A COMPUTER SOLUTION FOR ABSORBERS AND STRIPPERS USING THE NEWTON - RAPHSON ITERATIVE METHOD

BY

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ABSTRACT

The solution of absorber or stripper calculations by traditional methods can be a tedious, time consuming, if not a completely fruitless procedure. Hence a computer solution of these calculations is both desirable and, as the complexity of chemical process plants increases, necessary.

The component oriented Newton-Raphson procedure was programed to perform this calculation, and makes full use of the material and enthalpy balance equations to perform the iterative equilibrium stage calculations. A Newton-Raphson stage oriented method was also developed as a verification program to check the solutions obtained from the Newton-Raphson component oriented procedure.

APPROVAL OF THESIS

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PREFACE

The writer has attempted in this work to present a useful comparison between traditional calculation methods for absorbers and strippers and more sophisticated computer techniques.

The primary effort was to provide two computer programs using different iteration techniques for solution of absorber and stripper calculation. These programs should most likely be used by students in the Chemical Engineering Department at the Newark College of Engineering as a learning tool.

ACKNOWLEDGMENTS

I wish to express my gratitude to Dr. E. C. Roche, Jr. for his assistance and guidance during the past two years spent on this work. I would also like to thank him for the use of the many subroutines which were taken from his program for distillation calculations.

I would also like to thank Mr. E. Wells of the Foster Wheeler Corporation for running one of the sample problems using Foster Wheeler's facilities and program. This aided greatly in verifying the solutions obtained from the program developed here.

I would also like to thank several people at American Cyanamid Company for reproductions of portions of the paper and especially Mr. E. Perez for the graphics included in one of the chapters, and Miss D. De Maio for the typing.

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CHAPTER 1

INTRODUCTION

Absorption and stripping are two similar processes which are used to recover the more volatile components from a gas or oil stream respectively. In absorption, the more volatile components are concentrated in the oil and leave the bottom of the column and in stripping they are concentrated in the gas and leave the top.

Basic Principles

Absorption and stripping are related processes because they both function due to a concentration difference between enriched and lean streams of liquid and vapor. The processes are aided by a multiplication of this difference by a countercurrent contact of these streams. At each stage, a transfer of material takes place such that each stream is in equilibrium with the other. This equilibrium is dependent on the temperature, pressure, enthalpy, and relative volatility of those components present. The process by which this transfer takes place is diffusion, although some vaporization and condensation takes place. Even though these are called "equilibrium" processes, they operate far from equilibrium conditions. This occurs since the temperature and relative volatility of the liquid phase is far below those necessary for true equilibrium. In practice an equilibrium condition is somewhat reversible, while absorption and stripping are not due to the wide variation in temperature and composition of the streams involved.

The streams present are defined as follows:

Wet gas - feed to an absorber containing condensables

Lean gas - stripping gas fed to a stripper, sometimes an inert

Residue gas - off-gas leaving an absorber after condensables have been removed

Rich gas - lean gas plus recovered components leaving a stripper

Lean oil - stripped and denuded solvent going to the top of an absorber and leaving a stripper

Rich oil - lean oil plus recovered components leaving an absorber and being fed to a stripper

The overall flow of material is illustrated in Figure 1-1.

Since the overall flow of material is in one direction, one encounters rapid phase rate changes across the column if an appreciable amount of material is being transferred. This rapid and massive transfer of material also causes a rapid fluctuation of temperature from stage to stage. In extreme cases, a temperature inversion may result in the column, especially in strippers.

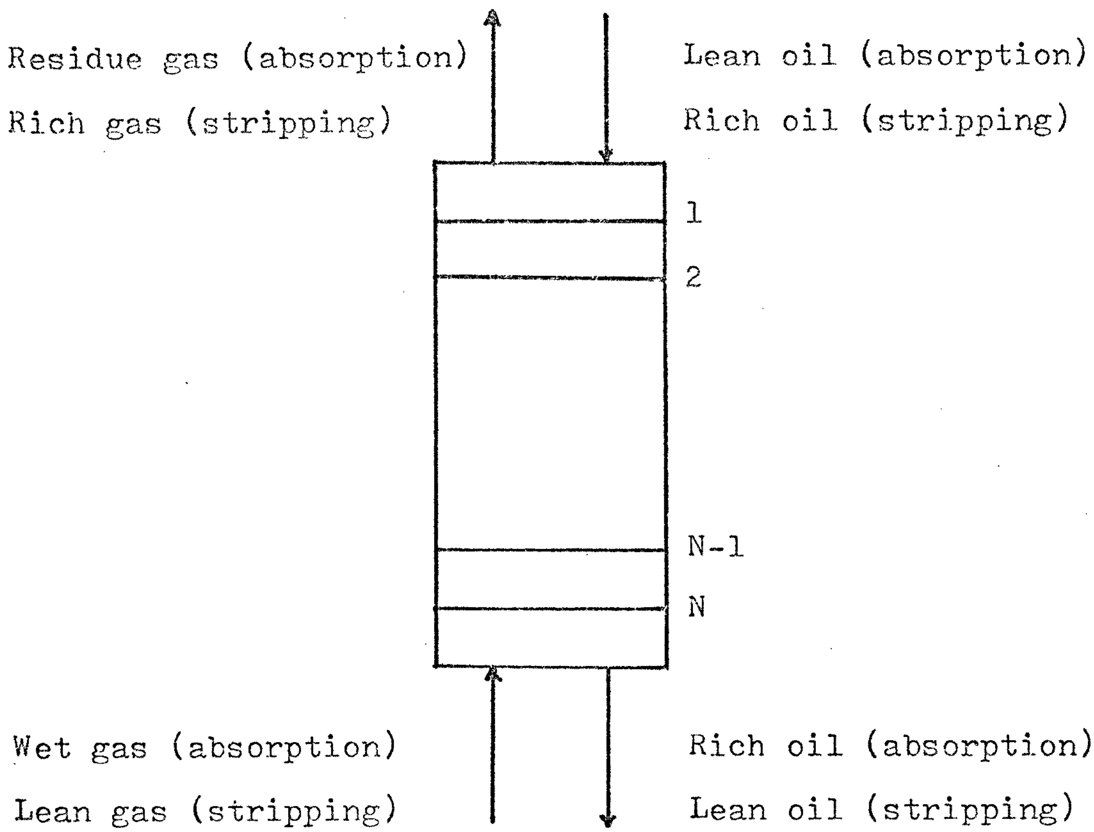

Figure 1-1. Flow Diagram for Absorption and Stripping

Referring to Figure 1-1, one can see that the flow of material is from the gas phase to the oil phase for absorption, while the reverse is true for stripping. During absorption, the wet gas rises through the column while it loses material to the descending oil phase. Very little of the oil, being relatively nonvolatile, passes to the gas phase. The resulting effect is a decrease in the gas and an equal increase in the oil phase. During stripping, the volatile components present in the oil phase are transferred to the gas phase. In this case the oil phase decreases while the gas phase increases a like amount.

This unidirectional transfer of material is what causes the wide variation in temperature. The material being transferred undergoes a phase change as it diffuses into the opposite phase. When this occurs, the heats of vaporization or condensation plus heat of solution to a smaller extent are involved. In absorption, the heat release due to condensation of the gas as it enters the oil phase causes an increase in the sensible heat of the oil. Since only a small quantity of vaporization occurs, being insufficient to absorb all the heat, the temperature of the oil phase increases as it passes down the column. In some cases this temperature rise may be considerable. This rise in liquid temperature occurs even though the liquid is at its bubble point (in an equilibrium stage). A relatively large increase in the bubble point is caused by the vaporization of even a small amount of a light component. The heat required to vaporize this small amount of material is small compared to the amount of sensible heat required to raise the temperature of the material. In stripping, the opposite is true. As the light components pass from the liquid to the gas phase, the heat of vaporization is supplied by the sensible heat of the liquid. This, then is the cause of the liquid decreasing in temperature as it travels down the column.(1)

Use of Absorbers and Strippers

These two operations, in practice, normally complement each other. Absorption is used for gas purification and component recovery. When used for component recovery, a stripper usually follows so as to recover the valuable components from the rich oil. Today, this type of equipment may be used to recover propane and ethane. In some instances as many as four absorber-stripper units may be operated in series each recovering a separate dry gas.(2)

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(1) Buford D. Smith, Design of Equilibrium Stage Processes, McGraw-Hill Book Company, Inc., New York: 1963, pp. 258-259.

(2) Wayne C. Edmister, Hydrocarbon Absorption and Fractionation Process Design Methods, The Petroleum Engineer, Texas, p. 123.

CHAPTER 2

TRADITIONAL CALCULATION METHODS

Calculation procedures for absorption and stripping used prior to the use of computers were primarily of the short-cut type. Use of short-cut methods enabled process designers to design a piece of equipment in much less time than use of a rigorous method would. In using these methods, a designer must use considerable judgment during the calculation to obtain a meaningful prediction of performance.

Sherwood Graphical Method

This procedure was first presented by W. K. Lewis (Trans. AIChE 1927). However, it is known as Sherwood's method because of the wide usage it acquired after presentation in Sherwood's "Absorption and Extraction" text by McGraw-Hill.

This method is based on the concept of theoretical plates but involves a graphical solution for the "key" component. The key component is one whose absorption or stripping factor is close to unity. The Sherwood graphical method of solving absorption and stripping problems illustrates the diffusional driving force graphically in a way that makes the concept very clear.[3]

For this method, the following are defined:

X - Mols Solute/Mol Lean Oil

Y - Mols Solute/Mol Inlet Gas

Since these quantities are defined in this manner, the equilibrium lines are determined by the temperature and pressure conditions and by the amounts absorbed. These lines are curves with the amount of curvature dependent on the quantity absorbed or stripped. Only for the special case of a lean gas with a low oil/gas ratio are they straight. The equilibrium line is plotted based on the slope of the origin and at least one additional point. This is shown plotted in Figure 2-1.

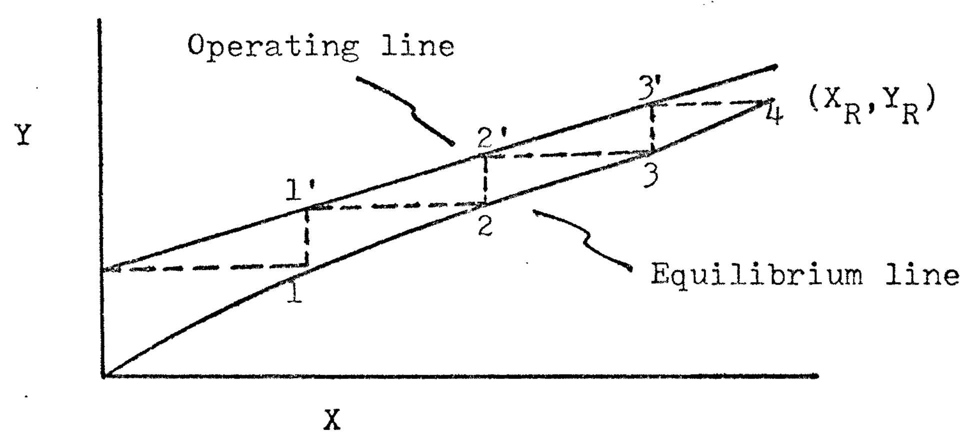

Figure 2-1. XY Diagram for Absorption

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[3] Edmister, ibid., p. 38.

The "equilibrium" line represents the relationship between the liquid and vapor leaving the same plate. The "operating" line represents the relationship between the gas leaving a plate and the liquid going to the same plate which are in fact passing streams. The operating line plots as shown in Figure 2-1 for the key component with each stage being a theoretical or equilibrium stage.

The equation for the equilibrium line for absorption can be developed in the following manner. Defining y_i as:

$$(y_a)_i = \left[\frac{V_a}{V_a + V_b + V_c + \cdots} \right]_i \qquad (2\text{-}1)$$

Dividing by $V_n + 1$ gives:

$$(y_a)_i = \left[\frac{\frac{V_a}{V_{n+1}}}{\frac{V_a}{V_{n+1}} + \frac{V_b}{V_{n+1}} + \cdots} \right]_i \qquad (2\text{-}2)$$

then:

$$(y_a)_i = \frac{Y_i}{\Sigma Y_i} \qquad (2\text{-}3)$$

An expression for x_i can be similarly derived:

$$(x_a)_i = \left[\frac{l_a}{L_o + l_a + l_b + \cdots}\right] \qquad (2\text{-}4)$$

Dividing by L_o gives:

$$(x_a)_i = \left[\frac{\frac{l_a}{L_o}}{1 + \frac{l_a}{L_o} + \frac{l_b}{L_o} + \cdots}\right] \qquad (2\text{-}5)$$

than:

$$(x_a)_i = \frac{x_i}{1 + \sum x_i} \qquad (2\text{-}6)$$

Combining equations 2-3 and 2-6 yields:

$$\frac{Y}{X} = K \frac{\sum Y}{(1 + \sum X)} \qquad (2\text{-}7)$$

where:

$\sum Y$ - sum of Y values for vapor phase components

$\sum X$ - sum of X values for liquid phase components

K - slope of equilibrium line

A similar procedure can be followed for the stripping equilibrium line.

The operating line for absorbers is simply a straight line having the slope $L_o/V_{n \quad 1}$, i.e. mols of lean oil entering divided by mols of wet gas entering. On the XY plot the distance between the two lines represents the driving force for the transfer.

As part of this procedure, analytical calculations are needed to approximate the amount of material absorbed and to locate the equilibrium lines for the graphical calculations to check the analytical approximation. The Kremser-Brown relation may be used in these calculations. For absorption:

$$E_a = \frac{Y_R - Y_L}{Y_R - Y_o} = \frac{A^{n+1} - A}{A^{n+1} - 1} \qquad (2\text{-}8)$$

and for stripping:

$$E_s = \frac{X_R - X_L}{X_R - X_o} = \frac{S^{m+1} - S}{S^{m+1} - 1} \qquad (2\text{-}9)$$

where:

A = average absorption factor

S = average stripping factor

The left sides of equations 2-8 and 2-9 may be called the efficiency of absorption or stripping, since they represent the ratio of the amount actually absorbed or stripped to that which would have been absorbed or stripped if the exit stream was in equilibrium with the entering stream. The average absorption factor can be estimated by using:

$$A = \left[\frac{L_o}{kV_{n+1}}(1+\Sigma x)\right] \tag{2-10}$$

which is based on equation 2-7.

Combining equation 2-8 and 2-10 gives:

$$E_a = \frac{Y_R - Y_L}{Y_R - Y_o} = \frac{\left[\frac{L_o}{kV_{n+1}}(1+\Sigma x)\right]^{n+1} - \left[\frac{L_o}{kV_{n+1}}(1+\Sigma x)\right]}{\left[\frac{L_o}{kV_{n+1}}(1+\Sigma x)\right]^{n+1} - 1} \tag{2-11}$$

where: L_o = mols of lean oil

V_{n+1} = mols of wet gas

Y_o = mols of component in vapor in equilibrium with the lean oil per mol of entering wet gas

K = equilibrium constant at average conditions

ΣX = 0 at lean end

ΣX = ΣX_R at rich end

Similar equations may be developed for stripping.

The procedure to be used is as follows:

1. find equilibrium constants, K
2. compute L/KV for each component, A
3. estimate fraction absorbed using equation 2-11, neglecting ΣX
4. compute ΣX from first estimate of absorption and then use equation 2-10
5. compute fraction absorbed from equation 2-11 using ΣX
6. construct the equilibrium curve using equation 2-7 and the slope at the origin
7. construct the operating line and step off stages
8. compare intersection of operating line and Y axis with value obtained for amount absorbed for key component on step 5. If they do not compare repeat step 5 using an adjusted X.

This procedure is repeated until the result obtained for the amount of the key component absorbed is the same for both the analytical and graphical procedures. A similar procedure can be followed for strippers.

This procedure has several inherent difficulties when applied to certain systems. If the lean oil is not completely denuded, the graphical procedure becomes quite awkward. This is because of the presence of the solute in the solvent introduces another convergence region. Another problem is that for a multicomponent system the procedure becomes quite tedious. This is due to the necessity of plotting an X-Y diagram for each component to check the analytical equations. In a system where the phase rates change markedly at each stage, the plotting of a straight operating line may not be correct either. A wide variation in temperature also has an effect on the procedure.

Kremser-Brown Approximation

The above heading refers to a process calculation method developed by Souder and Brown from Kremser's theoretical analysis of the absorption process. The equations for this method are developed from the following:

$$\frac{Y_{n+1}-Y_1}{Y_{n+1}} = \left(\frac{A_1A_2\cdots A_n + A_2\cdots A_n + \cdots + A_n}{A_1A_2\cdots A_n + A_2\cdots A_n + \cdots + A_n + 1}\right) - \frac{L_0 x_0}{V_{n+1}Y_{n+1}}\left(\frac{A_2\cdots A_n + \cdots A_n + \cdots + A_n + 1}{A_1A_2\cdots A_n + A_2\cdots A_n + \cdots A_n + 1}\right) \quad (2\text{-}12)$$

and:

$$A_0 Y_0 = \frac{L_0 X_0}{V_{n+1}} \tag{2-13}$$

An average value for the absorption (or stripping) factor A (or S) is used. Also the expression for the sums of the resulting series is used. This series is as follows:

$$\frac{A^{n+1} - A}{A-1} = A^n + A^{n-1} + \cdots + A^2 + A \tag{2-14}$$

$$\frac{A^{n+1} - 1}{A-1} = A^n + A^{n-1} + \cdots + A^2 + A + 1 \tag{2-15}$$

and is a simple power series convergent as long as $A < 1$. These are combined into what are known as the Kresmer-Brown relations. These are for absorption:

$$E_A = \frac{Y_{n+1} - Y_1}{Y_{n+1} - Y_0} = \frac{A^{n+1} - A}{A^{n+1} - 1} \tag{2-16}$$

and for stripping:

$$E_S = \frac{X_{m+1} - X_1}{X_{m+1} - X_0} = \frac{S^{m+1} - S}{S^{m+1} - 1} \tag{2-17}$$

These equations are used by neglecting Y_0 and X_0 since these are usually near zero. An average value for the absorption or stripping factor is used which is computed from the entering wet gas and lean oil streams at an average temperature estimated from the temperatures of the wet gas and lean oil.

Two drawbacks of this system are that the absorption effect of the absorbed components are neglected, and the heat of absorption is also neglected. For absorbers with very rich gas feeds and wide variations in temperature and phase rates, these assumptions may lead to relatively large errors.

Series Application of Absorption/Stripping Factors

The Series Application method revolves around equation 2-12 for absorption and equation 2-18

$$\frac{X_{m+1} - X_1}{X_{m+1}} = \left(\frac{S_1 S_2 \cdots S_m + S_2 \cdots S_m + \cdots + S_m}{S_1 S_2 \cdots S_m + S_2 \cdots S_m + \cdots + S_m + 1} \right)$$

$$- \frac{V_0 Y_0}{L_{m+1} X_{m+1}} \left(\frac{S_2 \cdots S_m + \cdots S_m + \cdots + S_m + 1}{S_1 S_2 \cdots S_m + S_2 \cdots S_m + \cdots S_m + 1} \right) \qquad (2\text{-}18)$$

for stripping. This method involves the use of separate absorption (or stripping) factor for each component on each stage of the column. These factors are then substituted in the general equations.

A rough estimate is made of the amounts of each component absorbed which is then used to calculate the rich oil temperature. A distribution of knockout, the amount absorbed, and temperature on each plate is then calculated using:

$$\left(\frac{V_1}{V_{n+1}}\right)^{1/n} = \frac{V_i}{V_{i+1}} \qquad (2\text{-}19)$$

and:

$$\frac{V_{n+1} - V_{i+1}}{V_{n+1} - V_1} = \frac{T_n - T_i}{T_n - T_0} \qquad (2\text{-}20)$$

These equations assume constant percent absorption through the column and temperature proportional to the contraction. Once the vapor, overflow rates, and temperature are computed from the above; the L/V ratio can be computed. Then the values of K(=y/x) can be obtained for every component on every plate and subsequently the absorption factor, A(=L/VK), can be calculated. These values are then substituted into equation 2-12 which gives us the absorption efficiencies from which the residue gas composition and total mols absorbed can be calculated. A similar procedure is followed for strippers.

The primary drawback to this procedure is the tediousness of the calculation for complicated absorbers or strippers. Again large changes in phase rate and temperature would make this procedure difficult. If absorption is high, the initial assumed value of total mols absorbed may be quite different from actual. This would require several passes through the procedure to obtain the correct results.

Horton-Franklin Method

The Horton-Franklin method is also based on effective absorption factors for each component in the mixture (equation 2-8 and 2-9). These factors are evaluated at different plates for each component. Horton and Franklin proposed the following table for locating the effective absorptions (or stripping) factor in a tower and their short cut method:[4]

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[4] Edmister, ibid., p. 34.

Table 2-1

Location of Effective Absorption Factor

Value of A (or S)	Ratio (i/n)*
0-0.1	1.0
0.1-0.4	0.9
0.4-1.0	0.8
1.0-4.0	0.7
Above 4.0	0.6

* "i" plate numbering from top to bottom for absorbers, and bottom to top for strippers.

In this method the amount of material absorbed is approximated and then the rich oil temperature is calculated by heat balance. Then from $K = P/\pi$ (assuming ideal liquid and vapor phases) on each stage and the L/V ratio the absorption factor is calculated. This is then used to determine the location (i) of the effective absorption factor from Table 2-1. Once this is done, the following equations:

$$V_i = V_1^{\frac{n+1-i}{n}} \qquad (2\text{-}21)$$

$$\frac{T_n - T_i}{T_n - T_o} = \frac{V_{n+1} - V_{i+1}}{V_{n+1} - V_1} \qquad (2\text{-}22)$$

and:

$$L_i = V_{i+1} + L_o - V_1 \qquad (2\text{-}23)$$

along with $K = P/\pi$ (P = vapor pressure, π = total pressure) are used to calculate L/V, T, and A at the effective points. Using equation 2-8 the absorption recovery efficiencies are calculated with:

$$Y_o = K_o X_o \frac{V}{V_{n+1}} \qquad (2\text{-}24)$$

The mols absorbed are calculated and then compared with the initial assumption at which point the calculation is ended or repeated. A similar procedure may be followed for strippers.

In this method it is assumed that the per cent absorption is constant on each stage and that the temperature change is proportional to the contraction. As in the other methods no allowance can be made for wide variations in phase rates and temperatures. The procedure also becomes tedious for a many component system. Sidestreams would also be difficult to handle.

Edmister Method

This method also makes use of effective absorption and stripping factors; however, the approach differs from that of Horton and Franklin. Edmister uses average values instead of plate or stage values. The development of the equations and necessary charts will not be dealt with here. The reader is referred to Edmister's work reprinted from the Petroleum Refiner. However, the calculation procedure is presented here for the sake of completeness.

The procedure begins by making an approximation of the quantity of material being absorbed and by performing a component material balance to determine the lean gas and rich oil rates. Using the results from the above calculations and the temperature of the feeds, an enthalpy balance is used to determine the rich oil temperature. Using:

$$\left(\frac{V_1}{V_{n+1}}\right)^{1/n} = \frac{V_i}{V_i + 1} \qquad (2\text{-}25)$$

and the material balance equation, the liquid leaving the top plate and the vapor leaving the bottom are estimated. Using equation 2-22, the top and bottom plate temperatures are estimated. The absorption factor for the wet gas component on the top and bottom plate is then calculated. If the lean oil contains large amounts of light components, the stripping factor must be used.

Using the charts or:

$$A_e = \sqrt{A_n(A_1+1)+.25}-.5 \qquad (2\text{-}26)$$

and:

$$A' = \frac{A_n(A_1+1)}{A_n+1} \qquad (2\text{-}27)$$

determine the effective absorption factors. These are substituted into:

$$E_a = \frac{Y_{n+1}-Y_1}{Y_{n+1}} = \left[1-\frac{L_o x_o}{A' V_{n+1} Y_{n+1}}\right] * \left[\frac{A_e^{n+1}-A_e}{A_e^{n+1}-1}\right] \qquad (2\text{-}28)$$

to determine the absorption efficiency, E_a. The calculation is completed by using a material balance to compute the lean gas and rich oil compositions and quantities. These are then compared with the initial assumptions.

The major drawback to this method is that it becomes a tedious calculation for most applications. Also, sidestreams become unwieldy. As in all other cases, a column with large material flows and temperature variations could be difficult to evaluate with this procedure.

Chapter 3

COMPUTER METHODS

This chapter is primarily intended to give the reader a synopsis of calculation methods that have been programed for computer use. A brief description of the methods used will be given along with the more important equations. No attempt will be made to prove or substantiate the procedures. An article by Burningham and Otto (Which Computer Design for Absorbers?) has compared several methods for absorbers. The basis for these calculations are the following equations:

$$L_{n-1} x_{n-1} + V_{n+1} y_{n+1} + F_n z_{i,n} - (V_n + SV_n) y_{i,n} - (L_n + SL_n) x_{i,n} = 0 \quad (3\text{-}1)$$

$$y_{i,n} = k_{i,n} x_{i,n} \quad (3\text{-}2)$$

$$E_n = -Q_n - FH_{F,n} - L_{n-1} h_{n-1} + (L_n + SL_n) h_n + (V_n + SV_n) H_n - V_{n+1} H_{n+1} = 0 \quad (3\text{-}3)$$

$$\Sigma x_{i,n} = 1 \qquad \Sigma y_{i,n} = 1 \quad (3\text{-}4)$$

$$L_{n-1} + V_{n+1} + F_n - (V_n + SV_n) - (L_n + SL_n) = 0 \quad (3\text{-}5)$$

These equations, which are the material, energy, equilibrium, and sum relationships; around an equilibrium stage n, are manipulated so as to be applicable for different procedures.

Bubble Point Method

The bubble point method is started by making initial assumptions for temperature and liquid and vapor rates. The iteration procedure is as follows:

1. combine equations (3-1) and (3-2) and then solve for phase compositions
2. use bubble point calculations to correct stage temperatures
3. use the energy balance to correct the liquid and vapor flows
4. check for convergence and repeat calculation

The use of the bubble point to correct temperatures is preferred since the use of dew points leads to a very slow rate of convergence. This is due to the fact that the rate of change of K with temperature for a heavy oil is very large while the change of K for a relatively light component is almost zero. Bubble point usage tends to overcorrect, but this can be dampened easier than it is to speed up a slow convergence.[5]

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[5] C. D. Holland, Multicomponent Distillation, Prentice-Hall, Inc., Englewood Cliffs, 1963, pp. 211-212.

This method has been programed using the Thiele-Geddes method with theta convergence and the Tri-diagonal Matrix of Amundson-Pontinen using both material and energy balance equations. The Thiele-Geddes method is described in Holland and will not be dealt with here. The Tri-diagonal Matrix procedure will be discussed briefly in the next chapter.

Sum-Rates

This method is also initiated by making initial assumptions of temperature and vapor and liquid flow rates. The procedure is continued as follows:

1. use material balance and equilibrium ratio to solve for compositions
2. estimate new liquid and vapor flows using unnormalized compositions
3. correct temperature such that the energy balance is satisfied.
4. check for convergence and then repeat calculation if necessary

This method was tested using the Thiele-Geddes and Tri-Diagonal methods by Burmingham and Otto. Their conclusions were that the Sum-Rates Tri-Diagonal Matrix method was the fastest of the four methods tested.

Other Approaches

Several other approaches to the solution of absorbers and strippers calculations have been developed. One developed by C. R. McNeese, in his article "Gas Absorber Solution by Digital Computer", uses trial-and-error calculations of the heat and material balance equations. In his material balance equation he makes use of the traditional absorption factor ($A = L/KV$). The concept of specific heat is used in the heat balance equations. The reader is referred to the original article for a discussion of the entire method.

CHAPTER 4

PROGRAM DEVELOPMENT

In this section the Wang-Henke method, as programed by Dr. E. C. Roche, Jr. for distillation, will be described briefly. This program was modified so as to be usable for absorbers and strippers. This was done so as to obtain a solution to a problem. This solution was then used as data during the development of the program for the Newton-Raphson technique. It was also used to compare the two methods. The Newton-Raphson method is described fully including the derivation of the specific equations used.

Wang-Henke Method

The Wang-Henke Method uses the tri-diagonal matrix method for the solution of the linearized material balance equations and uses Muller's method for temperature convergence via a bubble point calculation. The original method developed for a distillation column assumed the column had n equilibrium stages, a condenser, and a reboiler. The stages were numbered from top to bottom with the condenser as the first stage and reboiler as the last. For absorption, it was considered to have n equilibrium stages and a reboiler. The method solves the so-called MESH equations:

Material balance: (4-1)

$$M_{ij}(x_{ij}, V_j, T_i) = L_{j-1} x_{i,j-1} - (V_j + W_j) y_{i,j}$$

$$- (L_j + U_j) x_{ij} + V_{j+1} y_{i,j+1} + F_j z_{ij} = 0$$

Equilibrium equation: (4-2)

$$E_j(x_{ij}, V_j, T_j) = y_{ij} - k_{ij} x_{ij} = 0$$

Sum equation: (4-3)

$$S_j(x_{ij}, V_j, T_j) = \sum_{i=1}^{m} x_{ij} - 1.0 = 0$$

Heat equation: (4-4)

$$H_j(x_{ij}, V_j, T_j) = L_{j-1} h_{j-1} - (V_j + W_j) H_j$$

$$- (L_j + U_j) h_j + V_{j+1} H_{j+1} + F_j H_{F_j} - Q_j = 0$$

The material balance and equilibrium equations are combined into the following:

$$L_j = V_{j+1} + \sum_{k=2}^{j} (F_k - W_k - U_k) - D \qquad (4\text{-}5)$$

$$2 \le j \le n-1$$

where:

$$D = V_1 + U_1 \qquad (4\text{-}6)$$

for distillation.

For absorption, the constraint $2 \leq j \leq n-1$ is replaced with $1 \leq j \leq n-1$ since no condenser is present. Equation (4-5) then becomes:

$$L_j = V_{j+1} + \sum_{k=1}^{j} (F_k - W_k - U_k) - V_1 \qquad (4\text{-}7)$$

where V_1 is the lean gas leaving the column overhead. This equation is then reduced to the tridiagonal form:

$$B_1 x_{i1} + C_1 x_{i2} = D_1 \qquad (4\text{-}8)$$

$$A_j x_{i,j-1} + B_j x_{ij} + C_j x_{i+1,j+1} = D_j \qquad (4\text{-}9)$$

$$A_n x_{i,n-1} + B_n x_{in} = D_n \qquad (4\text{-}10)$$

for distillation.

Since an absorber or stripper calculation differs slightly from that of a distillation column, i.e. no condenser load, the tridiagonal procedure was modified. Sections of the program containing references to a condenser load were deleted. The Wang-Henke method is used to calculate an initial column profile of stage compositions, temperatures, and vapor and liquid flow rates. Since the procedure is somewhat simpler than that for a distillation column, the bubble point calculation needed and the Wang-Henke method are simpler. These sections have been modified accordingly.

Newton-Raphson Technique

The Newton-Raphson Technique is a matrix method which involves the elimination of matrices within the framework of a much larger matrix. This method is applicable to the problem of general, reliable, and flexible computer codes for the solution of chemical engineering design problems.[6] The primary objective of Goldstein and Stanfield was to develop a system that was general, reliable, and flexible. Their method was developed using the most general form of the heat and material balance equations. This procedure could be as easily programed for superfractionators as it was for absorbers and strippers.

A column consisting of i stages and separating j components can, at steady state, be fully described by j component material balances, an enthalpy balance, a mole fraction definition, and an overall material balance on every stage. These equations (defining out-in = 0) are:

---

[6] Goldstein and Stanfield, Industrial Engineering Chemistry Process Design and Development, Vol. 9, No. 1, Jan. 1970, p. 78.

Component Material Balance

$$-L_{i-1}\, x_{j,i-1} + (L_i + SSL_i)\, x_{j,i} + (V_i + SSV_i)\, K_{j,i}\, x_{j,i} - V_{i+1}\, K_{j,i+1}\, x_{j,i+1} = F_j\, z_{j,i} \tag{4-11}$$

Enthalpy Balance

$$-\sum L_{i-1}\, h_{j,i-1}\, x_{j,i-1} + \sum (L_i + SSL_i)\, h_{j,i}\, x_{j,i} + \sum (V_i + SSV_i)\, H_{j,i}\, K_{j,i}\, x_{j,i} - \sum V_{i+1}\, H_{j,i+1}\, K_{j,i+1}\, x_{j,i+1} = Q_i \tag{4-12}$$

Liquid Mole Fraction Definition

$$\sum x_{j,i} = 1 \tag{4-13}$$

Overall Material Balance

$$-L_{i-1} + L_i + SSL_i + V_i + SSV_i - V_{i+1} = F_i \tag{4-14}$$

The Component Material Balance equation will be developed fully for component j on stage i. A representation of one tower stage is shown in Figure 4-1. The component material balance, equation (4-11) is completely differentiated:

$$-L^{\circ}_{i-1}\, x^{\circ}_{j,i-1} - L^{\circ}_{i-1}\, \Delta x_{j,i-1} - x^{\circ}_{j,i-1}\, \Delta L_{i-1} + (L^{\circ}_i + SSL_i)\, x^{\circ}_{j,i} + (L^{\circ}_i + SSL_i)\, \Delta x_{j,i} + x^{\circ}_{j,i}\, \Delta L_i + (V^{\circ}_i + SSV_i)\, K^{\circ}_{j,i}\, x^{\circ}_{j,i} \tag{4-15}$$

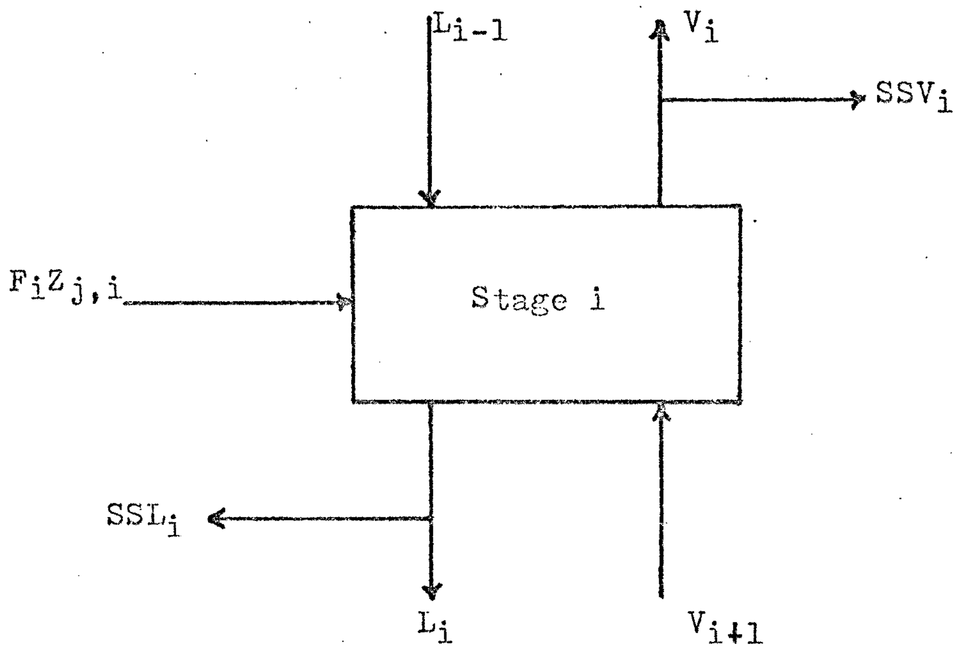


Figure 4-1. Representation of One Stage

$$+ (V_i^\circ + SSV_i) k_{j,i} \Delta x_{j,i} + k_{j,i}^\circ x_{j,i}^\circ \Delta V_i$$

$$+ (V_i^\circ + SSV_i) x_{j,i}^\circ \frac{dk_{j,i}^\circ}{dT} \Delta T_i$$

$$- V_{i+1}^\circ k_{j,i+1}^\circ \Delta x_{j,i+1} - V_{i+1}^\circ k_{j,i+1}^\circ x_{j,i+1}^\circ \qquad \text{(4-15) Cont'd}$$

$$- k_{j,i+1}^\circ x_{j,i+1}^\circ \Delta V_{i+1}$$

$$- V_{i+1}^\circ x_{j,i+1}^\circ \frac{dk_{j,i+1}}{dT} \Delta T_{i+1} = F_i z_{j,i}$$

The following are defined:

$$x_{j,i-1} \equiv x^{o}_{j,i-1} + \Delta x_{j,i-1} \tag{4-16}$$

$$x_{j,i} \equiv x^{o}_{j,i} + \Delta x_{j,i} \tag{4-17}$$

$$x_{j,i+1} \equiv x^{o}_{j,i+1} + \Delta x_{j,i+1} \tag{4-18}$$

Substituting into equation 4-15 and combining like terms, we obtain:

$$\begin{aligned} &\left[-L^{o}_{i-1}\right] x_{j,i-1} + \left[(L_i + SSL_i) + (V^{o}_i + SSV_i)K^{o}_{j,i}\right] x_{j,i} \\ &+ \left[-V^{o}_{i+1} K^{o}_{j,i+1}\right] x_{j,i+1} + \left[(V_i + SSV_i) x^{o}_{j,i} \frac{dK_{j,i}}{dT}\right] \Delta T_i \\ &+ \left[-V^{o}_{i+1} x^{o}_{j,i+1} \frac{dK_{j,i+1}}{dT}\right] \Delta T_{i+1} + \left[K^{o}_{j,i} x^{o}_{j,i}\right] \Delta V_i \\ &+ \left[-K^{o}_{j,i+1} x^{o}_{j,i+1}\right] \Delta V_{i+1} + \left[-x^{o}_{j,i-1}\right] \Delta L_{i-1} \\ &+ \left[x^{o}_{j,i}\right] \Delta L_i = F_i z_{j,i} \end{aligned} \tag{4-19}$$

Referring to Figure 4-2 and equation 4-12 one can see that a similar approach can be taken for the heat balance equation. Completely differentiating equation 4-12 we obtain:

$$-\sum L^{o}_{i-1} h^{o}_{j,i-1} x^{o}_{j,i-1} - \sum L^{o}_{i-1} h^{o}_{j,i-1} \Delta x_{j,i-1} \tag{4-20}$$

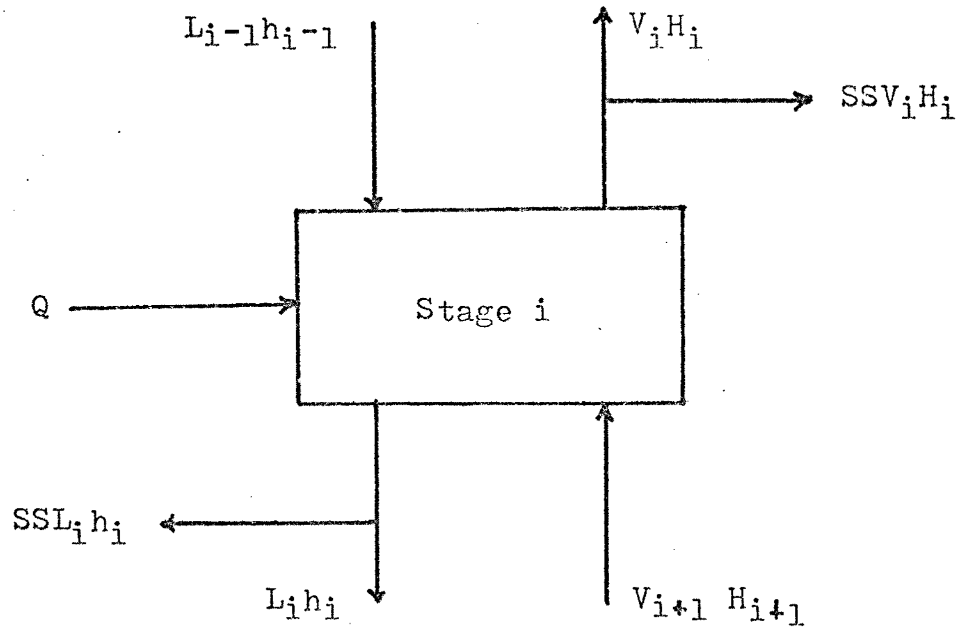


Figure 4-2. Heat Balance on One Stage

$$-\sum \Delta L_{i-1} h^o_{j,i-1} x^o_{j,i-1} + \sum (L^o_i + SSL_i) h^o_{j,i} x^o_{j,i}$$

$$+\sum (L^o_i + SSL_i) h^o_{j,i} \Delta x_{j,i} + \sum \Delta L_i h^o_{j,i} x^o_{j,i}$$

$$+\sum (L^o_i + SSL_i) x^o_{j,i} \frac{dh_{j,i}}{dT} \Delta T_i$$

$$-\sum L^o_{i-1} x^o_{j,i-1} \frac{dh_{j,i-1}}{dT} \Delta T_{i-1} \qquad \text{(4-20) Cont'd}$$

$$+\sum (V^o_i + SSV_i) H^o_{j,i} K^o_{j,i} x^o_{j,i}$$

$$+\sum H^o_{j,i} K^o_{j,i} x^o_{j,i} \Delta V_i + \sum (V^o_i + SSV_i) H^o_{j,i} K^o_{j,i} \Delta x_{j,i}$$

$$+ \sum (V_i^o + SSV_i) K_{j,i}^o x_{j,i}^o \frac{dH_{j,i}}{dT} \Delta T_i$$

$$+ \sum (V_i^o + SSV_i) x_{j,i}^o H_{j,i}^o \frac{dK_{j,i}}{dT} \Delta T_i$$

$$- \sum V_{i+1}^o H_{j,i+1}^o K_{j,i+1}^o x_{j,i+1}^o - \sum H_{j,i}^o K_{j,i+1}^o x_{j,i+1}^o \Delta V_{i+1}$$

(4-20) Cont'd

$$- \sum V_{i+1}^o K_{j,i+1}^o x_{j,i+1}^o \frac{dH_{j,i+1}}{dT} \Delta T_{i+1}$$

$$- \sum V_{i+1}^o H_{j,i+1}^o x_{j,i+1}^o \frac{dK_{j,i+1}}{dT} \Delta T_{i+1}$$

$$- \sum V_{i+1}^o H_{j,i+1}^o K_{j,i+1}^o \Delta x_{j,i+1} = Q$$

Substituting equations 4-16, 4-17, and 4-18 into equation 4-20, and combining like terms, we obtain:

$$\left[- \sum L_{i-1}^o h_{j,i-1}^o \right] x_{j,i-1} \qquad (4\text{-}21)$$

$$+ \left[\sum (L_i^o + SSL_i) h_{j,i}^o + \sum (V_i^o + SSV_i) H_{j,i}^o K_{j,i}^o \right] x_{j,i}$$

$$+ \left[- \sum V^{o}_{i+1} H^{o}_{j,i+1} K^{o}_{j,i+1} \right] x_{j,i+1}$$

$$+ \left[- \sum L^{o}_{i-1} \frac{dh_{j,i-1}}{dT} x^{o}_{j,i-1} \right] \Delta T_{i-1}$$

$$+ \left[\sum (L^{o}_{i} + SSL_{i}) \frac{dh_{j,i}}{dT} + \sum (V^{o}_{i} + SSV_{i}) \left(K^{o}_{j,i} \frac{dh_{j,i}}{dT} + H^{o}_{j,i} \frac{dK_{j,i}}{dT} \right) \right] x^{o}_{j,i} \Delta T_{i}$$

$$+ \left[- \sum V^{o}_{i+1} x^{o}_{j,i+1} \left(K^{o}_{j,i+1} \frac{dH_{j,i+1}}{dT} + H^{o}_{j,i+1} \frac{dK_{j,i+1}}{dT} \right) \right] \Delta T_{i+1} \qquad \text{(4-21) Cont'd}$$

$$+ \left[\sum H^{o}_{j,i} K^{o}_{j,i} x^{o}_{j,i} \right] \Delta V_{i}$$

$$+ \left[- \sum H^{o}_{j,i+1} K^{o}_{j,i+1} x^{o}_{j,i+1} \right] \Delta V_{i+1}$$

$$+ \left[- \sum h^{o}_{j,i-1} x^{o}_{j,i-1} \right] \Delta L_{i-1}$$

$$+ \left[\sum h^{o}_{j,i} x^{o}_{j,i} \right] \Delta L_{i} = Q$$

In order to make use of the equations developed above for the heat and material balance, coefficients must be assigned to the x, Δ L, Δ V, and Δ T terms. Referring to equation (4-19), the component balance, the coefficients are assigned. The subscripts 1, 2, 3 refer to the position of the variable in the matrix which will become more readily apparent later. For the component material balance equation the coefficients are:

$$a_{j,1} = -L \tag{4-22}$$

$$a_{j,2} = L + SSL + (V + SSV)K \tag{4-23}$$

$$a_{j,3} = -VK \tag{4-24}$$

$$b_{j,1} = (V + SSV)x\frac{dK}{dT} \tag{4-25}$$

$$b_{j,2} = -Vx\frac{dK}{dT} \tag{4-26}$$

$$c_{j,1} = Kx \tag{4-27}$$

$$c_{j,2} = -Kx \tag{4-28}$$

$$d_{j,1} = -x \tag{4-29}$$

$$d_{j,2} = x \tag{4-30}$$

The subscripts have been omitted for clarity.

