nor liquid level changed with time; this required from one minute at low pressures to ten minutes in the region of the critical point. Successive increments of gas were added until the bubble-point or the upper dew-point was reached; in some cases additional gas was added to obtain the compressibility in the single-phase region.

It is essential that no fluid be removed from the cell while two phases are present since this would result in a change of composition of the system. When the upper dew-point was reached at temperatures a few degrees above the critical point, the bath was cooled 2 or 3°F, causing a decrease of pressure and returning the system to the two-phase region. More gas was then added at this new temperature level until an upper dew-point was reached above the critical temperature or a bubble-point at temperatures below the critical point. This procedure yielded more detailed information about the critical region without the necessity of determining a large number of complete isotherms. Approximately three hours was required for each complete isotherm.

The percentage of liquid in the cell was calculated by dividing the volume of liquid present by the total volume of the cell, this total volume being obtained by filling the cell with water 1/2 inch into the 1/2 mm. I. D. neck. While the very small diameter of the neck makes it immaterial exactly where this boundary is chosen in the case of small percentages of liquid and for the determination of fluid density, it could conceivably cause significant errors in the location of the bubble-point pressure. For this reason an inverted cell (No. 51, Fig. 8) was used so that the final bubble of vapor could be observed. The results thus obtained agreed with those obtained with the regular cells.

COMPOSITIONS OF GASES STUDIED

Since considerable difficulty was encountered in determining the compositions of the gases studied and since the accuracy of analysis is probably the controlling experimental factor in the correlation of the measurements, it was considered desirable to describe the determination of these compositions in detail. The compositions of the ten gases studied are tabulated in Table I along with some measured properties and correlating variables, which were calculated from the gas compositions and the accepted properties (1) of the pure components. The analyses and calculated compositions are shown in Exhibit H. A detailed discussion of these analyses follows:

Gas "A" was obtained from the Phillips Petroleum Company. Its composition was reported in connection with earlier work (53).

Gases "A700/770, A700/840, and A700/940" were prepared by adding nitrogen to gas "A", which was contained in Jerguson gages at 100°F and 700 lb./sq. in. gage, until the pressure rose to 770, 840, and 940 lb/sq. in. gage, respectively. The gases were then mixed by passing them back and forth between the two Jerguson gages. The relative amount of nitrogen added was computed from the pressure rise using the compressibility factors of Standing and Katz (7, 74). The scatter of the bubble-point data for the various gases showed that this procedure was precise to less than 1% nitrogen. Analyses (Exhibit H) by low-temperature distillation, slow combustion, and mass spectrometer confirmed the mixing and calculation procedure to less than 1% nitrogen. These analysis were consistent with the accepted composition of Gas "A".

Gas "AB" was prepared by adding Gas "A" to Phillips Pure Grade methane at 82°F until the pressure in the methane cylinder rose from 522 to 738 lb./sq. in. gage. No samples were removed from the cylinder for 72 hours. The composition of gas "AB" was calculated as described above, and the calculation was confirmed by a mass spectrometer analysis.

Gases "AB700/800 and AB700/940" were prepared by adding nitrogen to gas "AB" as described above. Gas "AB 700/800" was analyzed by a mass spectrometer and Gas "AB 700/940" by a mass spectrometer and by slow combustion. The analytical results for gas "AB700/800" indicated nitrogen content about 1-1/2% higher than calculated while the results for gas "AB700/940" indicated nitrogen content about 2% lower than calculated. In view of the earlier confirmation of the calculation method, the accepted composition was weighted toward the calculated value, but it must be admitted that the nitrogen (and therefore the methane) content may be 1 - 2% in error. Uncertainty in the sum of nitrogen and methane is 1/2% or less as is true of all of these gases.

Gas "B" was obtained through courtesy of W. W. Bodle of J. F. Pritchard Company from a well in western Kansas. Results of low-temperature distillations, mass spectrometer analyses and slow combustion are shown for this gas in Exhibi H. The results of these analyses are in good agreement except that the nitrogen-methane split obtained by low-temperature distillation is inaccurate, as is generally known

Gas "C" was obtained from a pipeline at Lawrence through courtesy of Cities Service Company. Analyses by low-temperature distillation, mass spectrometer, and slow combustion are shown in Exhibit H.

Gas "D" was prepared by adding gas "AB" to gas "C" at 87°F until the pressure rose from 193 to 585 lb./sq. in. gage. The composition of gas "D" was calculated as before, and a low-temperature distillation was obtained.

The low-temperature distillations were made by Tulsa Testing Laboratories. Analyses by mass spectrometer were made by the Consolidated Engineering Corporation, Pasadena and by courtesy of the Phillips Petroleum Company. Analyses by slow combustion (Orsat method) were made by Quentin Wheatley, a graduate student in chemistry at the University of Kansas.

EXPERIMENTAL RESULTS

Phase Equilibrium Data

The experimental data for all gases investigated are tabulated in Exhibit I. The volume percent liquid is plotted against pressure for each experimental isotherm in Exhibit J. Charts of pressure versus temperature with volume percent liquid as a parameter are given as Figures 11-20. These pressure-temperature charts were prepared from the experiment isotherms of Exhibit J by cross-plotting at constant percent liquid. The critical temperature and pressure were determined as the point at which all constant percent liquid lines converge. These critical conditions are included in Table I where other properties of the gases are summarized.

The pressure-temperature charts of Figures 11-20 represent three interdependent quantities -- temperature, pressure, and volume percent liquid. The precision of the temperature measurements is approximately ±0.1°F, the accuracy ±0.5° at -200°F to ±0.1° at -40°F. Pressure measurements are accurate to ±2 lb./sq. in. The absolute error in percent liquid is ±2 percent at 10-90% liquid and decreases to approximately 1/2 percent at very low and very high amounts of liquid. The absolute errors at the dew-points, determined by the detection of traces of moisture on the steel ball used to agitate the mixture, are considerably

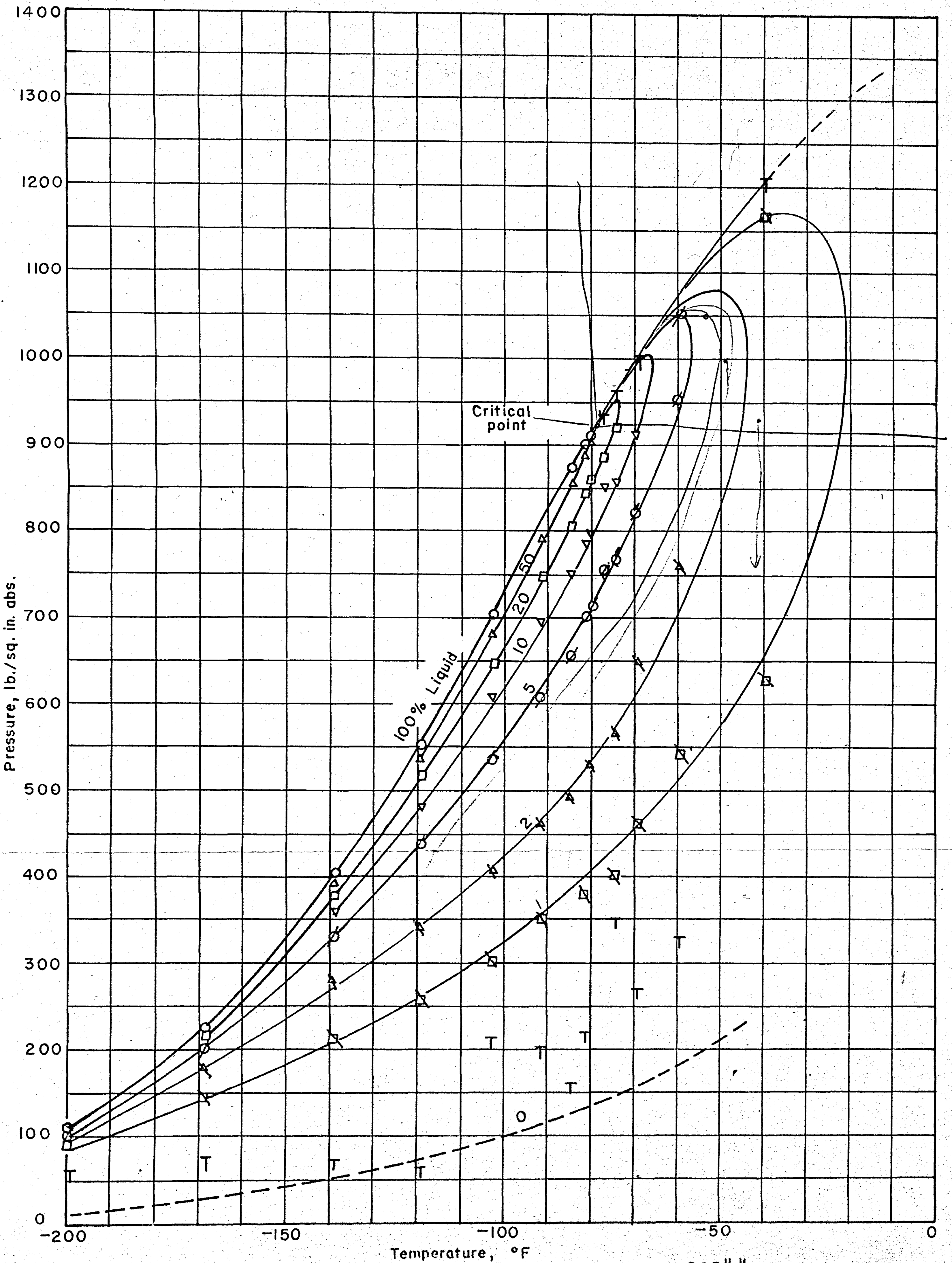


FIG. 11 PRESSURE-TEMPERATURE PHASE DIAGRAM OF GAS "A"

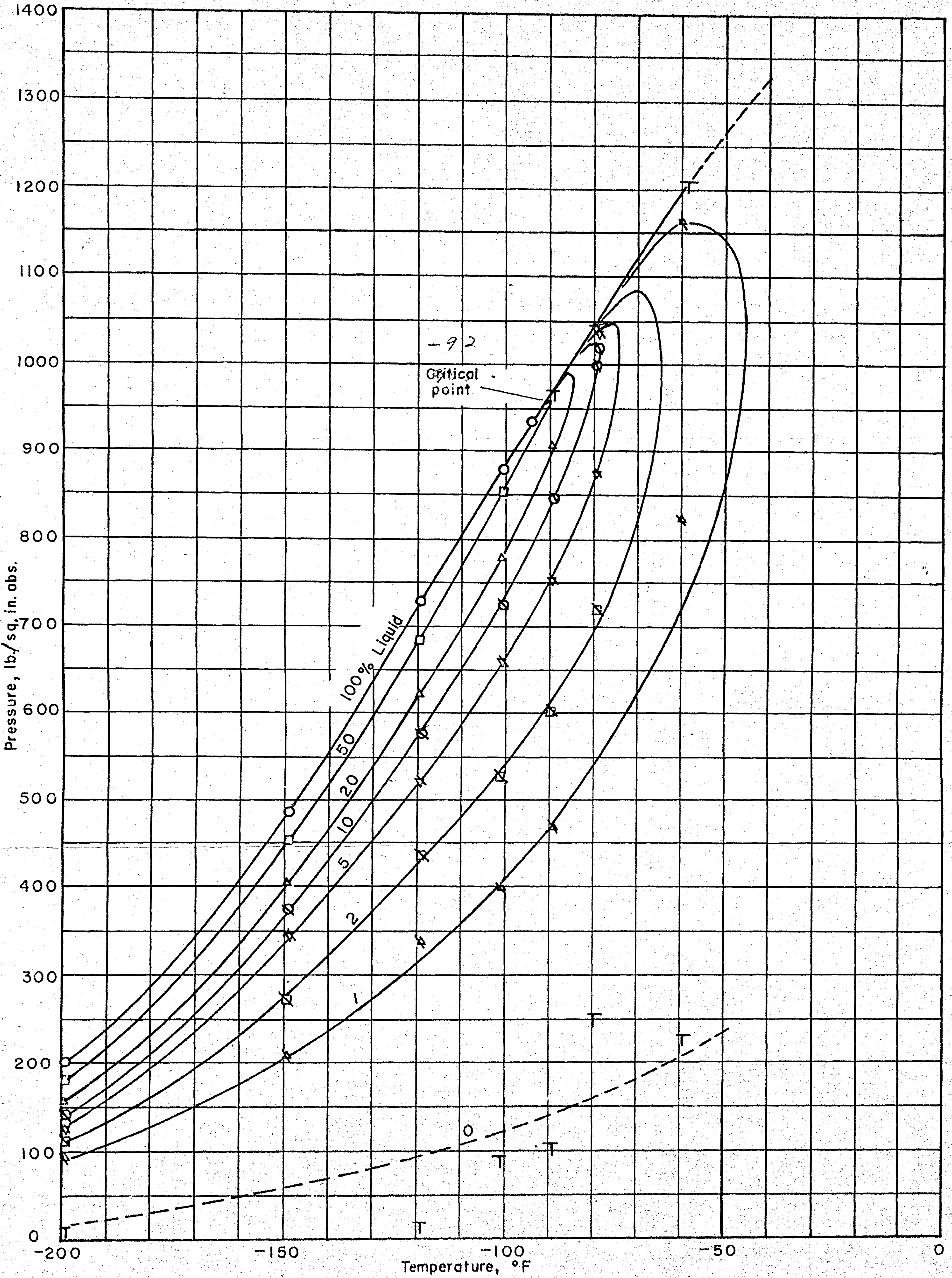


FIG. 12 PRESSURE-TEMPERATURE PHASE DIAGRAM OF GAS "A 700/770"

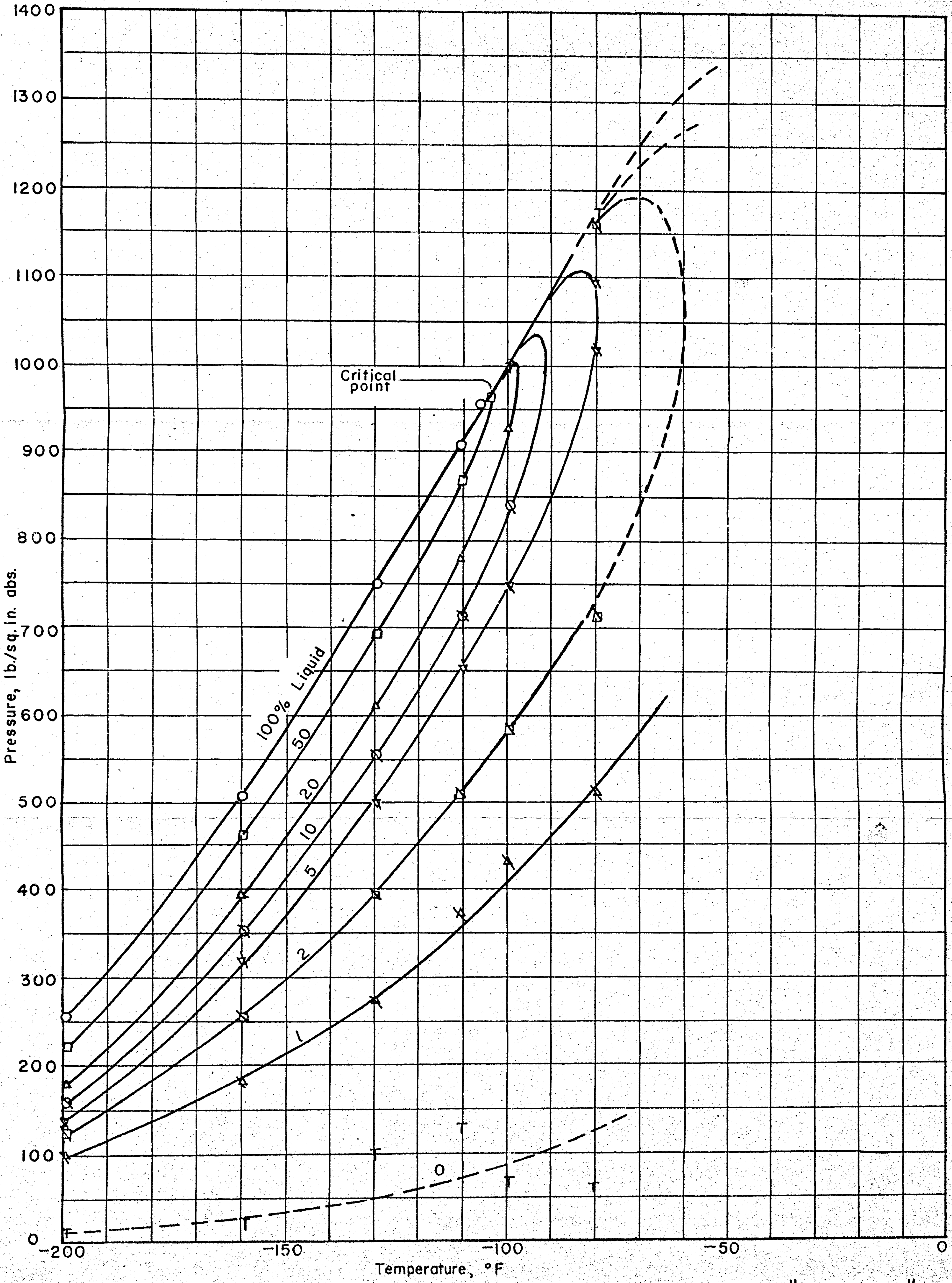


FIG. 13 PRESSURE—TEMPERATURE PHASE DIAGRAM OF GAS "A700/840"

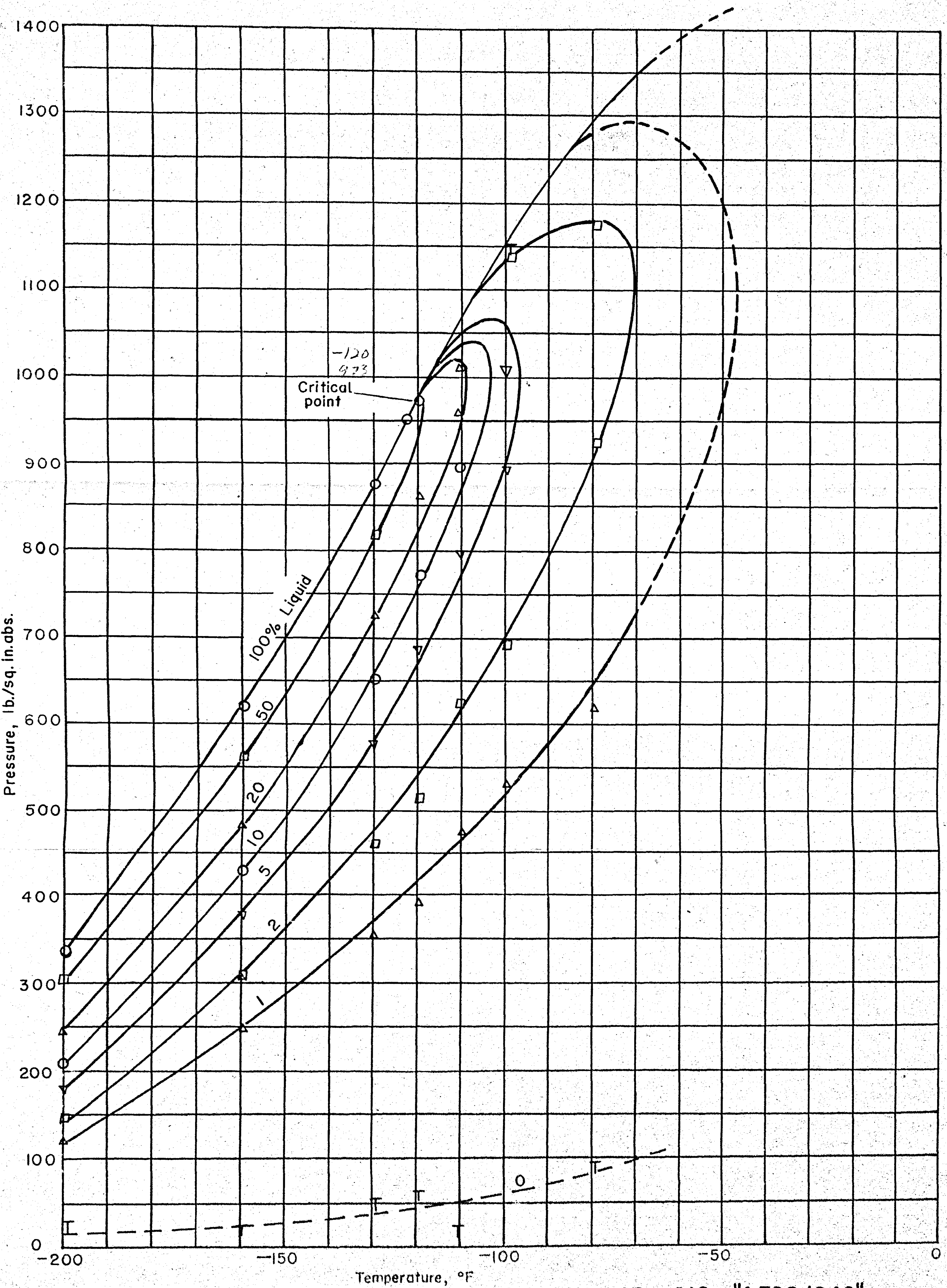


FIG. 14 PRESSURE- TEMPERATURE PHASE DIAGRAM OF GAS "A 700/940"

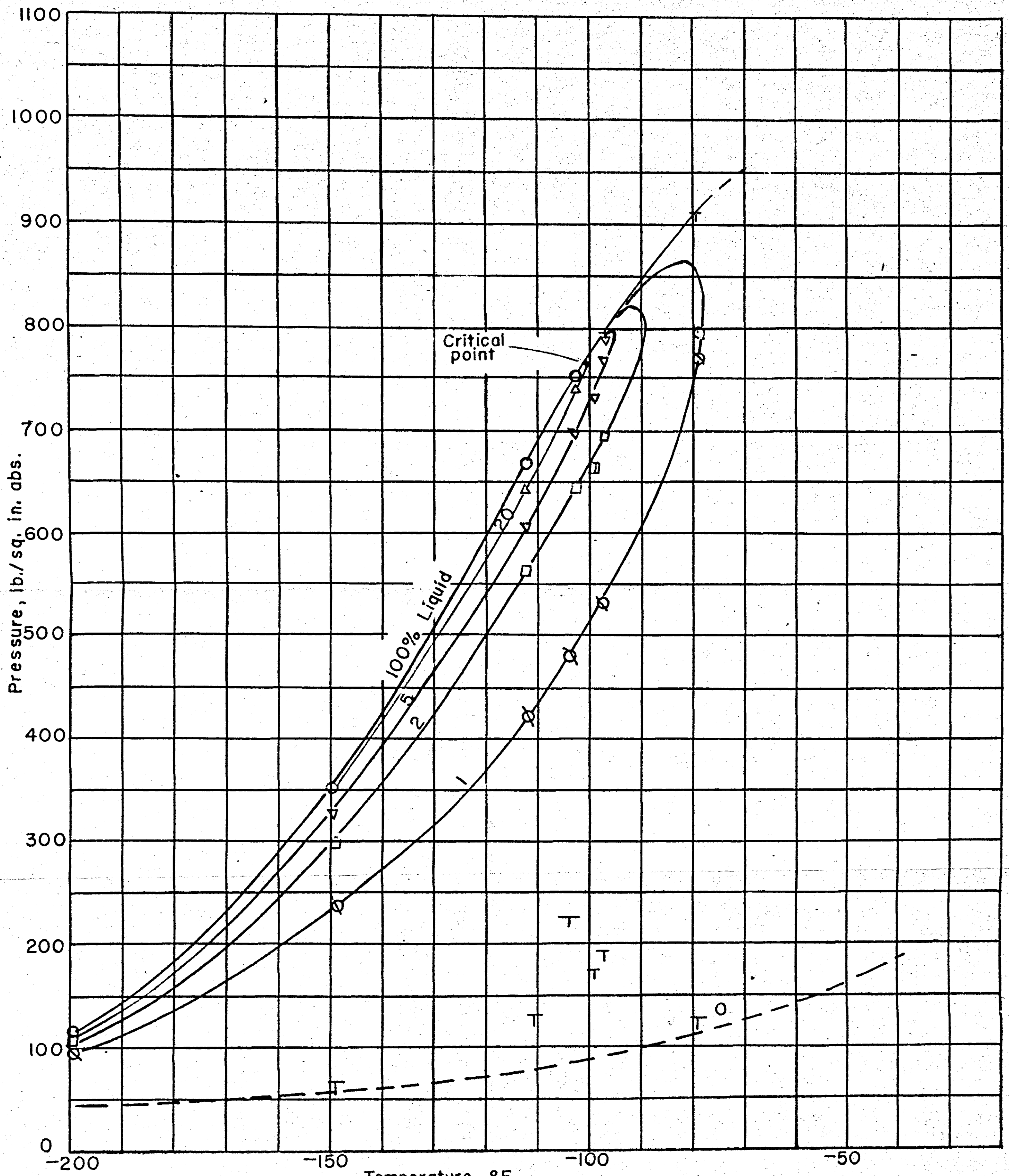


FIG. 15 PRESSURE- TEMPERATURE PHASE DIAGRAM OF GAS "AB"

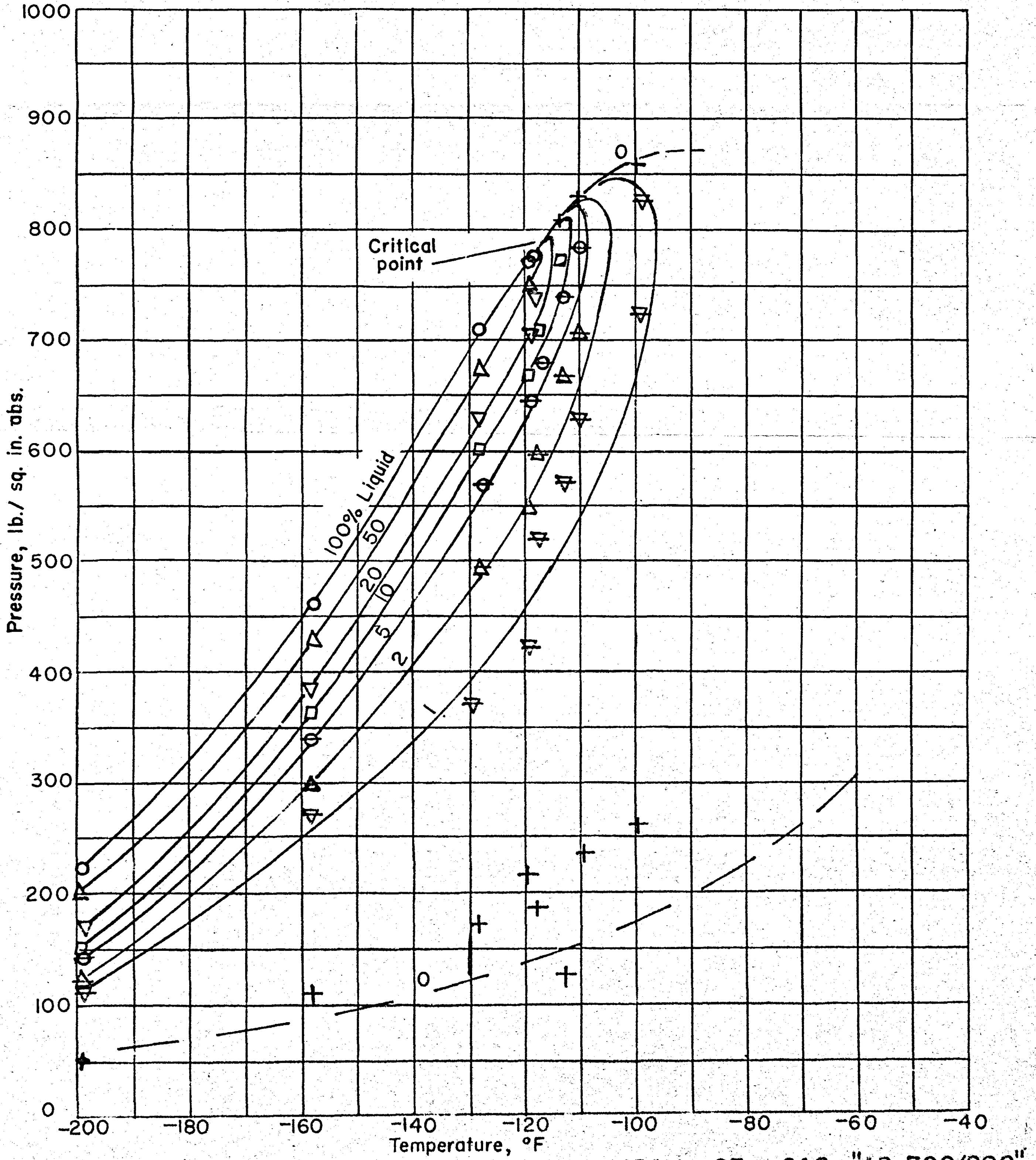


FIG. 16 PRESSURE– TEMPERATURE PHASE DIAGRAM OF GAS "AB 700/800"

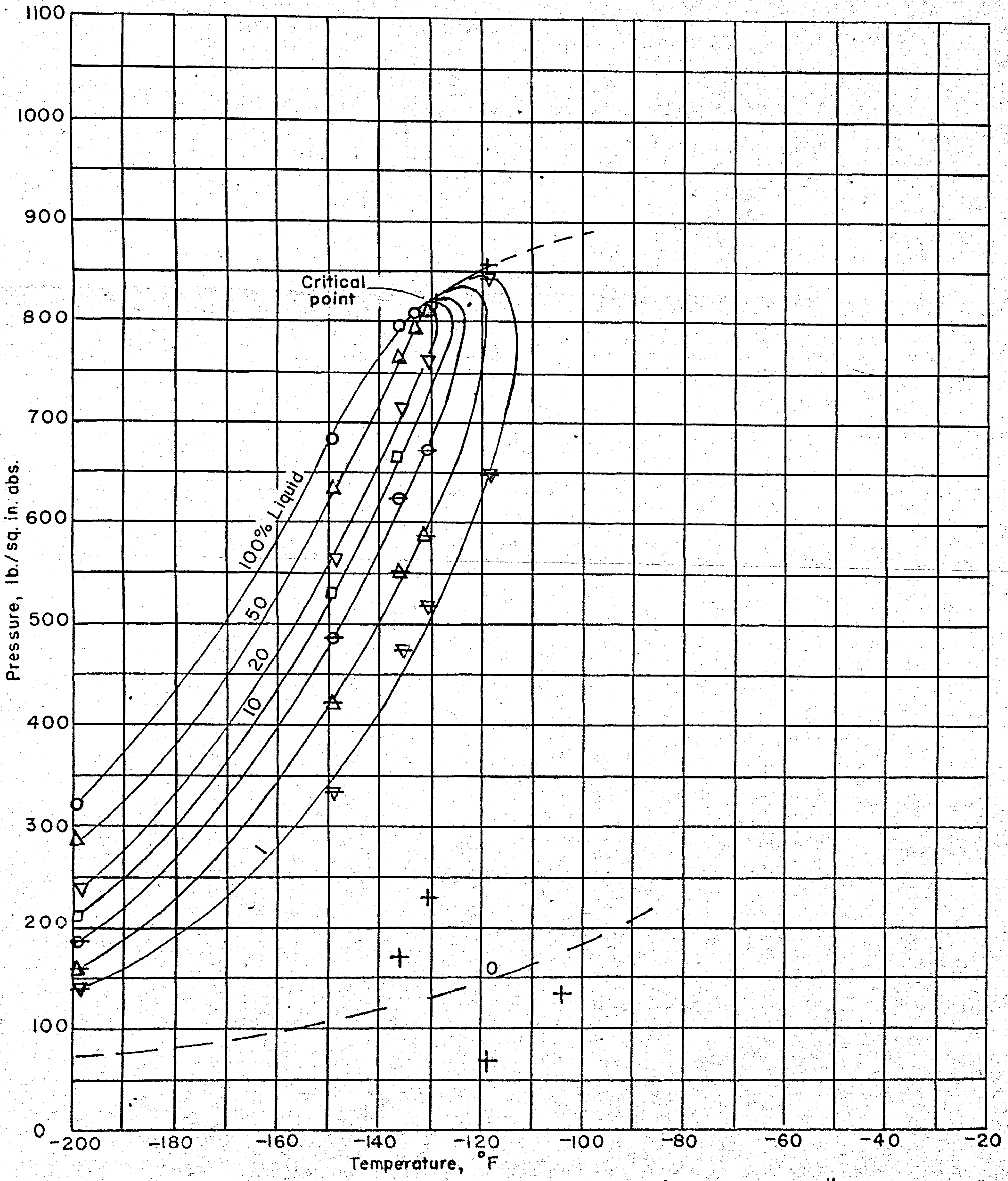


FIG. 17 PRESSURE-TEMPERATURE PHASE DIAGRAM OF GAS "AB 700/940"

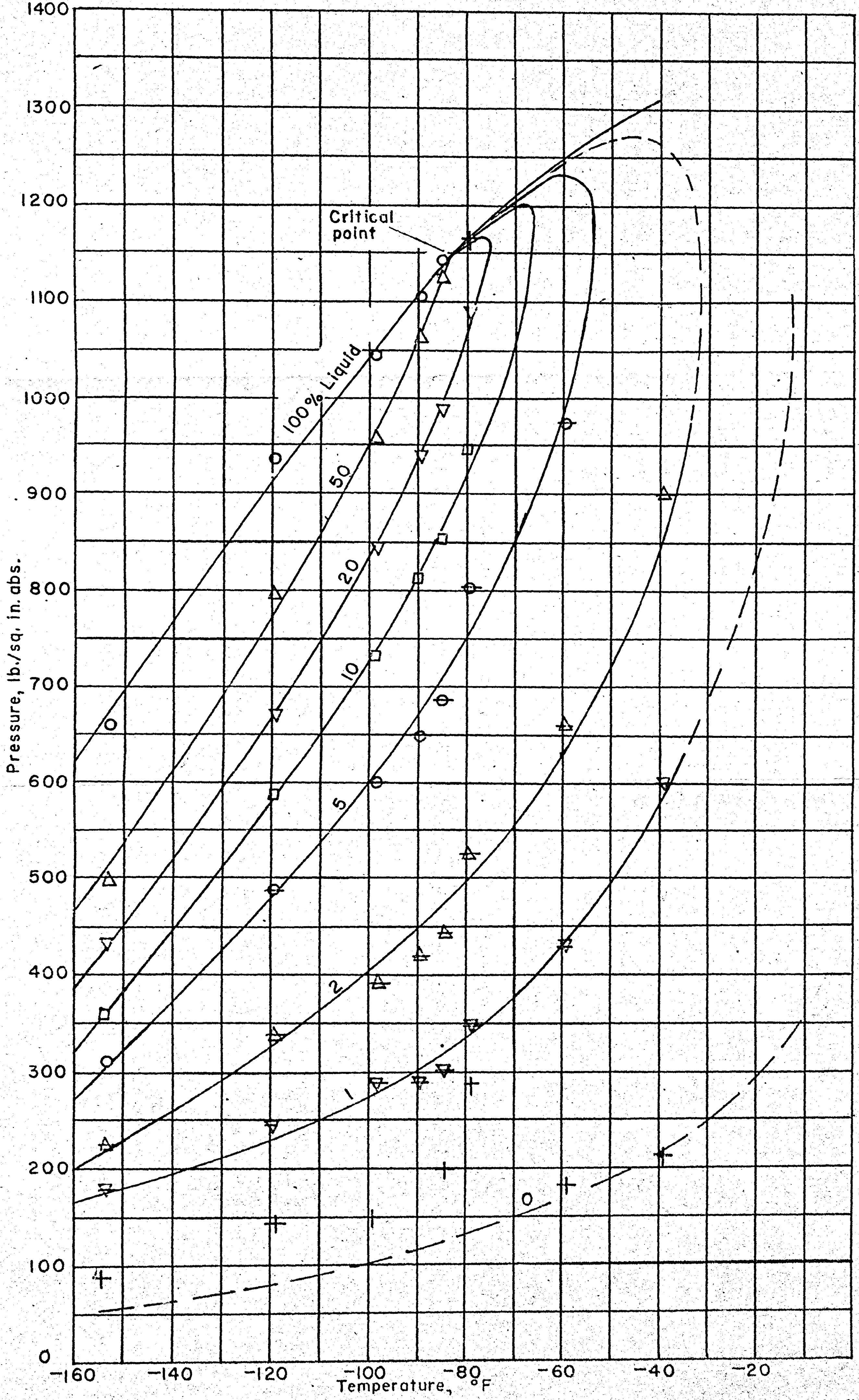


FIG. 18 PRESSURE–TEMPERATURE PHASE DIAGRAM OF GAS "B"

