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COMPUTER PROGRAM FOR BINARY DISTILLATION USING THE METHOD OF POCHON-SAVARIT WITH ENTHALPY DATA CALCULATED BY LAGRANGE INTERPOLATION

BY

JOSEPH J. ROGUS

A THESIS

PRESENTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE

OF

MASTER OF SCIENCE IN CHEMICAL ENGINEERING

AT

NEW JERSEY INSTITUTE OF TECHNOLOGY

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Newark, New Jersey
1975

APPROVAL OF THESIS

BINARY DISTILLATION USING THE METHOD OF POCHON-SAVARIT WITH ENTHALPY DATA CALCULATED BY LAGRANGE INTERPOLATION

BY

JOSEPH J. ROGUS

FOR

DEPARTMENT OF CHEMICAL ENGINEERING

NEW JERSEY INSTITUTE OF TECHNOLOGY

BY

FACULTY COMMITTEE

APPROVED:

NEWARK, NEW JERSEY

AUGUST, 1975

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Most of all, to my wife KAREN and daughters Kimberly and Denise, whose encouragement and deep understanding provided the most essential inspiration and guidance.

August, 1975 Joseph J. Rogus

ABSTRACT

This thesis presents a Fortran Computer Program to solve binary distillation problems. The solution is obtained by the method of Pochon-Savarit which is based upon graphical use of an enthalpy-concentration diagram. The enthalpy data in this program is calculated using Lagrange interpolation. This is accomplished by utilizing the Lagrange interpolation to get values for the enthalpy of the vapor until we find that value which lies on the same line as the enthalpy of the liquid from the preceding tray and its corresponding del point.

The required input data consist of liquid-vapor equilibrium data, heat of solution data with the reference temperature, the feed rate and temperature, the weight fraction of the lighter component in the feed, distillate, and bottoms, and the reflux ratio. In addition, for each component, the molecular weight, heat of vaporization, critical temperature, boiling point and specific heat of the liquid and vapor must be specified. The specific heats must be in terms of a third order polynomial with respect to temperature. The program output includes the mole fraction, quantity, and enthalpy of the feed, distillate, and bottoms, the condenser and reboiler heat loads, the feed tray location, the number of ideal trays, and the mole fraction and enthalpy of the vapor and the liquid at each tray. This program enables as many sets of data to be run within one execution of the program as desired by the user.

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LIST OF FIGURES

I. INTRODUCTION

The solution to binary distillation problems requires obtaining the number of trays or plates necessary to achieve the desired distillate and bottoms concentrations for a specific feed. The number of trays is a function of the feed condition and the specified reflux ratio. The final number of trays is usually determined by utilizing that reflux value which will minimize the total system cost.

There are several methods available for solving binary distillation problems. Some of the common methods involve solution to the problem by either graphical procedures or by the use of analytical equations. The methods of Pochon-Savarit and McCabe-Theile employ the use of graphical techniques where as others such as Underwood and Colburn compute the solution analytically.

Each method has advantages and disadvantages associated with it.

The Pochon-Savarit method is the subject of this thesis. Some of the major advantages of this method over several other methods will be discussed briefly before the detailed procedure is developed.

The McCabe-Theile method requires that the system have equal molal overflow. This condition is not necessarily available for all applications. The Pochon-Savarit does not require this condition and therefore is more applicable to actual industrial calculations.

The graphical solutions allow less complex equations to be used. Non-ideal vapor-liquid equilibrium relationships required for analytical solutions often become very complex and cumbersome. The data required for the

Pochon-Savarit method are more readily available (Appendix I) and does not require the use of intermediates such as fugacity, K factor or relative volatility. This method, because of its relative simplicity, as compared to some of the more complex methods, readily lends itself to use on some of the smaller computers available in industry today.

Following the discussion of the theory, two (2) distinct systems will be solved utilizing the computer program.

II. DISTILLATION THEORY

The equations developed in the text of this thesis will use the same nomenclature used in the computer program to facilitate reference.

A. MATERIAL BALANCE CALCULATIONS

1. OVER-ALL BALANCES

Figure 1 represents a continuous distillation plant. The feed enters the column at a rate of FEED moles per hour and a concentration of ℤFA. This results in the production of DIST moles per hour of overhead product with a concentration of XDA and BOT moles per hour of bottom product with a concentration of XBA. From this data, we can write two (2) over-all material balances for the system.

Total Material Balance:

$$FEED = DIST + BOT \tag{1}$$

Component A Balance:

$$(FEED)\ (\mathbb{Z}FA) = (DIST)\ (XDA) + (BOT)\ (XBA) \tag{2}$$

Providing the values for FEED, ℤFA, XDA and XBA are available, which is the case for our system, one can eliminate DIST from these equations. The result provides a solution for calculation of BOT.

$$BOT = (FEED)\ (XDA-\mathbb{Z}FA)/(XDA-XBA) \tag{3}$$

The value of DIST can now be obtained from Equation 1.

For most industrial applications, we are not so fortunate as to have the feed given in moles per hour and the mole fractions of the feed, distillate and bottoms specified.

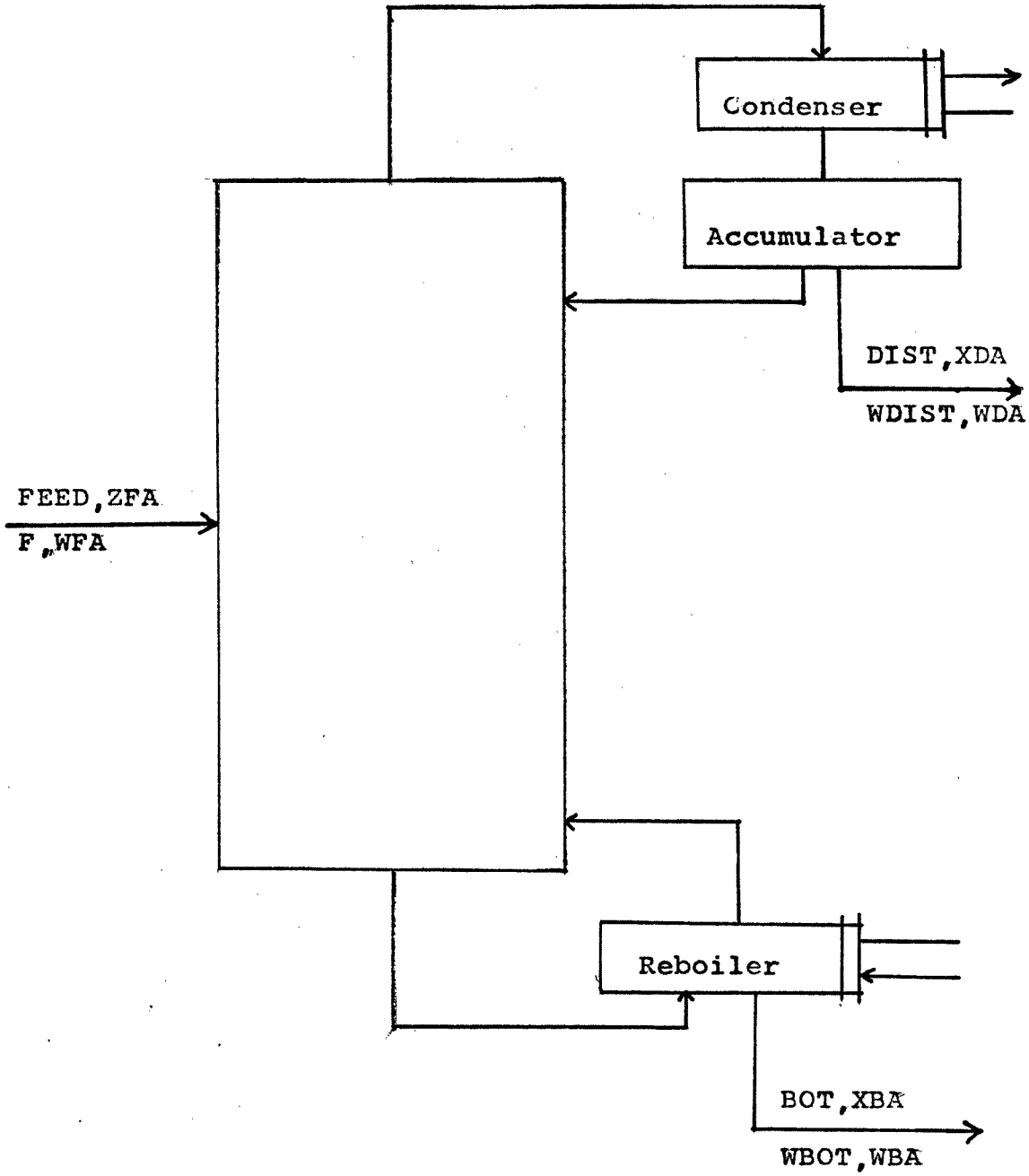


Figure 1

Overall Material Balance

of a Fractionator

A system is usually specified as follows:

The column is fed at a rate of F pounds per hour with a weight percent of WFA. This results in the production of an overhead product with weight percent of WDA and of a bottom product with a weight percent of WBA.

We must now determine the quantity of the products produced by this system.

We first determine the number of moles of components A and B, with molecular weights of MWA and MWB respectively, in the feed.

$$MOLA = (F)(WFA/MWA) \tag{4}$$

$$MOLB = (F)(WFB/MWB) \tag{5}$$

From these, we determine:

$$FEED = MOLA + MOLB \tag{6}$$

$$ZFA = MOLA/FEED \tag{7}$$

The mole fraction of the distillate and the bottom products are determined by use of Equation (8) and Equation (9) respectively.

$$XDA = (WDA/MWA)/(WDA/MWA + (1-WDA)/MWB) \tag{8}$$

$$XBA = (WBA/MWA)/(WBA/MWA + (1-WBA)/MWB) \tag{9}$$

With this data, we can now compute BOT and DIST using Equation (3) and Equation (1).

We must now compute the average molecular weight of the distillate.

$$MWDAV = 1/(WDA/MWA + (1-WDA)/MWB) \tag{10}$$

This enables us to compute quantity of distillate, WDIST, in pounds per hour.

$$WDIST = (DIST)(MWDAV) \tag{11}$$

The quantity of bottom product produced, WBOT, in pounds per hour is determined by the total material balance in Equation (12)

$$WBOT = F - WDIST \tag{12}$$

2. NET FLOWS OF EACH SECTION

Now that we have discussed the total system, we consider the flows in each section of the column.

Consider the upper or enriching section of the column as shown in Figure 2. DIST represents the difference between the flow rates of the streams entering and leaving the top of the column. A balance around the condenser yields

$$DIST = G1 - Lo \tag{13}$$

Since DIST represents the difference between the flow rates of vapor and liquid anywhere in the enriching section, a total material balance for this section gives

$$DIST = Gn+1 - Ln \tag{14}$$

A material balance for component A in the system yields the following

$$(DIST)(XDA) = (G1)(YA1)-(Lo)(XAo) \tag{15}$$

$$(DIST)(XDA) = (Gn+1)(YAn+1)-(Ln)(XAn) \tag{16}$$

Similarly, for the bottom or stripping section of the column, Figure 3, the following equations apply

