1941

The system benzene-methyl alcohol : ?b densities, refractive indices, boiling points, and specific heats.

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University of Louisville

Recommended Citation

UNIVERSITY OF LOUISVILLE

THE SYSTEM BENZENE - METHYL ALCOHOL

PART I - DENSITIES, REFRACTIVE INDICES,

BOILING POINTS, AND SPECIFIC HEATS

A Thesis

Submitted to the Faculty

of the Graduate School

of the University of Louisville

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF CHEMICAL ENGINEERING

Department of Chemical Engineering

By

Samuel Rosenberg

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Director . . . .

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August 14, 1941 . . . .

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ACKNOWLEDGMENT

ABSTRACT

This thesis presents information on the binary system benzene-methyl alcohol. The system is shown to be of a minimum boiling point type and does not follow the normal laws of solutions.

Experimental procedures and apparatus are described for the determination of several physical property curves for the mixture. Complete data and curves are presented for densities, refractive indices, boiling points, and vapor-liquid equilibriums. Specific heat curves are included but are considered to be of doubtful significance.

Further work is indicated on the latter data as well as the equilibrium enthalpy relationships of the system.

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INTRODUCTION

Several theoretical methods are now employed for the determination of the number of plates necessary in a distillation design problem. Of these, the more frequently used are the methods of Lewis (5), McCabe and Thiele (1), Smoker (7), and Ponchon and Savarit (6).

Although each method has its advantages, each also has its limitations. Theoretically, the system of Ponchon and Savarit is the most accurate when used on systems having a simple equilibrium diagram of the type represented by the system benzene-toluene.

To date, however, the method has not been employed on a system having a constant boiling mixture such as benzene-methyl alcohol (methanol).

The data necessary for the use of the method of Ponchon and Savarit are:

1. Liquid composition versus vapor composition (equilibrium diagram)

2. Equilibrium compositions versus temperature (boiling point diagram)

3. Composition versus enthalpy of liquid and vapor equilibria.

The disadvantage of this method is that, in practically all cases, the larger part of the necessary data is not available. Neither is there any published literature dealing with the application of this procedure to a system exhibiting a constant boiling point in its equilibrium curve. Hence, the problem of this thesis is

to obtain the preliminary data on the system chosen,
to furnish information in the published literature, and
to allow an initial investigation of the application of
this procedure.

This preliminary investigation involves determinations
of densities, refractive indices, boiling points, liquid-
vapor equilibria, and specific heats for mixtures of benzene
and methanol of all concentrations.

HISTORICAL

Previous to the publication of the method of distillation calculation as set forth by Ponchon and Savarit, the most frequently used method was that of McCabe and Thiele. This method is based on several assumptions which may be incorrect in many applications.

These assumptions, however, are normally taken care of in a factor which is called the plate efficiency. Because this method is so rapid and because only the equilibrium diagram is necessary for its application, it has met with considerable acceptane by the engineering profession.

Several of these assumptions are :

(1) Constant molar overflow

(2) Zero heat of mixing

(3) Zero radiation loss

(4) Sensible heat changes through the tower are negligible in comparison to the latent heat

(5) The algebraic sum of (2), (3), and (4) is zero.

The process of distillation is one of the transfer of heat from a vapor to a liquid. Hence, it can be seen that the first assumption is incorrect unless the molal latent heats of vaporization of the components are equal. As would be expected, therefore, the McCabe and Thiele method shows greater deviations for systems in which the latent heats of vaporization differ greatly than for systems in which these heats are more nearly equal.

It also can be seen that a true analysis of the problem of separation by distillation should be built around the assumption of constant enthalpy from plate to plate. The method of Ponchon and Savarit assumes that the mass heat transfer from plate to plate is a constant.

From this assumption the method of Ponchon and Savarit was developed in which the composition of liquid is plotted against the enthalpy of the liquid and composition of vapor is plotted against the enthalpy of the vapor.

This method has been proven to work fairly well for systems having a simple boiling point diagram, such as benzene-toluene, nitrogen-oxygen, and ammonia-water. To date no work has been done on the method as applied to systems having a minimum boiling mixture, such as benzene-methyl alcohol.

MATERIALS

The materials used in the experimental work of this thesis were C. P. grade methyl alcohol obtained from the Peaslee-Gaulbert Paint Company and Reagent grade benzene obtained from E. H. Sargent and Company, Chicago, Illinois.

These were purified for use by triple distillation through a glass packed distillation tower. In each of the distillations heads and tails of about 10% were discarded and the final product of benzene and methyl alcohol distilled entirely within a range of $0.1^\circ C$.

The specifications for these materials are:

	Benzene		Methanol	
	Experimental	I.C.T.	Experimental	I.C.T.
Color	Water white		Water white	
Odor	Characteristic		Non-pungent	
Density	$0.8724\frac{25}{4}$	$0.8787\frac{15}{4}$	$0.7865\frac{25}{4}$	$0.7910\frac{15}{4}$
Boiling Point	$80.1^\circ C$	$80.1^\circ C$	$64.1^\circ C$	$64.1^\circ C$
Refractive Index	1.4967^{25}	1.5016^{29}	1.3264^{25}	1.3276^{25}

After purification the methanol was kept in a bottle closely fitted with a rubber stopper and the benzene was stored in a bottle closely fitted with a cork stopper wrapped in tin foil.

EXPERIMENTAL

PROCEDURE AND RESULTS

1: Determination of Density versus Composition Values.

A standard Westphal balance was used for the determination of this data. Samples of the following compositions were made up with a Mohr pipette graduated to 0.1 cc and placed in clean dry test tubes closely fitted with tin foil wrapped stoppers.

Sample Number	Volume Per Cent Benzene	Volume Per Cent Methanol
1	100	0
2	90	10
3	80	20
4	70	30
5	60	40
6	50	50
7	40	60
8	30	70
9	20	80
10	10	90
11	0	100

The samples were placed in a water bath kept at 25° $\pm$ 0.5°C. The westphal balance was then checked against distilled water at 25° $\pm$ 0.5°C and set to correspond with that in the International Critical Tables (2).

A sample was taken from the bath, and the approximate density quickly determined with the balance. The sample was replaced in the bath for at least ten minutes and the bob

of the balance dried thoroughly. The density was again determined, this time more accurately and the sample again replaced in the bath. This procedure was repeated until the density checked to the fourth decimal place for each sample. These data were collected and are shown in table I.

The plot of these data both as density versus mol per cent composition and as density versus volume per cent composition is shown in figure 1.

2: Determination of Refractive Index versus Composition Values.

An Abbé refractometer was used for the determination of this property. The same samples used for the determination of the composition versus density plot were used for this phase of the procedure.

A water supply was prepared at a temperature to maintain the refractometer at 25°C. Then the water from this supply was run through the refractometer and the temperature of the instrument kept at 25° ± 0.5°C by regulating the rate of flow.

Each sample was placed in the water supply for at least ten minutes before its refractive index was run. At this time the sample was removed from the bath and a dropper immersed in the tube. This first dropperful of sample was discarded and a second quickly taken.

This material was then inserted between the ground glass plates of the refractometer and the refractive index