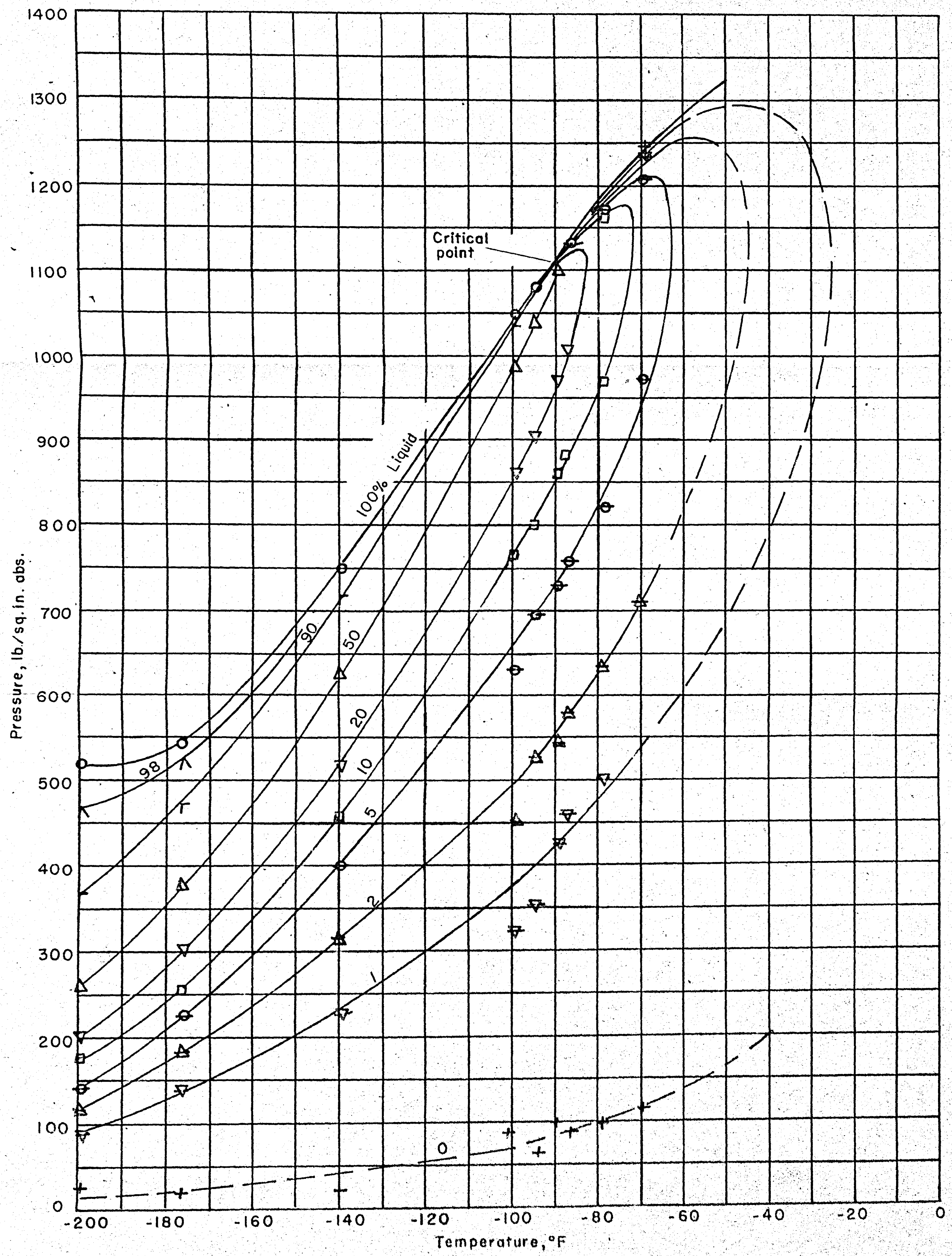


FIG. 19 PRESSURE—TEMPERATURE PHASE DIAGRAM OF GAS "C"

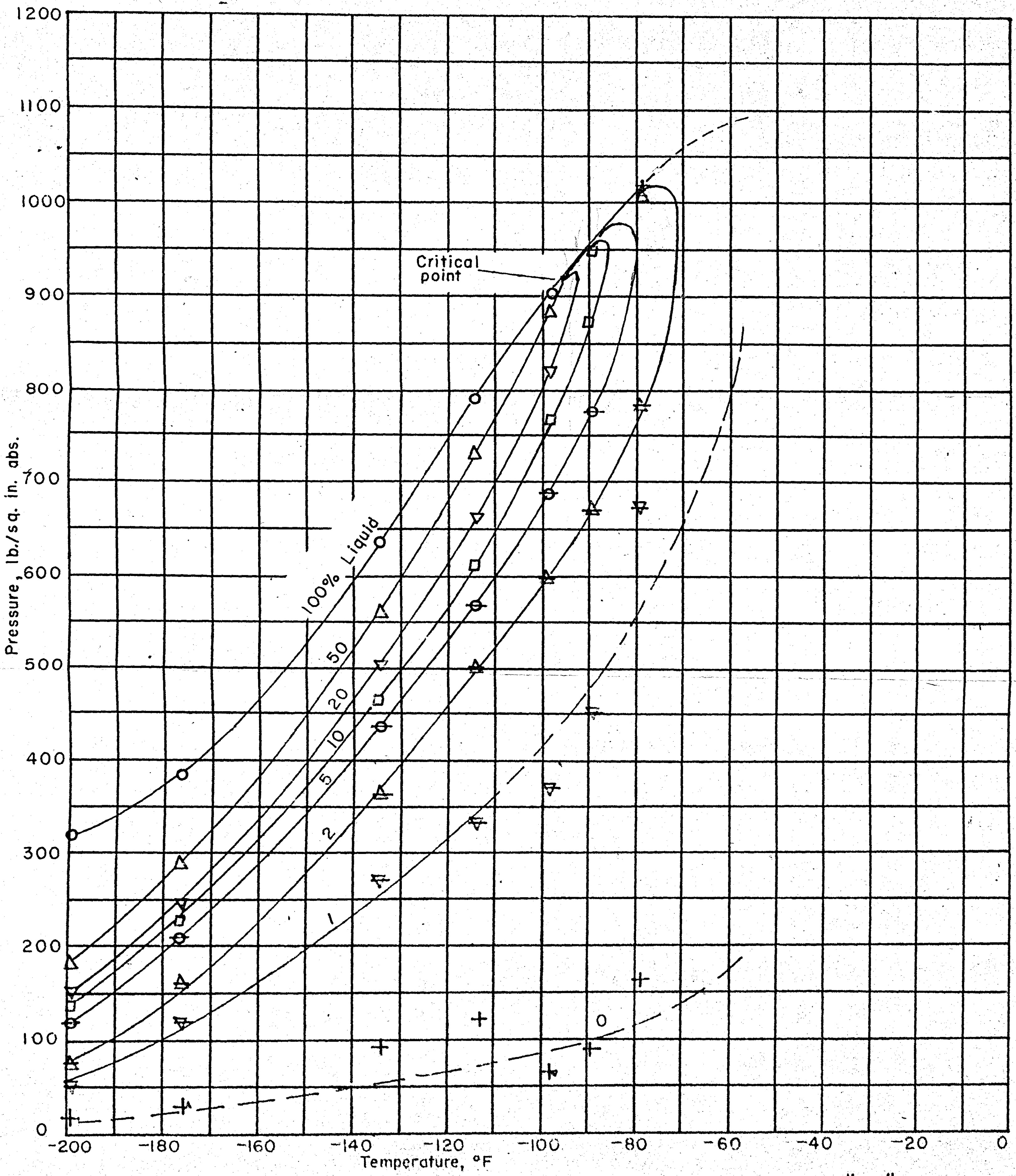


FIG. 20 PRESSURE-TEMPERATURE PHASE DIAGRAM OF GAS "D"

less than 1/10 percent liquid. Critical temperatures are believed to be accurate to ±1°F and critical pressures to ± 10 lb./sq. in. Further comments concerning accuracy of measurements are given in the discussions of the charts for each gas.

Gas "A" (Fig. 11)

The bubble-point (100 percent liquid) curve and the upper dew-point curve are seen to be continuous, meeting at the critical point without a cusp. This behavior is consistent with other hydrocarbon systems. The critical point is seen to be -79°F and 925 lb./sq. in. abs. There is a large retrograde region above -79°F and 925 lb./sq. in. abs. where condensation occurs upon decrease of pressure or upon increase of temperature. As would be expected from the fact that this gas contained 91 percent methane and no component more volatile than methane, the pressure increases very rapidly with the first liquid condensed and very slowly as the bubble point is approached; this may be seen more clearly in Exhibit J. The flat character of these isotherms at large amounts of liquid is evidence of a uniform temperature within the cold-bath.

Gas "A700/770" (Fig. 12)

This gas was prepared by adding 8.8 percent nitrogen to gas "A". The critical temperature was lowered to -92°F, and the critical pressure was increased to 955 lb./sq. in. abs. The bubble-point pressure increased 80 lb./sq. in. at -200°F and 150 lb./sq. in. at -100°F above the curve for gas "A". The pressure change during the condensation of the last 50 percent of the mixture increased, but the form of the curves was otherwise little changed.

Gas "A700/840" (Fig. 13)

This gas was prepared by adding 16.1 percent nitrogen to gas "A". The critical temperature was lowered to -104°F, and the critical pressure was increased to 968 lb./sq. in. abs. The bubble-point pressure increased 150 lb./sq. in. at -200°F and 200 lb./sq. in. at -110°F above the values for gas "A". There is a further increase in the pressure change during the condensation of the last 50 percent of the mixture and the slope of the bubble-point curve is noticeably less. The lack of scatter of points along the constant-liquid lines shows that there was less than 1 percent variation in the amount of nitrogen added to the gas for different isotherms.

Gas "A700/940" (Fig. 14)

This gas was prepared by adding 24.4 percent nitrogen to gas "A". The critical temperature was lowered to -120°F and the critical pressure was raised to 973 lb./sq. in. abs. A plot of critical pressure versus percent nitrogen shows that this is near the maximum critical pressure to be obtained by adding nitrogen to gas"A". The bubble-point increased 230 lb./sq. in. at -200°F and 430 lb./sq. in. at -120°F above the curve for gas "A". There was a further increase in pressure change during the condensation of the last 50 percent of the mixture.

Gas "AB" (Fig. 15)

This gas was prepared by adding methane to gas "A" until a mixture containing 96.7 percent methane was obtained. The critical temperature of this mixture was -101°F and the critical pressure was 765 lb./sq. in. abs. The bubble-point pressure was 1 lb./sq. in. lower than the boiling point of methane at -200°F and 23 lb./sq. in. lower at -120°F. The pressure changed only a few lb./sq. in. during the condensation of the last 50 percent of the mixture. All of these characteristics are to be expected since gas "AB" is nearly pure methane. It is interesting to note that the critical pressure is extremely sensitive to impurities; 2.3 percent heavy ends increased the critical temperature of methane 15°F, and the critical pressure was increased 92 lbs./sq. in.

Gas "AB700/800" (Fig. 16)

This gas was prepared by adding 11.3 percent nitrogen to gas "AB". The critical temperature was lowered to -117°F, and the critical pressure was increased to 790 lb./sq. in. abs. The bubble-point pressure and the pressure change during the condensation of the last 50 percent of the mixture were increased, as with gas "A".

Gas "AB700/940" (Fig. 17)

This gas was prepared by adding 24 percent nitrogen to gas "AB". The critical temperature was lowered to -131°F and the critical pressure was increased to 815 lb./sq. in. abs. The bubble-point pressure and the pressure increase during the condensation of the last 50 percent of the mixture were again increased as with gas "A". It appears that the maximum critical pressure would occur at a somewhat larger amount of nitrogen than with gas "A", but this maximum critical pressure would be near 825 lb./sq. in. abs.

Gas "B" (Fig. 18)

Gas "B" was collected from the first-stage separator of a well in western Kansas. It contained 1.0 percent helium in addition to 11.5 percent nitrogen. The critical temperature of this gas was -84°F, and the critical pressure was

1143 lb./sq. in. abs. This gas was received at low pressure, and due to the difficulties in compressing it from a nearly-empty cylinder no data were collected below -154°F. Aside from the higher critical pressure, the most notable differenc between gas"B" and the "A" series lies in the greater increas of pressure during the condensation of the last 50 percent of the mixture. This property is caused by the presence of helium as is discussed below.

Gas "C" (Fig. 19)

This gas was collected from a pipeline at Lawrence, Kansas and was similar to gas "B", both in composition and in measured properties. The critical temperature was -90°F and the critical pressure 1107 lb./sq. in. abs. A peculiarit of the gases which contain helium is the great increase of pressure during the condensation of the last few percent of the mixture. This effect is especially marked at low temperatures; at -200°F the pressure rose 50 lb./sq. in. during the condensation of the last 2 percent of the mixture. Mullins (43) reports a calculated phase diagram of similar form for a natural gas containing helium. Such behavior is to be expected from the fact that the solubility of helium in nitrogen and in methane goes through a minimum as the temperature is lowered. Kay (26) has reported a phase diagram for the system hydrogen-naphtha in which the bubble-point pressure falls, rises, then falls as the temperature is lowered.

Gas "D" (Fig. 20).

This gas was prepared by mixing gas "AB" and gas "C". The critical temperature was -96°F and the critical pressure 918 lb./sq. in. abs. The general form of the phase diagram is similar to that of gas "C". It is notable that helium has a definite effect at low temperatures although the helium content is only 0.3 percent.

Utility of Phase Diagrams

The main utility of the phase diagrams presented is believed to lie in their use to test existing or proposed correlations of equilibrium constants. This test can be carried out along the boundary curve of the two-phase region, where the composition of one phase is known. Gore (20) has calculated bubble-point curves for gases "A" and "AB" using the M. W. Kellogg Equilibrium Constants, and has obtained satisfactory agreement with the experimental data for these gases. Bertuzzi is presently engaged in developing a set of equilibrium constants for nitrogen which will be consisten with the experimental results of this investigation.

The phase diagrams of these gases can also be used to estimate the amount of condensate formed in natural gas pipelines.

Volumetric Data

The volumetric data which were obtained in this investigation were determined by metering gas into the test cell from a reservoir at temperatures from 100 to 110°F and at pressures from 750 to 1300 lb./sq. in. gage. The densities of the gases in the reservoir were computed from the correlation of Standing and Katz (74). This correlation has been shown (7) to be accurate to approximately 1 percent for dry gases containing up to 7.5 percent nitrogen within the pressure and temperature range mentioned above. The correlation has not been tested for high concentrations of nitrogen, but the success in calculating the composition of mixtures of gas "A" and nitrogen indicate that it is probably correct within 2 percent. Future investigations of the volumetric behavior of natural gases containing large amounts of nitrogen may materially reduce this uncertainty.

The experimental determination of the density of saturated liquid propane at 32°F is shown in Exhibit F. The results agreed to 0.2 percent with the recognized value (75). Other data indicate the reasonableness of the results of this investigation. For example, the compressibility factors of gas "AB" agree with those of pure methane (7) to less than 1 percent at a reduced temperature of 1.10 and at reduced pressures up to 0.6. At a reduced pressure of 1.00 the compressibility factor of gas "AB" is 0.650 as compared with 0.682 for pure methane, showing the effect of the condensatio of the heavy ends in gas "AB". It is believed that the compressibility factors are correct within 1 percent as far as the experimental determinations are concerned; uncertainty of the correlation of Standing and Katz increases the overall uncertainty to approximately 3 percent.

The volumetric data were calculated as compressibility factors (PV/RT). A sample calculation of the compressibility factors along one isotherm is given in Exhibit G. These compressibility factors scattered greatly at very low densities, but these errors were avoided by extrapolating the accurate portion of the compressibility curve to Z = 1 at zero pressure. Compressibility charts thus prepared were cross-plotted to obtain compressibilities at even values of reduced temperature. These charts are given for each gas in Exhibit K. The charts in Exhibit K were averaged to obtain the mean compressibility factor at various reduced temperatures and reduced pressures. The mean compressibility factor chart is shown as Fig. 21. The standard deviations of the values used to calculate mean compressibilities were computed; the probable errors of the mean compressibility factors, calculated as 0.67 times the standard deviations, are entered on Fig. 21. For convenience, the data of Standing and Katz are also entered.

The maximum reduced temperature of this investigation is about the same as the minimum reported by Standing and Katz. The agreement is good up to reduced pressures of 1.0 as is shown by Fig. 21 and by Exhibit K. Figure 21 shows that the mean chart may be used with an error of less than 2 percent when the reduced temperature is greater than 0.90 and the compressibility factor is greater than 0.6. Very large errors are shown where the reduced temperature is less than 0.90 and the reduced pressure is 0.2 to 0.8. In general it may be said that large errors are to be expected where large amounts of liquid are present and where the density of the liquid is much greater than that of the vapor.

Figure 21 is presented to show that the volumetric behavior of natural gases may be represented to a fair degree of accuracy on a single compressibility chart, even at high pressures, low temperatures and well into the two-phase region. Actually, it is not recommended that Fig. 21 be used in estimating the volumetric behavior of any natural gas. What is recommended is that the compressibility factor chart of Exhibit J be chosen which describes the behavior of the gas having the composition most nearly like that of the gas in question. It is suggested that compressibility

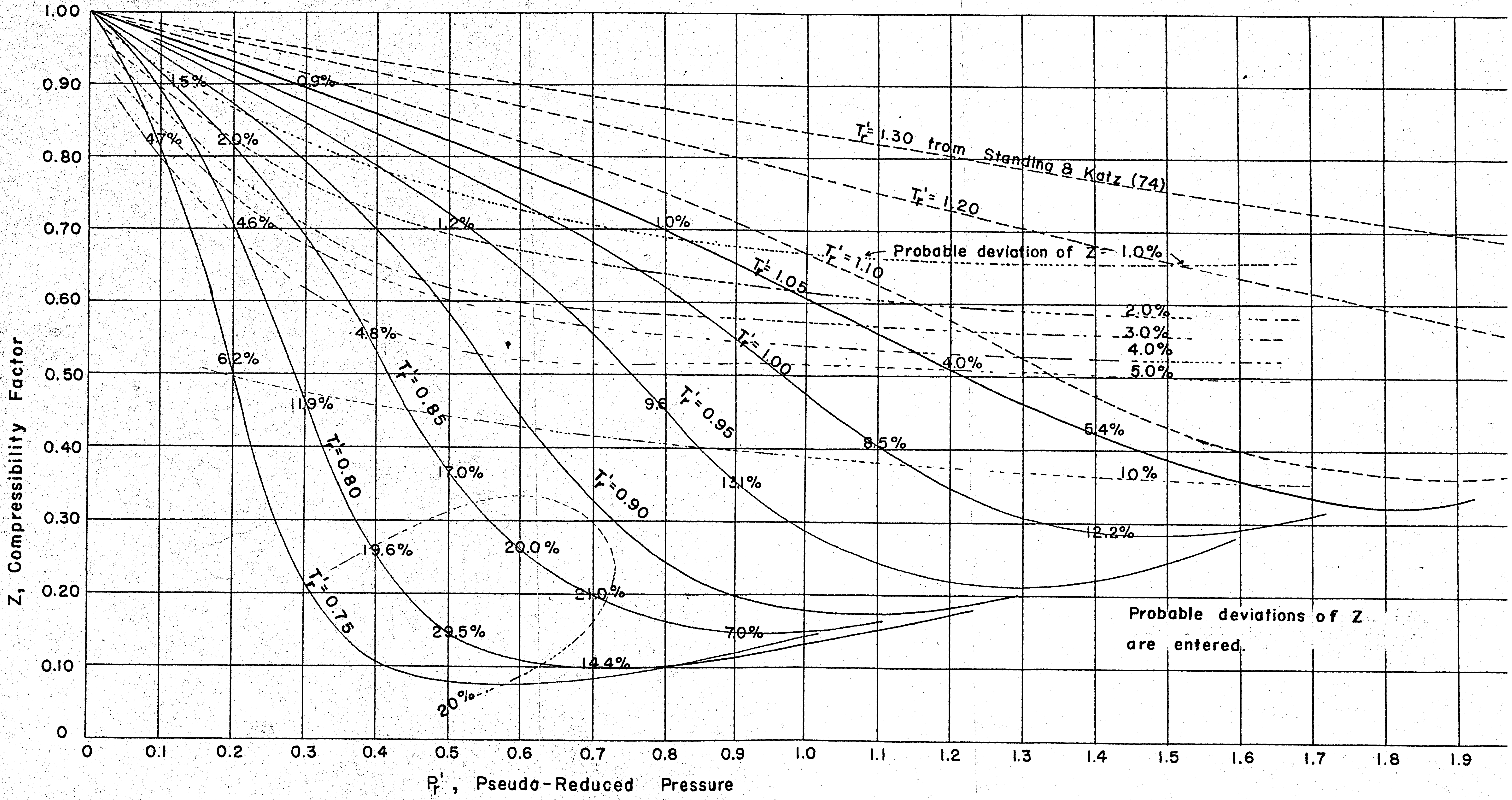


FIG. 21 MEAN COMPRESSIBILITY FACTORS

factors not be used in the region where the reduced pressure is less than 0.8 and the estimated compressibility factor is less than 0.5. In this region it will be necessary to calculate the amount and density of each of the two phases present.

CORRELATIONS OF CRITICAL TEMPERATURES AND PRESSURES

Critical Temperature

Various correlations have been proposed for estimating the critical temperature of hydrocarbon mixtures. Mayfield (42) used the weight average critical temperature as the estimated critical temperature for binary mixtures. Smith and Watson (73) correlated the critical temperatures of mixtures as a function of the weight average boiling point and the A.P.I. gravity. This method requires the use of fictive densities for the volatile hydrocarbons. Kurata and Katz (37) correlated the critical temperature as a function of the molal average critical temperature and implicitly of the molecular weight, with a correction factor to be used when methane is present. Edmister and Pollock (12) correlated the critical temperatures of refinery fractions as a function of the A.S.T.M. volumetric average boiling point and the A.P.I. gravity of the mixture. Organick (52) has recently correlated both critical temperatures and critical pressures as functions of the molal average boiling point and the weight average equivalent molecular weight.

None of these methods is completely general. The methods of Smith and Watson, and of Edmister and Pollock do not apply to volatile mixtures. The method of Kurata and Katz appears to be completely general as far as the volatility of the mixture is concerned, but does not allow for nonhydrocarbons such as nitrogen and carbon dioxide. Parameters could presumably be added to allow for such components, but would considerably complicate the method, since methane is already treated in this way. Organick's method seems to be general for complex mixtures but does not apply satisfactoril to binary systems or to pure compounds.

The first attempt to correlate the critical temperatures of the mixtures investigated was to apply the method of Kurata and Katz. The predicted critical temperatures were 25 to 34°F greater than the experimental value for the gases which contained no nitrogen, and the deviations were much greater for gases containing nitrogen. This method was modified so as to predict lower critical temperatures for mixtures very rich in methane, and the nitrogen content was added as a parameter on the chart used to correct for the presence of methane. This method was fairly successful but considerable errors were found when applied to the systems methane-butane, methane-pentane, and methane-decane. This modification of the method of Kurata and Katz was discarded in favor of the method to be discussed.

Existing data for hydrocarbon systems show critical temperature of mixtures that are not equal to the weighted mean of the critical temperatures of the components on either a molal or a weight basis. The true critical temperature is greater than the molal average critical temperature, a fact which was used by Kurata and Katz (37). The weight average critical temperature is more nearly equal to the true critical temperature, but is greater than the true value. The difference between the weight average and the true critical temperature for binary mixtures is greatest at near equal weight fractions of the two components. This difference can be approximately represented by:

$$T_c - {}_mT_c' = A_{1,2}\ m_1\ m_2 \qquad (1)$$

where T_c is the true critical temperature, ${}_mT_c'$ is the weight average critical temperature, m_1 is the weight fraction of component 1, m_2 is the weight fraction of component 2, and $A_{1,2}$ is a constant peculiar to the given binary mixture. The quantity $A_{1,2}\ m_1\ m_2$ suggests a reaction between like molecules; if such be the case it should be possible to extend equation (1) to predict the critical temperatures of complex mixtures. The form in which this extension was attempted was:

$$\begin{aligned} T_c - {}_mT_c' = {} & A_{1,2}\ m_1\ m_2 + A_{1,3}\ m_1\ m_3 + A_{1,4}\ m_1\ m_4 + \dots \\ & + A_{2,3}\ m_2\ m_3 + A_{2,4}\ m_2\ m_4 + \dots \\ & + A_{3,4}\ m_3\ m_4 + A_{3,5}\ m_3\ m_5 + \dots \\ & + A_{4,5}\ m_4\ m_5 + \dots \qquad (2) \end{aligned}$$

where a term is included for each possible binary system. The best way to test equation (2) would be to apply it to a ternary system for which the behavior of all the binary systems is known. Unfortunately such data were not available, and it was necessary to use data for complex systems. Further, it was necessary to use a trial-and-error procedure to estimate the characteristics of those component binary systems for which data were not available. The constants which were obtained from existing binary data and from trial-and-error calculations are given in Table IV. The results of applying equation (2) to a number of mixtures are summarized in Table V. No attempt was made to apply equation (2) to mixtures having large amounts of high-boiling constituents, the binary data for which were not known. Before the method could be applied to systems such as Roess' mixtures, data would have to be obtained on the critical temperatures of binary systems made from narrow cuts of such mixtures.

It is not claimed that $A_{1,2}\ m_1\ m_2$ best expresses the effect of the binary mixture composed of components 1 and 2, but it permitted this effect to be characterized by a single number which greatly facilitated the trial-and-error calculations necessary when binary critical data were not available. It might seem more reasonable to make the corrections on a molal basis, but the corrections to the average critical temperature are more complex than when a weight basis is used. Future experimental data will permit direct determination of the constants of equation (2) and will probably

Table IV Values of A_{ij} for Equation (2)

	N_2	C_1	C_2	C_3	C_4	C_5	C_6	C_7
N_2	0							
C_1	+50	0						
C_2	+25	$-150-400(C_1)^3$	0					
C_3	0	-30	0	0				
C_4	-100	-180	-27	+10	0			
C_5	-300	-150	-50	-30	0	0		
C_6	-500	-400	-50	-50	0	-25	0	
C_7	-600	-400	-100	-50	-10	-100	0	0

Table V COMPARISON OF ESTIMATED AND EXPERIMENTAL CRITICAL TEMPERATURES

Mixture	Expt T_c °R	Error, °F Organick's Method (52)	Error, °F Equation (2)	Error, °F Kurata's Method (36,37)
A	381	0	-5	+34
A 700/770	368	+1	-1	
A 700/840	356	-2	0	
A 700/940	339	0	+3	
AB	359	-2	+3	+25
AB 700/800	343	0	-3	
AB 700/940	329	-1	-4	
B	376	-5	+1	
C	365	-5	-3	
D	364	+1	-3	
Standard Deviation		2.8	3.3	

Volatile Mixtures

Mixture	Expt T_c °R	Error, °F Organick's Method (52)	Error, °F Equation (2)	Error, °F Kurata's Method (36,37)
S-2(36,37)	515	-17	-6	+5
S-3 "	569	-15	+11	+3
S-4 "	569	-14	+6	0
S-5 "	630	+15	+25	-3
T-1 "	514	-32	-11	-3
T-3 "	525	-27	-6	+3
T-4 "	550	-28	+4	+3
T-5 "	649	-11	+26	+2
B-1 "	538	+10	+5	-8
B-2 "	576	-6	-11	+10
B-3 "	602	-12	-17	-3
B-4 "	610	+6	-12	-5
A (23)	559	+1	-1	-14
B "	555	-7	+9	0
Standard Deviation		18.2	14.0	6.6

8 Naturally occuring Condensate Gases and Volatile Crudes, Critical Temperature Range 460-760 °F (49, 51, 78). Critical Temperatures obtained by extrapolation (52)

Standard Deviation (52) 23 ----- 96

50 Refinery Mixtures, Critical Temperature Range 1010-1260°R (59)

Standard Deviation (52) 7 ---- ----

Standard deviation calculated for N cases by $\sqrt{\frac{(\text{observed-Predicted})^2}{N-2}}$ assuming N-2 Degrees of freedom make it necessary to modify the form of the terms, but in the meantime the use of equation (2) is proposed as a method which gives good agreement with experimental data for single components, binary systems, and complex systems wherever it has been possible to test the method.

After equation (2) had been developed Organick's correlation became available (52). This correlation extended from 0° to 800°F. Using the data of this investigation Organick's correlation was extended to -160°F (Fig.22) with good results. Table V shows errors involved in predicting critical temperatures of several mixtures by various methods.

Table V shows that Organick's method has the most general range of applicability of all methods for prediction of critical temperature, but it is less accurate than either Kurata's method or equation (2) for volatile mixtures.

Organick's method is plainly superior in estimating critical temperatures of very complex systems such as refinery mixtures and naturally-occurring hydrocarbons, but it has the disconcerting property of failing to predict the critical temperatures of pure components and of binary mixtures. It is therefore suggested that Organick's method be used for very complex mixtures and equation (2) for others. It should be pointed out that all of these methods depend upon the analyses of the mixtures for their application and that the errors shown in Table V may be due more to errors

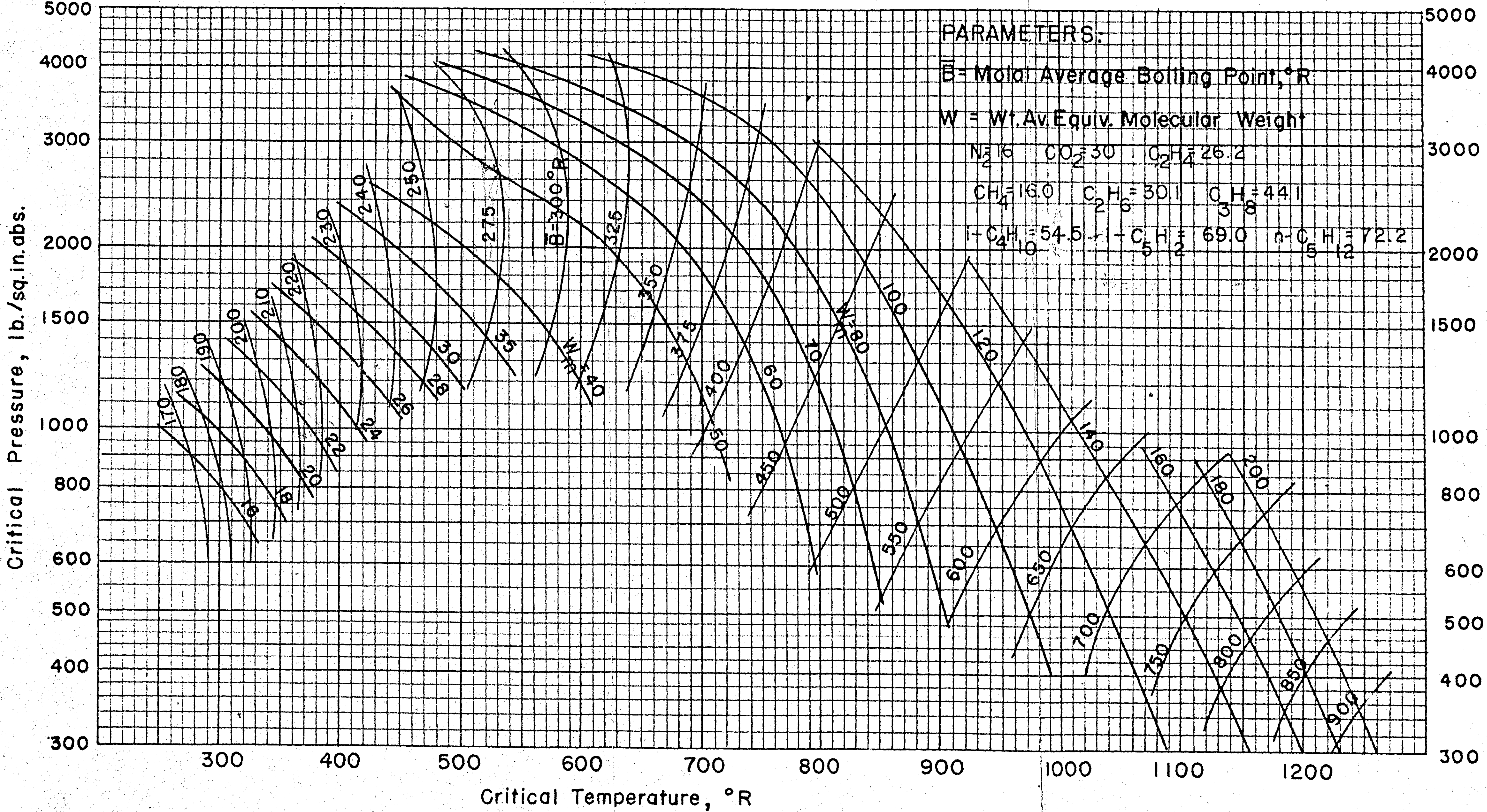


FIG. 22 EXTENSION OF ORGANICK'S CORRELATION (52)

in analyses than in the correlation. With respect to the ten mixtures studied in this investigation, the experimental error in determining the critical temperature is of the order of 1°F, and uncertainties in the analyses could easily cause this large an error in the predicted critical temperature. Thus both Organick's method and equation (2) predict the critical temperatures almost to within experimental errors. Particular caution is to be used in applying any of these correlations to mixtures whose analyses show large amounts of heavy ends of unknown composition.