$$BOT = Lb-Gb = Lm - Gm+1 \tag{17}$$

$$(BOT)(XBA) = (Lb)(XAb) - (Gb)(YAb) = (Lm)(XAm) - (Gm+1)(YAm+1) \tag{18}$$

The subscripts n and m are used to represent a plate in the enrich-

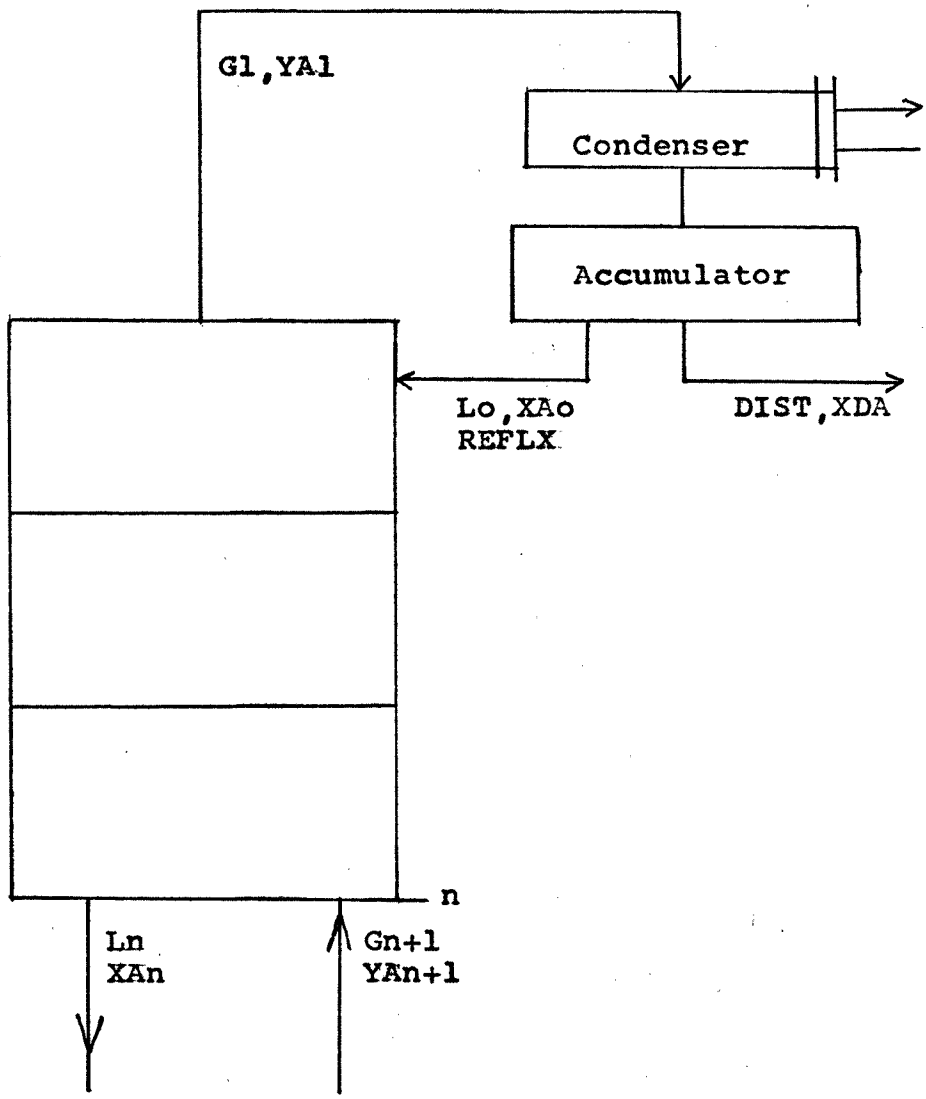


Figure 2

Material Balances for

Enriching Section

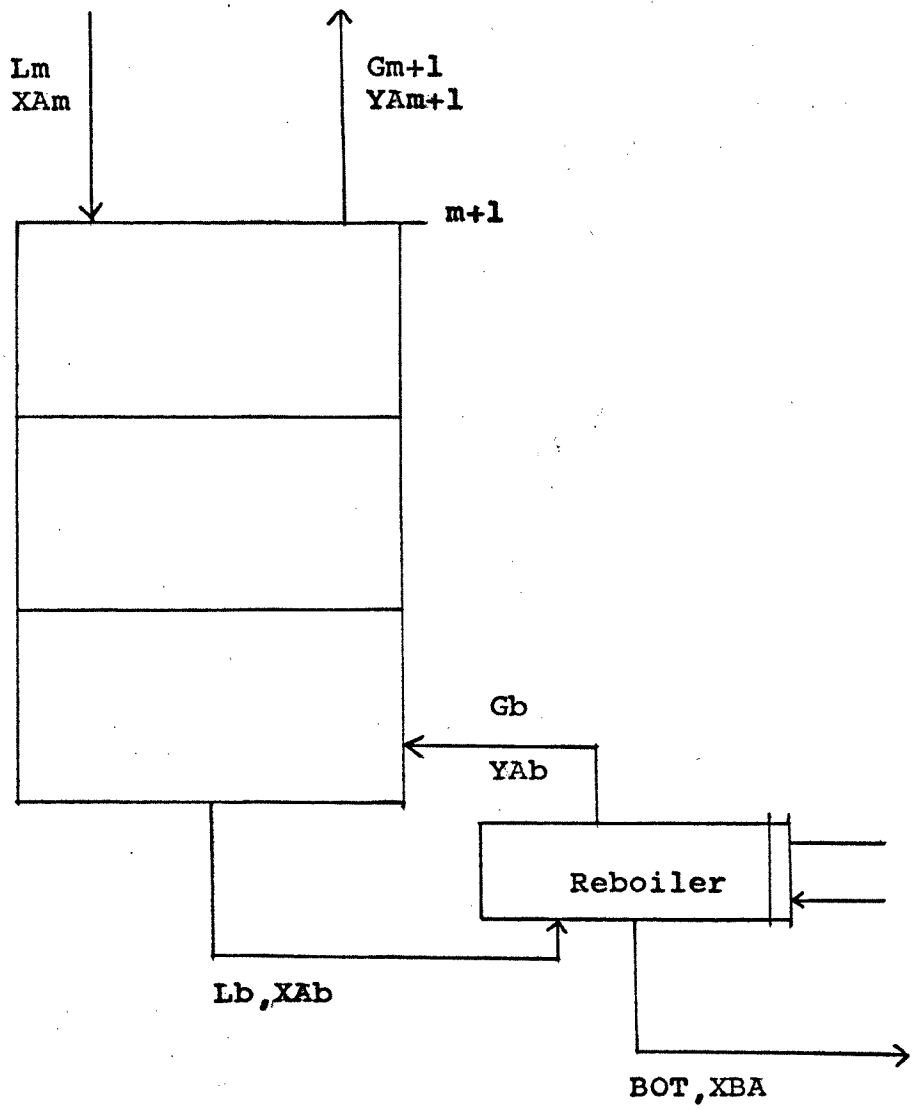


Figure 3

Material Balance for

Stripping Section

ing and stripping section respectively.

The feed plate is not included in either section. Since the feed plate separates the stripping and enriching sections and since the feed can have any condition from liquid below its bubble point to super-heated vapor, it requires special calculations.

B. ENTHALPY CALCULATIONS

OVER-ALL ENTHALPY BALANCE

Suppose we consider the overall enthalpy balances for a distillation plant with negligible heat losses. This system is represented in Figure 4.

We now define the reflux ratio as

$$REFLX = Lo/DIST \tag{19}$$

Consider the condenser, Section A(Figure 4). The total material balance is the same as Equation (13), but now we rewrite it as follows

$$G1 = DIST + Lo \tag{13a}$$

Solving for Lo in Equation (19) and substituting that value in Equation (13a)

$$G1 = DIST(REFLX + 1) \tag{20}$$

The enthalpy balance for Section A is

$$G1(HG1) = QCOND + Lo(HLo) + DIST(HDIST) \tag{21}$$

or

$$QCOND = DIST(REFLX + 1)HG1-REFLX(HLo)-HDIST) \tag{22}$$

Where QCOND represents the condenser heat load.

To obtain the reboiler heat load, we consider Section B of Figure 4 and employ a complete enthalpy balance for this section to obtain

$$QBOIL = DIST(HDIST) + BOT(HBOT) + QCOND-FEED(HFEED) \tag{23}$$

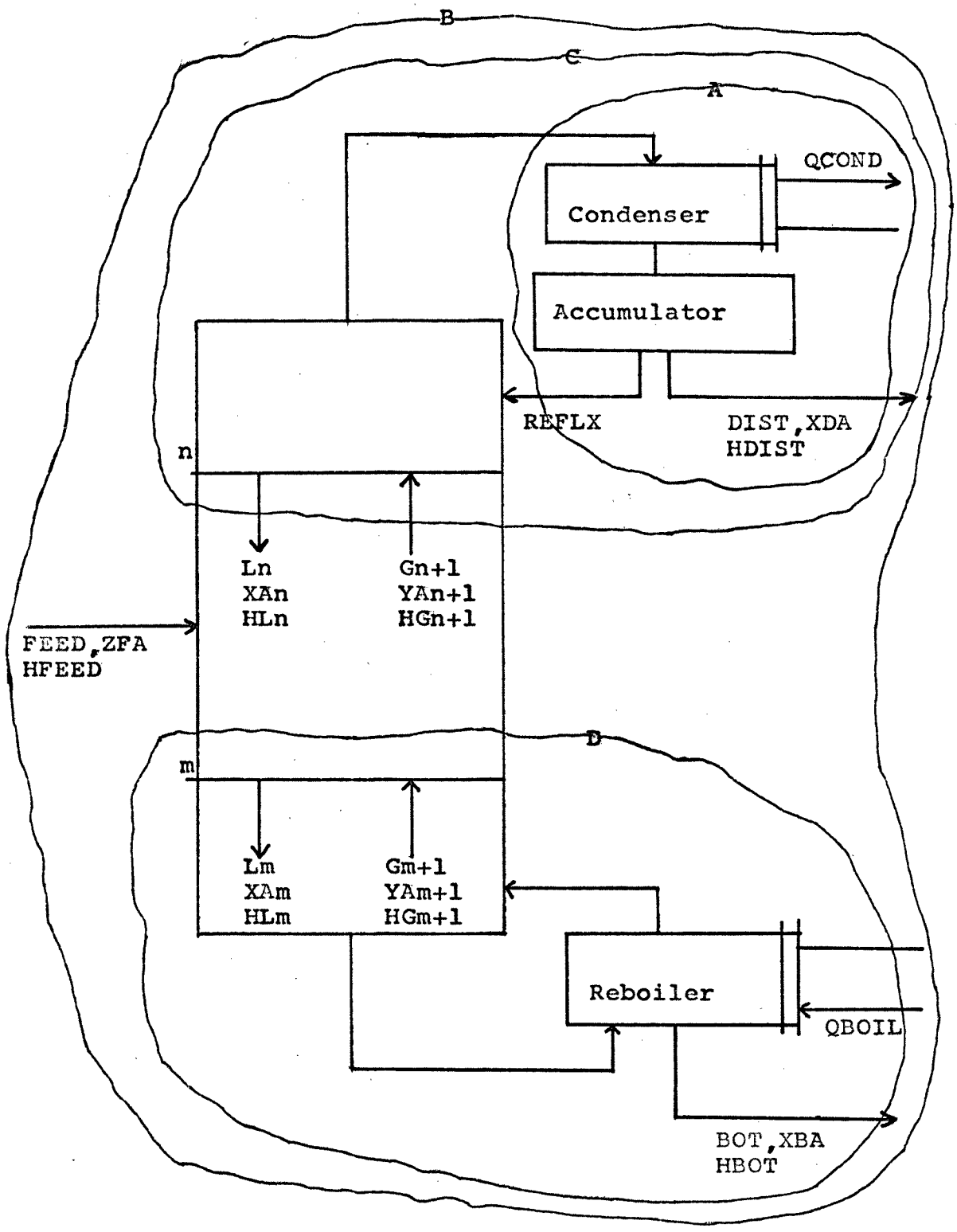


Figure 4
Enthalpy balance of
a distillation plant

III. METHOD OF POCHON-SAVARIT

As we mentioned previously, this thesis will only consider the case of negligible heat losses for the distillation plant.

A. THE ENRICHING SECTION

We will consider the enriching section through Tray n, Section C, Figure 4. As before, Tray n is any tray in this section. The material balances are developed in the same manner as those in Section IIA.

Total material balance from Equation (14)

$$Gn+1 = Ln + DIST \tag{24}$$

For Component A

Equation (16) DIST(XDA) = Gn+1(Yn+1)-LnXN

The enthalpy balance for this section is

$$(Gn+1)HGn+1 = (Ln)HLn + QCOND + DIST(HDIST) \tag{25}$$

If we let HDELD represent the heat removed in the condenser and permanently removed with the distillate per mole of distillate, we get

$$HDELD = \frac{QCOND + DIST(HDIST)}{DIST} = QCOND/DIST + HDIST \tag{26}$$

and

$$(Gn+1)HGn+1 - (Ln)HLn = DIST(HDELD) \tag{27}$$

Similar to the case of the material balance Equation (13) the left hand side of Equation (27) represents the difference in flow. This time, the difference is in heat flow. The right hand side of this equation as before is constant for a specific set of conditions. This difference remains constant in this section of the column, is independent of

the tray number, and is equal to the quantity of heat permanently removed at the top of the column with the distillate and at the condenser.

The elimination of DIST between Equations (24) and (16) and between Equations (24) and (27) yields

$$Ln/Gn+1 = \frac{XDA-YAn+1}{XDA-XAn} = \frac{HDELD-HGn+1}{HDELD-HLn} \qquad (28)$$

Equation (28) represents a straight line on the Hxy diagram through points (HGn+1, YAn+1) at Gn+1, (HLn, XAn) at Ln, and (HDELD, XDA) at Δ DIST.

Figure 5 represents a Hxy diagram for a total condenser. This is the only type of condenser considered in these calculations.

For a total condenser, the distillate, DIST, and the reflux Lo have identical coordinates. The saturated vapor from the top Tray G1, when totally condensed, has the same composition as DIST and Lo. The Liquid L1 leaving Tray 1 is in equilibrium with the vapor G1 and can be located by drawing a tie line from G1 to the saturated liquid curve.

Since Equation (28) is applicable to all trays in the enriching section, G2 can be located on the saturated vapor curve by the line drawn from Δ DIST to L1. Again, the Liquid L2 is located using a tie line from G2 to the saturated liquid curve. The number of ideal trays, represented by the number of tie lines, may now be determined for this section by alternate tie lines and construction lines through Δ DIST.

For any Tray n, the Ln/Gn+1 value is given by the ratio of line lengths HDELD-Gn+1/HDELD-Ln. Utilizing Equations (24) and (28), we obtain

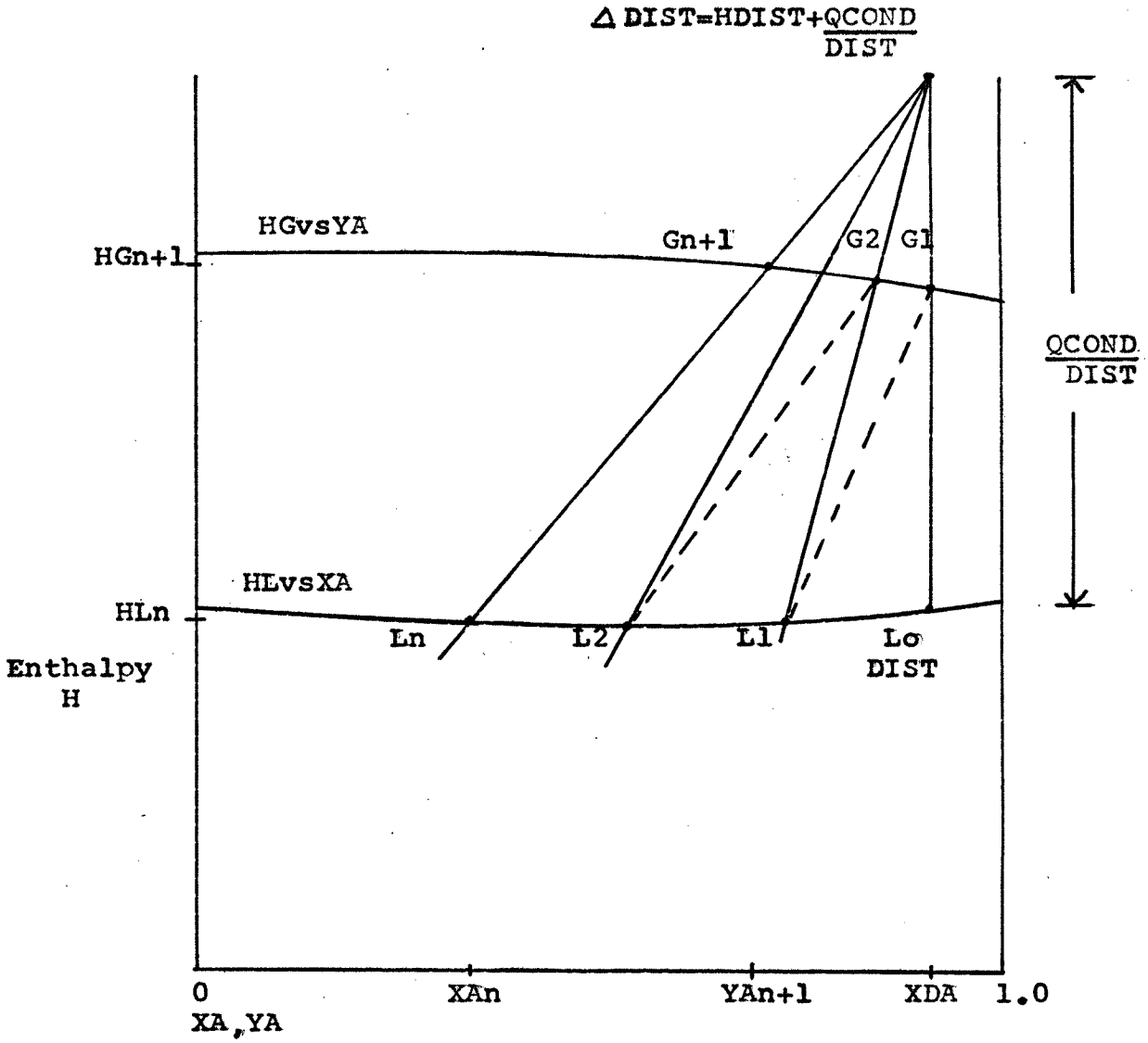


Figure 5
HXY diagram for
Enriching Section
Total Condenser Reflux
at Bubble Point

$$Ln/DIST = \frac{HDELD-HGn+1}{HGn+1-HLn} = \frac{XDA-YAn+1}{YAn+1-XAn} \quad (29)$$

If we apply Equation (29) to the top tray, we obtain the external reflux ratio, a value which is normally the one specified.

$$REFLX = Lo/DIST = \frac{HDELD-HG1}{HG1-HLo} = \frac{Line\ HDELD\ G1}{Line\ G1Lo} = \frac{Line\ HDELD\ G1}{Line\ G1\ DIST} \quad (30)$$

Thus, with the reflux ratio specified, Equation (30) may be used to locate ΔDIST on the Hxy diagram. The condenser heat load may now be calculated from the value of HDELD.

B. STRIPPING SECTION

In the stripping section, we will consider Section D of Figure 4. As we did in the enriching section, we will select a tray, m, and make our balances around it.

