

To the Graduate Council:

I am submitting herewith a thesis written by Landon Nelson Kenny entitled "A Generalized Digital Computer Program for Performing Process Material and Energy Balances." I recommend that it be accepted for eighteen quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Chemical Engineering.

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A GENERALIZED DIGITAL COMPUTER PROGRAM
FOR PERFORMING PROCESS MATERIAL
AND ENERGY BALANCES

A Thesis
Presented to
The Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

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ABSTRACT

A digital computer program was developed to perform material and energy balances for continuous chemical processes. The program is written in general form to permit calculations for any process, subject only to the limitations of computer memory, calculation time, and availability of user-provided subroutines to simulate the operation of each type of equipment in the process.

The program was intended for use by students in the Department of Chemical and Metallurgical Engineering of The University of Tennessee. It is expected that the equipment subroutines will be written by the students prior to the use of the generalized balance program.

Three types of processes were tested using abbreviated subroutines to demonstrate the program's ability to handle a wide range of process configurations, recycle parameters, etc. To permit evaluation of large processes which might exceed computer memory limitations with the basic program, a pair of alternate programs have been written to accomplish the same computations in two separate parts. The first portion will seek an optimum equipment sequence which minimizes the number of recycle parameters needed to specify the type of process considered; the second portion will perform any needed trial and error

recycle calculations to evaluate process conditions for this equipment sequence.

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INTRODUCTION

Although engineers have been performing material and energy balances for entire chemical processes for a number of years, no one has been able to omit trial and error methods when dealing with complex processes having one or more recycle streams, each of which may contain several different components. This type of iterative calculation can be programmed for a digital computer, thus enabling long, time consuming calculations to be completed in a reasonably short time. Engineers have written many programs which evaluate specific processes, but only a few have been developed which have the ability to perform complete material and energy balances for several different processes. In recent years a limited number of individuals and corporations have developed such generalized programs.

The development of a generalized digital computer program which can execute material and energy balances for a broad class of chemical processes was undertaken at The University of Tennessee. The use of this program and the accompanying development of the necessary computer skills should be of significant value to students in the Department of Chemical and Metallurgical Engineering. The flexibility of a program to be used as an educational tool is

of primary importance in such an industrially oriented, ever-changing course of study. Future Chemical Engineering graduates of The University of Tennessee will have the ability to utilize digital computers in the pursuit of their professional duties because they will be required to develop subroutines which simulate the operation of various types of equipment in order to use the program described herein.

There are two basic approaches to the problem of performing general material balances. In the first approach, the process is described by a number of component and total material balance equations which must be solved simultaneously for all unknowns; in the second approach, the unknown recycle parameters appearing in the process are guessed and are then corrected by a trial and error method until all balance equations are satisfied.

Most programs of this nature draw on the work of Nageiv (4), (5), Cavett (1), and Ravicz and Norman (7). A program developed by Rosen (8) utilizes the solution of simultaneous equations to perform material balances, but for a large process, the formulation of these equations requires extensive preliminary work, and the method was believed unsuitable for instructional purposes. The CHEOPS program of Shell Oil Co., described by Hughes, Singer, and Souders (2), while one of the most sophisticated efforts

described to date, is basically a design and economic optimization program for oil refineries and is beyond the goals of this thesis. Napthali (6) describes a generalized approach to the calculation of process material and energy balances, but gives no procedure for minimizing the number of recycle parameters needed to define the process. His work deals primarily with a number of convergence methods, such as the Newton-Ralphson Method, for correcting the unknown recycle values of the process. Molser (3) describes the PACER program developed at Purdue University by himself and Professor Paul Shannon. PACER uses the trial and error approach to calculate unknown recycle streams and determine what piece of equipment is to be calculated in any single pass through the program. Equipment operation is described by subroutines. The present version of PACER is limited to three recycle streams and requires a large number of control variables.

The generalized material balance program developed in this work is similar to PACER in its convergence method and use of equipment subroutines. However, a method due to Rubin (9) is employed which automatically reduces the number of unknown recycle parameters, where possible. This method is described in Chapter IV. Also, the present program is not limited in the number of recycle streams and requires a somewhat smaller number of control variables

than PACER. The program was written in Fortran IV language and is compatible with the facilities presently available in the University's computer center. It requires only a few alterations to be applied to virtually any continuous process, and a minimum number of limitations have been placed on its use to make it an attractive educational tool.

CHAPTER I

THE PROBLEMS OF DEVELOPING A GENERALIZED COMPUTER PROGRAM

Development of a generalized digital computer program for performing material and energy balances creates a number of problems which are not encountered when writing such a program for a specific process. Primarily, the program must be as efficient as possible to use a minimum portion of the computer memory, thus freeing a maximum space for subroutines and multi-variable arrays. Specifically, the nature and size of a process to be analyzed determine the types of subroutines needed and the sizes of the dimensioned arrays which specify the process variables and equipment arrangement.

When developing this type of generalized program, it is desirable that the process configuration (i. e., the sequence in which the various pieces of equipment are arranged and the pattern of the streams in the process) can be specified input data along with all known parameters of the entering streams as well as the variables required to describe the equipment and materials involved. The calculation of the operating effects of each piece of equipment should be performed in subroutines, and these subroutines should have as few restrictions as possible placed on them by the main program. Each subroutine is used to

calculate all output variables from a given piece of equipment from known values of the input variables and equipment parameters. Where recycle streams are involved, trial and error calculations must be employed since all input variables will not be known for some of the pieces of equipment. For performing these trial and error calculations, a convergence method must be developed which is dependable, rapid, and efficient with respect to computer memory space. In the present case a simple direct-iteration calculation was chosen for use when recycle streams are present in the process. This method, while not sophisticated, is dependable, rapid in compilation, and sufficiently fast in execution to merit its selection over more advanced convergence schemes.