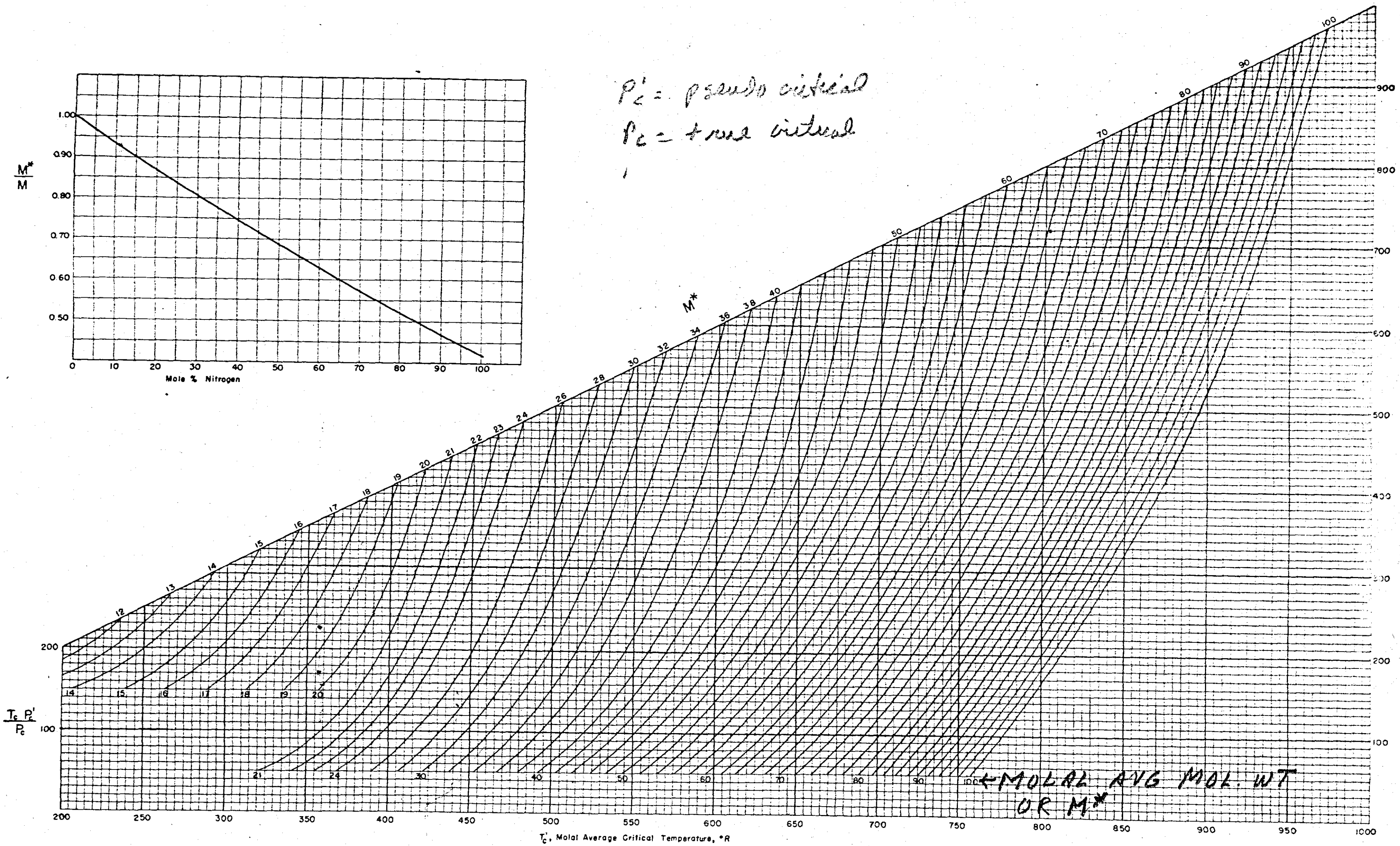
Critical Pressure

The estimation of critical pressures has been a more serious problem than has the estimation of critical temperatures. While critical temperatures could be estimated with some degree of accuracy by averaging processes, either on a weight or a mole basis, critical pressures may be as much as ten times the values calculated by averaging processe

There are a number of methods for predicting the critical pressures of mixtures. Mayfield (42) has presented a method for binary mixtures of hydrocarbons. Smith and Watson (73) correlated the ratio P_c/P_c' as a function of T_c/T_c', where P_c and T_c are the true critical pressure and temperature respectively. P_c' and T_c' are the molal-average critical properties. Kurata and Katz (37) plotted T_cP_c'/P_c

versus T_c' with the molal average molecular weight, M, as a parameter.

The method of Smith and Watson showed the general trend of the critical pressure data of this investigation, but with a considerable scatter. The method of Kurata and Katz, applied to the two mixtures of this investigation which contained no nitrogen, predicted critical pressures which were 20 and 150 pounds per square inch too high. The curves of the correlation were easily re-drawn in this extrapolated region to reduce these errors to less than 10 pounds per square inch. The adjusted chart is shown as Fig. 23. This chart predicted values of critical pressure for the nitrogen-bearing gases which were several times too large. This discrepancy was at first treated by assigning a fictive molecular weight to nitrogen. The fictive molecular weight was found to be a function largely of the mole fraction of nitrogen in the gas, but showed a considerable scatter when plotted versus the nitrogen content. It was found to be more satisfactory to assign a fictive molecular weight, $M*$, to the mixture and to plot $M*/M$ versus the mole percent of nitrogen in the gas. The modified correlation thus is a plot of T_cP_c'/P_c versus T_c' with $M*$ as a parameter. For hydrocarbon mixtures $M*$ is the same as M, while for gases containing nitrogen, $M*/M$ is plotted versus the mole percent of nitrogen on an inset to Fig. 23. The errors involved in



P_c' = pseudo critical
P_c = true critical

← MOLAL AVG MOL. WT
OR M*

FIG. 23 MODIFICATION OF CRITICAL PRESSURE CORRELATION OF KURATA AND KATZ (37) estimating critical pressures with Fig. 23 are shown by Table VI. Fig. 23 is idéntical to the correlation of Kurata and Katz for mixtures having a molecular weight greater than 24.

After this modification was completed Organick's correlation became available and was extended to the low-temperature region as was discussed in connection with the correlation of critical temperatures. This method simultaneously predicts critical temperatures and critical pressures and is shown as Fig. 22. The errors in estimating critical pressures by Organick's method are shown in Table VI.

Table VI shows that Organick's method gives the better results for naturally occurring mixtures and for refinery mixtures. The modified correlation of Kurata and Katz (Fig. 23) gives better results for volatile and very volatile mixtures. It is suggested that the correlation used be chosen accordingly. In particular, it is suggested that Fig. 23 be used for systems which approach binary mixtures or which approach being pure components.

Table VI COMPARISON OF ESTIMATED & EXPERIMENTAL

CRITICAL PRESSURES

Gas	Exptl P_c	Error Kurata's Method	Error Organick's Method	Error Modification of Kurata's Method
A	925	+150	+85	+1
A 700/770	955		+45	+15
A 700/840	968		+22	+6
A 700/940	973	+3453	+33	-20
AB	765	+20	-20	-9
AB 700/800	790		-20	+21
AB 700/940	815		-15	+7
B	1143	+1057	-3	-80
C	1107		-140	-100
D	918		-38	-18
Standard Deviation			64.2	47.4
VOLATILE MIXTURES				
S-2	2387	+227	-137	+227
S-3	2574	+56	-24	+56
S-4	2537	+3	+13	+3
S-5	2615	+65	-165	+65
T-1	2605	+35	-305	+35
T-3	2675	-65	-125	-65
T-4	2730	+60	+120	+60
T-5	2900	+10	-300	+10
B-1	1826	+14	-146	+14
B-2	1797	-9	+3	-9
B-3	1796	+4	-96	+4
B-4	1706	+4	-56	+4
Hanson A	1994	+6	+8	+6
Hanson B	1987	-7	+13	-7
Standard Deviation			75	158

8 Naturally Occurring Condensate Gases and Volatile Crudes, Critical Pressure Range 2600-5400 lb/sq. in. abs. (49, 51, 78).

Standard Deviation (52)	496	260	496

50 Refinery Mixtures, Critical Pressure Range 325-680 lb./sq. in. abs. (59).

Standard Deviation (52)	----	28	----

Standard Deviation calculated for N mixtures by

$$\sqrt{\frac{\Sigma(\text{Observed}-\text{Predicted})^2}{N - 2}}$$

assuming N-2 degrees of freedom

SAMPLE CALCULATION OF CRITICAL TEMPERATURE USING EQUATION (2)

Gas B $_mT_c'$ 397 °R

A_{ij} Table IV T_c 376

Obs. Δ -21 °F

i	j	i	Mj	Aij	$\Sigma m_j A_{ij}$	$m_i \Sigma m_j\ A_{ij}$
N_2	C_1		0.614	+50	+30.7	
	C_2		0.083	+25	+2.1	
	C_3		0.074	0		
	C_4		0.036	-100	-3.6	
	C_5		0.011	-300	-3.3	
	C_6		0.017	-500	-8.5	
	C_7					
		N_2	0.160		+17.4	+2.8
C_1	C_2		0.083	-242	-20.1	
	C_3		0.074	-30	-2.2	
	C_4		0.036	-180	-6.5	
	C_5		0.011	-150	-1.6	
	C_6		0.017	-400	-6.8	
	C_7					
		C_1	0.614		-37.2	-22.8
C_2	C_3		0.074	0		
	C_4		0.036	-27	-1.0	
	C_5		0.011	-50	-0.6	
	C_6		0.017	-50	-0.8	
	C_7					
		C_2	0.083		-2.4	-0.2

Calc Δ -20

Error +1°F

BIBLIOGRAPHY

1. American Petroleum Institute Research Project 44. National Bureau of Standards. Selected Values of Properties of Hydrocarbons. Washington, D.C.: 1949.
2. Atack, Evans, and McCormack (Given by Ruhemann, M. "The Separation of Gases" 2nd Edition, London: Oxford University Press, 1949.
3. Bahlke, W. H., and Kay, W. B., Ind. Eng. Chem., 24, 291-301 (1932).
4. Boomer, E. H., and Johnson, C. A., Can. J. Res. B16, 328-35 (1938).
5. Boomer, E. H., Johnson, C. A., and Piercey, A. G. A., Can. J. Res. B16 319-27 (1938).
6. Boomer, E. H., Johnson, C. A., and Piercey, A. G. A., Can. J. Res. B16, 396-410 (1938).
7. Brown, G. G., Katz, D. L., Oberfell, G. G., and Alden, R. C., "Natural Gasoline and the Volatile Hydrocarbons", Tulsa, Oklahoma: Midwest Printing Company, 1948.
8. Brown, G. M., and Stutzmann, L. F., Chem. Eng. Progress, 45, 142-7 (1949).
9. Cummings, W. T., Stones, F. W., and Volante, M. A., Ind. Eng. Chem., 25, 728-32 (1933).
10. Davis, P. C., Gore, T. L., and Kurata, Fred, Ind. Eng. Chem., 43, 1826-7 (1951).

11. Deschner, W. W. and Bodle, W. W., Oil and Gas J., 46, No. 50, 76-79, No. 51, 92-98, 112 (1948).

12. Edmister, W. C., and Pollock, W. C., Chem. Eng. Progress 44, 905-25 (1948).

13. Eilerts, C. K., Barr, V. L., Mullins, N. B., and Hanna, Betty, The Petroleum Engineer, 20, 502-15 (1948).

14. Fastowsky, V. G. and Gonikberg, M. G., Acta Physicochim (U.R.S.S.), 12, 485-8 (1940).

15. Fedoritenko, A. and Ruhemann, M., J. Tech. Phys. (U.S.S.R) 4, 36-43 (1937).

16. Gilliland, E. R., and Scheeline, H. W., Ind. Eng. Chem., 32, 48-54 (1940).

17. Gonikberg, M. G. and Fastowsky, V. G., Acta Physicochim (U.R.S.S.), 12, 67-72 (1940).

18. Gonikberg, M. G. and Fastowsky, V. G., Acta Physicochim (U.R.S.S.), 13, 399-404 (1940).

19. Gore, T. L., M. S. Thesis, University of Kansas, 1949.

20. Gore, T. L., Personal Communication, 1951.

21. Guter, M., Newitt, D. M., and Ruhemann, M., Proc. Roy. Soc. (London), 176A, 140-6 (1940).

22. Guter, M., Newitt, D. M., and Ruhemann, M., Proc. Roy. Soc. (Londond) 176A, 146-52 (1940).

23. Hanson, G. H., and Brown, G. G., Ind. Eng. Chem., 37, 821-5 (1945).

24. Holder, C. H., and Maass, O., Can. J. Res. 15 A-B, 345-51 (1937).

25. Katz, D. L., "Phase Relationships in Oil and Gas Reservoirs", Bulletin No. 114, College Station, Texas: Texas Engineering Experiment Station, 1948.

26. Kay, W. B., Chem. Rev., 29, 501-7 (1943).

27. Kay, W. B., Ind. Eng. Chem., 30, 459-65 (1938).

28. Kay, W. B., Ind. Eng. Chem., 32, 353-7 (1940).

29. Kay, W. B., Ind. Eng. Chem., 33, 590-4 (1941).

30. Kay, W. B., Ind. Eng. Chem., 40, 1459-67 (1948).

31. M. W. Kellogg Equilibrium Constants, New York: 1950.

32. Kharakhorin, F. F., Foreign Petroleum Tech, 9, 411-22 (1941).

33. Kharakhorin, F. F., J. Tech. Phys. (U.S.S.R.), 11, 1133-39 (1941).

34. Kuenen, J. P., Phil. Mag., 40, 173-94 (1895).

35. Kuenen, J. P., Phil. Mag., 44, 174-99 (1897).

36. Kurata, Fred, Ph. D. Thesis, University of Michigan, 1941

37. Kurata, F., and Katz, D. L., Trans. A.I.Ch.E., 38, 995-1020 (1942).

38. Levitskaja, E. P., J. Tech. Phys. (U.S.S.R.), 11, 197-204 (1941).

39. McCurdy, J. L., and Katz, D. L., Ind. Eng. Chem., 36, 674-80 (1944).

40. McCurdy, J. L. and Katz, D. L., Oil and Gas J., 43, No. 44, 102-4 (1945).

41. McTaggart, H. A., and Edwards, E., Trans. Roy. Soc. Can. 13, III, 57-66 (1919).

42. Mayfield, F. D., Ind. Eng. Chem., 34, 843-9 (1942).

43. Mullins, P. V., Chem. Eng. Progress, 44, 567-72 (1948).

44. Mullins, P. V., and Wilson, R. W., Am. Gas. Assoc. Proc., 30, 601-8 (1948).

45. Mullins, P. V., and Wilson, R. W., Oil and Gas. J., 43, No. 44, 102-4 (1945).

46. Nederbraght, D. W., Ind. Eng. Chem., 30, 587-8 (1938).

47. Nysewander, C. N., Sage, B. H., and Lacey, W. N., Ind. Eng. Chem., 32, 118-23 (1940).

48. Olds, R. H., Reamer, H. H., Sage, B. H., Lacey, W. N., Ind. Eng. Chem., 41, 475-82 (1949).

49. Olds, R. H., Sage, B. H., and Lacey, W. N., A.I.M.E. Trans. (Petroleum Development and Technology), 160, 77-99 (1945).

50. Olds, R. H., Sage, B. H., and Lacey, W. N., Ind. Eng. Chem., 34, 1008-13 (1942).

51. Olds, R. H., Sage, B. H., and Lacey, W. N., Petroleum Technology 11, TP 2412, 16 pp (1948).

52. Organick, E. I., Rough Draft of Paper to be presented at the annual meeting of the A.I.Ch.E., December 2-5, 1951.

53. Poettmann, F. H., J. Petroleum Tech., 192, 141-4 (1951)

54. Poettmann, F. H., and Katz, D. L., Ind. Eng. Chem., 37, 847-53 (1945).

55. Reamer, H. H., Olds, R. H., Sage, B. H., and Lacey, W. N. Ind. Eng. Chem., 34, 1526-31 (1942).

56. Reamer, H. H. Sage, B. H., and Lacey, W. N., Ind. Eng. Chem., 42, 534-9 (1950).

57. Reamer, H. H., Sage, B. H., and Lacey, W. N., Ind. Eng. Chem, 43, 2515-20 (1951).

58. Reamer, H. H., Sage, B. H., and Lacey, W. N., Ind. Eng. Chem., 43, 1436-44 (1951).

59. Roess, L. C., J. Inst. Pet. Tech., 22, 665-705 (1936).

60. Ruhemann, M., Proc. Roy. Soc. (London) 171A, 121-36 (1939).

61. Ruhemann, M., "The Separation of Gases," 2nd Edition, London: Oxford University Press, 1949.

62. Sage, B. H., Budenholzer, B. H., and Lacey, W. N., Ind. Eng. Chem., 32, 1262-77 (1940).

63. Sage, B. H., Hicks, B. L., Lacey, W. N., Ind. Eng. Chem. 32, 1085-92 (1940).

64. Sage, B. H., and Lacey, W. N., Ind. Eng. Chem., 32, 992-6 (1940).

65. Sage, B. H., Lacey, W. N., and Schaafsma, J. G., Ind. Eng. Chem., 26, 214-7 (1934).

66. Sage, B. H., Lavender, H. M., and Lacey, W. N., Ind. Eng. Chem., 32, 743-7 (1940).

67. Sage, B. H., Olds, R. H., and Lacey, W. N., Petroleum Tech, 11, 16 (1948).

68. Sage, B. H., Reamer, H. H., Olds, R. H., and Lacey, W. N., Ind. Eng. Chem., 34, 1108-17 (1942).

69. Sage, B. H., Webster, D. C., and Lacey, W. N., Ind. Eng. Chem., 28, 1045-7 (1936).

70. Scheeline, H. W., and Gilliland, E. R., Ind. Eng. Chem., 31, 1050-7 (1939).

71. Scheffer, F. E. C., K. Akad. Wet. Versl. van Vergad., 22, 427-41 (1913).

72. Scott, R. B.,"The Calibration of Thermocouples at Low Temperatures" in "Temperature, its Measurement and Control in Science and Industry", New York: Rheinhold Publishing Corporation, 1941.

73. Smith, R. L., and Watson, K. M., Ind. Eng. Chem., 29, 1408-14 (1937).

74. Standing, M. B., and Katz, D. L., A.I.M.E. Pet. Dev. Tech. 146, 140-9 (1942).

75. Stearns, W. V., and George, E. G., Ind. Eng. Chem., 35, 602-7 (1943).

76. Stutzman, L. F., and Brown, G. M., Chem. Eng. Progress, 45, 139-142 (1949).

77. Torochesknikov, N. S., and Levius, L. A., Chem. Ind. (U.S.S.R.), 16, 19-22 (1939).

78. Union Producing Company Files, quoted by Organick, Loc. Cit.

79. Vaughn, W. E., and Collins, F. C., Ind. Eng. Chem., 34, 885-90 (1942).

80. Volova, L. M., J. Phys. Chem. (U.S.S.R.), 14, 268-76 (1940

81. Weinaug, C. F., and Bradley, H. B., Petroleum Trans., A. I.M.E. 192, 233-8 (1951).

82. White, R. R., and Brown, G. G., Ind. Eng. Chem., 34, 1162-74 (1942).

APPENDIX

Exhibit A Calibration of Equilibrium Cells

A long capillary tube was sealed to the end of a calibrated 10 ml. burette, and water was metered from the burette into the cell. Calibration of the bottom portion of the cell was made with the ball resting upon the bottom and with the ball raised above the liquid interface.

Cell G

Ball Up

Vol. Delivered from Burette ml.	Cell Reading	Volume Percent Liquid
0.15	0.10	1.1
0.25	0.28	1.8
0.50	0.50	3.6
0.75	0.75	5.5
1.00	0.95	7.3

Ball Down

Vol. Delivered from Burette ml.	Cell Reading	Volume Percent Liquid
0.50	0.70	3.6
0.75	0.90	5.5
1.00	1.15	7.3
1.25	1.40	9.1
1.50	1.60	11.0
1.76	1.90	12.8
2.53	2.62	18.5
3.00	3.02	21.9
4.00	3.94	29.2
5.02	4.88	36.6
6.01	5.81	43.9
7.00	6.70	51.1
8.00	7.59	58.5
9.00	8.51	65.7
10.00	9.45	73.0
11.00	10.40	80.3
13.01	12.26	95.1
13.50	12.73	98.5
13.70	13.30	100.0

Exhibit A Cont. Calibration of Equilibrium Cells

Cell No. 18

Ball Up

Vol. Delivered from Burette ml.	Cell Reading	Volume Percent Liquid
0.15	0.10	1.5
0.40	0.30	3.9
0.75	0.50	7.4
1.00	0.66	9.8
1.30	0.85	12.7
1.60	1.05	15.7

Ball Down

0.40	0.45	3.9
0.75	0.65	7.4
1.00	0.85	9.8
1.30	1.05	12.7
1.90	1.49	18.6
2.71	2.00	26.6
4.15	3.00	40.7
5.62	4.00	55.1
7.08	5.00	69.4
8.55	6.00	83.8
9.93	7.00	97.4
10.13	7.30	99.3
10.16	7.40	100.0

Cell No. 20

Ball Up

Vol. Delivered from Burette ml.	Cell Reading	Volume Percent Liquid
0.15	0.25	1.5
0.35	0.45	3.4
0.70	0.70	6.9
0.95	0.85	9.3

Ball Down

0.35	0.58	3.4
0.95	1.00	9.3

Exhibit A Cont. Calibration of Equilibrium Cells

Cell No. 20 Continued

2.48	2.00	24.3
3.91	3.00	38.3
5.42	4.00	53.1
6.92	5.00	67.8
8.35	6.00	81.9
9.84	7.00	96.5
10.10	7.30	99.0
10.18	7.60	99.8
10.20	8.00	100.0

Cell No. 22

Ball Up

Vol. Delivered from Burette ml.	Cell Reading	Volume Percent Liquid
0.19	0.25	1.8
0.54	0.50	5.3

Ball Down

0.19	0.35	1.8
0.54	0.60	5.3
0.88	0.80	8.6
1.17	1.00	11.4
2.60	2.00	25.4
4.08	3.00	39.7
5.55	4.00	54.0
7.05	5.00	68.6
8.55	6.00	83.3
9.97	7.00	97.1
10.22	7.40	99.5
10.27	7.80	100.0

Cell No. 25

Ball Up

Vol. Delivered from Burette ml.	Cell Reading	Volume Percent Liquid
0.12	0.14	1.1
0.30	0.30	2.7
0.50	0.42	4.5
1.21	0.95	10.9

Exhibit A Cont. Calibration of Equilibrium Cells

Cell No. 25 Continued

<u>Ball Down</u>

0.22	0.38	2.0
0.54	0.60	4.9
0.86	0.81	7.7
1.13	1.00	10.2
2.64	2.00	23.7
4.13	3.00	37.1
5.63	4.00	50.6
7.14	5.00	64.2
8.66	6.00	77.8
10.16	7.00	91.3
10.80	7.40	97.0
10.96	7.60	98.5
11.13	8.18	100.0

Cell No. 24 (3/8" Straight)

<u>Ball Up</u>

Vol. Delivered from Burette ml.	Cell Reading	Volume Percent Liquid
0.05	0.06	1.1

<u>Ball Down</u>

0.11	0.22	2.4
0.48	0.85	10.3
0.98	1.70	21.1
1.66	2.90	35.8
2.18	3.80	47.0
3.50	6.00	75.4
3.96	6.80	85.3
4.45	7.62	95.9
4.52	7.75	97.4
4.58	7.83	98.7
4.61	7.99	99.4
4.63	8.20	99.8
4.64	8.50	100.0

Exhibit A Cont. Calibration of Equilibrium Cells

Cell No. 51 (3/8" Inverted)

<u>Ball in Liquid</u>

Vol Delivered from Burette ml.	Cell Reading	Volume Percent Liquid
0.05	0.05	98.1
0.08	0.11	96.9
0.21	0.34	91.8
0.53	0.88	79.3
0.79	1.33	69.1
1.10	1.90	57.0
1.23	2.10	52.0
1.53	2.59	40.2
2.25	3.79	12.1
2.56	4.60	0

Exhibit B. Determination of the Volume Between the Gas Reservoir and the Equilibrium Cell

The volume, V_S, between valve 1 and the neck of the equilibrium cell was determined by filling the cell into the capillary tube of the neck, metering methane into the volume and measuring the resulting increase of pressure. The initial pressure in all cases was atmospheric; different final pressures were used in order to evaluate the increase of volume with pressure. The volume is given by:

$$V_S = \frac{P_1 \; R_j \; M_j}{P_1 - \frac{Z_1}{Z_o} P_o}$$

Where P_1 = final pressure in cell which in all cases was the same as the pressure in the reservoir, lb./sq. in. abs.

P_o = 14 lb./sq. in. abs., the initial atmospheric pressure.

R_j = change in level of mercury in the calibrated Jerguson gage, cm.

M_j = calibration constant of Jerguson gage, ml./cm.

Z_1 = compressibility factor of methane at the pressure P_1, and the temperature of the volume V_s which was also the temperature of the Jerguson gage.

Z_o = compressibility factor of methane at the pressure P_o.

Exhibit B Cont. Determination of the Volume Between the Gas Reservoir and the Equilibrium Cell

The equation reduces to the following form within the precision of the measurements.

$$V_S \doteq \frac{P_1 R_j M_j}{P_1 - P_o}$$

The following data were obtained.

Cell	P_1	Average R_j	M_j	V_s, ml.
G	714	4.80	0.89	4.35
G	314	4.56	0.89	4.25
18	414	3.98	0.89	3.67
20	414	4.21	0.89	3.88
22	414	4.25	0.89	3.91
25	464	4.24	0.888	3.88

Exhibit C Calibration of Jerguson Gage

The Jerguson gages were calibrated by removing the mercury from valve no. 7 (in the case of the left Jerguson gage) while admitting gas from the other gage in order to maintain a constant pressure. The amount of mercury remove was measured in a calibrated 25 ml. burette.

Left Upper Gage, September, 1951

at 100°F and 2500 lb/sq. inch gage

Scale Reading	Vol. delivered, ml.
38.0	0.0
31.9	5.21
23.6	12.78
14.3	21.10
7.4	27.29
1.2	32.75

at 100°F and 100 lb./sq. inch gage

38.0	0.00
30.0	6.90
21.7	14.32
13.7	21.57
3.3	30.76

Left Jerguson Jerguson Gages

at 100°F and 1000 lb/sq. inch gage

Upper Gage

Feb. 16, 1951		August 15, 1951	
Gage Reading	Ml Delivered	Gage Reading	Ml. Delivered
38.0	0	38.0	0
36.0	1.72	33.1	4.18
34.0	3.62	28.2	8.53
32.0	5.34	20.2	15.67
30.0	7.04	12.1	22.98
28.0	8.85	2.0	31.91
26.0	10.55		
24.0	12.40		

Exhibit C Cont. Calibration of Jerguson Gage

22.0	14.18
20.0	15.93
18.0	17.70
16.0	19.58
12.0	23.10
10.0	24.96
8.0	26.74
6.0	28.56
4.0	30.31
2.0	31.96

Lower Gage

39.8	36.41
38.0	37.76
36.0	39.48
34.0	41.11
32.0	42.91
30.0	44.68
28.0	46.50
26.0	48.15
24.0	49.85
20.0	53.35

Jerguson Gage was dismantled and equipped with new gaskets February 1, 1951, but was not adjusted between February 16, and August 15, 1951.

Exhibit D Comparison of Pressure Gages with Dead-Weight Tester

The following data were obtained when the Bourdon-tube gages were compared with an Ashcraft 10,000 lb/sq. in. dead-weight tester in January, 1951 after they had been in service for one year. Since at this time the tester was new and would not seal at low pressures, no reliable comparison could be made below 600 lb./sq. in. The precision of the comparison was judged to be ±1 lb/sq. in.

Dead-weight tester lb/sq. in. gage	0-2000 lb/sq. in. Bourdon Gage lb./sq. in. gage	0-5000 lb/sq. in. Bourdon Gage lb/sq. in. gage
600	600	602
700	700	702
800	800	800
900	900	901
1000	1000	1002
1100	1101	1102
1200	1200	1200

The gages were again compared with the dead-weight tester in August, 1951 at increasing and decreasing pressure. These results are shown below.

Dead-weight Tester lb./sq. in. gage	0-2000 lb/sq. in. Bourdon gage lb./sq. in. gage	0-5000 lb/sq. in. Bourdon gage lb./sq. in. gage
0	0	0
100	100	101
200	200	200
300	300	302
400	400	400
500	500	501
600	600	602

Exhibit D Cont.

Comparison of Pressure Gages with Dead-Weight Tester

700	701	700
800	800	800
900	900	900
1000	1002	1002
1100	1102	1102
1200	1202	1202
1300	1303	1303
1200	1202	1203
1100	1103	1103
1000	1002	1002
900	900	900
800	800	800
700	700	700
600	600	600
500	500	500
400	400	400
300	300	300
200	200	200
100	100	100
0	1	2

Exhibit E Comparison of Thermocouple with Platinum Resistance Thermometer

The bath thermocouple was compared in July of 1950 with Leeds and Northrup Thermohm No. 755972. Temperatures were calculated from the resistance of the Thermohm using the van Deusen modification of the Callendar interpolation formula

$$t = \frac{1}{C}\ \frac{R_2 - R_o}{R_o} + d\left(\frac{t}{100} - 1\right)\frac{t}{100} + b\left(\frac{t}{100} - 1\right)\left(\frac{t}{100}\right)^3$$

where t represents temperature in degrees centigrade; R_t represents resistance at the temperature t, and R_o the resistance at the ice point. The specific constants were certified by the National Bureau of Standards to be

$C = 0.0039260\underline{4}$

$d = 1.492\underline{0}$

$b = 0.110\underline{4}$ (below 0°C)

The resistance R_t and R_o were determined by passing a current of 2 milliamperes through the Thermohm connected in series with a Leeds and Northrup 100 ohm resistor (List Number 4030) which was maintained at 100°F in a stirred oil bath. The potential terminals of the 100 ohm resistor were connected to the E.M.F. terminals of the potentiometer. Connected in this way, the reading of the potentiometer was proportional to the resistance of the Thermohm. The absence of spurious E.M.F.'s was established by duplicating the resistance R_o with the current through the Thermohm reversed. The E.M.F. of the thermocouple was determined with the K-2 potentiometer and an Eppley standard cell. Since the temperature of the bath drifted slowly this required plotting the reading of the Thermohm versus time to obtain simultaneous values of temperature and of thermocouple E.M.F. The following data were obtained:

Interpolated Resistance Thermometer Reading	Temperature °F	Thermocouple Reading Millivolts
0.26076	Ice Point	0
0.21824	-41.20	5.9008
0.17935	-107.20	10.661
0.17292	-118.10	11.370
0.15831	-142.53	12.953
0.15755	-143.79	13.030
0.15596	-146.43	13.223

μ The glass tube of the Thermohm was accidentally broken before this comparison could be completed, and the Thermohm was returned to Leeds and Northrup for repair and re-calibrati

The specific constants were reported to be:

$c = 0.0039261\underline{1}$

$d = 1.49\underline{2}$

$b = 0.110\underline{7}$

The thermocouple was again compared with the Thermohm in February of 1951. In this comparison the resistance of the Thermohm was determined by measuring the potential drop across the Thermohm and across the 100 ohm resistor with the K-2 potentiometer. With this arrangement the resistance of the Thermohm is 100 times the ratio of the two potential drops. The following data were obtained:

Exhibit E Cont. Comparison of Thermocouple with Platinum Resistance Thermometer

Thermohm Resistance	Temperature °F	Thermocouple E.M.F., Millivolts
25.592	Ice Point	0
12.499	-194.06	16,003
15.143	-149.31	13,400
15.131	-149.55	13,500
14.161	-166.38	14,400
14.153	-166.00	14,400

Another comparison was made on August 15, 1951 by placing both thermocouple and Thermohm in a six inch section of 3/4 inch copper tubing closed at the bottom and immersing the assembly in a mixture of solid and liquid pentane contained in a Dewar flask. The following data were obtained:

Thermohm Resistance	Temperature °F	Thermocouple E.M.F., millivolts
11.932	-203.55	16.500

Exhibit F Density of Propane at Icepoint

Phillips Pure Grade Propane
Temperature 32°F
Reservoir Pressure 100 lb./sq. in.
Reservoir Temperature 100°F

Cell No. 22
Cell Vol. 10.27ml.
Sep. Vol. 3.9 ml.

Change in Mercury Level, cm	Equilibrium Pressure lb/sq. in. abs.	Liquid in cell	Percent Liquid
	Filled to 10 Psig at 80°F		
0	21	dry	0
34.2	69	1.1	12.7
401.9	71	7.7	100

Calculation of Density of Saturated Liquid Propane at 32°F.

*Properties of propane are taken from Stearns & George, Ind. & Eng. Chem., 35, 602-607 (1943).

Initial propane in cell at 80°F and 10 Psig is $\frac{14.2X}{5.361^{*}}$ x $\underline{}$

$\underline{0.016018}$ = 0.0424 grams

Propane added from Jerguson gage is

$$\frac{401.9 \times 0.891 \times 0.016018}{1.0561^{*}} = 5431 \text{ grams}$$

Propane in separator at end of run is

$$\frac{3.9 \times 0.016018}{1.7100^{*}} = 0.0365$$

Propane in cell = 0.042 + 5.431 - 0.0361 = 5.437 grams

$$\text{Density} = \frac{5.437}{10.27} = 0.529 \frac{\text{gram}}{\text{ml}}$$

Stearns and George give

$$\frac{0.016018}{0.03020^{*}} = 0.5304 \frac{\text{grams}}{\text{ml}}$$

EXHIBIT G. SAMPLE CALCULATION OF COMPRESSIBILITIES

Gas "C"
Cell Vol = V_c = 11.1 ml.
Sep. Vol = V_s = 3.9 ml.
M = 19.975 gm./gm. mole

T = -69.38°F = 390.31°R
P'_c = 644.45 Psia
T'_c = 354.84°R
T'_r = 1.1000
R = 669.1 Psi ml/°R

Filled at 84 °F = 544°R, 48 psia

$$T'_r = \frac{544}{354.84} = 1.533 \qquad P'_r = \frac{48}{644.4} = 0.0745$$

From Katz, Brown, *et al* (7) p. 33   Z = 0.994

$$\text{Initial Gas} = \frac{P(V_s + V_c)}{ZT \times 669.1} = \frac{48}{0.994} \times \frac{15.0}{669.1} = 0.00199 \text{ gm. moles}$$

$$Z = \frac{PV_c}{n_c RT} ; \quad \frac{v_c}{RT} = \frac{11.1}{669.1 \times 390.31} = 4.250 \times 10^{-5}$$

Reservoir Pressure = 1314 Psia Temp. = 110°F = 570°R

$$T'_r = \frac{570}{354.84} = 1.606 \qquad P'_M = \frac{1314}{644.45} = 2.039$$

Z = 0.861   (From Brown, *et al* (7) p. 38)

$$\frac{n}{v} = \frac{P}{669.1 \times Z \times T} = \frac{1314}{669.1 \times 0.861 \times 570} = 0.004001 \ \frac{\text{g.moles}}{\text{ml.}}$$

CALCULATION OF COMPRESSIBILITIES - CONTINUED

Gas "C" $T = 390.31°R$ $T'_r = 1.1000$

P	R_{jg}	V_{jg}	N_{jg}	N_{Total}	N_s	N_c	Z	P'_r
37	2.0	0	0	.00199	.0004	.00159	.989	0.0574
220	5.4	3.0	.0120	.0140	.0025	.0115	.813	0.3414
352	8.0	5.3	.0212	.0232	.0040	.0192	.779	0.5462
464	10.5	7.5	.0300	.0320	.0054	.0266	.741	0.7200
601	14.0	10.7	.0428	.0430	.0073	.0357	.715	0.9326
737	18.1	14.3	.0572	.0592	.0091	.0501	.625	1.1436
869	22.7	18.4	.0736	.0756	.0093	.0663	.557	1.3484
946	25.9	21.2	.0848	.0868	.0120	.0748	.537	1.4679
1031	29.9	24.8	.0992	.1012	.0132	.0880	.498	1.5998
1111	34.1	28.5	.1140	.1160	.0144	.1016	.465	1.7240
1176	37.9	31.9	.1276	.1296	.0153	.1143	.437	1.8248
1176	11.0	31.9	.1276	.1296	.0153	.1143	.437	1.8248
1222	14.0	34.6	.1384	.1404	.0159	.1245	.417	1.8962
1249	15.8	36.1	.1444	.1464	.0165	.1299	.409	1.9381

$$\text{Sat. Density} = \frac{0.1299}{11.1} = 0.01170 \text{ gm. moles/ml.}$$

$$= 0.01170 \times 19.975 = 0.2337 \text{ gram/ml.}$$

EXHIBIT H

SUMMARY OF ANALYSES

GAS "A"

ANALYST METHOD DATE	Phillips Pod May, 1950	Accepted Composition
CO_2	1.200	1.200
O_2	-----	-----
He	-----	-----
N_2	-----	-----
CH_4	90.890	90.890
C_2H_6	4.395	4.395
C_3H_8	1.912	1.912
iC_4H_{10}	0.931	0.328
nC_4H_{10}		0.603
iC_5H_{12}	0.344	0.212
nC_5H_{12}		0.132
Hexanes	0.148	0.148
Heptanes +	0.180	0.180

Iso- and normal distributions calculated from analysis of "A700/940."