TABLE I

Average Densities and Refractive Indices of Benzene-Methanol Mixtures

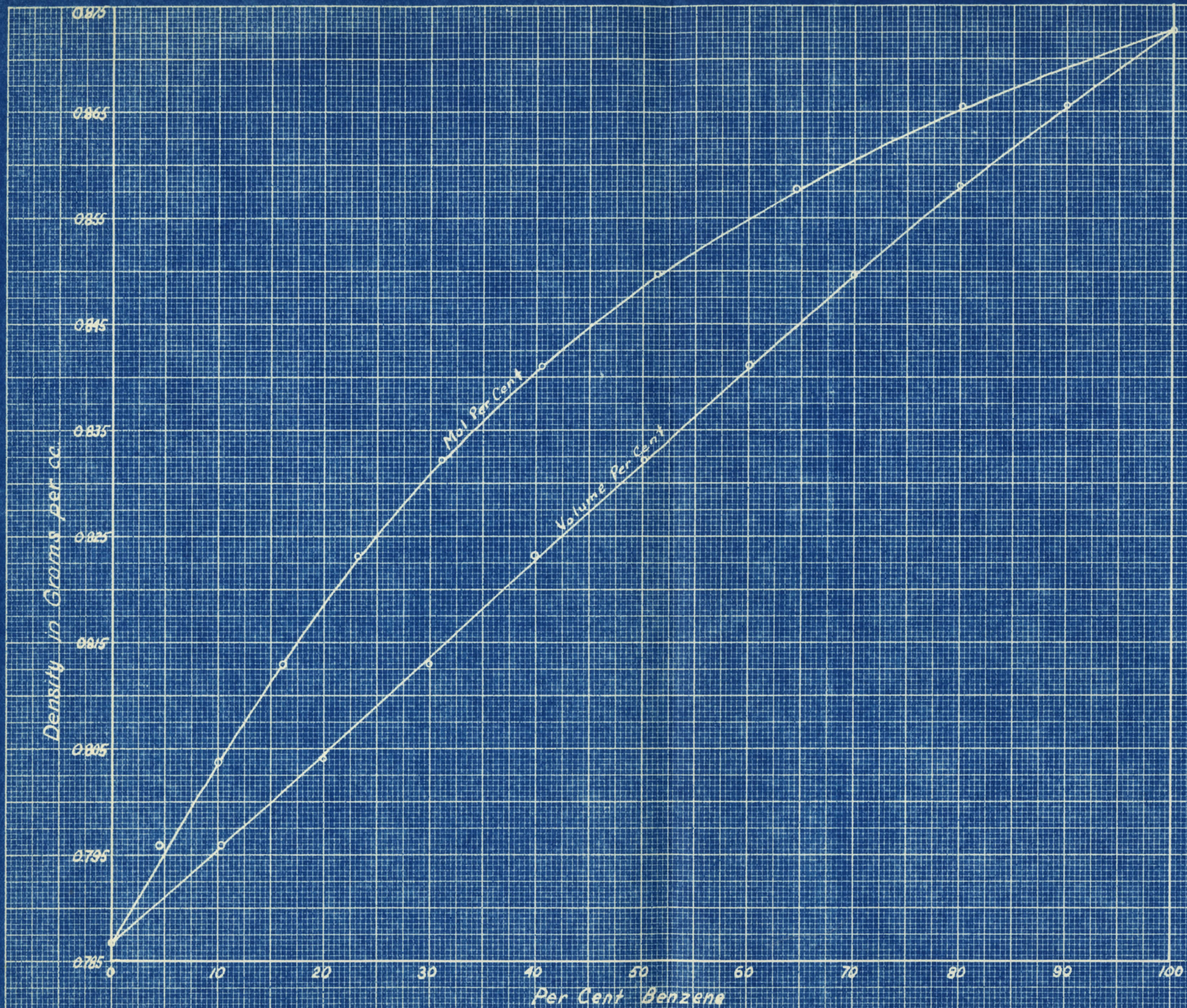| Sample No.	Volume % Benzene	Volume % Methanol	Mol % Benzene	Mol % Methanol	Density at 25°C	Average n_D at 25°C
1	0	100	0	100	0.7865	1.3264
2	10	90	4.81	95.19	0.7960	1.3429
3	20	80	10.21	89.79	0.8040	1.3595
4	30	70	16.29	83.71	0.8128	1.3765
5	40	60	23.28	76.72	0.8230	1.3942
6	50	50	31.25	68.75	0.8320	1.4121
7	60	40	40.60	59.40	0.8410	1.4296
8	70	30	51.50	48.50	0.8495	1.4471
9	80	20	64.50	35.50	0.8576	1.4640
10	90	10	80.10	19.90	0.8653	1.4809
11	100	0	100	0	0.8724	1.4967

Figure 1 - DENSITY VERSUS COMPOSITION

determined to four decimal places. The original sample was replaced in the bath for an additional ten minutes to bring it to 25° ± 0.5°C.

The refractometer was dried with lens tissue and the process repeated on the same sample. This was continued until three readings were obtained which were within 0.0003 of each other. These were recorded and the arithmetical average taken as the refractive index of the sample at 25°C.

The process was repeated with all samples and their refractive indices determined in the same manner.

These data were collected and are shown in table I. Graphically they are plotted both as refractive index versus mol per cent composition and refractive index versus volume per cent composition in figure 2.

3: Determination of Boiling Point Diagram (a).

A. Theory of Othmer Boiling Point Apparatus

In order to prepare the boiling point diagram and hence the equilibrium diagram, it is necessary to employ a unit of the Othmer type or its equivalent.

The unit, see figure 3, is a closed circuit with a condenser at one point. Vapor from the boiling liquid in the system is condensed and returned to the main charge. This process continues until the composition of the vapor leaving the main body of the liquid is the same as that of the liquid overflowing from the well below the condenser. At
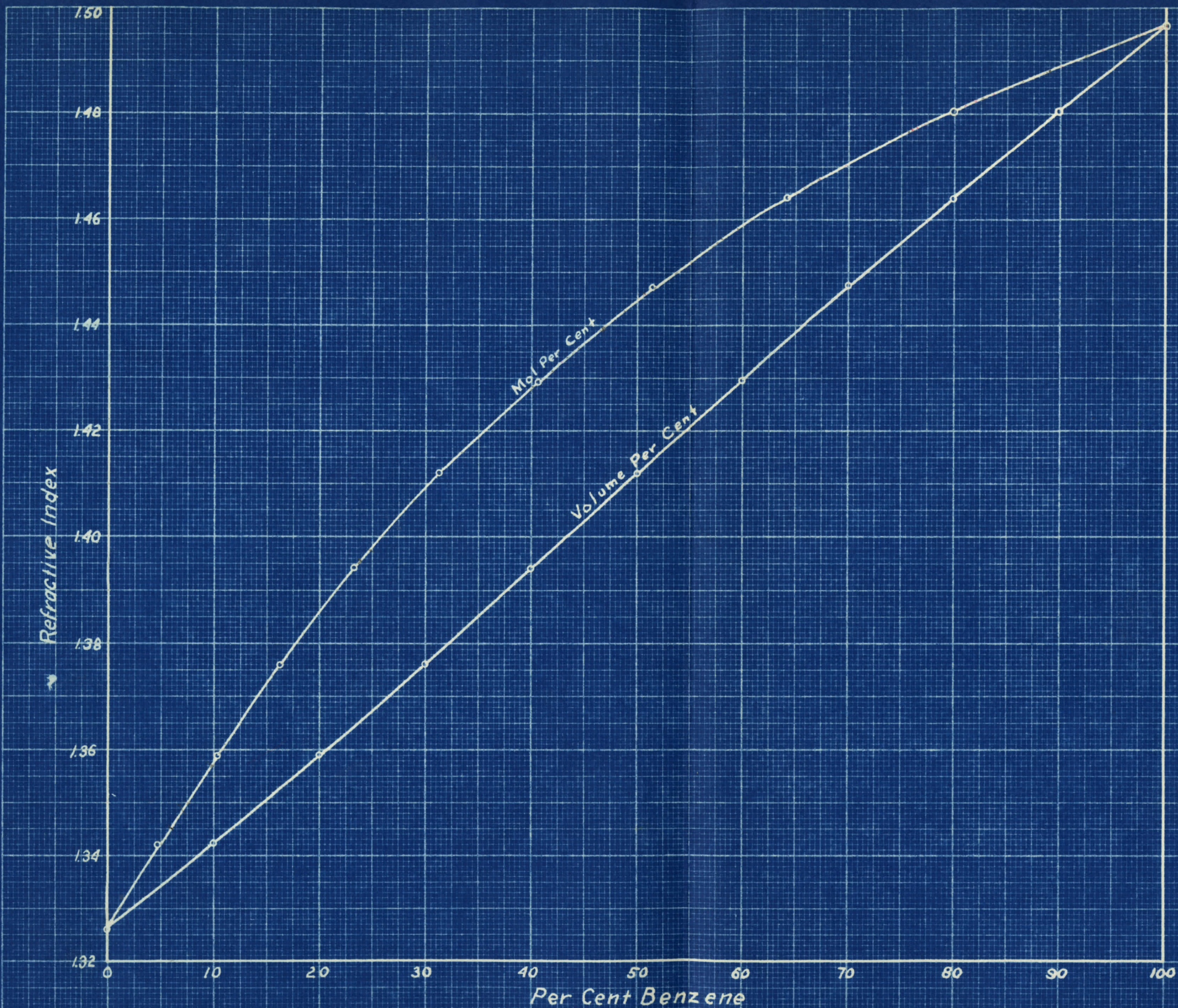
Figure 2.- REFRACTIVE INDEX VERSUS COMPOSITION.
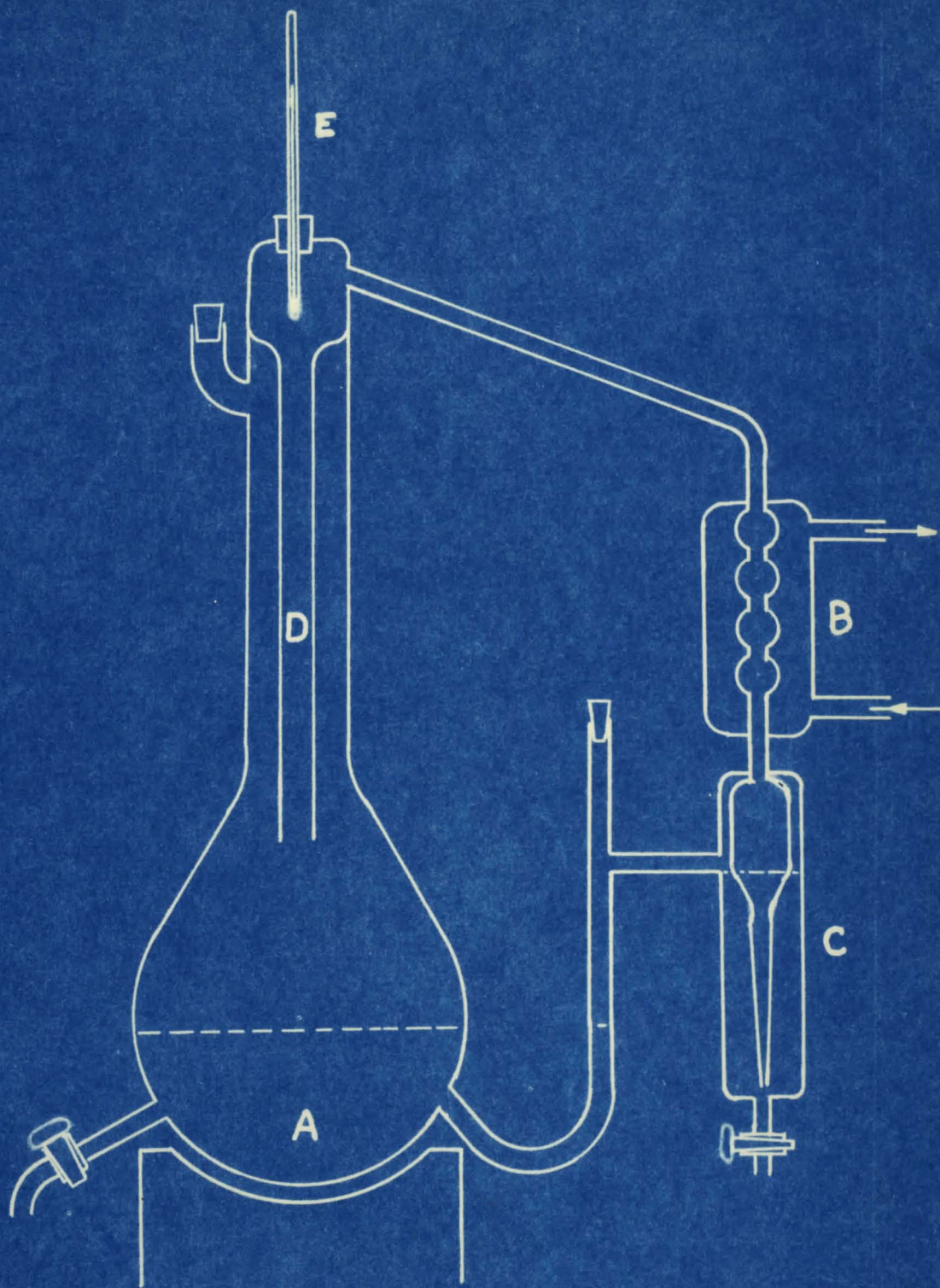
Figure 3.- Othmer Apparatus.