Some effort to minimize the number of recycle parameters involved in the process will appreciably reduce the time and expense involved in evaluating a complicated process. An optional portion of the program was developed which will seek such a reduction of recycle parameters. While this portion of the program is not absolutely necessary, the unknown complexities of future processes make it a valuable asset to the program.

CHAPTER II

A GENERAL DESCRIPTION OF THE PROGRAM

The program, named MAEBE, is a generalized Material And Energy Balance Execution for use in process evaluation. Here process evaluation implies the specification of numerical values for the process variables (e. g., temperatures, pressures, flow rates, and compositions) describing all output and intermediate streams, given such values for the input streams together with descriptions of equipment operations. The program has three major divisions which represent the three basic steps needed to evaluate any process having recycle streams. These divisions will be referred to as Phases I, II, and III throughout the presentation of this program.

The first step in evaluating a process from a generalized point of view is the description of the process. Phase I deals with conveying all known information about the process into the appropriate portions of the computer system. The configuration of the process, all entering stream conditions, and the physical properties of all materials found in the process must be read into the main program. All data needed by the equipment-simulating subroutines must be read into the respective subroutines before any computations are performed. This phase of the

program is described more completely in Chapter III.

The next two parts of the program are utilized only when the process has recycling streams. Phase II is the part of the program that examines the configuration of the process with the purpose of finding a sequence of equipment calculations which requires a minimum number of recycle parameters to be determined. This method does not alter the physical arrangement of the pieces of equipment, but simply attempts to rearrange the sequence in which the calculations will be performed during the process evaluation. A more detailed presentation of this method is found in Chapter IV along with an example process.

In the third part of the evaluation of a recycle process, the actual trial and error calculations are performed until the convergence criterion specified as input data in Phase I is satisfied for every recycle parameter. These parameters are the mass flow rates of the components appearing in each recycle stream. Once the material balance of the process is determined, the energy variables of the recycle streams can be evaluated without trial and error. The actual method used in the iterative calculations is simple direct-iteration on the recycle parameters. After initial guesses are made for these parameters, the process conditions at the output of each piece of equipment can be calculated directly. These calculated values

for the exiting streams are compared with the initial guesses by a relative convergence method. If the parameters do not agree within allowable limits, the calculated values replace the initial guesses for the recycle streams' variables, and a new set of exiting values are calculated. This method is repeated until convergence is obtained. An additional iteration is then performed for reasons discussed in Chapter V.

The simple direct-iteration method was compared with several more sophisticated schemes for determining new trial values, but the practical improvement obtained by faster convergence methods is not apparent since the actual computational time required to evaluate a process is usually but a small fraction of the total time needed for compilation, loading, etc. One other convergence method was programmed into MAEBE, but was rejected because it frequently led to machine underflows, overflows, and calculations of impossible conditions such as negative flow rates. Even when it worked, the more complicated convergence method required more compilation time than was actually saved in execution when compared with the direct-iteration method.

The final portion of the program makes the final evaluation of the process, including energy balances, and then prints out all stream flow rates, temperatures,

pressures, energy balances on each piece of equipment, and a complete process material balance error value. In this part of the program, an option is available to the user of having the output data punched on cards in addition to the normal output listing. This feature would enable the user to put a listing of the results into a report directly.

Due to the size of MAEBE and its necessity of being capable of handling processes of unknown size and complexity, an alternate procedure has been developed to carry out the same calculations by sequential execution of two smaller programs, SEEK/HUNT and FIND. The SEEK program is a small Fortran deck which reads the data needed to perform the calculations of Phase II of the MAEBE program. The actual computations of Phase II are accomplished in a large subroutine called HUNT. Since all variables needed by HUNT can be made available in SEEK, the subroutine has been converted into machine language in a binary deck which requires no compilation time. Therefore, the user of the SEEK/HUNT program system need only provide a dimensional statement for SEEK and the appropriate input data to minimize the number of recycle parameters involved in a process' evaluation. The compilation time needed by this system is about 50 seconds on the IBM 7040, as compared to approximately $2\frac{1}{2}$ minutes for the compilation of the complete MAEBE program.

Phases I and III of the MAEBE program have been combined in a program named FIND which will complete the evaluation of a process when used in sequence with the SEEK/HUNT system. This program differs from the MAEBE system in one basic fact; the initial guesses of the recycle parameters can be made by the user of FIND because the recycle streams are known prior to execution of the program. This knowledge is not available when using MAEBE because of the minimization operations of Phase II. Therefore, MAEBE must arbitrarily select initial values for the unknown recycle component flow rates. This requires that MAEBE needs more time to converge than FIND would if the first guesses used in FIND were closer to the actual parameters' values than those selected in the MAEBE program. However, MAEBE has proven itself to be very fast in the analysis of test processes, and from the user's standpoint MAEBE would be preferred for overall convenience, so long as its use does not exceed computer memory limitations.

Processes which do not contain recycle streams must be evaluated by MAEBE since the SEEK/HUNT system would not be required and FIND does not provide the necessary input operational options.

CHAPTER III

PHASE I, THE INPUT RESTRICTIONS

The order in which the necessary data are read into the programs and subroutines is of the greatest importance. The form for arrangement of data for the MAEBE system will be presented, and any deviation from this arrangement will be listed for the FIND program. The SEEK/HUNT system input instructions will also refer to the basic pattern of the MAEBE data formats.

For illustrative purposes a process to be evaluated will be described as one having "i" pieces of equipment or nodes, "j" streams flowing between pieces of equipment, "kc" compounds or elements appearing in the process as components of the various streams, and "ks" streams leaving or entering the process. The configuration of the process may be depicted numerically in a table or matrix called NP, having "i" rows and "j+ks" columns. Each element of this matrix, $NP_{k,n}$, will have a value of -1, 0, or +1, depending on whether it is to indicate that stream "n" leaves, has no connection with, or enters equipment "k" respectively. The streams must be numbered in the following manner: streams 1 through "j" are the unknown streams of the process which flow between equipment nodes, streams "j+1" through "j+instm" are the "instm" streams entering

the process, and the streams "j+instm+1" through "j+ks" are the exiting streams. A final row is added to this matrix to give the number of parameters needed to completely specify the flow rates of the components present in each internal stream. Thus the dimension of the configuration matrix NP is "i+1" by "j+ks". The value of each bottom-row element, $NP_{i+1,m}$, is the number of components of the process that appear, or may appear, in stream "m".