The total material balance is

Equation (17) BOT = Lm-Gm+1

and for Component A

Equation (18) BOT(XBA) = (Lm)XAm-Gm+1(YAm+1)

The right hand side of Equation (18) represents the difference in the rate of flow of Component A. For a given distillation, the left hand side of the equation is constant. This difference is therefore independent of the tray selected in the stripping section. Similar to the case in the enriching section, this difference represents the rate of A removed permanently out of the bottom. We may now write the enthalpy balance for this section.

$$(Lm)HLm + QBOIL = (Gm+1)HGm+1 + BOT(HBOT) \tag{31}$$

We now define HDELB as the net flow of heat out of the stripping section per mole of bottom product

$$HDELB = \frac{BOT(HBOT)-QBOIL}{BOT} = \frac{HBOT-\frac{QBOIL}{BOT}}{} \tag{32}$$

and

$$(Lm)HLm-(Gm+1)HGm+1 = (BOT)HDELB \tag{33}$$

This difference in heat as was the difference in mass in Equation (18) is constant for a given distillation and independent of the tray loca-

tion in the stripping section of the column.

If we now eliminate BOT, similarly to what we did for the enriching section, between Equations (17) and (18) and between Equations (17) and (33), we find

$$Lm/Gm+1 = \frac{YAm+1-XBA}{XAm-XBA} = \frac{HGm+1-HDELB}{HLm-HDELB} \qquad (34)$$

As did Equation (28), Equation (34) represents a straight line on a Hxy diagram. This straight line is drawn through (HGm+1, YAm+1) at Gm+1, (HLm, XAm) at Lm, and (HDELB, XBA) at Δ BOT. Analogous to the enriching section Equation (34) applies to all of the trays in the stripping section. If we consider the Hxy plot in Figure 6, the line from GNp+1 the vapor leaving the reboiler and entering the bottom tray Np of the tower, to ΔBOT intersects the enthalpy curve for the saturated liquid at LNp, corresponding to the liquid leaving the bottom tray.

Similar to the enriching section, the number of trays can be determined on the Hxy diagram by alternating construction lines from HG(i) to Δ BOT and tie lines between HG(i) and HL(i). Each tie line again representing an ideal stage for this section.

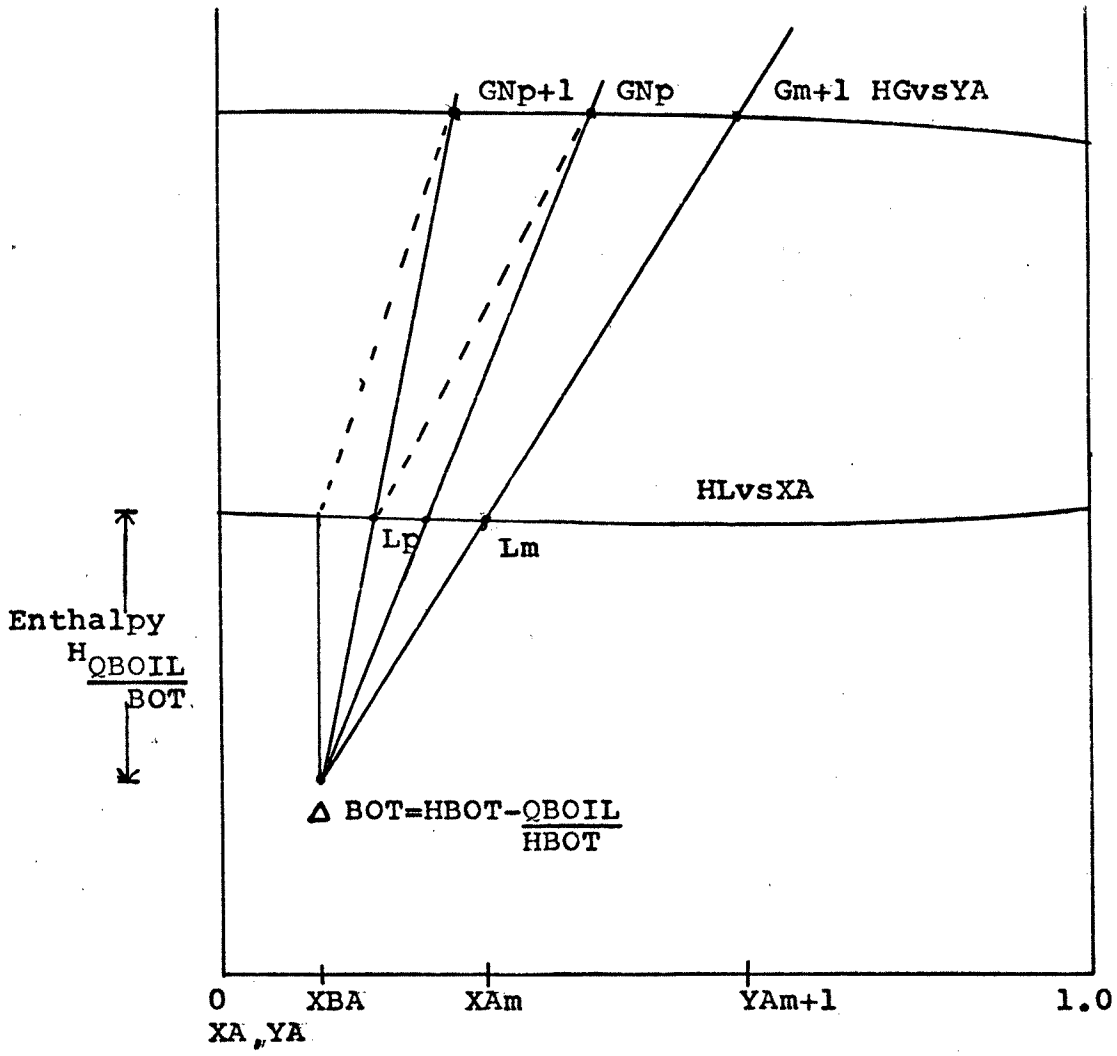


Figure 6

HXY Diagram for

Stripping Section

C. THE COMPLETE SYSTEM

If we go back to Figure 4 and consider the entire distillation plant, Section B, we can generate:

Material balances

Equation (1) FEED = DIST + BOT

Equation (2) FEED(ƵFA) + DIST(XDA) + BOT(XBA)

and the enthalpy balance

Equation (23) QBOIL = DIST(HDIST) + BOT(HBOT) + QCOND-FEED(HFEED)

Utilizing the values of HDELD AND HDELB, defined by Equations (26) and (32) respectively, in Equation (23) we obtain

$$FEED(HFEED) = DIST(HDELD) + BOT(HDELB) \tag{35}$$

The elimination of FEED from the three (3) above equations allows us to obtain

$$\frac{DIST}{BOT} = \frac{ƵFA-XBA}{XDA-ƵFA} = \frac{HFEED-HDELB}{HDELD-HFEED} \tag{36}$$

Equation (36) represents a straight line on the Hxy diagram in Figure 7. This line is through points (HDELD, XDA) at ΔDIST, (HFEED, ƵFA) at FD, and (HDELB, XBA) at ΔBOT.

We will call this line the overall operating line for the system.

The feed location shown in Figure 7 represents a feed condition of saturated liquid at its bubble point. This is only one case and the feed can be represented anywhere from liquid below its bubble point to super-heated vapor above the saturated-vapor curve.

Now that we have discussed the basic principles for tray determination in each section of the column, we will explain how total number of trays

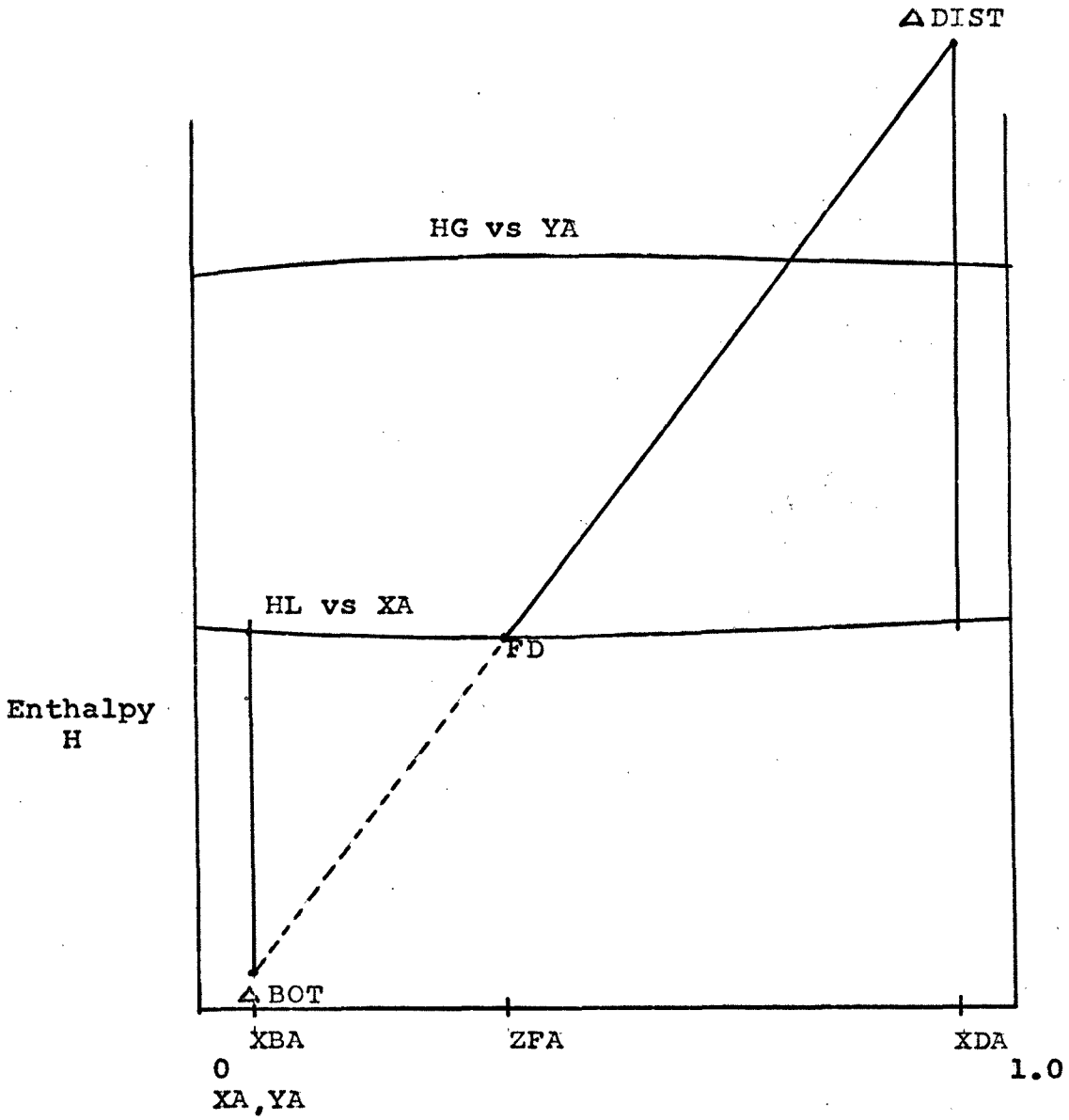


Figure 7

HXY Diagram with

Overall Operating Line

for the system is established. (Refer to Figure 8.)

Once we have established the location of FD on Hxy diagram, we determine the location of △DIST from the reflux ratio utilizing Equation (30). We then construct the overall operating line through △DIST and FD. This line establishes point △BOT where it intersects with XBA (Equation (36)). We now proceed, as discussed in Section IIIA, to construct a series of alternating tie lines and operating lines through △DIST commencing at point G1.

This is continued until we find the tray where the liquid concentration, point K, is less than the abscissa of the intersection of the overall operating line with the saturated liquid curve. This tray establishes the location for the introduction of the feed. This is a critical point for if the feed is introduced above or below it, the system will require additional trays to achieve the separation.

The feed tray separates the enriching section of the column from the stripping section of the column. When the feed tray is reached, we must change the construction of our operating lines from △DIST to △BOT. Line BOT1 represents this switch. We now determine the number of trays in the stripping section. This is done, as discussed in Section IIIB, by a series of tie lines and operating lines starting at point GB. The last tray is determined when we find the first tray where the liquid concentration, point P, is less than or equal to XBA.

The total number of trays required to achieve the separation is the number of tie lines commencing at point G1 and terminating at point P.

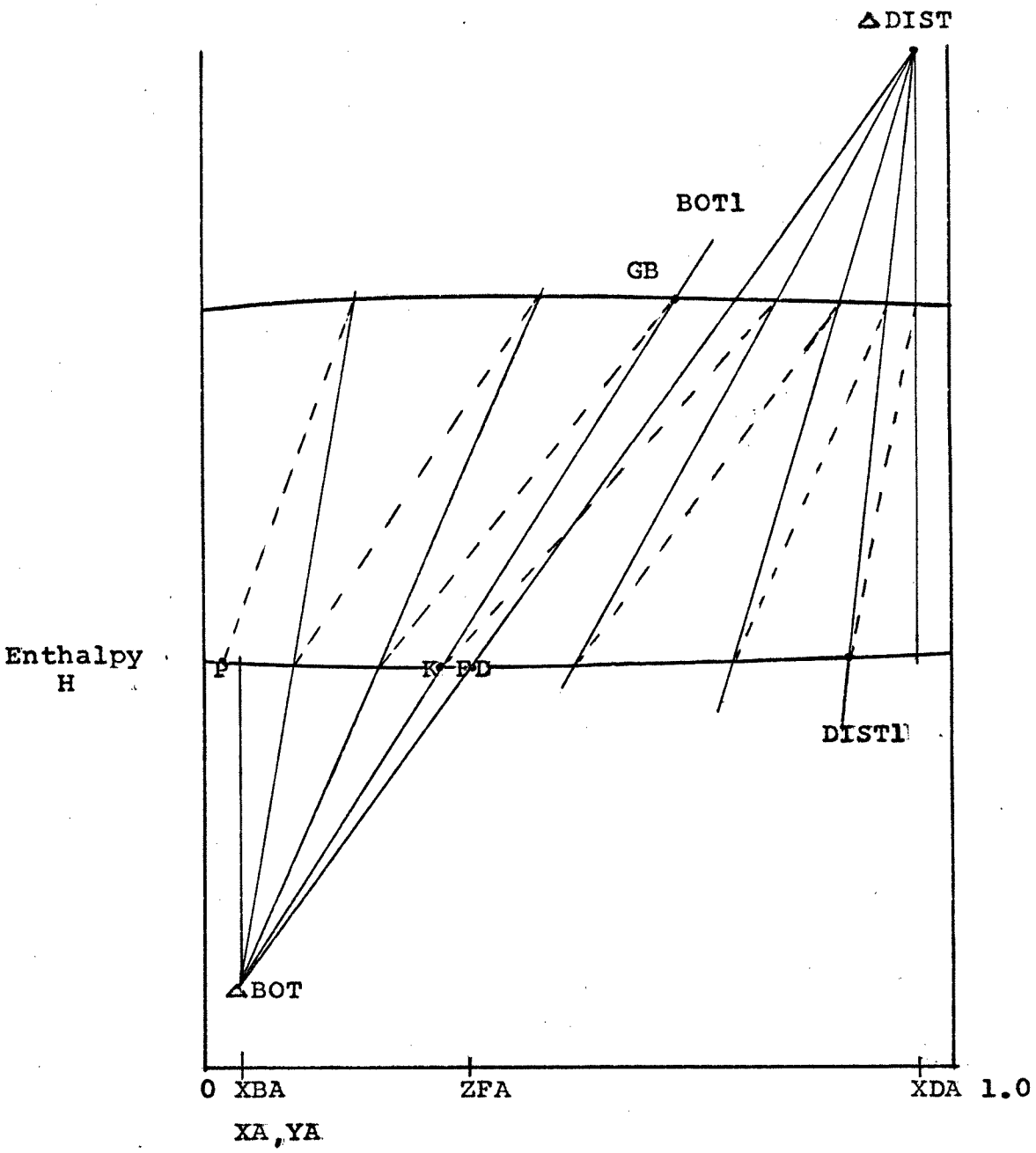


Figure 8

Pochon-Savarit

Solution

IV. LAGRANGE INTERPOLATION

The computer program utilizes Lagrange Interpolation for determination of the enthalpy data required for construction of the operating lines discussed previously. The Lagrange method allows for interpolation for unequally spaced data.