this point the temperature of the system is a constant, and the system is in equilibrium. Samples of the boiling liquid and of the condensed vapor are obtained and their composition determined by means of the refractive indices of the samples.

B. Procedure

The apparatus was set up as shown in figure 3. A mixture of purified benzene and purified methyl alcohol was placed in the bottom of the container at A. Heat was applied here, and the vapor was condensed in the condenser B and collected in the reservoir C. The lead to this well was run almost to the bottom so that the addition of more condensate caused the liquid at the top to overflow and a continuous change of material in the well was the result.

The tube D to the condenser was completely enclosed by a vapor jacket to eliminate droplets in the vapor. In this manner, the vapor reaching the condenser was assured of being in equilibrium with the liquid in A. The temperature of this vapor was determined by means of the 0.1°C thermometer placed at E.

As the condensate overflowed from C, it was returned to A so that in time, the composition of vapor leaving the liquid was the same as the composition of the liquid overflowing from the reservoir. This was shown by the constant reading on the thermometer. By taking samples from C and A, the vapor in equilibrium with the liquid was obtained. The composition of these two mixtures were

then determined by means of their refractive indices at 25°C. These values when compared with the plot of refractive index versus composition resulted in the composition of the samples. These compositions were plotted against the temperature at which the system was in equilibrium to obtain two points on the boiling point diagram.

By adding a slight amount of one material the run was repeated and another two points obtained on the curve. This was repeated until sufficient points had been obtained to define the curve definitely. The data taken from this procedure are shown in table II.

The plot of vapor composition versus temperature and of liquid composition versus temperature is shown on figure 5.

4: Determination of Boiling Point Diagram (b).

A. Theory

Before the vapor portion of the boiling point diagram was determined for mixtures containing less methyl alcohol than that in the constant boiling mixture, the Othmer apparatus was damaged beyond use. Hence another method for this determination had to be devised.

The method proposed to obtain the data for this curve was one employing the following system:

A mixture of purified benzene and purified methyl alcohol was placed in a small flask and slowly heated. Sam-

TABLE II

Liquid-Vapor Equilibria by the Othmer Apparatus.

| Run No.	Temp.	Average n_D of vapor	Average n_D of liquid	Mol % Methanol in vapor	Mol % Methanol in liquid
0-1	62.85	1.3450	1.3301	92.0	97.7
0-2	59.30	1.3952	1.3570	73.5	87.6
0-3	59.20	1.3978	1.3610	72.0	86.0
0-4	58.50	1.4069	1.3740	68.5	81.2
0-5	57.70	1.4160	1.3957	63.9	73.0
0-6	57.50	1.4216	1.4190	61.0	62.5
0-7	59.80	1.4285	1.4564	57.0	36.5
0-8	57.80	1.4280	1.4770	57.2	18.0
0-9	60.80	1.4395	1.4880	49.5	5.0
0-10	78.00	1.4931	1.4972	4.5	0.0
0-11	58.30	1.4340	1.4830	57.0	17.0
0-12	58.70	1.4359	1.4861	55.75	13.2
0-13	62.80	1.4429	1.4908	52.50	7.75
0-14	67.30	1.4557	1.4947	42.25	2.5
0-15	77.60	1.4791	1.4970	21.0	0.0
0-16	58.60	1.4349	1.4910	57.5	7.0
0-17	58.00	1.4311	1.4660	58.5	34.0
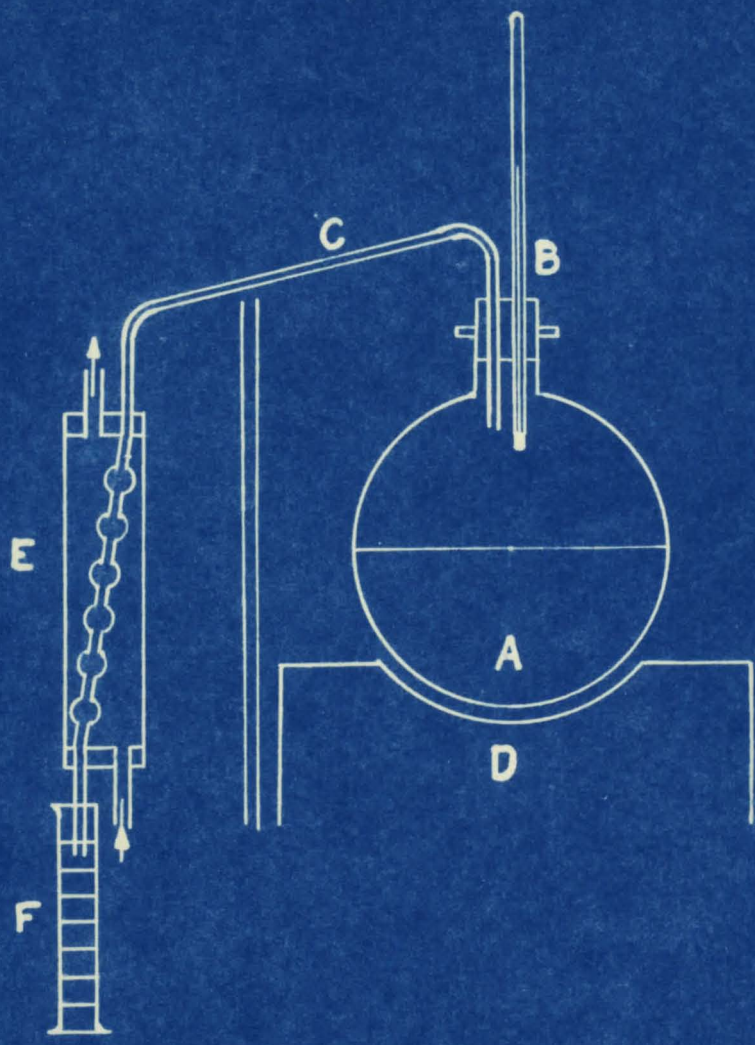
Figure 4.- Batch Distillation Unit.
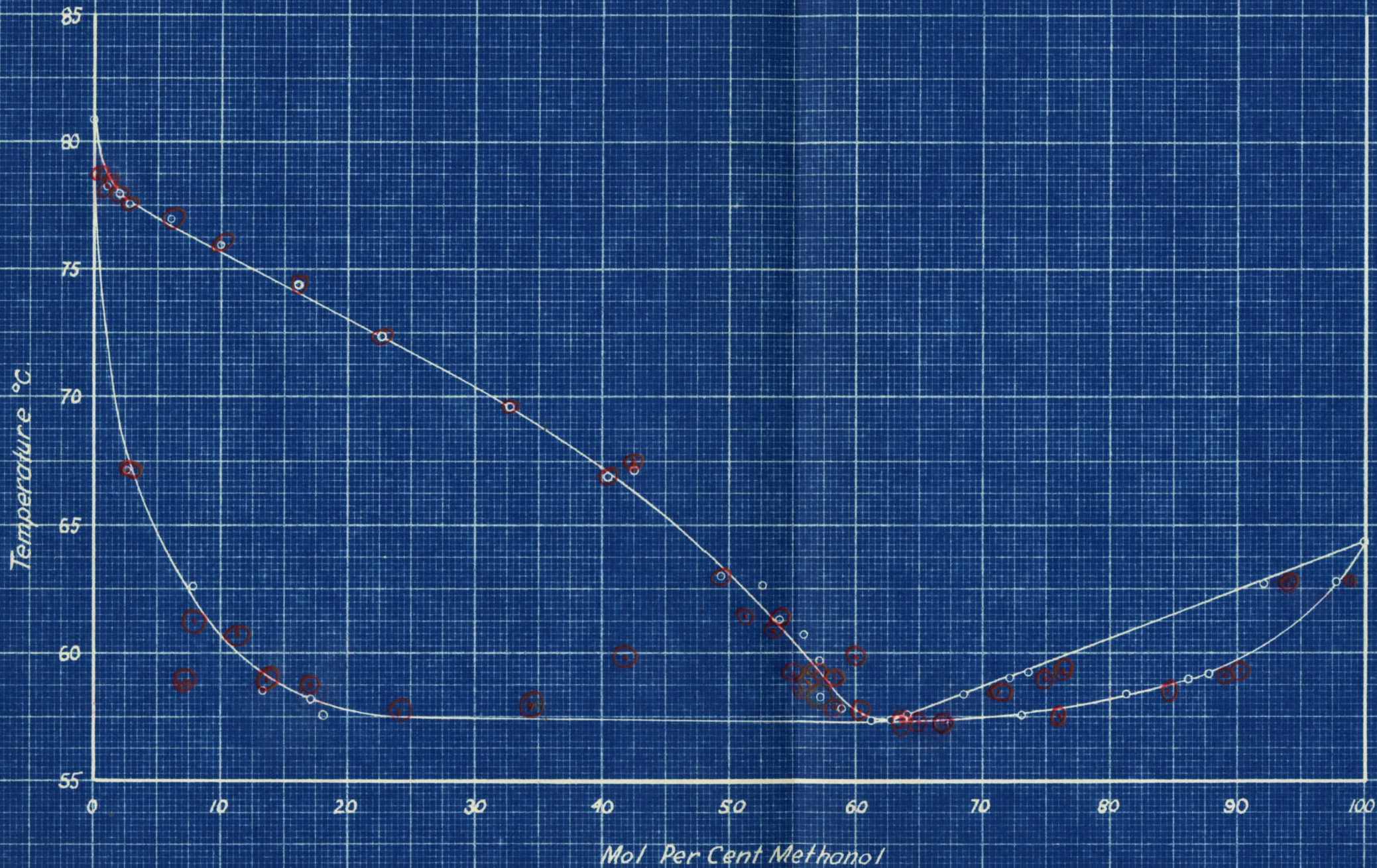
Figure 5.- BOILING POINT DIAGRAM.