Each piece of equipment is assigned a number by which it is to be known throughout the execution of the program, and these numbers must be integers from 1 through "i". Since the various pieces of equipment are to be calculated in different subroutines, subscripted control indicators have been provided to designate the subroutine to which the program must transfer to calculate a specific piece of equipment. These indicators must be fixed point numbers from 1 through "neqpsr" where "neqpsr" is the number of different types of equipment represented in the program system. Two pieces of equipment of the same type, such as two heat exchangers, will be calculated in the same subroutine. If the heat exchanger subroutine was designated as the fourth equipment-simulating subroutine, both equipment type elements of the indicator vector would have a value of 4 for the two heat exchangers. These subroutines are discussed more fully in Chapter VI.

The material balance information for the process is provided in a matrix of "kc+1" by "j+ks" dimensions, called VALUES, where each column represents a stream and each row a given stream property. The first "kc" rows of this matrix have mass fractions for each component in the process. The last or "kc+1"th. row contains total flow rates for all "j+ks" streams.

All "kc" components appearing in the entire process are designated according to a 24 field-width alphameric variable, and the molecular weight, heat capacity, and latent heat of the components are also read into the main program. Other physical property data required by any of the subroutines must be read into each subroutine as needed.

Temperature and pressure values are read in for all "instm" entering streams. Also, energy stream input values must be read for each equipment node, since each piece of equipment is considered to be fed by one heat stream (whose value may, of course, be zero).

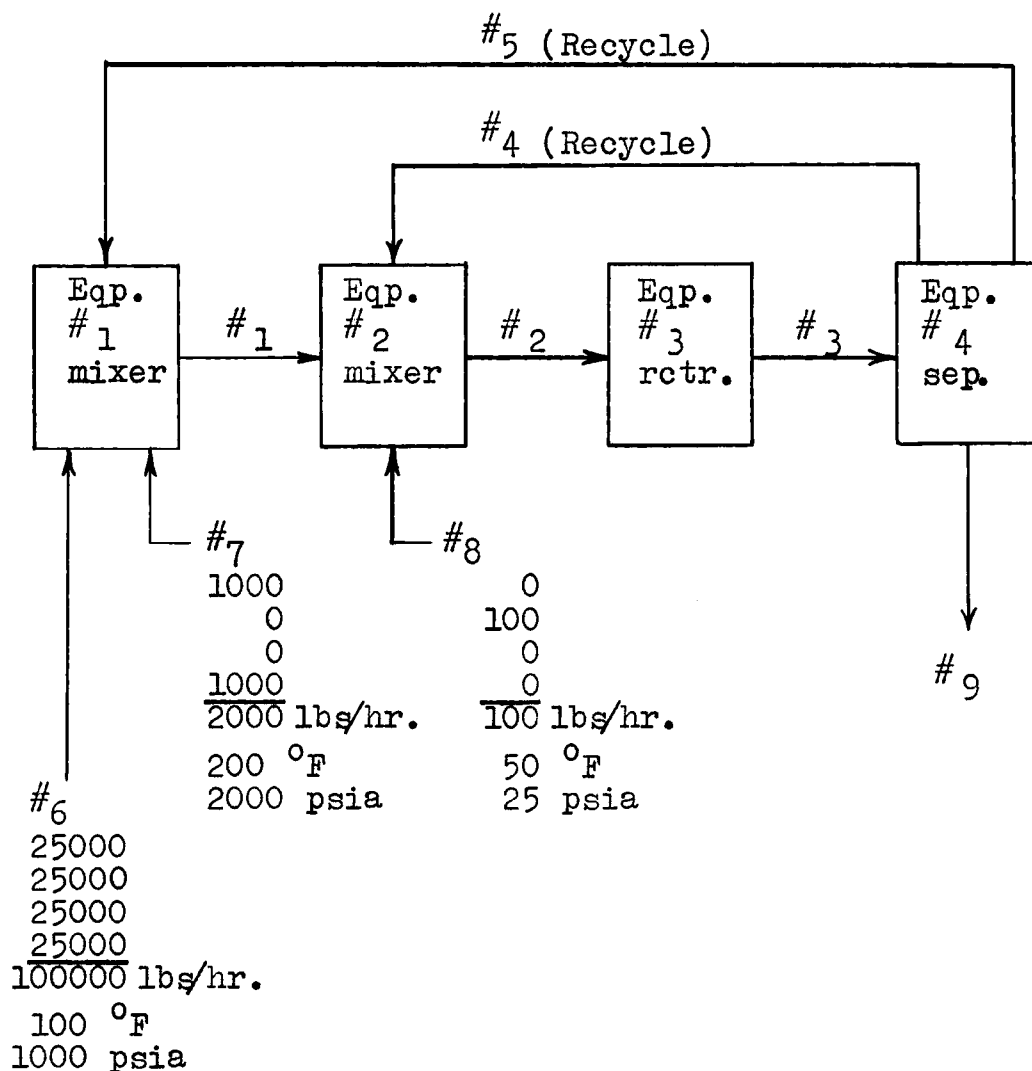
After all data are read into the main program, the subroutines are entered to read any data necessary to their computations. These subroutines are entered in the ascending order of their equipment type indicator values, and each one represented in the main program must be entered, regardless of whether any equipment of that type

is present in the process or not. If the subroutine is referred to in the main program system, it must be present in the system although it may not be needed for computations at all.

For purposes of illustration, the process depicted in Figure 1 will be used in the presentation of an example of the input data instructions for MAEBE. The variables used in this program are defined in Appendix A. The values of these variables for this example are presented in Table I, along with instructional definitions.