The Lagrange method lends itself to this type computer calculation, because it is less complex than other methods available. Other methods utilized for unequally-spaced arguments, such a determinant form or Aitken's method, require the setting up of matrices. Since the Lagrange method does not require matrices, it may be readily used with the smaller computers available today.

The method of Lagrange states that if we have three (3) sets of unequally spaced arguments

(X1, Y1), (X2, Y2), and (X3, Y3)

we can determine for any X its corresponding Y value. This is accomplished utilizing the following equations

$$A1 = \frac{(X-X2)(X-X3)}{(X1-X2)(X1-X3)} (Y1) \qquad (37)$$

$$A2 = \frac{(X-X1)(X-X3)}{(X2-X1)(X2-X3)} (Y2) \qquad (38)$$

$$A3 = \frac{(X-X1)(X-X2)}{(X3-X1)(X3-X2)} (Y3) \qquad (39)$$

$$Y = A1 + A2 + A3 \qquad (40)$$

Equation (40) represents the solution to the Lagrange interpolation.

V. PROGRAM DESCRIPTION

The computer program is written to allow as many sets of experimental data to be run within one execution as desired by the user. The only requirement is that the input data follow Appendices I and II. Should any set of data be read in missing a "Title" card, the program will terminate at that point with an appropriate error message printing out.

The program is divided into a main program consisting of three (3) distinct sections and five (5) subprograms. Each of these will be discussed briefly.

A. MAIN PROGRAM

1. MATERIAL BALANCE CALCULATIONS

This section utilized the equations developed in Section IIA. The data returned from this section includes:

1. Mole fraction of the feed
2. Mole fraction of the distillate
3. Mole fraction of the bottom
4. The distillate flow in pounds per hour
5. The bottoms flow in pounds per hour

2. ENTHALPY CALCULATIONS

Utilizing equations developed in Section IIB and III, this section returns the following data:

1. Enthalpy of the feed, BTU/lb-mole
2. Enthalpy of the distillate, BTU/lb-mole
3. Enthalpy of the distillate del point (Δ DIST), BTU/lb-mole
4. Condenser heat load, BTU/hr

5. Enthalpy of the bottom product, BTU/lb-mole
6. Enthalpy of the bottom del point (Δ BOT), BTU/lb-mole
7. Reboiler heat load, BTU/hr

3. POCHON-SAVARIT CALCULATIONS

The calculations in this section are basically the same as discussed in Section III. Since all the calculations are done mathematicaly, we are presented with problems that did not exist for a graphical solution. The values we obtained graphically for HG(i+1) by construction of the operating from HL(i) to Δ DIST must now be determined mathematically. This is accomplished by utilizing the Lagrange interpolation to get values of HG until we find the value on the same line as HL(i) and ΔDIST. We compare the slope of the line ΔDIST-HG to the slope of the line ΔDIST-HL(i). We consider the slopes equivalent when the dividend of the slope of our i^{th} iterative guess line and our initial guess line is less than 10^4 or when the increment (Y1NC) divided by the guess point (YATS) is less than 10^4. This same type of check is used in the stripping section.

To determine when we change from the enriching section calculation to stripping section calculations, we again compare slopes. This time we call for the change when the slope of line ΔDIST-FD is greater or equal to the slope of line ΔDIST-HL(i).

The last tray in the stripping section is reached when the XL(i) value is less than or equal to XBA.

Since the guess point (YATS) on our curve range from 1 to .01 (or

less), a factor of 100 in order of magnitude, the iterative increment (Y1NC) is set to YATS/100 at all points along the curve. This speeds up the calculations in enriching section without detriment to the calculations in stripping section.

This portion of the program returns the following:

1. The total number of trays required including the reboiler.
2. The enthalpy and concentration of the liquid for each tray.
3. The enthalpy and concentration of the vapor for each tray.
4. The feed tray location.

B. SUBPROGRAMS

1. WHERE is a search routine to locate a variable in an ascending or descending array.
2. YLIN is a linear interpolation.
3. YLAGR is the Lagrange interpolation described in Section IV.
4. EL is used to calculate the enthalpy of the saturated liquid.
5. EV is used to calculate the enthalpy of the saturated vapor.

VI. DISCUSSION OF RESULTS

Appendix V contains sample computer program outputs to confirm the validity of the program. The printout for each system includes the system tilte and all the input variables as well as all the required output data. Each printout will be discussed briefly.

SYSTEM I: METHANOL - WATER

To be sure the program would give valid results, an example problem from Mass-Transfer Operations by Treybal, pages 326-329 was selected for System I. This problem requires the design of a methanol-water distillation plant. The design parameters for the system are:

The feed to the system will be supplied at a temperature of 136^{o}F with a composition of fifty percent (50%) by weight of methanol at a rate of 5,000 pounds per hour. The system will produce a distillate containing ninety-five percent (95%) by weight methanol and a bottom product that is 1.0% by weight methanol. The reflux ratio for the system is 1.029.

All of the program calculations agree with text answers with the exception of the total number of trays required. The text answer is nine (9) trays including the reboiler and the program requires ten (10) trays including the reboiler.

This difference occurs in the stripping section. This is confirmed by the fact that the feed locations for both solutions are the same. The reason for the additional tray is believed to be related to the degree of accuracy of the computer calculation versus that of the graphical solution.

The values for XBA and the liquid concentrations leaving tray 9 and 10 are

0.00565, 0.006, and 0.001 respectively. Since completion of the program requires that the liquid concentration be less than or equal to XBA, ten (10) trays are required. If this were solved graphically, we would get nine (9) required trays because the difference between XBA and XA (9) would not be detected.

SYSTEM II: ETHANOL - WATER

This system requires the design of a plant for an ethanol - water distillation. The design parameters for this system include:

A feed to the system of a temperature of 177^{o}F, with a composition of fifty-two percent (52%) by weight ethanol and a rate of 2,000 pounds per hour. The system is to produce a distillate with a concentration of ninety-one percent (91%) ethanol and a bottom product composed of four percent (4%) by weight ethanol. The reflux ratio is specified at 3.00. The system requires ten (10) trays with the feed tray at stage 8. The system indicates we are getting very little separation in the enriching section per tray compared to that of the stripping section. This appears to be because of the azeotrope that occurs 10.57 mole percent ethanol.

These results are very similar to those obtained by direct graphical methods, but there is a great savings in time and labor with an increase in accuracy when utilizing this program. Essentially, this method evaluates only the necessary points on the HXY curves, thus a total picture of the system under study is not required.

VII. CONCLUSION

This program should be easily and widely used because it utilizes commonly available real data. Unlike the method of McCabe-Theile, it does not require equal molal overflow. The application of Lagrangian interpolation is relatively new with respect to machine solution of stage-to-stage calculations in chemical engineering. This procedure can easily be extended to solution of extraction problems expressed in a manner similar to that of the Pochon-Savarit method. This method is particularly useful because it can be used with unequally spaced data such as normally found or developed in a laboratory.

APPENDIX I

REQUIRED INPUT DATA

APPENDIX I

REQUIRED INPUT DATA

		SYMBOL	UNITS	SOURCE
1.	Equilibrium Data*			5
	Mole fraction of A in liquid	XA	-	
	Mole fraction of A in vapor	YA	-	
	Liquid temperature for XA	TL	^{o}F	
	Vapor temperature for YA	TG	^{o}F	
2.	Heat of solution	HSA	Kilojoule/g-mole	4
3.	Reference temperature for HSA	TO	^{o}F	4
4.	Molecular weight of A	MWA	lb/lb-mole	5
5.	Molecular weight of B	MWB	lb/lb-mole	5
6.	Heat of vaporization at normal boiling point, for A	LAMA1	cal/g-mole	6
7.	Heat of vaporization at normal boiling point, for B	LAMB1	cal/g-mole	6
8.	Critical temperature of A	TCA	^{o}K	8
9.	Critical temperature of B	TCB	^{o}K	8
10.	Boiling point of A	BPA	^{o}F	5
11.	Boiling point of B	BPB	^{o}F	5
12.	Specific heat of A	CPA**	BTU/lb ^{o}F	9
13.	Specific heat of B	CPB**	BUT/lb ^{o}F	9
14.	Feed rate	F	lbs/hour	***
15.	Weight fraction of A in feed	WFA		***

		SYMBOL	UNITS	SOURCE
16.	Weight fraction of A in distillate	WDA	-	***
17.	Weight fraction of A in bottoms	WBA	-	***
18.	Temperature of the feed	TF	^{o}F	***
19.	Reflux ratio	REFLX	-	***

*The equilibrium data and heats of solution used for these programs were obtained from the curves in Appendix III to facilitate the input data

**Since the specific heat is a function of temperature, the values for the liquids and vapor of each component are calculated for each temperature. The equations for these calculations are on the order of

$$CP = A + B\ TEMP + C\ TEMP^2 + D\ TEMP^3$$

This common form enables us to read in to the program only the coefficients A, B, C, D for the liquid and vapor calculations of each component for a given set of calculations.

***The terms are specified for a given distillation problem.

APPENDIX II

INPUT DATA SHEET

APPENDIX II

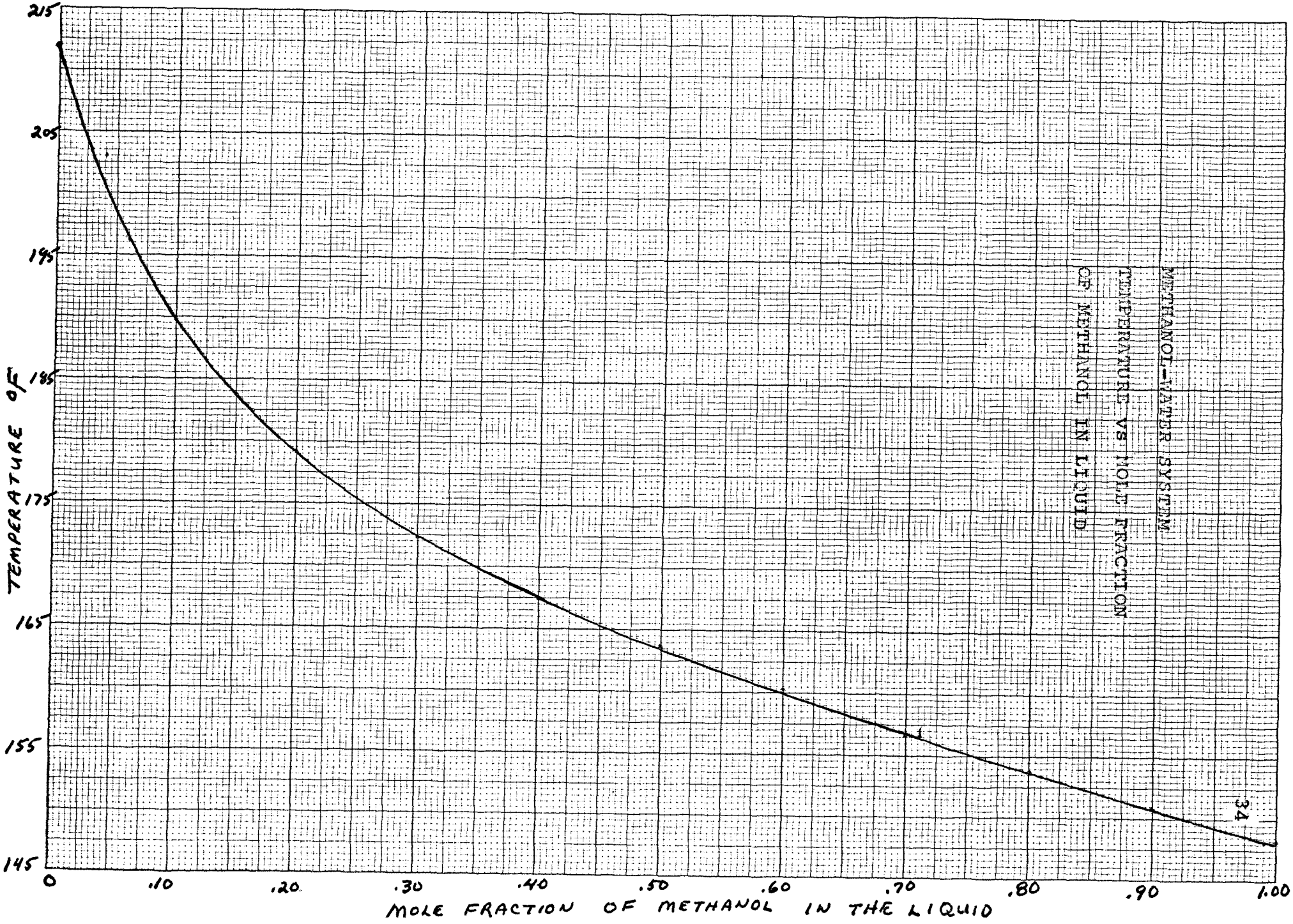
INPUT DATA SHEET

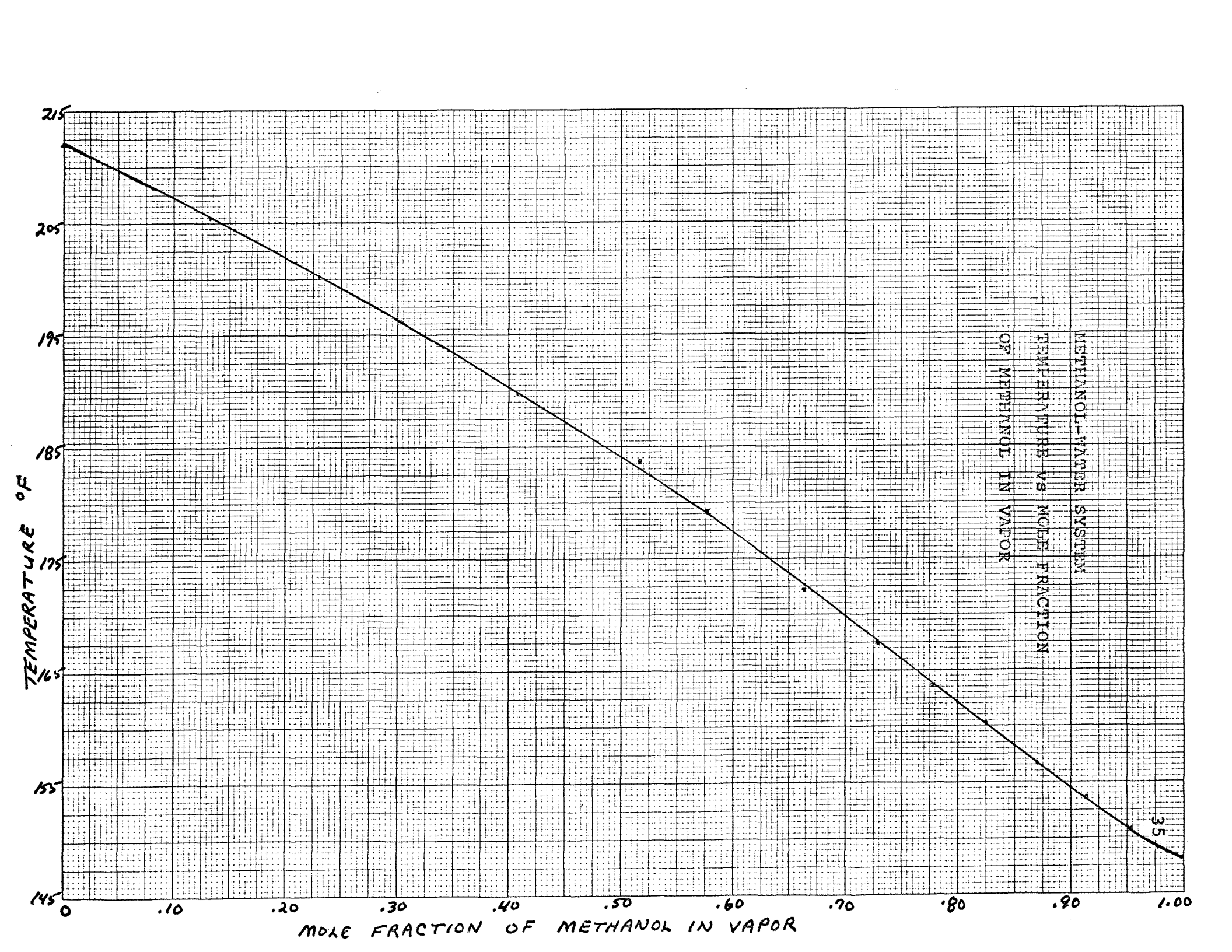
CARD NUMBER	INPUT	COLUMN NUMBER
1	Title Card	
	Titlebb	1-8
	Any user title for experiment	9-80
2-21	Table values for equilibrium data and heats of solution; 20 values for each XA(=YA), TL, HSA, TG 1 card for each set of variables in XA ascending order (F10.0 format)	
	XA(=YA)	1-10
	TL	11-20
	HSA	21-30
	TG	31-40
22	Input variables (F10.0 format)	
	F, WFA, MWA, MWB, WDA, WBA, TF, REFLX	1-80
24-27	Specific heat coefficients (E20.6 format)	
24	AEL coefficients for specific of liquid A	
	Coefficient of constant	1-20
	Coefficient of linear term	21-40
	Coefficient of quadratic term	41-60
	Coefficient of cubic term	61-80