ples were taken through a short lead tube run through a condenser. The temperature at the start of the sample and at the end of the sample were recorded.

Since the heating was slow, the lead tube short and insulated, and the samples taken were small, the average temperature could be plotted against the average composition of the sample as shown by means of the refractive indices of the samples. This resulted in reproducible data which gave the vapor curve of the equilibrium diagram to the left of the constant boiling mixture.

B. Apparatus

The apparatus used for this determination was set up as shown on figure 4. It consisted of a 500 cc round bottom flask at A. A $0.2^{\circ}C$ thermometer was placed at B. The lead tube C was as short as possible. It was also slanted downward to insure no return of any condensate to the flask. Heat was applied at D. The condenser was water cooled and led directly to the graduated receiver F.

C. Procedure

A mixture of purified methyl alcohol and purified benzene was prepared which contained slightly less methyl alcohol than the constant boiling mixture. This mixture was placed in the flask A. This was slowly heated and the vapors condensed at E.

As the distillation progressed, the distillate was collected in the graduate at F, and when four cc had been accumulated, the graduate was replaced with one that was clean and dry. This sample was then transferred to a clean, dry test tube and labeled. The temperatures at the start and finish of the four cc were also recorded as read at B.

When the temperature in the flask had risen to within about 0.5°C of the boiling point of pure benzene, the run was stopped.

The compositions of the samples were then determined by means of their refractive indices at 25°C. The data for this set of runs are shown in table III. This composition was then plotted against the average temperature at which the sample distilled over.

This procedure resulted in the vapor curve of the boiling point diagram.

5. Determination of Equilibrium Diagram.

A. Procedure

In order to prepare this plot of liquid composition versus vapor composition at equilibrium, it was necessary only to plot the compositions of liquid and vapor as shown in the boiling point diagram. This plot is shown in figure 6.

6. Determination of Plot of Specific Heat versus Composition.

A. Theory

TABLE III

Temperature-Vapor Equilibria of Boiling

Benzene-Methanol Mixtures

Run No.	Average Temperature	Average n_D	Mol % Methanol
BP-1	58.0	1.4313	58.5
BP-2	61.4	1.4390	53.8
BP-3	63.1	1.4460	49.3
BP-4	67.1	1.4582	40.4
BP-5	69.7	1.4677	32.5
BP-6	72.4	1.4777	22.6
BP-7	74.4	1.4838	16.0
BP-8	76.1	1.4890	9.8
BP-9	77.1	1.4921	6.0
BP-10	77.6	1.4946	2.7
BP-11	78.0	1.4951	2.0
BP-12	78.3	1.4960	0.9
BP-13	78.5	1.4961	0.8
BP-14	78.6	1.4966	0.1
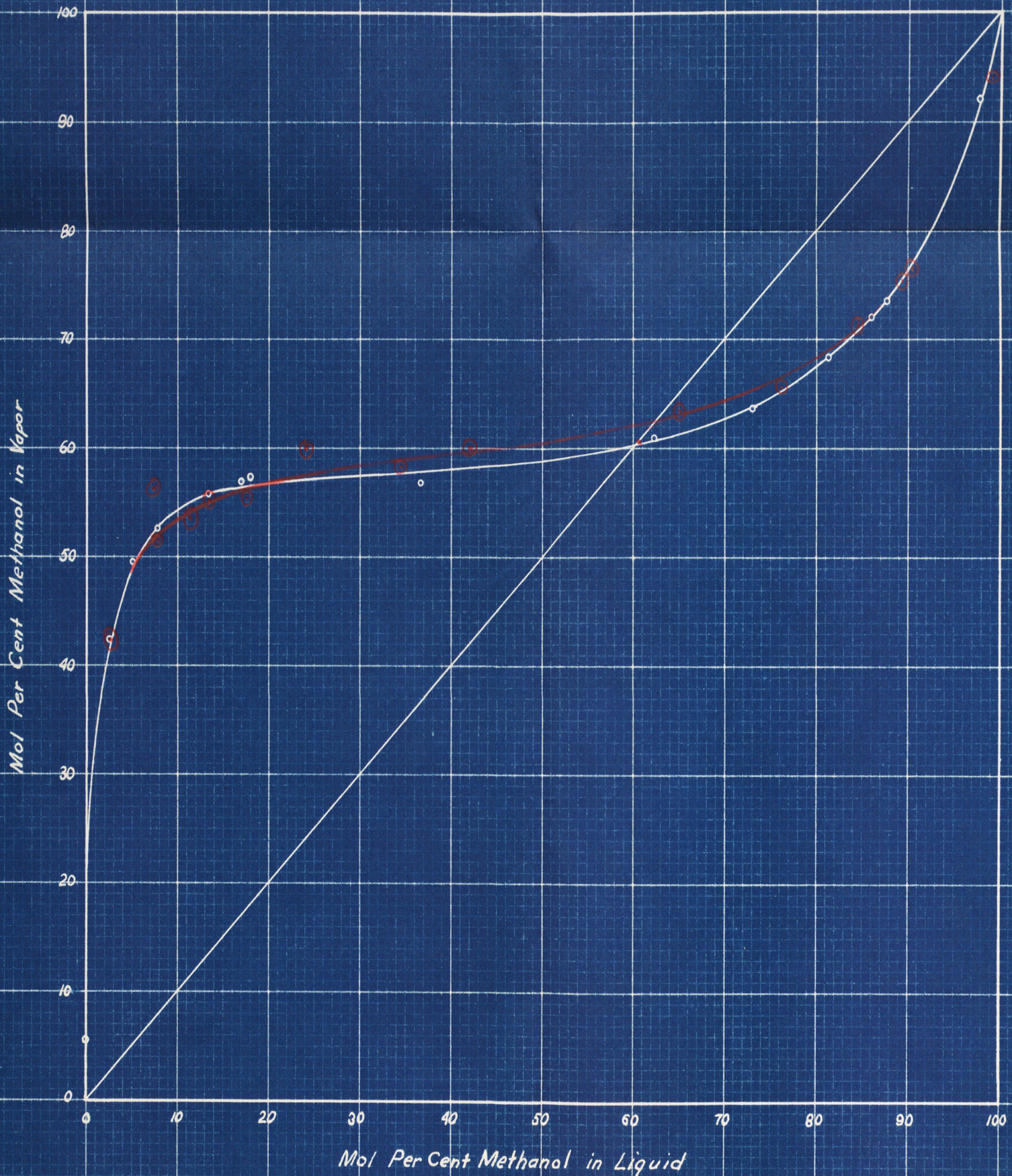
Figure 6.- EQUILIBRIUM DIAGRAM.