Due to the nature of the NP matrix, no internal stream "n" can exist which leaves and enters a single piece of equipment "m" because the value of $NP_{m,n}$ cannot be both -1 and +1 simultaneously. To handle such an unusual condition, the programmer may place a dummy equipment node into the process, on line in the "n" stream. Figure 2 presents both the unfeasible and feasible stream-equipment configurations.

The difference in input instructions for the MAEBE and FIND systems are listed in Table II, and the MAEBE instructions must be followed with the exceptions listed in this table when using the FIND program. The variable names are all common to the three program systems so the user of any program can refer to either the system Fortran listings or Appendix A for any problems which may occur.



$$NP_{i+1,1} \text{ through } j = NP_{5,1-5} = 4, 4, 4, 4, 3$$

(There are 4 components appearing in this process.
 All are expected to appear in streams 1-4, but only
 3 are believed to be in stream 5.)

Figure 1. Flow Diagram of the First Recycle Process.

TABLE I

INPUT INSTRUCTIONS FOR THE MAEBE PROGRAM AND SAMPLE DATA
FOR THE FIRST RECYCLE PROCESS IN FIGURE 1

Variable	Format	Data and explanation
NMLKJI	I5	The number of sets of data for an entire process to be evaluated. card 1, cc 1-5, value = 1
I	14I5	The number of pieces of equipment in the process. card 2, cc 1-5, value = 4
J	"	The number of internal streams in the process. card 2, cc 6-10, value = 5
KC	"	The total number of components present in the process. card 2, cc 11-15, value = 4
KS	"	The number of streams entering and leaving the process. card 2, cc 16-20, value = 4
INSTM	"	The number of streams entering the process. card 2, cc 21-25, value = 3
LRC	"	Recycle indicator: 0 for no recycle, 1 for presence of recycle streams. card 2, cc 26-30, value = 1
LCON	"	Energy balance option indicator: 0 for omission of the recycle energy calculations, 1 for performing these balance calculations during the iterative calculations. card 2, cc 31-35, value = 1
IDTV	"	The component flow indicator: 0 for

TABLE I (continued)

IDTV, con't.		reading in the component flows in the entering streams as mass flow rates, 1 for reading them in as mass fractions of the stream flow rate. card 2, cc 36-40, value = 1
NOUT	14I5	The optional internal output indicator: 0 for no internal output, 1 for all internal output options. card 2, cc 41-45, value = 0
NOUT2	"	The internal output of only the recycle guesses and calculated values: 0 for no output, 1 for print-out of the guessed and calculated values of the recycle parameters and the maximum relative deviation. card 2, cc 46-50, value = 0
NTYPE	"	Final output card punch option indicator: 0 for normal printed output only, 1 for both printed and punched output. card 2, cc 51-55, value = 0
IDENT	6X,11A6	The alphameric subscripted variable for identification of the process and the name, etc., of the user. card 3, cc 7-72, value unlimited
CONCRI*	E15.6	The relative convergence limit. card 4, cc 1-15, value = 1.E-6
LRCMX*	I5	The option indicator controlling the use of Phase II: 1 for the use of Phase II, 2 for omitting the Phase II calculations. card 5, cc 1-5, value = 1
MAXPAS*	"	The value of the maximum number of trial and error iterations to be attempted before giving up if convergence is not realized. card 6, cc 1-5, value = 100

TABLE I (continued)

Type of input statement for the VALUES variable array:

```

      DO 122 L=1,J+INSTM          101 FORMAT(5E15.6)
122  READ 101,(VALUES(L,K),K=1,KC1)

```

VALUES**	5E15.6	The first "J" cards contain values of -1.E+6 if the component, 1 through "KC", appears or may appear in the stream; 0.E+0 if the component definitely does not appear in the stream; and the last element of this column must have a value less than -1E+6, such as -2.E+6, for the total flow rate of the unknown stream. The next "INSTM" cards contain values of the entering streams' compositions and flow rates. The component flows are to be specified according to the IDTV option indicator; these are followed by the total flow rate of each stream. cards 7-15, see Appendix D for the values and card column locations.
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Type of input statement for the component data arrays:

```

      DO 128 K=1,KC
128  READ 107,(NAME(K,K1),K1=1,4),COMMW(K),COMHC(K),
      1COMHV(K))
107  FORMAT(1H ,4A6,F10.3,F10.5,F10.2)

```

NAME	4A6	Any alphameric identification of the components found in the process. 24 character field widths have been provided. Arbitrary component data were chosen for this process to aid in checking the execution of the program. cc 2-25 (Appendix D)
COMMW	F10.3	The molecular or atomic weight of each compound or element found in the process. cc 26-35 (Appendix D)
COMHC	F10.5	The heat capacity of each component. cc 36-45 (Appendix D)

TABLE I (continued)

COMHV	F10.2	The latent heat of each component. cc 46- 55 See Appendix D for the actual data values. cards 16-19
NEQ(1-I,1)	14I5	This subscripted variable gives the initial order in which the equipment is to be evaluated. This set of numbers does not necessarily have to be consecutive, but it must contain all integers from 1 through I. card 20 cc 1- 5, value = 1 cc 6-10, value = 2 cc 11-15, value = 3 cc 16-20, value = 4
IET	"	The type of equipment designation variable is provided for each piece of equipment: 1 for mixers, 2 for separators, 3 for reactors, and 4 for heat exchangers. These values are read across the card for the 1 through I pieces of equipment. card 21, cc 1- 5, value = 1 cc 6-10, value = 1 cc 11-15, value = 3 cc 16-20, value = 2

Type of input statement for the NP array variables:

```

DO 126 L1=1,I                      100 FORMAT(14I5)
  L=NEQ(L1,1)
126 READ 100,(NP(L,K),K=1,JKS)
    READ 100,(NP(IP1,K),K=1,J)