After developing the heat balance equation, equation 4-21 the coefficients are assigned:

$$e_{j,1} = -Lh \tag{4-31}$$

$$e_{j,2} = (L+SSL)h + (V+SSV)KH \tag{4-32}$$

$$e_{j,3} = -VKH \tag{4-33}$$

$$f_1 = -\sum L \frac{dh}{dT} x \tag{4-34}$$

$$f_2 = \sum \left[(L+SSL)\frac{dh}{dT} + (V+SSV)\left(K\frac{dH}{dT} + H\frac{dK}{dT}\right) \right] x \tag{4-35}$$

$$f_3 = -\sum V\left(K\frac{dH}{dT} + H\frac{dK}{dT}\right) x \tag{4-36}$$

$$g_1 = \sum KHx \tag{4-37}$$

$$g_2 = -\sum KHx \tag{4-38}$$

$$h_1 = -\sum hx \tag{4-39}$$

$$h_2 = \sum hx \tag{4-40}$$

The one other equation needed is the overall material balance:

$$K_i = L_i + SSL_i + V_i + SSV_i - L_{i-1} - V_{i+1} - F_i \tag{4-41}$$

The ordering of these terms is shown in Figure 4-3 for a three component, four stage tower. The upper portion of the matrix contains the component material balance (coefficients a, b, c, and d) and are numbered 1 through NC. The line containing e, f, g, and h contain the enthalpy balance equation and is identified as N1 (NC+1). Line number N2 (NC+2) contains the coefficientss of the sum equation and line N3 (NC+3) contains the coefficients of the overall material balance equation. The subscripts of 1, 2, and 3 given the coefficients, which determine their position in the matrix, refer to stage i-1, i, and i+1, respectively. Figure 4-4 gives the generalized picture of the matrix for a 3 component, n stage tower.

In this procedure, for the size tower represented, the matrix has been partitioned into a 6x6 matrix of submatrices. This is done to take full advantage of the regular structure of the problem. The method of ordering the component balances by component is more efficient for a tower with many components and few trays. The overall matrix will expand to the left and towards the top as more components are added. As trays are added, the submatrices will increase in size. The large overall size of the matrix makes direct inversion somewhat impractical. This is

FIGURE 4-3
NEWTON-RAPHSON SYSTEM FOR
A 3-COMPONENT, 4 STAGE TOWER

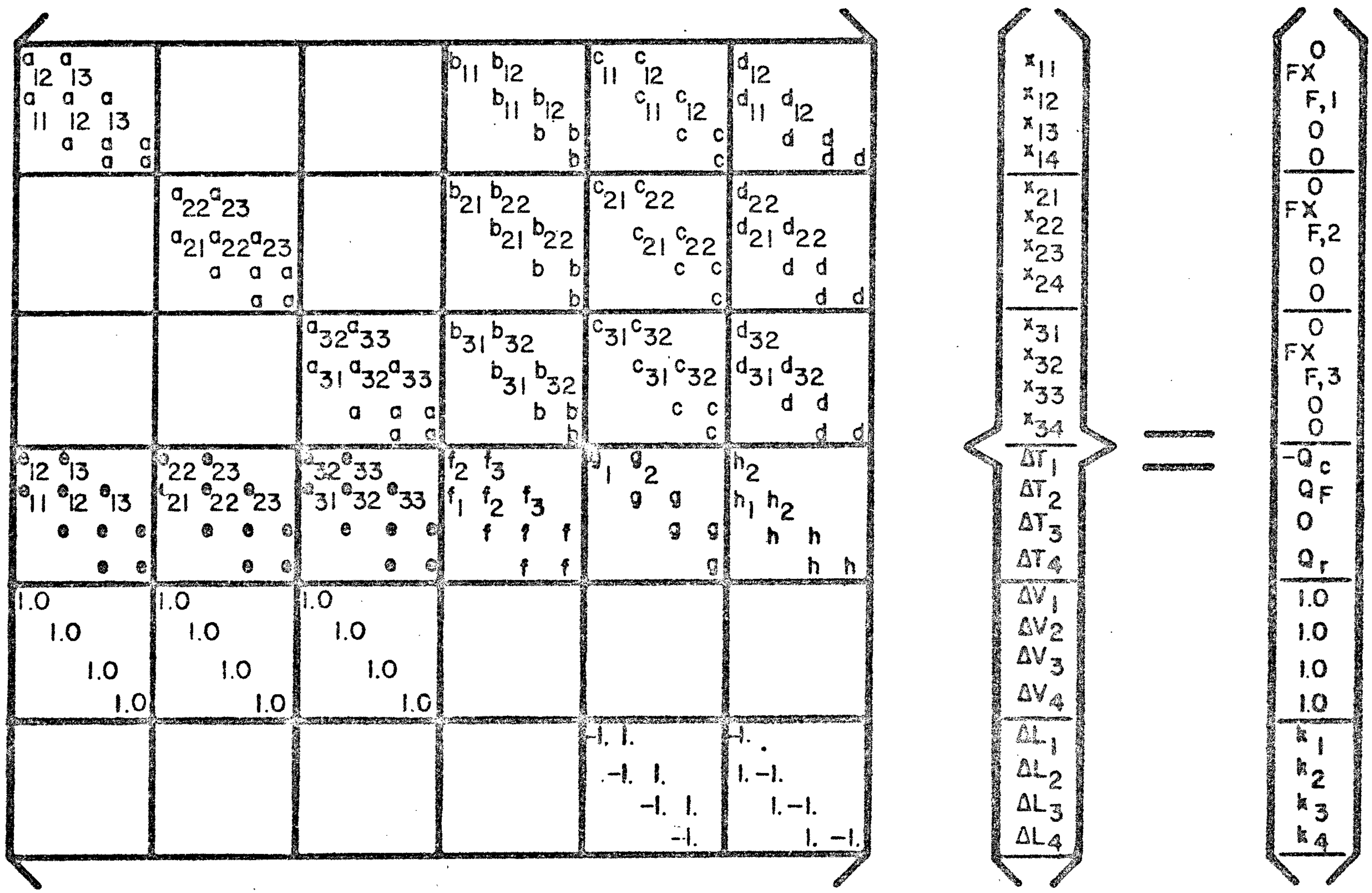
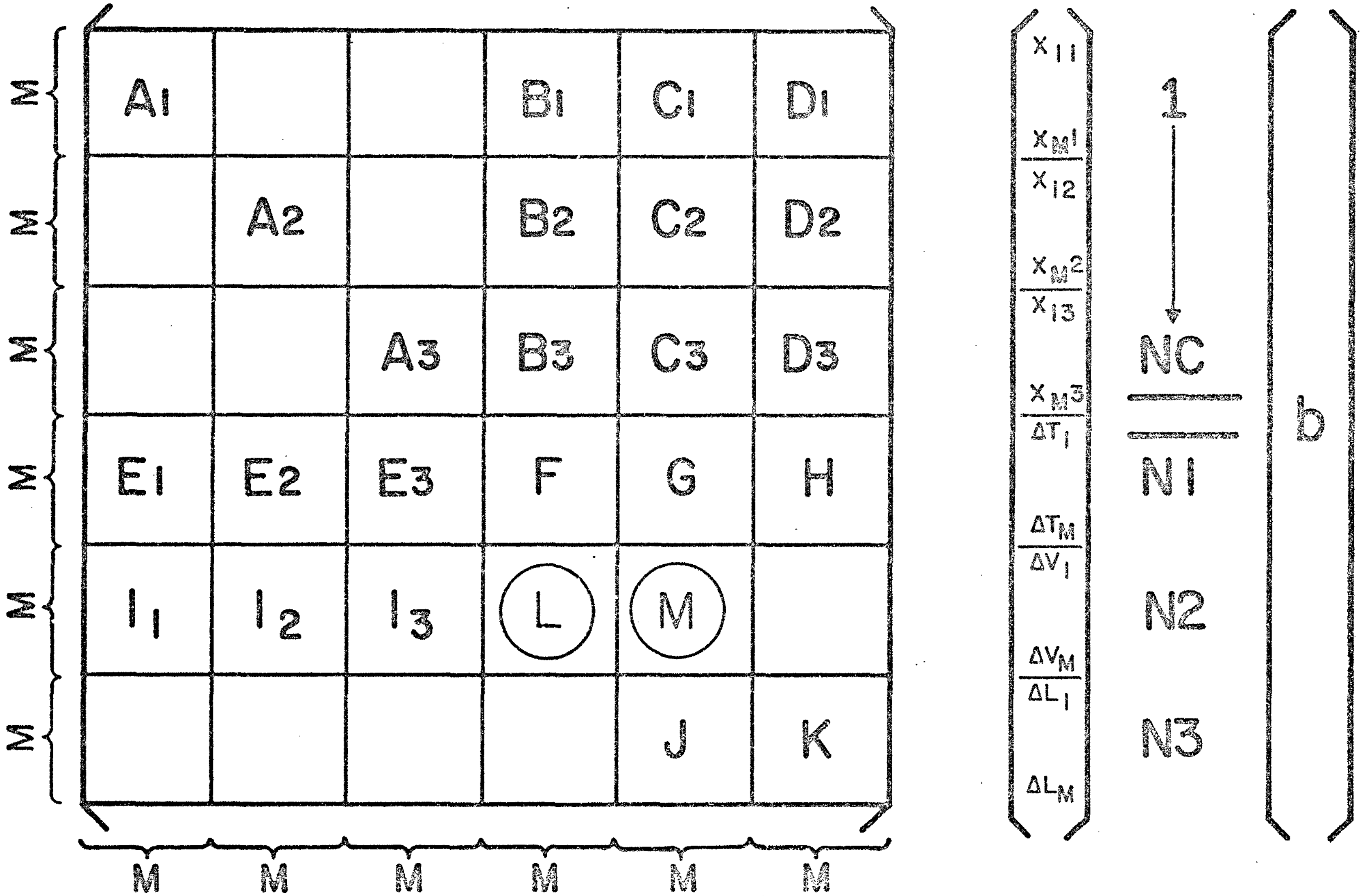


FIGURE 4-4
NEWTON-RAPHSON SYSTEM FOR
A 3-COMPONENT M STAGE TOWER



primarily due to time and storage limitations on most computers. Therefore, the inversion is done by performing a partial triangularization of the large matrix. This procedure produces a much smaller matrix which requires subsequent inversion.

The initialization and partial triangulation of the matrix proceeds as follows:

1. develop the overall stage material balance entries, J, K, and k; (equation 4-41)
2. invert K and multiply the bottom row by it
3. generate submatrices C and D on a component basis and the corresponding right hand side (RHS) entries
4. multiply the bottom row by D and subtract the result from the top row on a component basis - the result being the elimination of D
5. generate F, G, and H entries
6. multiply the bottom row by H and subtract from row N1 - thus H is eliminated
7. generate A, B, E, and I on a component by component basis - I is not actually generated since it is the entry for the sum equation and equal to the identity matrix
8. invert A matrix and multiply the j component row by it

9. multiply the j component row by E and subtract the result from row N1-E is eliminated
10. multiply the j component row by I and subtract the result from row N2-I is eliminated

As each step above is completed, for all the components on all the stages, the calculation proceeds. The result is shown in Figure 4-5. The area outlined in bold lines is the only area which requires inversion to calculate the Δ T and Δ V values.

The inversion procedure that was finally used. proceeds as follows:

1. invert F and multiply G and the RHS (-,N1) term by the inverse
2. multiply G and the N1 term by L and subtract from M and the RHS (-,N2) term, respectively
3. invert M and multiply the RHS (-,N2) term by the inverse
4. multiply G by the RHS (-,N2) term and subtract from the RHS (-,N1) term

Once the inversion is complete, the delta T terms are located in RHS (-,N1) and the delta V terms in RHS (-,N2).

FIGURE 4-5
RESULTS OF THE PARTIAL TRIANGULARIZATION OF THE NEWTON-RAPHSON MATRIX

I			$A_1^{-1} B_1$	$A_1^{-1} [C_1 - D_1 K^{-1} J]$	0
	I		$A_2^{-1} B_2$	$A_2^{-1} [C_2 - D_2 K^{-1} J]$	0
		I	$A_3^{-1} B_3$	$A_3^{-1} [C_2 - D_3 K^{-1} J]$	0
0	0	0	$F - \sum_{i=1}^{3} E_i A_i^{-1} B_i$	$G - \sum_{i=1}^{3} \{E_i A_i^{-1} (C_i - D_i K^{-1} J)\} - H K^{-1} J$	0
0	0	0	$- \sum_{i=1}^{3} A_i^{-1} B_i$	$- \sum_{i=1}^{3} \{A_i^{-1} (C_i - D_i K^{-1} J)\}$	
				$K^{-1} J$	I

$$\{\Psi\} = \{b'\}$$

I= identity matrix

The new x's and delta L's are now calculated by back substitution. The J term is multiplied by the delta V term and the result subtracted from RHS (-,N3) to obtain the delta L's. The B and C terms are multiplied component by component by the delta T and delta V terms, respectively. The result is subtracted from the old compositions to obtain the new compositions.

The above procedure represents one Newton-Raphson iteration. The computational procedure is continued until the convergence criteria are satisfied. The procedure represents a more generalized or hierarchical Gaussian elimination of matrices, rather than elimination of elements.[7] The Fortran listing of this procedure is given in Appendix I.

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[7] Goldstein and Stanfield, ibid., p. 80.

CHAPTER 5

PROGRAM PROCEDURE

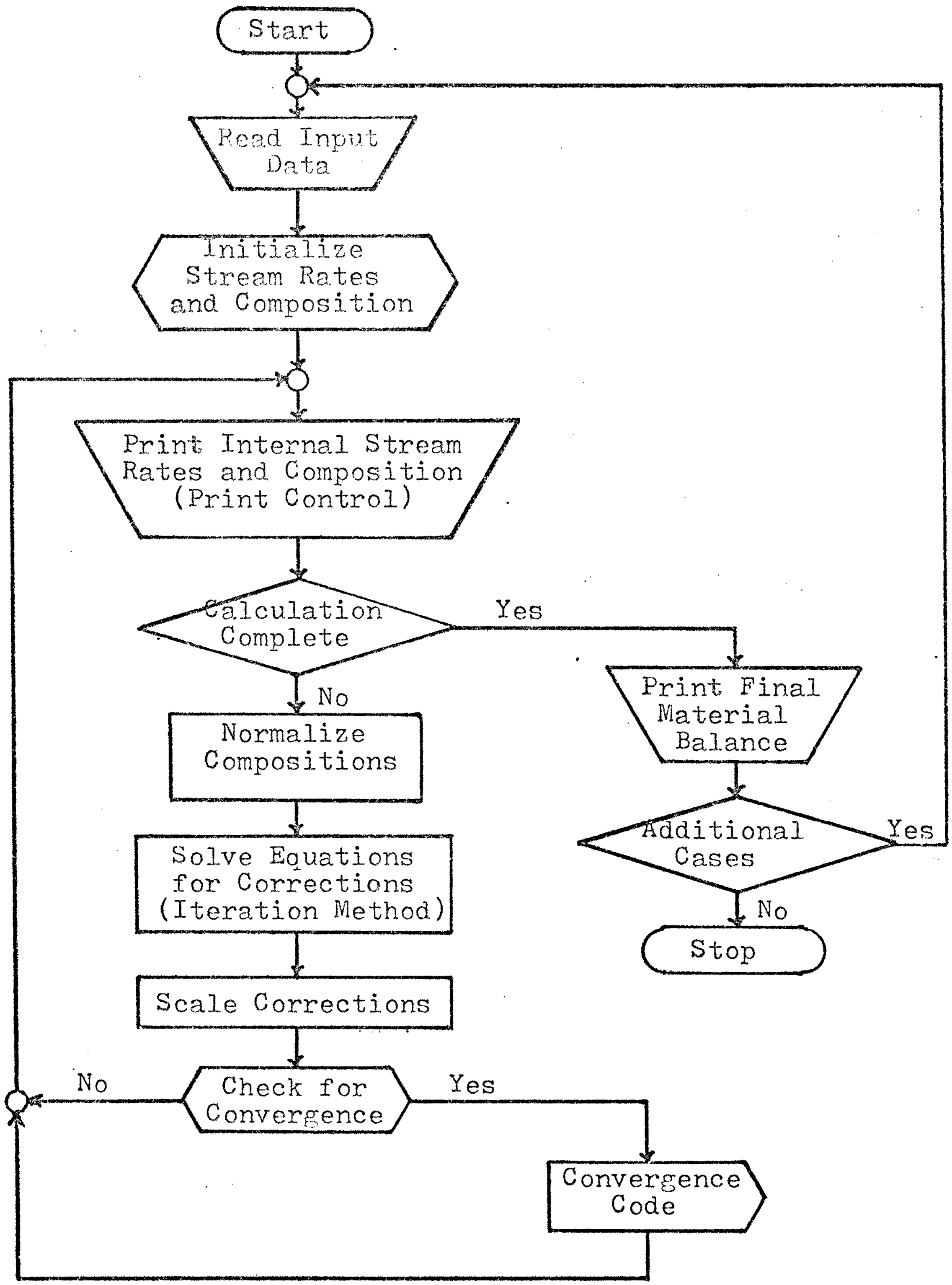
A necessary part of any iterative method is the input and output information plus any supporting subroutines. In this chapter a flowsheet for the program will be given along with a short description of the other subroutines used. The input information necessary will be described in detail with an example given.

Program Flowsheet

A computer program must follow a logical sequence of events during the calculation. In Figure 5-1, the flowsheet for the program is presented. Referring to the figure, the procedure is as follows:

1. initialize program
2. read input data and print
3. initialize stream rates
4. print initial rates and compositions
5. normalize compositions
6. solve iteration method
7. scale corrections
8. check for convergence
9. return
10. print stream rates and compositions
11. a. if converged, print final output

Figure 5-1. Computer Program Flowsheet



b. if not converged, repeat 5-10

12. do next problem or stop

Each of the above functions is performed by one or more subroutines. These subroutines can be broken into major and minor groups. The major ones perform basic steps as detailed above and the minor ones fulfill supporting rules. All of the subroutines are listed in the appendix.

The following will be considered as major subroutines that are common to both iteration procedures:

INPUT - reads necessary control data, initial temperatures, pressures, heat loads, and calculates initial profile by Amundson's method

CDATA - reads component data, K-data, enthalpy data, and curve fits data

FEED - reads feed data: rates, temperature, pressure, entering point of feed

OTPUT - prints final material balance

The minor subroutines are described:

KGEN - uses K-data to calculate K as function of temperature

HGEN - uses enthalpy data to calculate it as function of temperature

EQUA - evaluates polynominal coefficients, used for data

FITIT - curve fits data by regression analysis

WAYA - converges on a single value

MWRITE - prints out tray summary during calculation

FLASH - performs flash calculation on column feeds

MINV - matrix inversion

ALNUM - develops integer equivalents of numbers

There are also subroutines which are needed separately for each method. The subroutines used for the stage oriented Newton-Raphson method are:

ABSR1 - main calling program

INR - stage oriented Newton-Raphson and convergence check

ABCD - stage oriented Newton-Raphson

GET(I) - calculates K and enthalpy data plus derivatives on a stage by stage basis

The subroutines for the Newton-Raphson component oriented method are as follows:

ABSR2 - main calling program

MATRIX - Newton-Raphson procedure and convergence check

INI - Newton-Raphson procedure

ENTHAL - Newton-Raphson procedure

COMP - Newton-Raphson procedure

SUBST - Newton-Raphson procedure

ZERO - sets a matrix equal to zero

EQUAL - sets one matrix equal to another

MPLYM - matrix and vector multiplication

GET - calculates K and enthalpy data plus derivatives for all stages

The subroutines which form the Newton-Raphson iteration procedure are given in Appendix I. In order to give the reader a cohesive picture of both programs, a listing of both in their entirety has been included. In Appendix II, is located the program using the Newton-Raphson component oriented procedure with Amundson's initialization procedure. Appendix III contains the Newton-Raphson stage oriented procedure with Amundson's initialization procedure. Either program may be used to obtain a problem solution.

Input Information

The following section describes the input requirements for both programs and the sequence of the data cards.

1. Title card, columns 1-80

   Any information desired to describe the problem may be included on this card.

2. Control card

   All data on this card must be punched within the specified space right justified.

   a. Columns 1-5 Number of contact stages, excluding reboiler $1 \leq N \leq 20$

   b. Columns 6-10 Number of components $2 \leq C \leq 15$

   c. Columns 11-15 Number of feeds $2 \leq F \leq 6$

   d. Columns 16-20 Number of side stream and/or interstage heat exchanges $0 \leq SS/Q \leq 5$

   e. Column 21-25 Number of vapor-liquid equilibrium data points supplied as a function of temperature and pressure for each component $2 \leq K \leq 8$

      Two (2) has been found to be best

   f. Column 26-30 Number of vapor-liquid enthalpy data points supplied as a function of temperature and pressure for each component $2 \leq H \leq 8$. Two (2) has been found to be best

g. Columns 31-35 Number of iterations

h. Columns 36-40 Design variable - always equal to 2

i. Columns 41-45 Print output code

1 Input and Output

2 1 + trial data

3 2 + all data

4 3 + error print out

j. Columns 46-50 Column type

1 simple absorber

2 sidestream and/or interstage heat exchanger

3 strippers

4 reboiled absorbers

3. Design parameter card

a. Columns 1-10 Reboiler heat load MMBtu/hr

b. Columns 11-20 Overhead vapor rate, mols/hr

4. Temperature card

All temperatures must be entered with a decimal point and are in degrees F

a. Columns 1-10 Column top tray temperature

b. Columns 11-20 Column bottom tray temperature

c. Columns 21-30, 31-40 If desired, a temperature at some midpoint in the column may be specified so as to allow for a two straight line temperature estimation

Columns 21-30 tray number

Columns 31-40 temperature

5. Pressure card

Pressure is specified in psia and it is assumed pressure drop per stage is uniform. All data must be entered with a decimal point.

a. Columns 1-10 Top tray pressure

b. Columns 11-20 Pressure drop across the column

6. Feed definition cards

For each feed stream there will be one complete set of cards. For absorbers and strippers the oil will be fed at the top tray (tray no. 1) and the gas at the bottom (tray no. N). If any other feeds enter the column, at a location other than top or bottom, they will be listed as entering on the higher numbered tray

a. Specific feed data

1 Columns 1-12 Feed name

2 Columns 19-20 Feed stage number, right justified

3 Feed conditions

Columns 21-30 Pressure, psia

Columns 31-40 Temperature, °F

Columns 41-50 Heat content, MMBtu/hr

4 Columns 51-60 Feed preheat duty, MMBtu/hr

+ heat added

- heat removed

b. Feed component data, mols/hr

Columns 1-10 Component 1

Columns 11-20 Component 2

etc. etc.

If more than 8 components are present, additional cards should be used, maximum of eight components per card

c. Feed equilibrium data

If the feed heat content is not given, the battery limit liquid-vapor equilibrium data must be supplied so that the necessary feed flash can be performed so as to determine the associated enthalpy. If the heat content if specified, then this card must be omitted

Columns 1-10 Component 1

Columns 11-20 Component 2

etc. etc.

7. Sidestream and/or interstage heat exchangers

If there are no sidestreams and/or interstage heat exchangers present, this data is to be omitted. The following data is supplied on one card for each sidestream and/or interstage heat exchanger.

a. Columns 1-5 Tray number, right justified

b. Columns 11-20 Vapor withdrawal, mols/hr

c. Columns 21-30 Liquid withdrawal, mols/hr

d. Columns 31-40 Heat exchanger duty, MMBtu/hr

+ heat removed from stage

- heat added to stage

8. Component data

The following data is supplied for each component, one card per component.

a. Columns 1-8 Component name

b. Columns 11-20 Molecular weight

c. Columns 21-30 Density, lb/gal

9. Liquid-vapor equilibrium data

At least 2 data points must be supplied per component, the maximum being 8

a. Temperature data (one card)

Columns 1-10 Temperature #1, ^{o}F

Columns 11-20 Temperature #2, ^{o}F

etc. etc.

b. Pressure data (one card)

Columns 1-10 Pressure #1, psia

etc. etc.

c. Componential liquid-vapor equilibrium data (one card per component)

Columns 1-10 K-data corresponding to Temperature #1 and Pressure #1

Columns 11-20 K-data corresponding to Temperature #2 and Pressure #2

etc. etc.

The program will interpolate and extrapolate the data based on the K-data temperature relationship

$$\ln K \sim \frac{1}{T(^{o}R)}$$

If all of the K-data is specified at the same pressure then all the data will be pressure corrected assuming that

Pressure * K-data = constant

10. Liquid-vapor enthalpy data

At least 2 data points must be supplied per component, the maximum being 8

a. Temperature data (one card)

Column 1 Enthalpy units code

1 Btu/lb-mole

2 Btu/lb

Columns 2-10 Temperature #1, ^{o}F

Columns 11-20 Temperature #2, ^{o}F

etc. etc.

b. Pressure data (one card)

Columns 1-10 Pressure #1, psia

Columns 11-20 Pressure #2, psia

etc. etc.

c. Enthalpy data (two cards per component)

1 Vapor enthalpy data (one card)

Columns 1-10 Enthalpy data corresponding to Temperature #1 and Pressure #1

Columns 11-20 Enthalpy data corresponding to Temperature #2 and Pressure #2

etc. etc.

2 Liquid enthalpy data (one card)

Columns 1-10 Enthalpy data corresponding to Temperature #1 and Pressure #1

Columns 11-20 Enthalpy data corresponding to Temperature #2 and Pressure #2

etc. etc.

The program will interpolate and extrapolate the data based on the following relationship

$$H \sim T$$

11. Problem Termination

At the end of each problem, a control card must be placed consisting of

Columns 1-4 $$$$

Located in Appendix IV is a sample Fortran input coding form. A listing of the data used for each problem is also located in this Appendix.

CHAPTER 6

DISCUSSION OF RESULTS AND CONCLUSIONS

The original intent was to make the necessary modifications to a distillation program using the stage oriented Newton-Raphson matrix procedure so as to obtain a solution to a simple absorber problem. Once the problem was solved, a comparison solution was available during the debugging of the Newton-Raphson matrix method that is component oriented.

The initial coding of the component oriented procedure involved a total inversion of that portion of the matrix shown in Figure 4-4 labeled FGLM, after an initial compaction. For a total inversion, a compaction is necessary in order to eliminate the zero terms remaining in each matrix if a column contains less than twenty (20) stages so as to obtain a valid inverse. The corresponding right hand side terms (N1 and N2) are also compacted to eliminate zeros. The resulting inverted matrix and vector, respectively, are then multiplied to yield the delta T and delta V terms for each stage for that iteration. Indicated delta values on the order of 10^4-10^7 were obtained from this procedure after several iterations.

Since it was obvious that an error was present, each portion of the procedure was individually checked. The solution from the stage oriented program was used for this purpose. In theory, if a calculation procedure is correct, then supplying the solution as input data should yield identical output. However, this did not occur with the component oriented procedure. In order to locate the errors in the procedure and to verify the coding, the material and enthalpy balance entries were set equal to zero so that no modifications to the input would result. Here, again, no solution was obtained. By varying the entries which were set equal to zero, we were able to determine that the equations were derived correctly and also were able to uncover errors in coding.

Once it was proven that the equations and coding were correct, the only other source of problems could have been the inversion procedure. At this point, it was decided to perform a partial, instead of total, inversion of FGLM without a compaction of the respective submatrices. The procedure is described in a previous chapter. The incorporation of a partial inversion into the system yielded output results very nearly identical to the solution answers used as input.

The solution to the first problem obtained from the component oriented method is included in the appendix. A total of seven iterations was required versus the six needed using the stage oriented method.

A second simple absorber problem, labeled number four in the appendix, was run using both procedures. Initially, this problem would not converge using either procedure. A check of various data sources revealed that, for the heavier components especially, there was a discrepancy in the k and enthalpy data. The initial source of data was the appendix contained in <u>Design of Equilibrium Stage Processes</u> by Buford Smith. Smith's original source of data was the <u>Data Book on Hydrocarbons</u> by J. B. Maxwell. The difficulty was that the data in Smith's book is only a partial representation of the original data. For many components, Smith indicates a dashed line for liquid enthalpies at temperatures past the critical point. For most materials an extrapolation of the saturation line tangent to it will yield more realistic results. Similar variations in k data, due to different methods of plotting, were also present but were not as extreme.

Since no data for the oil phase was included in the problem statement other than molecular weight and API gravity, it was assumed to have a very high enthalpy and very low volatility. After using information obtained from Maxwell which correlate the molecular weight and API gravity with the mean average boiling point to yield the enthalpy, it was found that the above assumptions were not necessarily valid and caused large errors in calculation. The first set of data used also caused problems with the feed flash calculation in that it would not converge. Once a correct and consistent set of data was used, this error disappeared.

The conclusions to be drawn from this problem are that if the column conditions, temperature and pressure, fall near or just beyond the critical point on the enthalpy graph, it is best to assume a tangential extrapolation of the saturation line instead of using the dashed line as is normally presented. If problems with feed flash do arise, this is a good indication of an error in feed heat content and in the liquid enthalpy data.

Both procedures should be able to handle a column with side streams and/or heat trays. In order to verify this, an absorber with an intercooler on two stages was tested, problem number two in the appendix. Initially this calculation would not converge using either method. It was felt that the initialization procedure used gave a poor initial column profile for this type of problem. A linear interpolation of the input conditions across the column was made using the following assumptions:

1. liquid compositions on stage 1 equal to feed composition to stage 1
2. liquid compositions on stage NT equal to composition on stage 1 plus a varying percentage of the vapor feed to stage NT from light to heavy components
3. liquid flow leaving the column 30% higher than entering
4. a linear change in compositions and flows from top to bottom

This procedure was coded and was made a part of the component oriented procedure. By using a "logical if statement", the program would bypass the original profile calculation and use the above. This procedure did not work and was subsequently abandoned; however, the coding is still present in the program but does not form part of the calculation.

At this point Dr. Roche requested Mr. E. Wells of the Foster-Wheeler Corporation to run the problem using their program from which a converged solution was obtained. The enthalpy and k data used with the programs at Foster-Wheeler were compared with that used with these programs given here.

The comparison revealed problems with both the enthalpy data and the k data. The discrepancy in the enthalpy data was due to the same problem as discussed for the previous example. The k data used with the Newton-Raphson procedures was observed to contain a discontinuity which caused large errors in compositions. The composition errors were caused since the derivatives of the k data, due to temperature conditions in the column, were being taken at a point with a very large derivative with respect to temperature. The large derivative was due to a difference in the pressures used to evaluate the data. Once the correct data set was used, both the stage and component oriented methods converged to a solution.

With respect to k data, one can draw the conclusion that it is imperative that a consistent set of vapor-liquid equilibrium data be used, representative of the actual column operating conditions.

Since a stripping operation is analogous to absorption, except with the mass transfer being in the opposite direction, a steam stripping example was tried; but would not converge using either procedure. The same problem with discrepancies in data was discovered but corrections here did not improve the calculation. Again, it was felt that a linear interpolation of the input data would yield a better starting point than that being used. The following method was used:

1. a uniform liquid composition was assumed on all the stages
2. condensed steam was assumed to be not present
3. liquid rate entering the column was equal to the value obtained after the flash calculation
4. liquid leaving was equal to 80% of that entering
5. a linear change in flow rates across the column from top to bottom

The linear interpolation was coded with the component oriented procedure and entered by using a "logical if statement". This procedure did provide a better initial point for the calculation and did yield smaller errors in temperatures and flow rates but did not converge. However, the component oriented method did get closer to the desired overhead product rate than the stage oriented procedure. The temperatures calculated with either procedure oscillated badly from iteration to iteration.

Generally, both procedures presented in this paper are capable of solving absorber calculations with equal efficiency as related to number of iterations required. The stage oriented procedure appears to be much more efficient for the solution of absorbers with sidestreams and/or heat trays requiring on the order of 65% as many iterations as the component oriented method requires. In their present form, neither procedure is applicable to strippers.

It is recommended that two point data be used for any particular problem as long as the temperature range is not large. The program performs a smooth interpolation of the input data by a regression analysis and since absorbers operate under somewhat pseudo-equilibrium conditions, greater accuracy obtained by using more than two data points over a narrow temperature range is not especially warranted.

CHAPTER 7

RECOMMENDATIONS

In order to further verify the procedures, several other solved absorber problems should possibly be run. These may be obtained either from sources in the literature or possibly from industry.

Since neither procedure is now applicable in its present form for the solution of stripping columns, further work should possibly be done to determine what problems exist in the programs. Once these problem areas are defined, a solution to them should be incorporated into the programs.

The case using a reboiled absorber was not attempted with these programs. Possible modifications to them should be considered so as to expand the area of use for these programs.

As discussed earlier, a total inversion of FGLM would not result in a usable procedure. Since the work of Goldstein and Stanfield indicates a total inversion can be used for distillation, further studies should be undertaken to determine the reasons behind its failure to work here. The use of the total inversion may have an effect on the total number of iterations required for a particular problem. It may be possible to reduce the required computing time by changing the inversion technique.

Lastly, it may be worthwhile to further streamline the program to gain more efficiency of operation.