The specific heat of a liquid is defined as the heat necessary to raise a unit mass of the material one degree in temperature on some temperature scale.

Thus, by adding a known amount of heat to a known amount of liquid and recording the temperature rise, the specific heat could be calculated. Heat was added by means of an electric coil with a voltmeter and ammeter inserted in the circuit. A rheostat was also used to control the voltage drop across the coil and the current through the coil.

The heat was added for a known length of time as shown by a stop clock. Losses in the system were calculated by means of a standard liquid of known specific heat in the calorimeter, as explained subsequently.

B.   Procedure

In order to determine the enthalpy of the liquid a standard set-up was employed (3). In this set-up, a weighed amount of pure material whose specific heat was accurately known, was placed in a calorimeter equipped with a 0.2°C thermometer, motor driven stirrer, and heating coil.

The coil was connected across the terminals of a d-c source of supply and a voltmeter and ammeter inserted in the circuit along with a carbon plate rheostat as shown in figure 7.

The current was allowed to run for five minutes during which time the initial temperature was recorded, the voltage
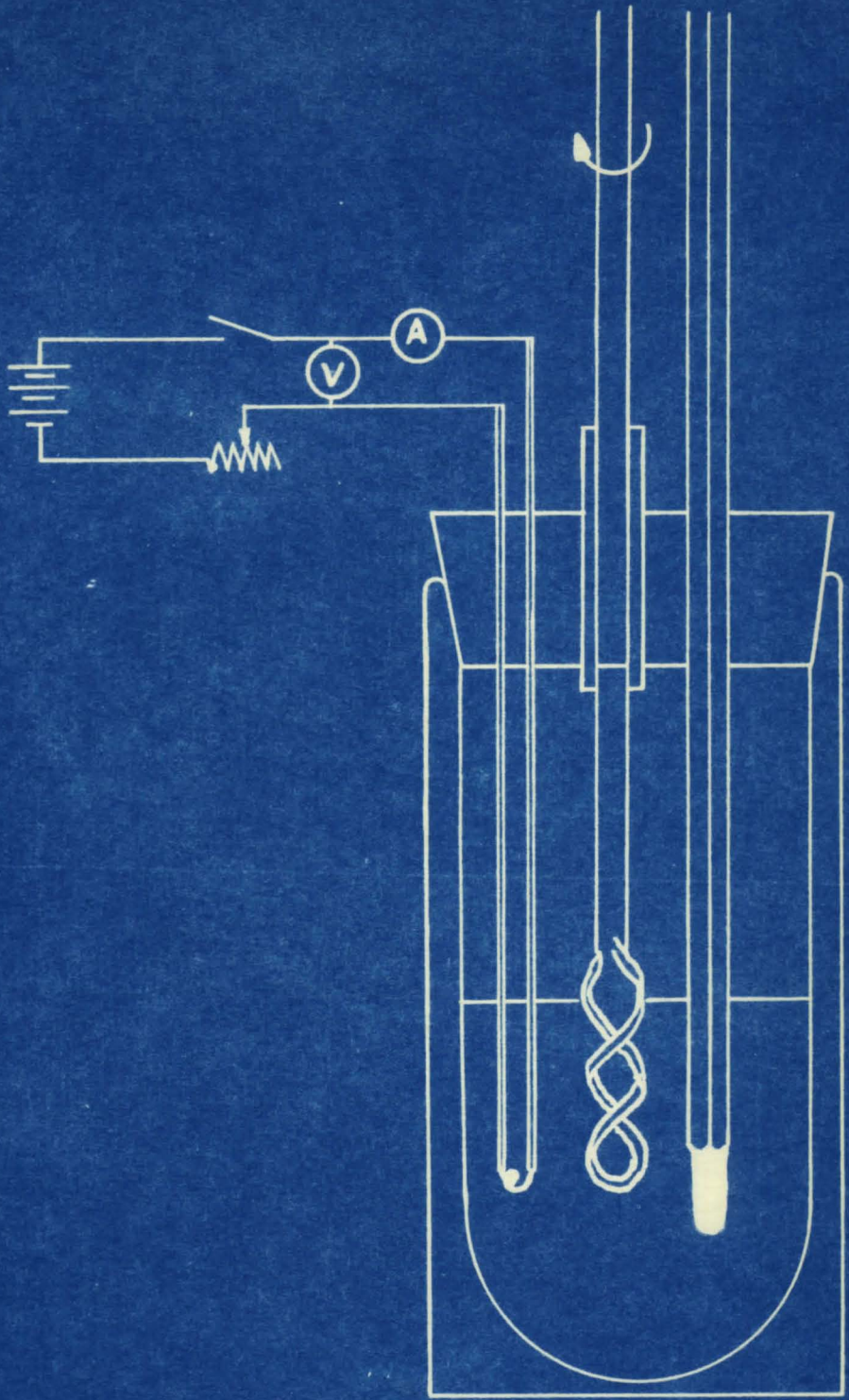
Figure 7.- Apparatus for Determination of Specific Heats.

and current kept constant and recorded, and the maximum temperature recorded.

At the end of five minutes, the current was cut off and the stirrer allowed to run for an additional five minutes in order to determine the loss. The drop in temperature during the second five minutes was added to the rise during the first five minutes, and the total used in calculating the heat capacity of the calorimeter at the average temperature of the run.

The equation is,

$$\frac{(E)(I)(t)}{(4.182)(\Delta T)} = (C_p'W) + (m)(C_p)$$

where E = potential drop in volts,

I = current in amperes,

ΔT = rise in first five minutes drop in second five minutes,

t = time of heating in seconds,

m = weight of liquid in grams,

C_p = specific heat of liquid in gram calories per $^{\circ}C$.

In this equation everything is known except $(C_p'W)$ which can be calculated. See table IV. When the calibration was run on methyl alcohol, benzene, and toluene as a check, the specific heat of a mixture of benzene and methyl alcohol could be determined.

Then with the known value of $(C_p'W)$ the specific heat of the mixture could be calculated at various temperatures. The same procedure was used and the same data were taken. These

TABLE IV

Calorimeter Calibration with Toluene, Benzene, and Methanol

Run No.	CC-1	CC-2	CC-3	CC-4	CC-5	CC-6	CC-7	CC-8
Material	Tol.	Tol.	Be.	Be.	Be.	Alc.	Alc.	Alc.
E	1.8	1.82	1.54	1.47	1.5	1.53	1.52	1.52
I	3.0	2.8	2.8	2.8	2.8	2.8	2.8	2.8
T_1	29	41	26	50	60	25	38	46
T_2	32.5	43.95	29.05	52.3	62	27.5	39.85	47.7
$T_{av.}$	30.75	42.50	27.5	51.65	61	26.26	38.9	46.85
drop	0.25	0.45	0.15	0.7	1.0	0.1	0.55	0.7
ΔT	3.75	3.4	3.2	3.0	3.0	2.6	2.4	2.4
t	300	300	300	300	300	300	300	300
m	203.5	203.5	175.4	175.4	175.4	156.3	156.3	156.3
C_p	0.407	0.412	0.414	0.437	0.444	0.601	0.618	0.627
$C_p'W$	20.4	21.1	23.4	21.3	22.6	20	30.4*	30.5*

* These values were obtained neglecting the loss of heat by vaporization of 0.4 grams of methanol per hour or a loss of 0.033 grams per run of ten minutes. When corrected for this factor, the true values of $C_p'W$ for these runs are 21.50 and 21.60 respectively.

The average value of $C_p'W$ = 21.50.

data are shown in table V. The specific heats of constant mixture compositions were plotted versus the average temperature of the run and are shown in figure 8.

Interpolated values of C_p were then picked off the curves for 30°, 40°, and 50°C. These values were plotted as constant temperature specific heats against varying compositions in figures 9, 10, and 11. Average curves were drawn and these assembled curves are presented in figure 12.