```

NP*	14I5	This is the process configuration matrix having values of -1, 0, or +1 and the IP1th. row has values of the number of parameters needed to specify the flow rate and composition of the "J" unknown internal streams. See Appendix D. cards 22-26
-----	------	--

TABLE I (continued)

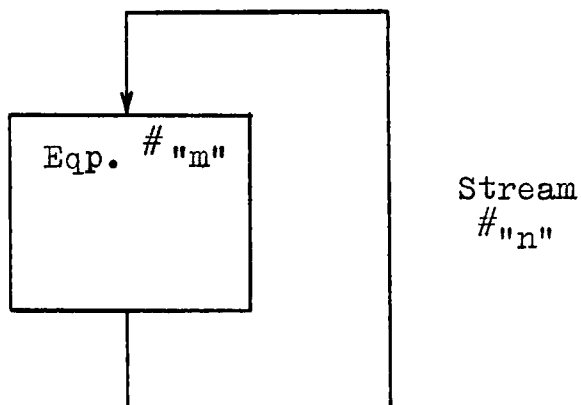
ST and SP***	2F15.6	These variables are the temperatures and pressures of the entering streams numbered 6, 7, and 8. card 27, cc 1-15, value = 100. cc 16-30, value = 1000. card 28, cc 1-15, value = 200. cc 16-30, value = 2000. card 29, cc 1-15, value = 50. cc 16-30, value = 25.
ENERGY***	5E15.6	This is the net energy input for each piece of equipment. card 30, cc 1-15, value = 0.E+0 cc 16-30, value = 1.E+3 cc 31-45, value = 6.E+4 cc 46-60, value = 1.E+6

Data for the first equipment subroutine, EQP1.
 Data for the second equipment subroutine, EQP2.
 Data for the third equipment subroutine, EQP3.
 Data for the fourth equipment subroutine, EQP4.

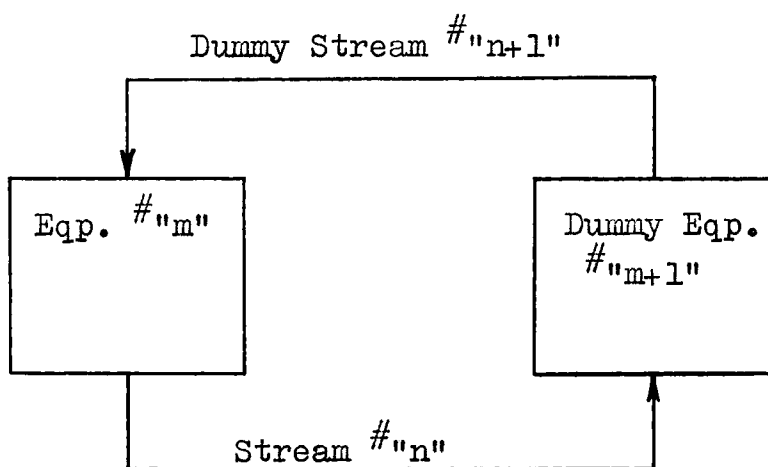
* These cards are to be used only when the process contains one or more recycling streams. (LRC = 1 on card no. 2, cc 26-30)

** Values of -1×10^6 or less represent impossible mass fractions and stream flow rates and are used initially as control indicators of what component may be found in each of the unknown streams during the determination of what recycle parameters are needed for process evaluation. These values are not utilized during the direct-iteration calculations.

*** These quantities must be expressed in units that are compatible with all subroutines that employ them.



Unfeasible Configuration



Feasible Configuration

Figure 2. Limitations on Process Configuration.

TABLE II

THE INPUT INSTRUCTION CHANGES FOR FIND FROM TABLE I

(Follow all MAEBE input instructions except as follows)

Change No.	Alternate Instructions
1	Omit the first card containing NMLKJI
2	After all variables listed on card 2, include the following variable data: NORC = The number of recycle streams in the process. card 2, cc 56-60, Format: I5 MU = The total number of parameters needed to specify the flow rates of all the recycle streams. card 2, cc 61-65, Format: I5
3	Place the IET variable card after the IDENT card.
4	Omit the LRCMX card.
5	In the VALUES matrix card series, place the selected recycle streams' component flow rates and the total flow rates in the vectors of the VALUES matrix which represent the recycle streams.
6	Do not place the IET, NEQ, or NP card sets in the positions indicated in the MAEBE input format.
7	After the ENERGY data card, place the following: MINOR = The subscripted variable indi- cator which has "NORC" by "KC+1" elements. For each recycle stream the first "KC" elements have

TABLE II (continued)

7 con't.	values of 0 if the component is not present and 1 if it may be part of the stream. The last element of each streams' row is the integer designation of that particular recycle stream. card "ENERGY"+1, Format: 14I5, cc 1- 5, value = 1 cc 6-10, value = 1 cc 11-15, value = 1 cc 16-20, value = 1 cc 21-25, value = 4 cc 26-30, value = 0 cc 31-35, value = 1 cc 36-40, value = 1 cc 41-45, value = 1 cc 46-50, value = 5
8	Omit the NP card series completely.
9*	Place the NEQ card set after the MINOR card.

* The NEQ card set is part of the basic output of the SEEK/HUNT program system, and may be inserted here directly if desired.

The input instructions for the SEEK/HUNT system do not require all the physical data concerning the process; therefore, a separate set of instructions are presented in Table III for this system. The variables used in this system are consistent with Phase II of MAEBE, with the exception of NOUT which has the opposite effect in this system that it does in FIND or MAEBE.

For purposes of comparison of the programs and their input instructions, the Fortran listings of MAEBE, SEEK/HUNT, and FIND are presented in Tables IV, V, and VI respectively.