EXHIBIT H CONT. SUMMARY OF ANALYSES GAS "A700/770"

ANALYST METHOD DATE	Calculated From "A" & Z Factors	Accepted Composition
CO_2	1.09	1.09
O_2	----	----
He	----	----
N_2	8.84	8.84
CH_4	82.86	82.86
C_2H_6	4.01	4.01
C_3H_8	1.74	1.74
iC_4H_{10}	0.30	0.30
nC_4H_{10}	0.55	0.55
iC_5H_{12}	0.19	0.19
nC_5H_{12}	0.12	0.12
Hexanes	0.14	0.14
Heptanes +	0.16	0.16

EXHIBIT H SUMMARY OF ANALYSES GAS "A700/840"

ANALYST METHOD DATE	Calculated From "A" & Z Factors	Consolidated Mass Spectrometer November 12, 1951	Accepted Composition
CO_2	1.00	0.6	1.00
O_2	----	---	----
He	----	---	----
N_2	16.11	16.7	16.11
CH_4	76.25	75.6	76.25
C_2H_6	3.69	4.1	3.69
C_3H_8	1.60	1.4	1.60
iC_4H_{10}	0.28	0.5	0.28
nC_4H_{10}	0.51	0.5	0.51
iC_5H_{12}	0.18	0.6	0.18
nC_5H_{12}	0.11		0.11
Hexanes	0.12		0.12
Heptanes +	0.15		0.15

EXHIBIT H CONT. SUMMARY OF ANALYSES GAS "A 700/940"

ANALYST	Calc. From "A"& Z Factors	Tulsa T.L.	Q. Wheatley	Consolidated	Accepted Composition
METHOD		Pod	Slow Comb.	M. S.	
DATE		6-25-51	9-10-51	11-12-51	
CO_2	0.91	0.5	0.69	0.4	0.91
O_2	0	0.1	0.30	---	----
He	----	---	----	---	----
N_2	24.41	30.9	23.92	24.2	24.41
CH_4	68.70	62.3	75.09	67.0	68.70
C_2H_6	3.33	3.47		3.7	3.33
C_3H_8	1.44	1.49		1.1	1.44
iC_4H_{10}	0.70	0.25		0.5	0.30
nC_4H_{10}		0.46		0.5	0.40
iC_5H_{12}	0.26	0.14		0.6	0.16
nC_5H_{12}		0.09			0.10
Hexanes	0.11	0.14			0.11
Heptanes+	0.14	0.16			0.14

EXHIBIT H CONT. SUMMARY OF ANALYSES GAS "AB"

ANALYST METHOD DATE	Calculated From Z Factors	Phillips Mass Spectrometer August 29, 1951	Accepted Composition
CO_2	0.44	---	0.44
O_2	0.00	0.2	0
He	0	0	0
N_2	0	0.4	0
CH_4	96.68	96.6	96.68
C_2H_6	1.60	1.6	1.60
C_3H_8	0.70	0.9	0.70
iC_4H_{10}	0.34	0.3	0.14
nC_4H_{10}			0.20
iC_5H_{12}	0.12		0.07
nC_5H_{12}			0.05
Hexanes	0.05		0.05
Heptanes +	0.07		0.07

EXHIBIT H CONT. SUMMARY OF ANALYSES GAS "AB 700/800"

ANALYST METHOD	Calculated from Z and Analysis of "A"	Consolidated Mass Spectrometer	Accepted Composition
DATE		11-12-51	
CO_2	0.39	0.2	0.30
O_2	----	---	----
He	----	---	----
N_2	11.34	12.9	11.30
CH_4	85.71	84.4	85.80
C_2H_6	1.42	1.7	1.50
C_3H_8	0.62	0.4	0.60
iC_4H_{10}	0.12	0.1	0.12
nC_4H_{10}	0.18	0.2	0.18
iC_5H_{12}	0.06	0.1	0.06
nC_5H_{12}	0.04		0.04
Hexanes	0.04		0.04
Heptanes +	0.06		0.06

EXHIBIT H CONT. SUMMARY OF ANALYSES GAS "AB 700/940"

ANALYST	Calculated	Phillips	Q. Wheatley	Consolidated	Accepted Composition
METHOD	From Analysis of "AB" & Z Factors	Mass Spectrometer	Slow Comb.	Mass Spectrometer	
DATE		8-29-51	9-12-51	11-12-51 Air 34.8%	
CO_2	0.33	---	0.36	0.2	0.20
O_2	-----	0.1	0.23	---	
He	-----	0	0	---	
N_2	24.81	22.0	20.47	31.9	24.00
CH_4	72.70	75.2	78.94	65.8	73.64
C_2H_6	1.20	1.3		1.4	1.20
C_3H_8	0.53	1.2		0.2	0.53
iC_4H_{10}	0.10	0.2		0.1	0.10
nC_4H_{10}	0.15			0.2	0.15
iC_5H_{12}	0.05			0.2	0.05
nC_5H_{12}	0.04				0.04
Hexanes	0.04				0.04
Heptanes +	0.05				0.05

EXHIBIT H CONT. SUMMARY OF ANALYSES GAS "B"

ANALYST	Saybolt, Tulsa T.L.	Tulsa T.L.	Phillips	Q. Wheatley	Accepted Composition
METHOD	Pod	Pod	Mass Spectrometer	Slow. Comb.	
DATE	1-8-51	8-13-51	8-29-51	8-28-51	
CO_2	0	0.20	---	0.15	0.13
O_2	0	0	0	0.25	----
He	9.22	14.38	1.0	12.84	1.00
N_2			11.3		11.46
CH_4	80.29	74.70	77.0	86.76	76.65
C_2H_6	5.21	5.51	5.6		5.51
C_3H_8	3.40	3.32	3.4		3.35
iC_4H_{10}	0.33	0.36	1.2		0.35
nC_4H_{10}	0.97	0.91			0.90
iC_5H_{12}	0.17	0.18	0.5		0.17
nC_5H_{12}	0.20	0.14			0.15
Hexanes +	0.21	0.46			0.33

EXHIBIT H CONT. SUMMARY OF ANALYSES GAS "C"

ANALYST METHOD	Tulsa T.L. Pod	Phillips Mass Spectrometer	Q. Wheatley Slow Comb.	Accepted Composition
DATE	8-13-51	8-29-51	8-28-51	
CO_2	0.2	---	0.18	0.20
O_2	0	0.1	0.24	----
He	17.21	0.6	15.54	0.60
N_2		13.5		13.50
CH_4	72.25	75.1	84.04	75.15
C_2H_6	6.16	6.1		6.10
C_3H_8	3.25	3.3		3.27
iC_4H_{10}	0.36	1.1		0.38
nC_4H_{10}	0.57			0.60
iC_5H_{12}	0.20	0.20		0.20
nC_5H_{12}				
Hexanes +				

EXHIBIT H CONT. SUMMARY OF ANALYSES GAS "D"

ANALYST	Calculated	Tulsa T.L.	Accepted Composition
METHOD		Pod	
DATE		8-29-51	
CO_2	0.31	0.20	0.25
O_2	0.03	0	----
He	7.36	8.95	0.31
N_2			7.05
CH_4	85.42	83.39	85.42
C_2H_6	3.95	4.27	4.11
C_3H_8	2.04	1.93	1.98
iC_4H_{10}	0.26	0.47	0.37
nC_4H_{10}	0.41	0.38	0.39
iC_5H_{12}	0.22	0.41	0.22
nC_5H_{12}			
Hexanes +			

EXHIBIT I ORIGINAL DATA

GAS IDENTIFICATION "A" CELL TYPE 1/2" Strt NO. G
TEMPERATURE -19.95°F CELL VOL.13.7ml. SEP.VOL.4.3ml.
THERMOCOUPLE, MV. 4.255 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	3.2	29			-----
"	8.0	243			0.927
"	10.4	343			0.902
"	12.6	443			0.925
"	14.6	514			0.803
"	16.1	564			0.867
"	17.4	614	Trace	Trace	0.866
"	18.4	642	"	"	-----
"	19.0	664	"	"	0.835
"	20.0	691	"	"	-----
"	21.0	720	"	"	0.811
"	21.9	745	"	"	-----
"	22.7	767	"	"	0.783
"	23.5	791	"	"	-----
"	24.6	817	"	"	0.761
"	25.3	839	"	"	0.757
"	26.3	863	"	"	-----
"	27.4	890	"	"	0.731
"	28.2	910	"	"	0.722
"	29.4	940	"	"	-----
"	30.4	964	"	"	0.704
"	31.6	992	"	"	-----
"	32.6	1014	"	"	0.680

ORIGINAL DATA

GAS IDENTIFICATION "A" CELL TYPE 3/8" Strt NO: 24
TEMPERATURE -39.84°F CELL VOL. 4.64ml.SEP VOL.3.8ml.
THERMOCOUPLE, MV. 5.80 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1500	2.6	22	dry	0	
"	4.4	249	dry	0	
"	6.2	479	dry	0	
"	8.7	714	0.10*	1.5	
"	11.7	949	0.12*	1.6	
"	13.3	1051	0.14*	1.8	
"	14.8	1140	0.10*	1.5	
"	15.6	1181	0.06	0.8	
"	16.1	1213	dry	0	

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "A"   CELL TYPE 1/2" Strt NO. G
TEMPERATURE   -59.80°F CELL VOL. 13.7ml. SEP VOL.4.3ml.
THERMOCOUPLE, MV. 7.30   RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	---	31	0		
"	5.8	125	0		
"	9.4	261	0		
"	11.4	331	Trace	Trace	
"	15.4	448	0.05*	0.7	
"	22.0	621	0.10*	1.0	
"	28.5	751	0.50	1.8	
"	35.7	863	0.65	3.1	
"	38.4	897	0.72	3.8	
"	3.4	897	0.72	3.8	
"	4.5	932	0.80	4.5	
"	12.0	988	0.92	5.5	
"	14.9	1014	0.95	5.6	

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "A" CELL TYPE 1/2" Strt NO. G
TEMPERATURE -69.74°F CELL VOL.13.7ml SEP VOL.4.3ml.
THERMOCOUPLE, MV. 8.03 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	3.8	22	dry	0	-----
"	6.5	128	dry	0	0.908
"	9.2	122	dry	0	-----
"	10.7	270	Trace	Trace	0.720
"	12.2	316	Trace	Trace	0.807
"	14.2	373	Trace	Trace	-----
"	15.8	419	Trace	Trace	0.746
"	18.6	493	0.0*	0.8	0.713
"	21.2	555	0.20*	1.5	0.686
"	23.8	609	0.25*	1.8	0.653
"	26.8	666	0.34*	2.3	-----
"	29.8	714	0.40*	2.8	0.582
"	32.5	754	0.50*	3.6	-----
"	36.8	810	0.88	5.0	0.517
1200	3.8	810	0.88	5.0	0.517
"	8.4	868	1.10	6.6	0.470
"	10.4	891	1.25	8.0	-----
"	12.6	910	1.40	9.2	0.432
"	14.2	932	1.66	10.7	-----
"	17.8	940	1.85	12.8	0.404
"	19.5	963	2.00	14.0	-----
"	21.8	976	2.26	16.0	0.363
"	23.2	983	2.30	16.2	-----
"	24.4	991	2.38	17.0	0.348
"	25.8	996	2.20	15.5	-----
"	26.4	1000	1.90	13.2	0.336
"	27.6	1004	0.90	5.5	-----
"	28.8	1009	Single Phase	0	0.322

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "A"   CELL TYPE 1/2" Strt NO. G
TEMPERATURE   -74.76°F   CELL VOL.13.7 ml. SEP VOL.4.3ml.
THERMOCOUPLE, MV. 8.39   RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
500	3.3	35	0	0	-----
"	12.0	181	0	0	0.837
"	22.7	350	Trace	Trace	0.792
"	29.2	436	0.15*	1.2	0.753
"	35.9	512	0.20*	1.4	0.709
1000	3.4	512	0.20*	1.4	0.709
"	9.1	622	0.35*	2.4	0.627
"	14.3	709	0.70*	3.6	0.574
"	22.0	801	1.06*	6.0	0.495
"	31.1	872	1.71*	11.6	0.420
"	38.0	912	2.40*	17.2	0.377
1200	10.8	912	2.40*	17.2	0.377
"	16.5	941	3.53	25.8	0.338
"	20.3	956	4.72	34.9	0.316
"	21.0	959	5.37	40.1	0.313
"	22.4	965	None Visible	None Visible	0.307
"	25.0	992	Single Phase	Single Phase	0.300

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "A"   CELL TYPE 1/2" Strt   NO. G
TEMPERATURE -77.67°F   CELL VOL. 13.7ml. SEP VOL. 4.3ml.
THERMOCOUPLE, MV. 8.60   RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	21.6	754	0.62*	4.7	
"	26.1	798	1.12	7.0	
"	28.0	814	1.24	8.0	
"	30.1	829	1.40	9.1	
"	31.7	840	1.60	10.7	
"	34.0	856	1.82	12.5	
"	36.5	868	2.10	14.6	
"	6.9	868	2.10	14.6	
"	9.0	878	2.38	16.7	
"	11.1	888	2.68	19.1	
"	13.6	898	3.13	22.8	
"	14.6	902	3.31	24.1	
"	17.5	912	3.90	28.7	
"	19.5	920	4.47	33.4	
"	21.0	924	4.95	37.3	
"	22.0	926	5.38	40.5	
"	23.3	936	5.98	45.3	
"	24.0	931	6.50	49.5	
"	24.3	932	6.87	52.4	
"	24.8	933	7.75	59.5	
"	24.9	934	None Visible	None Visible	
"	28.9	963	Single Phase	Single Phase	

Data at lower pressures was discarded when it was found that there was no ice at cold junction.

ORIGINAL DATA

GAS IDENTIFICATION "A"   CELL TYPE 1/2" Strt NO. G
TEMPERATURE   -80.46°F CELL VOL.13.7ml. SEP VOL.4.3ml.
THERMOCOUPLE, MV. 8.80   RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	3.0	22	dry	0	
"	5.4	114	Trace	Trace	
"	8.0	214	Trace	Trace	
"	11.2	315	0.05*	0.5	0.842
"	14.7	414	0.08*	0.6	-----
"	19.0	517	0.16	1.0	-----
"	23.8	560	0.55	2.5	0.583
"	31.0	715	0.85	4.7	-----
"	37.0	773	1.24	7.8	0.482
"	2.6	773	1.24	7.8	-----
"	12.4	838	2.13	15.0	-----
"	22.1	880	3.76	27.6	0.343
"	30.4	903	6.60	50.2	-----
"	32.8	908	None Visible	100	0.297
"	34.2	912	10.44	80.0	0.287
"	34.9	913	None Visible	0	0.284
"	38.0	938	Single Phase	0	0.279

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "A"   CELL TYPE 1/2" Strt NO. G
TEMPERATURE   -81.53°F   CELL VOL.13.7ml SEP VOL.4.3ml
THERMOCOUPLE, MV. 8.875   RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	3.2	23	0	0	-----
"	4.8	80	0	0	0.862
"	6.4	136	0	0	0.834
"	8.0	190	0	0	0.789
"	9.4	220	Trace	Trace	-----
"	10.0	256	0.02*	0.6	0.776
"	11.6	298	0.03*	0.8	-----
"	13.4	348	0.09*	1.0	0.717
"	14.8	383	0.10*	1.1	-----
"	17.0	435	0.15*	1.3	0.667
"	18.6	467	0.20*	1.5	-----
"	20.2	496	0.25*	1.8	-----
"	23.0	548	0.30*	2.1	0.698
"	25.4	589	0.36*	2.5	-----
"	29.0	631	0.46*	3.3	-----
"	31.8	664	0.58*	4.2	-----
"	34.0	688	0.60*	4.4	0.467
"	4.4	688	0.60*	4.4	0.467
"	9.3	759	1.20	7.5	0.443
"	14.0	794	1.60	10.8	-----
"	18.2	818	2.00	14.0	0.378
"	22.7	840	2.60	18.5	-----
"	26.4	866	3.23	23.5	0.335
"	31.0	871	4.18	31.0	-----
"	35.4	883	5.40	40.7	0.289
"	3.3	883	5.40	40.7	-----
"	8.4	892	6.70	51.0	-----
"	11.6	898	8.26	63.5	0.257
"	14.2	902	10.05	77.5	0.249
"	16.2	905	None Visible	100	0.243

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "A" CELL TYPE 1/2" Strt NO. G
TEMPERATURE -84.69°F CELL VOL.13.7ml SEP VOL.4.3ml
THERMOCOUPLE , MV. 9.10 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
500	5.8	27	0	0	-----
"	13.5	162	Trace	Trace	0.885
"	20.2	268	0.05	0.5	0.841
"	30.7	396	0.06	0.5	-----
"	38.3	476	0.60	3.0	0.663
1000	8.1	476	0.60	3.0	0.663
"	13.7	577	0.64	3.2	0.600
"	20.1	664	0.88	5.0	0.525
"	27.3	733	1.28	8.2	0.455
"	38.3	797	2.43	17.2	0.369
"	7.3	797	2.43	17.2	0.369
"	14.8	827	3.57	26.1	0.327
"	23.2	849	5.46	41.0	0.287
"	30.0	866	8.37	64.3	0.263
"	35.1	874	11.56	89.5	0.246
"	37.5	875	None Visible	100	0.238

ORIGINAL DATA
GAS IDENTIFICATION "A" CELL TYPE 1/2" Strt NO. G
TEMPERATURE -91.53°F CELL VOL. 13.7ml SEP VOL.4.3ml
THERMOCOUPLE, MV.9.58 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	6.7	24	-----	---	
"	11.0	203	Trace	Trace	
"	17.5	368	0.0*	0.7	
"	22.0	470	0.07*	0.9	
"	25.2	529	0.25*	1.8	
"	29.1	587	0.45*	3.2	
"	33.0	637	0.90*	5.7	
"	38.3	684	1.40	8.3	
"	8.2	684	1.40	8.3	
"	15.7	730	2.13	15.0	
"	19.3	744	2.67	19.1	
"	23.0	764	3.75	27.5	
"	28.2	772	4.52	33.7	
"	34.3	786	6.17	46.8	
"	38.6	793	7.44	57.1	

* Read with agitator ball raised above the interface.

Upon addition of the next increment of gas the equilibrium cell burst, preventing completion of this isotherm.

ORIGINAL DATA

GAS IDENTIFICATION "A" CELL TYPE 3/8" Inverted NO. 51
TEMPERATURE -97.60°F CELL VOL. ---
THERMOCOUPLE, MV. 10.00 RESERVOIR TEMP. ---

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
		21	dry	0	
		116	dry	0	
		206	dry	0	
		312	dry	0	
		407	dry	0	
		502	4.32	---	
		559	4.18	---	
		604	4.13	---	
		652	4.00	---	
		714	3.55	18	
		769	Single Phase	100	

ORIGINAL DATA

GAS IDENTIFICATION "A"   CELL TYPE 1/2" Strt NO. G
TEMPERATURE   -102.92°F CELL VOL. 13.7ml. SEP VOL.4.3ml
THERMOCOUPLE, MV. 10.366 RESERVOIR TEMP. 102°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
500	3.6	19	---	---	------
"	5.8	65	---	---	-----
"	9.6	122	---	---	0.921
"	12.4	164	---	---	-----
"	15.6	215	Trace	Trace	0.851
"	19.4	264	Trace	Trace	-----
"	22.0	301	Trace	Trace	-----
"	25.1	336	0.20	1.2	0.765
"	27.7	364	0.30	1.2	-----
"	29.8	388	0.40	1.5	-----
"	33.0	418	0.50	2.0	-----
"	39.0	467	0.60	2.9	0.644
1000	3.2	467	0.60	2.9	-----
"	6.8	517	0.80	4.5	-----
"	11.8	572	1.08	6.5	-----
"	15.4	601	1.38	9.0	-----
"	20.1	625	1.95	13.5	0.413
"	25.4	646	2.76	20.0	-----
"	29.6	658	3.50	25.5	-----
"	35.5	671	4.58	34.1	-----
"	38.0	675	5.10	38.2	0.285
"	3.0	675	5.10	38.2	0.285
"	6.5	681	5.87	44.2	-----
"	10.6	685	6.74	51.2	-----
"	14.7	689	7.78	59.3	-----
"	19.4	694	9.00	69.3	0.220
"	21.2	695	9.42	72.5	------
"	22.4	698	9.90	76.5	-----
"	24.4	699	10.30	79.6	-----
"	26.1	699	10.76	83.3	-----
"	27.2	700	11.00	85.0	-----
"	28.7	702	11.43	88.6	0.195
"	30.4	703	11.90	92.3	-----
"	31.8	704	12.34	95.7	-----
"	33.0	705	12.70	98.2	0.185
"	33.6	707	13.00	99.3	0.185
"	34.3	714	13.30	100	0.183
"	35.2	716	None Visible	100	-----

ORIGINAL DATA
GAS IDENTIFICATION "A"   CELL TYPE 1/2" Strt NO. G
TEMPERATURE   -119.53°F CELL VOL.13.7ml. SEP VOL.4.3ml.
THERMOCOUPLE, MV.11.48   RESERVOIR TEMP. 106°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
750	3.7	27	0	0	-----
"	5.6	62	Trace	Trace	0.704
"	7.6	118	Trace	Trace	0.836
"	9.7	161	Trace	Trace	0.874
"	11.9	210	Trace	Trace	-----
"	14.3	252	Trace	Trace	-----
"	16.2	278	0.1*	1.0	0.845
"	18.2	312	0.2*	1.6	0.696
"	21.4	354	0.3*	2.1	-----
"	23.9	380	0.4*	2.7	0.610
"	26.2	408	0.5*	3.5	-----
"	29.2	430	0.6*	4.3	0.546
"	32.6	452	0.75*	5.5	-----
"	35.6	472	1.18*	7.4	0.493
"	38.2	479	1.35*	8.6	0.446
"	3.5	479	1.35*	8.6	0.446
"	5.9	486	1.55	10.2	-----
"	8.5	495	1.80	12.2	0.399
"	11.9	502	2.10	14.3	-----
"	15.2	509	2.45	17.1	0.350
"	19.2	517	2.90	20.5	-----
"	22.8	521	3.30	23.6	0.305
"	26.5	525	3.73	27.0	-----
"	31.9	529	4.27	31.0	-----
"	36.5	533	4.99	36.6	0.247
"	3.6	533	4.99	36.6	0.247
"	9.4	535	5.88	43.5	-----
"	16.0	538	6.65	49.5	0.209
"	23.4	542	7.60	57.2	-----
"	28.5	544	8.30	62.7	-----
"	34.0	545	9.00	68.0	0.172
"	3.9	545	9.00	68.0	-----
"	10.6	548	10.00	76.1	-----
"	19.8	549	11.20	84.9	0.149
"	24.0	550	11.90	90.5	-----
"	26.7	551	12.25	93.0	0.141
"	28.9	552	12.58	95.2	-----
"	29.8	553	12.70	96.0	-----
"	31.0	553	12.96	97.1	0.136
"	31.4	553	13.08	98.5	-----
"	31.6	554	13.20	99.8	0.136

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "A" CELL TYPE 1/2" Strt NO. G
TEMPERATURE -139.34°F CELL VOL. 13.7ml. SEP VOL.4.3ml
THERMOCOUPLE, MV. 12.76 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
500	3.0	30	0	---	-----
"	5.5	72	Trace	Trace	1.000
"	9.3	122	Trace	Trace	-----
"	11.0	145	Trace	Trace	0.842
"	12.6	164	Trace	Trace	-----
"	14.7	192	0.0*	0.4	0.797
"	17.0	215	0.05*	0.8	0.755
"	22.6	268	0.23*	1.6	0.714
"	25.6	290	0.30*	2.1	0.577
"	29.7	313	0.68	3.4	-----
"	35.7	337	0.90	5.1	0.525
"	2.6	337	0.90	5.1	0.525
"	24.9	363	1.60	10.8	0.330
"	25.8	373	2.28	16.0	-----
"	31.6	376	2.68	19.2	-----
"	38.2	381	3.10	22.5	0.279
"	2.8	381	3.10	22.5	0.279
"	28.0	387	4.19	31.2	-----
"	33.2	390	5.30	40.0	0.196
"	2.8	390	5.30	40.0	0.196
"	18.8	393	6.50	49.5	-----
"	32.2	396	7.46	57.2	0.153
"	2.3	396	7.46	57.2	-----
"	16.1	397	8.50	65.3	-----
"	24.3	397	9.15	70.5	-----
"	34.1	399	9.90	76.5	0.123
"	2.6	399	9.90	76.5	-----
"	11.4	400	10.56	81.6	-----
"	19.7	400	11.15	86.4	-----
"	30.0	401	11.92	92.5	0.105
"	3.5	401	11.92	92.5	-----
"	8.8	401	12.35	96.0	-----
"	12.4	404	12.65	97.8	-----
"	13.8	406	12.80	98.5	0.101
"	27.0	418	None Visible	100	0.0975
"	28.0	444	Single Phase	100	0.103

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "A" CELL TYPE 1/2" Strt NO. 15
TEMPERATURE -140.06°F CELL VOL.11.80ml.SEP VOL.3.7ml.
THERMOCOUPLE, MV. 12.804 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 12 Psig at 80°F Lower Left Jerguson Gage				
1000	21.7	19	dry	0	0.607
"	23.0	64	dry	0	0.768
"	24.6	114	dry	0	0.715
"	26.2	164	dry?	0?	0.730
"	27.9	214	0.08*	1.0	-----
"	30.1	261	0.15*	1.7	0.658
"	33.1	307	0.25*	3.0	0.588
"	35.8	334	0.40*	4.8	-----
"	38.2	348	0.55*	6.3	0.449
	Upper Left Jerguson Gage				
"	3.4	372	1.30*	15.7	0.322
"	10.5	381	2.21	24.7	0.252
"	16.5	387	2.90	33.8	-----
"	22.3	389	3.55	41.8	0.184
"	27.4	390	4.09	48.3	-----
"	32.3	392	4.67	56.1	0.150
"	36.4	392	5.11	61.4	0.139
	Refill Upper Left Jerguson Gage				
"	2.9	392	5.11	61.4	0.139
"	9.6	392	5.89	70.1	-----
"	16.7	394	6.70	81.1	0.112
"	24.0	395	7.50	91.1	0.1018
"	----	398	8.00	97.7	------
"	30.4	398	8.45	99.5	0.0946
"	30.8	421	Single Phase	100	0.0999

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "A"   CELL TYPE 1/2" Strt NO. G
TEMPERATURE -169.29°F CELL VOL. 13.7ml. SEP VOL.4.3ml
THERMOCOUPLE, MV. 14.59 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 13 Psig at 73°F				
500	2.4	--	dry	---	-----
"	6.3	77	Trace	Trace	0.950
"	10.2	119	0.0*	0.7	0.823
"	14.5	157	0.13*	1.2	0.719
"	20.2	187	0.36*	2.5	0.589
"	23.9	198	0.55	3.9	0.513
"	29.5	206	1.06	6.5	0.421
"	34.2	208	1.28	8.1	0.361
"	38.7	212	1.57	10.5	0.321
1000	2.2	212	1.57	10.5	0.321
"	9.5	213	1.94	13.5	0.225
"	20.1	216	2.55	18.3	0.160
"	24.9	218	2.89	20.7	0.139
"	38.1	219	3.65	26.7	0.106
"	3.9	219	3.65	26.7	0.106
"	9.7	219	4.58	34.0	0.0950
"	18.3	221	5.71	43.0	0.0835
"	27.4	221	6.86	51.8	0.0735
"	38.1	222	8.17	62.5	0.0648
"	2.2	222	8.17	62.5	0.0648
"	26.0	223	11.23	87.0	0.0510
"	30.1	223	11.74	91.0	0.0493
"	36.6	225	12.70	98.0	0.0470
"	9.5	225	12.70	98.0	0.0470
"	11.5	229	12.88	99.0	0.0473
"	----	385	None Visible	100	------

* Read with agitator ball raised above the interface.

ORIGINAL DATA
GAS IDENTIFICATION "A"   CELL TYPE 1/2" Strt NO. G
TEMPERATURE   -198.90°F   CELL VOL. 13.7ml. SEP VOL. 4.3ml
THERMOCOUPLE, MV. 16.27   RESERVOIR TEMP. 100°F

Reservoir Pressure lb/sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
500	4.6	28	0	0	-----
"	5.8	44	0	0	0.909
"	7.6	63	Trace	Trace	1.052
"	10.4	86	0.0	0.7	0.718
"	12.2	94	0.15	1.3	0.636
"	14.6	99	0.30	2.1	0.532
"	17.6	102	0.50	3.6	-----
"	20.2	105	0.60	4.4	0.376
"	22.2	105	0.70	5.2	-----
"	23.9	106	0.80	6.0	0.310
"	26.4	107	0.92	7.1	-----
"	28.8	107	1.30	8.5	0.252
"	32.4	108	1.48	9.8	0.223
"	36.0	108	1.66	11.4	-----
"	38.0	108	1.76	12.0	0.187
"	2.8	108	1.76	12.0	0.187
"	9.6	108	2.10	14.6	0.156
"	17.8	108	2.52	18.0	-----
"	27.2	109	3.05	22.1	0.1104
"	37.9	109	3.62	22.6	0.0935
"	3.9	109	3.62	22.6	0.0935
"	16.8	110	4.33	32.4	0.0796
"	26.5	110	4.90+	36.7	0.0713
"	38.2	110	5.50	41.5	0.0633
"	2.0	110	5.50	41.5	0.0633
"	38.4	110	7.40	56.5	0.0468
"	2.6	110	7.40	56.5	0.0468
"	13.3	111	8.70	67.0	0.0439
"	38.0	115	11.45	88.5	0.0391

* Read with agitator ball raised above the interface.

\+ Agitator of the mixture in the cell could not be effected above this level because the agitator jammed.

ORIGINAL DATA

GAS IDENTIFICATION A700/770 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -59.80°F CELL VOL.11.1ml SEP VOL.3.9m
THERMOCOUPLE, MV. 7.30 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
		Filled to 10 Psig at 75°F			
1250	7.8	18	---	---	0.922
"	9.6	132	---	---	0.923
"	11.4	233	Trace	Trace	0.875
"	14.5	388	Trace	Trace	0.812
"	19.0	587	0.07*	0.3	0.733
"	23.4	747	0.10*	0.6	0.662
"	27.2	866	0.18*	1.2	-----
"	30.3	947	0.20*	1.4	0.577
"	34.2	1034	0.20*	1.4	-----
"	37.2	1091	0.20*	1.4	0.502
"	29.0	1091	0.20*	1.4	0.502
"	31.7	1143	0.18*	1.2	0.481
"	34.6	1197	0.10*	0.6	0.459
"	----	1220	0.02*	0.1	-----
"	37.4	1239	0	0	0.438

* Read with agitator ball raised above the interface.

Upper Dew pt. Density = 0.01056 gm mols/ml.

= 0.2033 gms./ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/770 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -79.64°F CELL VOL. 11.1ml SEP VOL.3.9
THERMOCOUPLE, MV. 8.74 RESERVOIR TEMP. 100°F

Filled to 15 Psig at 70°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1250	2.3	22	dry		0.970
"	4.5	148	Trace		0.858
"	6.6	261	Trace		0.854
"	10.9	456	0.07*	0.3	0.770
"	14.7	596	0.17*	1.0	0.692
"	20.0	745	0.30*	2.3	0.602
"	26.3	843	0.60	4.4	0.478
"	31.4	946	0.79	7.0	0.453
"	36.5	1002	1.00	10.0	0.404
"	6.0	1002	1.00	10.0	0.404
"	9.6	1038	0.67	5.1	0.375
"	---	1041	0.30*	2.3	-----
"	10.6	1044	dry	0	0.367
"	14.7	1119	dry		0.356

* Read with agitator ball raised above the interface.

Upper Dew pt. Density = .01118 gm. mols./ml.

= .2152 gms./ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/770 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -89.68°F CELL VOL.11.1ml SEP VOL.3.9ml
THERMOCOUPLE, MV. 9.45 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 12 Psig at 80°F				
1250	3.3	19	dry	0	0.979
"	4.9	108	Trace	Trace	0.895
"	6.6	201	Trace	Trace	0.871
"	9.5	341	0.11*	0.7	0.808
"	12.3	454	0.15*	1.0	0.743
"	16.4	584	0.24*	1.9	-----
"	19.9	673	0.35*	3.0	0.591
"	24.9	769	0.55*	5.2	-----
"	29.0	828	0.90	8.9	0.460
"	33.1	874	1.27	14.0	-----
"	37.1	909	1.71	21.0	-----
"	38.9	924	2.00	23.8	0.363
	Reservoir Refilled				
"	3.3	924	2.00	23.8	0.363
"	4.9	937	2.27	27.8	-----
"	6.5	948	2.56	31.7	-----
"	7.6	956	2.85	35.4	-----
"	8.3	961	3.00	37.2	0.329
"	---	962	3.10	38.4	-----
"	---	964	3.15	39.2	-----
"	---	965	3.40	42.5	-----
"	9.2	967	None Visible	None Visible	0.323
	Cooled to 9.58 mv (-91.53°F)				
"	9.2	950	4.30	54.3	
"	9.2+	950	None Visible	None Visible	
	Cooled to 9.70 mv (-93.26°F)				
"	9.2+	936	4.60	58.0	
	Cooled to 9.79 mv (-94.56°F)				
"	10.0	931	5.6	72.4	

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION A700/770 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -100.52°F CELL VOL.11.1ml SEP VOL.3.9ml
THERMOCOUPLE, MV. 10.20 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1250	10.6				
"	10.6	21	dry	0	
"	12.1	94	Trace	Trace	
"	13.8	167	Trace	Trace	
"	16.7	277	Trace	Trace	
"	20.8	344	0.10*	0.5	
"	25.0	519	0.25*	1.9	
"	29.4	608	0.37*	3.1	
"	33.3	666	0.55*	5.2	
"	37.0	708	0.78*	8.1	
"	39.2	719	0.88*	9.6	
	Reservoir Refilled				
"	20.9	719	0.88*	9.6	
"	25.3	755	1.31	14.5	
"	31.8	791	1.91	23.0	
"	36.2	825	2.85	35.5	
"	39.0	839	3.40	42.7	
	Reservoir Refilled				
"	3.6	839	3.40	42.7	
"	7.8	857	4.50	57.0	
"	9.4	862	4.90	62.6	
"	11.6	871	5.90	76.5	
"	13.2	879	6.90	89.7	
"	14.0	880	7.38	96.4	
"	14.4	882	7.60	98.6	
"	14.7	884	7.80	99.2	
"	14.9	886	None Visible	100	

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION A700/770 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -119.53°F CELL VOL.11.1ml SEP VOL.3.9ml
THERMOCOUPLE, MV. 11.48 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 11 Psig at 75°F				
1000	3.7	16	Trace	Trace	0.887
"	7.5	157	Trace	Trace	0.781
"	13.9	359	0.15*	1.0	0.703
"	19.4	464	0.44	2.5	0.592
"	26.3	554	0.82	7.5	-----
"	38.6	631	1.96	23.2	0.347
	Reservoir Refilled				
"	3.4	631	1.96	23.2	0.347
"	10.0	654	2.80	34.9	0.300
"	18.1	681	4.00	50.7	-----
"	24.3	700	4.90	62.5	0.236
"	29.9	713	5.93	77.0	-----
"	38.0	729	7.40	96.8	0.196
	Reservoir Refilled				
"	21.7	729	7.40	96.8	0.196
"	23.3	734	7.72	99.1	0.194
"	23.4	734	7.90	99.5	0.192
"	28.0	910	Single Phase	100	0.226

* Read with agitator ball raised above the interface.

Bubble pt. Density = 0.01685 gm. mols./ml.

= 0.3244 gms./ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/770 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -149.26°F CELL VOL. 11.1ml SEP VOL. 3.9ml
THERMOCOUPLE, MV. 13.38 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 13 Psig at 75°F				
750	2.0	17	dry	0	0.956
"	10.0	202	0.13*	0.9	0.732
"	20.5	339	0.58	4.3	0.533
"	29.0	380	1.06	11.0	0.402
"	38.0	406	1.64	19.5	0.318
"	2.0	406	1.64	19.5	0.318
"	15.2	431	2.60	32.0	0.245
"	26.2	446	3.55	44.5	-----
"	38.0	457	4.41	56.0	0.176
"	2.0	457	4.41	56.0	0.176
"	10.3	466	5.10	65.2	-----
"	20.1	475	5.90	76.5	0.145
"	30.0	484	6.74	87.8	-----
"	38.0	488	7.50	97.8	0.124
"	3.0	488	7.50	97.8	0.124
"	6.0	489	7.90	99.5	0.121
"	12.0	744	Single Phase	100	0.177

* Read with agitator ball raised above the interface.