TABLE V

Summary Data for Specific Heats

| Run No.	T_1	T_2	$T_{av.}$	drop	ΔT	m_1	m_2	$m_{av.}$	E	I	t	Q_T	C_pW	Q_L	n_D	Mol % Be.	C_p
E-1	28.4	31.4	29.9	0.2	3.2	190.9	190.9	190.9	2.19	2.6	300	127.5	21.5	106.0	1.3854	19.75	0.555
E-2	41.7	43.75	42.7	0.5	2.55	190.3	189.9	190.1	1.84	2.6	300	134.5	21.5	113.0	1.3854	19.75	0.594
E-3	52.2	53.7	52.9	0.9	2.4	187.4	187.2	187.3	1.79	2.6	300	139.5	21.5	118.0	1.3854	19.75	0.630
E-4	29.6	32.3	30.95	0.25	2.95	195.5	195.4	195.4	2.01	2.6	300	127.1	21.5	105.6	1.4433	49.0	0.540
E-5	42.3	43.95	43.1	0.5	2.15	194.0	193.8	193.9	1.52	2.6	300	131.9	21.5	110.4	1.4433	49.0	0.570
E-6	50.8	52.05	51.4	0.8	2.05	193.8	193.8	193.8	1.52	2.6	300	138.5	21.5	117.0	1.4433	49.0	0.605
E-7	29.5	31.9	30.7	0.2	2.6	191.0	190.7	190.9	1.54	2.6	300	110.0	21.5	88.5	1.4896	91.0	0.464
E-8	42.0	44.0	43.0	0.5	2.5	190.8	190.8	190.8	1.57	2.6	300	117.2	21.5	95.7	1.4896	91.0	0.503
E-9	50.6	52.35	51.4	0.85	2.6	190.8	190.8	190.8	1.76	2.6	300	126.4	21.5	104.9	1.4896	91.0	0.549
E-10	27.0	29.6	28.3	0.05	2.65	150.2	150.5	150.3	1.54	2.6	300	111.0	21.5	89.5	1.4489	53.2	0.595
E-11	38.0	40.25	39.13	0.45	2.65	150.8	150.7	150.8	1.57	2.6	300	110.5	21.5	89.0	1.4489	53.2	0.593
E-12	50.4	52.1	51.2	1.0	2.7	149.4	149.1	149.2	1.64	2.6	300	113.5	21.5	92.0	1.4489	53.2	0.616
E-13	27.2	29.5	28.3	0.3	2.6	179.9	180.9	180.4	1.5	2.6	300	107.5	21.5	86.0	1.4585	59.9	0.477
E-14	38.0	40.6	39.3	0.6	3.2	179.6	179.2	179.4	1.9	2.6	305	112.4	21.5	90.9	1.4585	59.9	0.506
E-15	54.0	55.2	54.6	1.2	2.4	177.7	177.0	177.4	1.65	2.6	300	127.5	21.5	106.0	1.4585	59.9	0.598
E-16	29.0	31.9	30.5	0.2	3.1	176.7	176.0	176.4	1.77	2.6	300	106.3	21.5	84.8	1.4670	67.0	0.471
E-17	45.8	48.0	46.9	0.7	2.9	175.1	175.0	175.1	1.72	2.6	300	110.4	21.5	88.9	1.4670	67.0	0.506
E-18	51.4	53.2	52.3	0.95	3.75	175.2	174.5	174.9	1.68	2.6	300	109.9	21.5	88.4	1.4670	67.0	0.506
E-19	28.2	30.6	29.4	0.25	2.65	163.4	162.9	163.2	1.45	2.6	300	102.5	21.5	81.0	1.4726	72.0	0.496
E-20	37.4	39.7	38.5	0.45	2.75	162.7	162.6	162.7	1.53	2.6	300	103.5	21.5	82.0	1.4726	72.0	0.504
E-21	52.6	54.15	53.37	1.1	2.65	160.8	159.7	160.3	1.63	2.6	300	114.4	21.5	92.9	1.4726	72.0	0.579
E-22	30.0	32.8	31.4	0.2	3.0	206.7	206.7	206.7	2.01	2.6	300	124.9	21.5	103.4	1.4826	82.7	0.500
E-23	48.0	50.0	49.0	0.7	2.7	206.4	205.2	205.8	1.79	2.6	300	123.8	21.5	102.3	1.4826	82.7	0.498
E-24	54.6	56.35	55.4	1.0	2.75	204.5	204.1	204.3	1.91	2.6	300	129.5	21.5	108.0	1.4826	82.7	0.527
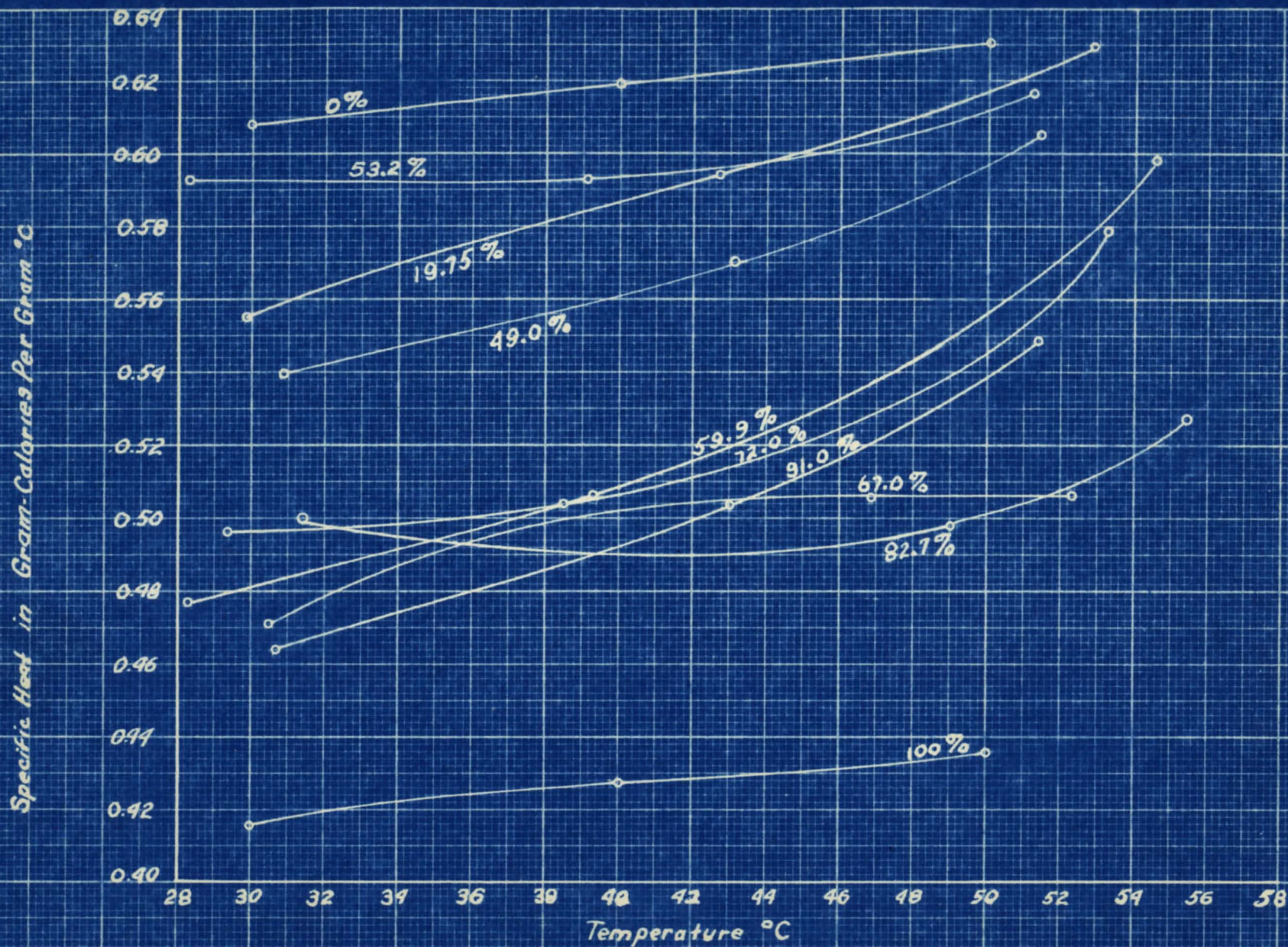
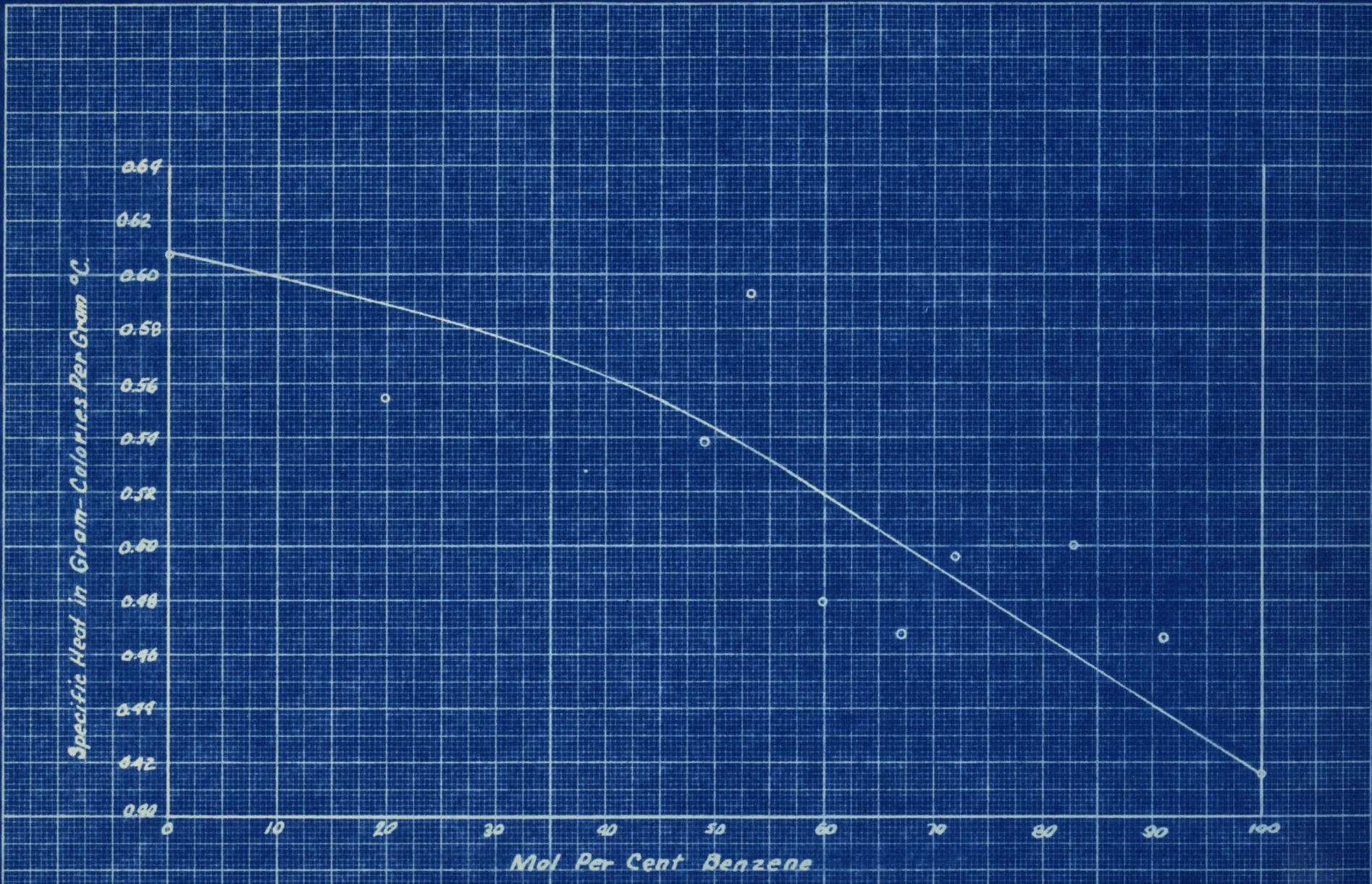Figure 8:- EXPERIMENTAL SPECIFIC HEAT DATA (Compositions in Mol Per Cent Benzene)