TABLE III

INPUT INSTRUCTIONS FOR THE SEEK/HUNT^{*} PROGRAM SYSTEM

Variable	Format	Data and explanation
I	14I5	Total number of equipment nodes in the process. card 1, cc 1- 5, value = 4
J	"	The number of internal streams. card 1, cc 6-10, value = 5
KS	"	The number of entering and exiting streams in the process. card 1, cc 11-15, value = 4
NOUT	"	The internal output option indicator: 0 for internal output, 1 for no output of internal data. card 1, cc 16-20, value = 1
NEQ	"	The equipment sequence designation variable. card 2, cc 1- 5, value = 1 cc 6-10, value = 2 cc 11-15, value = 3 cc 16-20, value = 4
NEP	"	The configuration matrix as defined in Table I. cards 3 through "I+1"
IDENT	6X,11A6	The alphameric identification header label, read in the HUNT subroutine.

* This program system applies only to the recycle process configurations.

TABLE IV
FORTRAN LISTING OF THE MAEBE PROGRAM DECK

```

C          MAEBE MASTER DECK          LNK
C          DIMENSION NEQ(1,2),IET(1),MIEQ(1),NDM(1,1),NGM(1,1),NP
C          1(1+1,J+KS),ENERGY(1),VALUES(J+KS,KC+1),ST(J+KS),SP(J+K
C          2S),SE(J+KS),COMMW(KC),COMHC(KC),COMHV(KC),CFR(KC),NAME
C          3(KC,4),PCE(KC),MINOR(NORC,KC+1),PHI(MU,2)
C          *** REPEAT THE ABOVE DIMENSIONS HERE ***
C          DIMENSION NSIG(2),IDENT(11)
100  FORMAT(14I5)
101  FORMAT(5E15.6)
102  FORMAT(5F15.6)
103  FORMAT(1H1,5X,11A6)
104  FORMAT(7I15)
105  FORMAT(1I12,F19.3,F15.5,F15.4)
106  FORMAT(25I5)
107  FORMAT(1H ,4A6,F10.3,F10.5,F10.2)
108  FORMAT(1H ,5X,11A6)
109  FORMAT(1H ,8X,9HCOMPONENT,11X,8HTOTAL IN,10X,9HTOTAL O
1UT)
110  FORMAT(1H ,6HSTREAM,14,1H,,5H FLOW,E14.6,14H LBS. PER
1HOUR,1H,,F6.1,7H F DEG.,1H,)
111  FORMAT(1H ,F6.1,5H PSIA,1H,E15.6,12H BTU PER HR.)
112  FORMAT(1H ,58HMASS FRACTION STREAM COMPOSITIONS AND CO
1MPONENT FLOW RATES)
113  FORMAT(1H ,4A6,1X,2E17.6)
114  FORMAT (1H ,29HHEAT BALANCE ON EQUIPMENT NO.,13,1X,3HW
1AS,E16.8,1X,3HBTU)
117  FORMAT(1H ,4A6,E14.6,E18./1H ,21HCOMP. PER CENT CHANGE
1F12.6)
118  FORMAT(1H ,31HCONVERGENCE WAS REALIZED IN THE15,10HTH.
1 TRIAL.)
119  FORMAT(1H ,5HAFTER15,37H TRIALS CONVERGENCE WAS NOT OB
1TAINED.)
131  FORMAT(1H ,3X,21HENTIRE SYSTEM BALANCE,E14.6,E18.6/1H
1,13HPROCESS ERRORF12.6,5H PCT.)
228  FORMAT(1H ,36HINPUT-OUTPUT FRACTION DIFFERENCES OF/1H
1,33HTHE RECYCLE COMPONENT FLOW RATES.)
900  FORMAT(1H ,60HERROR DETECTED IN STREAM ORIENTATION MAT
1RIX. PROGRAM DUMPED.)
901  FORMAT(1H ,47HSYSTEM YIELDED NO MINIMUM EQUIPMENT SEQU
1ENCE IN,15,3MH ATTEMPTS. BEST ORDER WAS AS FOLLOWS.)
902  FORMAT(1H ,51HOPTIONAL OUTPUT OF INPUT DATA. CHECK AGA
1INST SYSTEM,8H VALUES.)
903  FORMAT(1H ,11HTOT. EQP. =13,13H UNK. STMS. =13,12H TOT
1,COMP. =13,14H KNOWN STMS.=13,14H INLET STMS. =13,20H
2RECYCLE INDICATOR =12)

```

TABLE IV (continued)

```

904 FORMAT(1H ,20X,7HVALUES(13,1H,13,1H))
905 FORMAT(1H ,23HSTM. ORIENTATION MTX. (13,1H,13,1H))
906 FORMAT(1H ,9X,8HEQP. NO.,7X,9HEQP. TYPE)
907 FORMAT(1H ,9X,9HCOMPONENT,7X,9HMOLE. WT.,6X,9HHEAT CAP
  1.,4X,11HLATENT HEAT)
908 FORMAT(1H ,5X,10HINLET STM.,4X,11HTEMPERATURE,7X,8HPRE
  1SSURE)
909 FORMAT(1H/,7HSIGMA =14,38H FOR THE OPTIMUM EQUIPMENT S
  1EQUENCE OF13,19(1H,13))
910 FORMAT(1H/,59H***** OPTIONAL INTERNAL OUTPUT
  1T ***** )
911 FORMAT(1H ,30X)
912 FORMAT(1H ,14HENERGY BAL. ON,13,8H EQPS. =/10E12.5)
913 FORMAT(1H ,60H** (NEGATIVE VALUES OF RECYCLE PARAMETE
  1RS RESULTED FROM THE/1H ,60H CONVERGENCE METHODS. TWO
  2SETS OF RESULTS ARE PRESENTED. THE/1H ,60H LAST SET IS
  3 THE RESULT OF SETTING ALL NEGATIVE VALUES=ZERO))
914 FORMAT(1H/,20X,35HMATRIX OF SYSTEM STREAM ORIENTATION/
  11H ,9HEQP. NO./15X,10HSTREAM NO./1H ,9X,25I5)
915 FORMAT(1H ,16,3H /,25I5)
230 FORMAT(1H ,5HPhi (13,3H BY,13,1H))
259 FORMAT(1H1,29HACTUAL COMPUTATIONAL TIME WASF11.6,23H S
  1ECONDS TO COMPLETION.)
260 FORMAT(1H1,52HTOTAL COMPUTING TIME TO COMPLETE ANALYSI
  1S THRU PHASE12,4H WASF11.6,9H SECONDS.)
261 FORMAT(1H ,36HTIME LEFT TO RUN FROM START OF JOB =F11.
  14,9H SECONDS.)
C  ** (READ INPUT DATA) **
    READ 100,NMLKJI
    DO 500 IJKLMN=1,NMLKJI
      READ 100,I,J,KC,KS,INSTM,LRC,LCON,IDTV,NOUT,NOUT2,NTYP
      1E
      IF (NOUT) 201,201,200
200  LEFTT=34359738367-ITIMER(-1)
      X=LEFTT
      X=X/60.
      PRINT 261,X
      LTIME=ITIMER(0)
201  READ 108,IDENT
      IP1=I+1
      JKS=J+KS
      KC1=KC+1
      KOUT=JKS-(J+INSTM)
      IM1=I-1
      IM2=I-2