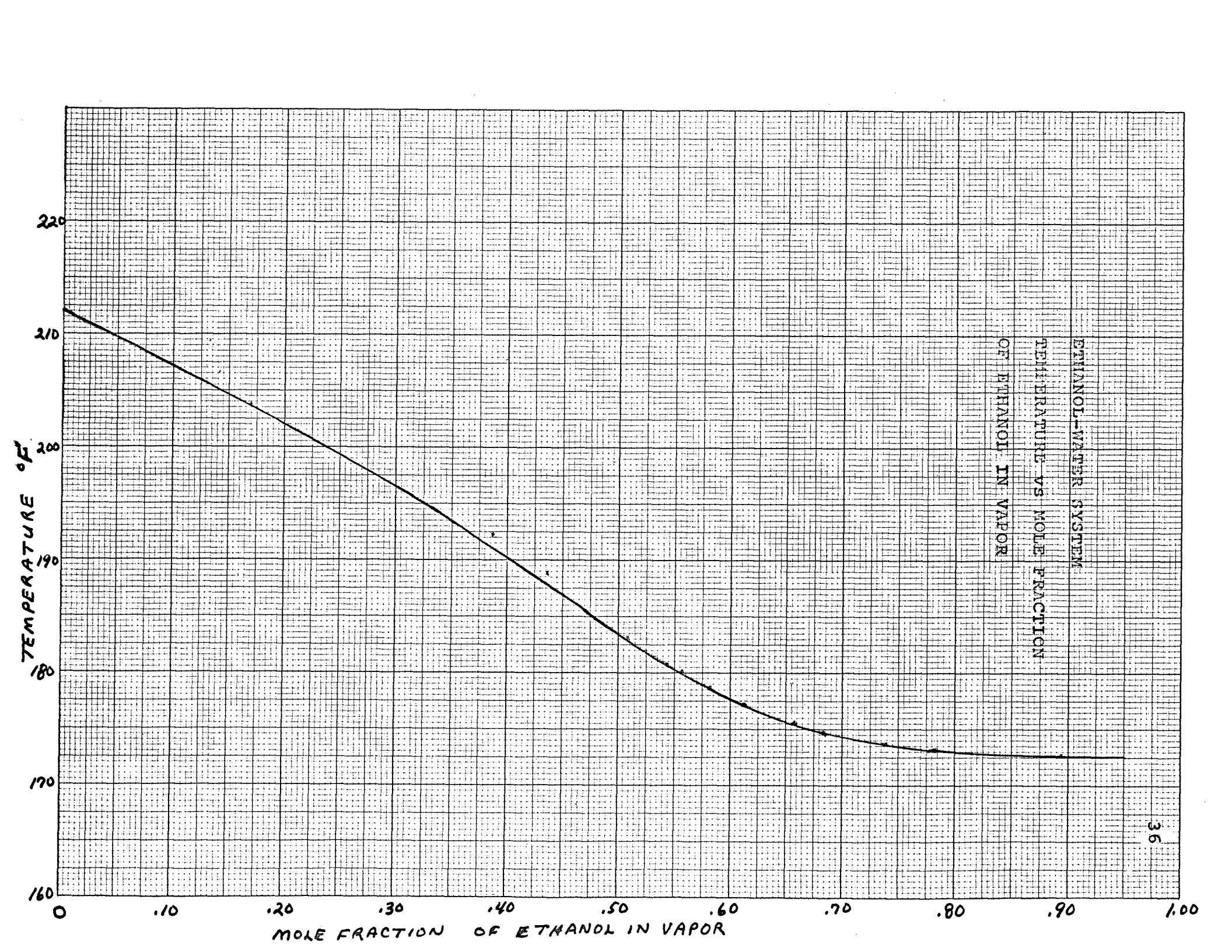
CARD NUMBER	INPUT	COLUMN NUMBER
25	BEL coefficients for specific heat of liquid B	(Same as Card 24)
26	AEV coefficients for specific heat of vapor A	(Same as Card 24)
27	BEV coefficients for specific heat of vapor B	(Same as Card 24)

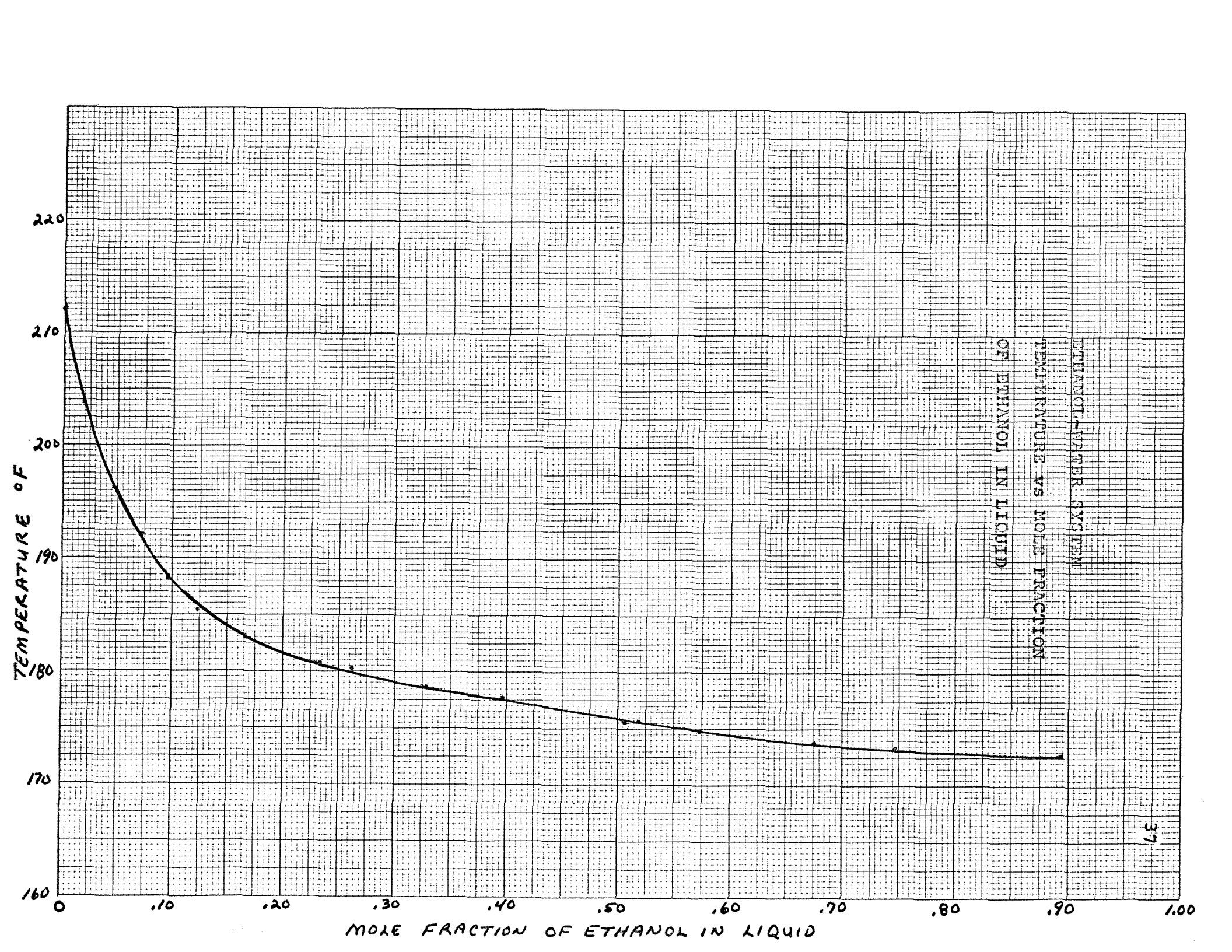
APPENDIX III

LIQUID - VAPOR EQUILIBRIUM DATA


METHANOL-WATER SYSTEM
TEMPERATURE VS MOLE FRACTION
OF METHANOL IN LIQUID
34
TEMPERATURE °F
215
205
195
185
175
165
155
145
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
MOLE FRACTION OF METHANOL IN THE LIQUID

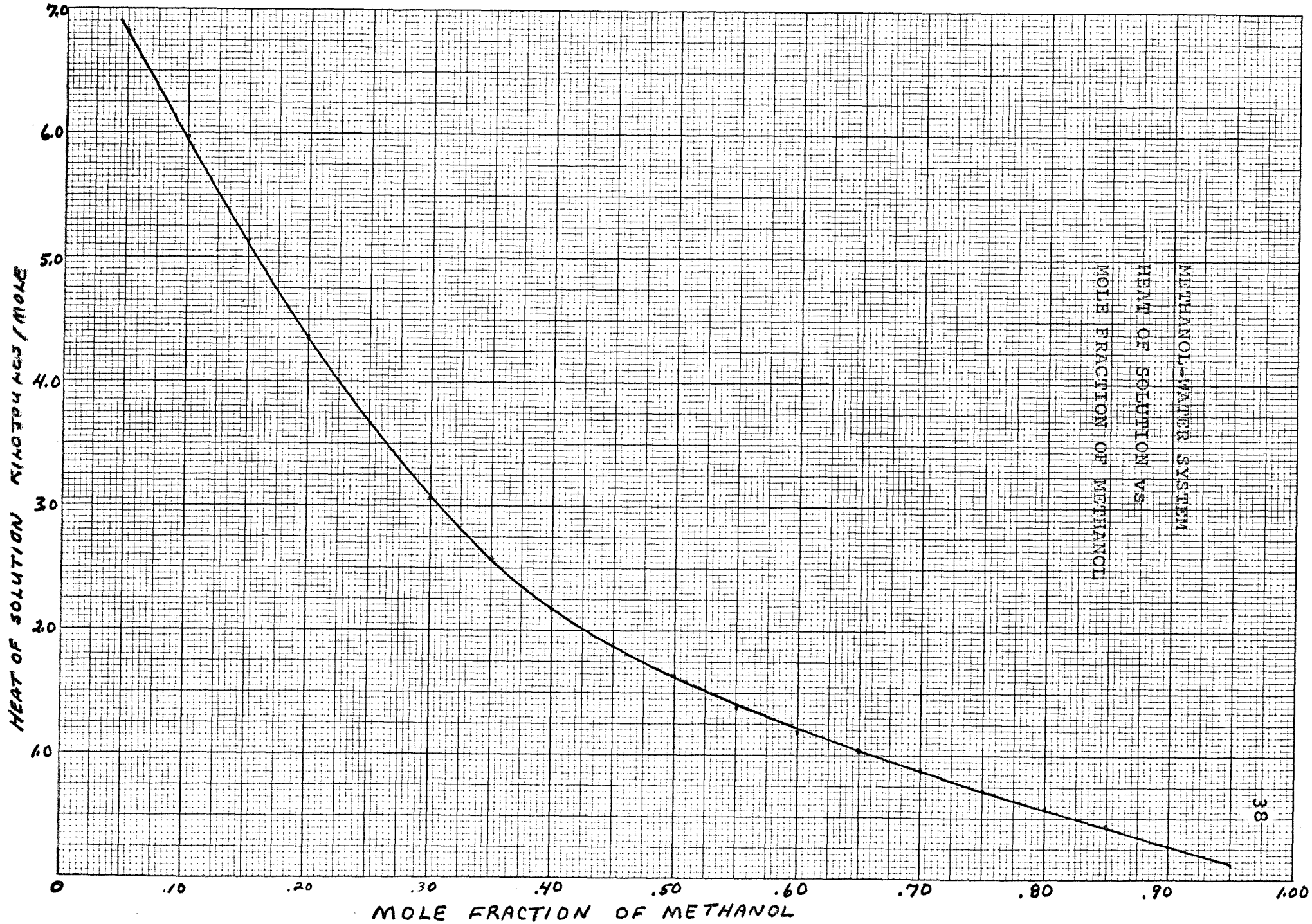

METHANOL-WATER SYSTEM
TEMPERATURE VS MOLE FRACTION
OF METHANOL IN VAPOR
35
TEMPERATURE °F
215
205
195
185
175
165
155
145
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
MOLE FRACTION OF METHANOL IN VAPOR