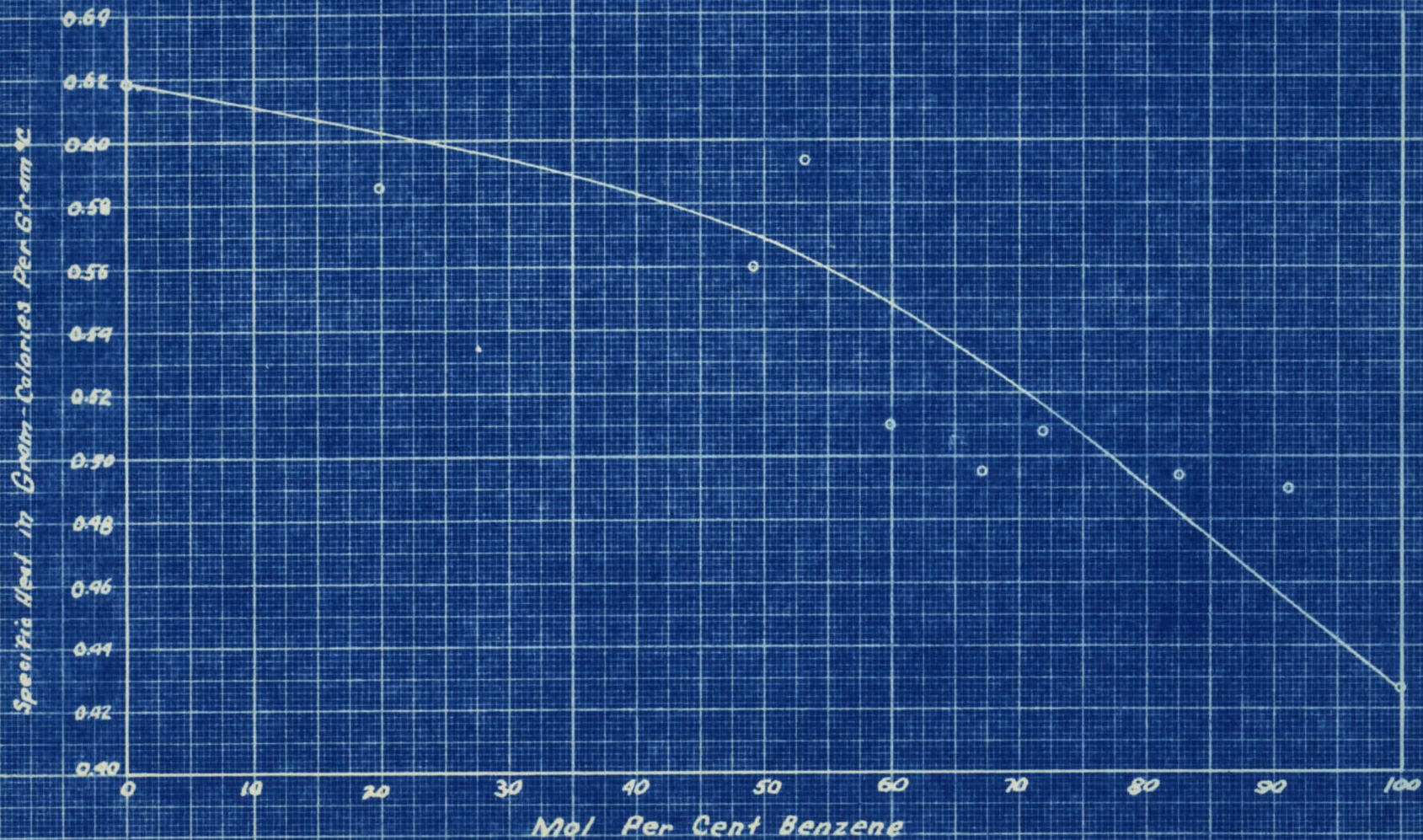Figure 9.- SPECIFIC HEATS OF BENZENE-METHANOL MIXTURES AT 30°C.