Bubble pt. Density = 0.01895 gm. mols./ml.

= 0.3648 gms./ml.

ORIGINAL DATA
GAS IDENTIFICATION A700/770 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -199.64°F CELL VOL.11.1ml SEP VOL.3.9ml
THERMOCOUPLE, MV. 16.31 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 25 Psig at 70°F				
1000	5.3	21	Trace	Trace	0.937
"	6.3	52	Trace	Trace	0.866
"	8.5	100	0.17*	1.0%	0.696
"	11.5	121	0.38*	3.2	0.444
"	15.6	134	0.77	7.8	0.303
"	19.6	143	1.09	11.2	-----
"	23.9	151	1.44	16.3	0.190
"	30.1	159	1.92	24.2	-----
"	34.8	165	2.30	28.0	-----
"	39.1	170	2.63	32.8	0.118
"	2.9	170	2.63	32.8	0.118
"	10.1	176	3.20	40.0	-----
"	18.7	181	3.93	49.7	0.086
"	27.9	187	4.73	60.4	-----
"	39.0	192	5.62	72.9	0.064
"	18.9	192	5.62	72.9	0.064
"	28.0	196	6.42	83.6	-----
"	36.0	199	7.08	92.1	-----
"	39.0	200	7.32	95.5	0.052
"	11.3	200	7.32	95.5	0.052
"	11.4	200	7.52	95.5	-----
"	13.8	200	7.56	98.2	0.051
"	15.6	202	8.5	100	0.050
"	18.8	467	Single Phase	100	0.113

* Read with agitator ball raised above the interface.

Bubble pt. Density = 0.02314 gm. mols./ ml.

= 0.4454 gms./ ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/840 CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -79.91°F CELL VOL.11.1ml. SEP VOL.3.9ml
THERMOCOUPLE, MV. 8.76 RESERVOIR PRESSURE 1300
RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Per cent Liquid	Z
Filled to 25 Psig at 70°F					
1300	3.6	29	dry		0.938
	---	64	Trace		-----
	7.4	218	Trace		0.725
	---	414	0.14*	1.4	-----
	14.0	522	0.16*	1.5	0.683
	----	670	0.20*	1.6	-----
	21.9	785	0.29*	2.5	0.587
	----	901	0.37*	3.7	-----
	30.1	971	0.42*	4.4	-----
	34.4	1044	0.49*	5.2	0.457
	----	1085	0.49*	5.2	-----
	38.0	1100	0.47*	4.9	0.428
	20.6	1100	0.47*	4.9	0.428
	----	1124	0.41*	4.2	-----
	23.7	1143	0.35*	3.4	0.407
	----	1152	0.27*	2.5	-----
	----	1169	0.17*	1.5	-----
	26.6	1191	dry	0	0.392
Cooled to 10.56 mv (-104.91°F)					
Reservoir refilled to 11.7 & 1000 Psig					
1000	11.7	937	2.77	34.5	0.299
	14.7	954	3.30	41.2	-----
	18.3	971	4.55	58.2	0.276
	----	971	4.10	51.8	-----
	----	972	2.70	33.5	-----
	----	972	Single Phase	0	-----
Cooled to 10.60 mv (-106.37°F)					
		960	5.5	71.1	
		960	6.8	88.5	
Cooled to 10.70 mv (-107.84°F)					
		949	5.5	71.1	
		952	5.9	76.5	
		952	7.2	94.0	
		952	Single Phase	100	

* Read with agitator ball raised above interface.

ORIGINAL DATA

GAS IDENTIFICATION A700/840 CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -99.78°F CELL VOL. 11.1ml. SEP VOL.3.9
THERMOCOUPLE, MV. 10.15 RESERVOIR PRESSURE 1250
RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 25 Psig at 80°F				
	3.7	27	dry	0	0.929
	---	73	Trace	Trace	------
	6.6	165	Trace	Trace	0.763
	9.7	315	0.12*	0.9	0.785
	16.3	543	0.23*	1.5	0.643
	24.1	728	0.47*	4.1	------
	31.1	834	0.95	9.5	0.448
	38.1	910	1.49	16.9	0.385
	2.9	910	1.49	16.9	0.385
	7.4	949	2.00	23.9	------
	11.5	982	2.54	31.5	0.329
	----	990	2.70	33.5	------
	----	999	2.40	29.3	------
	----	1001	None	0	------
	15.1	1016	None	0	0.313

* Read with agitator ball raised above the interface.

U. D. P. = 0.01197 g. mol/ml. = 0.2387 g./ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/840 CELL TYPE 1/2"Strt. NO. 25
TEMPERATURE -110.24°F CELL VOL.11.1ml. SEP VOL.3.9
THERMOCOUPLE, MV. 10.86 RESERVOIR TEMP.100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
		Filled to 18 Psig at 80°F			
1000	2.0	23	dry	0	1.011
"	---	65	dry	0	-----
"	4.7	134	Trace	Trace	0.892
"	7.8	245	Trace	Trace	0.811
"	15.0	455	0.17*	1.4	0.697
"	25.0	634	0.55*	3.9	0.541
"	38.1	756	1.41	15.9	0.403
"	2.0	756	1.41	15.9	0.403
"	12.0	822	2.50	31.1	0.338
"	20.0	867	3.89	49.0	0.302
"	26.0	892	5.65	73.2	0.278
"	29.6	908	7.58	98.4	0.267
"	----	912	7.82	99.2	-----
"	30.6	922	Single Phase	100	0.267

* Read with agitator ball raised above the interface.

B. P. = 0.01479 g. mol/ml. = 0.2949 gm/ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/840 CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -129.80°F CELL VOL.11.1ml. SEP.VOL.3.9m
THERMOCOUPLE, MV. 12.15 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 27 Psig at 70°F				
1000	3.2	27	dry	0	0.936
	5.2	105	Trace	Trace	0.879
	8.5	214	0.11*	0.8	0.790
	12.8	334	0.20*	1.3	-----
	20.0	472	0.40*	3.5	0.567
	29.7	569	1.11	11.8	-----
	38.2	621	1.89	22.9	0.350
	3.0	621	1.89	22.9	-----
	13.0	666	3.01	37.2	0.290
	23.1	702	4.42	56.0	0.248
	30.1	724	5.56	71.9	0.206
	37.8	744	6.90	89.5	-----
	10.0	744	6.90	89.5	-----
	13.1	752	7.49	97.5	0.199
	----	754	7.85	99.4	-----
	16.2	821	Single Phase	100	0.209

* Read with agitator ball raised above the interface.

B. P. = 0.01713 g. mol/ml. = 0.3416 gm/ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/840 CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -159.92°F CELL VOL.11.1ml. SEP VOL.3.9
THERMOCOUPLE, MV. 14.03 RESERVOIR TEMP. 100°F

Filled to 25 Psig at 65°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	6.1	27	Trace	Trace	1.075
	8.2	95	Trace	Trace	0.814
	10.7	166	0.13*	0.9	0.744
	14.4	250	0.23*	1.9	0.647
	18.9	309	0.44*	4.0	-----
	24.8	354	1.00	10.2	0.407
	31.3	384	1.50	17.0	-----
	38.0	410	2.10	25.2	0.274
	3.8	410	2.10	25.2	0.274
	11.3	434	2.82	35.0	0.233
	20.8	457	3.79	47.8	0.197
	30.0	474	4.80	61.1	-----
	37.7	487	5.59	72.2	0.150
	3.1	487	5.59	72.2	0.150
	11.2	499	6.50	84.5	0.136
	17.5	507	7.19	93.8	-----
	19.6	509	7.47	97.4	0.125
	21.3	510	7.73	99.0	0.123
	23.5	634	Single Phase	100	0.149

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION A700/840 CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -199.64°F CELL VOL. 11.1ml.SEP VOL.3.9m
THERMOCOUPLE, MV. 16.31 RESERVOIR PRESSURE 1000
RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. gage	Liquid in cell	Volume Percent Liquid	Z
	Filled to 16 Psig at 70°F				
1000	1.9	14	Trace	Trace	0.797
	---	86	Trace	Trace	------
	8.0	123	0.23*	1.9	0.481
	15.0	152	0.86	8.0	0.278
	20.2	169	1.23	13.5	------
	26.2	179	1.72	21.1	0.176
	30.1	186	2.05	24.5	------
	34.1	191	2.38	29.0	------
	39.0	198	2.74	34.1	0.127
	2.0	198	2.74	34.1	------
	10.0	212	3.38	42.1	------
	18.1	224	4.06	51.4	0.100
	26.0	233	4.73	60.1	------
	32.0	238	5.21	67.0	------
	39.0	245	5.80	75.1	0.079
	2.0	245	5.80	75.1	0.079
	7.0	251	6.25	81.3	------
	13.0	254	6.75	87.8	------
	17.0	257	7.12	92.9	0.069
	20.0	259	7.38	96.2	------
	23.0	262	7.78	99.2	0.066
	28.0	699	Single Phase	100	0.169

* Read with agitator ball raised above the interface.

B. P. = 0.02376 gm mol/ml. = 0.4738 gm/ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/940 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -79.91°F CELL VOL. 11.1ml SEP VOL. 3.9ml
THERMOCOUPLE, MV. 8.76 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 17 Psig at 81°F				
1250	2.2	24	dry	0	1.017
"	---	94	Trace	Trace	------
"	9.0	381	Trace	Trace	0.840
"	---	475	0.10*	0.7	------
"	15.0	628	0.14*	1.0	0.737
"	----	646	0.18	1.2	------
"	22.0	849	0.23	1.6	0.640
"	----	942	0.28	2.2	------
"	30.0	1045	0.29	2.2	0.556
"	34.0	1128	0.30	2.4	0.520
"	34.0	1128	0.30	2.4	------
"	38.0	1205	0.80	2.0	0.494
"	20.0	1205	0.26	2.0	-----
"	23.0	1266	0.16	1.0	0.476
"	----	1287	0.13	0.9	-----
"	25.0	1306	0.12	0.8	0.467

* Read with agitator ball raised above the interface.

Run terminated because of hazard of high pressure.

ORIGINAL DATA

GAS IDENTIFICATION A700/940 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -99.78°F CELL VOL. 11.1ml SEP VOL. 3.9ml
THERMOCOUPLE, MV. 10.15 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 27 Psig at 78°F				
1250	2.0	26	dry	0	0.856
"	15.2	574	0.18*	1.1	0.671
"	26.5	845	0.42*	3.9	0.525
"	38.3	1024	0.73*	7.5	0.424
"	2.0	1024	0.73*	7.5	------
"	7.6	1091	0.60*	5.9	0.388
"	---	1119	0.50*	4.7	------
"	11.0	1136	0.30*	2.5	0.373
"	----	1144	0.20*	1.5	------

* Read with agitator ball raised above the interface.

Bath too cloudy for further observations.

ORIGINAL DATA

GAS IDENTIFICATION A700/940 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -110.24°F CELL VOL.11.1ml SEP VOL.3.9ml
THERMOCOUPLE, MV. 10.86 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 18 Psig at 76°F					
1250	20.6	21	Trace	Trace	0.896
"	----	89	Trace	Trace	------
"	23.5	172	Trace	Trace	0.878
"	27.2	333	0.10*	0.5	0.790
"	32.4	505	0.20*	1.3	0.681
"	38.1	652	0.40	2.1	0.591
"	2.0	652	0.40	2.1	------
"	11.2	830	0.72	6.1	0.486
"	16.9	898	1.00	10.1	0.427
"	24.8	962	1.80	22.1	0.364
"	32.0	1009	1.86	22.7	------
"	32.2	1012	dry	0	0.320

* Read with agitator ball raised above the interface.

Upper Dew Point Density = 0.0135 g. moles/ml.

= 0.2801 grams/ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/940 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -119.83°F CELL VOL. 11.1 ml SEP VOL. 3.9ml
THERMOCOUPLE, MV. 11.50 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 23 Psig at 78°F					
1000	2.7	27	dry	0	1.046
"	---	64	Trace	Trace	------
"	5.0	114	0.10*	0.5	0.883
"	7.9	217	0.15*	1.0	0.815
"	12.5	355	0.16*	1.0	0.728
"	18.5	504	0.24*	1.9	0.654
"	24.4	617	0.38*	3.2	0.577
"	30.1	699	0.68	5.1	-----
"	38.0	781	1.02	10.6	0.443
"	3.0	781	1.02	10.6	-----
"	9.2	835	1.43	16.1	-----
"	15.1	881	1.92	23.1	0.367
"	21.0	924	2.60	32.1	-----
"	24.0	942	3.01	37.1	0.328
"	----	955	3.39	42.2	-----
"	----	964	3.70	46.5	-----
"	28.0	967	3.90	49.5	0.314
"	----	979	4.69	59.5	-----
"	30.3	979	4.65	59.0	0.307
"	30.3	979	dry	0	-----
Cooled to 11.75 mv (-122.65)					
		939	5.20	66.6	
		947	6.20	80.5	
		951	7.19	93.8	
		955	Single Phase	100	

* Read with agitator ball raised above the interface.

Upper Dew Point Sat. Density = 0.0135 gm mols/ml.
= 0.2801 gms/ml.

ORIGINAL DATA
GAS IDENTIFICATION A700/940 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -129.80°F CELL VOL.11.1ml SEP VOL.3.9ml
THERMOCOUPLE, MV. 12.15 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 12 Psig at 70°F				
1000	2.1	16	dry	0	0.865
"	---	53	Trace	Trace	------
"	4.3	102	Trace	Trace	0.855
"	8.8	254	0.05*	0.4	0.803
"	14.8	408	0.20*	1.3	0.677
"	20.4	516	0.46	2.8	0.590
"	30.2	639	0.90	8.7	0.469
"	37.8	701	1.40	15.7	0.401
"	2.0	701	1.40	15.7	-----
"	15.9	782	2.86	35.4	0.318
"	25.0	828	4.32	54.6	0.283
"	29.5	846	5.27	67.7	-----
"	34.1	865	6.46	84.0	-----
"	37.5	875	7.49	97.5	0.244
"	1.7	875	7.49	97.5	-----
"	2.2	876	7.64	98.8	-----
"	2.6	876	8.55	100	0.241

* Read with agitator ball raised above the interface.

Bubble Point Density = 0.01644 gm mols/ml.

0.3411 gms./ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/940 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -159.92°F CELL VOL.11.1ml SEP VOL.3.9ml.
THERMOCOUPLE, MV. 14.03 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 23 Psig at 70°F				
1000	2.5	23	Trace	Trace	0.964
"	13.6	312	0.28*	2.1	0.619
"	23.6	426	0.93	9.0	0.446
"	30.8	468	1.50	17.0	0.362
"	38.2	507	2.10	25.3	0.309
"	2.1	507	2.10	25.3	-----
"	10.1	540	2.88	35.8	0.267
"	23.2	568	4.38	55.4	0.215
"	30.3	587	5.24	67.5	0.197
"	38.1	604	6.19	80.2	0.180
"	2.0	604	6.19	80.2	-----
"	10.3	619	7.30	95.2	0.165
"	13.6	635	Single Phase	100	0.162

* Read with agitator ball raised above the interface.

Bubble Point Density = 0.01892 gm. mols/ml.

= 0.3926 gms/ml.

ORIGINAL DATA

GAS IDENTIFICATION A700/940 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -199.64°F CELL VOL.11.1ml SEP VOL.3.9ml
THERMOCOUPLE, MV. 16.31 RESERVOIR TEMP. 100°F

Filled to 27 Psig at 75°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	2.0	29	Trace	Trace	1.303
"	8.0	148	0.25*	2.0	0.586
"	15.4	203	0.77	6.8	0.368
"	28.0	231	1.44	16.0	0.215
"	30.2	251	1.78	22.0	-----
"	39.8	272	2.46	30.1	0.174
"	2.0	272	2.46	30.1	-----
"	10.2	289	3.10	38.5	0.152
"	18.0	302	3.73	47.0	-----
"	25.0	311	4.28	54.0	0.123
"	34.0	319	5.10	65.3	-----
"	39.8	325	5.54	71.7	0.104
"	2.0	325	5.54	71.7	-----
"	10.0	332	6.25	81.3	0.096
"	18.0	336	6.95	90.2	0.088
"	25.6	353	7.52	98.0	-----
"	25.6	343	7.54	98.4	0.083

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "AB" CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -79.91°F CELL VOL.11.1ml. SEP VOL.3.9ml
THERMOCOUPLE, MV.8.76 RESERVOIR PRESSURE 1250
RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 22 Psig at 75°F				
	5.5	26	dry	0	0.916
	---	74	dry	0	-----
	---	116	Trace	Trace	-----
	8.9	200	Trace	Trace	0.766
	---	293	Trace	Trace	-----
	12.1	356	Trace	Trace	0.759
	----	441	0.12*	0.8	-----
	16.2	524	0.13*	0.9	0.696
	20.8	668	0.14*	0.9	0.621
	25.6	774	0.15*	1.0	0.533
	----	827	0.14*	0.9	-----
	32.9	889	0.13*	0.9	0.449
	34.6	914	dry	0	0.436

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "AB" CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -97.00°F CELL VOL.11.1ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 9.96 RESERVOIR PRESSURE 1000
RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure, lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 17 Psig at 72°F					
1.7	23	dry	0	0.992
---	74	dry	0	-----
---	125	dry	0	-----
5.5	191	Trace	Trace	0.615
---	274	Trace	Trace	-----
10.1	368	Trace	Trace	0.881
13.6	462	Trace	Trace	0.768
17.8	561	0.10*	0.5	0.682
22.0	639	0.29	1.1	0.603
26.8	701	0.36	2.1	0.528
28.3	716	0.40	2.4	0.509
32.4	744	0.48	3.5	0.452
33.8	756	0.56	4.3	0.439
----	766	0.63	4.9	-----
38.3	780	0.75	6.5	0.392
2.0	780	0.75	6.5	0.392
---	783	0.77	6.9	-----
---	784	0.80	7.2	-----
---	786	0.77	6.9	-----
---	787	0.74	6.4	-----
---	791	0.67	5.2	-----
6.0	792	0.58	4.1	0.357
---	794	0.39	2.1	-----
6.8	795	Single Phase	0	0.351
11.7	814	Single Phase	0	0.320
25.2	899	Single Phase	0	0.270

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "AB" CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -99.78°F CELL VOL.11.1ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 10.15 RESERVOIR PRESSURE 1250
RESERVOIR TEMP. 105°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Per cent Liquid	Z
Filled to 24 Psig at 88°F					
	2.0	26	dry	0	0.936
	5.0	176	Trace	Trace	0.811
	11.0	429	0.10*	0.6	0.730
	18.5	626	0.17*	1.2	0.573
	25.1	713	0.39*	3.3	0.455
	31.9	755	0.90*	10.0	0.389
	38.0	775	dry	0	0.311

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "AB" CELL TYPE 1/2"Strt NO.25
TEMPERATURE -102.86°F CELL VOL.11.1ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 10.36 RESERVOIR PRESSURE 1000
RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	E
	Filled to 21 Psig at 75°F				
	1.7	26	dry	0	1.007
	---	125	dry	0	-----
	7.0	224	Trace	Trace	0.813
	---	313	Trace	Trace	-----
	12.1	391	0.10*	0.5	------
	----	454	0.11*	0.6	-----
	16.9	516	0.12*	0.7	0.648
	22.0	603	0.19*	1.2	-----
	29.2	681	0.39*	3.3	0.467
	37.8	727	1.10	11.7	0.373
	2.5	727	1.10	11.7	0.283
	9.8	746	2.1	26.2	-----
	14.8	753	3.91	49.3	0.286
	----	753	4.30	54.3	-----
	----	753	4.63	58.5	-----
	----	754	5.33	68.5	-----
	15.8	754	7.05	91.9	0.277
	16.0	754	None Visible	None Visible	0.276

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "AB" CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -112.30°F CELL VOL.11.1ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 11.00 RESERVOIR PRESSURE 1000
RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 24 Psig at 81°F					
	2.0	26	dry	0	0.955
	4.5	129	Trace	Trace	0.893
	10.2	310	Trace	Trace	0.744
	16.3	367	0.12*	0.8	0.491
	22.0	561	0.26*	2.0	0.545
	29.5	621	0.81	7.5	0.430
	38.1	646	1.96	23.3	0.335
	3.2	646	1.96	23.3	0.335
	10.3	657	3.20	40.0	0.269
	16.0	661	4.33	54.8	0.236
	21.0	666	5.55	71.8	0.226
	25.0	668	6.54	85.0	0.210
	28.2	670	6.56	95.2	0.200
	29.8	673	6.59	100	0.195

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "AB" CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -149.91°F CELL VOL. 11.1ml. SEP VOL3.9ml.
THERMOCOUPLE, MV. 13.42 RESERVOIR PRESSURE 1000
RESERVOIR TEMP.100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 22 Psig at 82°F				
	2.3	26	dry	0	1.123
	---	64	Trace	Trace	-----
	4.8	117	Trace	Trace	1.062
	8.9	231	0.14*	0.9	0.741
	15.1	322	0.52	3.8	0.529
	22.8	340	1.24	13.9	0.339
	30.1	345	2.00	23.9	0.251
	38.2	347	2.82	35.0	0.197
	2.2	347	2.82	35.0	0.197
	10.0	349	3.64	45.8	0.162
	18.6	349	4.53	57.2	0.1336
	26.3	351	5.40	69.6	------
	32.0	351	5.99	77.6	0.1066
	38.0	351	6.59	85.8	0.0976
	3.7	351	6.59	85.8	0.0976
	10.3	351	7.22	94.3	0.0892
	14.5	354	Single Phase	100	0.0855

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "AB"
TEMPERATURE -199.86°F
THERMOCOUPLE, MV. 16.32

CELL TYPE 1/2"Strt NO. 25
CELL VOL. 11.1ml. SEP VOL.3.9ml
RESERVOIR PRESSURE 1000
RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 28 Psig at 85°F				
	1.9	22	dry	0	
	6.2	105	0.20*	1.4	
	16.3	112	1.11	11.6	
	38.2	113	2.85	35.3	
	2.4	113	2.85	35.3	
	23.3	114	4.50	57	
	37.8	114	5.63	73	

Run not completed because nitrogen supply was exhausted.

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION AB700/800 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -99.78°F CELL VOL.11.1ml SEP VOL.3.9ml
THERMOCOUPLE, MV. 10.15 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 22 Psig at 75°F				
1000	2.6	27	dry	0	1.020
"	---	125	dry	0	-----
"	6.5	185	dry	0	0.853
"	---	262	Trace?	Trace?	-----
"	10.1	323	Trace	Trace	0.832
"	----	411	Trace	Trace	-----
"	15.4	481	Trace	Trace	0.737
"	20.0	594	0.12*	0.8	0.668
"	----	698	0.13*	0.9	-----
"	30.2	770	0.13*	0.9	0.540
"	35.4	829	0.14*	1.0	0.487
"	38.0	854	0.11*	0.1	0.462
"	2.7	854	0.11*	0.7	0.462
"	---	861	Trace	Trace	-----
"	5.4	875	dry	0	0.438
"	11.6	932	dry	0	0.398

* Read with agitator ball raised above the interface.

U. D. P. = 0.008297 g mol/ml. = 0.1503 g/ml.

ORIGINAL DATA

GAS IDENTIFICATION AB700/800 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -110.24°F CELL VOL.11.1ml SEP VOL.3.9ml
THERMOCOUPLE, MV. 10.86 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 22 Psig at 80°F					
1250	2.0	25	dry	dry	0.965
"	4.3	140	dry	dry	0.863
"	6.4	238	Trace	Trace	0.825
"	10.0	392	Trace	Trace	0.772
"	15.0	547	Trace	Trace	0.664
"	20.0	659	0.18*	1.1	0.571
"	25.2	733	0.31*	2.6	0.487
"	30.8	785	0.63	4.9	0.414
"	----	817	0.79	7.0	-----
"	----	827	0.49*	4.5	-----
"	----	832	dry	0	-----

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION AB700/800 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -113.51°F CELL VOL.11.1ml SEP VOL.3.9m
THERMOCOUPLE, MV. 11.08 RESERVOIR TEMP. 100°F

Reservoir Pressure lb/sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 24 Psig at 76°F				
1000	14.9	27	dry	0	0.988
"	17.4	127	Trace?	Trace?	0.895
"	20.8	249	Trace	Trace	0.829
"	26.0	407	Trace	Trace	0.733
"	32.0	546	0.10*	0.6	-----
"	38.0	640	0.20*	1.4	0.553
"	1.6	640	0.20*	1.4	-----
"	10.1	722	0.52	3.5	0.448
"	15.5	757	0.80	7.2	0.398
"	20.4	781	1.13	12.0	0.360
"	24.9	801	1.40	15.7	0.332
"	----	807	1.46	16.4	-----
"	----	808	1.16	12.5	-----
"	----	810	0.66	4.0	-----
"	27.5	811	dry	0	0.318
"	38.0	879	dry	0	0.282

* Read with agitator ball raised above the interface.

U. D. P. = 0.01101 g. mol/ml. = 0.1994 gram/ml.

ORIGINAL DATA
GAS IDENTIFICATION AB700/800 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -118.48°F CELL VOL.11.1ml SEP VOL.3.9m
THERMOCOUPLE, MV. 11.41 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
		Filled to 25 Psig at 76°F			
1000	8.3	26	dry	0	0.930
"	---	114	dry	0	-----
"	12.7	189	Trace	Trace	0.820
"	18.2	361	Trace	Trace	0.734
"	----	417	0.10*	0.7	-----
"	24.1	503	0.12*	0.8	0.650
"	30.7	608	0.24*	1.9	0.546
"	38.0	677	0.63	4.8	0.453
"	7.3	677	0.63	4.8	0.453
"	15.1	724	1.27	13.8	-----
"	22.5	756	2.29	27.8	0.326
"	----	775	3.82	48.3	-----
"	----	778	4.60	58.0	-----
"	30.4	779	5.73	74.2	0.285
"	30.6	779	None Visible	None Visible	0.283

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION AB700/800 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -119.83°F CELL VOL. 11.1ml SEP VOL. 3.9ml
THERMOCOUPLE, MV. 11.50 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 30 Psig at 77°F				
1000	2.0	31	dry	0	1.009
"	3.8	107	dry	0	0.950
"	6.5	214	Trace	Trace	0.900
"	11.9	388	Trace	Trace	0.792
"	19.3	544	0.18*	2.1	0.635
"	28.0	648	0.64	4.9	0.498
"	38.0	706	1.60	18.5	0.385
"	2.6	706	1.60	18.5	0.385
"	12.3	740	3.24	40.5	-----
"	18.1	756	4.84	61.9	0.284
"	21.2	766	6.09	78.8	-----
"	23.5	770	7.40	96.8	0.260
"	23.7	770	7.55	98.4	-----
"	23.9	771	Single Phase	100	0.258
"	31.0	838	Single Phase	100	0.242

* Read with agitator ball raised above the interface.

B. P. = 0.01312 g. mol/ml. = 0.2376 grams/ml.

ORIGINAL DATA
GAS IDENTIFICATION AB700/800 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -128.25°F CELL VOL.11.1ml SEP VOL.3.9ml
THERMOCOUPLE, MV. 12.05 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 23 Psig at 80°F				
1000	2.7	25	dry	0	0.985
"	---	74	dry	0	-----
"	6.7	173	Trace	Trace	0.833
"	10.5	299	Trace	Trace	0.796
"	15.4	423	0.12*	0.8	0.694
"	21.7	517	0.29*	2.2	-----
"	30.3	599	0.92	9.1	0.440
"	38.2	634	1.75	21.5	0.359
"	2.8	634	1.75	21.5	0.359
"	10.3	657	2.75	34.0	0.303
"	18.8	680	4.20	53.0	0.261
"	27.0	698	5.91	76.5	0.229
"	31.4	706	6.90	89.6	0.215
"	33.8	710	7.51	97.8	-----
"	34.4	712	Single Phase	100	0.207

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION AB700/800 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -158.58°F CELL VOL.11.1ml SEP VOL.3.9m
THERMOCOUPLE, MV. 13.95 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 23 Psig at 83°F				
1000	3.2	24	dry	0	1.041
"	4.4	106	Trace	Trace	-----
"	11.0	257	0.12*	0.8	0.734
"	19.0	346	0.70	5.9	0.481
"	26.2	375	1.30	14.5	0.353
"	32.1	390	1.87	22.7	-----
"	38.0	404	2.44	30.0	0.248
"	2.0	404	2.44	30.0	0.248
"	10.2	420	3.29	41.0	-----
"	18.0	433	4.12	52.1	0.181
"	26.0	443	5.00	64.0	0.159
"	32.0	450	5.67	73.5	-----
"	38.2	457	6.36	82.6	0.136
"	2.2	457	6.36	82.6	-----
"	8.4	461	7.05	91.9	-----
"	12.3	464	7.57	98.4	0.120
"	13.9	465	7.72	99.0	-----
"	14.8	499	Single Phase	100	0.126

* Read with agitator ball raised above the interface.

B. P. = 0.01919 g. mol/ml. = 0.3475 grams/ml.

ORIGINAL DATA

GAS IDENTIFICATION AB700/800 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -199.86°F CELL VOL.11.1ml SEP VOL.3.9m
THERMOCOUPLE, MV. 16.32 RESERVOIR TEMP. 102°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 28 Psig at 85°F				
1000	2.0	22	dry?	0?	0.943
"	---	49	Trace	Trace	-----
"	6.2	119	0.17*	1.1	0.661
"	10.4	139	0.47*	4.2	0.391
"	16.4	157	1.02	10.5	-----
"	25.9	174	1.80	22.2	0.176
"	38.0	188	2.70	33.6	0.126
"	1.9	188	2.70	33.6	0.126
"	15.1	202	3.78	47.5	0.099
"	28.4	211	4.87	62.1	0.081
"	38.0	215	5.64	73.2	-----
"	30.7	215	5.64	73.2	-----
"	38.0	219	6.26	81.1	0.072
"	15.5	219	6.26	81.1	0.072
"	25.4	223	7.01	91.5	0.060
"	32.0	227	7.63	98.8	0.057
"	32.7	227	Single Phase	100	0.057

* Read with agitator ball raised above the interface.

ORIGINAL DATA
GAS IDENTIFICATION AB 700/940   CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -104.91°F   CELL VOL.11.1 ml.SEP VOL.3.
THERMOCOUPLE, MV. 10.50   RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 20 Psig at 76°F				
1000	1.9	25	dry	dry	1.008
"	4.4	137	Trace?	Trace?	1.001
"	8.5	291	Trace	Trace	0.878
"	13.0	441	Trace	Trace	0.805
"	19.1	604	Trace	Trace	0.717
"	25.5	735	Trace?	Trace?	0.631
"	33.2	868	Trace?	Trace?	-----
"	38.0	934	Trace?	Trace?	0.516
"	10.0	934	Trace?	Trace?	-----
"	15.9	1009	?	?	0.478

ORIGINAL DATA

GAS IDENTIFICATION AB 700/940 CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -119.83°F CELL VOL.11.1ml SEP VOL.3.9
THERMOCOUPLE, MV. 11.50 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 23 Psig at 75°F					
1250	2.2	26	dry	0	0.999
"	---	68	Trace	Trace	-----
"	5.9	200	Trace	Trace	0.827
"	9.5	351	Trace	Trace	0.779
"	13.5	486	0.12*	0.8	0.712
"	18.1	610	0.16*	1.0	-----
"	23.1	712	0.18*	1.2	0.555
"	27.4	774	0.20*	1.3	-----
"	30.4	811	0.21*	1.4	0.465
"	33.0	840	0.18*	1.1	-----
"	----	848	0.12*	0.8	-----
"	34.4	854	dry	0	0.425
Cooled to 12.15 mv (-129.80°F) Gage Refilled to 17.2					
"	22.6	813	1.59	18.1	0.340
"	----	817	1.43	15.9	-----
"	----	819	0.96	9.4	-----
"	24.5	821	Single Phase	0	0.326
Cooled to 12.41 mv (-133.83°F)					
"	26.4	797	3.91	49.5	0.300
"	----	801	4.65	58.9	-----
"	----	802	5.18	66.4	-----
"	-----	803	5.90	76.4	-----
"	28.5	804	Single Phase	100	0.285

* Read with agitator ball raised above the interface.

Upper Dew pt. Density (-119.83°F) = .008829 gm mols/ml. = .1727 gms/ml.

Upper Dew pt. Density (-129.80°F) = .01108 gm mols/ml. = .2167 gms/ml.

Bubble pt. Density (-133.83°F) = .01228 gm mols/ml. = .2402 gms/ml.

ORIGINAL DATA

GAS IDENTIFICATION AB 700/940 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -130.58°F CELL VOL. 11.1ml.SEP VOL.3.9
THERMOCOUPLE, MV. 12.20 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 25 Psig at 76°F				
1000	2.0	26	dry	0	0.964
"	4.4	119	dry?	0?	0.923
"	8.0	236	Trace	Trace	0.815
"	12.8	326	Trace	Trace	0.625
"	16.6	473	0.11*	0.6	-----
"	24.5	600	0.38	2.6	0.565
"	29.3	653	0.51	3.3	-----
"	38.3	723	1.05	11.0	0.415
"	2.0	723	1.05	11.0	-----
"	8.2	757	1.63	19.2	-----
"	14.0	788	2.30	28.0	0.334
"	20.1	812	3.60	45.2	0.305
"	21.4	817	4.05	51.5	0.299
"	21.4	817	None Visible	None Visible	---
"	28.3	874	Single Phase	Single Phase	.284

* Read with agitator ball raised above the interface.

Upper Dew pt. Density = .01261 gm mols/ml.

= .2467 gms/ml.

ORIGINAL DATA

GAS IDENTIFICATION AB 700/940 CELL TYPE 1/2"Strt NO.25
TEMPERATURE -136.82°F CELL VOL.11.1ml. SEP VOL. 3.
THERMOCOUPLE, MV. 12.60 RESERVOIR TEMP. 110°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 22 Psig at 77°F				
1000	2.0	24	dry	0	0.986
"	---	124	dry?	0?	-----
"	6.0	169	Trace	Trace	0.851
"	---	274	Trace	Trace	-----
"	12.5	359	Trace	Trace	0.741
"	----	440	0.12*	0.7	-----
"	18.6	492	0.17*	1.1	0.643
"	24.6	581	0.32*	2.7	0.554
"	30.3	637	0.59*	5.7	-----
"	38.1	691	1.26	14.0	0.403
"	2.6	691	1.26	14.0	-----
"	8.5	719	1.84	22.5	-----
"	15.0	751	2.85	35.4	0.322
"	22.0	777	4.42	56.0	-----
"	24.0	784	5.12	65.6	-----
"	25.8	790	5.96	77.2	0.275
"	----	794	6.59	85.6	-----
"	----	796	7.30	95.2	-----
"	27.9	797	Single Phase	100	0.268
"	38.0	928	Single Phase	100	0.254

* Read with agitator ball raised above the interface.

Bubble pt. Density = .01377 gm mols/ml

= .2693 gms/ml.

ORIGINAL DATA

GAS IDENTIFICATION AB 700/940 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -149.91°F CELLVOL. 11.1ml. SEP VOL.3.9ml
THERMOCOUPLE, MV, 13.42 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 24 Psig at 80°F				
1000	2.0	25	dry	0	1.022
"	6.0	162	0.10*	0.6	0.859
"	10.0	195	0.10*	0.6	0.530
"	17.2	426	0.22*	1.8	0.648
"	25.2	511	0.70*	7.1	0.503
"	30.3	541	1.25	13.9	-----
"	38.2	578	2.05	24.5	0.359
"	2.0	578	2.05	24.5	-----
"	10.0	611	3.00	37.2	-----
"	18.2	636	4.10	51.8	0.269
"	24.0	654	5.03	64.4	-----
"	30.0	669	6.08	78.8	0.229
"	35.2	682	7.07	92.1	0.216
"	20.0	682	7.07	92.1	-----
"	22.6	687	7.49	97.5	-----
"	----	687	7.65	98.9	-----
"	23.5	695	Single Phase	100	0.209

* Read with agitator ball raised above the interface.