```

```

      KENNY=1
      JINSTM=J+INSTM
      NCOUNT=0
      NEG1=0
      IF (LRC) 120,120,121
121  READ 101,CONCR1
      READ 100,LRCMX
      READ 100,MAXPAS
120  DO 122 L=1,JINSTM
122  READ 101,(VALUES(L,K),K=1,KC1)
      DO 128 K=1,KC
128  READ 107,(NAME(K,K1),K1=1,4),COMMW(K),COMHC(K),COMHV(K
1)
      READ 100,(NEQ(K,1),K=1,1)
      READ 100,(IET(K),K=1,1)
      IF (LRC,LT,1) GO TO 125
      DO 126 L1=1,1
      L=NEQ(L1,1)
126  READ 100,(NP(L,K),K=1,JKS)
      READ 100,(NP(IP1,K),K=1,J)
125  DO 127 L=1,INSTM
      J1=J+L
127  READ 102,ST(J1),SP(J1)
      READ 101,(ENERGY(K),K=1,1)
C  ** (OPTIONAL OUTPUT OF INPUT DATA) **
      IF (NOUT) 401,401,400
400  PRINT 902,IJKLMN
      PRINT 103,IDENT
      PRINT 910
      PRINT 903,I,J,KC,KS,INSTM,LRC
      PRINT 904,JKS,KC1
      DO 402 K=1,JKS
402  PRINT 101,(VALUES(K,L),L=1,KC1)
      IF (LRC) 405,405,403
403  PRINT 905,IP1,JKS
      DO 404 K1=1,1
      K=NEQ(K1,1)
404  PRINT 106,(NP(K,L),L=1,JKS)
      PRINT 106,(NP(IP1,L),L=1,J)
405  PRINT 906
      DO 406 K=1,1
406  PRINT 104,NEQ(K,1),IET(K)
      PRINT 907
      DO 407 K=1,KC
407  PRINT 105,K,COMMW(K),COMHC(K),COMHV(K)

```

```

      PRINT 908
      DO 408 K=1,INSTM
      J1=J+K
408  PRINT 105,J1,ST(J1),SP(J1)
      PRINT 912,I,(ENERGY(K),K=1,I)
      PRINT 911
401  NDTRED=0
C   ** (READ INPUT DATA IN SUBROUTINES) **
      DO 700 KNOW=1,I
700  MIEQ(KNOW)=NEQ(KNOW,1)
      IF (IDTV) 750,750,752
750  DO 751 K=1,INSTM
      KPJ=K+J
      DO 751 L=1,KC
751  VALUES(KPJ,L)=VALUES(KPJ,L)/VALUES(KPJ,KC1)
752  CONTINUE
      CALL SELECT(NDTRED,MIEQ,IET,I,J,KS,JKS,KC,KC1,VALUES,S
1T,SP,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT,CFR)
      NDTRED=100
      IF (NOUT) 203,203,202
202  N123=1
      LEFT=34359738367-ITIMER(-1)
      X=LEFTT
      Y=LEFT
      X=(X-Y)/60.
      PRINT 260,N123,X
203  IF (LRC) 2,2,1
C   ** (START SEQUENCE OPTIMIZATION FOR RECYCLE) **
      1  IC=1
      IP1=I+1
      III=0
      NTR=0
      M=0
      N=0
      NEG=0
      NNR=0
C   ** (LRCMX= 2 IF SEQUENCE OPTIMIZATION HAS FAILED) **
      IF (LRCMX-1) 803,803,2
803  CONTINUE
C   ** (CALCULATE DELTA MATRIX) **
      DO 300 K=1,I
      DO 300 L=1,I
300  NDM(K,L)=0
      DO 312 K1=1,J
      DO 312 K2=1,I