APPENDIX I

```
      SUBROUTINE MATRIX (*,*)
C
      COMMON      //      X(15,20),V(20),XL(20),U(20),W(20),
     1                    Q(20),HL(20),HV(20),TA(20),F(15,20),
     2                    HF(20),PP(20),QG,DIST
      COMMON      /CONTRL/ NC,NT,LDBC,NID,NTM1,KTOP,
     1                    N1,N2,N3,N3N3,NT20
      COMMON      /DATA/  WK(15,20),DK(15,20),HVV(15,20),
     1                    HLL(15,20),DHV(15,20),DHL(15,20),
     2                    Y(15,20)
      COMMON      /FIX/   A(20,20),B(20,20,15),C(20,20,15),
     1                    E(20,20),AF(20,20),
     2                    AJ(20,20),RHS(20,18),
     3                    G(20,20),AL(20,20),AM(20,20)
C
      REAL                 CXL(20),CTA(20),CV(20)
C
      DATA                 DVMAX/0.001/,DLMAX/0.001/,DTMAX/0.05/
C
C
      WRITE (6,2)
      CALL MWRITE
    2 FORMAT (1H1)
  4   FORMAT(/)
      NDONE=0
      DO 399 NIT=1,NID
C
      DO 10 I=1,NT
      SUM=0.0
      DO 11 J=1,NC
   11 SUM=SUM+X(J,I)
      DO 12 J=1,NC
   12 X(J,I)=X(J,I)/SUM
   10 CONTINUE
      CALL GET
C
      CALL INI
      CALL ENTHAL
      CALL COMP
      CALL SUBST
      GO TO (501,501,501,502),LDBC
  502 CONTINUE
C
C   THE ERRORS ON EACH STAGE ARE PRINTED
      WRITE(6,2)
      WRITE(6,4)
C
      DO 80 I=1,NT
   80 WRITE(6,402) I,RHS(I,N3),RHS(I,N2),RHS(I,N1)
  402 FORMAT(//10X' UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE'
```

```
     1 I5//10X(1P3E18.5))
C
C   CALCULATE CORRECTIONS FOR EACH STAGE
C
      DO 135 I=1,NT
      CTA(I)=TA(I)+RHS(I,N1)
      CXL(I)=XL(I)+RHS(I,N3)
      CV(I)=V(I)+RHS(I,N2)
  135 CONTINUE
      IF(LODG.GT.2) WRITE(6,2)
C
C   PRINT CORRECTIONS FOR EACH STAGE
C
      WRITE(6,4)
      DO 136 I=1,NT
  136 WRITE(6,403) I,CXL(I),CV(I),CTA(I)
  403 FORMAT(//10X' CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE'
     1 I5//10X(1P3E18.5))
C
  501 CONTINUE
C
C   CHECK FOR CONVERGENCE
C        (1)  MAXIMUM ABS(DV).LT.DVMAX  V= VAPOR FLOW
C        (2)  MAXIMUM ABS(DL).LT.DLMAX  L= LIQUID FLOW
C        (3)  MAXIMUM ABS(DT).LT.DTMAX  T= TEMPERATURE
C   SCALE CORRECTIONS IF TOO LARGE ----CAUSE FOR SCALING
C        (1)  DV.GT.0.20*V
C        (2)  DL.GT.0.20*L
C        (3)  DT.GT.20.0
C
      DV=0.0
      DL=0.0
      DT=0.0
      SUMSQ=0.0
C
      DO 145 M=1,NT
      SUMSQ=SUMSQ+RHS(M,N1)**2
      DV=AMAX1(ABS(RHS(M,N2))/V(M),DV)
      DL=AMAX1(ABS(RHS(M,N3))/XL(M),DL)
  145 DT=AMAX1(ABS(RHS(M,N1)),DT)
C
      IF(DV.LT.DVMAX.AND.DL.LT.DLMAX.AND.DT.LT.DTMAX) NDONE=1
C
  505 DO 150 I=1,NT
      DO 150 J=1,NC
      CX=RHS(I,J)-X(J,I)
      IF(RHS(I,J).LT.1.0E-6) GO TO 506
      IF(RHS(I,J).LE.0.0.OR.RHS(I,J).GE.1.0) GO TO 509
      GO TO 150
  506 IF(RHS(I,J).LE.0.0) RHS(I,J)=X(J,I)/2.0
```

```
  150   CONTINUE
        GO TO 507
  509   NDONE=0
        DO 155 I=1,NT
        DO 155 J=1,NC
        CX=RHS(I,J)-X(J,I)
        RHS(I,J)=X(J,I)+SIGN(CX/2.,CX)
  155   CONTINUE
        GO TO 505
C
  507   DO 158 I=1,NT
        IF(ABS(RHS(I,N3)).GT.0.20*XL(I).OR.ABS(RHS(I,N2)).
       1GT.0.20*V(I)) GO TO 508
  158   CONTINUE
        GO TO 510
  508   NDONE=0
        DO 160 I=1,NT
        RHS(I,N3)=RHS(I,N3)*.5
        RHS(I,N2)=RHS(I,N2)*.5
  160   CONTINUE
        GO TO 507
C
  510   DO 165 I=1,NT
        IF(ABS(RHS(I,N1)).GT.20.0) GO TO 511
  165   CONTINUE
        GO TO 512
  511   NDONE=0
C
        DO 168 I=1,NT
        RHS(I,N1)=RHS(I,N1)*.5
  168   CONTINUE
        GO TO 510
  512   DO 170 I=1,NT
        DO 171 J=1,NC
  171   X(J,I)=RHS(I,J)
        XL(I)=XL(I)+RHS(I,N3)
        V(I)=V(I)+RHS(I,N2)
        TA(I)=TA(I)+RHS(I,N1)
  170   CONTINUE
C
        IF(LDOC.EQ.1) GO TO 513
        IF(LDOC.GT.2) WRITE(6,2)
        WRITE (6,404) NIT,SUMSQ,DT,DV,DL
        WRITE(6,4)
  404   FORMAT(//10X! ITERATION NUMBER! I5//
       112X! SUM DT SQUARED! F20.6/
       212X! DT MAX! F28.6/12X' MAX DV/V!F26.5/
       312X! MAX DL/L!F26.6)
        IF(LDOC.EQ.2.AND.MOD(NIT,15).EQ.0) WRITE(6,2)
C
```

```
      GO TO (513,513,514,514), LOOC
  514 CALL MWRITE
  513 IF(NDONE.NE.0) GO TO 515
C
  399 CONTINUE
C
      GO TO 515
C
  515 IF(NDONE.NE.0) GO TO 516
      WRITE (6,405)
  405 FORMAT(///20X' NO CLOSURE OBTAINED ON PROBLEM'/
     120X' FOR SPECIFIED NUMBER OF TRIALS'///)
      WRITE (6,2)
      CALL MWRITE
      RETURN 2
C
  516 GO TO (600,600,700,700), LOOC
  600 WRITE (6,2)
      CALL MWRITE
C
  700 RETURN
      END
```

```
      SUBROUTINE INI
C
      COMMON   //          X(15,20),V(20),XL(20),U(20),W(20),
     1                     Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                     HF(20),PP(20),QG,DIST
      COMMON   /CONTRL/    NC,NT,LOC,NIO,NTM1,KTOP,
     1                     N1,N2,N3,N3N3,NT20
      COMMON   /DATA/      WK(15,20),DK(15,20),HVV(15,20),
     1                     HLL(15,20),DHV(15,20),DHL(15,20),
     2                     Y(15,20)
      COMMON   /FIX/       A(20,20),B(20,20,15),C(20,20,15),
     1                     E(20,20),AF(20,20),
     2                     AJ(20,20),RHS(20,18),
     3                     G(20,20),AL(20,20),AM(20,20)
      REAL                 SM(20,20),SV(400),
     +                      AK(20,20),D(20,20)
C
      EQUIVALENCE        (SM(1,1),SV(1)),
     +                    (A(1,1),AK(1,1),D(1,1))
C
C   DEVELOP OVERALL MATERIAL BALANCE ENTRIES ----- BLOCK N3
C
C   AJ MATRIX IS SET EQUAL TO ZERO AND THEN THE
C   NON-ZERO TERMS ARE COMPUTED
C
      CALL ZERO(RHS,360)
      CALL ZERO (AJ,NT20)
C
      DO 10 I=1,NTM1
      AJ(I,I)=-1.
      AJ(I,I+1)=1.
   10 CONTINUE
      AJ(NT,NT)=-1.
C
C   AK MATRIX IS SET EQUAL TO ZERO AND THEN THE
C   NON-ZERO TERMS ARE COMPUTED
      CALL ZERO (AK,NT20)
      AK(1,1)=-1.
      DO 20 I=2,NT
      AK(I,I-1)=1.
      AK(I,I)=-1.
   20 CONTINUE
C
C   THE RIGHT HAND SIDE OF THE MATERIAL BALANCE IS DEVELOPED
C
      RHS(1,N3)=XL(1)+U(1)+V(1)+W(1)-F(NC+1,1)-V(2)
      DO 30 I=2,NTM1
      RHS(I,N3)=XL(I)+U(I)+V(I)+W(I)-F(NC+1,I)-XL(I-1)-V(I+1)
   30 CONTINUE
      RHS(NT,N3)=XL(NT)+U(NT)+V(NT)+W(NT)-F(NC+1,NT)-XL(NTM1)
```

```
C
C    GENERATE RHS OF SUM EQUATION
        DO 31 I=1,NT
        RHS(I,N2)=1.
   31   CONTINUE
C
C    INVERT AK
        L=0
        DO 34 N=1,NT
        DO 33 M=1,NT
        L=L+1
        SV(L)=AK(M,N)
   33   CONTINUE
   34   CONTINUE
C
C    MATRIX AK IS INVERTED
C
        CALL MINV(SV,NT,DETRM,AK(1,1),AK(1,2))
C
        L=0
        DO 38 N=1,NT
        DO 37 M=1,NT
        L=L+1
        AK(M,N)=SV(L)
   37   CONTINUE
   38   CONTINUE
C
C    AK AND AJ ARE MULTIPLIED TOGETHER ALONG WITH ASSOCIATED
C    RHS FOR MATERIAL BALANCE EQUATION
C
        CALL MPLYM(AK,AJ,SM,NT)
        CALL EQUAL(AJ,SM,NT)
        CALL MPLYV(AK,RHS(1,N3),SV,NT)
        CALL EQUALV(RHS(1,N3),SV,NT)
C
C    GENERATE C PART OF COMPONENT MATERIAL
C    BALANCE WHICH IS ORDERED COMPONENT WISE
C
C    SET C MATRIX EQUAL TO ZERO FOR COMPONENT
C    J AND GENERATE NON-ZERO TERMS
C
        DO 53 J=1,NC
        CALL ZERO (C(1,1,J),NT2)
        DO 41 I=1,NTM1
        C(I,I,J)=WK(J,I)*X(J,I)
        C(I,I+1,J)=-WK(J,I+1)*X(J,I+1)
   41   CONTINUE
        C(NT,NT,J)=WK(J,NT)*X(J,NT)
C
C    GENERATE D MATRIX
```

```
C     ----- ONLY NEEDED AT THIS TIME
C     TO MODIFY C MATRIX AND ASSOCIATED RHS
C
      CALL ZERO (D,NT20)
C
      D(1,1)=X(J,1)
      DO 42 I=2,NT
      D(I,I-1)=-Y(J,I-1)
      D(I,I)=X(J,I)
   42 CONTINUE
C
C     GENERATE RHS FOR EACH COMPONENT
C
      DO 45 I=1,NT
      RHS(I,J)=F(J,I)
   45 CONTINUE
C
C     MULTIPLY D * RHS(-,N3) AND
C     SUBTRACT FROM RHS(I,J)
C
      DO 48 I=1,NT
      DO 48 K=1,NT
      RHS(I,J)=RHS(I,J)-D(I,K)*RHS(K,N3)
   48 CONTINUE
C
C     MULTIPLY D * AJ AND SUBTRACT FROM C
C
      CALL MPLYM (D,AJ,SM,NT)
C
      DO 50 I=1,NT
      DO 50 K=1,NT
      C(I,K,J)=C(I,K,J)-SM(I,K)
   50 CONTINUE
C
   53 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE ENTHAL
C
      COMMON    //          X(15,20),Y(20),XL(20),U(20),W(20),
     1                      Q(20),HL(20),HV(20),TA(20),F(15,20),
     2                      HF(20),PP(20),QC,DIST
      COMMON    /CONTRL/    NC,NT,LOOC,NIO,NTM1,KTOP,
     1                      N1,N2,N5,N3N3,NT20
      COMMON    /DATA/      WK(15,20),DK(15,20),HVV(15,20),
     1                      HLL(15,20),DHV(15,20),DHL(15,20),
     2                      Y(15,20)
      COMMON    /FIX/       A(20,20),B(20,20,15),C(20,20,15),
     1                      E(20,20),AF(20,20),
     2                      AJ(20,20),RHS(20,18),
     3                      G(20,20),AL(20,20),AM(20,20)
      REAL                 SM(20,20),SV(400),H(20,20)
C
      EQUIVALENCE          (SM(1,1),SV(1)),
     +                      (A(1,1),H(1,1))
C
      CALL ZERO (AF,400)
      CALL ZERO (G,400)
C
C   GENERATE AF,G,H,AND RHS(-,1)
C
C
C      GENERATE AF ENTRIES
C
      DO 64 J=1,NC
C
      AF(1,1)=AF(1,1)+(XL(1)+U(1))*X(J,1)*DHL(J,1)
     1+(V(1)+W(1))*(WK(J,1)*DHV(J,1)+HVV(J,1)*DK(J,1))*X(J,1)
      AF(1,2)=AF(1,2)-( V(2)*X(J,2))*(WK(J,2)*
     1DHV(J,2)+HVV(J,2)*DK(J,2))
      DO 61 I=2,NTM1
      AF(I,I-1)=AF(I,I-1)-(XL(I-1)*X(J,I-1)*DHL(J,I-1))
      AF(I,I)=AF(I,I)+(XL(I)+U(I))*X(J,I)*DHL(J,I)
     1+(V(I)+W(I))*(WK(J,I)*DHV(J,I)+HVV(J,I)*DK(J,I))*X(J,I)
      AF(I,I+1)=AF(I,I+1)-(V(I+1)*X(J,I+1))*
     1(WK(J,I+1)*DHV(J,I+1)+HVV(J,I+1)*DK(J,I+1))
   61 CONTINUE
      AF(NT,NTM1)=AF(NT,NTM1)-(XL(NTM1)*X(J,NTM1)*DHL(J,NTM1))
      AF(NT,NT)=AF(NT,NT)+(XL(NT)+U(NT))*X(J,NT)*DHL(J,NT)
     1+(V(NT)+W(NT))*(WK(J,NT)*DHV(J,NT)+HVV(J,NT)*DK(J,NT))*X(J,NT)
   64 CONTINUE
C
C
C      GENERATE G ENTRIES
C
      DO 65 I=1,NTM1
      G(I,I)=HV(I)
```

```
      G(I,I+1)=-HV(I+1)
   65 CONTINUE
      G(NT,NT)=HV(NT)
C
C     GENERATE H ENTRIES
C
      CALL ZERO (H,NT20)
      H(1,1)=HL(1)
      DO 72 I=2,NT
      H(I,I-1)=-HL(I-1)
      H(I,I)=HL(I)
   72 CONTINUE
C
      DO 74 I=1,NT
   74 RHS(I,N1)=-Q(I)+F(N1,I)*HP(I)
C
C     MULTIPLY H BY AJ AND SUBTRACT FROM G
C
      DO 76 I=1,NT
      DO 76 L=1,NT
      DO 75 K=1,NT
   75 G(I,L)=G(I,L)-H(I,K)*AJ(K,L)
C
C     MULTIPLY H BY RHS(I,N3) AND SUBTRACT FROM RHS(I,N1)
C
      RHS(I,N1)=RHS(I,N1)-H(I,L)*RHS(L,N3)
   76 CONTINUE
C
C
C
      RETURN
      END
```

```
      SUBROUTINE COMP
C
      COMMON   //        X(15,20),V(20),XL(20),U(20),W(20),
     1                   Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                   HF(20),PP(20),QG,DIST
      COMMON   /CONTRL/  NC,NT,LDOC,NIO,NTM1,KTOP,
     1                   N1,N2,N3,N3N3,NT20
      COMMON   /DATA/    WK(15,20),DK(15,20),HVV(15,20),
     1                   HLL(15,20),DHV(15,20),DHL(15,20),
     2                   Y(15,20)
      COMMON   /FIX/     A(20,20),B(20,20,15),C(20,20,15),
     1                   E(20,20),AF(20,20),
     2                   AJ(20,20),RHS(20,18),
     3                   G(20,20),AL(20,20),AM(20,20)
      REAL               SM(20,20),SV(400)
C
      EQUIVALENCE        (SM(1,1),SV(1))
C
C     GENERATE COMPONENT BY COMPONENT A,B,E,AND I
C     I IS NOT ACTUALLY GENERATED SINCE IT IS THE
C     COMPONENTIAL ENTRIES FOR THE SUM EQUATION
C
C     COMPUTE INVERSE OF A AND MULTIPLY TOP ROW BY IT
C
      CALL ZERO (AL,400)
      CALL ZERO (AM,400)
C
      DO 150 J=1,NC
C
C     F + G ARE ADJUSTED AS A RESULT OF E ELIMINATION
C     L AND M ARE ADJUSTED BY I ELIMINATION
C
      CALL ZERO (A,NT20)
      CALL ZERO (B(1,1,J),NT20)
      CALL ZERO (E,NT20)
C
      A(1,1)=(V(1)+W(1))*WK(J,1)+XL(1)+U(1)
      A(1,2)=-V(2)*WK(J,2)
      E(1,1)=(V(1)+W(1))*WK(J,1)*HVV(J,1)+
     1(XL(1)+U(1))*HLL(J,1)
      E(1,2)=-V(2)*WK(J,2)*HVV(J,2)
      DO 82 I=2,NTM1
      A(I,I-1)=-XL(I-1)
      A(I,I)=(V(I)+W(I))*WK(J,I)+XL(I)+U(I)
      A(I,I+1)=-V(I+1)*WK(J,I+1)
C
      E(I,I-1)=-XL(I-1)*HLL(J,I-1)
      E(I,I)=(V(I)+W(I))*WK(J,I)*HVV(J,I)+
     1(XL(I)+U(I))*HLL(J,I)
      E(I,I+1)=-V(I+1)*WK(J,I+1)*HVV(J,I+1)
```

```
   82 CONTINUE
      A(NT,NTM1)=-XL(NTM1)
      A(NT,NT)=(V(NT)+W(NT))*WK(J,NT)+XL(NT)+U(NT)
      E(NT,NTM1)=-XL(NTM1)*HLL(J,NTM1)
      E(NT,NT)=(V(NT)+W(NT))*WK(J,NT)*HVV(J,NT)+
     1(XL(NT)+U(NT))*HLL(J,NT)
C
      DO 83 I=1,NTM1
      B(I,I,J)=(V(I)+W(I))*X(J,I)*DK(J,I)
      B(I,I+1,J)=-V(I+1)*X(J,I+1)*DK(J,I+1)
   83 CONTINUE
      B(NT,NT,J)=(V(NT)+W(NT))*X(J,NT)*DK(J,NT)
C
C    MATRIX A IS INVERTED
C
      L=0
      DO 90 N=1,NT
      DO 90 M=1,NT
      L=L+1
      SV(L)=A(M,N)
   90 CONTINUE
C
      CALL MINV(SV,NT,DETRM,A(1,1),A(1,2))
      L=0
      DO 91 N=1,NT
      DO 91 M=1,NT
      L=L+1
      A(M,N)=SV(L)
   91 CONTINUE
C
C    MULTIPLY A BY B
      CALL MPLYM (A,B(1,1,J),SM,NT)
      CALL EQUAL (B(1,1,J),SM,NT)
C
C    MULTIPLY A BY C
      CALL MPLYM (A,C(1,1,J),SM,NT)
      CALL EQUAL (C(1,1,J),SM,NT)
C
C    MULTIPLY A BY RHS(I,J)
      CALL MPLYV(A,RHS(1,J),SV,NT)
      CALL EQUALV(RHS(1,J),SV,NT)
C
C    MULTIPLY ROW J BY E AND SUBTRACT FROM ROW N1
C
      DO 95 I=1,NT
      DO 95 K=1,NT
      DO 94 L=1,NT
      AF(I,K)=AF(I,K)-E(I,L)*B(L,K,J)
   94 G(I,K)=G(I,K)-E(I,L)*C(L,K,J)
      RHS(I,N1)=RHS(I,N1)-E(I,K)*RHS(K,J)
```

```
   95 CONTINUE
C
C
C     MULTIPLY ROW J BY I AND SUBTRACT FROM ROW N2
C
      DO 110 I=1,NT
  110 RHS(I,N2)=RHS(I,N2)-RHS(I,J)
      DO 120 I=1,NT
      DO 120 K=1,NT
  120 AL(I,K)=AL(I,K)-B(I,K,J)
      DO 130 I=1,NT
      DO 130 K=1,NT
  130 AM(I,K)=AM(I,K)-C(I,K,J)
C
C
  150 CONTINUE
C
C
      RETURN
      END
```

```
      SUBROUTINE SUBST
C
      COMMON    //        X(15,20),V(20),XL(20),U(20),W(20),
     1                    Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                    HF(20),PP(20),QG,DIST
      COMMON    /CONTRL/  NC,NT,LDOC,NID,NTM1,KTOP,
     1                    N1,N2,N3,N3N3,NT20
      COMMON    /DATA/    WK(15,20),DK(15,20),HVV(15,20),
     1                    HLL(15,20),DHV(15,20),DHL(15,20),
     2                    Y(15,20)
      COMMON    /FIX/     A(20,20),B(20,20,15),C(20,20,15),
     1                    E(20,20),AF(20,20),
     2                    AJ(20,20),RHS(20,18),
     3                    G(20,20),AL(20,20),AM(20,20)
C
      REAL                SM(20,20),SV(400)
C
      EQUIVALENCE         (SM(1,1),SV(1))
C
C      INVERT AF
      L=0
      DO 10 N=1,NT
      DO 10 M=1,NT
      L=L+1
   10 SV(L)=AF(M,N)
      CALL MINV (SV,NT,DETRM,AF(1,1),AF(1,2))
      L=0
      DO 20 N=1,NT
      DO 20 M=1,NT
      L=L+1
   20 AF(M,N)=SV(L)
C
C     MULTIPLY G AND RHS(-,N1) BY AF INVERSE
      CALL MPLYM (AF,G,SM,NT)
      CALL EQUAL (G,SM,NT)
      CALL MPLYV (AF,RHS(1,N1),SV,NT)
      CALL EQUALV (RHS(1,N1),SV,NT)
C
C     MULTIPLY G AND RHS(-,N1) BY AL AND SUBTRACT
C     FROM AM AND RHS(-,N2) RESPECTIVELY
      CALL MPLYM (AL,G,SM,NT)
      CALL MPLYV (AL,RHS(1,N1),SV,NT)
      DO 40 I=1,NT
      DO 30 J=1,NT
   30 AM(I,J)=AM(I,J)-SM(I,J)
   40 RHS(I,N2)=RHS(I,N2)-SV(I)
C
C     INVERT AM
      L=0
      DO 50 N=1,NT
```

```
      DO 50 M=1,NT
      L=L+1
   50 SV(L)=AM(M,N)
      CALL MINV (SV,NT,DETRM,AM(1,1),AM(1,2))
      L=0
      DO 60 N=1,NT
      DO 60 M=1,NT
      L=L+1
   60 AM(M,N)=SV(L)
C
C     MULTIPLY RHS(-,N2) BY AM INVERSE
      CALL MPLYV (AM,RHS(1,N2),SV,NT)
      CALL EQUALV (RHS(1,N2),SV,NT)
C
C     MULTIPLY G BY RHS(-,N2) AND SUBSTRACT FROM RHS(-,N1)
      CALL MPLYV (G,RHS(1,N2),SV,NT)
      DO 70 I=1,NT
   70 RHS(I,N1)=RHS(I,N1)-SV(I)
C
C     THE X'S AND DELTA L'S
C  ARE CALCULATED BY BACK SUBSTITUTION
      DO 111 I=1,NT
      DO 111 K=1,NT
  111 RHS(I,N3)=RHS(I,N3)-AJ(I,K)*RHS(K,N2)
C
      DO 116 J=1,NC
      DO 116 I=1,NT
      DO 116 K=1,NT
      RHS(I,J)=RHS(I,J)-B(I,K,J)*RHS(K,N1)-C(I,K,J)*RHS(K,N2)
  116 CONTINUE
C
C
C
      RETURN
      END
```

APPENDIX II

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```
      PROGRAM ABSR2
C
C
C
      REAL      A(20)
      DATA      ZEND / '$$$$' /
C
      NTIME = 0
    2 READ (5,100,END=999) A
  100 FORMAT (20A4)
      WRITE (6,102) A
  102 FORMAT (1H1/12X,20A4)
      CALL INPUT (&8)
      CALL MATRIX (&8,&10)
    4 CALL OTPUT
      GO TO 10
C
    8 WRITE (6,104)
  104 FORMAT (/////10X 'PROBLEM FLUSHED'/10X 'PROCEEDING TO NEXT PROBLEM
     1'/////)
C
   10 READ (5,100,END=999) A(1)
      IF (A(1).EQ.ZEND) GO TO 2
      GO TO 10
C
  999 WRITE (6,106)
  106 FORMAT ('1')
      STOP
      END
```

```
      SUBROUTINE KGEN (T,E,M)
C
      COMMON    //          X(15,20),V(20),XL(20),U(20),W(20),
     1                      Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                      HF(20),PP(20),QG,DIST
      COMMON    /CONTRL/    NC, NT, LOOC, NIO, NTM1, KTOP,
     1                      N1,N2,N3,N3N3,NT20
      COMMON    /DATA1/     NK,EKTABL(8,15),TK(8),
     1                       PA, PK(8), KCODE
C
      REAL                  E(1)
      DOUBLE PRECISION      XX
C
    1 IF (NK.GT.2) GO TO 3
      J=1
      GO TO 9
    3 DO 6 L=2,NK
      IF (T.LT.TK(L)) GO TO 7
    6 CONTINUE
      L=NK
    7 J=L-1
    9 K=J+1
C
   10 XX=(1.0/(T+460.0)-1.0/(TK(J)+460.0)) /
     1    (1.0/(TK(K)+460.0)-1.0/(TK(J)+460.0))
      DO 14 I=1,NC
   14 E(I)=DEXP(EKTABL(J,I)+(EKTABL(K,I)-EKTABL(J,I))*XX)
C
      IF(KCODE.EQ.0) GO TO 41
   31 GO TO (41,32), KCODE
   32 PRATIO=PA/PP(M)
      DO 33 I=1,NC
   33 E(I)=E(I)*PRATIO
C
   41 RETURN
      END
```

```
      SUBROUTINE  HGEN  (T,ZV,ZL)
C
      COMMON   /CONTRL/  NC, NT, LOOC, NIO, NTM1, KTOP,
     1                   N1,N2,N3,N3N3,NT20
      COMMON   /DATA2/   NH,HLTABL(8,15),HVTABL(8,15),TH(8),PH(8)
C
      REAL               ZV(1), ZL(1)
C
      IF (NH.GT.2) GO TO 3
      J=1
      GO TO 8
    3 DO 6 L=2,NH
      IF (T.LT.TH(L)) GO TO 7
    6 CONTINUE
      L=NH
    7 J=L-1
    8 K=J+1
C
    9 XX=(T-TH(J))/(TH(K)-TH(J))
      DO 10 N=1,NC
      ZV(N)=HVTABL(J,N)+(HVTABL(K,N)-HVTABL(J,N))*XX
   10 ZL(N)=HLTABL(J,N)+(HLTABL(K,N)-HLTABL(J,N))*XX
C
      RETURN
      END
```

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```
      FUNCTION      EQUA  ( X, C )
C
C     THIS FUNCTION EVALUATES A SET OF POLYNOMINAL COEFFICIENTS BY
C     NESTED EXPANSION ---- AS GENERATED BY FUNCTION FITIT.
C
C          Y = AO + A1*X + A2*X**2 + ...... + AM*X**M
C
C               M = C(1)
C
C               AO = C(2)
C               A1 = C(3)
C               A2 = C(4)
C               .. . ....
C               .. . ....
C               AM = C(M+2)
C
      REAL      C(1)
C
      M = C(1)+0.1
      Y = C(M+2)
      MM = M+2
      DO  1  J=1,M
      MMJ=MM-J
      Y=Y*X+C(MMJ)
    1 CONTINUE
      EQUA = Y
      RETURN
      END
```

```
      FUNCTION FITIT ( X, Y, NO, MAX, C, LN, A )
C
C     WILL FIT POLYNOMIAL OF ORDER MAX ( MAX .LT. 7 ) TO NO Y VS. X DATA
C     POINTS SUPPLIED IN ARRAYS Y AND X. COEFFICIENTS RETURNED IN ARRAY
C     C IN FORM NEEDED BY FUNCTION EQUA. STANDARD DEVIATION OF Y RETURNE
C     D AS FITIT.
C
C     LN = LOG TRANSFORMATION CODE 1 = Y VS. X
C                                  2 = LN Y VS. X
C                                  3 = Y VS. LN X
C                                  4 = LN Y VS. LN X
C
C     A = INTERCEPT CODE ZERO = INTERCEPT = 0.0
C     NONZERO = INTERCEPT CALCULATED
C
      REAL X(1), Y(1), C(1), D(7), S(7), XY(7,7)
C
C     SET CONTROLS AND ZEROS AND XY.
C
      N = NO
      M = MIN0 ( MAX + 1, N, 7)
      L = MIN0 ( 4, MAX0 ( 1, LN ) )
      Z = N
      DO 10 I = 1, M
      S(I) = 0.0
      DO 10 J = I, M
   10 XY(I, J) = 0.0
C
C     FOR EACH DATUM, MOVE Y AND X TO D(1) AND D(2), GET LOGS IF NEEDED
C     AND POWERS OF X, AND ACCUMULATE SUMS, SQUARES, AND CROSS PRODUCTS
C     IN S AND XY.
C
      DO 80 K =1, N
      D(1) = Y(K)
      D(2) = X(K)
      GO TO ( 50, 20, 40, 30 ), L
   20 D(1) = ALOG ( D(1) )
      GO TO 50
   30 D(1) = ALOG ( D(1) )
   40 D(2) = ALOG ( D(2) )
   50 DO 60 I =3, M
   60 D(I) = D(2) * D(I - 1)
      DO 70 I = 1, M
      S(I) = S(I) + D(I)
      DO 70 J = I, M
   70 XY(I, J) = XY(I, J) + D(I) * D(J)
   80 CONTINUE
C
C     GET REDUCED SQUARES AND CROSS PRODUCTS IF A NONZERO AND FOLD XY
C     OVER.
```

```
      C
            IF ( A .EQ. 0.0 ) GO TO 110
            DO 100 I = 1, M
            Q = S(I) / Z
            DO 90 J = I, M
         90 XY(I, J) = XY(I, J) - Q * S(J)
        100 S(I) = Q
        110 DO 120 J = 1, M
            DO 120 I = J, M
        120 XY(I, J) = XY(J, I)
      C
      C     SOLVE REGRESSION MATRIX AND GET STANDARD DEVIATION OF Y.
      C
            DO 160 I = 2, M
            Q = XY(I, I)
            XY(I, I) = 1.0
            DO 130 J = 1, M
        130 XY(I, J) = XY(I, J) / Q
            DO 150 K = 1, M
            IF ( K .EQ. I ) GO TO 150
            Q = XY(K, I)
            XY(K, I) = 0.0
            DO 140 J = 1, M
        140 XY(K, J) = XY(K, J) - XY(I, J) * Q
        150 CONTINUE
        160 CONTINUE
            Q = MAX0 ( N - M, 1 )
            FITIT = SQRT ( AMAX1 ( XY (1, 1) / Q, 0.0 ) )
      C
      C     STORE COEFFICIENTS IN C ARRAY.
      C
            C(1) = M - 1
            C(2) = 0.0
            DO 170 I = 2, M
            S(1) = S(1) - S(I) * XY(I, 1)
        170 C(I + 1) = XY(I, 1)
            IF ( A .NE. 0.0 ) C(2) = S(1)
            RETURN
      C
            END
```

```
      FUNCTION WAYA(A,ANS,TOL,START,STOP,LEVEL)
C
C        ROUTINE TO CONVERGE ON SINGLE VALUED FUNCTION
C
C     A     =CURRENT VALUE OF DEPENDENT VARIABLE
C     ANS   =DESIRED VALUE OF DEPENDENT VARIABLE
C     TOL   =TOLERANCE
C     START=CURRENT VALUE OF INDEPENDENT VARIABLE. A BETTER VALUE RETURNED
C     STOP =LIMIT OF INDEPENDENT VARIABLE. ANSWER BETWEEN START AND STOP.
C     LEVEL= 1,2, OR 3 AS AN INDEX FOR MULTILEVEL USE.
C
C     WAYA WILL VARY START BETWEEN ITS INITIAL VALUE AND STOP UNTIL
C           ABS( ANS- A) .LE. TOL OR 30 TRIALS TAKEN.
C
C     ON EXIT WAYA IS:
C      - FOR NOT CONVERGED. REPEAT CALCULATION WITH NEW VALUE IN START.
C      0 FOR CONVERGED IN LIMITS OR 30 TRIALS TAKEN.
C      + FOR CANNOT CONVERGE. START WILL BE ITS INITIAL VALUE OR STOP,
C            WHICHEVER GIVES LESSER ERROR, OR ITS INITIAL VALUE IF LEVEL
C            IS NEGATIVE.
C
      DIMENSION X1(3),X2(3),Y1(3),Y2(3),KOUNT(3)
C
      DATA  KOUNT/ 3*0 /
C
C        SET X,Y & LEVEL
      X=START
      Y=ANS-A
      L=IABS(LEVEL)
      WAYA=1.0
C
C        SEE IF CONVERGED
C
      IF(ABS(Y).LE. TOL) GO TO 70
C
C        NOT CONVERGED. SEE WHICH CALL.
C
      IF(KOUNT(L)) 80,30,10
C
C        SECOND OR HIGHER CALL. SEE IF Y AND Y1(L) BRACKET ANSWER.
C
   10 IF(Y*Y1(L) .LT. 0.0) GO TO 20
C
C        NO Y-Y1 BRACKET. SEE IF SECOND OR HIGHER CALL.
C
      IF(KOUNT(L) .GT. 1) GO TO 30
C
C        NO BRACKET AT ALL. RE-DO AT START IF THAT LIMIT IS CLOSER OR IF
C        LEVEL IS MINUS
C
```

```
      IF(ABS(Y) .LE. ABS(Y1(L)) .AND. LEVEL .GT. 0) GO TO 80
      X=X1(L)
      KOUNT(L)= -1
      GO TO 60
C
C        Y-Y1 BRACKET. STORE X & Y IN X2(L) AND Y2(L)
C
   20 X2(L)=X
      Y2(L)=Y
      GO TO 40
C
C        FIRST CALL OR CONVERGING Y-Y2 BRACKET CALL.  STORE X & Y IN X1
C        & Y1.
C
   30 X1(L)=X
      Y1(L)=Y
      X=STOP
      IF(KOUNT(L).EQ. 0) GO TO 50
C
C        INTERPOLATE NEW X AND CONTINUE OR QUIT DEPENDING ON KOUNT(L).
C
   40 X=(X1(L)*(3.*Y2(L)-Y1(L))+X2(L)*(Y2(L)-3.*Y1(L)))/(4.*(Y2(L)-Y1(L)
     1))
      IF (KOUNT(L) .GE. 30) GO TO 70
   50 KOUNT(L)=KOUNT(L)+1
   60 WAYA=-1.0
      GO TO 90
C
C        CONVERGED OR TOO MANY TRIALS
C
   70 WAYA=0.0
   80 KOUNT(L)=0
C
C        SET NEW VALUE OF INDEPENDENT VARIABLE.
C
   90 START=X
      RETURN
C
      END
```

```
      SUBROUTINE MWRITE
C
      COMMON    //         X(15,20),V(20),XL(20),U(20),W(20),
     1                     Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                     HF(20),PP(20),QG,DIST
      COMMON    /CONTRL/   NC, NT, LOOC, NID, NTM1, KTOP,
     1                     N1,N2,N3,N3N3,NT20
      COMMON    /PROP/     CNAME(2,15),XMW(15),RHO(15)
      COMMON    /FIX/      SPACE(4845),AX(20)
C
      WRITE (6,101)(V(J),J=1,NT)
  101 FORMAT(//10X' CALCULATED VAPOR RATES'/4(9X,4F11.3/))
      WRITE (6,102) (XL(J),J=1,NT)
  102 FORMAT ( 11X,26HCORRESPONDING LIQUID RATES/4(9X,4F11.3/))
      WRITE (6,103) (TA(J),J=1,NT)
  103 FORMAT (10X' CALCULATED TEMPERATURES '     / 4(9X,4F11.3/))
C
C        NBL          NUMBER OF BLOCKS OF 4 OR PART THEREOF
C        NPP          NUMBER OF LINES ALREADY PRINTED
      KN=0
      KM=NT
      NBL=(NT+3)/4
      NPP=(7+3)+(NBL*3)+(NC+5)
C
    2 IF (KM.LE.4) GO TO 6
      KN=4+KN
      L=KN-3
      KM=KM-4
      KE=KN
      GO TO 10
    6 KN=KM+KN
      L=KN-KM+1
      KM=0
      KE=KN
   10 LE=L
      WRITE(6,1)
    1 FORMAT(//)
C
      WRITE(6,115) (J,J=LE,KE)
  115 FORMAT(10X' LIQUID COMPOSITIONS,MOL FRACTIONS' /10X' TRAY #'I10,
     +         9I11)
      DO 12 I=1,NC
   12 WRITE(6,116) (CNAME(K,I),K=1,2),(X(I,J),J=L,KN)
  116 FORMAT (12X,2A4,1X,4F11.8)
      DO 15 J=L,KN
      AX(J)=0.
      DO 15 I=1,NC
   15 AX(J)=AX(J)+X(I,J)
      WRITE (6,126) (AX(J),J=L,KN)
  126 FORMAT(10X'  TOTAL     ' 4F11.8/)
```

```
      IF (KM.LE.0) GO TO 31
      IF ( 57-NPP-NC-5 ) 22,22,23
   22 WRITE(6,154)
  154 FORMAT (1H1)
      NPP=0
   23 NPP=NPP+NC+5
      GO TO 2
C           PRINT REBOILER DUTY
C
C
   31 QNT=ABS(Q(NT))
      WRITE (6,220) QNT
  220 FORMAT(//11X,19HREBOILER DUTY, BTUS,      F16.1/)
      RETURN
      END
```

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```
      SUBROUTINE INPUT (*)
C
      COMMON   //        X(15,20),V(20),XL(20),U(20),W(20),
     1                   Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                   HF(20),PP(20),QG,DIST
      COMMON   /CONTRL/  NC, NT, LDOC, NIO, NTM1, KTOP,
     1                    N1,N2,N3,N3N3,NT20
     2                    ,KTYPE
      COMMON   /FIX/     EK(15,20),A(20),B(20),C(20),D(20),
     1                   AX(20),BX(20)
      COMMON   /SSDATA/  NSS,NSTRAY(5),XW(5),XU(5),QSS(5)
      COMMON   /FFDATA/  NF,NAMEF(3,6),NFTRAY(6),ZF(16,6),ZK(15,6),
     1                   QFN(6), TF(6), PF(6), QQQ(6), QEX(6), TTF(6)
      COMMON   /PROP/    CNAME(2,15),XMW(15),RHO(15)
      COMMON   /DATA1/   NK,EKTABL(8,15),TK(8),
     1                    PA, PK(8), KCODE
      COMMON   /DATA2/   NH,HLTABL(8,15),HVTABL(8,15),TH(8),PH(8)
      COMMON   /DATA3/   BXX(6),XXL(15,6)
C
C          KTOP    ---  DESIGN VARIABLE
C                  2    Q REBOILER
C                                    HEAT LOADS ARE IN  MMBTU/HR
C
C          LDOC   ---  PRINT CODE
C                 1    INPUT & OUTPUT
C                 2    1 + TRIAL DATA
C                 3    2 + ALL DATA
C                 4    3 + ERROR PRINT OUT
C
C     KTYPE ---- COLUMN TYPE
C                 1 -- SIMPLE ABSORPTION
C                 2 -- INTERCOOLERS/SIDESTREAMS
C                 3 -- STRIPPER
C                 4 -- REBOILED ABSORBER
C
      NOGO=0
      READ (5,101) NT,NC,NF,NSS,NK,NH,NIO,KTOP,LDOC,KTYPE
  101 FORMAT (10I5)
C
      READ(5,102) QR,DIST
  102 FORMAT(8F10.0)
      READ (5,102)TTOP, TBOT, DTRAY, TMID
      READ(5,102) PTOP, DPTWR
C
      NTM1=NT-1
C
      N1=NC+1
      N2=N1+1
      N3=N2+1
      N3N3=N3*N3
```

```
      NT20=NT*20
C
      PP(1)=PTOP
      DP=DPTWR/FLOAT(NTM1)
      DO 9 J=2,NT
    9 PP(J)=PP(J-1)+DP
C
      IF(NID.LE.0)NID=25
      IF (LDOC.LE.0 .OR. LDOC.GE.5) LDOC=2
C
      WRITE (6,105) NT,NC,NF,NSS,NK,NH,NID,KTOP,LDOC,KTYPE
  105 FORMAT (//12X,'NUMBER OF TRAYS' I20, /12X,'NUMBER OF COMPONENTS' I
     115,//12X,'NUMBER OF FEEDS' I20, /12X,'SIDESTREAM AND/OR HEAT TRAYS
     2' I7, //12X,'NUMBER OF K-DATA POINTS' I12, /12X'NUMBER OF H-DATA PO
     3OINTS' I12, //12X,'NUMBER OF ITERATIONS' I15,
     4//12X,'QR CODE' I28, //
     512X'DOCUMENTATION LEVEL' I16 ,//12X,'COLUMN TYPE' I24)
C
   14 DO 16 J=1,NT
      HF(J)=0.0
      U(J)=0.0
      W(J)=0.0
      Q(J)=0.0
      DO 15 I=1,NC
   15 X(I,J)=0.0
      DO 16 I=1,N1
   16 F(I,J)=0.0
C
C
      TA(1)=TTOP
      TA(NT)=TBOT
      NDTRAY = DTRAY
      IF (NDTRAY.EQ.0) GO TO 41
      NTMID=NDTRAY+1
      IF(NTMID.GE.NT)GOTO41
      DT=(TMID-TA(1))/FLOAT(NTMID-1)
      DO 31 J=2,NTMID
   31 TA(J)=TA(J-1)+DT
      DT=(TA(NT)-TMID)/FLOAT(NT-NTMID)
      NTMIDP=NTMID+1
      DO 32 J=NTMIDP,NTM1
   32 TA(J+1)=TA(J)+DT
      GOTO50
C
   41 DT=(TBOT-TTOP)/FLOAT(NTM1)
      DO 42 J=2,NTM1
   42 TA(J)=TA(J-1)+DT
C
   50 QG=QR*1.0E6
      IF (QR.EQ.0.0) GO TO 60
```

```
          WRITE (6,112) QR
      112 FORMAT (/12X,'REBOILER DUTY, MMBTU/HR' F20.6)
          Q(NT)=-QG
C
       60 IF (DIST.GT.0.0) GO TO 62
          WRITE (6,121)
      121 FORMAT (///30X,'INVALID DISTILLATE RATE'///)
          NOGO=1
C
       62 WRITE (6,122) DIST
      122 FORMAT (/12X,'OVERHEAD VAPOR PRODUCT, MOLS/HR' F10.3)
C
          WRITE (6,123) TTOP,TBOT
      123 FORMAT (/12X,'INPUT TEMPERATURES, DEG F' /
         117X 'TOP TRAY' F12.1 / 17X 'BOTTOM TRAY' F9.1 )
          IF (NDTRAY.EQ.0) GO TO 64
          WRITE (6,124) TMID,NDTRAY
      124 FORMAT (12X  'TEMPERATURE ESTIMATED AS' F8.1,2X'DEG F ON TRAY'I4)
C
       64 WRITE (6,125) PTOP, DPTWR, PP(1), PP(NT)
      125 FORMAT (/12X, 'INPUT PRESSURES, PSIA' / 17X'OVERHEAD'F18.4
         1/17X 'TOWER DELTA P' F13.4/ 17X 'TOWER TOP' F17.4
         2/17X 'TOWER BOTTOM' F14.4 )
C
C
C         READ GAS FEED IN FIRST
C         OIL FEED IN SECOND
C
C
          DO 68 J=1,NF
          READ (5,131) (NAMEF(I,J),I=1,3),NFTRAY(J),PF(J),TF(J),QFN(J),
         1                 QEX(J)
      131 FORMAT (3A4,I8,4F10.0)
          READ (5,102) (ZF(I,J),I=1,NC)
          IF(QFN(J).NE.0.0)GOTO68
          READ (5,102) (ZK(I,J),I=1,NC)
C
       68 CONTINUE
          IF(NSS.EQ.0)GOTO70
          DO 69 J=1,NSS
       69 READ (5,133) NSTRAY(J),XW(J),XU(J),QSS(J)
      133 FORMAT (I5,5X,3F10.0)
C
       70 CALL CDATA
          CALL ZFEED (SUMFD)
C
          IF(NSS.EQ.0)GOTO80
          WRITE(6,4)
    4     FORMAT(///////)
          WRITE(6,141)
```

```
 141  FORMAT(1H1 12X 'SIDESTREAM AND HEAT TRAY DATA'// 17X 'TRAY NO'7X'V
     1APOR MOLS/HR' 7X 'LIQUID MOLS/HR' 7X 'HEAT OUT MMBTU/HR')
      DO 79 N=1,NSS
  79  WRITE (6,142) N,NSTRAY(N),XW(N),XU(N),QSS(N)
 142  FORMAT (10X,I4,2X,I5,9X,F12.2,9X,F12.2,9X,F15.6)
C
C     Q IS HEAT OUT FROM STAGE (+)
  80  SUM=DIST
      IF(NSS.EQ.0)GOTO90
      DO 81 J=1,NSS
      K=NSTRAY(J)
      U(K)=XU(J)
      W(K)=XW(J)
      Q(K)=QSS(J)*1.0E6
  81  SUM=SUM+U(K)+W(K)
C
  90  IF(SUMFD-SUM .GT. 0.0)GOTO92
      WRITE (6,145)
 145  FORMAT (///30X 'BOTTOMS RATE IS INVALID')
      NOGO=1
C
  92  V(1)=DIST
      V(NT)=0.8*(SUMFD-DIST)
      XL(1)=0.9*F(N1,1)
      XL(NT)=SUMFD-SUM
      IF (NOGO.NE.0) RETURN 1
C
      DV=(V(NT)-V(1))/FLOAT(NTM1)
      DL=(XL(NT)-XL(1))/FLOAT(NTM1)
      DO 93 J=2,NTM1
      V(J)=V(J-1)+DV
  93  XL(J)=XL(J-1)+DL
      DO 94 J=1,NT
  94  CALL KGEN (TA(J),EK(1,J),J)
C
C
      IF (KTYPE.GT.2) GO TO 190
C
C           W = VAPOR     U = LIQUID
      DO 99 I=1,NC
      A(1)=0.0
      B(1)=V(1)*(1.0-EK(I,1))-V(2)-F(N1,1)
      C(1)=V(2)*EK(I,2)
      D(1)=-F(I,1)
      SUMJM1=F(N1,1)-DIST
      SUMJ=F(N1,2)-W(2)-U(2)+F(N1,1)-DIST
      DO 95 J=2,NTM1
      A(J)=V(J)+SUMJM1
      B(J)=-((V(J)+W(J))*EK(I,J)+V(J+1)+SUMJ+U(J))
      C(J)=V(J+1)*EK(I,J+1)
```

```
      D(J)=-F(I,J)
      SUMJM1=SUMJM1+F(N1,J)-W(J)-U(J)
   95 SUMJ=SUMJ+F(N1,J+1)-W(J+1)-U(J+1)
      A(NT)=V(NT)+XL(NT)-F(N1,NT)
      B(NT)=-V(NT)*EK(I,NT)-XL(NT)
      C(NT)=0.0
      D(NT)=-F(N1,NT)
      AX(1)=C(1)/B(1)
      BX(1)=D(1)/B(1)
      DO 96 J=2,NTM1
   96 AX(J)=C(J)/(B(J)-A(J)*AX(J-1))
      DO 97 J=2,NT
   97 BX(J)=(D(J)-A(J)*BX(J-1))/(B(J)-A(J)*AX(J-1))
      X(I,NT)=BX(NT)
      IF( X(I,NT) .LE. 0.0 ) X(I,NT)= 1.0E-25
      DO 98 K=1,NTM1
      J=NT-K
      X(I,J)=BX(J)-AX(J)*X(I,J+1)
      IF ( X(I,J) .LE. 0.0 ) X(I,J) = 1.0E-25
   98 CONTINUE
   99 CONTINUE
C
C
      GO TO 800
C
  190 AC=0.0
      ANTM1=NTM1
      ANC=NC
      ANT=0.0
      IF (KTYPE.EQ.3) GO TO 300
      DO 200 I=1,NC
      DO 200 J=2,NTM1
      X(I,1)=ZF(I,2)/ZF(N1,2)
      AC=AC+(1./ANC)/2.
      X(I,NT)=X(I,1)+(ZF(I,1)/ZF(N1,1))*AC
      ANT=ANT+(1./ANTM1)/2.
  200 X(I,J)=X(I,1)+ANT*(X(I,NT)-X(I,1))
      XL(1)=ZF(N1,2)
      XL(NT)=ZF(N1,2)+.3*ZF(N1,1)
      ANT=0.0
      DO 210 J=2,NTM1
      ANT=ANT+1./ANTM1
  210 XL(J)=XL(1)+ANT*(XL(NT)-XL(1))
      DO 220 J=2,NT
  220 V(J)=XL(J)+V(1)-XL(1)+W(J)+U(J)
C
      GO TO 800
C
  300 NCM1=NC-1
      DO 310 I=1,NCM1
```

```
      DO 310 J=1,NT
  310 X(I,J)=XXL(I,2)/BXX(2)
      DO 320 J=1,NT
  320 X(NC,J)=0.0
      XL(1)=BXX(2)
      XL(NT)=.8*BXX(2)
      ANT=0.0
      DO 330 J=2,NTM1
      ANT=ANT+(1./ANTM1)/2.
  330 XL(J)=XL(1)+ANT*(XL(NT)-XL(1))
      DO 340 J=2,NT
  340 V(J)=XL(J)+V(1)-XL(1)+W(J)+U(J)
C
  800 CONTINUE
C
C
      RETURN
      END
```

100

```
      SUBROUTINE  CDATA
C
      COMMON    //        X(15,20),V(20),XL(20),U(20),W(20),
     1                    Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                    HF(20),PP(20),QG,DIST
      COMMON    /CONTRL/  NC, NT, LOOC, NIO, NTM1, KTOP,
     1                    N1,N2,N3,N3N3,NT20
      COMMON    /PROP/    CNAME(2,15),XMW(15),RHO(15)
      COMMON    /DATA1/   NK,EKTABL(8,15),TK(8),
     1                     PA, PK(8), KCODE
      COMMON    /DATA2/   NH,HLTABL(8,15),HVTABL(8,15),TH(8),PH(8)
      COMMON    /COEF/    CK(8,15),DCK(7,15),CHV(6,15),
     1                    DCHV(5,15),CHL(6,15),DCHL(5,15),
     2                     PPA,MCODE
C
      REAL                T(20),AK(20,20),AHV(20,20),AHL(20,20)
      EQUIVALENCE         (AK(1,1),AHV(1,1))
C
      WRITE (6,100)
  100 FORMAT (1H1)
C
      READ (5,101) ((CNAME(K,J),K=1,2),XMW(J),RHO(J),J=1,NC)
  101 FORMAT (2A4,2X,2F10.0)
      WRITE (6,102)
  102 FORMAT (12X,'DATA ON COMPONENTS'// 18X,'NAME',17X, 'MOL WT', 8X,
     1 'LBS/GAL' /)
      WRITE (6,103) (J,(CNAME(K,J),K=1,2),XMW(J),RHO(J),J=1,NC)
  103 FORMAT (10X,I6,2X,2A4,F18.3,F15.4)
C
   21 READ (5,115) (TK(J),J=1,NK)
  115 FORMAT (8F10.0)
      READ (5,115) (PK(J),J=1,NK)
      READ (5,115) ((EKTABL(K,J),K=1,8),J=1,NC)
C
      WRITE (6,100)
C
   41 WRITE (6,122) (TK(J),J=1,NK)
  122 FORMAT (//12X 'MAIN COLUMN K-TABLE' //14X,'TEMPERATURE, F '8F14.2)
      WRITE (6,123) (PK(J),J=1,NK)
  123 FORMAT ( 14X 'PRESSURE, PSIA ' 8F14.4)
      WRITE (6,125)
  125 FORMAT (/)
      DO 43 J=1,NC
   43 WRITE (6,124) (CNAME(K,J),K=1,2),(EKTABL(K,J),K=1,NK)
  124 FORMAT (15X,2A4,6X,8F14.5)
C
      DO 45 J=1,NC
      DO 45 K=1,NK
   45 EKTABL(K,J)=ALOG(EKTABL(K,J))
C
```

```
C           KCODE   ---   PRESSURE CORRECT K-DATA
C             1          K-DATA ALREADY CORRECTED
C             2          PRESSURE CORRECT K-DATA
C
      PA=PK(1)
   48 KCODE=1
      NKM1=NK-1
      DO 49 J=1,NKM1
      IF (ABS(PK(J)-PK(J+1)).GT.0.001) GO TO 50
   49 CONTINUE
      KCODE = 2
      WRITE (6,126)
  126 FORMAT(//12X, 'K-DATA WILL BE PRESSURE CORRECTED TO THE TRAY PRESS
     1URE'/12X,' USING THE K-DATA REFERENCE PRESSURE AS THE DATUM')
C
   50 WRITE (6,100)
C
      READ (5,127) JCODE,(TH(J),J=1,NH)
  127 FORMAT (I1,F9.0,7F10.0)
C
C          JCODE --- UNITS OF ENTHALPY DATA
C             1   BTU/MOLE
C             2   BTU/LB
C
      READ (5,115) (PH(K),K=1,NH)
      READ (5,115) ((HVTABL(K,J),K=1,8),(HLTABL(K,J),K=1,8),J=1,NC)
      GO TO (55,51),JCODE
   51 DO 52 J=1,NC
      DO 52 K=1,NH
      HVTABL(K,J)=HVTABL(K,J)*XMW(J)
   52 HLTABL(K,J)=HLTABL(K,J)*XMW(J)
C
   55 WRITE (6,128) (TH(J),J=1,NH)
  128 FORMAT (//12X 'ENTHALPY TABLE'// 14X 'TEMPERATURE, F '8F14.2)
      WRITE (6,129) (PH(J),J=1,NH)
  129 FORMAT (14X 'PRESSURE, PSIA ' 8F14.4)
      WRITE (6,130)
  130 FORMAT (10X,' VAPOR, BTU/MOLE')
      DO 56 J=1,NC
   56 WRITE (6,131) (CNAME(K,J),K=1,2),(HVTABL(K,J),K=1,NH)
  131 FORMAT (15X,2A4,6X,8F14.1)
      WRITE (6,133)
  133 FORMAT (10X' LIQUID, BTU/MOLE')
      DO 57 J=1,NC
   57 WRITE (6,131) (CNAME(K,J),K=1,2),(HLTABL(K,J),K=1,NH)
C
      PPA=PA
      MCODE=KCODE
      KCODE=0
      DT=AMAX1((TA(NT)-T(1))/2.0,50.)
```