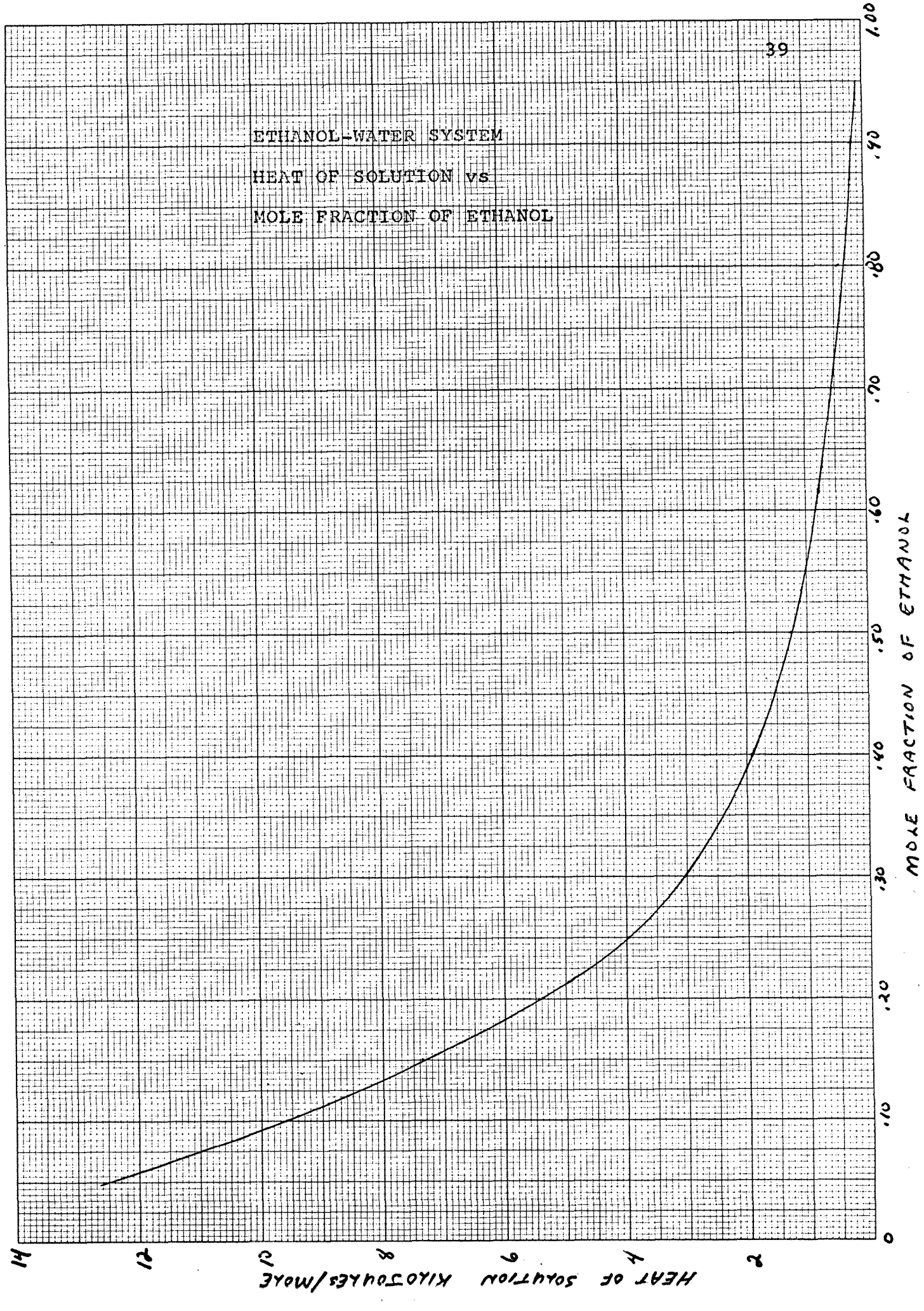

ETHANOL-WATER SYSTEM
TEMPERATURE VS MOLE FRACTION
OF ETHANOL IN VAPOR
TEMPERATURE °F
220
210
200
190
180
170
160
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
MOLE FRACTION OF ETHANOL IN VAPOR


ETHANOL-WATER SYSTEM
TEMPERATURE VS MOLE FRACTION
OF ETHANOL IN LIQUID
37
TEMPERATURE °F
220
210
200
190
180
170
160
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
MOLE FRACTION OF ETHANOL IN LIQUID

APPENDIX III

HEAT OF SOLUTION DATA


METHANOL-WATER SYSTEM
HEAT OF SOLUTION VS
MOLE FRACTION OF METHANOL
38
HEAT OF SOLUTION KILOJOULES / MOLE
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
MOLE FRACTION OF METHANOL


ETHANOL-WATER SYSTEM
HEAT OF SOLUTION vs
MOLE FRACTION OF ETHANOL
HEAT OF SOLUTION KILOJOULES/MOLE
MOLE FRACTION OF ETHANOL
14
12
10
8
6
4
2
0
.10
.20
.30
.40
.50
.60
.80
.90
1.00