Bubble pt. Density = .01603 gm mols/ml.

= .3154 gms/ml.

ORIGINAL DATA
GAS IDENTIFICATION AB 700/940 CELL TYPE 1/2" Strt NO. 25
TEMPERATURE 199.86°F CELL VOL 11.1ml SEP VOL.3.9ml.
THERMOCOUPLE, MV. 16.32 RESERVOIR TEMP. 102°F

Filled to 31 Psig at 87°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	2.0	26	dry	0	1.057
"	7.0	147	0.18*	1.1	0.711
"	12.0	183	0.57	4.1	0.449
"	22.0	225	1.21	13.2	0.278
"	33.1	252	2.16	26.0	-----
"	38.0	260	2.53	31.3	0.179
"	2.0	260	2.53	31.3	-----
"	16.0	284	3.59	45.0	0.141
"	28.1	297	4.73	60.0	-----
"	38.4	305	6.14	79.7	0.104
"	2.0	305	6.14	79.7	-----
"	16.4	319	6.90	89.6	0.091
"	22.3	325	7.45	97.2	0.087
"	25.2	325	Single Phase	100	0.084

* Read with agitator ball raised above the interface.

Bubble pt. Density = .02225 gm mols/ml.

= .4352 gms/ml.

ORIGINAL DATA

GAS IDENTIFICATION "B" CELL TYPE 1/2"Strt NO. 20
TEMPERATURE -39.84°F CELL VOL. 10.2 ml.SEP VOL.3.9ml.
THERMOCOUPLE, MV. 5.80 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 8 Psig at 0°F Hg in Cell to 0.2*					
1200	6.8	19	dry	0	0.903
"	9.9	213	Trace	Trace	0.836
"	13.5	408	Trace	Trace	0.788
"	14.5	524	0.25*	0.5	0.919
"	18.2	644	0.29*	0.9	0.736
"	21.5	785	0.34*	1.8	0.695
"	24.6	905	0.41*	1.9	0.661
"	29.0	1052	0.60	2.8	0.607
"	31.0	1112	0.60	2.8	0.586
"	33.1	1174	0.60	2.8	0.569
"	34.5	1214	0.61	2.9	0.558

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "B" CELL TYPE 1/2"Strt NO. 20
TEMPERATURE -59.80°F CELL VOL. 10.2 ml.SEP VOL.3.9ml.
THERMOCOUPLE, MV. 7.30 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 17 Psig at 75°F					
1200	4.6	24	dry		
"	7.3	183	dry?	0?	
"	9.4	305	Trace	Trace	
"	11.0	389	0.14*	1.0	
"	13.2	494	0.20*	1.3	
"	15.3	585	0.23*	1.6	
"	17.4	667	0.29*	2.0	
"	20.9	790	0.51	2.9	
"	24.3	892	0.60	3.8	
"	28.2	996	0.70	5.0	
"	30.4	1050	0.77	6.0	
"	32.4	1092	0.80	6.7	
"	34.4	1136	0.87	7.5	
"	36.4	1172	0.90	8.0	

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "B" CELL TYPE 1/2"Strt NO. 18
TEMPERATURE -79.64°F CELL VOL.10.2ml. SEP VOL.3.70ml
THERMOCOUPLE, MV. 8.74 RESERVOIR TEMP.100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 12 Psig at 76°F				
1000	5.0	20	dry	0	0.990
"	8.3	166	dry	0	0.802
"	10.2	263	dry	0	0.837
"	11.2	288	Trace	Trace	-----
"	12.3	340	Trace	Trace	0.729
"	14.1	405	0.10*	1.3	-----
"	16.2	482	0.13*	1.9	0.732
"	17.9	533	0.16*	2.1	-----
"	19.7	588	0.17*	2.4	0.674
"	23.0	674	0.24*	3.3	0.630
"	26.2	750	0.30*	4.0	0.593
"	28.4	795	0.37*	5.0	-----
"	30.8	842	0.60	5.1	0.544
"	33.0	866	0.67	6.5	0.509
"	35.3	917	0.77	8.5	-----
"	36.6	936	0.82	9.5	0.487
"	38.4	961	0.78*	11.0	0.472
"	16.3	961	0.78*	11.0	0.472
"	19.4	996	1.05	13.0	0.446
1150	26.3	996	1.05	13.0	0.446
"	29.3	1038	1.23	15.0	-----
"	35.0	1107	1.70	21.8	0.391
"	38.0	1145	2.08	27.5	0.367
1250	21.0	1145	2.08	27.5	0.367
"	22.1	1156	2.30	31.4	0.359
"	22.6	1158	1.82	24.0	0.355
"	22.7	1160	1.32	16.4	0.355
"	23.3	1164	Single Phase	0	0.351

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "B" CELL TYPE 1/2"Strt NO. 18
TEMPERATURE -84.69°F CELL VOL.10.2 ml. SEP VOL.3.7ml.
THERMOCOUPLE, MV. 9.10 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 12 Psig at 75°F				
1000	9.6	17	dry	0	
"	13.7	198	Trace	Trace	
"	19.0	399	0.15*	2.0	
"	28.2	655	0.45	2.5	
"	31.5	729	0.55	4.0	
"	34.3	773	0.61	5.1	
"	38.0	806	0.73	8.0	
"	13.7	806	0.73	8.0	
"	17.0	855	0.85	10.0	
"	20.8	901	1.01	12.3	
"	24.4	941	1.20	14.5	
"	27.2	970	1.38	17.1	
"	31.3	1003	1.62	20.5	
"	33.0	1014	1.76	22.7	
1150	14.9	1014	1.76	22.7	
"	18.1	1052	2.14	28.7	
"	24.1	1120	3.50	48.4	
"	25.7	1134	3.82	53.0	
"	25.8	1136	4.18	57.8	
"	26.0	1141	None Visible	None	
"	26.1	1144	None Visible	Visible	

Leaks were present in apparatus, invalidating density measurements.

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "B"   CELL TYPE 1/2"Strt NO. 18
TEMPERATURE -89.68°F   CELL VOL.16.2ml. SEP VOL.3.7ml.
THERMOCOUPLE, MV. 9.45   RESERVOIR TEMP.100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 8 Psig at 75°F					
1000	3.2	---	---	--	-----
"	26.1	743	0.59	4.5	0.553
"	31.7	831	0.88	10.5	0.492
"	38.0	909	1.30	16.0	0.436
1150	2.7	909	1.30	16.0	0.436
"	8.0	971	1.86	24.3	0.392
"	12.1	1020	2.43	33.0	0.367
"	16.1	1058	3.31	45.7	0.342
"	18.1	1077	3.98	55.0	0.332
"	19.0	1088	4.55	62.9	0.329
"	20.2	1098	5.63	78.3	0.324
"	20.4	1101	6.58	91.8	0.323
"	20.5	1104	Single Phase	100	0.323

Data at lower pressures discarded because of lack of ice at the cold junction.

ORIGINAL DATA

GAS IDENTIFICATION "B"　CELL TYPE 1/2"Strt NO. 18
TEMPERATURE -98.52°F　CELL VOL. 10.2ml. SEP VOL.3.7ml.
THERMOCOUPLE, MV. 10.13　RESERVOIR TEMP.Not controlled

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
		15	0	0	
		149	Trace	Trace	
		280	Trace	Trace	
		386	0.19*	2.6	
		480	0.20*	2.8	
		561	0.30*	3.8	
		624	0.55	4.2	
		676	0.69	7.0	
		772	1.08	13.2	
		857	1.70	21.8	
		910	2.41	33.0	
		969	3.75	52.0	
		999	4.85	67.2	
		1036	6.00	83.8	
		1091	Single Phase	100	

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "B" CELL TYPE 1/2"Strt NO. 22
TEMPERATURE -119.53°F CELL VOL.10.27ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 11.48 RESERVOIR TEMP.100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 16 Psig at 75°F				
1000	3.0	21	dry	0	0.877
"	6.0	142	Trace	Trace	0.791
"	9.0	254	0.12*	0.9	0.774
"	12.0	343	0.20*	1.5	0.697
"	15.3	427	0.32*	3.0	0.640
"	18.3	487	0.54	5.0	0.581
"	21.2	536	0.68	6.6	0.536
"	27.0	611	1.06	12.0	0.459
"	32.4	659	1.50	18.4	0.400
"	38.8	721	2.11	27.2	0.357
"	2.8	721	2.11	27.2	0.357
"	9.1	748	2.86	38.0	0.312
"	15.5	782	3.75	50.6	0.281
"	20.0	812	4.40	60.0	0.267
"	25.6	846	5.42	74.8	0.251
"	32.0	932	6.30	87.5	0.249
"	34.9	995	6.70	93.2	0.255
1200	34.9	995	6.70	93.2	0.255
"	36.5	1067	7.15	98.4	0.267
"	37.2	1097	7.28	99.1	0.272
"	37.6	1114	7.50	100	0.274
"	38.0	1114	9.00	100	0.272

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "B" CELL TYPE 3/8" Inverted
TEMPERATURE -119.53°F RESERVOIR PRESSURE ---
THERMOCOUPLE, MV. 11.48 RESERVOIR TEMP. ---

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
		174	None	0	
		411	4.26	----	
		571	4.10	----	
		728	3.23	25.4	
		819	2.07	52.8	
		887	0.77	82.1	
		917	0.25	94.1	
		938	0.07	97.8	
		944	Single Phase	100	

ORIGINAL DATA

GAS IDENTIFICATION "B" CELL TYPE 1/2"Strt NO. 20
TEMPERATURE -152.84°F CELL VOL. 10.2ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 13.60 RESERVOIR PRESSURE 1000
RESERVOIR TEMP.100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 16 Psig at 75°F Hg in bottom of cell to reading of 0.20*					
1000	5.9	19	dry	-----	0.964
"	7.6	89	Trace	Trace	0.893
"	12.0	216	0.30*	1.5	0.681
"	18.2	334	0.72	6.5	0.525
"	25.6	393	1.29	14.5	0.378
"	38.2	453	2.42	21.9	0.262
"	3.8	453	2.42	21.9	0.262
"	13.0	492	3.34	44.8	0.220
"	22.0	518	4.32	58.8	0.190
"	27.4	535	4.93	67.4	0.176
"	34.1	562	5.66	78.0	0.165
"	38.0	580	6.08	84.0	0.160
"	7.0	580	6.08	84.0	0.160
"	9.4	591	6.33	88.0	0.158
"	13.6	620	6.82	95.0	0.156
"	16.4	647	7.17	98.5	0.157
"	17.6	665	7.38	99.2	0.159
"	18.6	695	Single Phase	100	0.164

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "B" CELL TYPE 3/8"Inverted NO. 51
TEMPERATURE -152.84°F CELL VOL.---
THERMOCOUPLE, MV.13.60 RESERVOIR TEMP. ---

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
		--	dry		
		21	dry		
		254	dry?		
		398	3.90	10.3	
		451	3.35	22.8	
		475	2.73	37.4	
		543	1.39	68.0	
		579	0.74	82.7	
		607	0.47	89.2	
		614	0.34	92.1	
		623	0.27	93.6	
		630	0.20	95.3	
		637	0.14	96.5	
		641	0.11	97	
		645	0.09	97.4	
		658	Single Phase	100	

ORIGINAL DATA
GAS IDENTIFICATION "C"   CELL TYPE 1/2"Strt NO. 25
TEMPERATURE   -69.38°F CELL VOL.11.1ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 8.00   RESERVOIR TEMP. 110°F

Filled to 34 Psig at 84°F

Reservoir Pressure lb/sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1300	2.0	37	dry	0	0.989
"	---	116	Trace	Trace	-----
"	5.4	220	Trace	Trace	0.813
"	8.0	352	Trace	Trace	0.779
"	10.5	464	0.10*	0.7	0.741
"	14.0	601	0.16*	1.1	0.715
"	18.1	737	0.28*	2.2	0.625
"	22.7	869	0.50	3.2	0.557
"	25.9	946	0.59	4.5	0.537
"	29.9	1031	0.71	6.0	0.498
"	34.1	1111	0.81	7.4	0.465
"	----	1147	0.83	7.6	-----
"	37.9	1176	0.80	7.2	0.437
"	11.0	1176	0.80	7.2	0.437
"	14.0	1222	0.55	3.9	0.417
"	----	1246	0.12*	0.9	-----
"	15.8	1249	Single Phase	0	0.409

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "C" CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -79.64°F CELL VOL. 11.1ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 8.74 RESERVOIR TEMP. 110°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 39 Psig at 86°F					
1250	2.6	41	dry	0	1.080
"	---	95	Trace	Trace	-----
"	5.9	209	0.11*	0.6	0.829
"	8.9	352	0.14*	0.9	0.784
"	11.8	472	0.19*	1.3	0.731
"	14.9	558	0.27*	2.0	0.657
"	18.1	677	0.34*	3.0	0.633
"	22.6	794	0.58	4.0	0.574
"	28.1	911	0.81	7.5	0.516
"	32.4	985	1.04	10.9	0.473
"	----	1017	1.15	12.3	-----
"	----	1042	1.24	13.7	-----
"	37.8	1064	1.34	15.0	0.430
"	12.2	1064	1.34	15.0	0.430
"	13.3	1079	1.40	15.6	0.422
"	14.5	1093	1.47	16.4	0.414
"	16.4	1118	1.55	17.9	0.402
"	18.2	1139	1.58	18.2	0.391
"	----	1147	1.51	17.1	-----
"	----	1152	1.42	15.8	-----
"	19.9	1161	1.20	13.1	0.382
"	20.6	1169	dry	0	0.378

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "C" CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -86.84°F CELL VOL. 11.1 ml. SEP VOL. 3.9
THERMOCOUPLE, MV. 9.25 RESERVOIR TEMP. 110°F

Filled to 13 Psig at 81°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1250	3.8	19	dry	0	0.929
"	5.3	89	Trace	Trace	0.776
"	7.1	181	Trace	Trace	0.797
"	10.0	326	0.10*	0.6	0.801
"	13.7	464	0.30	1.1	0.705
"	17.2	577	0.38	1.9	0.648
"	23.8	752	0.60	4.6	0.560
"	30.0	872	0.90	8.7	0.490
"	38.4	989	1.51	17.1	0.415
"	2.9	989	1.51	17.1	0.415
"	10.0	1069	2.29	27.9	0.369
"	11.4	1082	2.42	29.8	0.369
"	13.8	1108	2.79	34.5	0.349
"	----	1117	2.90	36.0	-----
"	----	1119	2.98	36.8	-----
"	15.5	1123	3.00	37.0	0.340
"	----	1128	3.10	38.4	-----
"	----	1130	3.07	38.2	-----
"	----	1131	2.99	36.9	-----
"	----	1132	2.90	36.0	-----
"	----	1132	2.70	33.5	-----
"	16.3	1134	Single Phase	0	0.337

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "C"   CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -89.68°F   CELL VOL. 11.1ml.   SEP VOL. 3.9ml.
THERMOCOUPLE, MV. 9.45   RESERVOIR TEMP. 110°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 32 Psig at 86°F				
1250	2.8	33	dry	0	0.967
"	3.9	98	Trace	Trace	0.955
"	6.2	214	Trace	Trace	0.872
"	8.6	327	0.12*	0.9	0.814
"	11.1	419	0.17*	1.0	0.754
"	13.7	513	0.34	1.5	0.708
"	17.5	618	0.43	2.3	0.630
"	21.6	725	0.60	4.5	0.570
"	28.3	849	0.96	9.3	0.489
"	34.8	945	1.45	16.1	0.431
"	38.4	986	1.81	22.3	0.401
"	3.0	986	1.81	22.3	0.401
"	9.7	1046	2.54	31.3	0.354
"	11.3	1072	3.02	37.3	0.350
"	12.9	1087	3.40	42.6	0.342
"	----	1098	3.76	47.2	-----
"	15.0	1109	5.30?	68.0?	0.333
"	15.0	1109	None Visible	None Visible	0.333
"					

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "C"   CELL TYPE 1/2" Strt NO. 25
TEMPERATURE   -94.70°F CELL VOL. 11.1 ml. SEP VOL. 3.9ml
THERMOCOUPLE, MV. 9.80   RESERVOIR TEMP. 110°F

Filled to 19 Psig at 82°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1250	8.8	23	dry	0	0.933
"	---	64	Trace	Trace	-----
"	---	116	Trace	Trace	-----
"	11.6	165	Trace	Trace	0.824
"	14.7	299	0.15*	1.0	0.759
"	17.8	421	0.20*	1.3	0.709
"	21.1	527	0.30*	2.1	0.653
"	26.4	663	0.60	4.5	0.569
"	32.0	774	0.90	8.5	0.499
"	38.0	862	1.30	14.8	0.436
"	3.2	862	1.32	15.0	0.436
"	13.5	974	2.51	31.0	0.360
"	20.9	1051	4.29	54.0	0.325
"	24.0	1079	6.80	88.5	0.312
"	24.4	1083	8.50	100	0.311

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "C"   CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -99.78°F   CELL VOL. 11.1 ml. SEP VOL. 3.9ml
THERMOCOUPLE, MV. 10.15   RESERVOIR TEMP. 110°F

Filled to 23 Psig at 86°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1250	27.2	26	dry	0	0.996
"	----	84	Trace	Trace	-----
"	29.5	131	Trace	Trace	0.774
"	31.5	229	0.13*	0.9	0.788
"	34.3	342	0.18*	1.2	0.730
"	----	425	0.21*	1.5	-----
"	38.0	464	0.25*	1.9	0.652
"	2.6	464	0.25*	1.9	0.652
"	6.3	559	0.46	3.9	0.606
"	11.0	664	0.67	5.0	0.521
"	16.3	775	1.01	10.3	0.476
"	22.4	839	1.53	17.4	0.408
"	28.7	907	2.30	28.0	0.364
"	33.1	950	3.08	38.1	0.338
"	38.0	992	4.19	52.8	0.315
"	2.6	992	4.19	52.8	0.315
"	---	1021	5.49	70.9	-----
"	9.0	1040	7.25	94.6	0.288
"	---	1045	7.60	98.7	-----
"	9.4	1047	Single Phase	100	0.288

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "C" CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -139.99°F CELL VOL. 11.1ml SEP VOL. 3.9ml.
THERMOCOUPLE, MV. 12.80 RESERVOIR TEMP. 100°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 19 Psig at 86°F				
1000	3.9	23	Trace	Trace	1.075
"	7.1	134	Trace	Trace	0.818
"	12.8	286	0.22*	1.5	0.654
"	18.0	369	0.50	3.2	0.539
"	26.2	463	1.04	10.9	0.422
"	31.0	496	1.42	16.0	0.369
"	38.0	536	2.03	24.1	0.315
"	2.3	536	2.03	24.1	0.315
"	13.6	587	3.16	39.3	0.257
"	22.6	623	4.14	52.3	0.227
"	30.2	653	5.09	65.1	0.208
"	38.5	686	6.06	78.3	0.192
"	3.4	686	6.06	78.3	0.192
"	11.5	724	7.02	91.5	0.182
"	16.9	753	7.72	99.0	0.177
"	17.2	767	Single Phase	100	0.180
"	20.9	984	Single Phase	100	0.223

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "C" CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -176.31°F CELL VOL. 11.1ml SEP VOL. 3.9ml
THERMOCOUPLE, MV. 15.00 RESERVOIR TEMP. 110°f

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 22 Psig at 87°F				
1000	2.1	21	Trace	Trace	0.983
"	5.8	117	0.13*	0.9	0.678
"	11.8	211	0.50	3.2	0.494
"	18.1	256	0.94	9.4	0.364
"	26.2	292	1.55	17.6	0.274
"	32.0	314	2.04	24.4	0.237
"	38.0	327	2.54	31.2	0.205
"	2.6	327	2.54	31.2	0.205
"	12.8	358	3.40	42.4	0.174
"	24.0	386	4.40	55.5	0.151
"	37.9	419	5.70	74.0	0.132
"	24.7	419	5.70	74.0	0.132
"	31.7	443	6.38	83.0	0.127
"	38.0	472	6.93	90.0	0.125
"	2.9	472	6.93	90.0	0.125
"	8.0	504	7.35	96.0	0.126
"	10.1	536	7.53	98.0	0.131
"	----	538	7.68	98.9	-----
"	11.7	549	8.5	100	0.132

* Read with agitator ball raised above the interface.

ORIGINAL DATA
GAS IDENTIFICATION "C" CELL TYPE 1/2" Strt NO. 25
TEMPERATURE -199.86°F CELL VOL.11.1ml. SEP VOL. 3.9ml.
THERMOCOUPLE, MV. 16.32 RESERVOIR TEMP. 110°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 43 Psig at 85°F				
1000	3.4	27	Trace	Trace	0.829
"	7.5	112	0.20*	1.4	0.596
"	13.7	154	0.72	6.2	0.351
"	18.5	173	1.09	11.4	0.271
"	22.8	192	1.39	15.5	0.237
"	29.0	207	1.87	22.8	0.194
"	38.8	227	2.58	31.8	0.154
"	20.6	227	2.58	31.8	0.154
"	30.2	245	3.36	42.0	0.131
"	38.0	259	4.00	50.7	0.1180
"	3.9	259	4.00	50.7	0.1180
"	11.0	271	4.55	57.4	0.1090
"	20.1	290	5.32	68.5	0.1013
"	28.7	310	6.05	78.5	0.0964
"	38.0	347	6.80	88.4	0.0964
"	19.3	347	6.80	88.4	0.0964
"	24.5	390	7.22	94.2	0.1024
"	----	434	7.35	96.0	------
"	30.2	473	7.64	98.9	0.1273
"	31.6	555	Single Phase	100	0.1365

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "C" CELL TYPE 3/8" Initial NO.51
TEMPERATURE -199.86°F CELL VOL. ----
THERMOCOUPLE, MV. 16.32 RESERVOIR TEMP. 105°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 26 Psig at 81°F				
1000	2.0	25	Trace	Trace	
"	9.2	207	3.50	19.1	
"	12.7	237	2.85	34.5	
"	16.0	260	2.26	48.5	
"	18.9	281	1.72	62.8	
"	22.3	313	1.05	76.0	
"	24.3	345	0.65	84.8	
"	25.5	369	0.47	89.3	
"	----	423	0.24	94.2	
"	28.0	476	0.10	97.4	

Nitrogen exhausted before next addition could be made.

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "D" CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -79.91°F CELL VOL. 11.1ml.SEP VOL.3.9ml.
THERMOCOUPLE, MV. 8.76 RESERVOIR TEMP. 110°F

Filled to 25 Psig at 79°F

Drop of mercury in bottom of cell equivalent to reading of 0.12*

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1250	2.7	29	dry	0	0.966
	---	117	dry	0	-----
	---	164	Trace?	Trace?	-----
	6.2	212	Trace	Trace	0.834
	---	264	Trace	Trace	-----
	9.5	350	Trace	Trace	0.739
	---	424	0.17*	0.4	-----
	13.0	499	0.18*	0.4	0.711
	----	566	0.19*	0.5	-----
	17.2	633	0.21*	0.6	0.634
	20.0	714	0.27*	1.2	0.599
	23.0	783	0.33*	2.1	0.559
	27.0	858	0.52	2.7	0.508
	30.8	916	0.61	3.9	0.464
	34.0	954	0.69	4.8	0.433
	38.0	999	0.60	3.7	0.400
	9.7	999	0.60	3.7	0.400
	---	1007	0.51	2.8	-----
	10.7	1014	0.34*	2.2	0.394
	11.5	1018	0.21*	0.6	0.386
	11.8	1021	Single Phase	0	0.383

* Read with agitator ball raised above the interface.

ORIGINAL DATA
GAS IDENTIFICATION "D" CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -89.97°F CELL VOL. 11.1ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 9.47 RESERVOIR TEMP.110°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 25 Psig at 81°F				
1000	2.1	28	dry	0	0.952
	3.5	91	Trace	Trace	0.972
	5.4	165	Trace	Trace	0.871
	9.0	300	Trace	Trace	0.821
	16.0	516	0.17*	1.1	0.717
	22.9	661	0.39	3.2	0.607
	28.4	748	0.50	4.5	0.537
	34.2	819	0.69	5.6	0.480
	38.0	854	0.89	9.3	0.444
	2.0	854	0.89	9.3	0.444
	6.8	895	1.13	12.0	0.406
	11.5	925	1.40	15.7	0.376
	14.7	945	1.47	16.3	0.357
	15.3	947	1.40	15.7	0.353
	15.8	951	1.25	13.8	0.350
	16.5	954	0.72	6.2	0.347
	16.8	956	0.40	2.0	0.346
	16.9	957	Single Phase	0	0.345
	20.6	992	Single Phase	0	0.333

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "D" CELL TYPE 1/2"Strt NO. 25
TEMPERATURE -98.32°F CELL VOL. 11.1ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 10.05 RESERVOIR TEMP. 110°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
Filled to 26 Psig at 82°F					
1000	2.8	19	dry	0	0.602
"	---	64	Trace	Trace	-----
"	---	89	Trace	Trace	-----
"	---	115	Trace	Trace	-----
"	6.5	175	Trace	Trace	0.828
"	9.8	291	0.10*	0.8	0.791
"	16.5	486	0.19*	1.1	0.687
"	23.5	626	0.34*	3.0	0.586
"	30.3	718	0.70	5.9	0.501
"	37.9	785	1.16	12.5	0.422
"	21.2	785	1.16	12.5	0.422
"	27.4	829	1.75	21.5	0.377
"	32.2	854	2.41	29.7	0.345
"	38.0	882	3.53	44.2	0.315
"	2.9	882	3.53	44.2	0.315
"	6.3	895	4.60	58.1	0.299
"	8.1	903	6.03	78.2	0.292
"	8.6	905	6.93	90.2	0.290
"	---	905	7.38	196.1	-----
"	8.8	906	8.5	100	0.290
"	12.5	944	Single Phase	100	0.283

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "D"   CELL TYPE 1/2"Strt NO. 25
TEMPERATURE   -114.56°F CELL VOL. 11.1ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 11.15   RESERVOIR TEMP 110°F

Filled to 28 Psig at 84°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
1000	2.0	28	dry	dry	0.935
"	4.8	124	Trace	Trace	0.764
"	8.3	249	Trace	Trace	0.767
"	14.0	402	0.20*	1.3	0.666
"	19.8	510	0.46	2.7	0.572
"	29.3	614	1.00	10.1	0.442
"	38.2	667	1.80	22.2	0.358
"	1.8	667	1.80	22.2	0.358
"	10.1	705	2.83	35.0	0.312
"	17.1	727	3.86	48.7	0.270
"	23.6	747	5.00	64.0	0.245
"	28.2	762	5.89	76.1	0.235
"	32.3	774	6.70	87.0	0.220
"	35.2	781	7.34	96.0	0.213
"	37.3	791	Single Phase	100	0.209

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "D"   CELL TYPE 1/2"Strt NO. 25
TEMPERATURE   -134.40°F CELL VOL.11.1ml. SEP VOL.3.9ml.
THERMOCOUPLE, MV. 12.44   RESERVOIR TEMP. 110°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 30 Psig at 81°F				
1000	2.0	28	dry	0	0.924
"	3.7	91	Trace	Trace	0.875
"	9.0	254	0.12*	0.8	0.740
"	14.7	374	0.40	2.1	0.609
"	21.0	446	0.76	6.6	0.483
"	30.2	497	1.51	17.2	0.358
"	38.0	526	2.30	28.0	0.294
"	2.0	526	2.30	28.0	0.294
"	10.0	548	3.20	40.0	0.249
"	20.0	572	4.48	56.5	0.211
"	30.1	594	5.74	74.3	0.183
"	38.2	613	6.77	87.8	0.168
"	19.4	613	6.77	87.8	0.168
"	25.0	629	7.50	97.8	0.160
"	25.7	632	7.63	98.8	0.159
"	26.2	638	7.80	99.2	0.160
"	26.8	659	Single Phase	100	0.164
"	33.1	964	Single Phase	100	0.226

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "D"   CELL TYPE 1/2"Strt NO. 25
TEMPERATURE   -176.31°F CELL VOL. 11.1ml. SEP VOL. 3.9ml.
THERMOCOUPLE, MV. 15.00   RESERVOIR TEMP. 110°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 37 Psig at 79°F				
1000	4.2	29	Trace?	Trace	0.933
"	---	62	Trace	Trace	-----
"	6.4	94	0.11*	0.7	1.376
"	9.0	157	0.19*	1.2	0.643
"	12.5	197	0.39*	3.4	0.524
"	16.5	219	0.80	7.2	0.397
"	22.0	236	1.20	13.1	0.295
"	29.4	252	1.81	22.2	0.223
"	38.0	267	2.53	31.1	0.176
"	2.2	267	2.53	31.1	0.176
"	12.0	281	3.36	42.0	0.143
"	22.1	294	4.25	53.8	0.122
"	32.2	307	5.67	73.6	0.107
"	38.1	315	5.69	73.8	0.100
"	2.5	315	5.69	73.8	0.100
"	12.1	332	6.52	84.9	0.0930
"	21.7	362	7.33	95.9	0.0906
"	----	377	7.59	98.6	------
"	25.4	386	8.10	100	0.0929
"	30.5	802	Single Phase	100	0.187

* Read with agitator ball raised above the interface.

ORIGINAL DATA

GAS IDENTIFICATION "D"
TEMPERATURE -199.86°F
THERMOCOUPLE, MV. 16.32

CELL TYPE 1/2"Strt NO. 25
CELL VOL.11.1ml. SEP VOL.3.9ml.
RESERVOIR PRESSURE 1000
RESERVOIR TEMP. 110°F

Reservoir Pressure lb./sq. in. gage	Mercury Level in Reservoir	Equilibrium Pressure lb./sq. in. abs.	Liquid in cell	Volume Percent Liquid	Z
	Filled to 30 Psig at 82°F				
	2.0	23	Trace	Trace	0.929
	10.0	124	0.57	5.2	0.350
	18.0	144	1.15	12.3	0.215
	26.2	157	1.81	22.4	0.151
	38.0	172	2.71	33.6	0.113
	2.0	172	2.71	33.6	0.113
	12.0	182	3.48	43.4	0.0952
	22.2	192	4.29	54.1	0.0823
	30.3	199	4.93	63.0	0.0746
	38.0	209	5.58	72.0	0.0700
	2.0	209	5.58	72.0	0.0700
	10.0	221	6.21	80.8	0.0667
	19.6	246	6.92	89.9	0.0663
	25.2	274	7.35	96.0	0.0696
	27.8	300	7.57	98.4	0.0742
	30.6	399	Single Phase	100	0.0964
	36.0	962	Single Phase	100	0.227

* Read with agitator ball raised above the interface.

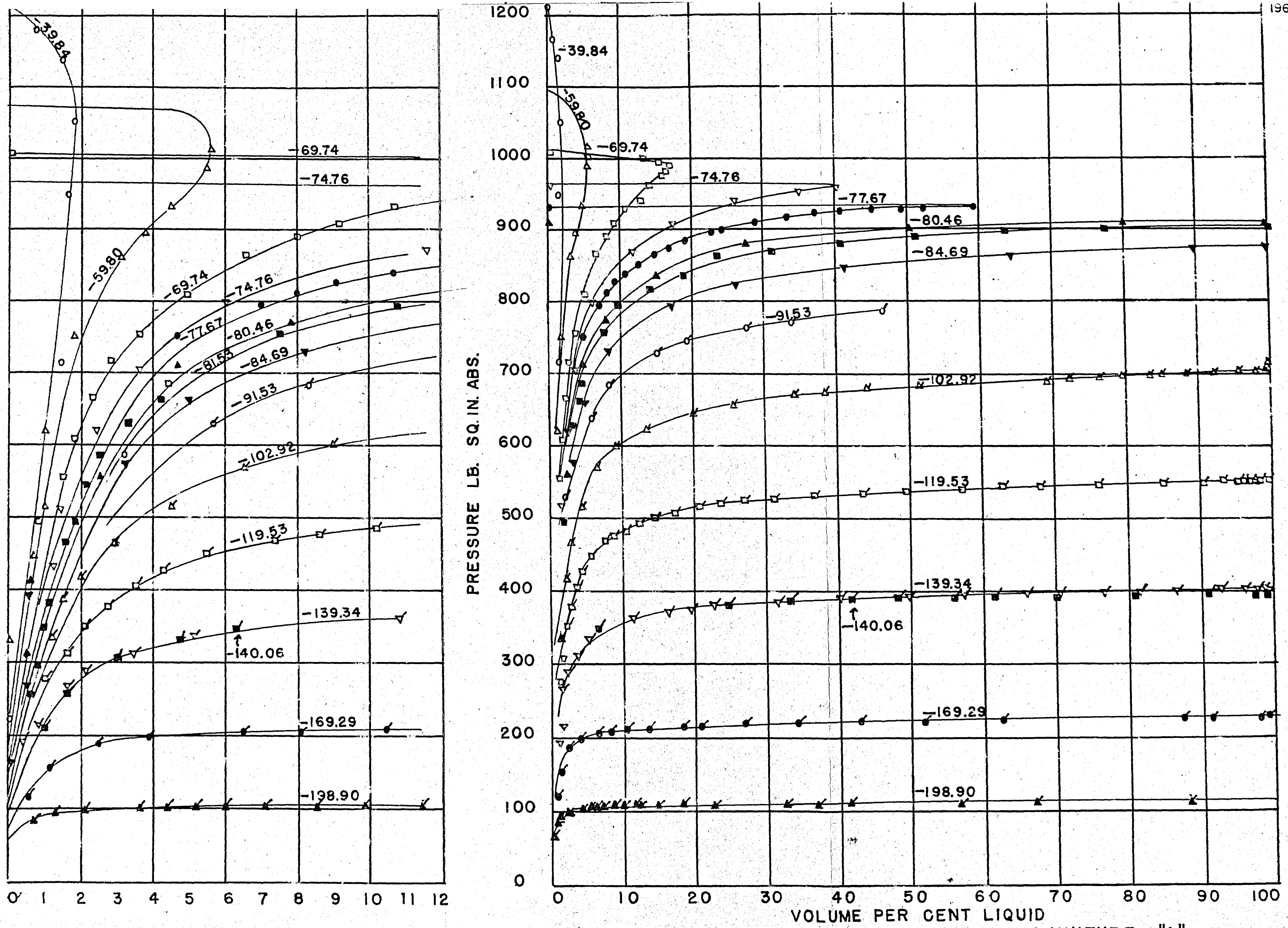


EXHIBIT J EXPERIMENTAL ISOTHERMS OF MIXTURE "A"