```
      T(1)=TA(1)-DT
      T(20)=TA(NT)+DT
      DT=(T(20)-T(1))/19.
      DO 62 J=2,19
   62 T(J)=T(J-1)+DT
      DO 63 K=1,20
   63 CALL KGEN(T(K),AK(1,K),K)
      DO 65 J=2,20
      JM1=J-1
      DO 65 K=1,JM1
      HOLD=AK(J,K)
      AK(J,K)=AK(K,J)
   65 AK(K,J)=HOLD
      NPWR=4
      DO 66 J=1,NC
      HOLD=1.0
   66 HOLD=FITIT(T,AK(1,J),20,NPWR,CK(1,J),1,HOLD)
      KCODE=MCODE
      NPWRM1=NPWR-1
      DO 67 J=1,NC
      DCK(1,J)=CK(1,J)-1.0
      DO 67 K=2,NPWRM1
   67 DCK(K,J)=CK(K+1,J)*FLOAT(K-1)
      DO 68 K=1,20
   68 CALL HGEN(T(K),AHV(1,K),AHL(1,K))
      DO 71 J=2,20
      JM1=J-1
      DO 71 K=1,JM1
      HOLD=AHV(J,K)
      AHV(J,K)=AHV(K,J)
      AHV(K,J)=HOLD
      HOLD=AHL(J,K)
      AHL(J,K)=AHL(K,J)
   71 AHL(K,J)=HOLD
      NPWR=3
      DO 73 J=1,NC
      HOLD=1.0
      HOLD=FITIT(T,AHV(1,J),20,NPWR,CHV(1,J),1,HOLD)
      HOLD=1.0
   73 HOLD=FITIT(T,AHL(1,J),20,NPWR,CHL(1,J),1,HOLD)
      NPWRM1=NPWR-1
      DO 75 J=1,NC
      DCHV(1,J)=CHV(1,J)-1.0
      DCHL(1,J)=CHL(1,J)-1.0
      DO 75 K=2,NPWRM1
      DCHV(K,J)=CHV(K+1,J)*FLOAT(K-1)
   75 DCHL(K,J)=CHL(K+1,J)*FLOAT(K-1)
C
      RETURN
      END
```

```
      SUBROUTINE  ZFEED  ( SUMT )
C
      COMMON    //        X(15,20),V(20),XL(20),U(20),W(20),
     1                    Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                    HF(20),PP(20),QG,DIST
      COMMON    /CONTRL/  NC, NT, LDOC, NID, NTM1, KTOP,
     1                    N1,N2,N3,N3N3,NT20
      COMMON    /PROP/    CNAME(2,15),XMW(15),RHO(15)
      COMMON    /FFDATA/  NF,NAMEF(3,6),NFTRAY(6),ZF(16,6),ZK(15,6),
     1                    QFN(6), TF(6), PF(6), QQQ(6), QFX(6), TTF(6)
      COMMON    /DATA3/   BXX(6),XXL(15,6)
C
      REAL                QFG(6), QFC(6), AX(6), BX(6), QV(6), QL(6),
     1                    XLL(15),VV(15),YK(15)
C
      WRITE (6,100)
  100 FORMAT (1H1)
C
      WRITE (6,111) (J,J=1,NF)
  111 FORMAT (//15X,15HINPUT FEED DATA/17X,7HFEED NO,14X,6I14)
      WRITE (6,112) ((NAMEF(I,J),I=1,3),J=1,NF)
  112 FORMAT (17X,9HFEED NAME,21X,6(3A4,2X))
      WRITE (6,116) (NFTRAY(J),J=1,NF)
  116 FORMAT (17X,19HENTERING AT TRAY NO,2X,6I14/)
C
      DO 10 N=1,NF
      ZF(N1,N)=0.0
      DO 10 I=1,NC
   10 ZF(N1,N)=ZF(N1,N)+ZF(I,N)
C
      WRITE (6,117)
  117 FORMAT (17X,19HCOMPOSITION,MOLS/HR)
C
C
C    STEAM MUST BE LAST COMPONENT GIVEN
C
C
      DO 19 I=1,NC
   19 WRITE (6,120) (CNAME(K,I),K=1,2),(ZF(I,K),K=1,NF)
  120 FORMAT (18X,2A4,14X,6F14.2)
      WRITE (6,121) (ZF(N1,N),N=1,NF)
  121 FORMAT (17X,5HTOTAL,18X,6F14.2)
C
C          FEED HEAT CONTENT NOT GIVEN IF QFN = 0.0
C
      SUMT=0.0
      DO 40 N=1,NF
      IF (QFN(N).NE.0.0) GO TO 21
C
C            FEED ENTHALPY IS NOT GIVEN AND MUST BE CALCULATED.
```

```
C
      CALL FLASH (ZF(1,N),ZK(1,N),TF(N),VV,XLL,QV(N),QL(N),QFN(N))
C
      QFG(N)=0.
      QFC(N)=QFN(N)
      GO TO 22
C
   21 QFN(N)=QFN(N)*1.0E6
      QFG(N)=QFN(N)
      QFC(N)=0.
C
C            ADIABATIC FLASH ON FEEDS TO DETERMINE VAPORIZATION AT ENTRY
C
   22 K=NFTRAY(N)
      QEX(N)=QEX(N)*1.0E6
      QQQ(N)=QFN(N)+QEX(N)
C
C              QQQ(N) IS TOTAL FEED ENTHALPY AT ENTRY TO TOWER.
C
      TTT=TA(1)-100.
      TBIG=TA(NT)+100.
      TOL=QQQ(N)*1.0E-4
C
   23  CALL KGEN (TTT,YK,K)
       CALL FLASH (ZF(1,N),YK,TTT,VV,XLL,QV(N),QL(N),QQ)
C      WRITE (6,200) QQ,QQQ(N),TOL,TTT
C 200  FORMAT (10X,4E25.7)
C
       IF ( WAYA(QQ,QQQ(N),TOL,TTT,TBIG,2) ) 23,27,26
C
   26 WRITE (6,122) N
  122 FORMAT (// 15X 'FEED FLASH FAILED TO CONVERGE FOR FEED #' I3 //)
C
   27 QV(N)=QV(N)/QQQ(N)*QQ
      QL(N)=QL(N)/QQQ(N)*QQ
   28 TTF(N)=TTT
      AX(N)=0.0
      BX(N)=0.0
      DO 29 I=1,NC
      XXL(I,N)=XLL(I)
      AX(N)=AX(N)+VV(I)
   29 BX(N)=BX(N)+XLL(I)
      BXX(N)=BX(N)
C
      IF (K-2) 34,38,32
   32 IF (K-NTM1) 38,38,34
   34 AXBX=ZF(N1,N)
      QFK=F(N1,K)*HF(K)
      DO 37 I=1,NC
   37 F(I,K)=F(I,K)+ ZF(I,N)
```

```
      F(N1,K)=F(N1,K)+AXBX
      IF(F(N1,K).NE.0.0) HF(K)=(QFK+QQ)/F(N1,K)
      GO TO 40
C
   38 QFKM1=F(N1,K-1)*HF(K-1)
      QFK=F(N1,K)*HF(K)
      DO 39 I=1,NC
      F(I,K-1)=F(I,K-1)+VV(I)
   39 F(I,K)=F(I,K)+XLL(I)
      F(N1,K-1)=F(N1,K-1)+AX(N)
      F(N1,K)=F(N1,K)+BX(N)
      IF (F(N1,K-1).NE.0.0) HF(K-1)=(QFKM1+QV(N))/F(N1,K-1)
      IF (F(N1,K).NE.0.0) HF(K)=(QFK+QL(N))/F(N1,K)
   40 SUMT=SUMT+ZF(N1,N)
C
C
      WRITE (6,123)(TF(N),N=1,NF)
  123 FORMAT (/17X 'TEMPERATURE, F' 9X 6F14.1)
      WRITE (6,124)(PF(N),N=1,NF)
  124 FORMAT (17X 'PRESSURE, PSIA'  9X 6F14.4)
      WRITE (6,125)(QFC(N),N=1,NF)
  125 FORMAT (/17X 'HEAT CONTENT, BTUS (CALC)' F12.0,5F14.0)
      WRITE (6,126) (QFG(N),N=1,NF)
  126 FORMAT ( 17X 'HEAT CONTENT, BTUS (GIVEN)' F11.0,5F14.0)
      WRITE (6,127) (QEX(N),N=1,NF)
  127 FORMAT (/17X 'ADDITIONAL HEAT, BTUS' 2X 6F14.0)
      WRITE (6,128) (QQQ(N),N=1,NF)
  128 FORMAT (/17X 'HEAT CONTENT, BTUS (INLET)' F11.0,5F14.0)
      WRITE (6,129) (TTF(N),N=1,NF)
  129 FORMAT (17X 'TEMPERATURE, F (INLET)' 1X 6F14.2)
      WRITE (6,130) (AX(N),N=1,NF)
  130 FORMAT (/17X 'VAPOR, MOLS (INLET)' 4X 6F14.3)
      WRITE (6,131) (BX(N),N=1,NF)
  131 FORMAT (17X 'LIQUID, MOLS (INLET)' 3X 6F14.3)
C
      RETURN
      END
```

```
      SUBROUTINE   FLASH  (XX,ZK,TT,XV,XL,QV,QL,QQT)
C
      COMMON   /CONTRL/  NC, NT, LDOC, NID, NTM1, KTOP,
     1                   N1,N2,N3,N3N3,NT20
C
      REAL               XX(1),ZK(1),XV(1),XL(1),HVAP(15),HLIQ(15)
C
C           SUM         TOTAL FEED
C           SUMX        TOTAL LIQUID
C           SUMY        TOTAL VAPOR
C
      SUM=0.0
      SUMX=0.
      SUMY=0.
      DO 1 I=1,NC
      IF(XX(I).EQ.0.0)GOTO1
      SUM=SUM+XX(I)
      SUMY=SUMY+XX(I)*ZK(I)
      SUMX=SUMX+XX(I)/ZK(I)
    1 CONTINUE
C     WRITE (6,310) SUMX,SUMY,SUM
C 310 FORMAT('1' /3E25.7)
      IF (SUM -SUMY)4,2,2
C
C     SUBCOOLED LIQUID
C
    2 DO 3 I=1,NC
      XL(I)=XX(I)
    3 XV(I)=0.
      SUMX=SUM
      SUMY=0.0
C     WRITE (6,300)
C 300 FORMAT (////' SUBCOOLED LIQUID')
C     WRITE (6,20) (XX(J),ZK(J),XV(J),XL(J),J=1,NC)
C 20  FORMAT (4E20.6)
      GO TO 30
    4 IF (SUM -SUMX)7,5,5
C
C     SUPERHEATED VAPOR
C
    5 DO 6 I=1,NC
      XV(I)=XX(I)
    6 XL(I)=0.
      SUMY=SUM
      SUMX=0.0
C     WRITE (6,301)
C 301 FORMAT (////' SUPERHEATED VAPOR')
C     WRITE (6,20) (XX(J),ZK(J),XV(J),XL(J),J=1,NC)
       GO TO 30
C
```

```
C      TWO-PHASE SYSTEM
C
     7 XLF=0.9999999
       XLF$=0.0000001
C
     8 XVF=1.0-XLF
       SUMY=SUM*XVF
       SUMX=SUM*XLF
       YTOT=0.0
       XTOT=0.0
       DO 9 I=1,NC
       FAC=XLF+XVF*ZK(I)
       XV(I)=XX(I)/SUM *ZK(I)/FAC
       YTOT=YTOT+XV(I)
       XL(I)=XX(I)/SUM /FAC
     9 XTOT=XTOT+XL(I)
C
C   13 WRITE (6,200)
C  200 FORMAT (////' MIXED PHASE')
C      WRITE (6,410) SUMX,SUMY,SUM ,YTOT,XTOT
C  410 FORMAT (5E25.7)
C      WRITE (6,20) (XX(J),ZK(J),XV(J),XL(J),J=1,NC)
       IF ( WAYA (    (YTOT-XTOT),0.0,0.000005,XLF,XLF$,1) ) 8,22,18
C
    18 WRITE (6,100)
   100 FORMAT (//5X 'FEED FLASH CALCULATION FAILED TO CONVERGE'
      + /5X 'LIQUID FRACTION EITHER > 0.999999 OR < 0.000001' / 5X 'CALCU
      2LATION CONTINUING' //)
C
    22 DO 24 I=1,NC
       XL(I)=XL(I)*SUMX
    24 XV(I)=XV(I)*SUMY
C
    30 QV=0.0
       QL=0.0
       CALL HGEN (TT,HVAP,HLIQ)
       DO 32 I=1,NC
       QV=QV+HVAP(I)*XV(I)
    32 QL=QL+HLIQ(I)*XL(I)
       QQT=QV+QL
C
       RETURN
       END
```

```
      SUBROUTINE MPLYM (A,B,C,N)
C
C     MATRIX MULTIPLICATION
C     A*B=C
C     N=ACTUAL SIZE OF MATRIX
C
      REAL             A(20,20),B(20,20),C(20,20)
C
      M=N
    5 DO 10 J=1,M
      DO 20 I=1,N
      C(I,J)=0.0
      DO 30 K=1,N
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
   30 CONTINUE
   20 CONTINUE
   10 CONTINUE
C
      RETURN
C
      ENTRY MPLYV (A,B,C,N)
      M=1
      GO TO 5
C
      END
```

```
      SUBROUTINE ZERO(A,K)
      REAL A(1)
      DO 10 J=1,K
   10 A(J)=0.0
      RETURN
      END
```

```
      SUBROUTINE EQUAL (A,B,M)
C
C    MATRIX A = MATRIX B, WHERE MATRIX B IS GIVEN
      REAL          A(20,1),B(20,1)
C
      N=M
    5 DO 10 J=1,N
      DO 10 I=1,M
   10 A(I,J)=B(I,J)
      RETURN
C
      ENTRY EQUALV (A,B,M)
      N=1
      GO TO 5
C
      END
```

111

```
          SUBROUTINE MATRIX (*,*)
C
          COMMON     //          X(15,20),V(20),XL(20),U(20),W(20),
         1                       Q(20),HL(20),HV(20),TA(20),F(16,20),
         2                       HF(20),PP(20),QG,DIST
          COMMON     /CONTRL/    NC,NT,LDOC,NIO,NTM1,KTOP,
         1                       N1,N2,N3,N3N3,NT20
          COMMON     /DATA/      WK(15,20),DK(15,20),HVV(15,20),
         1                       HLL(15,20),DHV(15,20),DHL(15,20),
         2                       Y(15,20)
          COMMON     /FIX/       A(20,20),B(20,20,15),C(20,20,15),
         1                       E(20,20),AF(20,20),
         2                       AJ(20,20),RHS(20,18),
         3                       G(20,20),AL(20,20),AM(20,20)
C
          REAL                    CXL(20),CTA(20),CV(20)
C
          DATA                    DVMAX/0.001/,DLMAX/0.001/,DTMAX/0.05/
C
C
          WRITE (6,2)
          CALL MWRITE
    2     FORMAT (1H1)
  4       FORMAT(/)
          NDONE=0
          DO 399 NIT=1,NIO
C
          DO 10 I=1,NT
          SUM=0.0
          DO 11 J=1,NC
   11     SUM=SUM+X(J,I)
          DO 12 J=1,NC
   12     X(J,I)=X(J,I)/SUM
   10     CONTINUE
          CALL GET
C
          CALL INI
          CALL ENTHAL
          CALL COMP
          CALL SUBST
          GO TO (501,501,501,502),LDOC
  502     CONTINUE
C
C      THE ERRORS ON EACH STAGE ARE PRINTED
          WRITE(6,2)
          WRITE(6,4)
C
          DO 80 I=1,NT
   80     WRITE(6,402) I,RHS(I,N3),RHS(I,N2),RHS(I,N1)
  402     FORMAT(//10X' UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE'
```

```
         1 I5//10X(1P3E18.5))
C
C    CALCULATE CORRECTIONS FOR EACH STAGE
C
          DO 135 I=1,NT
          CTA(I)=TA(I)+RHS(I,N1)
          CXL(I)=XL(I)+RHS(I,N3)
          CV(I)=V(I)+RHS(I,N2)
  135     CONTINUE
          IF(LDOC.GT.2) WRITE(6,2)
C
C    PRINT CORRECTIONS FOR EACH STAGE
C
          WRITE(6,4)
          DO 136 I=1,NT
  136     WRITE(6,403) I,CXL(I),CV(I),CTA(I)
  403     FORMAT(//10X' CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE'
         1 I5//10X(1P3E18.5))
C
  501     CONTINUE
C
C    CHECK FOR CONVERGENCE
C         (1)  MAXIMUM ABS(DV).LT.DVMAX   V= VAPOR FLOW
C         (2)  MAXIMUM ABS(DL).LT.DLMAX   L= LIQUID FLOW
C         (3)  MAXIMUM ABS(DT).LT.DTMAX   T= TEMPERATURE
C    SCALE CORRECTIONS IF TOO LARGE ----CAUSE FOR SCALING
C         (1)  DV.GT.0.20*V
C         (2)  DL.GT.0.20*L
C         (3)  DT.GT.20.0
C
          DV=0.0
          DL=0.0
          DT=0.0
          SUMSQ=0.0
C
          DO 145 M=1,NT
          SUMSQ=SUMSQ+RHS(M,N1)**2
          DV=AMAX1(ABS(RHS(M,N2))/V(M),DV)
          DL=AMAX1(ABS(RHS(M,N3))/XL(M),DL)
  145     DT=AMAX1(ABS(RHS(M,N1)),DT)
C
          IF(DV.LT.DVMAX.AND.DL.LT.DLMAX.AND.DT.LT.DTMAX) NDONE=1
C
  505     DO 150 I=1,NT
          DO 150 J=1,NC
          CX=RHS(I,J)-X(J,I)
          IF(RHS(I,J).LT.1.0E-6) GO TO 506
          IF(RHS(I,J).LE.0.0.OR.RHS(I,J).GE.1.0) GO TO 509
          GO TO 150
  506     IF(RHS(I,J).LE.0.0) RHS(I,J)=X(J,I)/2.0
```

```
150   CONTINUE
      GO TO 507
509   NDONE=0
      DO 155 I=1,NT
      DO 155 J=1,NC
      CX=RHS(I,J)-X(J,I)
      RHS(I,J)=X(J,I)+SIGN(CX/2.,CX)
155   CONTINUE
      GO TO 505
C
507   DO 158 I=1,NT
      IF(ABS(RHS(I,N3)).GT.0.20*XL(I).OR.ABS(RHS(I,N2)).
     1GT.0.20*V(I)) GO TO 508
158   CONTINUE
      GO TO 510
508   NDONE=0
      DO 160 I=1,NT
      RHS(I,N3)=RHS(I,N3)*.5
      RHS(I,N2)=RHS(I,N2)*.5
160   CONTINUE
      GO TO 507
C
510   DO 165 I=1,NT
      IF(ABS(RHS(I,N1)).GT.20.0) GO TO 511
165   CONTINUE
      GO TO 512
511   NDONE=0
C
      DO 168 I=1,NT
      RHS(I,N1)=RHS(I,N1)*.5
168   CONTINUE
      GO TO 510
512   DO 170 I=1,NT
      DO 171 J=1,NC
171   X(J,I)=RHS(I,J)
      XL(I)=XL(I)+RHS(I,N3)
      V(I)=V(I)+RHS(I,N2)
      TA(I)=TA(I)+RHS(I,N1)
170   CONTINUE
C
      IF(LDOC.EQ.1) GO TO 513
      IF(LDOC.GT.2) WRITE(6,2)
      WRITE (6,404) NIT,SUMSQ,DT,DV,DL
      WRITE(6,4)
404   FORMAT(//10X' ITERATION NUMBER' I5//
     112X' SUM DT SQUARED' F20.6/
     212X' DT MAX' F28.6/12X' MAX DV/V'F26.6/
     312X' MAX DL/L'F26.6)
      IF(LDOC.EQ.2.AND.MOD(NIT,15).EQ.0) WRITE(6,2)
C
```

```
      GO TO (513,513,514,514), LDOC
  514 CALL MWRITE
  513 IF(NDONE.NE.0) GO TO 515
C
  399 CONTINUE
C
      GO TO 515
C
  515 IF(NDONE.NE.0) GO TO 516
      WRITE (6,405)
405   FORMAT(///20X' NO CLOSURE OBTAINED ON PROBLEM'/
     120X' FOR SPECIFIED NUMBER OF TRIALS'///)
      WRITE (6,2)
      CALL MWRITE
      RETURN 2
C
  516 GO TO (600,600,700,700), LDOC
  600 WRITE (6,2)
      CALL MWRITE
C
  700 RETURN
      END
```

```
      SUBROUTINE INI
C
      COMMON    //        X(15,20),V(20),XL(20),U(20),W(20),
     1                    Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                    HF(20),PP(20),QG,DIST
      COMMON    /CONTRL/   NC,NT,LOOC,NIO,NTM1,KTOP,
     1                    N1,N2,N3,N3N3,NT20
      COMMON    /DATA/    WK(15,20),DK(15,20),HVV(15,20),
     1                    HLL(15,20),DHV(15,20),DHL(15,20),
     2                    Y(15,20)
      COMMON    /FIX/     A(20,20),B(20,20,15),C(20,20,15),
     1                    E(20,20),AF(20,20),
     2                    AJ(20,20),RHS(20,18),
     3                    G(20,20),AL(20,20),AM(20,20)
      REAL                SM(20,20),SV(400),
     +                     AK(20,20),D(20,20)
C
      EQUIVALENCE        (SM(1,1),SV(1)),
     +                     (A(1,1),AK(1,1),D(1,1))
C
C    DEVELOP OVERALL MATERIAL BALANCE ENTRIES ----- BLOCK N3
C
C    AJ MATRIX IS SET EQUAL TO ZERO AND THEN THE
C    NON-ZERO TERMS ARE COMPUTED
C
      CALL ZERO(RHS,360)
      CALL ZERO (AJ,NT20)
C
      DO 10 I=1,NTM1
      AJ(I,I)=-1.
      AJ(I,I+1)=1.
   10 CONTINUE
      AJ(NT,NT)=-1.
C
C    AK MATRIX IS SET EQUAL TO ZERO AND THEN THE
C    NON-ZERO TERMS ARE COMPUTED
      CALL ZERO (AK,NT20)
      AK(1,1)=-1.
      DO 20 I=2,NT
      AK(I,I-1)=1.
      AK(I,I)=-1.
   20 CONTINUE
C
C    THE RIGHT HAND SIDE OF THE MATERIAL BALANCE IS DEVELOPED
C
      RHS(1,N3)=XL(1)+U(1)+V(1)+W(1)-F(NC+1,1)-V(2)
      DO 30 I=2,NTM1
      RHS(I,N3)=XL(I)+U(I)+V(I)+W(I)-F(NC+1,I)-XL(I-1)-V(I+1)
   30 CONTINUE
      RHS(NT,N3)=XL(NT)+U(NT)+V(NT)+W(NT)-F(NC+1,NT)-XL(NTM1)
```

```
      C
      C   GENERATE RHS OF SUM EQUATION
            DO 31 I=1,NT
            RHS(I,N2)=1.
         31 CONTINUE
      C
      C   INVERT AK
            L=0
            DO 34 N=1,NT
            DO 33 M=1,NT
            L=L+1
            SV(L)=AK(M,N)
         33 CONTINUE
         34 CONTINUE
      C
      C   MATRIX AK IS INVERTED
      C
            CALL MINV(SV,NT,DETRM,AK(1,1),AK(1,2))
      C
            L=0
            DO 38 N=1,NT
            DO 37 M=1,NT
            L=L+1
            AK(M,N)=SV(L)
         37 CONTINUE
         38 CONTINUE
      C
      C  AK AND AJ ARE MULTIPLIED TOGETHER ALONG WITH ASSOCIATED
      C  RHS FOR MATERIAL BALANCE EQUATION
      C
            CALL MPLYM(AK,AJ,SM,NT)
            CALL EQUAL(AJ,SM,NT)
            CALL MPLYV(AK,RHS(1,N3),SV,NT)
            CALL EQUALV(RHS(1,N3),SV,NT)
      C
      C   GENERATE C PART OF COMPONENT MATERIAL
      C   BALANCE WHICH IS ORDERED COMPONENT WISE
      C
      C   SET C MATRIX EQUAL TO ZERO FOR COMPONENT
      C   J AND GENERATE NON-ZERO TERMS
      C
            DO 53 J=1,NC
            CALL ZERO (C(1,1,J),NT2O)
            DO 41 I=1,NTM1
            C(I,I,J)=WK(J,I)*X(J,I)
            C(I,I+1,J)=-WK(J,I+1)*X(J,I+1)
         41 CONTINUE
            C(NT,NT,J)=WK(J,NT)*X(J,NT)
      C
      C   GENERATE D MATRIX
```

```
C     ------ ONLY NEEDED AT THIS TIME
C     TO MODIFY C MATRIX AND ASSOCIATED RHS
C
      CALL ZERO (D,NT20)
C
      D(1,1)=X(J,1)
      DO 42 I=2,NT
      D(I,I-1)=-X(J,I-1)
      D(I,I)=X(J,I)
   42 CONTINUE
C
C     GENERATE RHS FOR EACH COMPONENT
C
      DO 45 I=1,NT
      RHS(I,J)=F(J,I)
   45 CONTINUE
C
C     MULTIPLY D * RHS(-,N3) AND
C     SUBTRACT FROM RHS(I,J)
C
      DO 48 I=1,NT
      DO 48 K=1,NT
      RHS(I,J)=RHS(I,J)-D(I,K)*RHS(K,N3)
   48 CONTINUE
C
C     MULTIPLY D * AJ AND SUBTRACT FROM C
C
      CALL MPLYM (D,AJ,SM,NT)
C
      DO 50 I=1,NT
      DO 50 K=1,NT
      C(I,K,J)=C(I,K,J)-SM(I,K)
   50 CONTINUE
C
   53 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE ENTHAL
C
      COMMON      //          X(15,20),V(20),XL(20),U(20),W(20),
     1                        Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                        HF(20),PP(20),QG,DIST
      COMMON      /CONTRL/     NC,NT,LDOC,NIO,NTM1,KTOP,
     1                        N1,N2,N3,N3N3,NT20
      COMMON      /DATA/      WK(15,20),DK(15,20),HVV(15,20),
     1                        HLL(15,20),DHV(15,20),DHL(15,20),
     2                        Y(15,20)
      COMMON      /FIX/       A(20,20),B(20,20,15),C(20,20,15),
     1                        E(20,20),AF(20,20),
     2                        AJ(20,20),RHS(20,18),
     3                        G(20,20),AL(20,20),AM(20,20)
      REAL                   SM(20,20),SV(400),H(20,20)
C
      EQUIVALENCE            (SM(1,1),SV(1)),
     +                         (A(1,1),H(1,1))
C
      CALL ZERO (AF,400)
      CALL ZERO (G,400)
C
C    GENERATE AF,G,H,AND RHS(-,N1)
C
C
C     GENERATE AF ENTRIES
C
      DO 64 J=1,NC
C
      AF(1,1)=AF(1,1)+(XL(1)+U(1))*X(J,1)*DHL(J,1)
     1+(V(1)+W(1))*(WK(J,1)*DHV(J,1)+HVV(J,1)*DK(J,1))*X(J,1)
      AF(1,2)=AF(1,2)-( V(2)*X(J,2))*(WK(J,2)*
     1DHV(J,2)+HVV(J,2)*DK(J,2))
      DO 61 I=2,NTM1
      AF(I,I-1)=AF(I,I-1)-(XL(I-1)*X(J,I-1)*DHL(J,I-1))
      AF(I,I)=AF(I,I)+(XL(I)+U(I))*X(J,I)*DHL(J,I)
     1+(V(I)+W(I))*(WK(J,I)*DHV(J,I)+HVV(J,I)*DK(J,I))*X(J,I)
      AF(I,I+1)=AF(I,I+1)-(V(I+1)*X(J,I+1))*
     1(WK(J,I+1)*DHV(J,I+1)+HVV(J,I+1)*DK(J,I+1))
   61 CONTINUE
      AF(NT,NTM1)=AF(NT,NTM1)-(XL(NTM1)*X(J,NTM1)*DHL(J,NTM1))
      AF(NT,NT)=AF(NT,NT)+(XL(NT)+U(NT))*X(J,NT)*DHL(J,NT)
     1+(V(NT)+W(NT))*(WK(J,NT)*DHV(J,NT)+HVV(J,NT)*DK(J,NT))*X(J,NT)
   64 CONTINUE
C
C
C     GENERATE G ENTRIES
C
      DO 65 I=1,NTM1
      G(I,I)=HV(I)
```

```
      G(I,I+1)=-HV(I+1)
   65 CONTINUE
      G(NT,NT)=HV(NT)
C
C   GENERATE H ENTRIES
C
      CALL ZERO (H,NT20)
      H(1,1)=HL(1)
      DO 72 I=2,NT
      H(I,I-1)=-HL(I-1)
      H(I,I)=HL(I)
   72 CONTINUE
C
      DO 74 I=1,NT
   74 RHS(I,N1)=-Q(I)+F(N1,I)*HF(I)
C
C   MULTIPLY H BY AJ AND SUBTRACT FROM G
C
      DO 76 I=1,NT
      DO 76 L=1,NT
      DO 75 K=1,NT
   75 G(I,L)=G(I,L)-H(I,K)*AJ(K,L)
C
C   MULTIPLY H BY RHS(I,N3) AND SUBTRACT FROM RHS(I,N1)
C
      RHS(I,N1)=RHS(I,N1)-H(I,L)*RHS(L,N3)
   76 CONTINUE
C
C
C
      RETURN
      END
```

```
      SUBROUTINE COMP
C
      COMMON    //          X(15,20),V(20),XL(20),U(20),W(20),
     1                      Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                      HF(20),PP(20),QG,DIST
      COMMON    /CONTRL/     NC,NT,LDOC,NIO,NTM1,KTOP,
     1                      N1,N2,N3,N3N3,NT20
      COMMON    /DATA/      WK(15,20),DK(15,20),HVV(15,20),
     1                      HLL(15,20),DHV(15,20),DHL(15,20),
     2                      Y(15,20)
      COMMON    /FIX/       A(20,20),B(20,20,15),C(20,20,15),
     1                      E(20,20),AF(20,20),
     2                      AJ(20,20),RHS(20,18),
     3                      G(20,20),AL(20,20),AM(20,20)
      REAL                  SM(20,20),SV(400)
C
      EQUIVALENCE          (SM(1,1),SV(1))
C
C    GENERATE COMPONENT BY COMPONENT A,B,E,AND I
C    I IS NOT ACTUALLY GENERATED SINCE IT IS THE
C    COMPONENTIAL ENTRIES FOR THE SUM EQUATION
C
C    COMPUTE INVERSE OF A AND MULTIPLY TOP ROW BY IT
C
      CALL ZERO (AL,400)
      CALL ZERO (AM,400)
C
      DO 150 J=1,NC
C
C    F + G ARE ADJUSTED AS A RESULT OF E ELIMINATION
C    L AND M ARE ADJUSTED BY I ELIMINATION
C
      CALL ZERO (A,NT20)
      CALL ZERO (B(1,1,J),NT20)
      CALL ZERO (E,NT20)
C
      A(1,1)=(V(1)+W(1))*WK(J,1)+XL(1)+U(1)
      A(1,2)=-V(2)*WK(J,2)
      E(1,1)=(V(1)+W(1))*WK(J,1)*HVV(J,1)+
     1(XL(1)+U(1))*HLL(J,1)
      E(1,2)=-V(2)*WK(J,2)*HVV(J,2)
      DO 82 I=2,NTM1
      A(I,I-1)=-XL(I-1)
      A(I,I)=(V(I)+W(I))*WK(J,I)+XL(I)+U(I)
      A(I,I+1)=-V(I+1)*WK(J,I+1)
C
      E(I,I-1)=-XL(I-1)*HLL(J,I-1)
      E(I,I)=(V(I)+W(I))*WK(J,I)*HVV(J,I)+
     1(XL(I)+U(I))*HLL(J,I)
      E(I,I+1)=-V(I+1)*WK(J,I+1)*HVV(J,I+1)
```

```
   82  CONTINUE
       A(NT,NTM1)=-XL(NTM1)
       A(NT,NT)=(V(NT)+W(NT))*WK(J,NT)+XL(NT)+U(NT)
       E(NT,NTM1)=-XL(NTM1)*HLL(J,NTM1)
       E(NT,NT)=(V(NT)+W(NT))*WK(J,NT)*HVV(J,NT)+
      1(XL(NT)+U(NT))*HLL(J,NT)
C
       DO 83 I=1,NTM1
       B(I,I,J)=(V(I)+W(I))*X(J,I)*DK(J,I)
       B(I,I+1,J)=-V(I+1)*X(J,I+1)*DK(J,I+1)
   83  CONTINUE
       B(NT,NT,J)=(V(NT)+W(NT))*X(J,NT)*DK(J,NT)
C
C   MATRIX A IS INVERTED
C
       L=0
       DO 90 N=1,NT
       DO 90 M=1,NT
       L=L+1
       SV(L)=A(M,N)
   90  CONTINUE
C
       CALL MINV(SV,NT,DETRM,A(1,1),A(1,2))
       L=0
       DO 91 N=1,NT
       DO 91 M=1,NT
       L=L+1
       A(M,N)=SV(L)
   91  CONTINUE
C
C   MULTIPLY A BY B
       CALL MPLYM (A,B(1,1,J),SM,NT)
       CALL EQUAL (B(1,1,J),SM,NT)
C
C   MULTIPLY A BY C
       CALL MPLYM (A,C(1,1,J),SM,NT)
       CALL EQUAL (C(1,1,J),SM,NT)
C
C   MULTIPLY A BY RHS(I,J)
       CALL MPLYV(A,RHS(1,J),SV,NT)
       CALL EQUALV(RHS(1,J),SV,NT)
C
C   MULTIPLY ROW J BY E AND SUBTRACT FROM ROW N1
C
       DO 95 I=1,NT
       DO 95 K=1,NT
       DO 94 L=1,NT
       AF(I,K)=AF(I,K)-E(I,L)*B(L,K,J)
   94  G(I,K)=G(I,K)-E(I,L)*C(L,K,J)
       RHS(I,N1)=RHS(I,N1)-E(I,K)*RHS(K,J)
```

```
   95 CONTINUE
C
C
C    MULTIPLY ROW J BY I AND SUATRACT FROM ROW N2
C
      DO 110 I=1,NT
  110 RHS(I,N2)=RHS(I,N2)-RHS(I,J)
      DO 120 I=1,NT
      DO 120 K=1,NT
  120 AL(I,K)=AL(I,K)-B(I,K,J)
      DO 130 I=1,NT
      DO 130 K=1,NT
  130 AM(I,K)=AM(I,K)-C(I,K,J)
C
C
  150 CONTINUE
C
C
      RETURN
      END
```

123

```
      SUBROUTINE SUBST
C
      COMMON    //          X(15,20),V(20),XL(20),U(20),W(20),
     1                      Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                      HF(20),PP(20),QG,DIST
      COMMON    /CONTRL/     NC,NT,LDOC,NIO,NTM1,KTOP,
     1                      N1,N2,N3,N3N3,NT20
      COMMON    /DATA/      WK(15,20),DK(15,20),HVV(15,20),
     1                      HLL(15,20),DHV(15,20),DHL(15,20),
     2                      Y(15,20)
      COMMON    /FIX/       A(20,20),B(20,20,15),C(20,20,15),
     1                      E(20,20),AF(20,20),
     2                      AJ(20,20),RHS(20,18),
     3                      G(20,20),AL(20,20),AM(20,20)
C
      REAL                  SM(20,20),SV(400)
C
      EQUIVALENCE         (SM(1,1),SV(1))
C
C      INVERT AF
      L=0
      DO 10 N=1,NT
      DO 10 M=1,NT
      L=L+1
   10 SV(L)=AF(M,N)
      CALL MINV (SV,NT,DETRM,AF(1,1),AF(1,2))
      L=0
      DO 20 N=1,NT
      DO 20 M=1,NT
      L=L+1
   20 AF(M,N)=SV(L)
C
C     MULTIPLY G AND RHS(-,N1) BY AF INVERSE
      CALL MPLYM (AF,G,SM,NT)
      CALL EQUAL (G,SM,NT)
      CALL MPLYV (AF,RHS(1,N1),SV,NT)
      CALL EQUALV (RHS(1,N1),SV,NT)
C
C     MULTIPLY G AND RHS(-,N1) BY AL AND SUBTRACT
C     FROM AM AND RHS(-,N2) RESPECTIVELY
      CALL MPLYM (AL,G,SM,NT)
      CALL MPLYV (AL,RHS(1,N1),SV,NT)
      DO 40 I=1,NT
      DO 30 J=1,NT
   30 AM(I,J)=AM(I,J)-SM(I,J)
   40 RHS(I,N2)=RHS(I,N2)-SV(I)
C
C     INVERT AM
      L=0
      DO 50 N=1,NT
```

```
      DO 50 M=1,NT
      L=L+1
   50 SV(L)=AM(M,N)
      CALL MINV (SV,NT,DETRM,AM(1,1),AM(1,2))
      L=0
      DO 60 N=1,NT
      DO 60 M=1,NT
      L=L+1
   60 AM(M,N)=SV(L)
C
C     MULTIPLY RHS(-,N2) BY AM INVERSE
      CALL MPLYV (AM,RHS(1,N2),SV,NT)
      CALL EQUALV (RHS(1,N2),SV,NT)
C
C     MULTIPLY G BY RHS(-,N2) AND SUBSTRACT FROM RHS(-,N1)
      CALL MPLYV (G,RHS(1,N2),SV,NT)
      DO 70 I=1,NT
   70 RHS(I,N1)=RHS(I,N1)-SV(I)
C
C     THE X'S AND DELTA L'S
C   ARE CALCULATED BY BACK SUBSTITUTION
      DO 111 I=1,NT
      DO 111 K=1,NT
  111 RHS(I,N3)=RHS(I,N3)-AJ(I,K)*RHS(K,N2)
C
      DO 116 J=1,NC
      DO 116 I=1,NT
      DO 116 K=1,NT
      RHS(I,J)=RHS(I,J)-B(I,K,J)*RHS(K,N1)-C(I,K,J)*RHS(K,N2)
  116 CONTINUE
C
C
C
      RETURN
      END
```

125

```
      SUBROUTINE MINV(A,N,D,L,M)
C
C        PURPOSE
C           INVERT A MATRIX
C
C        USAGE
C           CALL MINV(A,N,D,L,M)
C
C        DESCRIPTION OF PARAMETERS
C           A - INPUT MATRIX, DESTROYED IN COMPUTATION AND REPLACED BY
C               RESULTANT INVERSE.
C           N - ORDER OF MATRIX A
C           D - RESULTANT DETERMINANT
C           L - WORK VECTOR OF LENGTH N
C           M - WORK VECTOR OF LENGTH N
C
C        REMARKS
C           MATRIX A MUST BE A GENERAL MATRIX
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           THE STANDARD GAUSS-JORDAN METHOD IS USED. THE DETERMINANT
C           IS ALSO CALCULATED. A DETERMINANT OF ZERO INDICATES THAT
C           THE MATRIX IS SINGULAR.
C
C     ..................................................................
C
      DIMENSION A(1),L(1),M(1)
C
C        ...............................................................
C
C        IF A DOUBLE PRECISION VERSION OF THIS ROUTINE IS DESIRED, THE
C        C IN COLUMN 1 SHOULD BE REMOVED FROM THE DOUBLE PRECISION
C        STATEMENT WHICH FOLLOWS.
C
C     DOUBLE PRECISION A,D,BIGA,HOLD
C
C        THE C MUST ALSO BE REMOVED FROM DOUBLE P-ECISION STATEMENTS
C        APPEARING IN OTHER ROUTINES USED IN CONJUNCTION W&TH TH&S
C        ROUTINE.
C
C        THE DOUBLE PRECISION VERSION OF THIS SUBROUTINE MUST ALSO
C        CONTAIN DOUBLE PRECISION FORTRAN FUNCTIONS.  ABS IN STATEMENT
C        10 MUST BE CHANGED TO DABS.
C
C        ...............................................................
C
C        SEARCH FOR LARGEST ELEMENT
```

```
C
      D=1.0
      NK=-N
      DO 80 K=1,N
      NK=NK+N
      L(K)=K
      M(K)=K
      KK=NK+K
      BIGA=A(KK)
      DO 20 J=K,N
      IZ=N*(J-1)
      DO 20 I=K,N
      IJ=IZ+I
   10 IF( ABS(BIGA)- ABS(A(IJ))) 15,20,20
   15 BIGA=A(IJ)
      L(K)=I
      M(K)=J
   20 CONTINUE
C
C        INTERCHANGE ROWS
C
      J=L(K)
      IF(J-K) 35,35,25
   25 KI=K-N
      DO 30 I=1,N
      KI=KI+N
      HOLD=-A(KI)
      JI=KI-K+J
      A(KI)=A(JI)
   30 A(JI) =HOLD
C
C        INTERCHANGE COLUMNS
C
   35 I=M(K)
      IF(I-K) 45,45,38
   38 JP=N*(I-1)
      DO 40 J=1,N
      JK=NK+J
      JI=JP+J
      HOLD=-A(JK)
      A(JK)=A(JI)
   40 A(JI) =HOLD
C
C        DIVIDE COLUMN BY MINUS PIVOT (VALUE OF PIVOT ELEMENT IS
C        CONTAINED IN BIGA)
C
   45 IF(BIGA) 48,46,48
   46 D=0.0
      RETURN
   48 DO 55 I=1,N
```

```
      IF(I-K) 50,55,50
   50 IK=NK+I
      A(IK)=A(IK)/(-BIGA)
   55 CONTINUE
C
C        REDUCE MATRIX
C
      DO 65 I=1,N
      IK=NK+I
      HOLD=A(IK)
      IJ=I-N
      DO 65 J=1,N
      IJ=IJ+N
      IF(I-K) 60,65,60
   60 IF(J-K) 62,65,62
   62 KJ=IJ-I+K
      A(IJ)=HOLD*A(KJ)+A(IJ)
   65 CONTINUE
C
C        DIVIDE ROW BY PIVOT
C
      KJ=K-N
      DO 75 J=1,N
      KJ=KJ+N
      IF(J-K) 70,75,70
   70 A(KJ)=A(KJ)/BIGA
   75 CONTINUE
C
C        PRODUCT OF PIVOTS
C
      D=D*BIGA
C
C        REPLACE PIVOT BY RECIPROCAL
C
      A(KK)=1.0/BIGA
   80 CONTINUE
C
C        FINAL ROW AND COLUMN INTERCHANGE
C
      K=N
  100 K=(K-1)
      IF(K) 150,150,105
  105 I=L(K)
      IF(I-K) 120,120,108
  108 JQ=N*(K-1)
      JR=N*(I-1)
      DO 110 J=1,N
      JK=JQ+J
      HOLD=A(JK)
      JI=JR+J
```

```
      A(JK)=-A(JI)
  110 A(JI) =HOLD
  120 J=M(K)
      IF(J-K) 100,100,125
  125 KI=K-N
      DO 130 I=1,N
      KI=KI+N
      HOLD=A(KI)
      JI=KI-K+J
      A(KI)=-A(JI)
  130 A(JI) =HOLD
      GO TO 100
  150 RETURN
      END
```

```
      SUBROUTINE GET
C
      COMMON    //          X(15,20),V(20),XL(20),U(20),W(20),
     1                      Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                      HF(20),PP(20),QG,DIST
      COMMON    /CONTRL/    NC, NT, LOOC, NIO, NTM1, KTOP,
     1                      N1,N2,N3,N3N3,NT20
      COMMON    /DATA/      WK(15,20),DK(15,20),HVV(15,20),
     1                      HLL(15,20),DHV(15,20),DHL(15,20),
     2                      Y(15,20)
      COMMON    /COEF/      CK(8,15),DCK(7,15),CHV(6,15),
     1                      DCHV(5,15),CHL(6,15),DCHL(5,15),
     2                       PPA,MCODE
C
      DO 22 I=1,NT
      T=TA(I)
      SUM=0.0
      HV(I)=0.0
      HL(I)=0.0
      DO 11 J=1,NC
      WK(J,I)=EQUA(T,CK(1,J))
      DK(J,I)=EQUA(T,DCK(1,J))
      HVV(J,I)=EQUA(T,CHV(1,J))
      DHV(J,I)=EQUA(T,DCHV(1,J))
      HLL(J,I)=EQUA(T,CHL(1,J))
   11 DHL(J,I)=EQUA(T,DCHL(1,J))
      IF(MCODE.EQ.0) GO TO 19
      GO TO (19,14), MCODE
   14 PRATIO=PPA/PP(I)
      DO 17 J=1,NC
      WK(J,I)=WK(J,I)*PRATIO
      DK(J,I)=DK(J,I)*PRATIO
   17 CONTINUE
   19 DO 21 J=1,NC
      Y(J,I)=WK(J,I)*X(J,I)
      SUM=SUM+Y(J,I)
      HV(I)=HV(I)+HVV(J,I)*Y(J,I)
      HL(I)=HL(I)+HLL(J,I)*X(J,I)
   21 CONTINUE
      HV(I)=HV(I)/SUM
   22 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE OTPUT
C
C
      COMMON    //          X(15,20),V(20),XL(20),U(20),W(20),
     1                      Q(20),HL(20),HV(20),TA(20),F(16,20),
     2                      HF(20),PP(20),QG,DIST
      COMMON    /CONTRL/    NC, NT, LDOC, NIO, NTM1, KTOP,
     1                      N1,N2,N3,N3N3,NT20
      COMMON    /FFDATA/    NF,NAMEF(3,6),NFTRAY(6),ZF(16,6),ZK(15,6),
     +                      QFN(6), TF(6), PF(6), QQQ(6), QEX(6), TTF(6)
      COMMON    /PROP/      CNAME(2,15),XMW(15),RHO(15)
      COMMON    /FIX/       EK(15,20),Z(15),XX(15,11),IAA(2,9),
     +                      IBB(2,9),ICC(2,9),IDD(9),SUMM(11),SUMP(9),
     +                      SUMG(9), TEMP(9), QOS(9), NTT(9), NNN(9),
     +                      SLOP(14552)
      COMMON    /COEF/      CK(8,15),DCK(7,15),CHV(6,15),
     1                      DCHV(5,15),CHL(6,15),DCHL(5,15),
     2                      PPA,MCODE
C
      DATA                  NOUT /6/
C
      INTEGER   BLANK /'    '/,                        MOLS /'MOLS'/,
     +          FOND(2) /'FEED',' NO '/,               TRNO(2) /'TRAY',' NO '/,
     +          COMB(2) /'COMB','INED'/,               FD(2)   /'  FE','ED  '/,
     +          OVHD(2) /'OVER','HEAD'/,               LIQ(2)  /' LIQ','UID '/,
     +          VAP(2)  /' VAP','OR  '/,               PROD(2) /' PRO','DUCT'/,
     +          BTM(2)  /' BOT','TOMS'/,
     +          SSNO(2) /' SS ',' NO '/
C
C
      NBLK=0
      TA(1)=TA(1)+ABS(DTSUB)
      DO 10 N=1,NT
      PRATIO=1.0
      IF(MCODE.EQ.0) GO TO 8
      GO TO ( 8,6), MCODE
    6 PRATIO=PPA/PP(N)
    8 DO 10 J=1,NC
   10 EK(J,N)=EQUA(TA(N),CK(1,J))*PRATIO
      TA(1)=TA(1)-ABS(DTSUB)
C
      WRITE (NOUT,201)
  201 FORMAT (1H1,/////10X ' FEED AND PRODUCT COMPOSITIONS' // )
C
      ASSIGN 15 TO INDEX
C
   11 K=0
      DO 12 J=1,9
      SUMM(J)=0.0
      SUMP(J)=0.0
```