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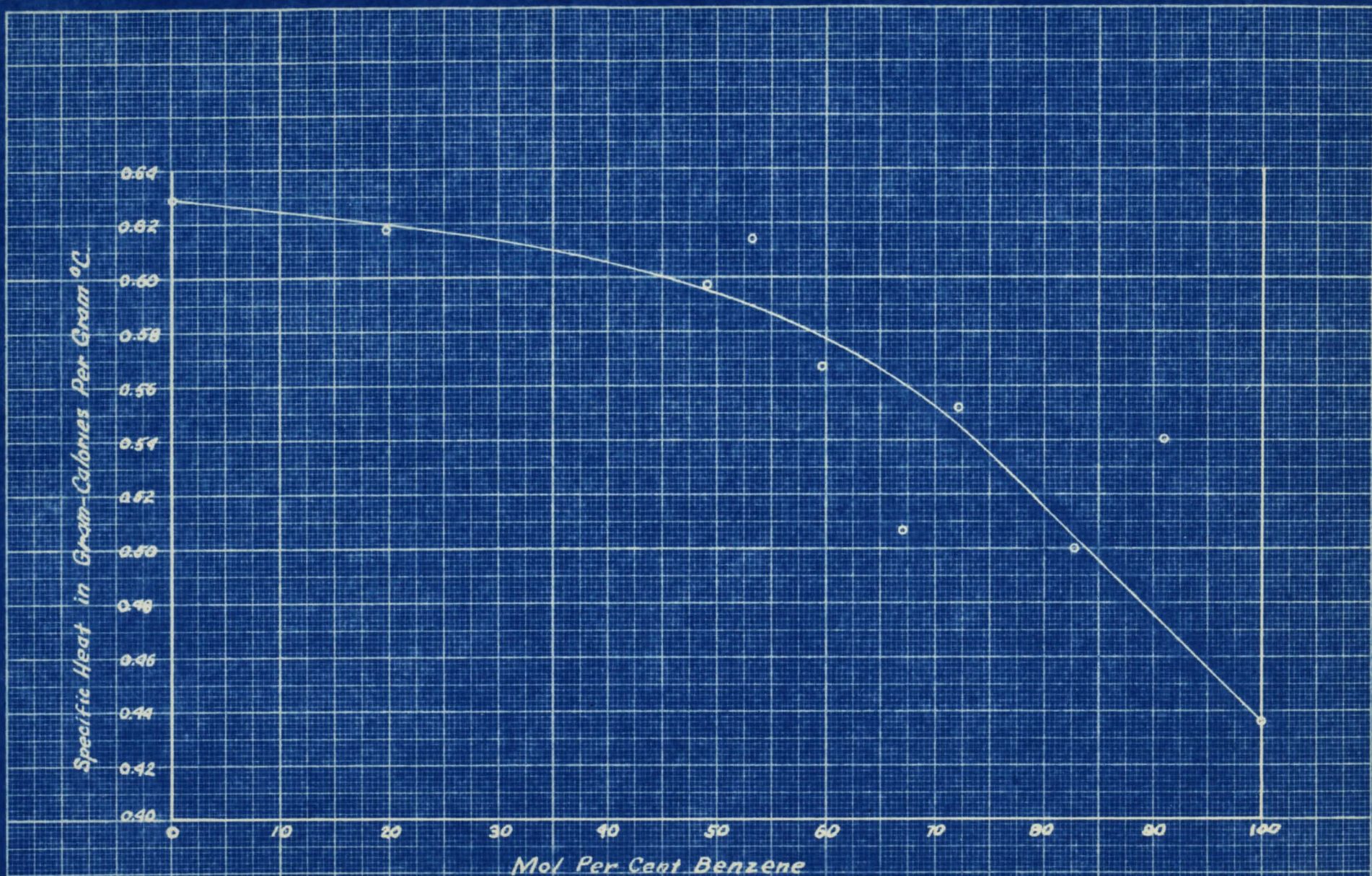Figure 10 :- SPECIFIC HEATS OF BENZENE-METHANOL MIXTURES AT 40°C

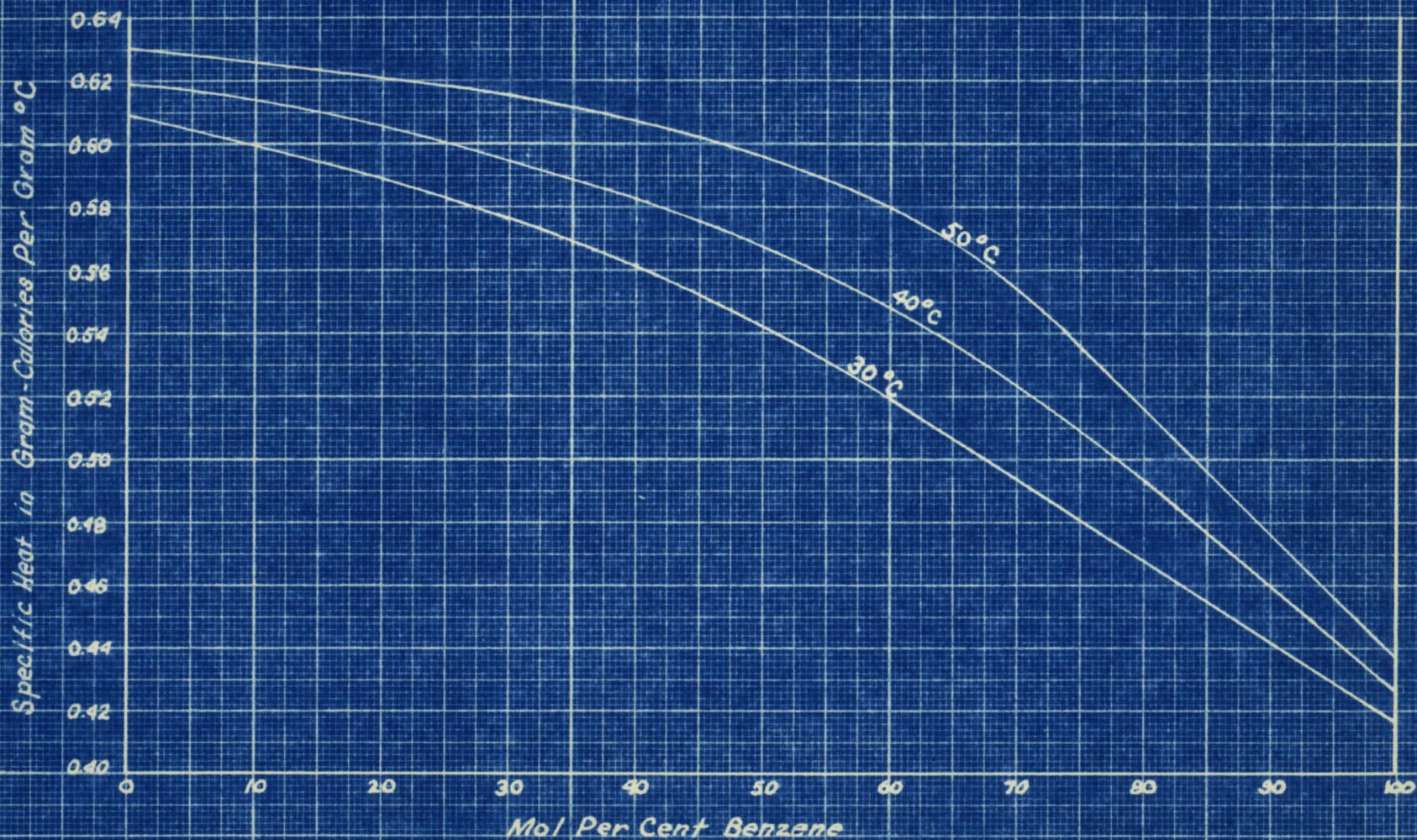Figure II:- SPECIFIC HEATS OF BENZENE-METHANOL MIXTURES AT 50°C.

Figure 12:- DERIVED SPECIFIC HEAT CURVES.

DISCUSSION OF RESULTS

The density-composition curves follow normal expectations. The curve for volume per cent composition versus density is practically a straight line. This is as would be expected since the density is a physical property and since there is almost no reduction in volume upon the mixing of the two materials.

The curve for mol per cent composition versus density is therefore markedly different from the first due to the effect of different molecular weights and densities of the components.

In a like manner, the curves of composition versus refractive index indicate a volume per cent composition versus refractive index as practically a straight line. The curve for mol per cent composition versus refractive index deviates as in the previous property.

In the case of the boiling point diagram, it would be expected that the minimum boiling mixture would occur closer to one of the pure materials than the other. This is because of the different nature of the two materials. Benzene is definitely a non-polar compound while the methanol is a polar compound.

The equilibrium diagram follows the boiling point diagram in that the two sections of the curve are not balanced.

The erratic nature of the data in the specific heat runs is reflected in the curves of figure 8. It is obvious

that many of these points are in error and the series of
graphical averaging plots (figures 9, 10, and 11) were
made in an attempt to show which values could be discarded.
Specific heats of binary mixtures should be continuous
functions both in respect to temperature and composition.
This graphical procedure is allowable only under these
conditions. The results as shown in figure 12 will necess-
itate confirmations before complete acceptance is obtained.

CONCLUSIONS AND RECOMMENDATIONS

The plots obtained as a result of the experimental work of this thesis can be employed in the solution of distillation problems. With the addition of a plot of composition versus enthalpy, all the data are available for the solution of a distillation problem by the method of Ponchon and Savarit.

It is recommended that the data of specific heats be substantiated by more experimental work. Several changes are necessary in order to eliminate some of the inaccuracies of this phase of the work.

These changes should be designed to eliminate, as much as possible, the loss in material as vapor from the system. With the present apparatus, the material loss amounted to only about 0.1 grams in 190 grams of mixture. However, on a heat basis, this is a large quantity of loss since the heat of vaporization is very high compared to the specific heat of the solution.

APPENDIX

ACKNOWLEDGMENT

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     Chemical Engineering", McGraw-Hill Publishing
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VITA

Samuel Rosenberg, son of Benjamin and Sadie Rosenberg, was born at Trenton, New Jersey, on July 26, 1918.

He attended grade school at Trenton until 1929, when his family moved to Louisville, Kentucky. Here he attended Louisville Male High School and graduated in June, 1936.

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In June, 1940, he received the degree of Bachelor of Chemical Engineering, and was awarded a graduate assistantship in the Department of Chemical Engineering at the University of Louisville. In October, 1941, he received the degree of Master of Chemical Engineering from the University of Louisville.