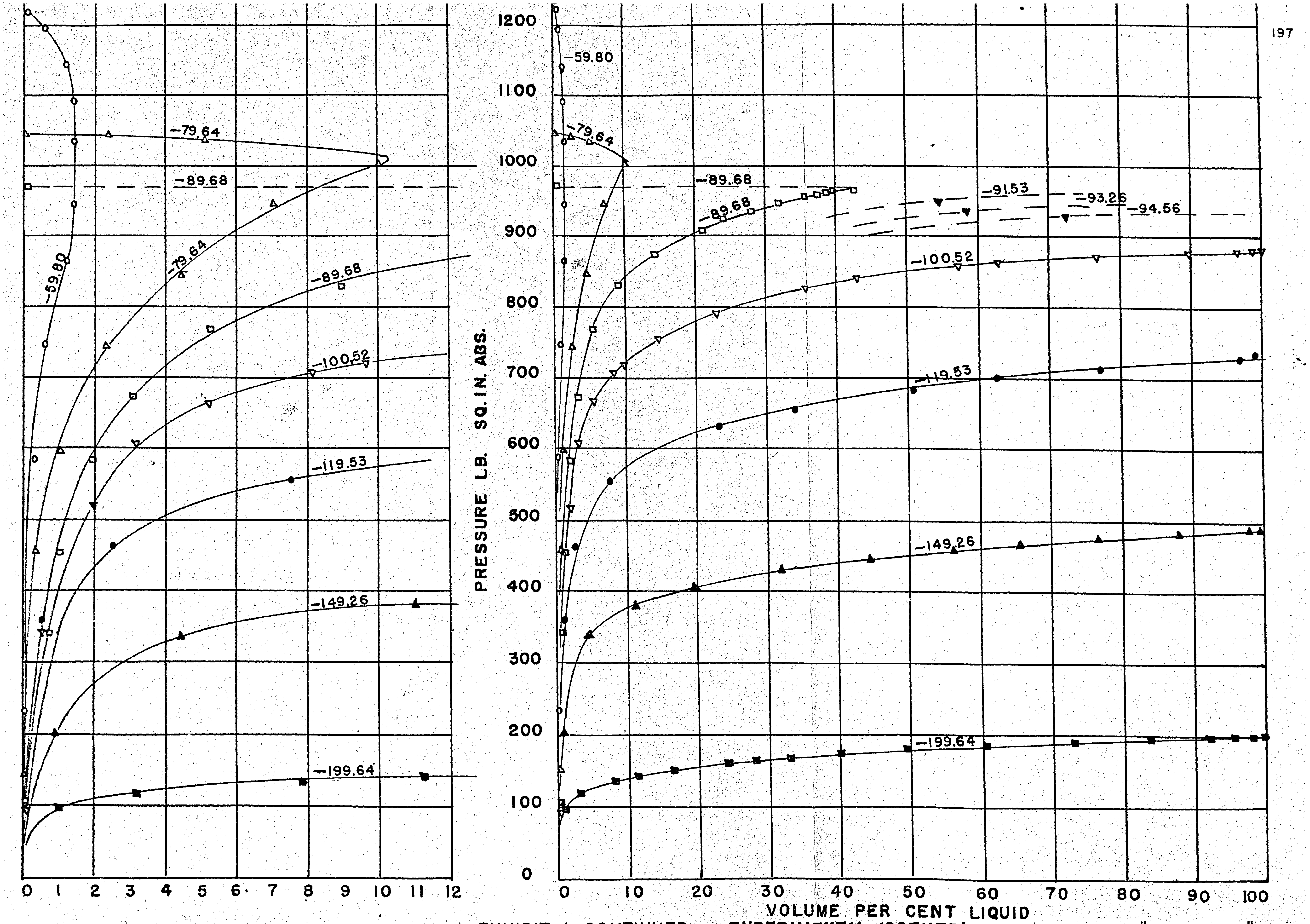
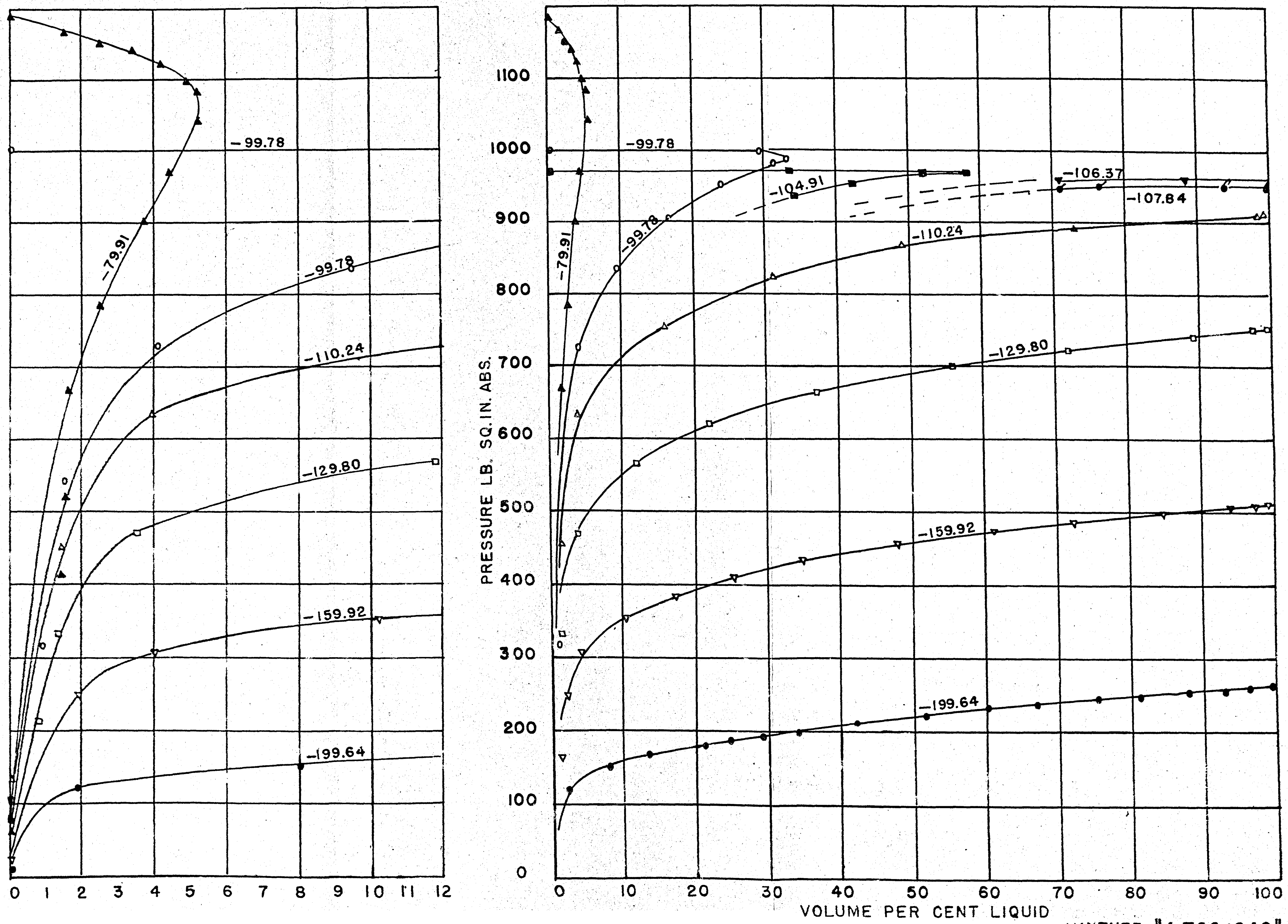


EXHIBIT J-CONTINUED EXPERIMENTAL ISOTHERMS OF MIXTURE "A 700/770"



MIXTURE "A 700/840"

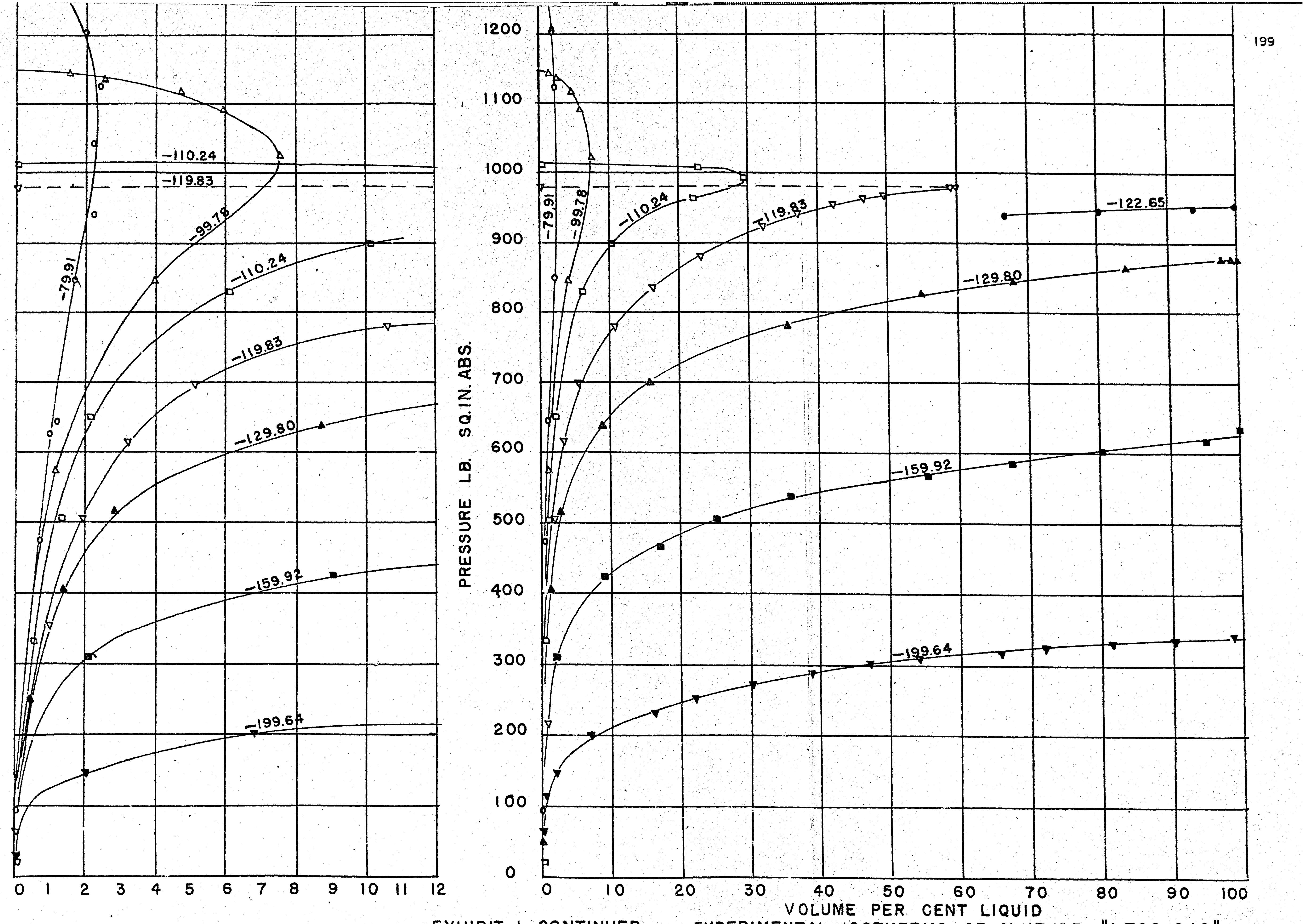


EXHIBIT J–CONTINUED EXPERIMENTAL ISOTHERMS OF MIXTURE "A 700/940"

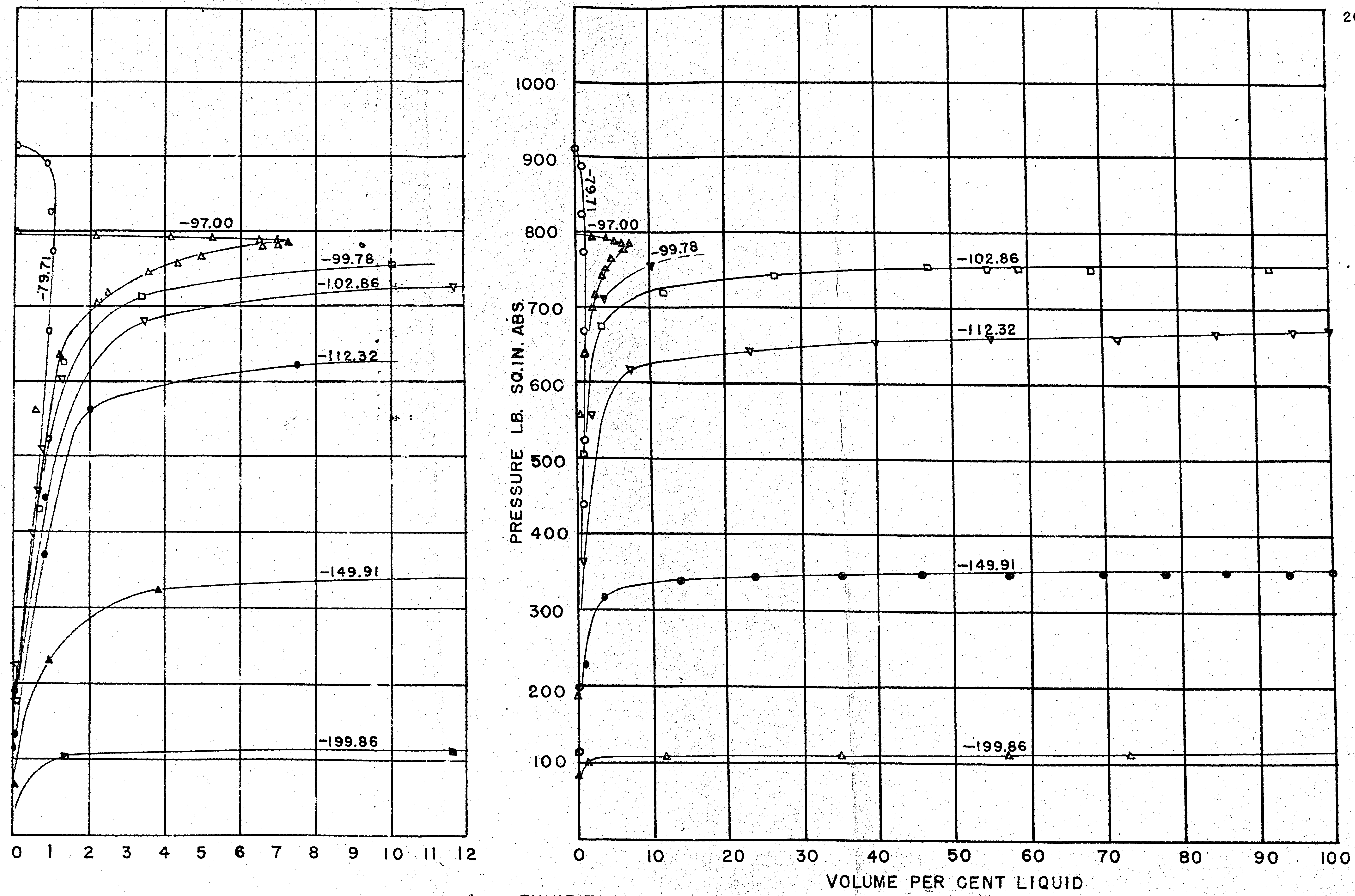


EXHIBIT J-CONTINUED EXPERIMENTAL ISOTHERMS OF MIXTURE "AB"

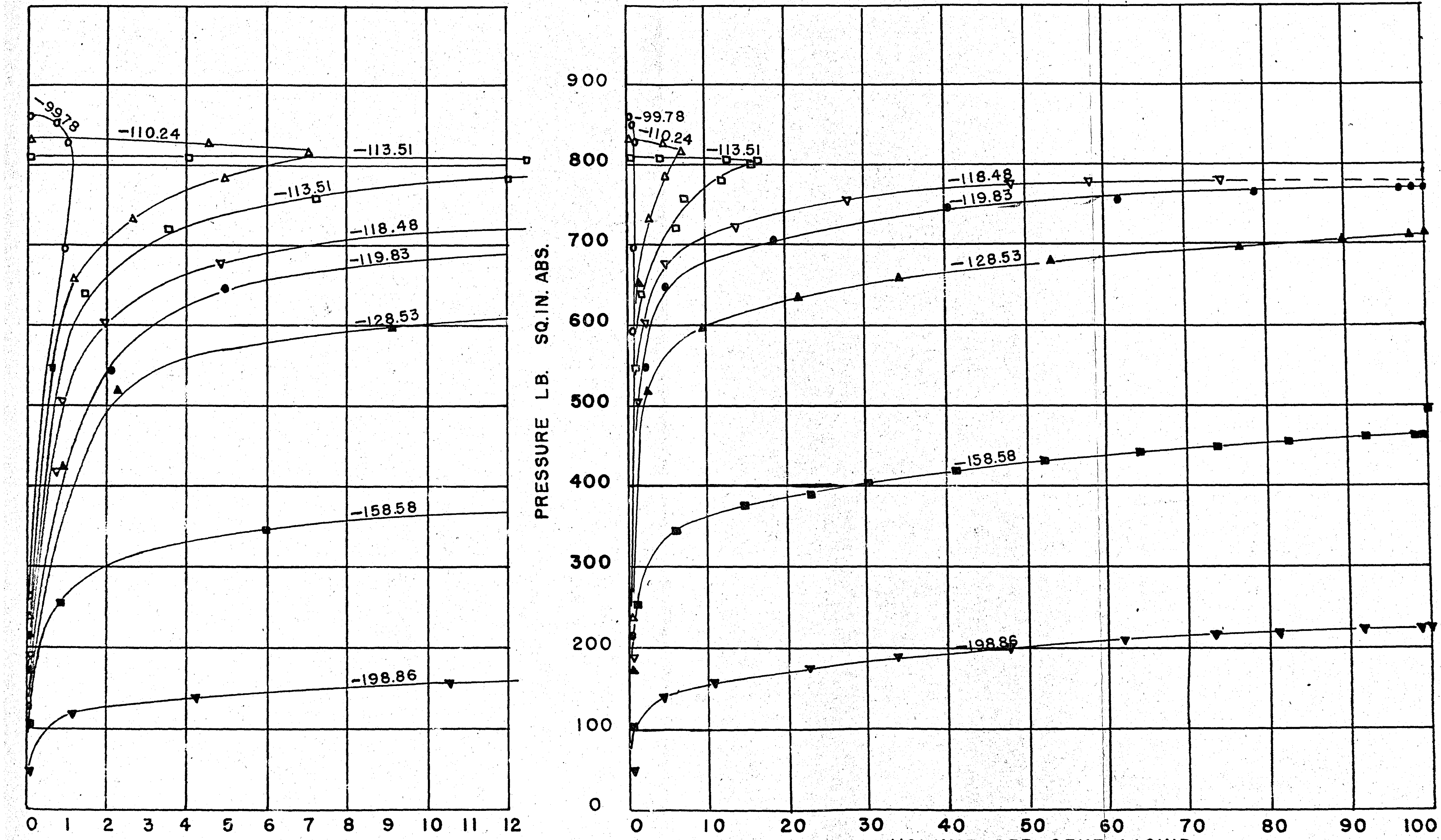


EXHIBIT J—CONTINUED EXPERIMENTAL ISOTHERMS OF MIXTURE "AB 700/800"

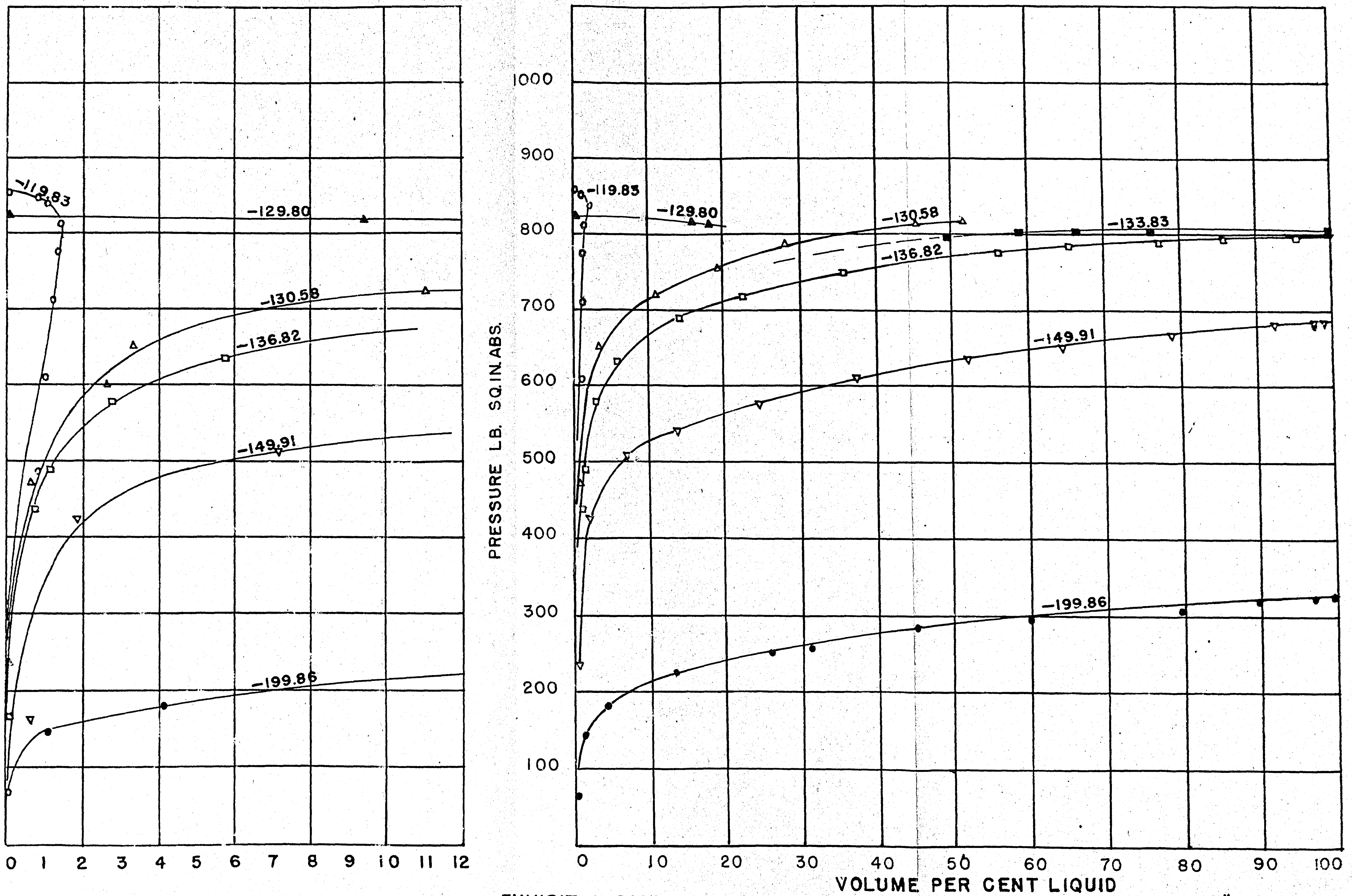


EXHIBIT J–CONTINUED EXPERIMENTAL ISOTHERMS OF MIXTURE "AB 700/940"

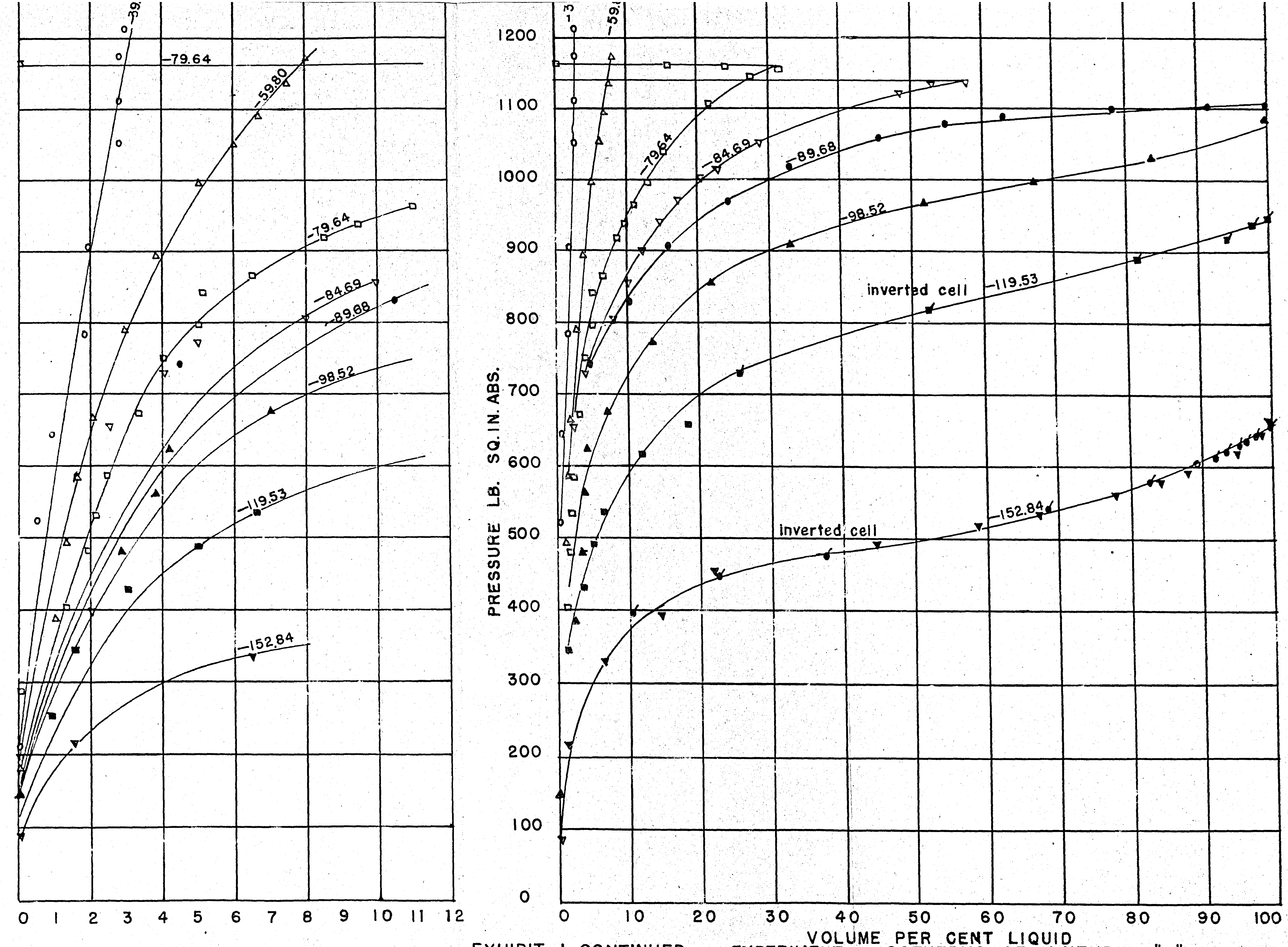


EXHIBIT J-CONTINUED EXPERIMENTAL ISOTHERMS OF MIXTURE "B"

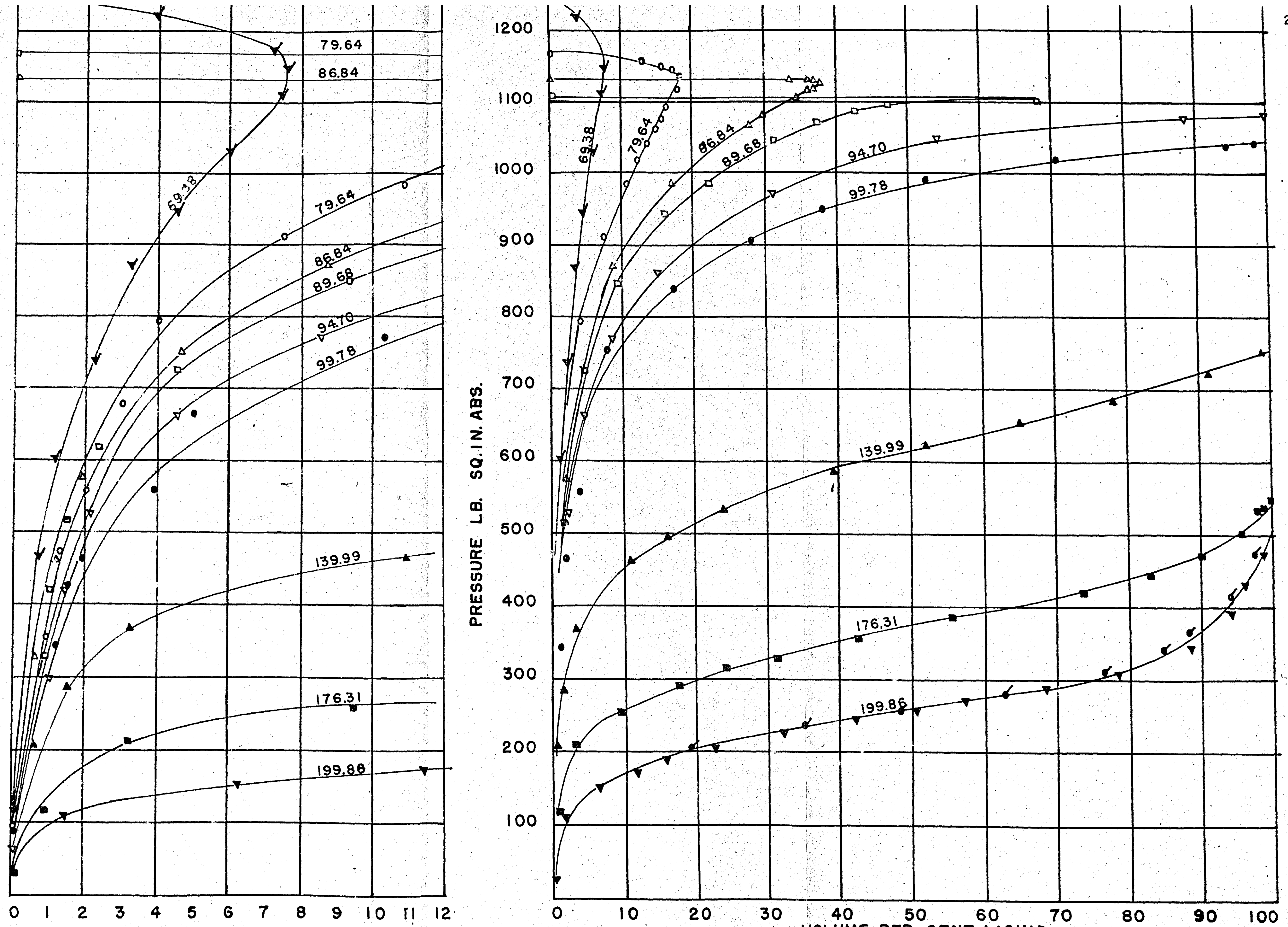


EXHIBIT J—CONTINUED EXPERIMENTAL ISOTHERMS OF MIXTURE "C"

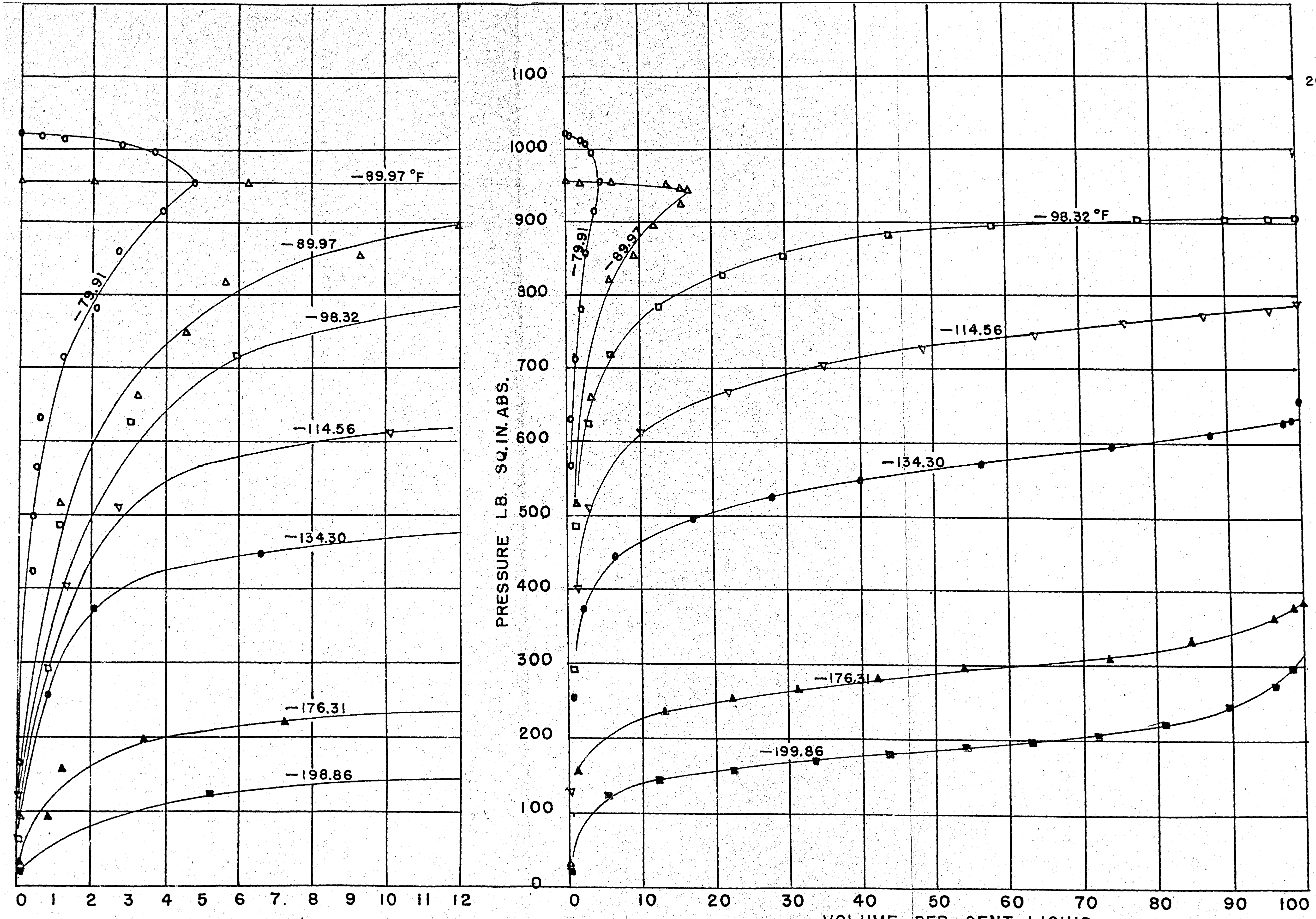


EXHIBIT J-CONTINUED EXPERIMENTAL ISOTHERMS OF MIXTURE "D"

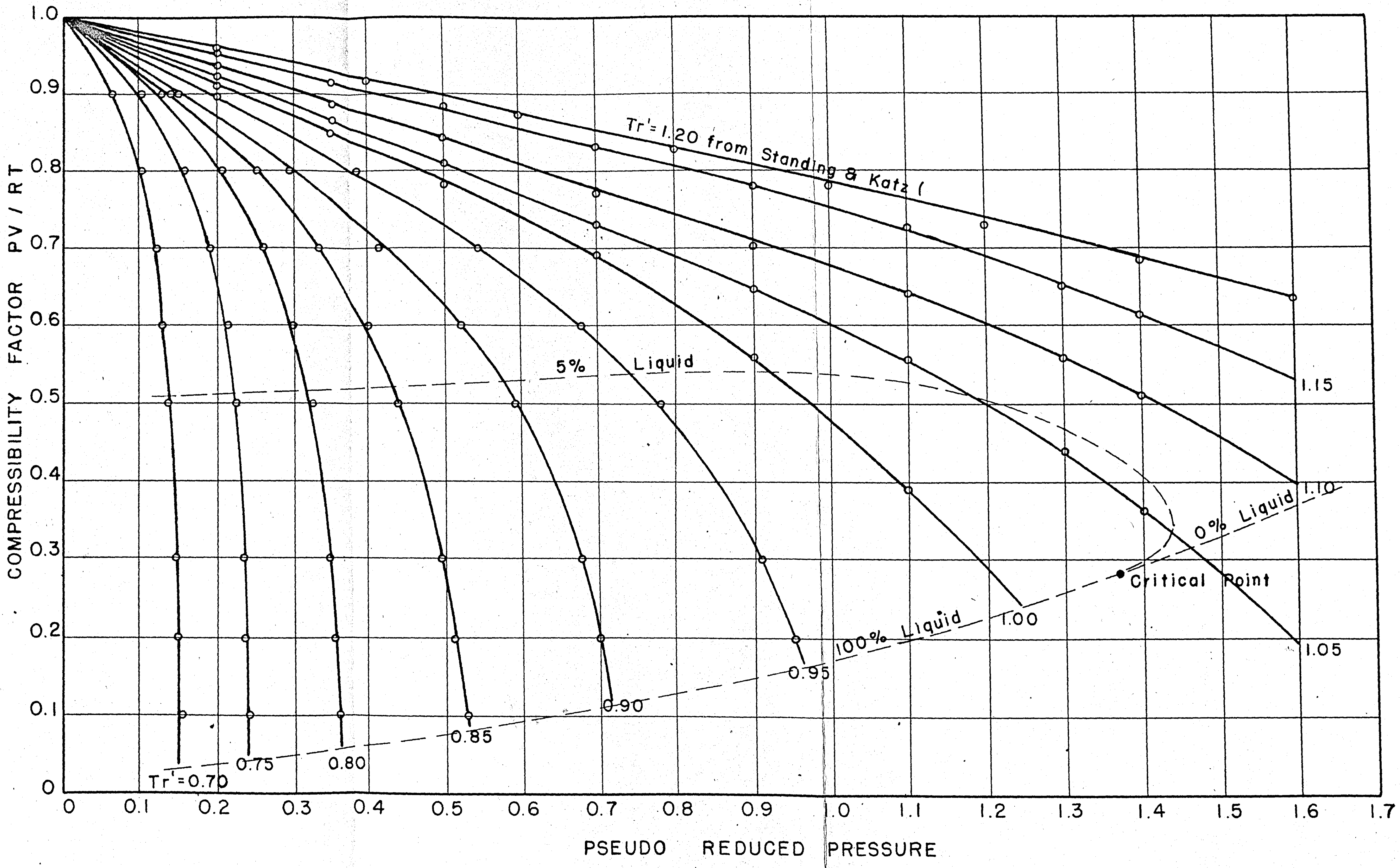


EXHIBIT K PRESSURE - VOLUME - TEMPERATURE BEHAVIOR OF MIXTURE "A"