APPENDIX IV

COMPUTER PROGRAM

```
//B616     JOB (050557$####,FFFF,0*20$003,05,0,99,1)                    JOB  879
//S1 EXEC FORTHCL,PARM='XREF'
XXFORT    PROC MEMBER=GO                                                00000010
***                                                                     00000020
***            FORTRAN H                                                00000030
***                                                                     00000040
***       PROCEDURE TO COMPILE AND LINK EDIT A FORTRAN SOURCE MODULE     00000050
***                                                                     00000060
XXFORT    EXEC PGM=FRTH,REGION=250K                                     00000070
***                                                                     00000080
XXCONTROLP DD  DSN=SYS6.CONTROL(IEKAA00),DISP=SHR                       00000090
XXMSGPRINT DD  SYSOUT=A                                                 00000100
XXSYSLIN   DD  DSN=&&LOADSET,UNIT=SYSSQ,DISP=(MOD,PASS,DELETE),         00000110
XX             DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200),                    00000120
XX             SPACE=(CYL,(1,1),,CONTIG)                                00000130
XXSYSPRINT DD  SYSOUT=A                                                 00000140
XXSYSPUNCH DD  SYSOUT=B                                                 00000150
XXSYSUT1   DD  UNIT=SYSSQ,SPACE=(CYL,(1,1),,CONTIG)                     00000160
XXSYSUT2   DD  UNIT=SYSSQ,SPACE=(CYL,(1,1),,CONTIG)                     00000170
***                                                                     00000180
***                                                                     00000190
//FORT.SYSIN DD *
IEF236I ALLOC. FOR B616     FORT     S1
IEF237I 343   ALLOCATED TO CONTROLP
IEF237I A45   ALLOCATED TO MSGPRINT
IEF237I 345   ALLOCATED TO SYSLIN
IEF237I A49   ALLOCATED TO SYSPRINT
IEF237I A11   ALLOCATED TO SYSPUNCH
IEF237I 345   ALLOCATED TO SYSUT1
IEF237I 345   ALLOCATED TO SYSUT2
IEF237I AA4   ALLOCATED TO SYSIN
IEF142I - STEP WAS EXECUTED - COND CODE 0004
IEF285I   SYS6.CONTROL                                  KEPT
IEF285I   VOL SER NOS= SYSLB2.
IEF285I   SYS75227.T073405.RV000.B616.LOADSET           PASSED
IEF285I   VOL SER NOS= DISK01.
IEF285I   SYS75227.T073405.RV000.B616.R0005906          DELETED
IEF285I   VOL SER NOS= DISK01.
IEF285I   SYS75227.T073405.RV000.B616.R0005907          DELETED
IEF285I   VOL SER NOS= DISK01.
IEF373I STEP /FORT    / START 75227.1219
IEF374I STEP /FORT    / STOP  75227.1220 CPU   0MIN 02.16SEC STOR VIRT 256K
XXLKED    EXEC PGM=IEWL,PARM=(MAP,LIST),REGION=130K,COND=(4,LT,FORT)    00000200
***                                                                     00000210
XXSYSLIB   DD  DSN=SYS6.USERLIB.DISP=SHR                                00000220
XX         DD  DSN=SYS6.USERLIB.DISP=SHR                                00000230
XX         DD  DSN=SYS6.FORTLIB.DISP=SHR                                00000240
XX         DD  DSN=SYS7.FORTLIB.DISP=SHR                                00000250
XXSYSLIN   DD  DSN=*.FORT.SYSLIN.DISP=(OLD,DELETE)                      00000260
XX         DD  DDNAME=SYSIN                                             00000270
//LKED.SYSLMOD DD DSN=RESEARCH.MODLIB(B616),DISP=SHR
X/SYSLMOD  DD  DSN=&&GOSET(&MEMBER),UNIT=SYSDA,DISP=(MOD,PASS,DELETE),  00000280
IEF653I SUBSTITUTION JCL - DSN=&&GOSET(GO),UNIT=SYSDA,DISP=(MOD,PASS,DELETE),
XX             SPACE=(CYL,(1,1,1),,CONTIG)                              00000290
XXSYSPRINT DD  SYSOUT=A                                                 00000300
XXSYSUT1   DD  UNIT=SYSSQ,SPACE=(CYL,(1,1),,CONTIG)                     00000310
IEF236I ALLOC. FOR B616     LKED     S1
IEF237I 521   ALLOCATED TO SYSLIB
IEF237I 521   ALLOCATED TO
IEF237I 343   ALLOCATED TO
IEF237I 521   ALLOCATED TO
IEF237I 345   ALLOCATED TO SYSLIN
IEF237I 13A   ALLOCATED TO SYSLMOD
```

```
IEF237I A42   ALLOCATED TO SYSPRINT
IEF237I 345   ALLOCATED TO SYSUT1
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I   SYS6.USERLIB                                    KEPT
IEF285I   VOL SER NOS= SYSLB1.
IEF285I   SYS6.USERLIB                                    KEPT
IEF285I   VOL SER NOS= SYSLB1.
IEF285I   SYS6.FORTLIB                                    KEPT
IEF285I   VOL SER NOS= SYSLB2.
IEF285I   SYS7.FORTLIB                                    KEPT
IEF285I   VOL SER NOS= SYSLB1.
IEF285I   SYS75227.T073405.RV000.B616.LOADSET             DELETED
IEF285I   VOL SER NOS= DISK01.
IEF285I   RESEARCH.MODLIB                                 KEPT
IEF285I   VOL SER NOS= DSK014.
IEF285I   SYS75227.T073405.RV000.B616.R0005910            DELETED
IEF285I   VOL SER NOS= DISK01.
IEF373I STEP /LKED    / START 75227.1220
IEF374I STEP /LKED    / STOP  75227.1221 CPU   0MIN 00.40SEC STOR VIRT 124K
//S2 EXEC PGM=B616
//STEPLIB DD DSN=RESEARCH.MODLIB,DISP=SHR
//FT06F001 DD SYSOUT=A
//FT05F001 DD *
//
IEF236I ALLOC. FOR B616     S2
IEF237I 13A   ALLOCATED TO STEPLIB
IEF237I A45   ALLOCATED TO FT06F001
IEF237I AA3   ALLOCATED TO FT05F001
COMPLETION CODE - SYSTEM=322  USER=0000
IEF285I   RESEARCH.MODLIB                                 KEPT
IEF285I   VOL SER NOS= DSK014.
IEF373I STEP /S2      / START 75227.1221
IEF374I STEP /S2      / STOP  75227.1226 CPU   0MIN 17.44SEC STOR VIRT  44K
IEF375I  JOB /B616    / START 75227.1219
IEF376I  JOB /B616    / STOP  75227.1226 CPU   0MIN 20.00SEC
```

```
LEVEL 21.6 ( MAY 72 )                          OS/360  FORTRAN H

         COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=62,SIZE=0000K,
                            SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,XREF
                C
                C       B616
                C
                C       PROGRAM FOR J.ROGUS.
                C       SEE FORMAT 6000 FOR SYSTEM TITLE
                C
                C
                C
                C
                C
                C
   ISN 0002             DIMENSION  TITLE(20),HG1(100),HL1(100)
   ISN 0003             DIMENSION  XA(20),TL(20),HSA(20),YA(20),TG(20)
   ISN 0004             EQUIVALENCE (XA,YA)
   ISN 0005             REAL*4 MWA,MWB,LAMA1,LAMB1,MOLA,MOLB,MWFAV,MWDAV,MWBAV
   ISN 0006             DATA TITL/'TITL'/
   ISN 0007             COMMON F,WFA,MWA,MWB,WDA,WBA,TF,REFLX,TO,LAMA1,LAMB1,TCA,TCB,BPA
                       1     BPB
   ISN 0008             COMMON /CPAB/ AEL(4),BEL(4), AEV(4),BEV(4)
                C
                C
                C       READ IN DATA- TITLE CARD SIGNIFIES BREAK BETWEEN EXPS.
                C
                C       NP=NO. OF POINTS
   ISN 0009             NP=20
   ISN 0010          10 READ(5,500,END=999) TITLE
   ISN 0011             IF(TITLE(1).NE.TITL)  GO TO 800
   ISN 0013             READ(5,501) (XA(I),TL(I),HSA(I),TG(I),I=1,NP)
   ISN 0014             READ(5,502) F,WFA,MWA,MWB,WDA,WBA,TF,REFLX
   ISN 0015             READ(5,502) TO,LAMA1,LAMB1,TCA,TCB,BPA,BPB
   ISN 0016             READ(5,503) AEL,BEL,AEV,BEV
   ISN 0017             WRITE(6,6000)  (TITLE(I),I=3,15)
   ISN 0018             WRITE(6,600)
                       1             (XA(I),TL(I),HSA(I),TG(I),I=1,NP),
                       2             F,WFA,MWA,MWB,WDA,WBA,TF,REFLX
                       3             TO,LAMA1,LAMB1,TCA,TCB,BPA,BPB
   ISN 0019             WRITE(6,616) AEL,BEL,AEV,BEV
                C
                C       MATERIAL BALANCE CALCULATIONS
                C
   ISN 0020             MOLA=F*WFA/MWA
   ISN 0021             MOLB=F*(1.-WFA)/MWB
   ISN 0022             FEED=MOLA+MOLB
   ISN 0023             ZFA=MOLA/FEED
   ISN 0024             WRITE(6,601) (TITLE(I),I=3,15),ZFA
   ISN 0025             MWFAV=F/FEED
   ISN 0026             XDA=(WDA/MWA)/(WDA/MWA+(1.-WDA)/MWB)
   ISN 0027             WRITE(6,602) XDA
   ISN 0028             MWDAV=1.   /(WDA/MWA+(1.-WDA)/MWB)
   ISN 0029             XBA=(WBA/MWA)/(WBA/MWA+(1.-WBA)/MWB)
   ISN 0030             WRITE(6,603) XBA
   ISN 0031             MWBAV=1.   /(WBA/MWA+(1.-WBA)/MWB)
   ISN 0032             BOT=FEED*(XDA-ZFA)/(XDA-XBA)
   ISN 0033             DIST=FEED-BOT
   ISN 0034             WDIST=DIST*MWDAV
   ISN 0035             WRITE(6,6031)  WDIST
   ISN 0036             WBOT =BOT *MWBAV
   ISN 0037             WRITE(6,6032)  WBOT
```

```
                C
                C     FEED ENTHALPY CALCS.
                C
ISN 0038              XATS=ZFA
                C
                C     CALL  WHERE  TO FIND WHERE IN TABLE VALUE FITS
                C
                C         WHERE RETURNS THE LAST I VALUE OF THE ARRAY <=THE ARG
                C
ISN 0039              II=+1
ISN 0040              CALL WHERE(XA,NP,XATS,II)
                C
                C     DO LINEAR INTERP. TO GET TLT + HSAT
                C
ISN 0041              I=II
ISN 0042              TLT=YLIN(XATS,XA(I),XA(I+1),TL(I),TL(I+1))
ISN 0043              HSAT=YLIN(XATS,XA(I),XA(I+1),HSA(I),HSA(I+1))
                C
                C     CALL EL TO RETURN ENTHALPY OF LIQUID =HL
                C
ISN 0044              CALL EL(XATS,HSAT,TF,HL)
ISN 0045              IF((TF-TLT).GT.0.)  GO TO 12
ISN 0047              GO TO 15
ISN 0048           12 YATS=ZFA
ISN 0049              II=+1
ISN 0050              CALL WHERE(YA,NP,YATS,II)
ISN 0051              TGT=YLIN(YATS,YA(II),YA(II+1),TG(II),TG(II+1))
ISN 0052              CALL EV(YATS,TGT,HG)
ISN 0053              HFEED=HG
                C     .........
                C     NOTE DIVISION CAN OCCUR IF TGT=TLT ---- THIS SHOULD NOT OCCUR
ISN 0054              IF((TF-TGT).LT.0.)  HFEED=((HG-HL)/(TGT-TLT))*(TF-TLT) + HL
ISN 0056              GO TO 18
ISN 0057           15 HFEED=HL
ISN 0058           18 WRITE(6,604) HFEED
                C
ISN 0059              I=1
                C
                C     ENTHALPY CALC. FOR HG1
                C
ISN 0060              YATS=XDA
ISN 0061              II=+1
ISN 0062              CALL WHERE(YA,NP,YATS,II)
                C
                C     DO LINEAR INTERP TO GET TGT
                C
ISN 0063              TGT=YLIN(YATS,YA(II),YA(II+1),TG(II),TG(II+1))
                C
                C     CALL EV TO RETURN ENTHALPY OF VAPOR = HG
                C
ISN 0064              CALL EV(YATS,TGT,HG)
ISN 0065              HG1(I)=HG
                C
                C     CALC. ENTHALPY OF DISTILLATE
                C
ISN 0066              XATS=XDA
ISN 0067              II=+1
ISN 0068              CALL WHERE(XA,NP,XATS,II)
ISN 0069              TLT=YLIN(XATS,XA(II),XA(II+1),TL(II),TL(II+1))
ISN 0070              HSAT=YLIN(XATS,XA(II),XA(II+1),HSA(II),HSA(II+1))
```

```
ISN 0071            CALL EL(XATS,HSAT,TLT,HL)
ISN 0072            HDIST=HL
ISN 0073            WRITE(6,606) HDIST
                C
                C   ENTHALPY OF DEL PT.
                C
ISN 0074            HDELD=(REFLX*(HG1(I)-HDIST))+ HG1(I)
ISN 0075            WRITE(6,607) HDELD
                C
                C   CONDENSER HEAT LOAD
                C
ISN 0076            QCOND=(HDELD-HDIST)*DIST
ISN 0077            WRITE(6,608) QCOND
                C
                C   ENTHALPY OF BOTTOMS
                C
ISN 0078            XATS=XBA
ISN 0079            II=+1
ISN 0080            CALL WHERE(XA,NP,XATS,II)
ISN 0081            TLT=YLIN(XATS,XA(II),XA(II+1),TL(II),TL(II+1))
ISN 0082            HSAT=YLIN(XATS,XA(II),XA(II+1),HSA(II),HSA(II+1))
ISN 0083            CALL EL(XATS,HSAT,TLT,HL)
ISN 0084            HBOT=HL
ISN 0085            WRITE(6,610) HBOT
                C
                C   ENTHALPY OF BOT. DEL. PT.
                C
ISN 0086            HDELB=(FEED*HFEED-DIST*HDELD)/BOT
ISN 0087            WRITE(6,611) HDELB
                C
                C   REBOILER HEAT LOAD
                C
ISN 0088            QBOIL=(HBOT-HDELB)*BOT
ISN 0089            WRITE(6,612) QBOIL
                C
                C
ISN 0090            WRITE(6,605) I,HG1(I),YATS
                C
                C
                C
                C   ENTHALPY CALCS. FOR ENRICHING & STRIPPING SECTION BY ITERATIVE TECHNIQUE
                C   LFLAG=0     -- ENRICHING SECTION
                C   LFLAG=2     -- STRIPPING SECTION
                C
ISN 0091            LFLAG=0
                C
ISN 0092            YTRY=YATS
ISN 0093         20 YATS=YTRY
ISN 0094            II=+1
ISN 0095            CALL WHERE(YA,NP,YATS,II)
ISN 0096            TGT=YLIN(YATS,YA(II),YA(II+1),TG(II),TG(II+1))
ISN 0097         21 TLT=TGT
ISN 0098            II=-1
ISN 0099            CALL WHERE(TL,NP,TLT,II)
ISN 0100            HSAT=YLIN(TLT,TL(II),TL(II+1),HSA(II),HSA(II+1))
ISN 0101            XATS=YLIN(TLT,TL(II),TL(II+1),XA(II),XA(II+1))
ISN 0102         25 CONTINUE
ISN 0103            CALL EL(XATS,HSAT,TLT,HL)
ISN 0104            IF(LFLAG.EQ.0)   WRITE(6,6051) I,HL,XATS
ISN 0106            IF(LFLAG.EQ.2)   WRITE(6,615 ) I,HL,XATS
```

```
                C.....
                C.....   TEMP IN THIS(MAIN) PROGRAM INDICATES TEMPORARY ARGUMENT  .....
                C.....   TEMP IN EL AND EV SUBROUTINES INDICATES TEMPERATURE      .....
                C.....
ISN 0108            IF(LFLAG.EQ.2)  GO TO 28
ISN 0110            TEMP=(HDELD-HFEED)/(XDA-ZFA) - (HDELD-HL)/(XDA-XATS)
ISN 0111            IF(TEMP.GE.0.) GO TO 66
ISN 0113            GO TO 30
ISN 0114         28 IF((XATS-XBA).LE.(0.00))  GO TO 101
                C
                C      SEARCH FOR NEXT HG1 POINT
                C
                C  30 GET NEXT 3 YA TABLE VALUES < HG1(I)
ISN 0116         30 DO 35 J=1,19
ISN 0117            JJ=20-J
ISN 0118            IF(YA(JJ).LE. YATS ) GO TO 37
ISN 0120         35 CONTINUE
                C     JJ=1 IF FALL THRU
ISN 0121         37 IF(JJ.LE.3) JJ=3
ISN 0123            YAT1=YA(JJ)
ISN 0124            YAT2=YA(JJ-1)
ISN 0125            YAT3=YA(JJ-2)
ISN 0126            TGT1=TG(JJ)
ISN 0127            TGT2=TG(JJ-1)
ISN 0128            TGT3=TG(JJ-2)
ISN 0129            CALL EV(YAT1,TGT1,HGT1)
ISN 0130            CALL EV(YAT2,TGT2,HGT2)
ISN 0131            CALL EV(YAT3,TGT3,HGT3)
ISN 0132            YTRY=YATS
ISN 0133            YINC=YTRY/100.
ISN 0134            SAVE=-1.
ISN 0135            SAVET=0.
                C
ISN 0136         45 YTRY=YTRY-YINC
ISN 0137            ANS=YLAGR(YTRY,YAT1,YAT2,YAT3,HGT1,HGT2,HGT3)
ISN 0138            IF(LFLAG.EQ.2)  GO TO 46
ISN 0140            TEMP=(HDELD-HL)/(XDA-XATS) - (HDELD-ANS)/(XDA-YTRY)
ISN 0141            GO TO 47
ISN 0142         46 TEMP=(ANS-HDELB)/(YTRY-XBA) - (HL-HDELB)/(XATS-XBA)
ISN 0143         47 CONTINUE
ISN 0144            IF(SAVE.EQ.-1.  .AND.  SAVET.EQ.0.)  SAVET=TEMP
ISN 0146            YINTR=YINC/YTRY
ISN 0147            IF(ABS(TEMP/SAVET).LT.1.E-4  .OR. ABS(YINTR).LT.1.E-4)  GO TO 49
ISN 0149            IF((TEMP*SAVE).GT.0.)  GO TO 45
ISN 0151            SAVE=TEMP
ISN 0152         48 YINC=-YINC/2.
ISN 0153            GO TO 45
ISN 0154         49 I=I+1
ISN 0155            HG1(I)=ANS
ISN 0156            IF(LFLAG.EQ.0)  WRITE(6,605 ) I,HG1(I),YTRY
ISN 0158            IF(LFLAG.EQ.2)  WRITE(6,6151) I,HG1(I),YTRY
ISN 0160            GO TO 20
                C
ISN 0161         66 WRITE(6,609) I
ISN 0162            LFLAG=2
ISN 0163            GO TO 30
                C
                C
                C
                C
```

```
ISN 0164        101 WRITE(6,614) I
ISN 0165            GO TO 10
                C
                C
ISN 0166        500 FORMAT(20A4)
ISN 0167        501 FORMAT(4F10.0)
ISN 0168        502 FORMAT(8F10.0)
ISN 0169        503 FORMAT(  4E20.6  )
ISN 0170       6000 FORMAT('1',//,18X,'***** BINARY DISTILLATION CALCULATION BY PONCH
                   1ON-SAVARIT METHOD  *****',//
                   220X,'*****  ENTHALPY DATA CALCULATED USING LAGRANGE INTERPOLATION
                   3 *****',//
                   420X,'*****   ',13A4,'  *****',//
                   525X,'-------------------------------------------------------'//)
ISN 0171        600 FORMAT('0'////
                   1   5X,'XA=YA',5X,'TL',8X,'HSA',7X,'TG',//,
                   2   20(4F10.3,/), ///
                   3  ' F=',F10.3,5X,'WFA=',F10.3,5X,'MWA=',F10.3,5X,'MWB=',F10.3,//,
                   4  ' WDA=',F10.3,5X,'WBA=',F10.3,5X,'TF=',F10.3,5X,'REFLX=',F10.3//
                   5  ' TO=',F10.3,5X,'LAMA1=',F10.3,5X,'LAMB1=',F10.3,5X,'TCA=',F10.3
                   6,   //,' TCB=',F10.3,5X,'BPA=',F10.3,5X,'BPB=',F10.3,//)
ISN 0172        601 FORMAT(10X,'OUTPUT FOR ',13A4,/
                   110X,'-------------------------------------------------------------
                   2--',//
                   3       10X,'MOLE FRACTION OF FEED = ',F5.3,/)
ISN 0173        602 FORMAT(10X,'MOLE FRACTION OF DISTILLATE =',F5.3,/)
ISN 0174        603 FORMAT(10X,'MOLE FRACTION OF BOTTOMS =',F7.5,/)
ISN 0175       6031 FORMAT(10X,'DISTILLATE(POUNDS/HOUR) =',E14.6)
ISN 0176       6032 FORMAT(10X,'BOTTOMS   (POUNDS/HOUR) =',E14.6,/)
ISN 0177        604 FORMAT(10X,'ENTHALPY OF FEED =',E14.6,/)
ISN 0178        605 FORMAT('0ENTHALPY OF  VAPOR ENRICHING SECTION - STAGE ',I2,
                   1    ' =',E14.6,5X,'YA=',F5.3)
ISN 0179       6051 FORMAT(' ENTHALPY OF LIQUID ENRICHING SECTION - STAGE ',I2,
                   1    ' =',E14.6,5X,'XA=',F5.3,/)
ISN 0180        606 FORMAT(10X,'ENTHALPY OF DISTILLATE =',E14.6,/)
ISN 0181        607 FORMAT(10X,'ENTHALPY OF DISTILLATE DEL POINT =',E14.6,/)
ISN 0182        608 FORMAT(10X,'CONDENSER HEAT LOAD =',E14.6,/)
ISN 0183        609 FORMAT(70X,'FEED TRAY LOCATION PLATE =',I3,/)
ISN 0184        610 FORMAT(10X,'ENTHALPY OF BOTTOMS =',E14.6,/)
ISN 0185        611 FORMAT(10X,'ENTHALPY OF BOTTOMS DEL POINT =',E14.6,/)
ISN 0186        612 FORMAT(10X,'REBOILER HEAT LOAD =',E14.6,/)
ISN 0187        614 FORMAT(//,75X,'TOTAL NUMBER OF IDEAL PLATES INCLUDING REBOILER=',
                   1   I3)
ISN 0188        615 FORMAT(' ENTHALPY OF LIQUID STRIPPING SECTION - STAGE ',I2,
                   1    ' =',E14.6,5X,'XA=',F5.3,/)
ISN 0189       6151 FORMAT('0ENTHALPY OF  VAPOR STRIPPING SECTION - STAGE ',I2,
                   1    ' =',E14.6,5X,'YA=',F5.3)
ISN 0190        616 FORMAT('0AEL COEFFICIENTS  - ',4E15.6,/
                   1       ' BEL COEFFICIENTS  - ',4E15.6,/
                   2       ' AEV COEFFICIENTS  - ',4E15.6,/
                   3       ' BEV COEFFICIENTS  - ',4E15.6,/ ,'1')
                C
                C
                C     ERROR
                C
ISN 0191        800 WRITE(6,801)
ISN 0192        801 FORMAT('1',//,'0*****  ERROR  - NO TITLE CARD FOR EXPERIMENT  ****
                   1*')
                C
ISN 0193        999 STOP
```

```
ISN 0194          END
```

```
LEVEL 21.6 ( MAY 72 )                          OS/360  FORTRAN H

          COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=62,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,XREF
  ISN 0002            SUBROUTINE EL(XATS,HSAT,TLT,HL)
                C
                C     EL  CALCS. ENTHALPY OF LIQUID = HL
                C
  ISN 0003            REAL*4 MWA,MWB,LAMA1,LAMB1,MOLA,MOLB,MWFAV,MWDAV,MWBAV
  ISN 0004            REAL*4 MWAV
  ISN 0005            COMMON F,WFA,MWA,MWB,WDA,WBA,TF,REFLX,TO,LAMA1,LAMB1,TCA,TCB,BPA,
                     1       BPB
  ISN 0006            COMMON /CPAB/ AEL(4),BEL(4), AEV(4),BEV(4)
                C
                C     DELHS= HEAT OF SOL.
  ISN 0007            DELHS= -238.9*1.8*HSAT*XATS
                C
  ISN 0008            MWAV=XATS*MWA + (1.-XATS)*MWB
  ISN 0009            TEMP=(TLT+460.)/1.8
  ISN 0010            CPA=AEL(1)+AEL(2)*TEMP+AEL(3)*TEMP**2+AEL(4)*TEMP**3
  ISN 0011            CPB=BEL(1)+BEL(2)*TEMP+BEL(3)*TEMP**2+BEL(4)*TEMP**3
  ISN 0012            CPM=XATS*CPA + (1.-XATS)*CPB
  ISN 0013            HL=(CPM*(TLT-TO)*MWAV) + DELHS
  ISN 0014            RETURN
  ISN 0015            END
```

```
LEVEL 21.6 ( MAY 72 )                          OS/360  FORTRAN H

          COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=62,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,XREF
  ISN 0002            SUBROUTINE EV(YAT ,TGT,HG)
                    C
                    C     EV CALCS. ENTHALPY OF VAPOR =HG
                    C
  ISN 0003            REAL*4 MWA,MWB,LAMA1,LAMB1,MOLA,MOLB,MWFAV,MWDAV,MWBAV
  ISN 0004            REAL*4 LAMA2,LAMB2
  ISN 0005            COMMON F,WFA,MWA,MWB,WDA,WBA,TF,REFLX,TO,LAMA1,LAMB1,TCA,TCB,BPA,
                     1       BPB
  ISN 0006            COMMON /CPAB/ AEL(4),BEL(4), AEV(4),BEV(4)
                    C
                    C
  ISN 0007            TRA1=(BPA+460.)/(1.8*TCA)
  ISN 0008            TRB1=(BPB+460.)/(1.8*TCB)
  ISN 0009            TRA2=(TGT+460.)/(1.8*TCA)
  ISN 0010            TRB2=(TGT+460.)/(1.8*TCB)
  ISN 0011            LAMA2=LAMA1*((1.-TRA2)/(1.-TRA1))**.38 *(1.8/MWA)
  ISN 0012            LAMB2=LAMB1*((1.-TRB2)/(1.-TRB1))**.38 *(1.8/MWB)
  ISN 0013            TEMP=(TGT+460.)/1.8
  ISN 0014            CPA=AEV(1)+AEV(2)*TEMP+AEV(3)*TEMP**2+AEV(4)*TEMP**3
  ISN 0015            CPB=BEV(1)+BEV(2)*TEMP+BEV(3)*TEMP**2+BEV(4)*TEMP**3
  ISN 0016            HG=    YAT   * (  CPA*MWA*(TGT-TO) + LAMA2*MWA )
                     1    +(1.-YAT)*(  CPB*MWB*(TGT-TO) + LAMB2*MWB )
  ISN 0017            RETURN
  ISN 0018            END
```

```
LEVEL 21.6 ( MAY 72 )                          OS/360  FORTRAN H

         COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=62,SIZE=0000K,
                            SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,XREF
  ISN 0002              SUBROUTINE WHERE(ARRAY,N,ELEM,I)
                C
                C       WHERE WILL DETERMINE WHERE IN THE ARRAY ELEM FITS
                C           AND RETURN I OF THE LAST ARRAY ELEMENT <= ELEM.
                C
  ISN 0003              DIMENSION ARRAY(N)
                C
                C       ARRAY IS STRICTLY MONOTONIC INCREASING OR DECREASING
                C            DEPENDING ON I       IF I=+1,INCREASING ----- IF I=-1,DECREAS
                C
                C
  ISN 0004              IF(I.LT.0)  GO TO 50
                C
  ISN 0006              DO 10 J=2,N
  ISN 0007              IF(ARRAY(J).GT.ELEM)  GO TO 20
  ISN 0009           10 CONTINUE
  ISN 0010              I=N
  ISN 0011              RETURN
  ISN 0012           20 I=J-1
  ISN 0013              RETURN
                C
  ISN 0014           50 CONTINUE
  ISN 0015              DO 60 J=2,N
  ISN 0016              IF(ARRAY(J).LT.ELEM)  GO TO 70
  ISN 0018           60 CONTINUE
  ISN 0019              I=N
  ISN 0020              RETURN
  ISN 0021           70 I=J-1
  ISN 0022              RETURN
                C
  ISN 0023              END
```

```
LEVEL 21.6 ( MAY 72 )                          OS/360  FORTRAN H

          COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=62,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,XREF
  ISN 0002            FUNCTION YLAGR(X,X1,X2,X3,Y1,Y2,Y3)
                C
                C     YLAGR  IS A NON-LINEAR LAGRANGE INTERPOLATION FUNCTION
                C
                C     YLAGR WILL RETURN THE Y VALUE ON THE Y1,Y2,Y3 SCALE
                C      CORRESPONDING TO THE X VALUE ON THE X1,X2,X3 SCALE.
                C     (I.E. GIVEN PTS. (X1,Y1),(X2,Y2),(X3,Y3) AND X ON THIS CURVE.
                C           GET Y)
                C
                C
  ISN 0003            A1=((X-X2)*(X-X3))/((X1-X2)*(X1-X3)) * Y1
  ISN 0004            A2=((X-X1)*(X-X3))/((X2-X1)*(X2-X3)) * Y2
  ISN 0005            A3=((X-X1)*(X-X2))/((X3-X1)*(X3-X2)) * Y3
  ISN 0006            YLAGR=A1+A2+A3
  ISN 0007            RETURN
  ISN 0008            END
```

```
LEVEL 21.6 ( MAY 72 )                          OS/360  FORTRAN H

          COMPILER OPTIONS - NAME=. MAIN,OPT=00,LINECNT=62,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,XREF
  ISN 0002            FUNCTION YLIN(X,X1,X2,Y1,Y2)
                C
                C     YLIN  IS A LINEAR INTERPOLATION FUNCTION
                C
                C     YLIN WILL RETURN THE Y VALUE ON THE Y1,Y2 SCALE
                C     CORRESPONDING TO THE X VALUE ON THE X1,X2 SCALE.
                C     (I.E. GIVEN PT.(X1,Y1),(X2,Y2) AND X ON THIS LINE - GET Y)
  ISN 0003            YLIN=(Y2-Y1)/(X2-X1) * (X-X1)   +  Y1
  ISN 0004            RETURN
  ISN 0005            END
```