```
      SUMG(J)=0.0
      QQS(J)=0.0
      TEMP(J)=0.0
C
      NTT(J)=BLANK
      NNN(J)=BLANK
      IDD(J)=MULS
      DO 12 I=1,NC
   12 XX(I,J)=0.0
C
      DO 13 J=1,2
      DO 13 I=1,9
      IAA(J,I)=BLANK
      IBB(J,I)=BLANK
   13 ICC(J,I)=BLANK
C
      GO TO INDEX, (15,41,47,61,70)
C
C     CALCULATE SEPARATE FEEDS
C
   15 DO 17 N=1,NF
      K=K+1
      L=NFTRAY(N)
      CALL ALNUM (L,NTT(K))
      CALL ALNUM (N,NNN(K))
      DO 16 I=1,NC
   16 XX(I,K)=ZF(I,N)
      SUMM(K)=ZF(N1,N)
      TEMP(K)=TTF(N)
      QQS(K)=QQQ(N)
      DO 17 J=1,2
      IAA(J,K)=FDNO(J)
   17 ICC(J,K)=TRNO(J)
C
C     CALCULATE TOTAL FEED --- ONLY IF MORE THAN ONE FEED
C
      IF (NF.EQ.1) GO TO 30
      K=K+1
      DO 19 N=1,NF
      SUMM(K)=SUMM(K)+SUMM(N)
      QQS(K)=QQS(K)+QQS(N)
      DO 19 I=1,NC
   19 XX(I,K)=XX(I,K)+XX(I,N)
      DO 20 J=1,2
      IAA(J,K)=COMB(J)
   20 IBB(J,K)=FD(J)
C
C     CALCULATE OVERHEAD DISTILLATE   ***VAPOR***
C
   30 IF(V(1).EQ.0.0) GO TO 39
```

```
      K=K+1
      KK=KK+1
      DO 31 I=1,NC
   31 XX(I,K)=X(I,1)*EK(I,1)*V(1)
      SUMM(K)=V(1)
      TEMP(K)=TA(1)
      QQS(K)=SUMM(K)*HL(1)
      DO 32 J=1,2
      IAA(J,K)=OVHD(J)
      IBB(J,K)=VAP(J)
   32 ICC(J,K)=PROD(J)
C
C
C     CALCULATE SIDESTREAMS
C
   39 KK=0
      DO 58 M=2,NTM1
C
C     *** LIQUID SIDESTREAMS ***
C
      IF (U(M).EQ.0.0) GO TO 46
      IF (K.LT.9) GO TO 41
      ASSIGN 41 TO INDEX
      GO TO 64
   41 K=K+1
      DO 44 I=1,NC
   44 XX(I,K)=U(M)*X(I,M)
      SUMM(K)=U(M)
      QQS(K)=HL(M)*U(M)
      DO 45 J=1,2
   45 IBB(J,K)=LIQ(J)
      GO TO 53
C
C     *** VAPOR SIDESTREAMS ***
C
   46 IF (W(M).EQ.0.0) GO TO 58
      IF (K.LT.9) GO TO 47
      ASSIGN 47 TO INDEX
      GO TO 64
   47 K=K+1
      DO 49 I=1,NC
   49 XX(I,K)=X(I,M)*EK(I,M)
      SUMM(K)=W(M)
      QQS(K)=W(M)*HV(M)
      DO 52 J=1,2
   52 IBB(J,K)=VAP(J)
C
   53 CALL ALNUM (M-1,NTT(K))
      CALL ALNUM (KK+2,NNN(K))
      DO 54 J=1,2
```

```
      IAA(J,K)=SSNO(J)
   54 ICC(J,K)=TRNO(J)
      TEMP(K)=TA(M)
   58 CONTINUE
C
C     CALCULATE BOTTOMS
C
      IF (K.LT.9) GO TO 61
      ASSIGN 61 TO INDEX
      GO TO 64
   61 K=K+1
      DO 62 I=1,NC
   62 XX(I,K)=X(I,NT)*XL(NT)
      SUMM(K)=XL(NT)
      QQS(K)=SUMM(K)*HL(NT)
      TEMP(K)=TA(NT)
      DO 63 J=1,2
      IAA(J,K)=BTM(J)
   63 IBB(J,K)=PROD(J)
      ASSIGN 70 TO INDEX
C
C     PRINT OUT DATA SUMMARY
C
   64 NL=K
C
      WRITE (NOUT,111) ((IAA(N,K),N=1,2),NNN(K),K=1,NL)
  111 FORMAT (24X,27A4)
      WRITE (NOUT,112) ((IBB(N,K),N=1,2),K=1,NL)
  112 FORMAT (25X,8(2A4,4X),2A4)
      WRITE (NOUT,111) ((ICC(N,K),N=1,2),NTT(K),K=1,NL)
      WRITE (NOUT,113) (IDD(K),K=1,NL)
  113 FORMAT (10X ' COMPONENT' 7X,A4, 8(8X,A4))
      DO 65 I=1,NC
   65 WRITE (NOUT,121) (CNAME(K,I),K=1,2),(XX(I,K),K=1,NL)
  121 FORMAT ( 11X,2A4,1X,9F12.4 )
C
      WRITE (NOUT,123) (SUMM(K),K=1,NL)
  123 FORMAT (10X ' TOTAL' 4X,9F12.4 )
      DO 67 K=1,NL
      DO 66 I=1,NC
      FAC=XX(I,K)*XMW(I)
      SUMP(K)=SUMP(K)+FAC
   66 SUMG(K)=SUMG(K)+FAC/RHO(I)
   67 QQS(K)=QQS(K)/1000.0
      WRITE (NOUT,124) (SUMP(K),K=1,NL)
  124 FORMAT (/10X ' POUNDS' 3X,9F12.2 )
      WRITE (NOUT,126) (SUMG(K),K=1,NL)
  126 FORMAT (10X ' GALLONS' 2X,9F12.2 )
      WRITE (NOUT,128) (QQS(K),K=1,NL)
  128 FORMAT (/10X ' Q, MBTU' 2X,9F12.3 )
```

```
      WRITE (NOUT,129) (TEMP(K),K=1,NL)
  129 FORMAT (/10X ' TEMP, F' 2X,9F12.2 )
C
      NBLK=NBLK+1
      GO TO (69,68), NBLK
C
   68 WRITE (NOUT,136)
  136 FORMAT ( '1' // )
      GO TO 11
C
   69 WRITE (NOUT,137)
  137 FORMAT (////)
      NBLK=0
      GO TO 11
C
C     CALCULATE AND PRINT-OUT TRAY SUMMARY
C
   70 WRITE (NOUT,140)
  140 FORMAT ( '1' 15X 'NET LIQUID & VAPOR LEAVING EACH STAGE' // )
C
      NL=4
      DO 71 J=8,10
   71 SUMM(J)=100.0
C
      DO 98 N=1,NT
      K=N
      IF(NL+NC+9.LT.58) GO TO 73
      WRITE (NOUT,140)
      NL=4
C
   73 IF (N.EQ.NT .AND. QG.NE.0.0) GO TO 74
      WRITE (NOUT,143) K,TA(N),PP(N)
  143 FORMAT(6X' TRAY NO'I4,5X'TEMP,F' F8.2,5X 'PRESS,PSIA' F8.2)
      GO TO 76
   74 WRITE (NOUT,144) TA(N),PP(N)
  144 FORMAT(6X' REBOILER' 8X 'TEMP,F' F8.2,5X 'PRESS,PSIA' F8.2 )
C
   76 WRITE (NOUT,149)
  149 FORMAT ( 23X 7('- '),'VAPOR' 7(' -'),8X 12('- '),'LIQUID' 12(' -')
     +/3X ' NO  COMP' 10X 'MOLS' 7X 'LBS' 6X 'MOL%' 6X 'WT %' 8X 'MOLS'
     + 7X 'LBS' 6X 'GALS' 6X 'MOL%' 7X 'WT%' 5X 'VOL%' 7X 'K-DATA' )
      DO 77 J=1,7
   77 SUMM(J)=0.0
      SUMM(3)=100.0
      SUMM(4)=100.0
      SHL=0.0
      SHV=0.0
      SUMV=0.0
      DO 78 I=1,NC
      DO 78 J=1,11
```

```
   78 XX(I,J)=0.0
C
      DO 79 I=1,NC
      Z(I)=EK(I,N)*X(I,N)
   79 SUMV=SUMV+Z(I)
      IF (V(N).EQ.0.0) GO TO 85
      FAC=V(N)/SUMV
      DO 81 I=1,NC
      XX(I,1)=Z(I)*FAC
      XX(I,2)=XX(I,1)*XMW(I)
      SUMM(1)=SUMM(1)+XX(I,1)
   81 SUMM(2)=SUMM(2)+XX(I,2)
      FAC=100.0/SUMM(1)
      FBC=100.0/SUMM(2)
      DO 83 I=1,NC
      XX(I,3)=XX(I,1)*FAC
   83 XX(I,4)=XX(I,2)*FBC
C
   85 DO 87 I=1,NC
      XX(I,5)=X(I,N)*XL(N)
      XX(I,6)=XX(I,5)*XMW(I)
      XX(I,7)=XX(I,6)/RHO(I)
      SUMM(5)=SUMM(5)+XX(I,5)
      SUMM(6)=SUMM(6)+XX(I,6)
      SUMM(7)=SUMM(7)+XX(I,7)
   87 XX(I,11)=EK(I,N)
      FAC=100.0/SUMM(5)
      FBC=100.0/SUMM(6)
      FCC=100.0/SUMM(7)
      DO 88 I=1,NC
      XX(I,8)=XX(I,5)*FAC
      XX(I,9)=XX(I,6)*FBC
   88 XX(I,10)=XX(I,7)*FCC
C
      WRITE (NOUT,152) (I,(CNAME(K,I),K=1,2),(XX(I,K),K=1,11),I=1,NC)
  152 FORMAT(3X,I3,2X,2A4,F11.3,F10.1,2F10.4,F12.3,2F10.1,3F10.4,F12.5)
      WRITE (NOUT,153) (SUMM(K),K=1,10)
  153 FORMAT (3X ' TOTAL' 8X F10.3,F10.1,2F10.4, F12.3,2F10.1,3F10.4 )
      VMW=0.0
      IF (V(N).EQ.0.0) GO TO 91
      VMW=SUMM(2)/SUMM(1)
      SHV=HV(N)*V(N)
   91 XLMW=SUMM(6)/SUMM(5)
      ZDEN=SUMM(6)/SUMM(7)
      SHL=HL(N)*XL(N)
      WRITE (NOUT,161) VMW,SHV,XLMW,ZDEN,SHL
  161 FORMAT ( '0' 9X 'VAPOR MW =' F7.3,5X 'VAPOR ENTHALPY =' F11.0,' BT
     +US' / 9X 'LIQUID MW =' F7.3,5X 'LIQUID LB/GAL =' F7.3,5X 'LIQUID E
     +NTHALPY =' F11.0,' BTUS' / )
C
```

```
   98 NL=NL+9+NC                                                  21
C                                                                 21
      RETURN                                                      21
      END                                                         21
```

```
      SUBROUTINE ALNUM (NN, MM)
C
C           THIS SUBROUTINE DEVELOPS INTEGER EQUIVALENTS OF NUMBERS
C           FROM 0 TO 99, LEFT JUSTIFIED WITHIN 4 COLUMN FIELD.
C           NN = NUMBER TO BE CONVERTED.  MM = INTEGER EQUIVALENT.
C
      IF(NN-9) 1, 1, 2
C
C           NUMBER IS 9 OR LESS.
C
    1 MM=-268435456+NN*16777216
      RETURN
C
C           NUMBER IS BETWEEN 10 AND 99, INCLUSIVE.
C
    2 M=NN/10
      L=NN-M*10
      MM=-252690368+M*16777216+L*65536
      RETURN
C
      END
```

APPENDIX III

```
      PROGRAM ABSR1
C
C
      DEFINE FILE 10 ( 100, 529, U, NBLOCK )
C
      REAL      A(20)
      DATA      ZEND / '$$$$' /
C
      NTIME = 0
    2 READ (5,100,END=999) A
  100 FORMAT (20A4)
      WRITE (6,102) A
  102 FORMAT (1H1,72X,20A4)
      CALL INPUT (&8)
      CALL INR (&8,&10)
    4 CALL OTPUT
      GO TO 10
C
    8 WRITE (6,104)
  104 FORMAT (/////10X 'PROBLEM FLUSHED'/10X 'PROCEEDING TO NEXT PROBLEM
     1'/////)
C
   10 READ (5,100,END=999) A(1)
      IF (A(1).EQ.ZEND) GO TO 2
      GO TO 10
C
  999 WRITE (6,106)
  106 FORMAT ('1')
      STOP
      END
```

```
      SUBROUTINE KGEN (T,E,M)
C
      COMMON    //          X(20,100), V(100), XL(100), U(100), W(100),
     1                      Q(100), HL(100), HV(100), TA(100), F(21,100),
     2                      HF(100), PP(100), QG, DIST
      COMMON    /CONTRL/    NC, NT, LOOC, NIO, NTM1, KTOP,
     1                      N1, N2, N3, N3N3
      COMMON    /DATA1/     NK, EKTABL(8,20), TK(8),
     1                       PA, PK(8), KCODE
C
      REAL                  E(1)
      DOUBLE PRECISION      XX
C
    1 IF (NK.GT.2) GO TO 3
      J=1
      GO TO 9
    3 DO 6 L=2,NK
      IF (T.LT.TK(L)) GO TO 7
    6 CONTINUE
      L=NK
    7 J=L-1
    9 K=J+1
C
   10 XX=(1.0/(T+460.0)-1.0/(TK(J)+460.0)) /
     1    (1.0/(TK(K)+460.0)-1.0/(TK(J)+460.0))
      DO 14 I=1,NC
   14 E(I)=DEXP(EKTABL(J,I)+(EKTABL(K,I)-EKTABL(J,I))*XX)
C
      IF(KCODE.EQ.0) GO TO 41
   31 GO TO (41,32), KCODE
   32 PRATIO=PA/PP(M)
      DO 33 I=1,NC
   33 E(I)=E(I)*PRATIO
C
   41 RETURN
      END
```

```
      SUBROUTINE HGEN (T,ZV,ZL)
C
      COMMON    /CONTRL/  NC, NT, LBDC, NID, NTH1, KTOP,
     1                    N1, N2, N3, N3N3
      COMMON    /DATA2/   NH, HLTABL(8,20), HVTABL(8,20), TH(8), PH(8)
C
      REAL                ZV(1), ZL(1)
C
      IF (NH.GT.2) GO TO 3
      J=1
      GO TO 8
    3 DO 6 L=2,NH
      IF (T.LT.TH(L)) GO TO 7
    6 CONTINUE
      L=NH
    7 J=L-1
    8 K=J+1
C
    9 XX=(T-TH(J))/(TH(K)-TH(J))
      DO 10 N=1,NC
      ZV(N)=HVTABL(J,N)+(HVTABL(K,N)-HVTABL(J,N))*XX
   10 ZL(N)=HLTABL(J,N)+(HLTABL(K,N)-HLTABL(J,N))*XX
C
      RETURN
      END
```

```
      FUNCTION      EQUA ( X, C )
C
C     THIS FUNCTION EVALUATES A SET OF POLYNOMINAL COEFFICIENTS BY
C     NESTED EXPANSION ---- AS GENERATED BY FUNCTION FITIT.
C
C              Y = A0 + A1*X + A2*X**2 + ..... + AM*X**M
C
C                        M = C(1)
C
C                        A0 = C(2)
C                        A1 = C(3)
C                        A2 = C(4)
C                        ..   ....
C                        ..   ....
C                        AM = C(M+2)
C
      REAL          C(1)
C
      M = C(1)
      Y = C(M+2)
      MM = M+2
      DO 1 J=1,M
      MMJ=MM-J
      Y=Y*X+C(MMJ)
    1 CONTINUE
      EQUA = Y
      RETURN
      END
```

```
      FUNCTION FITIT ( X, Y, NO, MAX, C, LN, A )
C
C     WILL FIT POLYNOMIAL OF ORDER MAX ( MAX .LT. 7 ) TO NO Y VS. X DATA
C     POINTS SUPPLIED IN ARRAYS Y AND X. COEFFICIENTS RETURNED IN ARRAY
C     C IN FORM NEEDED BY FUNCTION EQUA. STANDARD DEVIATION OF Y RETURNE
C     D AS FITIT.
C
C     LN = LOG TRANSFORMATION CODE 1 = Y VS. X
C                                  2 = LN Y VS. X
C                                  3 = Y VS. LN X
C                                  4 = LN Y VS. LN X
C
C     A = INTERCEPT CODE ZERO = INTERCEPT = 0.0
C     NONZERO = INTERCEPT CALCULATED
C
      REAL X(1), Y(1), C(1), D(7), S(7), XY(7,7)
C
C     SET CONTROLS AND ZEROS AND XY.
C
      N = NO
      M = MIN0 ( MAX + 1, N, 7)
      L = MIN0 ( 4, MAX0 ( 1, LN ) )
      Z = N
      DO 10 I = 1, M
      S(I) = 0.0
      DO 10 J = I, M
   10 XY(I, J) = 0.0
C
C     FOR EACH DATUM, MOVE Y AND X TO D(1) AND D(2), GET LOGS IF NEEDED
C     AND POWERS OF X, AND ACCUMULATE SUMS, SQUARES, AND CROSS PRODUCTS
C     IN S AND XY.
C
      DO 80 K =1, N
      D(1) = Y(K)
      D(2) = X(K)
      GO TO ( 50, 20, 40, 30 ), L
   20 D(1) = ALOG ( D(1) )
      GO TO 50
   30 D(1) = ALOG ( D(1) )
   40 D(2) = ALOG ( D(2) )
   50 DO 60 I =3, M
   60 D(I) = D(2) * D(I - 1)
      DO 70 I = 1, M
      S(I) = S(I) + D(I)
      DO 70 J = I, M
   70 XY(I, J) = XY(I, J) + D(I) * D(J)
   80 CONTINUE
C
C     GET REDUCED SQUARES AND CROSS PRODUCTS IF A NONZERO AND FOLD XY
C     OVER.
```

```
C
      IF ( A .EQ. 0.0 ) GO TO 110
      DO 100 I = 1, M
      Q = S(I) / Z
      DO 90 J = I, M
   90 XY(I, J) = XY(I, J) - Q * S(J)
  100 S(I) = W
  110 DO 120 J = 1, M
      DO 120 I = J, M
  120 XY(I, J) = XY(J, I)
C
C     SOLVE REGRESSION MATRIX AND GET STANDARD DEVIATION OF Y.
C
      DO 160 I = 2, M
      Q = XY(I, I)
      XY(I, I) = 1.0
      DO 130 J = 1, M
  130 XY(I, J) = XY(I, J) / Q
      DO 150 K = 1, M
      IF ( K .EQ. I ) GO TO 150
      Q = XY(K, I)
      XY(K, I) = 0.0
      DO 140 J = 1, M
  140 XY(K, J) = XY(K, J) - XY(I, J) * Q
  150 CONTINUE
  160 CONTINUE
      Q = MAX0 ( N - M, 1 )
      FITIT = SQRT ( AMAX1 ( XY (1, 1) / Q, 0.0 ) )
C
C     STORE COEFFICIENTS IN C ARRAY.
C
      C(1) = M - 1
      C(2) = 0.0
      DO 170 I = 2, M
      S(1) = S(1) - S(I) * XY(I, 1)
  170 C(I + 1) = XY(I, 1)
      IF ( A .NE. 0.0 ) C(2) = S(1)
      RETURN
C
      END
```

```
      FUNCTION WAYA(A,ANS,TOL,START,STOP,LEVEL)
C
C        ROUTINE TO CONVERGE ON SINGLE VALUED FUNCTION
C
C     A     =CURRENT VALUE OF DEPENDENT VARIABLE
C     ANS   =DESIRED VALUE OF DEPENDENT VARIABLE
C     TOL   =TOLERANCE
C     START=CURRENT VALUE OF INDEPENDENT VARIABLE. A BETTER VALUE RETURNED
C     STOP =LIMIT OF INDEPENDENT VARIABLE. ANSWER BETWEEN START AND STOP.
C     LEVEL= 1,2, OR 3 AS AN INDEX FOR MULTILEVEL USE.
C
C     WAYA WILL VARY START BETWEEN ITS INITIAL VALUE AND STOP UNTIL
C          ABS( ANS- A) .LE. TOL OR 30 TRIALS TAKEN.
C
C     ON EXIT WAYA IS:
C      - FOR NOT CONVERGED, REPEAT CALCULATION WITH NEW VALUE IN START.
C      0 FOR CONVERGED IN LIMITS OR 30 TRIALS TAKEN.
C      + FOR CANNOT CONVERGE. START WILL BE ITS INITIAL VALUE OR STOP,
C           WHICHEVER GIVES LESSER ERROR, OR ITS INITIAL VALUE IF LEVEL
C           IS NEGATIVE.
C
      DIMENSION X1(3),X2(3),Y1(3),Y2(3),KOUNT(3)
C
      DATA  KOUNT/ 3*0 /
C
C        SET X,Y & LEVEL
      X=START
      Y=ANS-A
      L=IABS(LEVEL)
      WAYA=1.0
C
C        SEE IF CONVERGED
C
      IF(ABS(Y).LE. TOL) GO TO 70
C
C        NOT CONVERGED. SEE WHICH CALL.
C
      IF(KOUNT(L)) 80,30,10
C
C        SECOND OR HIGHER CALL. SEE IF Y AND Y1(L) BRACKET ANSWER.
C
   10 IF(Y*Y1(L) .LT. 0.0) GO TO 20
C
C        NO Y-Y1 BRACKET. SEE IF SECOND OR HIGHER CALL.
C
      IF(KOUNT(L) .GT. 1) GO TO 30
C
C        NO BRACKET AT ALL. RE-DO AT START IF THAT LIMIT IS CLOSER OR IF
C        LEVEL IS MINUS
C
```

```
      IF(ABS(Y) .LE. ABS(Y1(L)) .AND. LEVEL .GT. 0) GO TO 80
      X=X1(L)
      KOUNT(L)= -1
      GO TO 60
C
C        Y-Y1 BRACKET. STORE X & Y IN X2(L) AND Y2(L)
C
   20 X2(L)=X
      Y2(L)=Y
      GO TO 40
C
C        FIRST CALL OR CONVERGING Y-Y2 BRACKET CALL.  STORE X & Y IN X1
C        & Y1.
C
   30 X1(L)=X
      Y1(L)=Y
      X=STOP
      IF(KOUNT(L).EQ. 0) GO TO 50
C
C        INTERPOLATE NEW X AND CONTINUE OR QUIT DEPENDING ON KOUNT(L).
C
   40 X=(X1(L)*(3.*Y2(L)-Y1(L))+X2(L)*(Y2(L)-3.*Y1(L)))/(4.*(Y2(L)-Y1(L)
     1))
      IF (KOUNT(L) .GE. 30) GO TO 70
   50 KOUNT(L)=KOUNT(L)+1
   60 WAYA=-1.0
      GO TO 90
C
C        CONVERGED OR TOO MANY TRIALS
C
   70 WAYA=0.0
   80 KOUNT(L)=0
C
C        SET NEW VALUE OF INDEPENDENT VARIABLE.
C
   90 START=X
      RETURN
C
      END
```

```
      SUBROUTINE MWRITE
C
      COMMON    //          X(20,100), V(100), XL(100), U(100), W(100),
     1                      Q(100), HL(100), HV(100), TA(100), F(21,100),
     2                      HF(100), PP(100), QG, DIST
      COMMON    /CONTRL/    NC, NT, LOOC, NIO, NTM1, KTOP,
     1                      N1, N2, N3, N3N3
      COMMON    /PROP/      CNAME(2,20), XMW(20), RHO(20)
      COMMON    /FIX/       SPACE(4845), AX(100)
C
      WRITE (6,101)(V(J),J=1,NT)
  101 FORMAT(//' CALCULATED VAPOR RATES'/10(9X,10F11.3/))
      WRITE (6,102) (XL(J),J=1,NT)
  102 FORMAT ( 1X,26HCORRESPONDING LIQUID RATES/10(9X,10F11.3/))
      WRITE (6,103) (TA(J),J=1,NT)
  103 FORMAT ( ' CALCULATED TEMPERATURES '      / 10(9X,10F11.3/))
C
C        NBL        NUMBER OF BLOCKS OF 10 OR PART THEREOF
C        NPP        NUMBER OF LINES ALREADY PRINTED
      KN=0
      KM=NT
      NBL=(NT+9)/10
      NPP=(7+3)+(NBL*3)+(NC+5)
C
    2 IF (KM.LE.10) GO TO 6
      KN=10+KN
      L=KN-9
      KM=KM-10
      KE=KN
      GO TO 10
    6 KN=KM+KN
      L=KN-KM+1
      KM=0
      KE=KN
   10 LE=L
C
      WRITE(6,115) (J,J=LE,KE)
  115 FORMAT ('0LIQUID COMPOSITIONS, MOL FRACTIONS' / ' TRAY #' I10,
     +        9I11)
      DO 12 I=1,NC
   12 WRITE(6,116) (CNAME(K,I),K=1,2),(X(I,J),J=L,KN)
  116 FORMAT (2X,2A4,1X,10F11.8)
      DO 15 J=L,KN
      AX(J)=0.
      DO 15 I=1,NC
   15 AX(J)=AX(J)+X(I,J)
      WRITE (6,126) (AX(J),J=L,KN)
  126 FORMAT(' TOTAL     ' 10F11.8)
      IF (KM.LE.0) GO TO 31
      IF ( 57-NPP-NC-5 ) 22,22,23
```

148

```
   22 WRITE(6,154)
  154 FORMAT (1H1)
      NPP=0
   23 NPP=NPP+NC+5
      GO TO 2
C           PRINT REBOILER DUTY
C
C
   31 QNT=ABS(Q(NT))
      WRITE (6,220) QNT
  220 FORMAT(//1X,19HREBOILER DUTY, BTUS,      F16.1/)
      RETURN
      END
```

```
      SUBROUTINE INPUT (*)
C
      COMMON  //            X(20,100), Y(100), XL(100), U(100), W(100),
     1                      Q(100), HL(100), HV(100), TA(100), F(21,100),
     2                      HF(100), PP(100), QG, DIST
      COMMON  /CONTRL/      NC, NT, LDOC, NID, NTM1, KTOP,
     1                      N1, N2, N3, N3N3
      COMMON  /FIX/         EK(20,100), A(100), B(100), C(100), D(100),
     1                      AX(100), BX(100)
      COMMON  /SSDATA/      NSS, NSTRAY(10), XW(10), XU(10), QSS(10)
      COMMON  /FFDATA/      NF, NAMEF(3,6), NFTRAY(6), ZF(21,6), ZK(20,6),
     1                      QFN(6), TF(6), PF(6), QQQ(6), QEX(6), TTF(6)
      COMMON  /PROP/        CNAME(2,20), XMW(20), RHO(20)
      COMMON  /DATA1/       NK, EKTABL(8,20), TK(8),
     1                       PA, PK(8), KCODE
      COMMON  /DATA2/       NH, HLTABL(8,20), HVTABL(8,20), TH(8), PH(8)
C
C        KTOP    ---  DESIGN VARIABLE
C                 2    Q REBOILER
C                                HEAT LOADS ARE IN  MMBTU/HR
C
C        LDOC    ---   PRINT CODE
C                 1     INPUT & OUTPUT
C                 2     1 + TRIAL DATA
C                 3     2 + ALL DATA
C                 4     3 + ERROR PRINT OUT
C
      NOGO=0
      READ (5,101) NT,NC,NF,NSS,NK,NH,NID,KTOP,LDOC
C 101 FORMAT (9I5)
C
      READ(5,102) QR,DIST
  102 FORMAT(8F10.0)
      READ (5,102)TTOP, TBOT, DTRAY, TMID
      READ(5,102) PTOP, DPTWR
C
      NTM1=NT-1
C
      N1=NC+1
      N2=N1+1
      N3=N2+1
      N3N3=N3*N3
C
      PP(1)=PTOP
      DP=DPTWR/FLOAT(NTM1)
      DO 9 J=2,NT
    9 PP(J)=PP(J-1)+DP
C
      IF(NID.LE.0)NID=25
      IF (LDOC.LE.0 .OR. LDOC.GE.5) LDOC=2
```

```
C
      WRITE (6,105) NT,NC,NF,NSS,NK,NH,NIO,KTOP,LDOC
  105 FORMAT (//2X,'NUMBER OF TRAYS' I20, /2X,'NUMBER OF COMPONENTS' I15
     1,//2X,'NUMBER OF FEEDS' I20, /2X,'SIDESTREAM AND/OR HEAT TRAYS'
     2 I7, //2X,'NUMBER OF K-DATA POINTS' I12, /2X'NUMBER OF H-DATA POIN
     3TS' I12, //2X,'NUMBER OF ITERATIONS' I15,
     4//2X,'OR CODE' I28, //
     52X'DOCUMENTATION LEVEL' I16 )
C
   14 DO 16 J=1,NT
      HF(J)=0.0
      U(J)=0.0
      W(J)=0.0
      Q(J)=0.0
      DO 15 I=1,NC
   15 X(I,J)=0.0
      DO 16 I=1,N1
   16 F(I,J)=0.0
C
C
      TA(1)=TTOP
      TA(NT)=TBOT
      NDTRAY = DTRAY
      IF (NDTRAY.EQ.0) GO TO 41
      NTMID=NDTRAY+1
      IF(NTMID.GE.NT)GOTO41
      DT=(TMID-TA(1))/FLOAT(NTMID-1)
      DO 31 J=2,NTMID
   31 TA(J)=TA(J-1)+DT
      DT=(TA(NT)-TMID)/FLOAT(NT-NTMID)
      NTMIDP=NTMID+1
      DO 32 J=NTMIDP,NTM1
   32 TA(J+1)=TA(J)+DT
      GOTO50
C
   41 DT=(TBOT-TTOP)/FLOAT(NTM1)
      DO 42 J=2,NTM1
   42 TA(J)=TA(J-1)+DT
C
   50 QG=QR*1.0E6
      IF (QR.EQ.0.0) GO TO 60
      WRITE (6,112) QR
  112 FORMAT (/2X,'REBOILER DUTY, MMBTU/HR' F20.6)
      Q(NT)=-QG
C
   60 IF (DIST.GT.0.0) GO TO 62
      WRITE (6,121)
  121 FORMAT (///20X,'INVALID DISTILLATE RATE'///)
      MOGO=1
C
```

```
   62 WRITE (6,122) DIST
  122 FORMAT (/2X,'OVERHEAD VAPOR PRODUCT, MOLS/HR' F10.3)
C
      WRITE (6,123) TTOP,TBOT
  123 FORMAT (/2X,'INPUT TEMPERATURES, DEG F' /
     17X 'TOP TRAY' F12.1 / 7X 'BOTTOM TRAY' F9.1 )
      IF (NDTRAY.EQ.0) GO TO 64
      WRITE (6,124) TMID,NDTRAY
  124 FORMAT (2X 'TEMPERATURE ESTIMATED AS' F8.1,2X'DEG F ON TRAY'I4)
C
   64 WRITE (6,125) PTOP, DPTWR, PP(1), PP(NT)
  125 FORMAT (/2X, 'INPUT PRESSURES, PSIA' / 7X'OVERHEAD'F18.4
     1/7X 'TOWER DELTA P' F13.4/ 7X 'TOWER TOP' F17.4
     2/7X 'TOWER BOTTOM' F14.4 )
C
      DO 68 J=1,NF
      READ (5,131) (NAMEF(I,J),I=1,3),NFTRAY(J),PF(J),TF(J),QFN(J),
     1             QEX(J)
  131 FORMAT (3A4,I3,4F10.0)
      READ (5,102) (ZF(I,J),I=1,NC)
      IF(QFN(J).NE.0.0)GOTO68
      READ (5,102) (ZK(I,J),I=1,NC)
C
   68 CONTINUE
      IF(NSS.EQ.0)GOTO70
      DO 69 J=1,NSS
   69 READ (5,133) NSTRAY(J),XW(J),XU(J),QSS(J)
  133 FORMAT (I5,5X,3F10.0)
C
   70 CALL CDATA
      CALL ZFEED (SUMFD)
C
      IF(NSS.EQ.0)GOTO80
      WRITE(6,141)
  141 FORMAT(1H1 2X 'SIDESTREAM AND HEAT TRAY DATA' / 7X 'TRAY NO'7X'VAP
     1OR MOLS/HR' 7X 'LIQUID MOLS/HR' 7X 'HEAT OUT MMBTU/HR')
      DO 79 N=1,NSS
   79 WRITE (6,142) N,NSTRAY(N),XW(N),XU(N),QSS(N)
  142 FORMAT (I4,I5,2F12.2,F15.6)
C
   80 SUM=DIST
      IF(NSS.EQ.0)GOTO90
      DO 81 J=1,NSS
      K=NSTRAY(J)
      U(K)=XU(J)
      W(K)=XW(J)
      Q(K)=QSS(J)*1.0E6
   81 SUM=SUM+U(K)+W(K)
C
   90 IF(SUMFD-SUM .GT. 0.0)GOTO92
```

```
      WRITE (6,145)
  145 FORMAT (///20X 'BOTTOMS RATE IS INVALID')
      NOGO=1
C
   92 V(1)=DIST
      V(NT)=0.8*(SUMFD-DIST)
      XL(1)=0.5*F(N1,1)
      XL(NT)=SUMFD-SUM
      IF (NOGO.NE.0) RETURN 1
C
      DV=(V(NT)-V(1))/FLOAT(NTM1)
      DL=(XL(NT)-XL(1))/FLOAT(NTM1)
      DO 93 J=2,NTM1
      V(J)=V(J-1)+DV
   93 XL(J)=XL(J-1)+DL
      DO 94 J=1,NT
   94 CALL KGEN (TA(J),EK(1,J),J)
C
C
C
C            W = VAPOR     U = LIQUID
      DO 99 I=1,NC
      A(1)=0.0
      B(1)=V(1)*(1.0-EK(I,1))-V(2)-F(N1,1)
      C(1)=V(2)*EK(I,2)
      D(1)=-F(I,1)
      SUMJM1=F(N1,1)-DIST
      SUMJ=F(N1,2)-W(2)-U(2)+F(N1,1)-DIST
      DO 95 J=2,NTM1
      A(J)=V(J)+SUMJM1
      B(J)=-((V(J)+W(J))*EK(I,J)+V(J+1)+SUMJ+U(J))
      C(J)=V(J+1)*EK(I,J+1)
      D(J)=-F(I,J)
      SUMJM1=SUMJM1+F(N1,J)-W(J)-U(J)
   95 SUMJ=SUMJ+F(N1,J+1)-W(J+1)-U(J+1)
      A(NT)=V(NT)+XL(NT)-F(N1,NT)
      B(NT)=-V(NT)*EK(I,NT)-XL(NT)
      C(NT)=0.0
      D(NT)=-F(N1,NT)
      AX(1)=C(1)/B(1)
      BX(1)=D(1)/B(1)
      DO 96 J=2,NTM1
   96 AX(J)=C(J)/(B(J)-A(J)*AX(J-1))
      DO 97 J=2,NT
   97 BX(J)=(D(J)-A(J)*BX(J-1))/(B(J)-A(J)*AX(J-1))
      X(I,NT)=BX(NT)
      IF( X(I,NT) .LE. 0.0 ) X(I,NT)= 1.0E-25
      DO 98 K=1,NTM1
      J=NT-K
      X(I,J)=BX(J)-AX(J)*X(I,J+1)
```

```
      IF ( X(I,J) .LE. 0.0 ) X(I,J) = 1.0E-25
   98 CONTINUE
   99 CONTINUE
C
C
C
C
      RETURN
      END
```

```
      SUBROUTINE CDATA
C
      COMMON   //        X(20,100), V(100), XL(100), U(100), W(100),
     1                   Q(100), HL(100), HV(100), TA(100), F(21,100),
     2                   HF(100), PP(100), QG, DIST
      COMMON   /CONTRL/  NC, NT, LODC, NIO, NTM1, KTOP,
     1                   N1, N2, N3, N3N3
      COMMON   /PROP/    CNAME(2,20), XMW(20), RHO(20)
      COMMON   /DATA1/   NK, EKTABL(8,20), TK(8),
     1                   PA, PK(8), KCODE
      COMMON   /DATA2/   NH, HLTABL(8,20), HVTABL(8,20), TH(8), PH(8)
      COMMON   /COEF/    CK(8,20),DCK(7,20),CHV(6,20),
     1                   DCHV(5,20),CHL(6,20),DCHL(5,20),
     2                   PPA,HCODE
C
      REAL               T(20),AK(20,20),AHV(20,20),AHL(20,20)
      EQUIVALENCE        (AK(1,1),AHV(1,1))
C
      WRITE (6,100)
  100 FORMAT (1H1)
C
      READ (5,101) ((CNAME(K,J),K=1,2),XMW(J),RHO(J),J=1,NC)
  101 FORMAT (2A4,2X,2F10.0)
      WRITE (6,102)
  102 FORMAT (2X, 'DATA ON COMPONENTS',// 8X, 'NAME', 17X, 'MOL WT', 8X,
     1 'LBS/GAL' /)
      WRITE (6,103) (J,(CNAME(K,J),K=1,2),XMW(J),RHO(J),J=1,NC)
  103 FORMAT (I6,2X,2A4,F18.3,F15.4)
C
   21 READ (5,115) (TK(J),J=1,NK)
  115 FORMAT (8F10.0)
      READ (5,115) (PK(J),J=1,NK)
      READ (5,115) ((EKTABL(K,J),K=1,8),J=1,NC)
C
      WRITE (6,100)
C
   41 WRITE (6,122) (TK(J),J=1,NK)
  122 FORMAT (//2X 'MAIN COLUMN K-TABLE' //4X,'TEMPERATURE, F '8F14.2)
      WRITE (6,123) (PK(J),J=1,NK)
  123 FORMAT ( 4X 'PRESSURE, PSIA ' 8F14.4)
      WRITE (6,125)
  125 FORMAT (/)
      DO 43 J=1,NC
   43 WRITE (6,124) (CNAME(K,J),K=1,2),(EKTABL(K,J),K=1,NK)
  124 FORMAT (5X,2A4,6X,8F14.5)
C
      DO 45 J=1,NC
      DO 45 K=1,NK
   45 EKTABL(K,J)=ALOG(EKTABL(K,J))
C
```

```
C          KCODE  ---   PRESSURE CORRECT K-DATA
C            1          K-DATA ALREADY CORRECTED
C            2          PRESSURE CORRECT K-DATA
C
      PA=PK(1)
   48 KCODE=1
      NKM1=NK-1
      DO 49 J=1,NKM1
      IF (ABS(PK(J)-PK(J+1)).GT.0.001) GO TO 50
   49 CONTINUE
      KCODE = 2
      WRITE (6,126)
  126 FORMAT(//2X, ',K-DATA WILL BE PRESSURE CORRECTED TO THE TRAY PRESSU
     1RE USING THE K-DATA REFERENCE PRESSURE AS THE DATUM')
C
   50 WRITE (6,100)
C
      READ (5,127) JCODE,(TH(J),J=1,NH)
  127 FORMAT (I1,F9.0,7F10.0)
C
C          JCODE --- UNITS OF ENTHALPY DATA
C            1    BTU/MOLE
C            2    BTU/LB
C
      READ (5,115) (PH(K),K=1,NH)
      READ (5,115) ((HVTABL(K,J),K=1,8),(HLTABL(K,J),K=1,8),J=1,NC)
      GO TO (55,51),JCODE
   51 DO 52 J=1,NC
      DO 52 K=1,NH
      HVTABL(K,J)=HVTABL(K,J)*XMW(J)
   52 HLTABL(K,J)=HLTABL(K,J)*XMW(J)
C
   55 WRITE (6,128) (TH(J),J=1,NH)
  128 FORMAT (//2X 'ENTHALPY TABLE'// 4X 'TEMPERATURE, F '8F14.2)
      WRITE (6,129) (PH(J),J=1,NH)
  129 FORMAT (4X 'PRESSURE, PSIA ' 8F14.4)
      WRITE (6,130)
  130 FORMAT ('0 VAPOR, BTU/MOLE')
      DO 56 J=1,NC
   56 WRITE (6,131) (CNAME(K,J),K=1,2),(HVTABL(K,J),K=1,NH)
  131 FORMAT (5X,2A4,6X,8F14.1)
      WRITE (6,133)
  133 FORMAT ('0 LIQUID, BTU/MOLE')
      DO 57 J=1,NC
   57 WRITE (6,131) (CNAME(K,J),K=1,2),(HLTABL(K,J),K=1,NH)
C
      PPA=PA
      MCODE=KCODE
      KCODE=0
      DT=AMAX1((TA(NT)-T(1))/2.0,50.)
```

```
          T(1)=TA(1)-DT
          T(20)=TA(NT)+DT
          DT=(T(20)-T(1))/19.
          DO 62 J=2,19
   62     T(J)=T(J-1)+DT
          DO 63 K=1,20
   63     CALL KGEN(T(K),AK(1,K),K)
          DO 65 J=2,20
          JM1=J-1
          DO 65 K=1,JM1
          HOLD=AK(J,K)
          AK(J,K)=AK(K,J)
   65     AK(K,J)=HOLD
          NPWR=4
          DO 66 J=1,NC
          HOLD=1.0
   66     HOLD=FITIT(T,AK(1,J),20,NPWR,CK(1,J),1,HOLD)
          KCODE=NCODE
          NPWRM1=NPWR-1
          DO 67 J=1,NC
          DCK(1,J)=CK(1,J)-1.0
          DO 67 K=2,NPWRM1
   67     DCK(K,J)=CK(K+1,J)*FLOAT(K-1)
          DO 68 K=1,20
   68     CALL HGEN(T(K),AHV(1,K),AHL(1,K))
          DO 71 J=2,20
          JM1=J-1
          DO 71 K=1,JM1
          HOLD=AHV(J,K)
          AHV(J,K)=AHV(K,J)
          AHV(K,J)=HOLD
          HOLD=AHL(J,K)
          AHL(J,K)=AHL(K,J)
   71     AHL(K,J)=HOLD
          NPWR=3
          DO 73 J=1,NC
          HOLD=1.0
          HOLD=FITIT(T,AHV(1,J),20,NPWR,CHV(1,J),1,HOLD)
          HOLD=1.0
   73     HOLD=FITIT(T,AHL(1,J),20,NPWR,CHL(1,J),1,HOLD)
          NPWRM1=NPWR-1
          DO 75 J=1,NC
          DCHV(1,J)=CHV(1,J)-1.0
          DCHL(1,J)=CHL(1,J)-1.0
          DO 75 K=2,NPWRM1
          DCHV(K,J)=CHV(K+1,J)*FLOAT(K-1)
   75     DCHL(K,J)=CHL(K+1,J)*FLOAT(K-1)
      C
          RETURN
          END
```