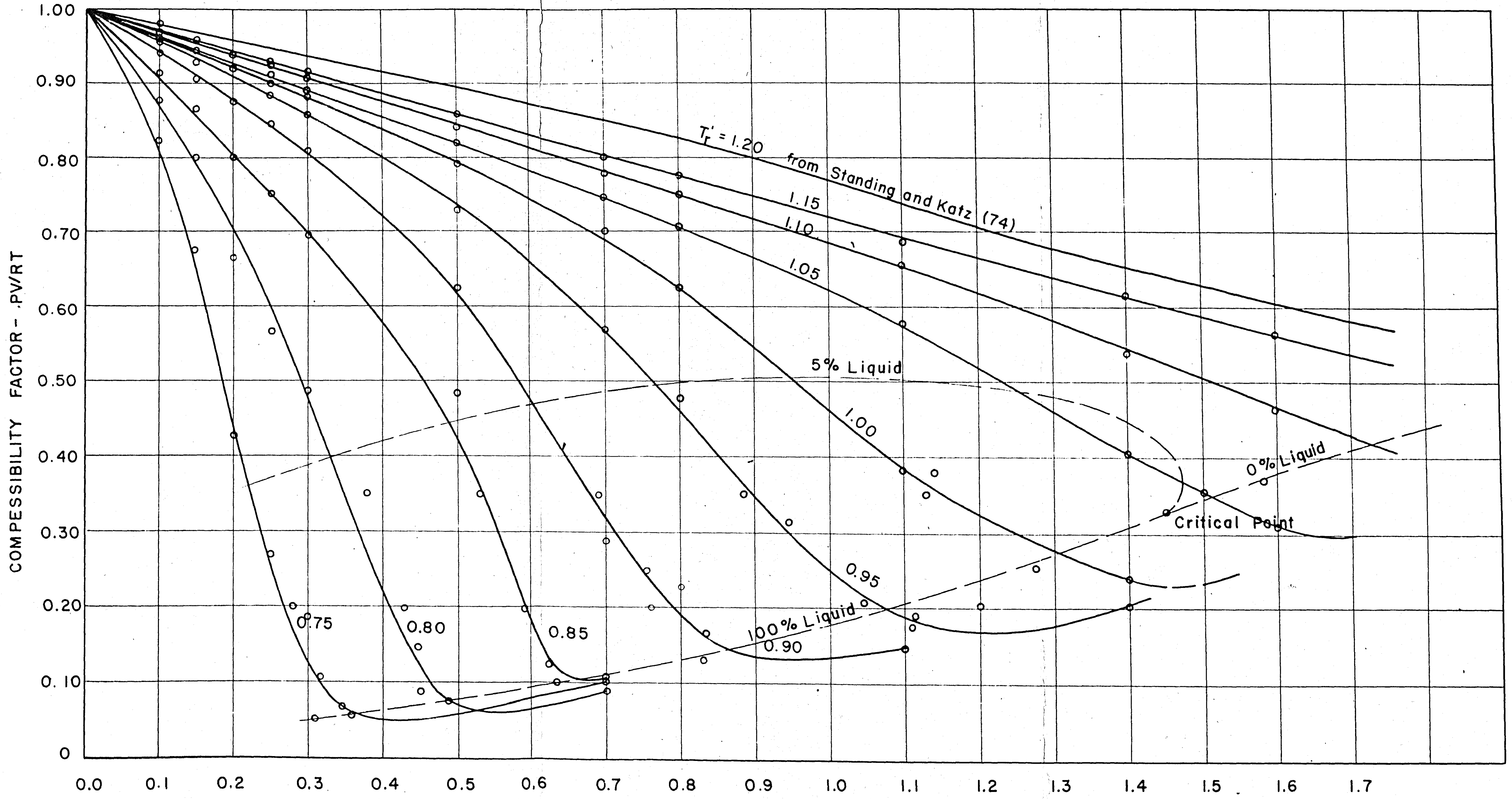


EXHIBIT K — CONTINUED PRESSURE-VOLUME-TEMPERATURE BEHAVIOR OF MIXTURE "A 700/770"

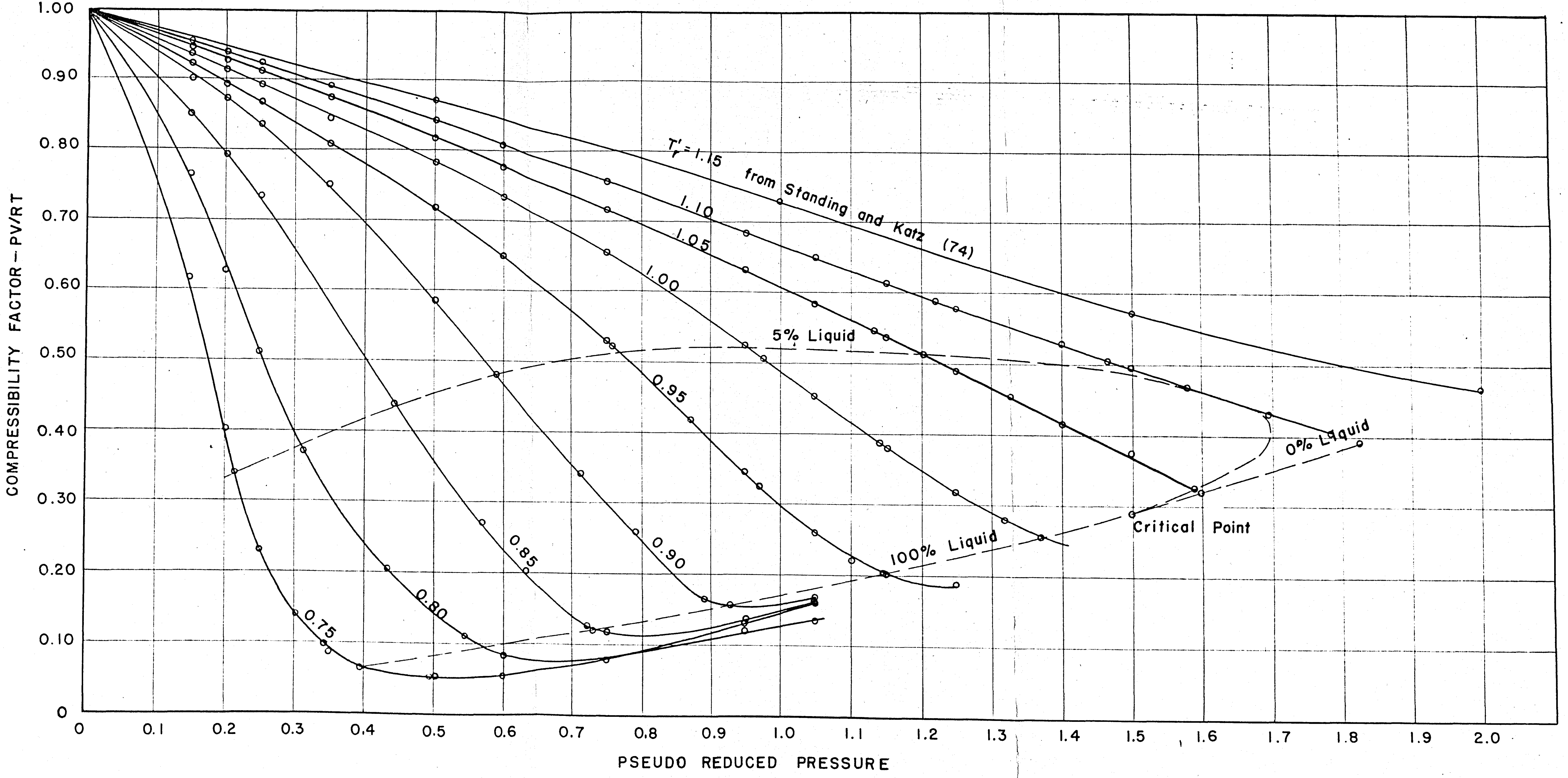


EXHIBIT K — CONTINUED PRESSURE-VOLUME-TEMPERATURE BEHAVIOR OF MIXTURE "A 700/840"

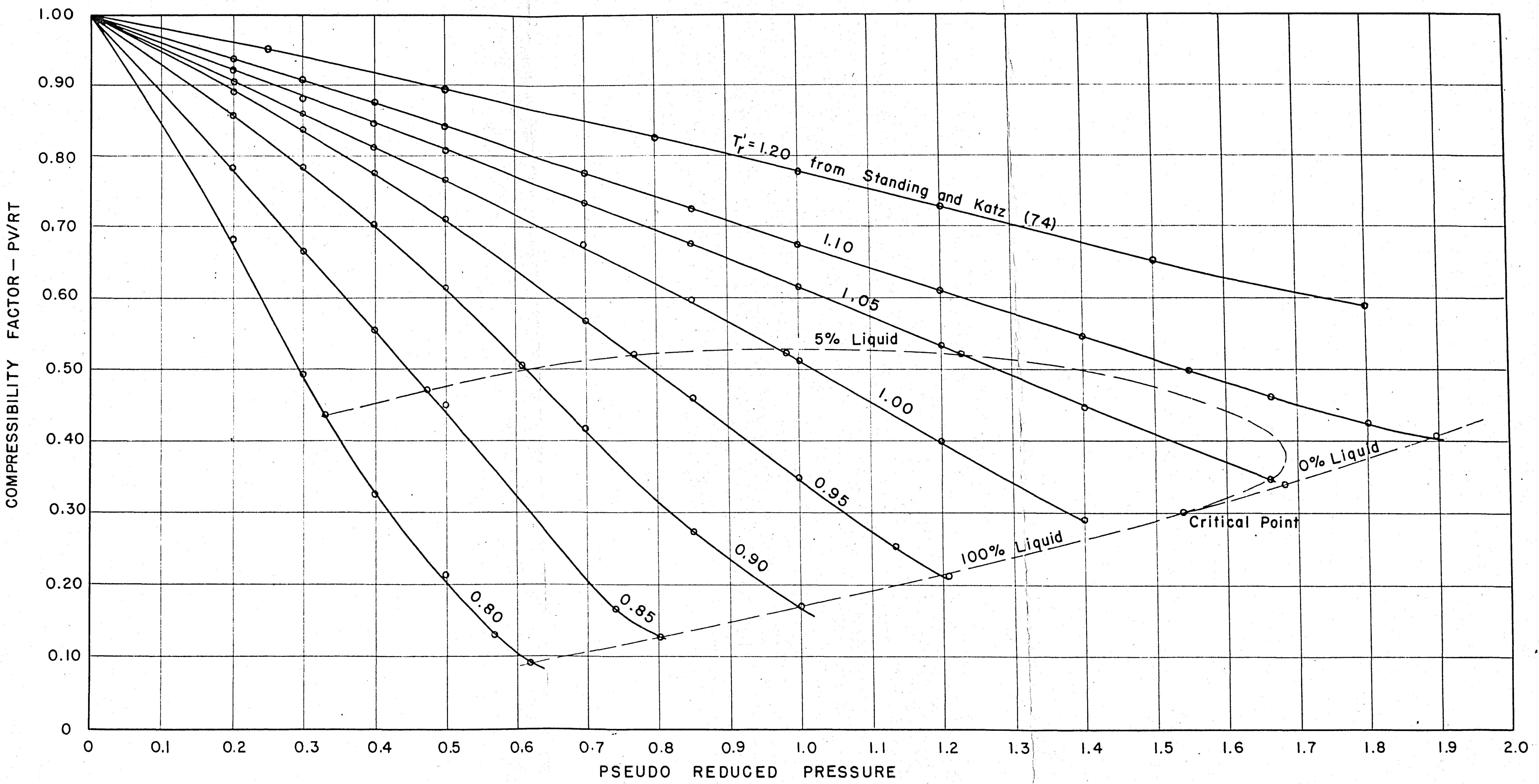


EXHIBIT K—CONTINUED PRESSURE-VOLUME-TEMPERATURE BEHAVIOR OF MIXTURE "A700/940"

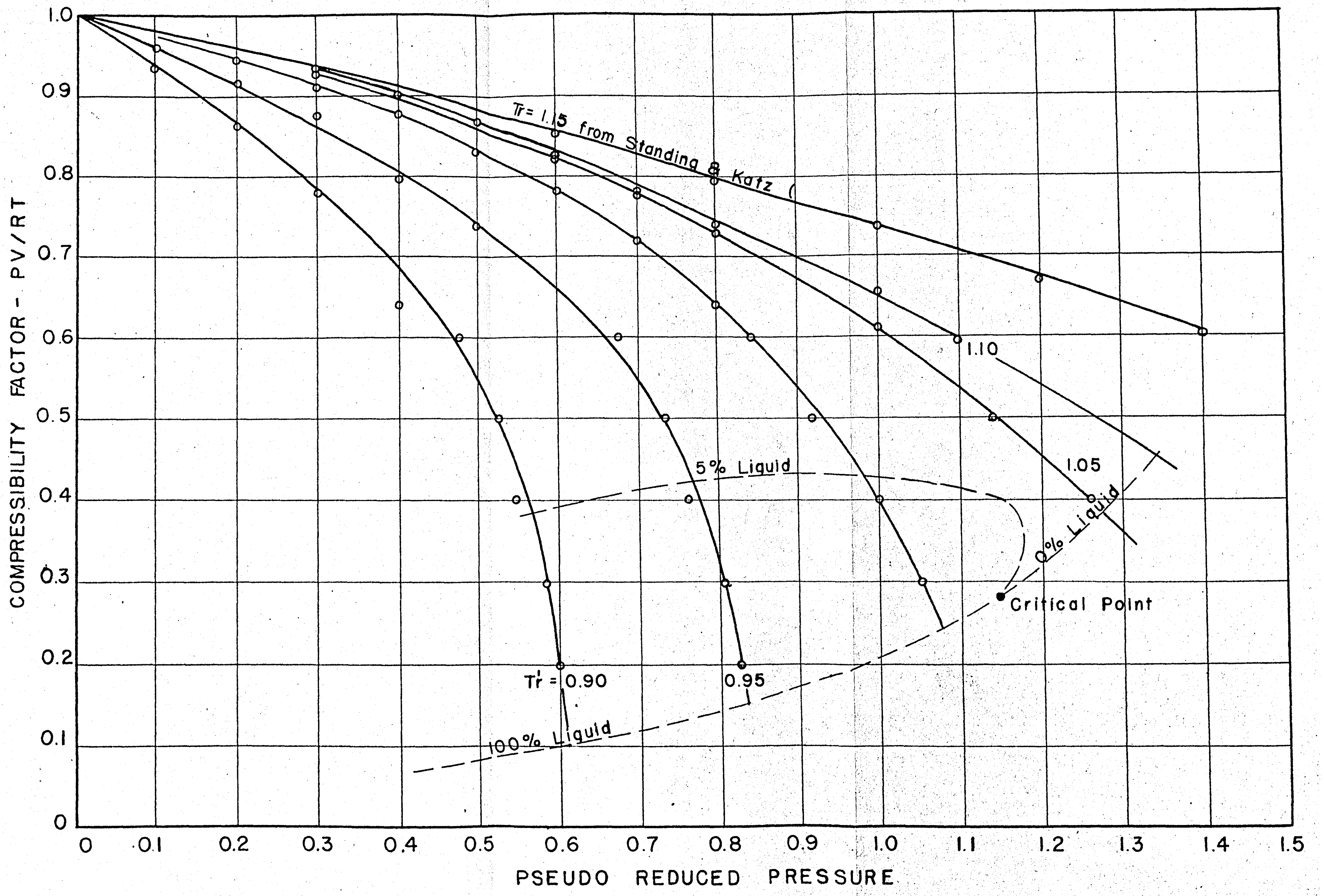


EXHIBIT K-CONTINUED PRESSURE-VOLUME-TEMPERATURE BEHAVIOR OF MIXTURE "AB"

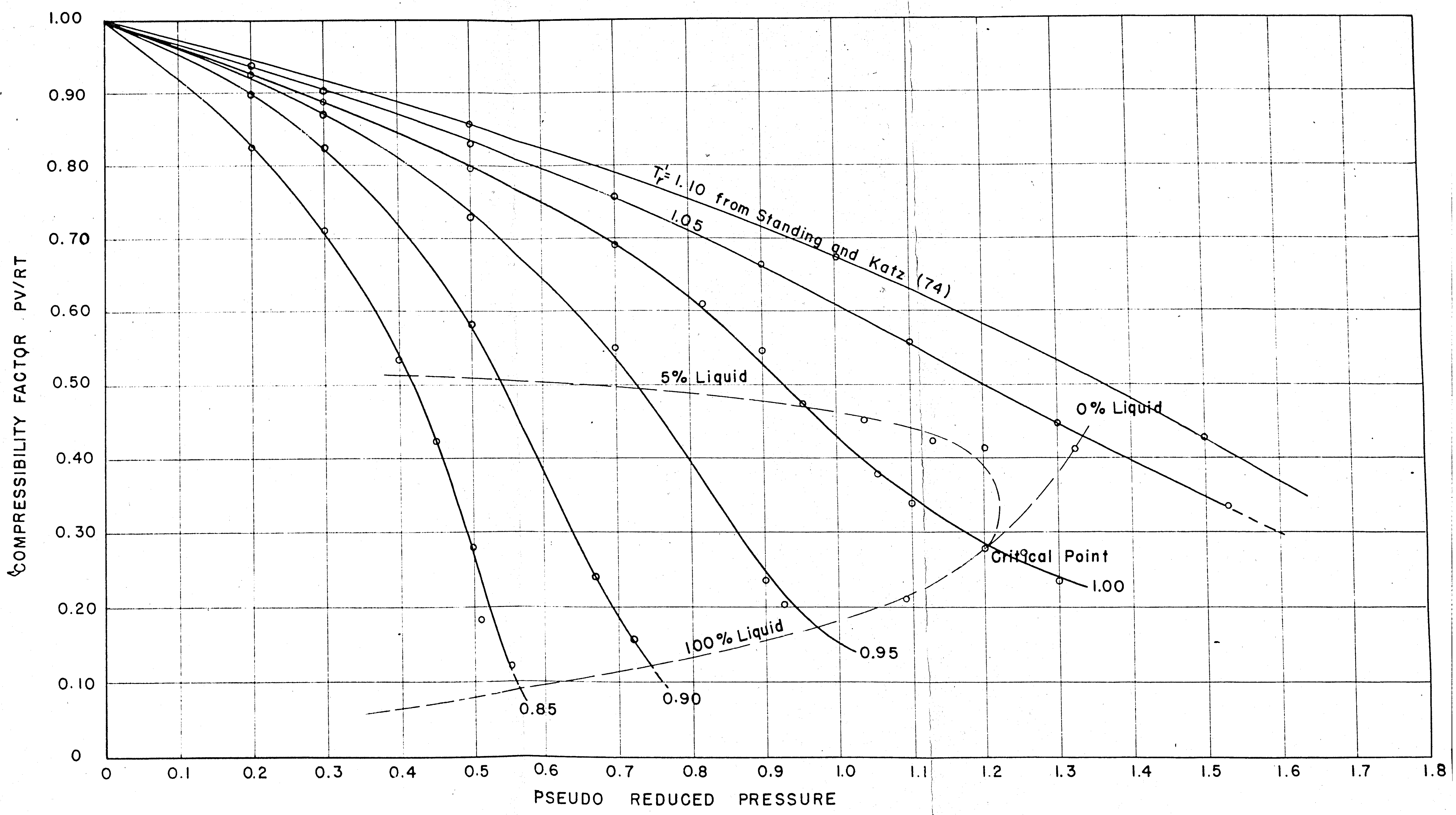


EXHIBIT K – CONTINUED PRESSURE–VOLUME–TEMPERATURE BEHAVIOR OF MIXTURE "AB 700/800"

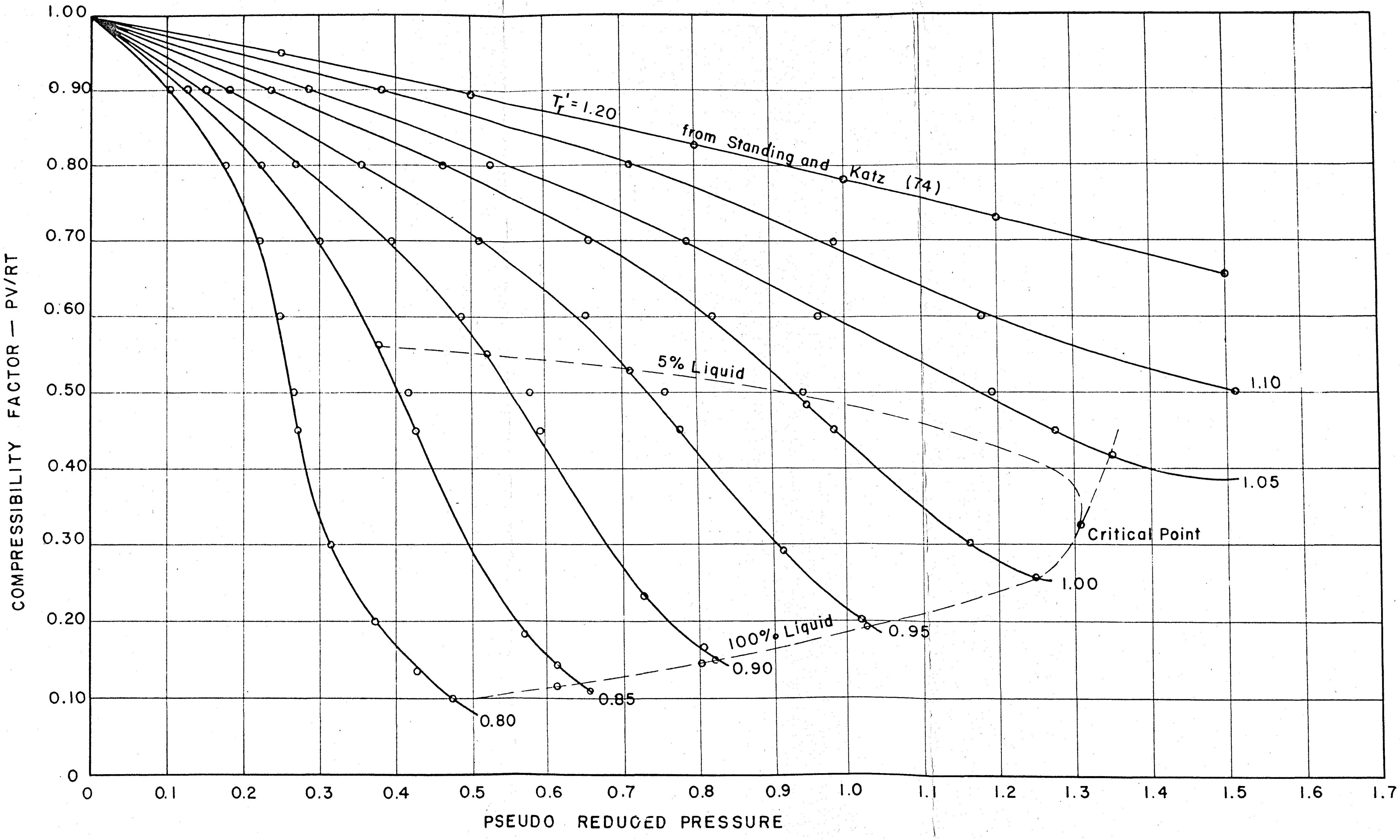


EXHIBIT K—CONTINUED PRESSURE-VOLUME-TEMPERATURE BEHAVIOR OF MIXTURE "AB 700/940"

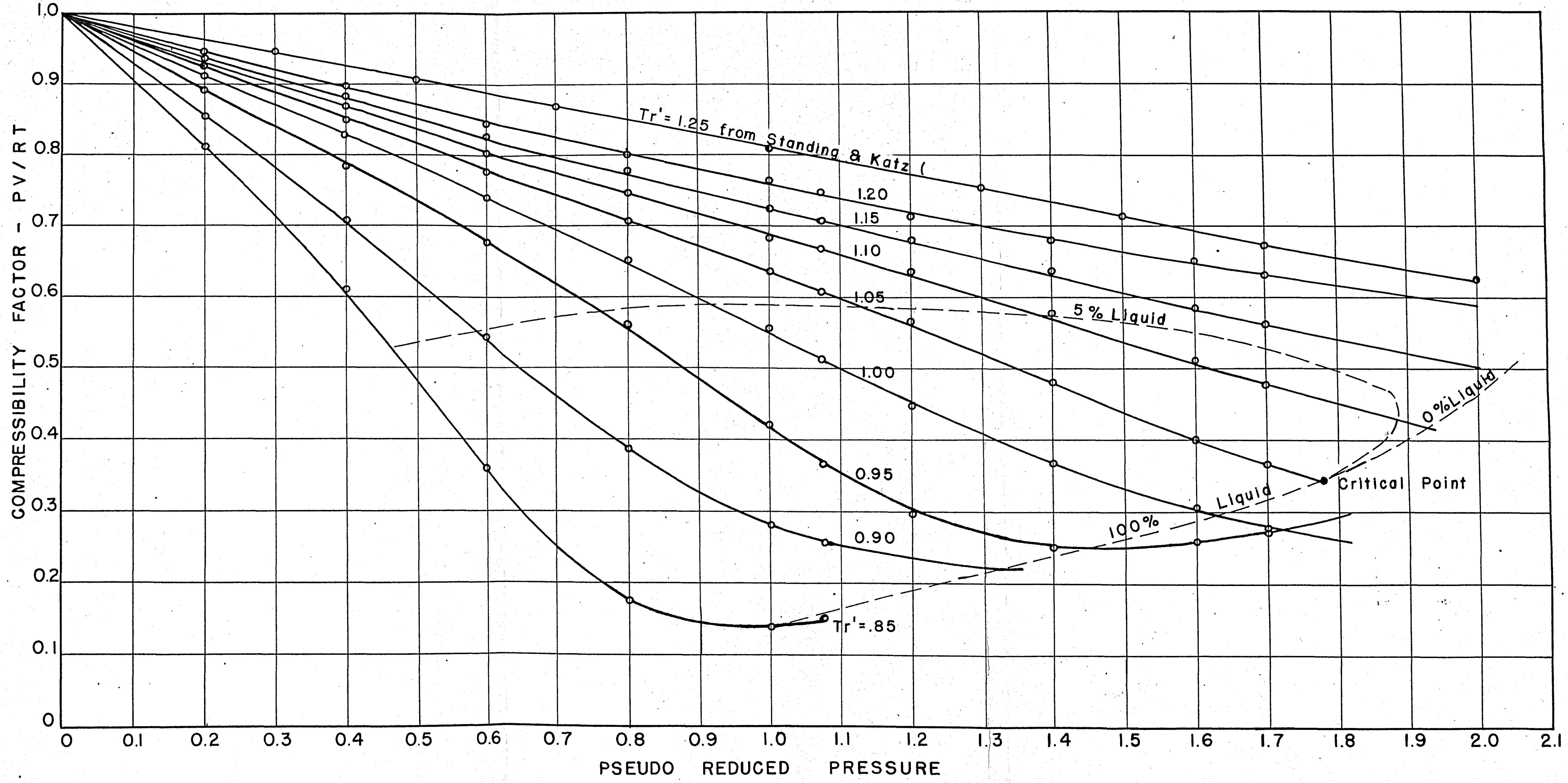


EXHIBIT K-CONTINUED PRESSURE - VOLUME - TEMPERATURE BEHAVIOR OF MIXTURE "B"

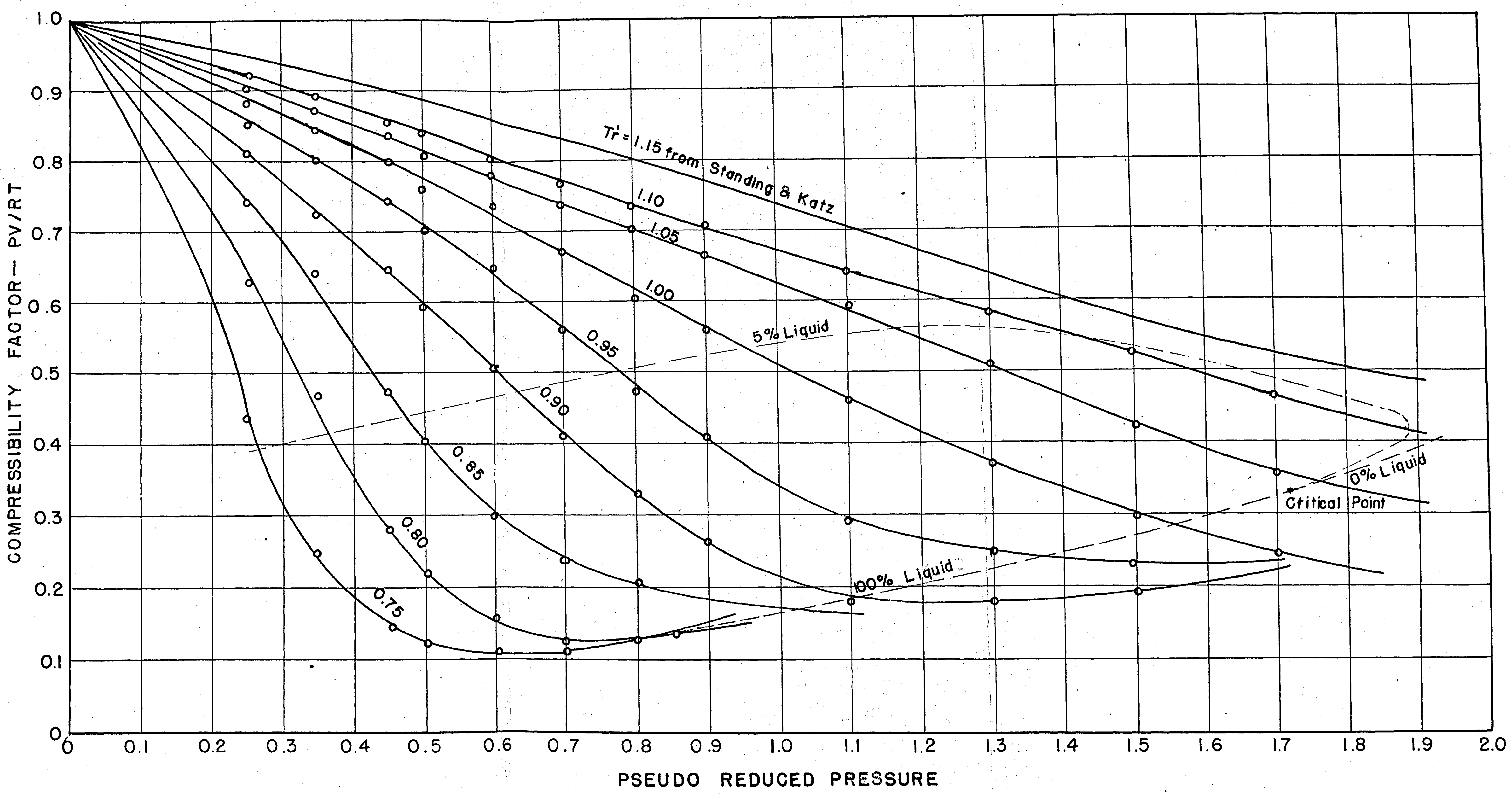


EXHIBIT K-CONTINUED PRESSURE-VOLUME-TEMPERATURE BEHAVIOR OF MIXTURE "C"

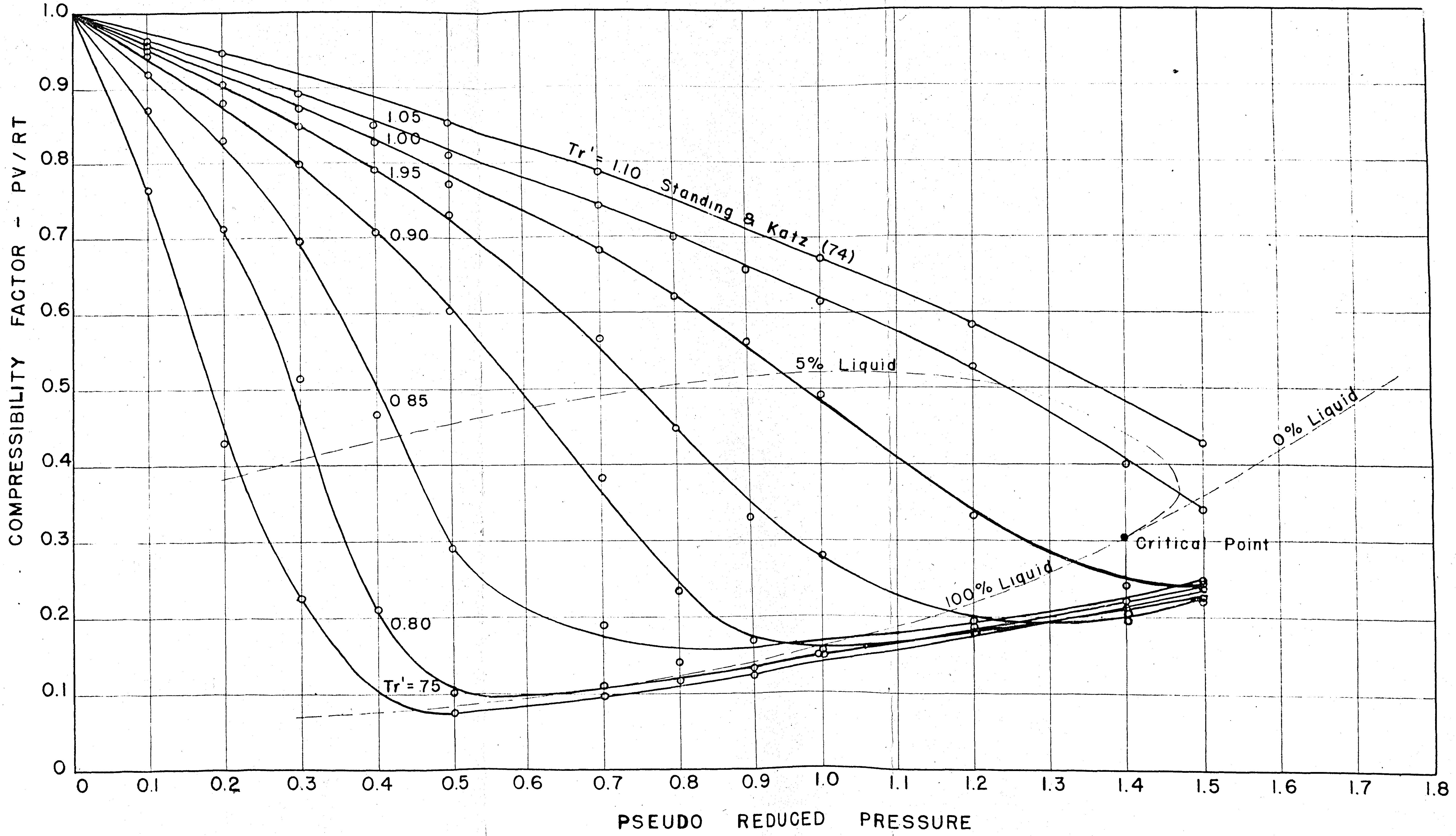


EXHIBIT K - CONTINUED PRESSURE - VOLUME - TEMPERATURE BEHAVIOR OF MIXTURE "D"