APPENDIX V

SAMPLE OUTPUTS

***** BINARY DISTILLATION CALCULATION BY PONCHON-SAVARIT METHOD *****

***** ENTHALPY DATA CALCULATED USING LAGRANGE INTERPOLATION *****

***** SYSTEM 1: COMPONENT A=METHANOL COMPONENT B=WATER *****

XA=YA	TL	HSA	TG
0.0	212.000	7.700	212.000
0.050	199.000	6.838	209.500
0.100	190.000	5.989	207.200
0.150	183.800	5.114	204.600
0.200	179.200	4.357	202.000
0.250	175.500	3.666	199.100
0.300	172.500	3.055	196.400
0.350	170.000	2.591	193.300
0.400	167.600	2.218	190.300
0.450	165.500	1.896	187.200
0.500	163.600	1.632	184.000
0.550	161.900	1.398	181.000
0.600	160.100	1.197	177.500
0.650	158.500	1.017	173.600
0.700	157.000	0.862	170.000
0.750	155.400	0.716	166.000
0.800	153.900	0.569	162.000
0.850	152.400	0.419	158.400
0.900	150.800	0.272	154.500
0.950	149.500	0.134	151.000

F= 5000.000 WFA= 0.500 MWA= 32.040 MWB= 18.020

WDA= 0.950 WBA= 0.010 TF= 136.000 REFLX= 1.029

TO= 67.500 LAMA1= 8430.000 LAMB1= 9717.000 TCA= 513.000

TCB= 647.000 BPA= 148.000 BPB= 212.000

AEL COEFFICIENTS	-	0.582480E+00	-0.375646E-03	-0.157844E-05	0.106214E-07
BEL COEFFICIENTS	-	0.213974E+01	-0.968137E-02	0.268536E-04	-0.242139E-07
AEV COEFFICIENTS	-	0.189431E+00	0.361729E-03	0.540825E-06	-0.443004E-09
BEV COEFFICIENTS	-	0.452219E+00	-0.129224E-03	0.417008E-06	-0.200401E-09

OUTPUT FOR SYSTEM 1: COMPONENT A=METHANOL COMPONENT B=WATER

MOLE FRACTION OF FEED = 0.360

MOLE FRACTION OF DISTILLATE =0.914

MOLE FRACTION OF BOTTOMS =0.00565

DISTILLATE(POUNDS/HOUR) = 0.260638E+04
BOTTOMS (POUNDS/HOUR) = 0.239362E+04

ENTHALPY OF FEED = 0.996142E+03

ENTHALPY OF DISTILLATE = 0.170925E+04

ENTHALPY OF DISTILLATE DEL POINT = 0.313272E+05

CONDENSER HEAT LOAD = 0.250309E+07

ENTHALPY OF BOTTOMS = 0.258734E+04

ENTHALPY OF BOTTOMS DEL POINT = -0.183865E+05

REBOILER HEAT LOAD = 0.277379E+07

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 1 = 0.163066E+05 YA=0.914
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 1 = 0.168723E+04 XA=0.814

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 2 = 0.164300E+05 YA=0.864
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 2 = 0.168173E+04 XA=0.689

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 3 = 0.165814E+05 YA=0.802
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 3 = 0.168633E+04 XA=0.552

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 4 = 0.167428E+05 YA=0.736
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 4 = 0.169819E+04 XA=0.412

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 5 = 0.169069E+05 YA=0.670
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 5 = 0.173396E+04 XA=0.306

FEED TRAY LOCATION PLATE = 5

ENTHALPY OF VAPOR STRIPPING SECTION - STAGE 6 = 0.172365E+05 YA=0.538
ENTHALPY OF LIQUID STRIPPING SECTION - STAGE 6 = 0.187420E+04 XA=0.173

ENTHALPY OF VAPOR STRIPPING SECTION - STAGE 7 = 0.178461E+05 YA=0.304
ENTHALPY OF LIQUID STRIPPING SECTION - STAGE 7 = 0.222230E+04 XA=0.066

ENTHALPY OF VAPOR STRIPPING SECTION - STAGE 8 = 0.183517E+05 YA=0.113
ENTHALPY OF LIQUID STRIPPING SECTION - STAGE 8 = 0.248506E+04 XA=0.021

ENTHALPY OF VAPOR STRIPPING SECTION - STAGE 9 = 0.185765E+05 YA=0.033

```
ENTHALPY OF LIQUID STRIPPING SECTION - STAGE  9 =  0.258273E+04     XA=0.006

ENTHALPY OF  VAPOR STRIPPING SECTION - STAGE 10 =  0.186479E+05     YA=0.007
ENTHALPY OF LIQUID STRIPPING SECTION - STAGE 10 =  0.261636E+04     XA=0.001

                                    TOTAL NUMBER OF IDEAL PLATES INCLUDING REBOILER= 10
```

***** BINARY DISTILLATION CALCULATION BY PONCHON-SAVARIT METHOD *****

***** ENTHALPY DATA CALCULATED USING LAGRANGE INTERPOLATION *****

***** SYSTEM 2: COMPONENT A=ETHANOL COMPONENT B=WATER *****

XA=YA	TL	HSA	TG
0.0	212.000	16.000	212.000
0.050	196.000	12.540	209.500
0.100	188.000	9.856	207.100
0.150	184.000	7.407	204.500
0.200	181.600	5.428	202.000
0.250	180.100	3.972	199.400
0.300	179.000	3.038	196.500
0.350	178.400	2.385	193.500
0.400	177.500	1.900	190.200
0.450	176.700	1.523	187.000
0.500	176.000	1.251	183.500
0.550	175.200	1.004	180.500
0.600	174.500	0.824	177.800
0.650	174.000	0.691	175.800
0.700	173.530	0.590	174.440
0.750	173.250	0.478	173.620
0.800	172.960	0.410	173.030
0.850	172.820	0.289	172.860
0.900	172.700	0.176	172.700
0.950	172.500	0.088	172.500

F= 2000.000 WFA= 0.520 MWA= 46.050 MWB= 18.020

WDA= 0.910 WBA= 0.040 TF= 177.000 REFLX= 3.000

TO= 32.000 LAMA1= 9220.000 LAMB1= 9717.000 TCA= 516.000

TCB= 647.000 BPA= 173.000 BPB= 212.000

AEL COEFFICIENTS -	0.504351E+00	-0.481584E-03	-0.921631E-06	0.114379E-07
BEL COEFFICIENTS -	0.213974E+01	-0.968137E-02	0.268536E-04	-0.242139E-07
AEV COEFFICIENTS -	0.131120E+00	0.918566E-03	-0.235957E-06	-0.719165E-10
BEV COEFFICIENTS -	0.452219E+00	-0.129224E-03	0.417008E-06	-0.200401E-09

OUTPUT FOR SYSTEM 2: COMPONENT A=ETHANOL COMPONENT B=WATER

MOLE FRACTION OF FEED = 0.298

MOLE FRACTION OF DISTILLATE =0.798

MOLE FRACTION OF BOTTOMS =0.01604

DISTILLATE(POUNDS/HOUR) = 0.110345E+04
BOTTOMS (POUNDS/HOUR) = 0.896551E+03

ENTHALPY OF FEED = 0.312547E+04

ENTHALPY OF DISTILLATE = 0.427635E+04

ENTHALPY OF DISTILLATE DEL POINT = 0.643590E+05

CONDENSER HEAT LOAD = 0.164125E+07

ENTHALPY OF BOTTOMS = 0.313950E+04

ENTHALPY OF BOTTOMS DEL POINT = -0.313332E+05

REBOILER HEAT LOAD = 0.167337E+07

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 1 = 0.192970E+05 YA=0.798
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 1 = 0.425532E+04 XA=0.784

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 2 = 0.192947E+05 YA=0.788
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 2 = 0.422270E+04 XA=0.763

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 3 = 0.192918E+05 YA=0.772
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 3 = 0.416531E+04 XA=0.730

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 4 = 0.192871E+05 YA=0.747
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 4 = 0.408411E+04 XA=0.686

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 5 = 0.192802E+05 YA=0.714
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 5 = 0.398303E+04 XA=0.629

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 6 = 0.192711E+05 YA=0.672
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 6 = 0.382616E+04 XA=0.550

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 7 = 0.192565E+05 YA=0.613
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 7 = 0.350584E+04 XA=0.414

ENTHALPY OF VAPOR ENRICHING SECTION - STAGE 8 = 0.192247E+05 YA=0.514
ENTHALPY OF LIQUID ENRICHING SECTION - STAGE 8 = 0.283177E+04 XA=0.177

FEED TRAY LOCATION PLATE = 8

ENTHALPY OF VAPOR STRIPPING SECTION - STAGE 9 = 0.191071E+05 YA=0.254

ENTHALPY OF LIQUID STRIPPING SECTION - STAGE 9 = 0.296176E+04 XA=0.040

ENTHALPY OF VAPOR STRIPPING SECTION - STAGE 10 = 0.189898E+05 YA=0.051
ENTHALPY OF LIQUID STRIPPING SECTION - STAGE 10 = 0.320362E+04 XA=0.008

TOTAL NUMBER OF IDEAL PLATES INCLUDING REBOILER= 10

NOMENCLATURE

BOT	bottom product, pounds per hour
BPA	natural boiling point of A, ^{o}F (A is the more volital component.)
BPB	natural boiling point of B, ^{o}F
CPA	specific heat of A, BTU/lb-^{o}F
CPB	specific heat of B, BTU/lb-^{o}F
CPM	specific heat of the mixture of the two (2) components, BTU/lb-^{o}F
DELHS	heat of solution at TO and the prevailing concentration, BTU/lb-mole
DIST	distillate, lb-mole/hour
F	feed, lbs/hour
FEED	feed, lb-moles/hour
G	vapor flow rate, lb-moles/hr
Gm	vapor flow rate at any tray m in the stripping section, lb-moles/hr
Gn	vapor flow rate at any tray n in the enriching section, lb-moles/hr
HBOT	enthalpy of the bottom product, BTU/lb-mole
HDELB	enthalpy of the bottom del point, BTU/lb-mole
HDELD	enthaly of the distillate del point, BTU/lb-mole
HDIST	enthalpy of the distillate, BTU/lb-mole
HFEED	enthalpy of the feed, BTU/lb-mole

HG	enthalpy of the vapor, BTU/lb-mole
HG(i)	enthalpy of the vapor at tray i, BTU/lb-mole
HL	enthalpy of the liquid, BTU/lb-mole
HL(i)	enthalpy of the liquid at tray i, BTU/lb-mole
HSA	heat of solution, kilojoules/g-mole A
LAMA	latent heat of vaporization of A at its natural boiling point, cal/g-mole
LAMB	latent heat of vaporization of B at its natural boiling point, cal/g-mole
L	liquid flow rate, lb-moles/hour
Lm	liquid flow rate at any tray m in the stripping section, lb-moles/hour
Ln	liquid flow rate at any tray n in the enriching section, lb-moles/hour
MOLA	lb-moles of A in the feed
MOLB	lb-moles of B in the feed
MWA	molecular weight of A, lbs/lb-mole
MWAV	average molecular weight of component mixture, lbs/lb-mole
MWB	molecular weight of B, lbs/lb-mole
MWBAV	average molecular weight of bottom product, lbs/lb-mole
MWDAV	average molecular weight of the distillate, lbs/lb-mole
MWFAV	average molecular weight of the feed, lbs/lb-mole
QBOIL	reboiler heat load, BTU/hour
QCOND	condenser heat load, BTU/hour
REFLX	reflux ratio, lb-mole reflux/lb-mole distillate

TCA	critical temperature of A, ^{o}K
TCB	critical temperature of B, ^{o}K
TEMP	In main program, it is used as a temporary value used in the check equations. In the enthalpy calculation, it is the temperature in the CP calculations, ^{o}K
TF	feed temperature, ^{o}F
TG	dew point temperature, ^{o}F
TL	bubble point temperature, ^{o}F
TR	reduced temperature
WBA	weight fraction of A in bottom product
WBOT	bottom product flow, lbs/hour
WDA	weight fraction of A in the distillate
WDIST	distillate flow, lbs/hour
WFA	weight fraction of A in the feed
XA	mole fraction of A in the liquid
XBA	mole fraction of A in the bottom product
XDA	mole fraction of A in the distillate
YA	mole fraction of A in the vapor
ZFA	mole fraction of the feed

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