```
      SUBROUTINE ZFEED ( SUMT )
C
      COMMON   //        X(20,100), V(100), XL(100), U(100), W(100),
     1                   Q(100), HL(100), HV(100), TA(100), F(21,100),
     2                   HF(100), PP(100), QG, DIST
      COMMON   /CNTRL/   NC, NT, LOOC, N10, NTM1, KTOP,
     1                   N1, N2, N3, N3N3
      COMMON   /PROP/    CNAME(2,20), XMW(20), RHO(20)
      COMMON   /FFDATA/  NF, NAMEF(3,6), NFTRAY(6), ZF(21,6), ZK(20,6),
     1                   QFN(6), TF(6), PF(6), QOQ(6), QEX(6), TTF(6)
C
      REAL               QFG(6), QFC(6), AX(6), BX(6), QV(6), QL(6),
     1                   XLL(20), VV(20), YK(20)
C
      WRITE (6,100)
  100 FORMAT (1H1)
C
      WRITE (6,111) (J,J=1,NF)
  111 FORMAT (//5X,15HINPUT FEED DATA/7X,7HFEED NO,14X,6I14)
      WRITE (6,112) ((NAMEF(I,J),I=1,3),J=1,NF)
  112 FORMAT (7X,9HFEED NAME,21X,6(3A4,2X))
      WRITE (6,116) (NFTRAY(J),J=1,NF)
  116 FORMAT (7X,19HENTERING AT TRAY NO,2X,6I14/)
C
      DO 10 N=1,NF
      ZF(N1,N)=0.0
      DO 10 I=1,NC
   10 ZF(N1,N)=ZF(N1,N)+ZF(I,N)
C
      WRITE (6,117)
  117 FORMAT (7X,19HCOMPOSITION,MOLS/HR)
      DO 19 I=1,NC
   19 WRITE (6,120) (CNAME(K,I),K=1,2),(ZF(I,K),K=1,NF)
  120 FORMAT (8X,2A4,14X,6F14.2)
      WRITE (6,121) (ZF(N1,N),N=1,NF)
  121 FORMAT (7X,5HTOTAL,18X,6F14.2)
C
C          FEED HEAT CONTENT NOT GIVEN IF QFN = 0.0
C
      SUMT=0.0
      DO 40 N=1,NF
      IF (QFN(N).NE.0.0) GO TO 21
C
C           FEED ENTHALPY IS NOT GIVEN AND MUST BE CALCULATED.
C
      CALL FLASH (ZF(1,N),ZK(1,N),TF(N),VV,XLL,QV(N),QL(N),QFN(N))
C
      QFG(N)=0.
      QFC(N)=QFN(N)
      GO TO 22
```

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```
      C
   21 QFN(N)=QFN(N)*1.0E6
      QFG(N)=QFN(N)
      QEC(N)=0.
      C
      C        ADIABATIC FLASH ON FEEDS TO DETERMINE VAPORIZATION AT ENTRY
      C
   22 K=NFTRAY(N)
      QEX(N)=QEX(N)*1.0E6
      QQQ(N)=QFN(N)+QEX(N)
      C
      C         QQQ(N) IS TOTAL FEED ENTHALPY AT ENTRY TO TOWER.
      C
      TTT=TA(1)-100.
      TBIG=TA(NT)+100.
      TOL=QQQ(N)*1.0E-4
      C
   23 CALL KGEN (TTT,YK,K)
      CALL FLASH (ZF(1,N),YK,TTT,VV,XLL,QV(N),QL(N),QQ)
      C WRITE (6,200) QQ,QQQ(N),TOL,TTT
      C 200 FORMAT (4E25.7)
      C
      IF ( WAYA(QQ,QQQ(N),TOL,TTT,TBIG,2) ) 23,27,26
      C
   26 WRITE (6,122) N
  122 FORMAT (// 5X 'FEED FLASH FAILED TO CONVERGE FOR FEED #' I3 //)
      C
   27 QV(N)=QV(N)/QQQ(N)*QQ
      QL(N)=QL(N)/QQQ(N)*QQ
   28 TTF(N)=TTT
      AX(N)=0.0
      BX(N)=0.0
      DO 29 I=1,NC
      AX(N)=AX(N)+VV(I)
   29 BX(N)=BX(N)+XLL(I)
      C
      IF (K-2) 34,38,32
   32 IF (K-NTM1) 38,38,34
   34 AXBX=ZF(N1,N)
      QFK=F(N1,K)*HF(K)
      DO 37 I=1,NC
   37 F(I,K)=F(I,K)+ ZF(I,N)
      F(N1,K)=F(N1,K)+AXBX
      IF(F(N1,K).NE.0.0) HF(K)=(QFK+QQ)/F(N1,K)
      GO TO 40
      C
   38 QFKM1=F(N1,K-1)*HF(K-1)
      QFK=F(N1,K)*HF(K)
      DO 39 I=1,NC
      F(I,K-1)=F(I,K-1)+VV(I)
```

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```
   39 F(I,K)=F(I,K)+XLL(I)
      F(N1,K-1)=F(N1,K-1)+AX(N)
      F(N1,K)=F(N1,K)+BX(N)
      IF (F(N1,K-1).NE.0.0) HF(K-1)=(QFKM1+QV(N))/F(N1,K-1)
      IF (F(N1,K).NE.0.0) HF(K)=(QFK+QL(N))/F(N1,K)
   40 SUMT=SUMT+ZF(N1,N)
C
C
      WRITE (6,123)(TF(N),N=1,NF)
  123 FORMAT (/7X 'TEMPERATURE, F' 9X 6F14.1)
      WRITE (6,124)(PF(N),N=1,NF)
  124 FORMAT (7X 'PRESSURE, PSIA' 9X 6F14.4)
      WRITE (6,125)(QFC(N),N=1,NF)
  125 FORMAT (/7X 'HEAT CONTENT, BTUS (CALC)' F12.0,5F14.0)
      WRITE (6,126) (QFG(N),N=1,NF)
  126 FORMAT ( 7X 'HEAT CONTENT, BTUS (GIVEN)' F11.0,5F14.0)
      WRITE (6,127) (QEX(N),N=1,NF)
  127 FORMAT (/7X 'ADDITIONAL HEAT, BTUS' 2X 6F14.0)
      WRITE (6,128) (QQQ(N),N=1,NF)
  128 FORMAT (/7X 'HEAT CONTENT, BTUS (INLET)' F11.0,5F14.0)
      WRITE (6,129) (TTF(N),N=1,NF)
  129 FORMAT (7X 'TEMPERATURE, F (INLET)' 1X 6F14.2)
      WRITE (6,130) (AX(N),N=1,NF)
  130 FORMAT (/7X 'VAPOR, MOLS (INLET)' 4X 6F14.3)
      WRITE (6,131) (BX(N),N=1,NF)
  131 FORMAT (7X 'LIQUID, MOLS (INLET)' 3X 6F14.3)
C
      RETURN
      END
```

```
      SUBROUTINE  FLASH  (XX,ZK,TT,XV,XL,QV,QL,QQT)
C
      COMMON  /CONTRL/  NC, NT, LOOC, NID, NTM1, KTOP,
     1                  N1, N2, N3, N3N3
C
      REAL              XX(1), ZK(1), XV(1), XL(1), HVAP(20), HLIQ(20)
C
C          SUM        TOTAL FEED
C          SUMX       TOTAL LIQUID
C          SUMY       TOTAL VAPOR
C
      SUM=0.0
      SUMX=0
      SUMY=0.
      DO 1 I=1,NC
      IF(XX(I).EQ.0.0)GOTO1
      SUM=SUM+XX(I)
      SUMY=SUMY+XX(I)*ZK(I)
      SUMX=SUMX+XX(I)/ZK(I)
    1 CONTINUE
C     WRITE (6,310) SUMX,SUMY,SUM
C 310 FORMAT('1' /3E25.7)
      IF (SUM -SUMY)4,2,2
C
C     SUBCOOLED LIQUID
C
    2 DO 3 I=1,NC
      XL(I)=XX(I)
    3 XV(I)=0.
      SUMX=SUM
      SUMY=0.0
C     WRITE (6,300)
C 300 FORMAT (////' SUBCOOLED LIQUID')
C     WRITE (6,20) (XX(J),ZK(J),XV(J),XL(J),J=1,NC)
C  20 FORMAT (4E20.6)
      GO TO 30
    4 IF (SUM -SUMX)7,5,5
C
C     SUPERHEATED VAPOR
C
    5 DO 6 I=1,NC
      XV(I)=XX(I)
    6 XL(I)=0.
      SUMY=SUM
      SUMX=0.0
C     WRITE (6,301)
C 301 FORMAT (////' SUPERHEATED VAPOR')
C     WRITE (6,20) (XX(J),ZK(J),XV(J),XL(J),J=1,NC)
      GO TO 30
C
```

```
C      TWO-PHASE SYSTEM
C
     7 XLF=0.9999999
       XLF$=0.0000001
C
     8 XVF=1.0-XLF
       SUMY=SUM*XVF
       SUMX=SUM*XLF
       YTOT=0.0
       XTOT=0.0
       DO 9 I=1,NC
       FAC=XLF+XVF*ZK(I)
       XV(I)=XX(I)/SUM *ZK(I)/FAC
       YTOT=YTOT+XV(I)
       XL(I)=XX(I)/SUM /FAC
     9 XTOT=XTOT+XL(I)
C
C   13 WRITE (6,200)
C  200 FORMAT (////' MIXED PHASE')
C      WRITE (6,410) SUMX,SUMY,SUM ,YTOT,XTOT
C  410 FORMAT (5E25.7)
C      WRITE (6,20) (XX(J),ZK(J),XV(J),XL(J),J=1,NC)
       IF ( WAYA (    (YTOT-XTOT),0.0,0.000005,XLF,XLF$,1) ) 8,22,18
C
    18 WRITE (6,100)
   100 FORMAT (//5X 'FEED FLASH CALCULATION FAILED TO CONVERGE'
     + /5X 'LIQUID FRACTION EITHER > 0.999999 OR < 0.000001' / 5X 'CALCU
     2LATION CONTINUING' //)
C
    22 DO 24 I=1,NC
       XL(I)=XL(I)*SUMX
    24 XV(I)=XV(I)*SUMY
C
    30 QV=0.0
       QL=0.0
       CALL HGEN (TT,HVAP,HLIQ)
       DO 32 I=1,NC
       QV=QV+HVAP(I)*XV(I)
    32 QL=QL+HLIQ(I)*XL(I)
       QOT=QV+QL
C
       RETURN
       END
```

```
      SUBROUTINE  INR  (*,*)
C
      COMMON   //         X(20,100), V(100), XL(100), U(100), W(100),
     1                    Q(100), HL(100), HV(100), TA(100), F(21,100),
     2                    HF(100), PP(100), QG, DIST
      COMMON   /CONTRL/   NC, NT, LODC, NIO, NTM1, KTOP,
     1                    N1, N2, N3, N3N3
      COMMON   /FIX/      A(23,23), B(23,23), C(23,23,3), D(23,100)
C
      REAL                Z(1), CC(5290)
      EQUIVALENCE         (Z,A)
C
      DATA                DXMAX/0.00050/, DLVMAX/0.001/, DTMAX/0.05/
C
      WRITE (6,102)
      CALL MWRITE
      IF (LODC.LE.2) WRITE (6,102)
C
      DO 1 J=1,NT
      IF ( XL(J) GT.0.0) GO TO 1
      WRITE (6,100)
  100 FORMAT (///20X 'AN INITIAL LIQUID FLOW IS ZERO OR NEGATIVE'///)
      RETURN 1
    1 CONTINUE
C
    2 NN=0
      NNN=-9
      NMAX=5290/N3N3
      NCHECK=0
      NDONE=0
C
C
      DO 90 NIT=1,NIO
C
      DO 14 J=1,NT
      SUM = 0.0
      DO 12 K=1,NC
   12 SUM=SUM+X(K,J)
      DO 13 K=1,NC
   13 X(K,J)=X(K,J)/SUM
   14 CONTINUE
C
C     GENERAL PROCEDURE IS TO SOLVE A TRIDIAGONAL MATRIX BY
C         (1) CLEARING THE LOWER LEFT ELEMENTS AND MAKING THE
C             DIAGONAL ELEMENTS THE IDENTITY MATRIX
C         (2) CLEARING THE UPPER RIGHT ELEMENTS BY BACK SUBSTITUTION
C
      DO  40   I=1,NT
C
      CALL ABCD (I)
```

```
      IF (I.EQ.1) GO TO 23
C
      DO 22 L=1,N3
      DPM=0.0
      DO 21 K=1,N3
      DPM=DPM+A(L,K)*D(K,I-1)
      DDN=0.0
      DO 20 M=1,N3
   20 DDN=DDN+A(K,M)*C(M,L,1)
   21 B(K,L)=B(K,L)-DDN
   22 D(L,I)=D(L,I)-DPM
C
   23 L=0
      DO 24 N=1,N3
      DO 24 M=1,N3
      L=L+1
   24 Z(L)=B(M,N)
      CALL MINV (Z,N3,DETRM,B(1,1),B(1,2))
      IF (DETRM.EQ.0.0) GO TO 61
      L=0
      DO 25 N=1,N3
      DO 25 M=1,N3
      L=L+1
   25 B(M,N)=Z(L)
      IF(I.EQ.NT)GOTO30
C
      DO 27 L=1,N3
      DO 27 K=1,N3
      A(K,L)=0.
      DO 27 M=1,N3
   27 A(K,L)=A(K,L)+B(K,M)*C(M,L,2)
      DO 28 L=1,N3
      DO 28 K=1,N3
   28 C(K,L,2)=A(K,L)
C
   30 DO 31 K=1,N3
      Z(K)=0.0
      DO 31 M=1,N3
   31 Z(K)=Z(K)+B(K,M)*D(M,I)
      DO 33 K=1,N3
   33 D(K,I)=Z(K)
      IF (I.EQ.NT) GO TO 41
C
      L=NN*N3N3
      DO 36 N=1,N3
      DO 36 M=1,N3
      L=L+1
   36 CC(L)=C(M,N,2)
      NN=NN+1
      IF (NN.LT.NMAX)GO TO 37
```

```
      IF ( NTM1.LE.NMAX ) GO TO 37
      NN=0
      NNN=NNN+10
      WRITE (10'NNN) CC
   37 DO 38 L=1,N3
      DO 38 K=1,N3
      C(K,L,1)=C(K,L,2)
   38 C(K,L,2)=0.0
   40 CONTINUE
C
   41 DO 46 N=1,NTM1
      I=NT-N
      IF ( NN.GT.0 ) GO TO 42
      READ ( 10'NNN ) CC
      NN=NMAX
      NNN=NNN-10
   42 L=(NN-1)*N3N3
      DO 43 K=1,N3
      DO 43 M=1,N3
      L=L+1
   43 C(M,K,2)=CC(L)
      NN=NN-1
      DO 45 K=1,N3
      DPM=0.0
      DO 44 M=1,N3
   44 DPM=DPM+C(K,M,2)*D(M,I+1)
   45 D(K,I)=D(K,I)-DPM
   46 CONTINUE
C
      IF (LDOC.NE.4) GO TO 50
      WRITE (6,102)
      DO 49 N=1,NT
      WRITE (6,119) N,(D(J,N),J=1,N3)
  119 FORMAT (//' COMPUTED CORRECTIONS ON STAGE' I10/(1P5E20.5))
   49 CONTINUE
C
C     CHECK FOR CONVERGENCE
C         (1) MAXIMUM  ABS(DX) .LT. DXMAX                X = COMPOSITION
C         (2) MAXIMUM  ABS(DF)/F .LT. DFVMAX             F = FLOW L & V
C         (3) MAXIMUM  ABS(DT) .LT. DTMAX                T = TEMPERATURE
C     SCALE CORRECTIONS IF TOO LARGE --- CAUSE FOR SCALING
C         (1)  X .LE. 0.0  .AND.  X .GE. 1.0
C         (2)  DF .GT. 0.20*F
C         (3)  DT .GT. 20.0
C
   50 RX=0.0
      RT=0.0
      DLV=0.0
      SUMSQ=0.0
C
```

```
      DO 52 N=1,NT
C     IF (ABS(D(N3,N)).GT.5000.) GO TO 53
      SUMSQ=SUMSQ+D(N3,N)**2
      DLV=AMAX1(ABS(D(N1,N))/XL(N),ABS(D(N2,N))/V(N),DLV)
      DT=AMAX1(ABS(D(N3,N)),DT)
      DO 51 J=1,NC
   51 DX=AMAX1(ABS(D(J,N)),DX)
   52 CONTINUE
C
      IF(DX.LT.DXMAX .AND. DLV.LT.DLVMAX .AND. DT.LT.DTMAX)NDONE=1
      IF(NDONE.EQ.1) GO TO 54
   53 NCHECK=NCHECK+1
      GO TO 55
   54 IF (NCHECK.EQ.0) GO TO 55
      NDONE=0
      NCHECK=0
C
   55 DO 57 N=1,NT
      DO 57 J=1,NC
      CK=X(J,N)+D(J,N)
      IF(X(J,N).LT.1.0E-6) GO TO 56
      IF(CK.LE.0.0 .OR. CK.GE.1.0) GO TO 59
      GO TO 57
   56 IF (CK.LE.0.0) D(J,N)=SIGN(X(J,N)/2.0,D(J,N))
   57 CONTINUE
      GOTO61
   59 NDONE=0
      DO 60 N=1,NT
      DO 60 J=1,NC
   60 D(J,N)=D(J,N)*0.5
      GOTO55
C
   61 DO 62 N=1,NT
      IF (ABS(D(N1,N)).GT.0.20*XL(N) .OR. ABS(D(N2,N)).GT.0.20*V(N))
     1 GOTO65
   62 CONTINUE
      GOTO71
   65 NDONE=0
      DO 67 N=1,NT
      DO 67 K=N1,N2
   67 D(K,N)=D(K,N)*0.5
      GOTO61
C
   71 DO 72 N=1,NT
      IF (ABS(D(N3,N)).GT.20.0) GO TO 75
   72 CONTINUE
      GOTO81
   75 NDONE=0
      DO 76 N=1,NT
   76 D(N3,N)=D(N3,N)*0.5
```

```
      GOTO71
C
   81 DO 84 N=1,NT
      DO 83 J=1,NC
   83 X(J,N)=X(J,N)+D(J,N)
      XL(N)=XL(N)+D(N1,N)
      V(N)=V(N)+D(N2,N)
   84 TA(N)=TA(N)+D(N3,N)
C
   85 IF ( LDOC .EQ. 1 ) GO TO 89
      IF (LDOC.GT.2) WRITE (6,102)
      WRITE (6,108) NIT,NCHECK,SUMSQ,DT,DLV,DX
  108 FORMAT ('0ITERATION NUMBER' I5,I80/ ' SUM DT SQUARED' F20.6, 10X
     1 'DT MAX' F20.6/ ' MAX DF/F' F26.6, 10X 'MAX DX' F20.6)
      IF (LDOC.EQ.2 .AND. MOD(NIT,15).EQ.0) WRITE (6,102)
C
   87 GO TO (89,89,88,88), LDOC
   88 CALL MWRITE
   89 IF (NDONE.EE.0) GO TO 93
C
C
   90 CONTINUE
      GO TO 93
C
C
   91 WRITE (6,101) I
  101 FORMAT (/// 20X 'PROBLEM CANNOT INVERT MATRIX ON STAGE' I5, 20X
     1 'CHECK INPUT DATA'///)
      WRITE(6,102)
  102 FORMAT (1H1)
      CALL MWRITE
      RETURN 1
C
C     CONVERGENCE CHECK
C
   93 IF (NDONE.NE.0) GO TO 95
      WRITE (6,111)
  111 FORMAT (///20X 'NO CLOSURE OBTAINED ON PROBLEM FOR SPECIFIED NUMBE
     1R OF TRIALS'///)
      WRITE (6,102)
      CALL MWRITE
      RETURN 2
C
   95 GO TO (96,96,999,999), LDOC
   96 WRITE (6,102)
      CALL MWRITE
C
  999 RETURN
      END
```

```
      SUBROUTINE ABCD (I)
C
      COMMON    //        X(20,100), V(100), XL(100), U(100), W(100),
     1                    Q(100), HL(100), HV(100), TA(100), F(21,100),
     2                    HF(100), PP(100), QG, DIST
      COMMON    /CONTRL/  NC, NT, LOOC, NIO, NTM1, KTOP,
     1                    N1, N2, N3, N3N3
      COMMON    /DATA/    WK(20), DK(20), HVV(20), HLL(20), DHV(20),
     1                    DHL(20), Y(20)
      COMMON    /FIX/     A(23,23), B(23,23), C(23,23,3), D(23,100)
C
      REAL                Z(1)
      EQUIVALENCE         (B(1,1),Z(1))
C
      ASSIGN 46 TO JJ
C
      IF (I.GT.1) GO TO 14
      IF (LOOC.EQ.4) WRITE (6,101)
  101 FORMAT ('1')
C
C     CLEAR AREA /FIX/  --  B, C, AND D ONLY
C
      DO 11 J=1,4416
   11 Z(J)=0.0
      CALL GET(1)
      GO TO 25
   14 IF (I.EQ.NT) ASSIGN 61 TO JJ
C
C     CLEAR B BEFORE GENERATING NON-ZERO ENTRIES
C     TRANSFER STAGE (I-1) DATA FROM C(K,J,3) INTO A
C     A CONTAINS STAGE (I-1) DATA
C
      DO 21 J=1,N3
      DO 21 K=1,N3
      B(K,J)=0.0
      A(K,J)=C(K,J,3)
   21 C(K,J,3)=0.0
C
C     B CONTAINS STAGE (I) DATA
C     D CONTAINS ERROR TERMS
C
   25 VW=V(I)+W(I)
      XLU=XL(I)+U(I)
      DO 32 J=1,NC
      B(J,J)=-VW*WK(J)-XLU
      B(J,N1)=-X(J,I)
      B(J,N2)=-Y(J)
      B(J,N3)=-VW*X(J,I)*DK(J)
      D(J,I)=D(J,I)+(VW*WK(J)+XLU)*X(J,I)-F(J,I)
      B(N2,J)=1.0
```

```
      D(N2,I)=D(N2,I)-X(J,I)
      B(N3,J)=-VW*WK(J)*HVV(J)-XLU*HLL(J)
      B(N3,N1)=B(N3,N1)-X(J,I)*HLL(J)
      B(N3,N2)=B(N3,N2)-Y(J)*HVV(J)
      B(N3,N3)=B(N3,N3)-VW*(Y(J)*DHV(J)+HVV(J)*DK(J)*X(J,I))
     1        -XLU*DHL(J)*X(J,I)
      D(N3,I)=D(N3,I)+VW*Y(J)*HVV(J)+XLU*X(J,I)*HLL(J)
   32 CONTINUE
C
      B(N1,N1)=-1.0
      B(N1,N2)=-1.0
      D(N1,I)=D(N1,I)+VW+XLU-F(N1,I)
      D(N2,I)=D(N2,I)+1.0
      D(N3,I)=D(N3,I)+Q(I)-F(N1,I)*HF(I)
C
C     SINCE DATA FOR STAGE (I) IS NEEDED FOR NEXT ENTRY INTO FIXUP ---
C     GENERATE INFORMATION AND STORE A DATA IN NEXT C AND D VALUES WHERE
C     THEY BELONG
C
      GO TO JJ, (46,61)
   46 DO 49 J=1,NC
      C(J,J,3)=XL(I)
      C(J,N1,3)=X(J,I)
      D(J,I+1)=D(J,I+1)-XL(I)*X(J,I)
      C(N3,J,3)=XL(I)*HLL(J)
      C(N3,N1,3)=C(N3,N1,3)+X(J,I)*HLL(J)
      C(N3,N3,3)=C(N3,N3,3)+XL(I)*X(J,I)*DHL(J)
      D(N3,I+1)=D(N3,I+1)-XL(I)*X(J,I)*HLL(J)
   49 CONTINUE
      C(N1,N1,3)=1.0
      D(N1,I+1)=-XL(I)
C
C     GENERATE THERMODYNAMIC DATA FOR STAGE (I+1)
C     C CONTAINS STAGE (I+1) DATA
C         NOTE: THE STAGE (I+1) THERMODYNAMIC DATA WILL BE USED
C               ON NEXT ENTRY INTO FIXUP
C
      CALL GET(I+1)
      DO 51 J=1,NC
      C(J,J,2)=V(I+1)*WK(J)
      C(J,N2,2)=Y(J)
      C(J,N3,2)=V(I+1)*X(J,I+1)*DK(J)
      D(J,I)=D(J,I)-V(I+1)*Y(J)
      C(N3,J,2)=V(I+1)*WK(J)*HVV(J)
      C(N3,N2,2)=C(N3,N2,2)+Y(J)*HVV(J)
      C(N3,N3,2)=C(N3,N3,2)+V(I+1)*(Y(J)*DHV(J)+X(J,I+1)*HVV(J)*DK(J))
      D(N3,I)=D(N3,I)-V(I+1)*Y(J)*HVV(J)
   51 CONTINUE
      C(N1,N2,2)=1.0
      D(N1,I)=D(N1,I)-V(I+1)
```

```
C
   61 GO TO (71,71,71,67), LDOC
   67 WRITE (6,102) I,(D(J,I),J=1,N3)
  102 FORMAT (//' ERRORS ON STAGE' I10/(1P5E20.5))
C
C
   71 RETURN
      END
```

170

```
      SUBROUTINE MINV(A,N,D,L,M)
C
C        PURPOSE
C           INVERT A MATRIX
C
C        USAGE
C           CALL MINV(A,N,D,L,M)
C
C        DESCRIPTION OF PARAMETERS
C           A - INPUT MATRIX, DESTROYED IN COMPUTATION AND REPLACED BY
C               RESULTANT INVERSE.
C           N - ORDER OF MATRIX A
C           D - RESULTANT DETERMINANT
C           L - WORK VECTOR OF LENGTH N
C           M - WORK VECTOR OF LENGTH N
C
C        REMARKS
C           MATRIX A MUST BE A GENERAL MATRIX
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           THE STANDARD GAUSS-JORDAN METHOD IS USED. THE DETERMINANT
C           IS ALSO CALCULATED. A DETERMINANT OF ZERO INDICATES THAT
C           THE MATRIX IS SINGULAR.
C
C     ..................................................................
C
      DIMENSION A(1),L(1),M(1)
C
C        ...............................................................
C
C        IF A DOUBLE PRECISION VERSION OF THIS ROUTINE IS DESIRED, THE
C        C IN COLUMN 1 SHOULD BE REMOVED FROM THE DOUBLE PRECISION
C        STATEMENT WHICH FOLLOWS.
C
C     DOUBLE PRECISION A,D,BIGA,HOLD
C
C        THE C MUST ALSO BE REMOVED FROM DOUBLE PRECISION STATEMENTS
C        APPEARING IN OTHER ROUTINES USED IN CONJUNCTION WITH THIS
C        ROUTINE.
C
C        THE DOUBLE PRECISION VERSION OF THIS SUBROUTINE MUST ALSO
C        CONTAIN DOUBLE PRECISION FORTRAN FUNCTIONS.  ABS IN STATEMENT
C        10 MUST BE CHANGED TO DABS.
C
C        ...............................................................
C
C        SEARCH FOR LARGEST ELEMENT
```

```
C
      D=1.0
      NK=-N
      DO 80 K=1,N
      NK=NK+N
      L(K)=K
      M(K)=K
      KK=NK+K
      BIGA=A(KK)
      DO 20 J=K,N
      IZ=N*(J-1)
      DO 20 I=K,N
      IJ=IZ+I
   10 IF( ABS(BIGA)- ABS(A(IJ))) 15,20,20
   15 BIGA=A(IJ)
      L(K)=I
      M(K)=J
   20 CONTINUE
C
C        INTERCHANGE ROWS
C
      J=L(K)
      IF(J-K) 35,35,25
   25 KI=K-N
      DO 30 I=1,N
      KI=KI+N
      HOLD=-A(KI)
      JI=KI-K+J
      A(KI)=A(JI)
   30 A(JI) =HOLD
C
C        INTERCHANGE COLUMNS
C
   35 I=M(K)
      IF(I-K) 45,45,38
   38 JP=N*(I-1)
      DO 40 J=1,N
      JK=NK+J
      JI=JP+J
      HOLD=-A(JK)
      A(JK)=A(JI)
   40 A(JI) =HOLD
C
C        DIVIDE COLUMN BY MINUS PIVOT (VALUE OF PIVOT ELEMENT IS
C        CONTAINED IN BIGA)
C
   45 IF(BIGA) 48,46,48
   46 D=0.0
      RETURN
   48 DO 55 I=1,N
```

```
      IF(I-K) 50,55,50
   50 IK=NK+I
      A(IK)=A(IK)/(-BIGA)
   55 CONTINUE
C
C        REDUCE MATRIX
C
      DO 65 I=1,N
      IK=NK+I
      HOLD=A(IK)
      IJ=I-N
      DO 65 J=1,N
      IJ=IJ+N
      IF(I-K) 60,65,60
   60 IF(J-K) 62,65,62
   62 KJ=IJ-I+K
      A(IJ)=HOLD*A(KJ)+A(IJ)
   65 CONTINUE
C
C        DIVIDE ROW BY PIVOT
C
      KJ=K-N
      DO 75 J=1,N
      KJ=KJ+N
      IF(J-K) 70,75,70
   70 A(KJ)=A(KJ)/BIGA
   75 CONTINUE
C
C        PRODUCT OF PIVOTS
C
      D=D*BIGA
C
C        REPLACE PIVOT BY RECIPROCAL
C
      A(KK)=1.0/BIGA
   80 CONTINUE
C
C        FINAL ROW AND COLUMN INTERCHANGE
C
      K=N
  100 K=(K-1)
      IF(K) 150,150,105
  105 I=L(K)
      IF(I-K) 120,120,108
  108 JQ=N*(K-1)
      JR=N*(I-1)
      DO 110 J=1,N
      JK=JQ+J
      HOLD=A(JK)
      JI=JR+J
```

```
      A(JK)=-A(JI)
  110 A(JI) =HOLD
  120 J=M(K)
      IF(J-K) 100,100,125
  125 KI=K-N
      DO 130 I=1,N
      KI=KI+N
      HOLD=A(KI)
      JI=KI-K+J
      A(KI)=-A(JI)
  130 A(JI) =HOLD
      GO TO 100
  150 RETURN
      END
```

174

```
      SUBROUTINE GET(I)
C
      COMMON    //          X(20,100), Y(100), XL(100), U(100), W(100),
     1                      Q(100), HL(100), HV(100), TA(100), F(21,100),
     2                      HF(100), PP(100), QG, DIST
      COMMON    /CONTRL/    NC, NT, LOOC, NIO, HTM1, KTOP,
     1                      N1,N2,N3,N3N3
      COMMON    /DATA/      WK(20), DK(20), HVV(20), HLL(20), DHV(20),
     1                      DHL(20), Y(20)
      COMMON   /COEF/        CK(8,20),DCK(7,20),CHV(6,20),
     1                       DCHV(5,20),CHL(6,20),DCHL(5,20),
     2                       PPA,MCODE
C
      T=TA(I)
      SUM=0.0
      HV(I)=0.0
      HL(I)=0.0
      DO 11 J=1,NC
      WK(J)=EQUA(T,CK(1,J))
      DK(J)=EQUA(T,DCK(1,J))
      HVV(J)=EQUA(T,CHV(1,J))
      DHV(J)=EQUA(T,DCHV(1,J))
      HLL(J)=EQUA(T,CHL(1,J))
   11 DHL(J)=EQUA(T,DCHL(1,J))
      IF(MCODE.EQ.0) GO TO 19
      GO TO (19,14), MCODE
   14 PRATIO=PPA/PP(I)
      DO 17 J=1,NC
      WK(J)=WK(J)*PRATIO
   17 DK(J)=DK(J)*PRATIO
   19 DO 21 J=1,NC
      Y(J)=WK(J)*X(J,I)
      SUM=SUM+Y(J)
      HV(I)=HV(I)+HVV(I)*Y(J)
   21 HL(I)=HL(I)+HLL(I)*X(J,I)
      HV(I)=HV(I)/SUM
C
C
      RETURN
      END
```

```
      SUBROUTINE   OTPUT
C
C
      COMMON  //         X(20,100), V(100), XL(100), U(100), W(100),
     +                   Q(100), HL(100), HV(100), TA(100), F(21,100),
     +                   HF(100), PP(100), QG, DIST
      COMMON  /CONTRL/   NC, NT, LOOPC, NI, NTM1, KTOP,
     1                   N1,N2,N3,N3N3
      COMMON  /FFDATA/   NF, NAMEF(3,6), NFTRAY(6), ZF(21,6), ZK(20,6),
     +                   QFN(6), TF(6), PF(6), QQQ(6), QEX(6), TTF(6)
      COMMON  /PROP/     CNAME(2,20), XMW(20), RHO(20)
      COMMON  /FIX/      EK(20,100), Z(20), XX(20,11), IAA(2,9),
     +                   IBB(2,9), ICC(2,9), IDD(9), SUMM(11), SUMP(9),
     +                   SUMG(9), TEMP(9), QQS(9), NTT(9), NNN(9),
     +                   SLOP(2577)
      COMMON  /COEF/      CK(8,20),DCK(7,20),CHV(6,20),
     1                   DCHV(5,20),CHL(6,20),DCHL(5,20),
     2                   PPA,MCODE
C
      DATA               NOUT /6/
C
      INTEGER  BLANK /'    '/,                  MOLS /'MOLS'/,
     +         FDNO(2) /'FEED',' NO '/,        TRNO(2) /'TRAY',' NO '/,
     +         COMB(2) /'COMB','INED'/,        FD(2)   /' FE','ED  '/,
     +         OVHD(2) /'OVER','HEAD'/,        LIQ(2)  /' LIQ','UID '/,
     +         VAP(2)  /' VAP','OR  '/,        PROD(2) /' PRO','DUCT'/,
     +         BTM(2)  /' BOT','TOMS'/,
     +         SSNO(2) /' SS ',' NO '/
C
C
      NBLK=0
      TA(1)=TA(1)+ABS(DTSUB)
      DO 10 N=1,NT
      PRATIO=1.0
      IF(MCODE.EQ.0) GO TO 8
      GO TO ( 8,6), MCODE
    6 PRATIO=PPA/PP(N)
    8 DO 10 J=1,NC
   10 EK(J,N)=EQUA(TA(N),CK(1,J))*PRATIO
      TA(1)=TA(1)-ABS(DTSUB)
C
      WRITE (NOUT,201)
  201 FORMAT ( '1FEED AND PRODUCT COMPOSITIONS' // )
C
      ASSIGN 15 TO INDEX
C
   11 K=0
      DO 12 J=1,9
      SUMM(J)=0.0
      SUMP(J)=0.0
```

```
      SUMG(J)=0.0
      QQS(J)=0.0
      TEMP(J)=0.0
C
      NTT(J)=BLANK
      NNN(J)=BLANK
      IDD(J)=MOLS
      DO 12 I=1,NC
   12 XX(I,J)=0.0
C
      DO 13 J=1,2
      DO 13 I=1,9
      IAA(J,I)=BLANK
      IBB(J,I)=BLANK
   13 ICC(J,I)=BLANK
C
      GO TO INDEX, (15,41,47,61,70)
C
C     CALCULATE SEPARATE FEEDS
C
   15 DO 17 N=1,NF
      K=K+1
      L=NFTRAY(N)
      CALL ALNUM (L,NTT(K))
      CALL ALNUM (N,NNN(K))
      DO 16 I=1,NC
   16 XX(I,K)=ZF(I,N)
      SUMM(K)=ZF(N1,N)
      TEMP(K)=TTF(N)
      QQS(K)=QQQ(N)
      DO 17 J=1,2
      IAA(J,K)=FDNO(J)
   17 ICC(J,K)=TRND(J)
C
C     CALCULATE TOTAL FEED --- ONLY IF MORE THAN ONE FEED
C
      IF (NF.EQ.1) GO TO 30
      K=K+1
      DO 19 N=1,NF
      SUMM(K)=SUMM(K)+SUMM(N)
      QQS(K)=QQS(K)+QQS(N)
      DO 19 I=1,NC
   19 XX(I,K)=XX(I,K)+XX(I,N)
      DO 20 J=1,2
      IAA(J,K)=COBB(J)
   20 IBB(J,K)=FD(J)
C
C     CALCULATE OVERHEAD DISTILLATE   ***VAPOR***
C
   30 IF(V(1).EQ.0.0) GO TO 39
```

```
          K=K+1
          KK=KK+1
          DO 31 I=1,NC
       31 XX(I,K)=X(I,1)*EK(I,1)*V(1)
          SUMM(K)=V(1)
          TEMP(K)=TA(1)
          QQS(K)=SUMM(K)*HL(1)
          DO 32 J=1,2
          IAA(J,K)=OVHD(J)
          IBB(J,K)=VAP(J)
       32 ICC(J,K)=PROD(J)
C
C
C         CALCULATE SIDESTREAMS
C
       39 KK=0
          DO 58 M=2,NTM1
C
C         *** LIQUID SIDESTREAMS ***
C
          IF (U(M).EQ.0.0) GO TO 46
          IF (K.LT.9) GO TO 41
          ASSIGN 41 TO INDEX
          GO TO 64
       41 K=K+1
          DO 44 I=1,NC
       44 XX(I,K)=U(M)*X(I,M)
          SUMM(K)=U(M)
          QQS(K)=HL(M)*U(M)
          DO 45 J=1,2
       45 IBB(J,K)=LIQ(J)
          GO TO 53
C
C         *** VAPOR SIDESTREAMS ***
C
       46 IF (W(M).EQ.0.0) GO TO 58
          IF (K.LT.9) GO TO 47
          ASSIGN 47 TO INDEX
          GO TO 64
       47 K=K+1
          DO 49 I=1,NC
       49 XX(I,K)=X(I,M)*EK(I,M)
          SUMM(K)=W(M)
          QQS(K)=W(M)*HV(M)
          DO 52 J=1,2
       52 IBB(J,K)=VAP(J)
C
       53 CALL ALNUM (M-1,NTT(K))
          CALL ALNUM (KK+2,NNN(K))
          DO 54 J=1,2
```

```
      IAA(J,K)=SSND(J)
   54 ICC(J,K)=TRND(J)
      TEMP(K)=TA(M)
   58 CONTINUE
C
C     CALCULATE BOTTOMS
C
      IF (K.LT.9) GO TO 61
      ASSIGN 61 TO INDEX
      GO TO 64
   61 K=K+1
      DO 62 I=1,NC
   62 XX(I,K)=X(I,NT)*XL(NT)
      SUMM(K)=XL(NT)
      QQS(K)=SUMM(K)*HL(NT)
      TEMP(K)=TA(NT)
      DO 63 J=1,2
      IAA(J,K)=BTM(J)
   63 IBB(J,K)=PROD(J)
      ASSIGN 70 TO INDEX
C
C     PRINT OUT DATA SUMMARY
C
   64 NL=K
C
      WRITE (NOUT,111) ((IAA(N,K),N=1,2),NNN(K),K=1,NL)
  111 FORMAT (14X,27A4)
      WRITE (NOUT,112) ((IBB(N,K),N=1,2),K=1,NL)
  112 FORMAT (15X,8(2A4,4X),2A4)
      WRITE (NOUT,111) ((ICC(N,K),N=1,2),NTT(K),K=1,NL)
      WRITE (NOUT,113) (IDD(K),K=1,NL)
  113 FORMAT ( ' COMPONENT' 7X,A4, 8(8X,A4))
      DO 65 I=1,NC
   65 WRITE (NOUT,121) (CNAME(K,I),K=1,2),(XX(I,K),K=1,NL)
  121 FORMAT ( 1X,2A4,1X,9F12.4 )
C
      WRITE (NOUT,123) (SUMM(K),K=1,NL)
  123 FORMAT ( ' TOTAL' 4X,9F12.4 )
      DO 67 K=1,NL
      DO 66 I=1,NC
      FAC=XX(I,K)*XMW(I)
      SUMP(K)=SUMP(K)+FAC
   66 SUMG(K)=SUMG(K)+FAC/RHO(I)
   67 QQS(K)=QQS(K)/1000.0
      WRITE (NOUT,124) (SUMP(K),K=1,NL)
  124 FORMAT ( '0POUNDS' 3X,9F12.2 )
      WRITE (NOUT,126) (SUMG(K),K=1,NL)
  126 FORMAT ( ' GALLONS' 2X,9F12.2 )
      WRITE (NOUT,128) (QQS(K),K=1,NL)
  128 FORMAT ( '0Q, MBTU' 2X,9F12.3 )
```

```
      WRITE (NOUT,129) (TEMP(K),K=1,NL)
  129 FORMAT ( '0TEMP, F' 2X,9F12.2 )
C
      NBLK=NBLK+1
      GO TO (69,68), NBLK
C
   68 WRITE (NOUT,136)
  136 FORMAT ( '1' // )
      GO TO 11
C
   69 WRITE (NOUT,137)
  137 FORMAT (////)
      NBLK=0
      GO TO 11
C
C     CALCULATE AND PRINT-OUT TRAY SUMMARY
C
   70 WRITE (NOUT,140)
  140 FORMAT ( '1' 10X 'NET LIQUID & VAPOR LEAVING EACH STAGE' // )
C
      NL=4
      DO 71 J=8,10
   71 SUMM(J)=100.0
C
      DO 98 N=1,NT
      K=N
      IF(NL+NC+9.LT.58) GO TO 73
      WRITE (NOUT,140)
      NL=4
C
   73 IF (N.EQ.NT .AND. QG.NE.0.0) GO TO 74
      WRITE (NOUT,143) K,TA(N),PP(N)
  143 FORMAT ( '0  TRAY NO' I4,5X 'TEMP, F' F8.2,5X 'PRESS, PSIA' F8.2)
      GO TO 76
   74 WRITE (NOUT,144) TA(N),PP(N)
  144 FORMAT ( '0  REBOILER' 8X 'TEMP, F' F8.2,5X 'PRESS, PSIA' F8.2 )
C
   76 WRITE (NOUT,149)
  149 FORMAT ( 20X 7('- '),'VAPOR' 7(' -'),8X 12('- '),'LIQUID' 12(' -')
     + / ' NO  COMP' 10X 'MOLS' 7X 'LBS' 6X 'MOL%' 6X 'WT %' 8X 'MOLS'
     + 7X 'LBS' 6X 'GALS' 6X 'MOL%' 7X 'WT%' 5X 'VOL%' 7X 'K-DATA' )
C
      DO 77 J=1,7
   77 SUMM(J)=0.0
      SUMM(3)=100.0
      SUMM(4)=100.0
      SHL=0.0
      SHV=0.0
      SUMV=0.0
      DO 78 I=1,NC
```

```
      DO 78 J=1,11
   78 XX(I,J)=0.0
C
      DO 79 I=1,NC
      Z(I)=EK(I,N)*X(I,N)
   79 SUMV=SUMV+Z(I)
      IF (V(N).EQ.0.0) GO TO 85
      FAC=V(N)/SUMV
      DO 81 I=1,NC
      XX(I,1)=Z(I)*FAC
      XX(I,2)=XX(I,1)*XMW(I)
      SUMM(1)=SUMM(1)+XX(I,1)
   81 SUMM(2)=SUMM(2)+XX(I,2)
      FAC=100.0/SUMM(1)
      FBC=100.0/SUMM(2)
      DO 83 I=1,NC
      XX(I,3)=XX(I,1)*FAC
   83 XX(I,4)=XX(I,2)*FBC
C
   85 DO 87 I=1,NC
      XX(I,5)=X(I,N)*XL(N)
      XX(I,6)=XX(I,5)*XMW(I)
      XX(I,7)=XX(I,6)/RHO(I)
      SUMM(5)=SUMM(5)+XX(I,5)
      SUMM(6)=SUMM(6)+XX(I,6)
      SUMM(7)=SUMM(7)+XX(I,7)
   87 XX(I,11)=EK(I,N)
      FAC=100.0/SUMM(5)
      FBC=100.0/SUMM(6)
      FCC=100.0/SUMM(7)
      DO 88 I=1,NC
      XX(I,8)=XX(I,5)*FAC
      XX(I,9)=XX(I,6)*FBC
   88 XX(I,10)=XX(I,7)*FCC
C
      WRITE (NOUT,152) (I,(CNAME(K,I),K=1,2),(XX(I,K),K=1,11),I=1,NC)
  152 FORMAT ( I3,2X 2A4, F11.3,F10.1,2F10.4, F12.3,2F10.1,3F10.4,F12.3)
      WRITE (NOUT,153) (SUMM(K),K=1,10)
  153 FORMAT ( ' TOTAL' 8X F10.3,F10.1,2F10.4, F12.3,2F10.1,3F10.4 )
      VMW=0.0
      IF (V(N).EQ.0.0) GO TO 91
      VMW=SUMM(2)/SUMM(1)
      SHV=HV(N)*V(N)
   91 XLMW=SUMM(6)/SUMM(5)
      ZDEN=SUMM(6)/SUMM(7)
      SHL=HL(N)*XL(N)
      WRITE (NOUT,161) VMW,SHV,XLMW,ZDEN,SHL
  161 FORMAT ( '0' 6X 'VAPOR MW =' F7.3,5X 'VAPOR ENTHALPY =' F11.0,' BT
     +US' / 6X 'LIQUID MW =' F7.3,5X 'LIQUID LB/GAL =' F7.3,5X 'LIQUID E
     +NTHALPY =' F11.0,' BTUS' / )
```

```
C
   98 NL=NL+9+NC
C
      RETURN
      END
```

182

```
      SUBROUTINE ALNUM (NN, MM)                                        1809
C                                                                      1810
C       THIS SUBROUTINE DEVELOPS INTEGER EQUIVALENTS OF NUMBERS        1811
C       FROM 0 TO 99, LEFT JUSTIFIED WITHIN 4 COLUMN FIELD.            1812
C       NN = NUMBER TO BE CONVERTED.  MM = INTEGER EQUIVALENT.         1813
C                                                                      1814
      IF(NN-9) 1, 1, 2                                                 1815
C                                                                      1816
C       NUMBER IS 9 OR LESS.                                           1817
C                                                                      1818
    1 MM=-268435456+NN*16777216                                        1819
      RETURN                                                           1820
C                                                                      1821
C       NUMBER IS BETWEEN 10 AND 99, INCLUSIVE.                        1822
C                                                                      1823
    2 M=NN/10                                                          1824
      L=NN-M*10                                                        1825
      MM=-252690368+M*16777216+L*65536                                 1826
      RETURN                                                           1827
C                                                                      1828
      END                                                              1829
```

APPENDIX IV

IBM FORTRAN Coding Form

PROGRAM: Simple Absorption - Data File Example

PROGRAMMER: R.J. Lukach | DATE: March, 1973

PUNCHING INSTRUCTIONS: GRAPHIC / PUNCH

FORTRAN STATEMENT

```
PROBLEM NUMBER ONE - SIMPLE ABSORPTION
    8    6    2    0    2    2   20    2    4    1
     0.0     51.78
   95.      110.
   60.        0.0
WET GAS            8     60.        95.    1.288       0.0
   25.5         15.8     24.        16.9    14.8
LEAN OIL           1     60.        90.    1.655       0.0
  0.0       0.0       0.0       2.21     5.52      102.67
METHANE    16.042    2.5
ETHANE     30.06     3.144
PROPANE    44.094    4.22
N BUTANE   58.12     4.865
NPENTANE   72.146    5.253
OIL        114.224   5.883
   90.       110.
   60.       65.
   37.       37.
   7.4      8.1
     2.55    2.45
   .76      .93
   .242      .32
  .0125      .019
1     90.      110.
```

*A standard card form, IBM electro 888157, is available for punching statements from this form

IBM

FORTRAN Coding Form

PROGRAM	Simple Absorption - Data File Example	PUNCHING INSTRUCTIONS	GRAPHIC
PROGRAMMER	R.J. Lukach	DATE March, 1973	PUNCH

STATEMENT NUMBER | CONT. | FORTRAN STATEMENT

```
   14.7      14.7
 5610.     5500.
 4200.     4500.
10000.    10250.
 6600.     7300.
13850.    14200.
 7200.     7850.
17400.    18400.
 8850.     9600.
21900.    22400.
10600.    11400.
32400.    33400.
15000.    16200.
8888
```


*A standard card form, IBM electro 888157, is available for punching statements from this form

Problem Number One - Simple Absorption

An absorber containing 20 trays (efficiency 20%) operates at 60 psia and is fed a wet gas at 90 degrees F with the following composition:

Component	Mole Fraction
C_1	0.285
C_2	0.158
C_3	0.240
$n\text{-}C_4$	0.169
$n\text{-}C_5$	0.148
	1.000

The lean oil has the properties of normal octane and is fed at 1.104 times the wet gas rate. The oil is at 90 degrees F and contains 2 mol per cent $n\text{-}C_4$ and 5 mol per cent $n\text{-}C_5$. Estimate the recovery of each of the gas components at the oil rate given and determine the product rates and compositions.

Initial assumptions:

overhead vapor - 51.78 mols/hr

top temperature - 95 degrees F

bottom temperature - 110 degrees F

column pressure - 60 psia

wet gas heat content - 1.288 MM Btu/hr

lean oil heat content - 1.655 MM Btu/hr

Source - Smith p. 266.

```
PROBLEM NUMBER ONE - SIMPLE ABSORPTION
     4     6     2     0     2     2    20     2     4     1
         0.0       51.78
   95.0          110.
         60.         0.0
WET GAS                    4         60.         95.       1.288       0.0
         28.5        15.8        24.0        16.9       14.8
LEAN OIL                   1         60.         90.       1.655       0.0
   0.0        0.0         0.0        2.21        5.52      102.67
METHANE    16.042     2.5
ETHANE     30.06      3.144
PROPANE    44.094     4.22
N BUTANE   58.12      4.865
NPENTANE   72.146     5.253
OIL       114.224     5.883
   90.       110.
   60.        65.
   37.        39.
   7.4        8.1
     2.55      2.95
   .76        .93
   .242       .32
  .0125      .019
1     90.       110.
   14.7       14.7
   5610.      5600.
   4200.      4500.
   10000.    10250.
  6600.       7300.
  13850.     14200.
   7200.      7850.
  17900.     18400.
   8850.      9600.
   21900.    22400.
  10600.      11400.
  32400.     33400.
   15000.     16200.
$$$$
```

Problem Number Two - Intercooled Absorption

A wet gas and lean oil are feed to an absorber operating at 50 psig with the feeds entering at 90 degrees F. The feed compositions are as follows:

Component	Wet Gas Mols/Hr	Lean Oil Mols/Hr
C_1	10	
C_2	30	
C_3	40	
C_4	30	10
C_5	10	50
C_6		15
C_7		5
Total	120	80

A portion of the material in the oil is stripped out and is lost overhead. Intercoolers are used on two stages.

Initial assumptions:

overhead - 79.93 mols/hr

top temperature - 102 degrees F

bottom temperature - 94 degrees F

column pressure - 64.7 psia

wet gas heat content - 1.667 MM Btu/hr

lean oil heat content - .886 MM Btu/hr

intercooler load - .125 MM Btu/hr

Compute the off gas and the rich oil rates and compositions.

Source - Edmister p. 57.

```
PROBLEM NUMBER TWO - ABSORPTION WITH INTERCOOLERS
     4     7     2     2     2     2    20     2     3     2
     0.0         79.93
   102.          94.         0.0         0.0
    64.7          0.0
WET GAS                  4         65.        90.      1.667       0.0
    10.          30.        40.        30.       10.         0.0         0.0
LEAN OIL                 1         65.        90.       .886       0.0
     0.0          0.0        0.0        10.       50.        15.          5.
     2            0.0        0.0       .125
     3            0.0        0.0       .125
METHANE         16.042       2.5
ETHANE          30.068       3.144
PROPANE         44.094       4.22
BUTANE          58.12        4.865
PENTANE         72.146       5.253
HEXANE          86.172       5.526
HEPTANE        100.198       5.728
    90.         120.
    65.          65.
    39.47        43.16
     7.47         9.32
     2.278        3.12
     0.695        1.046
      .219         .361
      .0731        .1311
      .0256        .0499
1    90.         120.
        65.          65.
    5593.        5861.7
     4343.4      4671.9
    9837.4      10255.
     6101.3      7438.3
    13307.1     13989.5
     7228.0      8191.9
    16459.6     17460.1
     8859.8      9959.
    19110.3     20433.
    10475.1     11781.
    20797.3     22482.7
    12002.6     13503.4
    22500.6     24524.
    13515.6     15194.9
$$$$
```

Problem Number Three - Steam Stripping

The rich oil produced in Problem Number One is stripped with steam in a 12 tray column (20% efficiency) operating at 45 psia. The steam is superheated and enters at 290 degrees F at 45 psia. The oil enters at 250 degrees F. A steam/rich oil ratio of 0.1 will be assumed.

Initial assumptions:

overhead vapor - 23.5 mols/hr

top temperature - 250 degrees F

bottom temperature - 290 degrees F

column pressure - 45 psia

steam heat content - .221 MM Btu/hr

rich oil heat content - 3.7 MM Btu/hr

Calculate the rich gas and the lean oil rates and compositions.

Source - Smith p. 271.

```
PROBLEM NUMBER THREE - STEAM STRIPPING
   3     7     2     0     2     2    20     2     2     3
     0.0        23.5
     250.       290.         0.0          0.0
     45.         0.0
STEAM                     3        45.        290.       .221       0.0
      0.         0.         0.         0.         0.         0.        10.41
RICH OIL                  1        45.        250.       3.7        0.0
   1.188      3.007     11.834     17.917     19.508    101.815      0.0
METHANE        16.042       2.5
ETHANE         20.068       3.144
PROPANE        44.094       4.22
N BUTANE       58.12        4.865
NPENTANE       72.146       5.253
OIL           114.224       5.883
STEAM          18.          8.33
    250.        290.
     45.         45.
     80.         81.
    26.         30.
     12.        14.5
     5.4        7.
     2.5        3.5
     .34        .54
     68.        71.
1    250.       290.
     45.        45.
    7100.      7500.
    6200.      6700.
   11600.     12200.
    8700.       9300.
   17000.     17800.
    13400.    14000.
   21500.     22800.
   14500.      16900.
   26200.     27600.
   17300.     19300.
   40000.     42200.
   24600.     27600.
  21000.     21400.
   3600.      3920.
$$$$
```

Problem Number Four - Simple Absorption

A 30 plate absorber (20% efficiency) operates at 60 psig treating 18 x 10^6 scf (atm and 60 degrees F) per 24 hours of the following gas (1975 lb mols/hr).

Component	Mole per cent
C_1	83.0
C_2	8.4
C_3	4.8
i-C_4	.9
n-C_4	1.7
i-C_5	.4
n-C_5	.8
	100.0

The tower will be supplied with 300,000 gallons per 24 hour (534 lb mols/hr) of a denuded oil having a gravity of 40 degrees API and an average molecular weight of 161. The tower will operate at an average oil temperature of 90 degrees F.

Initial assumptions:

overhead vapor - 1906.46 mols/hr

top temperature - 90 degrees F

bottom temperature - 90 degrees F

column pressure - 74.7 psia

rich gas heat content - 13.82 MM Btu/hr

lean oil heat content - 3.45 MM Btu/hr

Find the recovery of each component in the wet gas.

Source - Edmister p. 44.

```
PROBLEM NUMBER FOUR - SIMPLE ABSORPTION
     6     8     2     0     2     2    20     2     2     1
      0.0       1906.45
      90.         90.
      74.7         0.0
WET GAS                     6   74.7      60.     13.82      0.0
  1639.2       165.8           94.9     17.8       33.53       7.9       15.8       0.0
OIL                         1   74.7      90.      3.45      0.0
      0.0        0.0            0.0      0.0        0.0        0.0        0.0      534.
METHANE         16.042          2.5
ETHANE          30.06           3.144
PROPANE         44.094          4.22
I BUTANE        58.12           4.686
N BUTANE        58.12           4.865
IPENTANE        72.146          5.199
NPENTANE        72.146          5.253
OIL             161.            6.87
     60.          90.
     75.          75.
      34.         39.
      5.          6.6
      1.4         1.96
      .55         .82
      .38         .61
      .155        .25
     .125         .2
     .003         .006
1     60.         90.
      75.         75.
    5900.       6200.
    4100.       4500.
    9600.       9950.
    5150.       7200.
   12950.      13650.
    6050.       6850.
   16200.      16800.
    7650.       8700.
   16700.      17400.
    7550.       8450.
   19500.      20300.
    9830.       9200.
   20200.      21200.
    8500.      10100.
   29800.      31400.
    4000.       6450.
$$$$
```

APPENDIX V

PROBLEM NUMBER ONE - SIMPLE ABSORPTION

NUMBER OF TRAYS	4
NUMBER OF COMPONENTS	6
NUMBER OF FEEDS	2
SIDESTREAM AND/OR HEAT TRAYS	0
NUMBER OF K-DATA POINTS	2
NUMBER OF H-DATA POINTS	2
NUMBER OF ITERATIONS	20
QR CODE	2
DOCUMENTATION LEVEL	4
COLUMN TYPE	1
OVERHEAD VAPOR PRODUCT, MOLS/HR	51.780

INPUT TEMPERATURES, DEG F

TOP TRAY	95.0
BOTTOM TRAY	110.0

INPUT PRESSURES, PSIA

OVERHEAD	60.0000
TOWER DELTA P	0.0000
TOWER TOP	60.0000
TOWER BOTTOM	60.0000

DATA ON COMPONENTS

	NAME	MOL WT	LBS/GAL
1	METHANE	16.042	2.5000
2	ETHANE	30.060	3.1440
3	PROPANE	44.094	4.2200
4	N BUTANE	58.120	4.8650
5	NPENTANE	72.146	5.2530
6	OIL	114.224	5.8830

MAIN COLUMN K-TABLE

TEMPERATURE, F	90.00	110.00
PRESSURE, PSIA	60.0000	65.0000
METHANE	37.00000	39.00000
ETHANE	7.40000	8.10000
PROPANE	2.55000	2.95000
N BUTANE	0.76000	0.93000
NPENTANE	0.24200	0.32000
OIL	0.01250	0.01900

ENTHALPY TABLE

TEMPERATURE, F	90.00	110.00
PRESSURE, PSIA	14.7000	14.7000
VAPOR, BTU/MOLE		
METHANE	5610.0	5800.0
ETHANE	10000.0	10250.0
PROPANE	13850.0	14200.0
N BUTANE	17900.0	18400.0
NPENTANE	21900.0	22400.0
OIL	32400.0	33400.0
LIQUID, BTU/MOLE		
METHANE	4200.0	4500.0
ETHANE	6600.0	7300.0
PROPANE	7200.0	7850.0
N BUTANE	8850.0	9600.0
NPENTANE	10600.0	11400.0
OIL	15000.0	16200.0

INPUT FEED DATA

FEED NO	1	2
FEED NAME	WET GAS	LEAN OIL
ENTERING AT TRAY NO	4	1
COMPOSITION,MOLS/HR		
METHANE	28.50	0.00
ETHANE	15.80	0.00
PROPANE	24.00	0.00
N BUTANE	16.90	2.21
NPENTANE	14.80	5.52
OIL	0.00	102.67
TOTAL	100.00	110.40
TEMPERATURE, F	95.0	90.0
PRESSURE, PSIA	60.0000	60.0000
HEAT CONTENT, BTUS (CALC)	0.	0.
HEAT CONTENT, BTUS (GIVEN)	1288000.	1654999.
ADDITIONAL HEAT, BTUS	0.	0.
HEAT CONTENT, BTUS (INLET)	1288000.	1654999.
TEMPERATURE, F (INLET)	96.59	95.70
VAPOR, MOLS (INLET)	100.000	0.000
LIQUID, MOLS (INLET)	0.000	110.400

CALCULATED VAPOR RATES

51.780	76.819	101.857	126.896

CORRESPONDING LIQUID RATES

99.360	119.113	138.867	158.620

CALCULATED TEMPERATURES

95.000	100.000	105.000	110.000

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.04981844	0.03544871	0.02611839	0.02052750
ETHANE	0.21202391	0.18794030	0.14039153	0.10623455
PROPANE	0.34662634	0.44774753	0.41159320	0.33089966
N BUTANE	0.08874756	0.20847487	0.38724118	0.62118155
NPENTANE	0.04613956	0.06300557	0.17115998	0.66132134
OIL	0.75965041	0.64254308	0.56703895	1.27425570
TOTAL	1.50300590	1.58515930	1.70354270	3.01441950

REBOILER DUTY, BTUS 0.0

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 1

-8.39388E 00 -8.46500E-02 8.52031E 01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 2

7.89758E 01 -4.45572E 01 -2.42371E 01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 3

-1.64760E 01 3.75272E 01 4.79396E 00

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 4

9.47111E-02 -6.32099E 01 1.46506E 01

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 1

9.09661E 01   5.16953E 01   1.80203E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 2

1.98089E 02   3.22615E 01   7.57629E 01

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 3

1.22391E 02   1.39384E 02   1.09794E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 4

1.58705E 02   6.36860E 01   1.24651E 02

ITERATION NUMBER 1

SUM DT SQUARED	8084.621000
DT MAX	85.203125
MAX DV/V	0.580031
MAX DL/L	0.663031

CALCULATED VAPOR RATES

51.759	65.679	111.239	111.093

CORRESPONDING LIQUID RATES

97.262	138.857	134.748	158.641

CALCULATED TEMPERATURES

105.650	96.970	105.599	111.831

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.01797779	0.02340372	0.00875023	0.00764510
ETHANE	0.10579991	0.10616958	0.04524532	0.03107982
PROPANE	0.17296654	0.24667889	0.16961426	0.10135341
N BUTANE	0.04428503	0.08749187	0.14658689	0.16041285
NPENTANE	0.04005245	0.03810142	0.07805252	0.17059964
OIL	0.78668165	0.50133634	0.55606157	0.53137910
TOTAL	1.16776270	1.00318140	1.00431060	1.00246900

REBOILER DUTY, BTUS 0.0

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 1

3.74524E 01 5.39719E-01 3.58920E 00

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 2

-3.07002E 01 1.09331E 01 4.71373E 01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 3

1.00379E 01 -6.11835E 01 3.73489E 01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 4

-5.39490E-01 -2.44094E 01 2.96461E 01

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 1

1.34714E 02 5.22986E 01 1.09240E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 2

1.08157E 02 7.66124E 01 1.44108E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 3

1.44786E 02 5.00556E 01 1.42948E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 4

1.58102E 02 8.66841E 01 1.41477E 02

ITERATION NUMBER 2

SUM DT SQUARED	4508.628900
DT MAX	47.137268
MAX DV/V	0.550018
MAX DL/L	0.385069

CALCULATED VAPOR RATES

51.894	68.413	95.943	104.991

CORRESPONDING LIQUID RATES

106.625	131.182	137.257	158.506

CALCULATED TEMPERATURES

106.548	108.755	114.936	119.243

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.01330709	0.00352344	0.00979255	0.00735244
ETHANE	0.02781873	0.00162604	0.02975905	0.02240159
PROPANE	0.08045042	0.01708783	0.06888872	0.07134277
N BUTANE	0.04072978	0.04771616	0.07577872	0.10874712
NPENTANE	0.04902871	0.05311573	0.06317341	0.12370801
OIL	0.80017269	0.85312986	0.72599453	0.64427501
TOTAL	1.01150700	0.97619903	0.97338694	0.97782689

REBOILER DUTY, BTUS 0.0

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 1

2.00082E 01 8.79482E-01 6.88274E 00

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 2

2.43451E 00 5.93400E-01 1.41994E 01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 3

4.33356E 00 -1.99533E 01 1.57955E 01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 4

-8.79466E-01 -2.10272E 01 2.09419E 01

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 1

1.26633E 02 5.27732E 01 1.13430E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 2

1.33617E 02 6.90060E 01 1.22954E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 3

1.41591E 02 7.59899E 01 1.30732E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 4

1.57627E 02 8.39639E 01 1.40185E 02

ITERATION NUMBER 3

SUM DT SQUARED	937.055660
DT MAX	20.941925
MAX DV/V	0.207970
MAX DL/L	0.187651

CALCULATED VAPOR RATES

52.333	68.709	85.967	94.478

CORRESPONDING LIQUID RATES

116.629	132.399	139.424	158.067

CALCULATED TEMPERATURES

109.989	115.854	122.834	129.714

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.01301061	0.01063915	0.00901100	0.00767069
ETHANE	0.02897529	0.02909213	0.02537867	0.02132758
PROPANE	0.07261246	0.10295445	0.09254611	0.07820815
N BUTANE	0.03380306	0.05653752	0.08246166	0.11041069
NPENTANE	0.04660762	0.04979523	0.06494147	0.12388849
OIL	0.81746930	0.77060044	0.72948146	0.64627159
TOTAL	1.01247780	1.01961800	1.00381940	0.98777717

REBOILER DUTY, BTUS 0.0

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 1

1.02742E 01	1.17838E 00	3.45577E 00

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 2

2.04735E 00	1.30542E 00	7.93841E 00

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 3

3.02478E 00	-8.40792E 00	1.08107E 01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 4

-1.17841E 00	-8.91698E 00	1.03337E 01

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 1

1.26903E 02 5.35119E 01 1.13445E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 2

1.34447E 02 7.00147E 01 1.23793E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 3

1.42449E 02 7.75587E 01 1.33645E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 4

1.56888E 02 8.55605E 01 1.40048E 02

ITERATION NUMBER 4

SUM DT SQUARED	298.617910
DT MAX	10.810722
MAX DV/V	0.097805
MAX DL/L	0.088093

CALCULATED VAPOR RATES

53.512	70.015	77.559	85.561

CORRESPONDING LIQUID RATES

126.903	134.447	142.449	156.888

CALCULATED TEMPERATURES

113.445	123.793	133.645	140.048

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.01289319	0.01009189	0.00874649	0.00777133
ETHANE	0.02869716	0.02717537	0.02375031	0.02061760
PROPANE	0.07257050	0.09136182	0.08861440	0.07815909
N BUTANE	0.03585767	0.05699636	0.08241206	0.11019778
NPENTANE	0.04725346	0.05059981	0.06615412	0.12424171
OIL	0.81238359	0.76872623	0.72653562	0.64903086
TOTAL	1.00965490	1.00495050	0.99621296	0.99001837

REBOILER DUTY, BTUS 0.0

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 1

1.48213E 00	2.51552E 00	5.94460E-01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 2

9.91147E-01	3.99764E 00	6.68585E-01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 3

-9.86719E-02	3.50665E 00	7.90126E-01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 4

-2.51550E 00	2.41685E 00	-6.62132E-01

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 1

1.28385E 02 5.60274E 01 1.14039E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 2

1.35438E 02 7.40124E 01 1.24461E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 3

1.42350E 02 8.10653E 01 1.34435E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 4

1.54373E 02 8.79774E 01 1.39385E 02

ITERATION NUMBER 5

SUM DT SQUARED	1.863167
DT MAX	0.790126
MAX DV/V	0.057097
MAX DL/L	0.016034

CALCULATED VAPOR RATES

56.027 74.012 81.065 87.977

CORRESPONDING LIQUID RATES

128.385 135.438 142.350 154.373

CALCULATED TEMPERATURES

114.039 124.461 134.435 139.385

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.01233577	0.00962156	0.00850198	0.00774933
ETHANE	0.02761304	0.02551393	0.02224639	0.01972985
PROPANE	0.07139552	0.08622554	0.08526331	0.07684052
N BUTANE	0.03808303	0.06019706	0.08465654	0.11050493
NPENTANE	0.04758063	0.05212813	0.06889588	0.12581730
OIL	0.80356044	0.76442719	0.72849822	0.65905440
TOTAL	1.00056740	1.00011250	0.99806231	0.99969631

REBOILER DUTY, BTUS 0.0

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 1

3.92105E-02 -1.74707E-02 8.00418E-02

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 2

-5.49950E-02 2.17246E-02 -2.67627E-02

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 3

-5.03174E-01 -7.24809E-02 -3.07226E-01

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 4

1.74859E-02 -5.20660E-01 -5.67835E-02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 1

1.28424E 02 5.60099E 01 1.14119E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 2

1.35383E 02 7.40341E 01 1.24435E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 3

1.41847E 02 8.09928E 01 1.34128E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 4

1.54390E 02 8.74567E 01 1.39329E 02

ITERATION NUMBER 6

SUM DT SQUARED	0.104735
DT MAX	0.307226
MAX DV/V	0.005918
MAX DL/L	0.003535

CALCULATED VAPOR RATES

56.010	74.034	80.993	87.457

CORRESPONDING LIQUID RATES

128.424	135.383	141.847	154.390

CALCULATED TEMPERATURES

114.119	124.435	134.128	139.329

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.01236350	0.00965250	0.00854423	0.00778864
ETHANE	0.02757856	0.02552375	0.02229482	0.01986302
PROPANE	0.07110542	0.08802301	0.08541262	0.07712656
N BUTANE	0.03798582	0.05985243	0.08418763	0.11044449
NPENTANE	0.04759488	0.05212724	0.06872320	0.12577921
OIL	0.80337244	0.76482362	0.73083705	0.65899426
TOTAL	1.00000000	1.00000190	0.99999952	0.99999613

REBOILER DUTY, BTUS 0.0

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 1

-6.23208E-03 -9.94985E-04 -1.42278E-02

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 2

-1.66358E-02 -7.22706E-03 -2.98311E-02

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 3

-7.33652E-04 -1.76308E-02 1.54456E-03

UNSCALED COMPUTED CORRECTIONS,DL-DV-DT,ON STAGE 4

1.01024E-03 -1.72864E-03 2.70118E-03

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 1

1.28418E 02	5.60089E 01	1.14105E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 2

1.35366E 02	7.40268E 01	1.24405E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 3

1.41846E 02	8.09752E 01	1.34129E 02

CORRECTED L-V-T USING UNSCALED CORRECTIONS ON STAGE 4

1.54391E 02	8.74550E 01	1.39331E 02

ITERATION NUMBER 7

SUM DT SQUARED	0.001182
DT MAX	0.029831
MAX DV/V	0.000218
MAX DL/L	0.000123

CALCULATED VAPOR RATES

56.009	74.027	80.975	87.455

CORRESPONDING LIQUID RATES

128.418	135.366	141.846	154.391

CALCULATED TEMPERATURES

114.105	124.405	134.129	139.331

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.01236610	0.00965429	0.00854108	0.00778795
ETHANE	0.02757603	0.02552749	0.02230842	0.01986721
PROPANE	0.07111448	0.08805048	0.08542252	0.07712865
N BUTANE	0.03796019	0.05981379	0.08418876	0.11045200
NPENTANE	0.04758339	0.05209249	0.06870914	0.12577778
OIL	0.80339921	0.76486081	0.73082906	0.65898532
TOTAL	0.99999928	0.99999923	0.99999893	0.99999887

REBOILER DUTY, BTUS 0.0

FEED AND PRODUCT COMPOSITIONS

COMPONENT	FEED NO 1 TRAY NO 4 MOLS	FEED NO 2 TRAY NO 1 MOLS	COMBINED FEED MOLS	OVERHEAD VAPOR PRODUCT MOLS	BOTTOMS PRODUCT MOLS
METHANE	28.5000	0.0000	28.5000	27.2982	1.2024
ETHANE	15.8000	0.0000	15.8000	12.7325	3.0673
PROPANE	24.0000	0.0000	24.0000	12.0920	11.9080
N BUTANE	16.9000	2.2100	19.1100	2.0571	17.0528
NPENTANE	14.8000	5.5200	20.3200	0.9009	19.4190
OIL	0.0000	102.6700	102.6700	0.9283	101.7414
TOTAL	100.0000	110.4000	210.4000	56.0089	154.3911
POUNDS	4040.39	12254.06	16294.45	1644.42	14649.98
GALLONS	989.88	2095.65	3085.53	478.22	2607.30
Q, MBTU	1288.000	1654.999	2942.999	838.109	2390.271
TEMP, F	96.59	95.70	0.00	114.11	139.33

NET LIQUID & VAPOR LEAVING EACH STAGE

TRAY NO 1 TEMP,F 114.11 PRESS,PSIA 60.00

NO	COMP	VAPOR MOLS	VAPOR LBS	VAPOR MOL%	VAPOR WT %	LIQUID MOLS	LIQUID LBS	LIQUID GALS	LIQUID MOL%	LIQUID WT%	LIQUID VOL%	K-DATA
1	METHANE	27.298	437.9	48.7390	26.6305	1.588	25.5	10.2	1.2366	0.1953	0.4460	39.41347
2	ETHANE	12.732	382.7	22.7329	23.2749	3.541	106.5	33.9	2.7576	0.8161	1.4819	8.24373
3	PROPANE	12.092	533.2	21.5894	32.4238	9.132	402.7	95.4	7.1115	3.0873	4.1764	3.03588
4	N BUTANE	2.057	119.6	3.6727	7.2704	4.875	283.3	58.2	3.7960	2.1721	2.5489	0.96753
5	NPENTANE	0.901	65.0	1.6085	3.9525	6.111	440.9	83.9	4.7583	3.3799	3.6732	0.33804
6	OIL	0.928	106.0	1.6574	6.4479	103.171	11784.6	2003.2	80.3400	90.3492	87.6736	0.02063
TOTAL		56.009	1644.4	100.0000	100.0000	128.418	13043.4	2284.8	100.0000	100.0000	100.0000	

VAPOR MW = 29.360 VAPOR ENTHALPY = 552707. BTUS
LIQUID MW =101.570 LIQUID LB/GAL = 5.709 LIQUID ENTHALPY = 1921628. BTUS

TRAY NO 2 TEMP,F 124.40 PRESS,PSIA 60.00

NO	COMP	VAPOR MOLS	VAPOR LBS	VAPOR MOL%	VAPOR WT %	LIQUID MOLS	LIQUID LBS	LIQUID GALS	LIQUID MOL%	LIQUID WT%	LIQUID VOL%	K-DATA
1	METHANE	28.887	463.4	39.0225	19.0414	1.307	21.0	8.4	0.9654	0.1558	0.3539	40.41980
2	ETHANE	16.273	489.2	21.9830	20.1003	3.456	103.9	33.0	2.5528	0.7720	1.3942	8.61148
3	PROPANE	21.225	935.9	28.6716	38.4554	11.919	525.6	124.5	8.8051	3.9057	5.2553	3.25626
4	N BUTANE	4.722	274.4	6.3782	11.2758	8.097	470.6	96.7	5.9814	3.4972	4.0817	1.06634
5	NPENTANE	1.491	107.6	2.0145	4.4209	7.052	508.7	96.8	5.2093	3.7808	4.0868	0.38672
6	OIL	1.429	163.2	1.9302	6.7062	103.536	11826.3	2010.3	76.4861	87.8885	84.8282	0.02524
TOTAL		74.027	2433.7	100.0000	100.0000	135.366	13456.1	2369.8	100.0000	100.0000	100.0000	

VAPOR MW = 32.876 VAPOR ENTHALPY = 819345. BTUS
LIQUID MW = 99.405 LIQUID LB/GAL = 5.678 LIQUID ENTHALPY = 2065880. BTUS

TRAY NO 3 TEMP,F 134.13 PRESS,PSIA 60.00

NO	COMP	VAPOR MOLS	VAPOR LBS	VAPOR MOL%	VAPOR WT %	LIQUID MOLS	LIQUID LBS	LIQUID GALS	LIQUID MOL%	LIQUID WT%	LIQUID VOL%	K-DATA
1	METHANE	28.604	458.9	35.3249	16.1208	1.212	19.4	7.8	0.8541	0.1400	0.3168	41.35870
2	ETHANE	16.188	486.6	19.9917	17.0957	3.164	95.1	30.3	2.2308	0.6850	1.2329	8.96148
3	PROPANE	24.011	1058.7	29.6524	37.1952	12.117	534.3	126.6	8.5423	3.8473	5.1594	3.47125
4	N BUTANE	7.944	461.7	9.8103	16.2202	11.942	694.1	142.7	8.4189	4.9979	5.8137	1.16528
5	NPENTANE	2.433	175.5	3.0041	6.1656	9.746	703.1	133.9	6.8709	5.0633	5.4548	0.43722
6	OIL	1.795	205.0	2.2166	7.2025	103.665	11841.1	2012.8	73.0830	85.2666	82.0224	0.03033
TOTAL		80.975	2846.5	100.0000	100.0000	141.846	13887.1	2453.9	100.0000	100.0000	100.0000	

VAPOR MW = 35.152 VAPOR ENTHALPY = 963339. BTUS
LIQUID MW = 97.903 LIQUID LB/GAL = 5.659 LIQUID ENTHALPY = 2211793. BTUS

NET LIQUID & VAPOR LEAVING EACH STAGE

TRAY NO 4 TEMP,F 139.33 PRESS,PSIA 60.00

		VAPOR				LIQUID						
NO	COMP	MOLS	LBS	MOL%	WT %	MOLS	LBS	GALS	MOL%	WT%	VOL%	K-DATA
1	METHANE	28.509	457.3	32.5984	13.9539	1.202	19.3	7.7	0.7788	0.1317	0.2959	41.85744
2	ETHANE	15.897	477.9	18.1775	14.5802	3.067	92.2	29.3	1.9867	0.6294	1.1248	9.14948
3	PROPANE	24.209	1067.5	27.6814	32.5693	11.908	525.1	124.4	7.7129	3.5841	4.7721	3.58899
4	N BUTANE	11.789	685.2	13.4802	20.9056	17.053	991.1	203.7	11.0452	6.7653	7.8135	1.22046
5	NPENTANE	5.127	369.9	5.8627	11.2863	19.419	1401.0	266.7	12.5778	9.5632	10.2292	0.46611
6	OIL	1.924	219.7	2.1998	6.7048	101.741	11621.3	1975.4	65.8986	79.3264	75.7644	0.03338
TOTAL		87.455	3277.5	100.0000	100.0000	154.391	14650.0	2607.3	100.0000	100.0000	100.0000	

VAPOR MW = 37.477 VAPOR ENTHALPY = 1109479. BTUS

LIQUID MW = 94.889 LIQUID LB/GAL = 5.619 LIQUID ENTHALPY = 2390271. BTUS

PROBLEM NUMBER TWO - ABSORPTION WITH INTERCOOLERS

NUMBER OF TRAYS	4
NUMBER OF COMPONENTS	7
NUMBER OF FEEDS	2
SIDESTREAM AND/OR HEAT TRAYS	2
NUMBER OF K-DATA POINTS	2
NUMBER OF H-DATA POINTS	2
NUMBER OF ITERATIONS	20
QR CODE	2
DOCUMENTATION LEVEL	3
COLUMN TYPE	2
OVERHEAD VAPOR PRODUCT, MOLS/HR	79.930

INPUT TEMPERATURES, DEG F

TOP TRAY	102.0
BOTTOM TRAY	94.0

INPUT PRESSURES, PSIA

OVERHEAD	64.7000
TOWER DELTA P	0.0000
TOWER TOP	64.7000
TOWER BOTTOM	64.7000

DATA ON COMPONENTS

	NAME	MOL WT	LBS/GAL
1	METHANE	16.042	2.5000
2	ETHANE	30.068	3.1440
3	PROPANE	44.094	4.2200
4	BUTANE	58.120	4.8650
5	PENTANE	72.146	5.2530
6	HEXANE	86.172	5.5260
7	HEPTANE	100.198	5.7280

MAIN COLUMN K-TABLE

TEMPERATURE, F	90.00	120.00
PRESSURE, PSIA	65.0000	65.0000
METHANE	39.47000	43.16000
ETHANE	7.47000	9.32000
PROPANE	2.27800	3.12000
BUTANE	0.69500	1.04600
PENTANE	0.21900	0.36100
HEXANE	0.07310	0.13110
HEPTANE	0.02560	0.04990

K-DATA WILL BE PRESSURE CORRECTED TO THE TRAY PRESSURE
USING THE K-DATA REFERENCE PRESSURE AS THE DATUM

ENTHALPY TABLE

TEMPERATURE, F	90.00	120.00
PRESSURE, PSIA	65.0000	65.0000
VAPOR, BTU/MOLE		
METHANE	5593.0	5861.7
ETHANE	9837.4	10255.0
PROPANE	13307.1	13989.5
BUTANE	16459.6	17460.1
PENTANE	19110.3	20433.0
HEXANE	20797.3	22482.7
HEPTANE	22500.6	24524.0
LIQUID, BTU/MOLE		
METHANE	4343.4	4671.9
ETHANE	6101.3	7438.3
PROPANE	7228.0	8191.9
BUTANE	8859.8	9959.0
PENTANE	10475.1	11781.0
HEXANE	12002.6	13503.4
HEPTANE	13515.6	15194.9

INPUT FEED DATA

FEED NO	1	2
FEED NAME	WET GAS	LEAN OIL
ENTERING AT TRAY NO	4	1
COMPOSITION, MOLS/HR		
METHANE	10.00	0.00
ETHANE	30.00	0.00
PROPANE	40.00	0.00
BUTANE	30.00	10.00
PENTANE	10.00	50.00
HEXANE	0.00	15.00
HEPTANE	0.00	5.00
TOTAL	120.00	80.00
TEMPERATURE, F	90.0	90.0
PRESSURE, PSIA	65.0000	65.0000
HEAT CONTENT, BTUS (CALC)	0.	0.
HEAT CONTENT, BTUS (GIVEN)	1666999.	886000.
ADDITIONAL HEAT, BTUS	0.	0.
HEAT CONTENT, BTUS (INLET)	1666999.	886000.
TEMPERATURE, F (INLET)	124.58	97.27
VAPOR, MOLS (INLET)	120.000	0.000
LIQUID, MOLS (INLET)	0.000	80.000

SIDESTREAM AND HEAT TRAY DATA

	TRAY NO	VAPOR MOLS/HR	LIQUID MOLS/HR	HEAT OUT MMBTU/HR
1	2	0.00	0.00	0.125000
2	3	0.00	0.00	0.125000

CALCULATED VAPOR RATES

79.930	85.305	90.681	96.056

CORRESPONDING LIQUID RATES

72.000	88.023	104.047	120.070

CALCULATED TEMPERATURES

102.000	99.333	96.667	94.000

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.03535945	0.03426662	0.03252360	0.03096121
ETHANE	0.15390068	0.16622043	0.16226614	0.15702432
PROPANE	0.30626363	0.41623384	0.45502579	0.46814013
BUTANE	0.25044084	0.41095084	0.62988126	0.94489545
PENTANE	0.58749866	0.58302641	0.69687963	1.31007480
HEXANE	0.17542809	0.17025793	0.23106241	1.11342900
HEPTANE	0.05848650	0.05574131	0.07969803	1.03973960
TOTAL	1.56737610	1.83669560	2.28733530	5.06426420

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 1

SUM DT SQUARED	15318.160000
DT MAX	110.540770
MAX DV/V	2.079558
MAX DL/L	2.116372

CALCULATED VAPOR RATES

79.958	86.138	78.895	98.396

CORRESPONDING LIQUID RATES

73.641	76.380	105.864	120.042

CALCULATED TEMPERATURES

107.787	113.151	93.195	92.304

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.01127982	0.00932833	0.03411578	0.00184942
ETHANE	0.02638151	0.00393470	0.16344839	0.04743491
PROPANE	0.09769946	0.11331046	0.22009575	0.19042063
BUTANE	0.13672078	0.16381848	0.16198766	0.26066250
PENTANE	0.69884372	0.92538750	0.30697221	0.34619051
HEXANE	0.18835497	0.33806902	0.11328709	0.11210364
HEPTANE	0.05869898	0.11760843	0.03906637	0.04080715
TOTAL	1.21797840	1.67145630	1.03897280	0.99946868

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 2

SUM DT SQUARED	2595247.000000
DT MAX	1430.717000
MAX DV/V	6.463747
MAX DL/L	6.646581

CALCULATED VAPOR RATES

79.962	86.826	70.927	103.485

CORRESPONDING LIQUID RATES

74.520	68.448	110.833	120.038

CALCULATED TEMPERATURES

112.628	124.328	90.790	90.243

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00810346	0.00279048	0.09802258	0.00402779
ETHANE	0.01895257	0.00510677	0.41170800	0.06802630
PROPANE	0.07018763	0.03389570	0.42756271	0.37406635
BUTANE	0.11429137	0.13483387	0.20805174	0.27175176
PENTANE	0.89554453	0.85443884	0.14772868	0.14238149
HEXANE	0.20918834	0.48908818	0.02207673	0.10009032
HEPTANE	0.05523516	0.18054795	0.01041822	0.03939841
TOTAL	1.37150190	1.70070070	1.32556720	0.99974239

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 3

SUM DT SQUARED	8994.187500
DT MAX	91.209884
MAX DV/V	0.251351
MAX DL/L	0.318827

CALCULATED VAPOR RATES

80.868	93.439	69.085	116.491

CORRESPONDING LIQUID RATES

86.400	66.958	119.278	119.132

CALCULATED TEMPERATURES

113.714	112.927	87.849	91.087

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00228065	0.00381925	0.02116251	0.00202481
ETHANE	0.03604642	0.03443059	0.09053320	0.03456081
PROPANE	0.08782834	0.14331281	0.37890667	0.14793521
BUTANE	0.14111704	0.11244035	0.17535186	0.24706089
PENTANE	0.45912606	0.64227563	0.40321267	0.39036769
HEXANE	0.15789396	0.21884298	0.12880266	0.11364341
HEPTANE	0.05464050	0.07591671	0.04341152	0.04060775
TOTAL	0.93893290	1.23103710	1.24137970	0.97620052

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 4

SUM DT SQUARED	5154.375000
DT MAX	67.706192
MAX DV/V	0.109493
MAX DL/L	0.151873

CALCULATED VAPOR RATES

82.573	101.433	75.344	103.736

CORRESPONDING LIQUID RATES

98.859	72.771	101.163	117.427

CALCULATED TEMPERATURES

109.715	96.001	88.873	95.400

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00313469	0.00416068	0.00160952	0.00202385
ETHANE	0.03569372	0.03587460	0.04797536	0.03628649
PROPANE	0.13210720	0.29343611	0.23464888	0.13380581
BUTANE	0.12265754	0.12443137	0.17869788	0.25452131
PENTANE	0.50608635	0.63232803	0.46281880	0.40832961
HEXANE	0.15305775	0.19922954	0.13872087	0.11615449
HEPTANE	0.04992651	0.06817877	0.04695746	0.04119619
TOTAL	1.00266360	1.35763740	1.11142820	0.99231768

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 5

SUM DT SQUARED	315.669180
DT MAX	13.515660
MAX DV/V	0.285507
MAX DL/L	0.282358

CALCULATED VAPOR RATES

83.055	99.408	86.100	108.759

CORRESPONDING LIQUID RATES

96.353	83.044	105.704	116.945

CALCULATED TEMPERATURES

104.940	82.485	92.802	105.134

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00290361	0.00290872	0.00291240	0.00204696
ETHANE	0.03626821	0.03905398	0.03983932	0.03318976
PROPANE	0.11583608	0.21261662	0.18116134	0.13526881
BUTANE	0.12743652	0.15659714	0.20675224	0.25915986
PENTANE	0.51222301	0.51324111	0.45223367	0.40669447
HEXANE	0.15728885	0.15647838	0.13470101	0.11684358
HEPTANE	0.05277086	0.05368626	0.04537852	0.04145243
TOTAL	1.00472640	1.13658140	1.06297680	0.99465585

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 6

SUM DT SQUARED	370.405270
DT MAX	17.511550
MAX DV/V	0.310332
MAX DL/L	0.301933

CALCULATED VAPOR RATES

83.878	98.442	99.459	120.037

CORRESPONDING LIQUID RATES

94.564	95.561	116.159	116.122

CALCULATED TEMPERATURES

107.514	99.997	99.724	102.099

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00271684	0.00232317	0.00191300	0.00185081
ETHANE	0.03755793	0.04166494	0.03484641	0.02749884
PROPANE	0.10722691	0.10517389	0.11510092	0.12262911
BUTANE	0.13332236	0.19338500	0.24633157	0.26289660
PENTANE	0.51248592	0.45134121	0.41185850	0.41105872
HEXANE	0.15749842	0.13561618	0.11857468	0.11847156
HEPTANE	0.05328732	0.04550844	0.03914852	0.04192387
TOTAL	1.00409500	0.97501272	0.96777356	0.98632944

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 7

SUM DT SQUARED	1455.327600
DT MAX	27.560348
MAX DV/V	0.401177
MAX DL/L	0.298231

CALCULATED VAPOR RATES

86.701	108.316	98.838	114.381

CORRESPONDING LIQUID RATES

101.615	92.137	107.680	113.299

CALCULATED TEMPERATURES

111.680	86.216	87.315	100.487

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00221407	0.00208384	0.00289645	0.00243029
ETHANE	0.03088976	0.02350013	0.03769829	0.03521131
PROPANE	0.06244937	0.14446354	0.20279610	0.16524172
BUTANE	0.15521771	0.18682665	0.22934866	0.25973439
PENTANE	0.41419858	0.57238603	0.54301232	0.44603044
HEXANE	0.11796755	0.17690867	0.16409266	0.12987804
HEPTANE	0.03774678	0.05900529	0.05483475	0.04587461
TOTAL	0.82068372	1.16517350	1.23467730	1.08439920

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 8

SUM DT SQUARED	321.051020
DT MAX	11.305599
MAX DV/V	0.098620
MAX DL/L	0.100632

CALCULATED VAPOR RATES

87.145	99.175	107.728	125.661

CORRESPONDING LIQUID RATES

92.030	100.583	118.516	112.855

CALCULATED TEMPERATURES

100.375	95.931	97.040	102.556

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00292524	0.00238736	0.00219112	0.00188441
ETHANE	0.03529822	0.03887666	0.03811737	0.03003887
PROPANE	0.12255895	0.14400214	0.13525909	0.12294006
BUTANE	0.12067443	0.16025406	0.22709620	0.26433128
PENTANE	0.51721466	0.47206950	0.42928356	0.41626769
HEXANE	0.15708351	0.14394474	0.12517595	0.11994833
HEPTANE	0.05297557	0.04892877	0.04191767	0.04268390
TOTAL	1.00872990	1.01046270	0.99904090	0.99809450

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 9

SUM DT SQUARED	92.402069
DT MAX	9.187446
MAX DV/V	0.027405
MAX DL/L	0.036267

CALCULATED VAPOR RATES

86.449	97.138	110.680	124.581

CORRESPONDING LIQUID RATES

90.689	104.230	118.131	113.551

CALCULATED TEMPERATURES

109.562	98.191	96.071	101.160

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00253830	0.00250171	0.00225520	0.00197716
ETHANE	0.03711668	0.03904118	0.03499129	0.02997626
PROPANE	0.08880812	0.13211042	0.14467072	0.13238168
BUTANE	0.14737308	0.18486345	0.22776091	0.26180822
PENTANE	0.53138661	0.46660000	0.42988622	0.41313487
HEXANE	0.16327393	0.14239216	0.12746507	0.12025189
HEPTANE	0.05482188	0.04772452	0.04245869	0.04258510
TOTAL	1.02531810	1.01523300	1.00948710	1.00211420

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 10

SUM DT SQUARED	14.467209
DT MAX	2.840320
MAX DV/V	0.027205
MAX DL/L	0.034973

CALCULATED VAPOR RATES

85.920	99.781	111.856	125.692

CORRESPONDING LIQUID RATES

93.861	105.935	119.772	114.080

CALCULATED TEMPERATURES

108.038	95.350	94.216	100.364

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00273581	0.00252949	0.00225526	0.00196003
ETHANE	0.03569158	0.03778982	0.03494602	0.03001474
PROPANE	0.10453957	0.14596474	0.15227693	0.13432080
BUTANE	0.13416982	0.16822946	0.21628278	0.25795025
PENTANE	0.51012307	0.45330697	0.42046380	0.40968031
HEXANE	0.15687484	0.13870460	0.12453890	0.11879748
HEPTANE	0.05284408	0.04677957	0.04170224	0.04224851
TOTAL	0.99697870	0.99330455	0.99246591	0.99497205

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 11

SUM DT SQUARED	0.590084
DT MAX	0.579760
MAX DV/V	0.007013
MAX DL/L	0.011635

CALCULATED VAPOR RATES

86.523	99.612	111.226	125.072

CORRESPONDING LIQUID RATES

93.089	104.703	118.549	113.477

CALCULATED TEMPERATURES

107.459	95.078	94.382	100.754

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00271106	0.00250238	0.00224306	0.00195449
ETHANE	0.03576000	0.03841316	0.03546476	0.03026955
PROPANE	0.10529536	0.14470071	0.14992481	0.13227987
BUTANE	0.13314342	0.16975993	0.21976620	0.26134992
PENTANE	0.51328725	0.45841622	0.42511529	0.41227990
HEXANE	0.15800840	0.14028430	0.12588149	0.11956018
HEPTANE	0.05326991	0.04732377	0.04214201	0.04249381
TOTAL	1.00147530	1.00139990	1.00053690	1.00018690

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 12

SUM DT SQUARED	0.469827
DT MAX	0.444800
MAX DV/V	0.001765
MAX DL/L	0.003456

CALCULATED VAPOR RATES

86.377	99.788	111.414	125.178

CORRESPONDING LIQUID RATES

93.411	105.037	118.801	113.623

CALCULATED TEMPERATURES

107.864	95.523	94.705	100.817

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00269686	0.00248508	0.00223485	0.00195575
ETHANE	0.03591394	0.03839382	0.03536465	0.03018137
PROPANE	0.10391051	0.14225239	0.14814317	0.13205093
BUTANE	0.13405812	0.17132533	0.22108167	0.26136672
PENTANE	0.51255679	0.45819485	0.42520571	0.41225255
HEXANE	0.15761447	0.14004207	0.12581342	0.11953485
HEPTANE	0.05310774	0.04720173	0.04208054	0.04245730
TOTAL	0.99985838	0.99989522	0.99992394	0.99979943

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 13

SUM DT SQUARED	0.116431
DT MAX	0.218900
MAX DV/V	0.001971
MAX DL/L	0.001499

CALCULATED VAPOR RATES

86.547	99.893	111.523	125.242

CORRESPONDING LIQUID RATES

93.345	104.976	118.695	113.453

CALCULATED TEMPERATURES

107.758	95.374	94.486	100.629

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00270042	0.00249116	0.00224036	0.00195858
ETHANE	0.03578144	0.03827395	0.03528563	0.03016325
PROPANE	0.10416096	0.14306533	0.14926738	0.13278186
BUTANE	0.13410878	0.17116350	0.22057515	0.26100028
PENTANE	0.51259893	0.45800543	0.42504609	0.41236240
HEXANE	0.15768796	0.14006668	0.12584656	0.11961973
HEPTANE	0.05313997	0.04722154	0.04210775	0.04250795
TOTAL	1.00017830	1.00028700	1.00036810	1.00039380

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 14

SUM DT SQUARED	0.020070
DT MAX	0.128272
MAX DV/V	0.001671
MAX DL/L	0.001275

CALCULATED VAPOR RATES

86.403	99.804	111.441	125.176

CORRESPONDING LIQUID RATES

93.401	105.038	118.773	113.597

CALCULATED TEMPERATURES

107.782	95.383	94.540	100.757

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00270272	0.00249143	0.00223863	0.00195552
ETHANE	0.03584873	0.03833534	0.03534512	0.03020092
PROPANE	0.10431176	0.14317238	0.14907098	0.13229406
BUTANE	0.13382798	0.17069471	0.22029024	0.26115370
PENTANE	0.51240301	0.45783961	0.42491299	0.41214997
HEXANE	0.15760624	0.13998872	0.12576854	0.11951178
HEPTANE	0.05311007	0.04719428	0.04208010	0.04245971
TOTAL	0.99981052	0.99971640	0.99970651	0.99972558

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 15

SUM DT SQUARED	0.004488
DT MAX	0.062445
MAX DV/V	0.001028
MAX DL/L	0.000782

CALCULATED VAPOR RATES

86.491	99.844	111.475	125.221

CORRESPONDING LIQUID RATES

93.353	104.984	118.730	113.509

CALCULATED TEMPERATURES

107.759	95.385	94.545	100.695

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00270088	0.00249039	0.00223841	0.00195718
ETHANE	0.03581633	0.03831875	0.03532628	0.03017599
PROPANE	0.10423303	0.14301610	0.14895862	0.13250846
BUTANE	0.13396239	0.17101598	0.22064728	0.26113850
PENTANE	0.51258087	0.45802355	0.42505318	0.41231430
HEXANE	0.15767443	0.14005494	0.12582195	0.11958444
HEPTANE	0.05313565	0.04721792	0.04209692	0.04249027
TOTAL	1.00010290	1.00013730	1.00014200	1.00016880

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 16

SUM DT SQUARED	0.002022
DT MAX	0.034398
MAX DV/V	0.000654
MAX DL/L	0.000499

CALCULATED VAPOR RATES

86.435	99.820	111.456	125.193

CORRESPONDING LIQUID RATES

93.386	105.021	118.758	113.565

CALCULATED TEMPERATURES

107.785	95.398	94.543	100.729

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.00270165	0.00249081	0.00223889	0.00195640
ETHANE	0.03583840	0.03832636	0.03533057	0.03018853
PROPANE	0.10423183	0.14304793	0.14904374	0.13240731
BUTANE	0.13393050	0.17089492	0.22043699	0.26112318
PENTANE	0.51247972	0.45792407	0.42496514	0.41220361
HEXANE	0.15763146	0.14001614	0.12579036	0.11953884
HEPTANE	0.05311874	0.04720259	0.04208638	0.04247094
TOTAL	0.99993223	0.99990278	0.99989206	0.99988878

REBOILER DUTY, BTUS 0.0

FEED AND PRODUCT COMPOSITIONS

COMPONENT	FEED NO 1 TRAY NO 4 MOLS	FEED NO 2 TRAY NO 1 MOLS	COMBINED FEED MOLS	OVERHEAD VAPOR PRODUCT MOLS	BOTTOMS PRODUCT MOLS
METHANE	10.0000	0.0000	10.0000	9.7763	0.2222
ETHANE	30.0000	0.0000	30.0000	26.5754	3.4284
PROPANE	40.0000	0.0000	40.0000	24.9558	15.0368
BUTANE	30.0000	10.0000	40.0000	10.3494	29.6545
PENTANE	10.0000	50.0000	60.0000	13.1907	46.8119
HEXANE	0.0000	15.0000	15.0000	1.4250	13.5754
HEPTANE	0.0000	5.0000	5.0000	0.1769	4.8232
TOTAL	120.0000	80.0000	200.0000	86.4349	113.5651
POUNDS	5291.27	5982.06	11273.34	3749.98	7523.59
GALLONS	1264.77	1127.55	2392.32	907.77	1484.59
Q, MBTU	1666.999	886.000	2552.998	943.384	1162.330
TEMP, F	124.58	97.27	0.00	107.79	100.73

NET LIQUID & VAPOR LEAVING EACH STAGE

TRAY NO 1 TEMP,F 107.79 PRESS,PSIA 64.70

		VAPOR				LIQUID						
NO	COMP	MOLS	LBS	MOL%	WT %	MOLS	LBS	GALS	MOL%	WT%	VOL%	K-DATA
1	METHANE	9.775	156.8	11.3087	4.1822	0.252	4.0	1.6	0.2702	0.0625	0.1287	41.86563
2	ETHANE	26.571	798.9	30.7409	21.3086	3.347	100.6	32.0	3.5841	1.5532	2.5436	8.57911
3	PROPANE	24.952	1100.2	28.8675	29.3441	9.734	429.2	101.7	10.4239	6.6244	8.0824	2.77001
4	BUTANE	10.348	601.4	11.9716	16.0402	12.507	726.9	149.4	13.3940	11.2194	11.8739	0.89402
5	PENTANE	13.189	951.5	15.2583	25.3777	47.858	3452.8	657.3	51.2514	53.2910	52.2339	0.29779
6	HEXANE	1.425	122.8	1.6484	3.2746	14.720	1268.5	229.6	15.7642	19.5783	18.2419	0.10459
7	HEPTANE	0.177	17.7	0.2046	0.4725	4.961	497.0	86.8	5.3122	7.6714	6.8957	0.03852
TOTAL		86.435	3749.4	100.0000	100.0000	93.379	6479.1	1258.4	100.0000	100.0000	100.0000	

VAPOR MW = 43.378 VAPOR ENTHALPY = 1140512. BTUS
LIQUID MW = 69.385 LIQUID LB/GAL = 5.149 LIQUID ENTHALPY = 1019246. BTUS

TRAY NO 2 TEMP,F 95.40 PRESS,PSIA 64.70

		VAPOR				LIQUID						
NO	COMP	MOLS	LBS	MOL%	WT %	MOLS	LBS	GALS	MOL%	WT%	VOL%	K-DATA
1	METHANE	10.029	160.9	10.0469	3.7885	0.262	4.2	1.7	0.2491	0.0594	0.1209	40.33849
2	ETHANE	29.918	899.6	29.9721	21.1838	4.025	121.0	38.5	3.8330	1.7132	2.7732	7.82074
3	PROPANE	34.690	1529.6	34.7526	36.0204	15.023	662.4	157.0	14.3062	9.3772	11.3087	2.42959
4	BUTANE	12.854	747.1	12.8771	17.5924	17.948	1043.1	214.4	17.0911	14.7661	15.4466	0.75356
5	PENTANE	11.047	797.0	11.0664	18.7672	48.092	3469.6	660.5	45.7969	49.1155	47.5839	0.24168
6	HEXANE	1.145	98.7	1.1472	2.3238	14.705	1267.1	229.3	14.0030	17.9373	16.5194	0.08194
7	HEPTANE	0.137	13.8	0.1376	0.3240	4.957	496.7	86.7	4.7207	7.0313	6.2472	0.02915
TOTAL		99.820	4246.6	100.0000	100.0000	105.011	7064.2	1388.1	100.0000	100.0000	100.0000	

VAPOR MW = 42.542 VAPOR ENTHALPY = 1273927. BTUS
LIQUID MW = 67.271 LIQUID LB/GAL = 5.089 LIQUID ENTHALPY = 1064535. BTUS

TRAY NO 3 TEMP,F 94.54 PRESS,PSIA 64.70

		VAPOR				LIQUID						
NO	COMP	MOLS	LBS	MOL%	WT %	MOLS	LBS	GALS	MOL%	WT%	VOL%	K-DATA
1	METHANE	10.039	161.1	9.0074	3.3331	0.266	4.3	1.7	0.2239	0.0543	0.1099	40.23221
2	ETHANE	30.596	920.0	27.4510	19.0396	4.196	126.2	40.1	3.5334	1.6048	2.5838	7.76993
3	PROPANE	39.986	1763.1	35.8760	36.4904	17.700	780.5	184.9	14.9060	9.9277	11.9086	2.40713
4	BUTANE	18.292	1063.2	16.4121	22.0032	26.179	1521.5	312.7	22.0461	19.3537	20.1375	0.74454
5	PENTANE	11.279	813.8	10.1201	16.8419	50.468	3641.1	693.1	42.5011	46.3149	44.6310	0.23814
6	HEXANE	1.129	97.3	1.0131	2.0138	14.939	1287.3	233.0	12.5804	16.3745	14.9997	0.08054
7	HEPTANE	0.134	13.4	0.1203	0.2780	4.998	500.8	87.4	4.2091	6.3702	5.6296	0.02858
TOTAL		111.456	4831.8	100.0000	100.0000	118.746	7861.6	1553.0	100.0000	100.0000	100.0000	

VAPOR MW = 43.352 VAPOR ENTHALPY = 1444235. BTUS
LIQUID MW = 66.205 LIQUID LB/GAL = 5.062 LIQUID ENTHALPY = 1184764. BTUS

NET LIQUID & VAPOR LEAVING EACH STAGE

TRAY NO 4 TEMP,F 100.73 PRESS,PSIA 64.70

		VAPOR				LIQUID						
NO	COMP	MOLS	LBS	MOL%	WT %	MOLS	LBS	GALS	MOL%	WT%	VOL%	K-DATA
1	METHANE	10.041	161.1	8.0208	2.8614	0.222	3.6	1.4	0.1957	0.0474	0.0960	40.99907
2	ETHANE	30.772	925.2	24.5794	16.4355	3.428	103.1	32.8	3.0192	1.3701	2.2085	8.14227
3	PROPANE	42.646	1880.4	34.0639	33.4027	15.037	663.0	157.1	13.2422	8.8127	10.5832	2.57276
4	BUTANE	26.536	1542.3	21.1962	27.3963	29.654	1723.5	354.3	26.1152	22.9082	23.8631	0.81176
5	PENTANE	13.659	985.5	10.9106	17.5052	46.812	3377.3	642.9	41.2249	44.8894	43.3066	0.26470
6	HEXANE	1.364	117.5	1.0894	2.0876	13.575	1169.8	211.7	11.9552	15.5487	14.2594	0.09113
7	HEPTANE	0.175	17.5	0.1398	0.3114	4.823	483.3	84.4	4.2476	6.4235	5.6831	0.03291
TOTAL		125.193	5629.6	100.0000	100.0000	113.552	7523.6	1484.6	100.0000	100.0000	100.0000	

VAPOR MW = 44.967 VAPOR ENTHALPY = 1689264. BTUS

LIQUID MW = 66.256 LIQUID LB/GAL = 5.068 LIQUID ENTHALPY = 1162330. BTUS

PROBLEM NUMBER THREE - STEAM STRIPPING

NUMBER OF TRAYS	3
NUMBER OF COMPONENTS	7
NUMBER OF FEEDS	2
SIDESTREAM AND/OR HEAT TRAYS	0
NUMBER OF K-DATA POINTS	2
NUMBER OF H-DATA POINTS	2
NUMBER OF ITERATIONS	20
QR CODE	2
DOCUMENTATION LEVEL	2
COLUMN TYPE	3
OVERHEAD VAPOR PRODUCT, MOLS/HR	23.500

INPUT TEMPERATURES, DEG F

TOP TRAY	250.0
BOTTOM TRAY	290.0

INPUT PRESSURES, PSIA

OVERHEAD	45.0000
TOWER DELTA P	0.0000
TOWER TOP	45.0000
TOWER BOTTOM	45.0000

DATA ON COMPONENTS

	NAME	MOL WT	LBS/GAL
1	METHANE	16.042	2.5000
2	ETHANE	20.068	3.1440
3	PROPANE	44.094	4.2200
4	N BUTANE	58.120	4.8650
5	NPENTANE	72.146	5.2530
6	OIL	114.224	5.8830
7	STEAM	18.000	8.3300

MAIN COLUMN K-TABLE

TEMPERATURE, F	250.00	290.00
PRESSURE, PSIA	45.0000	45.0000
METHANE	80.00000	81.00000
ETHANE	26.00000	30.00000
PROPANE	12.00000	14.50000
N BUTANE	5.40000	7.00000
NPENTANE	2.50000	3.50000
OIL	0.34000	0.54000
STEAM	68.00000	71.00000

K-DATA WILL BE PRESSURE CORRECTED TO THE TRAY PRESSURE
USING THE K-DATA REFERENCE PRESSURE AS THE DATUM

ENTHALPY TABLE

TEMPERATURE, F	250.00	290.00
PRESSURE, PSIA	45.0000	45.0000
VAPOR, BTU/MOLE		
METHANE	7100.0	7500.0
ETHANE	11600.0	12200.0
PROPANE	17000.0	17800.0
N BUTANE	21500.0	22800.0
NPENTANE	26200.0	27600.0
OIL	40000.0	42200.0
STEAM	21000.0	21400.0
LIQUID, BTU/MOLE		
METHANE	6200.0	6700.0
ETHANE	8700.0	9300.0
PROPANE	13400.0	14000.0
N BUTANE	14500.0	16900.0
NPENTANE	17300.0	19300.0
OIL	24600.0	27600.0
STEAM	3600.0	3920.0

INPUT FEED DATA

FEED NO	1	2
FEED NAME	STEAM	RICH OIL
ENTERING AT TRAY NO	3	1
COMPOSITION,MOLS/HR		
METHANE	0.00	1.19
ETHANE	0.00	3.01
PROPANE	0.00	11.83
N BUTANE	0.00	17.92
NPENTANE	0.00	19.51
OIL	0.00	101.82
STEAM	10.41	0.00
TOTAL	10.41	155.27
TEMPERATURE, F	290.0	250.0
PRESSURE, PSIA	45.0000	45.0000
HEAT CONTENT, BTUS (CALC)	0.	0.
HEAT CONTENT, BTUS (GIVEN)	221000.	3699999.
ADDITIONAL HEAT, BTUS	0.	0.
HEAT CONTENT, BTUS (INLET)	221000.	3699999.
TEMPERATURE, F (INLET)	272.92	245.41
VAPOR, MOLS (INLET)	10.410	51.750
LIQUID, MOLS (INLET)	0.000	103.519

CALCULATED VAPOR RATES

23.500	18.324	2.796

CORRESPONDING LIQUID RATES

103.519	98.343	82.815

CALCULATED TEMPERATURES

250.000	270.000	290.000

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3
METHANE	0.00028037	0.00028037	0.00028037
ETHANE	0.00210905	0.00210905	0.00210905
PROPANE	0.01665909	0.01665909	0.01665909
N BUTANE	0.04787193	0.04787193	0.04787193
NPENTANE	0.08567554	0.08567554	0.08567554
OIL	0.84740406	0.84740406	0.84740406
STEAM	0.00000000	0.00000000	0.00000000
TOTAL	1.00000000	1.00000000	1.00000000

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 1

SUM DT SQUARED	325.310300
DT MAX	16.376434
MAX DV/V	12.396779
MAX DL/L	0.793419

ITERATION NUMBER 2

SUM DT SQUARED	65573.750000
DT MAX	252.678930
MAX DV/V	3.523100
MAX DL/L	0.534874

ITERATION NUMBER 3

SUM DT SQUARED	56893.957000
DT MAX	236.495040
MAX DV/V	2.618818
MAX DL/L	0.520697

ITERATION NUMBER 4

SUM DT SQUARED	35357.296000
DT MAX	186.155190

ITERATION NUMBER 5

SUM DT SQUARED	251165.180000
DT MAX	496.305170
MAX DV/V	4.352040
MAX DL/L	0.443115

ITERATION NUMBER 6

SUM DT SQUARED	34721.878000
DT MAX	179.734860
MAX DV/V	1.292465
MAX DL/L	0.396691

ITERATION NUMBER 7

SUM DT SQUARED	5990.359300
DT MAX	66.849136
MAX DV/V	0.957675
MAX DL/L	0.335657

ITERATION NUMBER 8

SUM DT SQUARED	1038561.200000
DT MAX	1014.893000
MAX DV/V	9.359883
MAX DL/L	3.095642

ITERATION NUMBER 9

SUM DT SQUARED	2336.619300
DT MAX	36.568344
MAX DV/V	0.397224
MAX DL/L	0.353115

ITERATION NUMBER 10

SUM DT SQUARED	4429.839800
DT MAX	55.144241
MAX DV/V	1.429289
MAX DL/L	0.222071

SUM DT SQUARED	1770.963300
DT MAX	34.630874
MAX DV/V	1.102293
MAX DL/L	0.182795

ITERATION NUMBER 12

SUM DT SQUARED	1275.026300
DT MAX	26.928421
MAX DV/V	1.420276
MAX DL/L	0.249944

ITERATION NUMBER 13

SUM DT SQUARED	37161.878000
DT MAX	130.902020
MAX DV/V	4.625005
MAX DL/L	0.429507

ITERATION NUMBER 14

SUM DT SQUARED	55370.089000
DT MAX	157.457150
MAX DV/V	7.768880
MAX DL/L	1.408155

ITERATION NUMBER 15

SUM DT SQUARED	33231.441000
DT MAX	122.777190
MAX DV/V	0.399387
MAX DL/L	0.030510

ITERATION NUMBER 16

SUM DT SQUARED	14499.191000
DT MAX	73.939651
MAX DV/V	2.235490
MAX DL/L	0.155541

ITERATION NUMBER 17

SUM DT SQUARED	10921.847000
DT MAX	71.256271
MAX DV/V	0.751208
MAX DL/L	0.070527

ITERATION NUMBER 18

SUM DT SQUARED	2994248.000000
DT MAX	1060.786100
MAX DV/V	27.149475
MAX DL/L	5.374336

ITERATION NUMBER 19

SUM DT SQUARED	1408.881100
DT MAX	25.468978
MAX DV/V	7.750542
MAX DL/L	0.233829

ITERATION NUMBER 20

SUM DT SQUARED	111984.560000
DT MAX	277.847650
MAX DV/V	4.569650
MAX DL/L	1.204160

NO CLOSURE OBTAINED ON PROBLEM
FOR SPECIFIED NUMBER OF TRIALS

CALCULATED VAPOR RATES

23.957	6.368	0.573

CORRESPONDING LIQUID RATES

134.639	129.520	137.847

CALCULATED TEMPERATURES

256.290	260.847	272.844

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3
METHANE	0.00560410	0.00098729	0.00074083
ETHANE	0.04106759	0.00947283	0.00826426
PROPANE	0.18123549	0.03479108	0.03154382
N BUTANE	0.24880725	0.07733881	0.07702440
NPENTANE	0.29407650	0.23527342	0.22317564
OIL	0.14724386	0.39929271	0.41409045
STEAM	0.00988762	0.01309348	0.04936618
TOTAL	0.92792237	0.77024961	0.80420554

REBOILER DUTY, BTUS 0.0

PROBLEM NUMBER FOUR - SIMPLE ABSORPTION

NUMBER OF TRAYS	6
NUMBER OF COMPONENTS	8
NUMBER OF FEEDS	2
SIDESTREAM AND/OR HEAT TRAYS	0
NUMBER OF K-DATA POINTS	2
NUMBER OF H-DATA POINTS	2
NUMBER OF ITERATIONS	20
QR CODE	2
DOCUMENTATION LEVEL	2
COLUMN TYPE	1
OVERHEAD VAPOR PRODUCT, MOLS/HR	1906.460

INPUT TEMPERATURES, DEG F

TOP TRAY	90.0
BOTTOM TRAY	90.0

INPUT PRESSURES, PSIA

OVERHEAD	74.7000
TOWER DELTA P	0.0000
TOWER TOP	74.7000
TOWER BOTTOM	74.7000

DATA ON COMPONENTS

	NAME	MOL WT	LBS/GAL
1	METHANE	16.042	2.5000
2	ETHANE	30.060	3.1440
3	PROPANE	44.094	4.2200
4	I BUTANE	58.120	4.6860
5	N BUTANE	58.120	4.8650
6	IPENTANE	72.146	5.1990
7	NPENTANE	72.146	5.2530
8	OIL	161.000	6.8700

MAIN COLUMN K-TABLE

TEMPERATURE, F	60.00	90.00
PRESSURE, PSIA	75.0000	75.0000
METHANE	34.00000	39.00000
ETHANE	5.00000	6.60000
PROPANE	1.40000	1.96000
I BUTANE	0.55000	0.82000
N BUTANE	0.38000	0.61000
IPENTANE	0.15500	0.25000
NPENTANE	0.12500	0.20000
OIL	0.00300	0.00600

K-DATA WILL BE PRESSURE CORRECTED TO THE TRAY PRESSURE
USING THE K-DATA REFERENCE PRESSURE AS THE DATUM

ENTHALPY TABLE

TEMPERATURE, F	60.00	90.00
PRESSURE, PSIA	75.0000	75.0000
VAPOR, BTU/MOLE		
METHANE	5900.0	6200.0
ETHANE	9600.0	9950.0
PROPANE	12950.0	13650.0
I BUTANE	16200.0	16800.0
N BUTANE	16700.0	17400.0
IPENTANE	19500.0	20300.0
NPENTANE	20200.0	21200.0
OIL	29800.0	31400.0
LIQUID, BTU/MOLE		
METHANE	4100.0	4500.0
ETHANE	5150.0	7200.0
PROPANE	6050.0	6850.0
I BUTANE	7650.0	8700.0
N BUTANE	7550.0	8450.0
IPENTANE	9830.0	9200.0
NPENTANE	8500.0	10100.0
OIL	4000.0	6450.0

INPUT FEED DATA

FEED NO	1	2
FEED NAME	WET GAS	OIL
ENTERING AT TRAY NO	6	1
COMPOSITION,MOLS/HR		
METHANE	1639.20	0.00
ETHANE	165.80	0.00
PROPANE	94.90	0.00
I BUTANE	17.80	0.00
N BUTANE	33.53	0.00
IPENTANE	7.90	0.00
NPENTANE	15.80	0.00
OIL	0.00	534.00
TOTAL	1974.93	534.00
TEMPERATURE, F	60.0	90.0
PRESSURE, PSIA	74.7000	74.7000
HEAT CONTENT, BTUS (CALC)	0.	0.
HEAT CONTENT, BTUS (GIVEN)	13819999.	3449999.
ADDITIONAL HEAT, BTUS	0.	0.
HEAT CONTENT, BTUS (INLET)	13819999.	3449999.
TEMPERATURE, F (INLET)	60.32	90.13
VAPOR, MOLS (INLET)	1974.929	0.000
LIQUID, MOLS (INLET)	0.000	534.000

CALCULATED VAPOR RATES

1906.460	1621.563	1336.666	1051.769
766.872	481.975		

CORRESPONDING LIQUID RATES

480.600	504.974	529.347	553.721
578.095	602.469		

CALCULATED TEMPERATURES

90.000	90.000	90.000	90.000
90.000	90.000		

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.02566045	0.03026948	0.03657829	0.04622788
ETHANE	0.13495857	0.16179854	0.19183487	0.23580188
PROPANE	0.38796973	0.48641962	0.54673380	0.61852980
I BUTANE	0.86679035	1.18081470	1.19787880	1.12753100
N BUTANE	1.16932580	1.66806790	1.59485340	1.32555580
IPENTANE	0.00000000	0.00000050	0.00000000	0.00000000
NPENTANE	0.00000000	0.00000000	0.00000000	0.00000000
OIL	2.04921240	0.00000000	0.00000000	0.00000000
TOTAL	4.63391680	3.52736940	3.56787870	3.35364620

LIQUID COMPOSITIONS,MOL FRACTIONS

TRAY #	5	6
METHANE	0.06286013	0.09853435
ETHANE	0.30740887	0.44811940
PROPANE	0.71629047	0.86211526
I BUTANE	1.07335750	1.01985740
N BUTANE	1.19781580	1.01184840
IPENTANE	0.00000000	3.68937960
NPENTANE	0.00000000	3.40175620
OIL	0.00000000	4.13539880
TOTAL	3.3577327014.66700900	

REBOILER DUTY, BTUS 0.0

ITERATION NUMBER 1

SUM DT SQUARED	2442568.000000
DT MAX	1319.303400
MAX DV/V	8.915141
MAX DL/L	10.250596

ITERATION NUMBER 2

SUM DT SQUARED	32510.332000
DT MAX	130.058190
MAX DV/V	3.424022

ITERATION NUMBER 3

SUM DT SQUARED	115125.000000
DT MAX	193.542230
MAX DV/V	2.562383
MAX DL/L	1.533284

ITERATION NUMBER 4

SUM DT SQUARED	13133.367000
DT MAX	100.582700
MAX DV/V	2.077899
MAX DL/L	0.340913

ITERATION NUMBER 5

SUM DT SQUARED	10315.398000
DT MAX	96.463088
MAX DV/V	1.848833
MAX DL/L	0.391049

ITERATION NUMBER 6

SUM DT SQUARED	1018.617100
DT MAX	17.049331
MAX DV/V	1.493426
MAX DL/L	0.102749

ITERATION NUMBER 7

SUM DT SQUARED	1574.073200
DT MAX	37.790100
MAX DV/V	1.064797
MAX DL/L	0.161610

ITERATION NUMBER 8

SUM DT SQUARED	827.959470
DT MAX	21.732574
MAX DV/V	0.835420
MAX DL/L	0.115103

ITERATION NUMBER 9

SUM DT SQUARED	[illegible]
DT MAX	7.663537
MAX DV/V	0.643421
MAX DL/L	0.122588

ITERATION NUMBER 10

SUM DT SQUARED	147.475580
DT MAX	11.895473
MAX DV/V	0.431728
MAX DL/L	0.067402

ITERATION NUMBER 11

SUM DT SQUARED	68.946075
DT MAX	8.207462
MAX DV/V	0.287677
MAX DL/L	0.039744

ITERATION NUMBER 12

SUM DT SQUARED	14.324841
DT MAX	3.240744
MAX DV/V	0.121780
MAX DL/L	0.038358

ITERATION NUMBER 13

SUM DT SQUARED	1.944204
DT MAX	1.234169
MAX DV/V	0.002925
MAX DL/L	0.008458

ITERATION NUMBER 14

SUM DT SQUARED	0.022962
DT MAX	0.114763
MAX DV/V	0.000130
MAX DL/L	0.000413

ITERATION NUMBER 15

SUM DT SQUARED	0.000835
DT MAX	0.023584
MAX DV/V	0.000036
MAX DL/L	0.000118

CALCULATED VAPOR RATES

1901.266	1944.389	1951.392	1955.055
1958.623	1964.466		

CORRESPONDING LIQUID RATES

577.123	584.126	587.789	591.356
597.200	607.662		

CALCULATED TEMPERATURES

96.045	97.163	96.754	94.750
90.030	79.723		

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	1	2	3	4
METHANE	0.02127617	0.02086376	0.02082313	0.02096124
ETHANE	0.01184822	0.01197555	0.01198500	0.01217251
PROPANE	0.01973928	0.02183568	0.02218544	0.02268552
I BUTANE	0.00632322	0.00818325	0.00884467	0.00929651
N BUTANE	0.01243345	0.01738233	0.01968070	0.02133007
IPENTANE	0.00115504	0.00233801	0.00363295	0.00519379
NPENTANE	0.00121373	0.00278226	0.00492401	0.00807023
OIL	0.92601061	0.91463870	0.90792370	0.90028960
TOTAL	0.99999970	0.99999946	0.99999946	0.99999934

LIQUID COMPOSITIONS, MOL FRACTIONS

TRAY #	5	6
METHANE	0.02135188	0.02228287
ETHANE	0.01266909	0.01388119
PROPANE	0.02389970	0.02686603
I BUTANE	0.01003069	0.01175504
N BUTANE	0.02370349	0.02913623
IPENTANE	0.00746256	0.01200691
NPENTANE	0.01339864	0.02516712
OIL	0.88748354	0.85890418
TOTAL	0.99999946	0.99999940

REBOILER DUTY, BTUS 0.0

FEED AND PRODUCT COMPOSITIONS

COMPONENT	FEED NO 1 TRAY NO 6 MOLS	FEED NO 2 TRAY NO 1 MOLS	COMBINED FEED MOLS	OVERHEAD VAPOR PRODUCT MOLS	BOTTOMS PRODUCT MOLS
METHANE	1639.2000	0.0000	1639.2000	1625.6772	13.5405
ETHANE	165.8000	0.0000	165.8000	157.3679	8.4351
PROPANE	94.9000	0.0000	94.9000	78.5693	16.3255
I BUTANE	17.8000	0.0000	17.8000	10.6561	7.1431
N BUTANE	33.5300	0.0000	33.5300	15.8245	17.7050
IPENTANE	7.9000	0.0000	7.9000	0.6039	7.2961
NPENTANE	15.8000	0.0000	15.8000	0.5069	15.2931
OIL	0.0000	534.0000	534.0000	12.0761	521.9236
TOTAL	1974.9290	534.0000	2508.9290	1901.2664	607.6624
POUNDS	40157.68	85974.00	126131.63	37837.45	88294.19
GALLONS	14043.20	12514.41	26557.61	13376.76	13180.91
Q, MBTU	13819.996	3449.999	17269.980	13200.488	3568.620
TEMP, F	60.32	90.13	0.00	96.05	79.72

NET LIQUID & VAPOR LEAVING EACH STAGE

TRAY NO 1 TEMP,F 96.05 PRESS,PSIA 74.70

		VAPOR				LIQUID						
NO	COMP	MOLS	LBS	MOL%	WT %	MOLS	LBS	GALS	MOL%	WT%	VOL%	K-DATA
1	METHANE	1625.665	26078.9	85.5043	68.9241	12.279	197.0	78.8	2.1276	0.2247	0.6090	40.18814
2	ETHANE	157.367	4730.4	8.2769	12.5021	6.838	205.5	65.4	1.1848	0.2344	0.5053	6.98587
3	PROPANE	78.569	3464.4	4.1324	9.1561	11.392	502.3	119.0	1.9739	0.5729	0.9201	2.09353
4	I BUTANE	10.656	619.3	0.5605	1.6368	3.649	212.1	45.3	0.6323	0.2419	0.3499	0.88637
5	N BUTANE	15.824	919.7	0.8323	2.4307	7.176	417.0	85.7	1.2433	0.4757	0.6626	0.66941
6	IPENTANE	0.604	43.6	0.0318	0.1151	0.667	48.1	9.3	0.1155	0.0549	0.0715	0.27497
7	NPENTANE	0.507	36.6	0.0267	0.0967	0.700	50.5	9.6	0.1214	0.0576	0.0744	0.21966
8	OIL	12.076	1944.2	0.6352	5.1384	534.422	86041.9	12524.3	92.6011	98.1379	96.8072	0.00686
TOTAL		1901.266	37837.2	100.0000	100.0000	577.122	87674.4	12937.3	100.0000	100.0000	100.0000	

VAPOR MW = 19.901 VAPOR ENTHALPY = 13702953. BTUS
LIQUID MW =151.917 LIQUID LB/GAL = 6.777 LIQUID ENTHALPY = 4006963. BTUS

TRAY NO 2 TEMP,F 97.16 PRESS,PSIA 74.70

		VAPOR				LIQUID						
NO	COMP	MOLS	LBS	MOL%	WT %	MOLS	LBS	GALS	MOL%	WT%	VOL%	K-DATA
1	METHANE	1637.979	26276.5	84.2413	66.4624	12.187	195.5	78.2	2.0864	0.2220	0.6006	40.37775
2	ETHANE	164.220	4936.4	8.4458	12.4860	6.995	210.3	66.9	1.1976	0.2388	0.5137	7.05271
3	PROPANE	89.926	3965.2	4.6249	10.0293	12.755	562.4	133.3	2.1836	0.6386	1.0235	2.11808
4	I BUTANE	14.299	831.1	0.7354	2.1021	4.780	277.8	59.3	0.8183	0.3155	0.4553	0.89871
5	N BUTANE	22.996	1336.5	1.1827	3.3805	10.153	590.1	121.3	1.7382	0.6701	0.9316	0.68041
6	IPENTANE	1.271	91.7	0.0653	0.2319	1.366	98.5	19.0	0.2338	0.1119	0.1455	0.27951
7	NPENTANE	1.208	87.1	0.0621	0.2204	1.625	117.3	22.3	0.2782	0.1331	0.1714	0.22322
8	OIL	12.493	2011.4	0.6425	5.0875	534.264	86016.4	12520.6	91.4639	97.6701	96.1584	0.00702
TOTAL		1944.390	39535.9	100.0000	100.0000	584.125	88068.3	13020.8	100.0000	100.0000	100.0000	

VAPOR MW = 20.333 VAPOR ENTHALPY = 14261380. BTUS
LIQUID MW =150.770 LIQUID LB/GAL = 6.764 LIQUID ENTHALPY = 4119298. BTUS

TRAY NO 3 TEMP,F 96.75 PRESS,PSIA 74.70

		VAPOR				LIQUID						
NO	COMP	MOLS	LBS	MOL%	WT %	MOLS	LBS	GALS	MOL%	WT%	VOL%	K-DATA
1	METHANE	1637.871	26274.7	83.9334	65.8009	12.240	196.3	78.5	2.0823	0.2225	0.6013	40.30833
2	ETHANE	164.369	4940.9	8.4232	12.3738	7.045	211.8	67.4	1.1985	0.2400	0.5157	7.02820
3	PROPANE	91.306	4026.0	4.6790	10.0826	13.040	575.0	136.3	2.2185	0.6516	1.0432	2.10907
4	I BUTANE	15.433	897.0	0.7909	2.2463	5.199	302.2	64.5	0.8845	0.3424	0.4937	0.89418
5	N BUTANE	25.975	1509.7	1.3311	3.7808	11.568	672.3	138.2	1.9681	0.7619	1.0581	0.67637
6	IPENTANE	1.970	142.1	0.1009	0.3559	2.135	154.1	29.6	0.3633	0.1746	0.2269	0.27785
7	NPENTANE	2.132	153.8	0.1093	0.3853	2.894	208.8	39.8	0.4924	0.2366	0.3044	0.22191
8	OIL	12.338	1986.4	0.6323	4.9746	533.667	85920.4	12506.6	90.7924	97.3703	95.7566	0.00696
TOTAL		1951.393	39930.7	100.0000	100.0000	587.788	88240.8	13060.8	100.0000	100.0000	100.0000	

VAPOR MW = 20.463 VAPOR ENTHALPY = 14370312. BTUS
LIQUID MW =150.124 LIQUID LB/GAL = 6.756 LIQUID ENTHALPY = 4135016. BTUS

NET LIQUID & VAPOR LEAVING EACH STAGE

TRAY NO 4 TEMP,F 94.75 PRESS,PSIA 74.70

NO	COMP	VAPOR MOLS	VAPOR LBS	VAPOR MOL%	VAPOR WT %	LIQUID MOLS	LIQUID LBS	LIQUID GALS	LIQUID MOL%	LIQUID WT%	LIQUID VOL%	K-DATA
1	METHANE	1637.914	26275.4	83.7784	65.5189	12.396	198.8	79.5	2.0961	0.2251	0.6075	39.96860
2	ETHANE	164.415	4942.3	8.4097	12.3239	7.198	216.4	68.8	1.2173	0.2449	0.5257	6.90886
3	PROPANE	91.600	4039.0	4.6853	10.0715	13.415	591.5	140.2	2.2686	0.6696	1.0707	2.06534
4	I BUTANE	15.853	921.4	0.8109	2.2975	5.498	319.5	68.2	0.9297	0.3617	0.5208	0.87224
5	N BUTANE	27.391	1592.0	1.4010	3.9697	12.614	733.1	150.7	2.1330	0.8299	1.1510	0.65684
6	IPENTANE	2.739	197.6	0.1401	0.4928	3.071	221.6	42.6	0.5194	0.2508	0.3255	0.26978
7	NPENTANE	3.401	245.4	0.1740	0.6119	4.772	344.3	65.5	0.8070	0.3898	0.5006	0.21558
8	OIL	11.742	1890.4	0.6006	4.7139	532.392	85715.0	12476.7	90.0290	97.0282	95.2981	0.00667
TOTAL		1955.055	40103.5	100.0000	100.0000	591.355	88340.3	13092.3	100.0000	100.0000	100.0000	

VAPOR MW = 20.513 VAPOR ENTHALPY = 14385958. BTUS
LIQUID MW =149.386 LIQUID LB/GAL = 6.748 LIQUID ENTHALPY = 4079602. BTUS

TRAY NO 5 TEMP,F 90.03 PRESS,PSIA 74.70

NO	COMP	VAPOR MOLS	VAPOR LBS	VAPOR MOL%	VAPOR WT %	LIQUID MOLS	LIQUID LBS	LIQUID GALS	LIQUID MOL%	LIQUID WT%	LIQUID VOL%	K-DATA
1	METHANE	1638.060	26277.8	83.6333	65.3618	12.751	204.6	81.8	2.1352	0.2312	0.6227	39.16916
2	ETHANE	164.565	4946.8	8.4021	12.3044	7.566	227.4	72.3	1.2669	0.2571	0.5506	6.63198
3	PROPANE	91.984	4056.0	4.6964	10.0885	14.273	629.3	149.1	2.3900	0.7114	1.1350	1.96504
4	I BUTANE	16.153	938.8	0.8247	2.3352	5.990	348.2	74.3	1.0031	0.3936	0.5655	0.82221
5	N BUTANE	28.438	1652.8	1.4519	4.1111	14.156	822.7	169.1	2.3704	0.9300	1.2871	0.61254
6	IPENTANE	3.675	265.2	0.1876	0.6595	4.457	321.5	61.8	0.7463	0.3635	0.4707	0.25145
7	NPENTANE	5.279	380.9	0.2695	0.9474	8.002	577.3	109.9	1.3399	0.6526	0.8364	0.20117
8	OIL	10.468	1685.3	0.5345	4.1920	530.005	85330.8	12420.8	88.7484	96.4606	94.5320	0.00602
TOTAL		1958.623	40203.6	100.0000	100.0000	597.199	88461.8	13139.2	100.0000	100.0000	100.0000	

VAPOR MW = 20.526 VAPOR ENTHALPY = 14330522. BTUS
LIQUID MW =148.128 LIQUID LB/GAL = 6.733 LIQUID ENTHALPY = 3923295. BTUS

TRAY NO 6 TEMP,F 79.72 PRESS,PSIA 74.70

NO	COMP	VAPOR MOLS	VAPOR LBS	VAPOR MOL%	VAPOR WT %	LIQUID MOLS	LIQUID LBS	LIQUID GALS	LIQUID MOL%	LIQUID WT%	LIQUID VOL%	K-DATA
1	METHANE	1638.415	26283.5	83.4025	65.1789	13.540	217.2	86.9	2.2283	0.2460	0.6592	37.42903
2	ETHANE	164.932	4957.9	8.3958	12.2947	8.435	253.6	80.6	1.3881	0.2872	0.6119	6.04832
3	PROPANE	92.844	4093.8	4.7262	10.1521	16.325	719.9	170.6	2.6866	0.8153	1.2942	1.75916
4	I BUTANE	16.646	967.5	0.8474	2.3992	7.143	415.2	88.6	1.1755	0.4702	0.6721	0.72087
5	N BUTANE	29.980	1742.4	1.5261	4.3210	17.705	1029.0	211.5	2.9136	1.1654	1.6047	0.52379
6	IPENTANE	5.061	365.1	0.2576	0.9054	7.296	526.4	101.2	1.2007	0.5962	0.7681	0.21455
7	NPENTANE	8.509	613.9	0.4331	1.5223	15.293	1103.3	210.0	2.5167	1.2496	1.5935	0.17210
8	OIL	8.081	1301.0	0.4114	3.2264	521.924	84029.7	12231.4	85.8905	95.1701	92.7963	0.00479
TOTAL		1964.467	40325.1	100.0000	100.0000	607.662	88294.2	13180.9	100.0000	100.0000	100.0000	

VAPOR MW = 20.527 VAPOR ENTHALPY = 14174921. BTUS
LIQUID MW =145.301 LIQUID LB/GAL = 6.699 LIQUID ENTHALPY = 3568620. BTUS

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