```

```

      K=NEQ(K2,1)
      DO 312 L2=1,I
      L=NEQ(L2,1)
      IF (NP(K,K1)) 301,312,301
301 IF (NP(L,K1)) 302,312,302
302 IF (NP(K,K1)+NP(L,K1)) 312,303,312
303 IF (NP(L,K1)+IABS(NP(K,K1))) 312,304,305
304 NDM(K,L)=NP(IP1,K1)
      GO TO 306
305 NDM(K,L)=-NP(IP1,K1)
306 DO 311 KK=1,J
      IF (K1-KK) 307,311,307
307 IF (NP(K,KK)+NP(L,KK)) 311,308,311
308 IF (NP(K,KK)) 309,311,310
309 NDM(K,L)=NDM(K,L)-NP(IP1,KK)
      GO TO 311
310 NDM(K,L)=NDM(K,L)+NP(IP1,KK)
311 CONTINUE
312 CONTINUE
C ** (MAXIMUM POSSIBLE SEQUENCES=(I) FACTORIAL) **
      NMATER=1
      DO 351 K=1,I
351 NMATER=NMATER*K
C ** (CHECK DELTA CALCULATION.. NDM(K,L)=-NDM(L,K) )**
313 DO 314 K=1,I
      DO 314 L=1,I
      IF (NDM(K,L)+NDM(L,K)) 950,314,950
314 CONTINUE
C ** (CALCULATE SIGMA(IC) OF NEQ(I,IC) ORDER OF DELTA) **
      3 NSIG(IC)=0
      DO 315 KK=1,IM1
      K=NEQ(KK,IC)
      KP1=KK+1
      DO 315 LL=KP1,I
      L=NEQ(LL,IC)
315 NSIG(IC)=NSIG(IC)+NDM(K,L)
      GO TO (4,5),IC
950 PRINT 900
      GO TO 500
C ** (CALCULATE GAMMA UPPER TRIANGLE FROM NEQ(I,1) SEQUENCE
C   OF DELTA MATRIX) **
      4 CONTINUE
      DO 319 KK=1,IM1
      K=NEQ(KK,1)
      KL=KK+1

```

```

      DO 319 LL=KL,1
      LLL=NEQ(LL,1)
      NGM1=0
      NGM2=0
      DO 316 LK=KL,LL
      L=NEQ(LK,1)
316  NGM1=NGM1+NDM(K,L)
      LM1=LL-1
      DO 318 LK=KL,LM1
      IF (LL-KK-2) 319,317,317
317  CONTINUE
      L=NEQ(LK,1)
318  NGM2=NGM2+NDM(L,LLL)
319  NGM(KK,LL)=NGM1+NGM2
      GO TO 13
C  ** (COMPARE SIGMAS 1 AND 2 FOR MINIMUM) **
      5  IF (NSIG(2)-NSIG(1)) 7,6,6
      6  NTX=0
      NC=0
      GO TO 8
      7  NTX=1
      NC=1
      8  IF (NNR) 9,9,11
      9  IF (NTX) 10,10,12
     10  IF (NC) 322,322,320
     11  IF (III) 24,24,25
     24  IF (NTX) 22,22,23
     25  IF (NTX) 18,18,26
     26  NSIG(1)=NSIG(2)
      DO 342 K=1,I
342  NEQ(K,1)=NEQ(K,2)
      GO TO 18
C  ** (INITIALLY SET LOWER GAMMA = UPPER GAMMA TRIANGLE) **
320  CONTINUE
      DO 321 K=1,IM1
      KP1=K+1
      DO 321 L=KP1,I
321  NGM(L,K)=NGM(K,L)
C  ** (SET LOWER GAMMA(N,M)= -1000000) **
322  CONTINUE
      IF (M) 325,325,323
323  IF (N) 325,325,324
324  NGM(N,M)=-1000000
325  CONTINUE
C  ** (SELECT MAXIMUM ELEMENT OF LOWER GAMMA) **

```

TABLE IV (continued)

```

      DO 350 K=1,IM1
      KP1=K+1
      DO 350 L=KP1,I
      IF (NGM(L,K)+1000000) 350,350,352
350  CONTINUE
      IF (NOUT) 210,210,209
209  PRINT 901,NTR
210  NNR=1
      NTX=0
      GO TO 11
352  CONTINUE
      L1=IM1
      K1=I
      DO 332 K=1,IM1
      L=I-K
      LP1=L+1
      DO 332 KK=LP1,I
      IF (NGM(K1,L1)) 327,327,328
327  IF (NGM(KK,L)) 329,329,330
328  IF (NGM(KK,L)) 331,331,329
329  CONTINUE
      IF (NGM(K1,L1)-NGM(KK,L)) 330,330,331
330  L1=L
      K1=KK
331  CONTINUE
332  CONTINUE
C  ** (M,N = COORDINATES OF MAXIMUM UNTRANSFORMED GAMMA) **
      M=L1
      N=K1
      NC=0
      NNR=0
      NTR=NTR+1
C  ** (IC= 2, NEQ(I,2)=TRANSFORMED SEQUENCE OF NEQ(I,1) ) **
      DO 333 K=1,I
333  NEQ(K,2)=NEQ(K,1)
      NEQ(M,2)=NEQ(N,1)
      NEQ(N,2)=NEQ(M,1)
      IC=2
C  ** (CHECK... NUMBER OF SEQUENCES NOT TO EXCEED NMATER) **
      IF (NTR-NMATER) 3,3,21
C  ** (IC= 1, NEQ(I,1)= BETTER SEQUENCE NEQ(I,2), WHEN
C  NSIG(2) WAS LESS THAN NSIG(1) ) **
      12 DO 334 K=1,I
334  NEQ(K,1)=NEQ(K,2)
      NSIG(1)=NSIG(2)

```

```

      IC=1
      NC=0
      N=0
      M=0
      GO TO 4
C  ** (SEARCH UPPER GAMMA FOR POSITIVE ELEMENTS) **
      13 CONTINUE
         DO 335 K=1,IM1
            KP1=K+1
            DO 335 L=KP1,I
               IF (NGM(K,L)) 335,335,320
      335 CONTINUE
         GO TO 14
C  ** (ALL GAMMA ELEMENTS=0 OR LESS, SEARCH INNER, UPPER
C  DELTA MATRIX FOR POSITIVE ELEMENTS) **
      14 DO 336 KK=2,IM2
         KP1=KK+1
         K=NEQ(KK,1)
         DO 336 LL=KP1,IM1
            L=NEQ(LL,1)
            IF (NDM(K,L)) 336,336,320
      336 CONTINUE
         GO TO 15
C  ** (GAMMA AND DELTA ELEMENTS INDICATE A POSSIBLE SOLUTION
      15 IF (III) 16,16,18
C  ** (III=0 FOR FIRST SEQUENCE, MIEQ(I)= NEQ(I,1) AND
C  NSIGMA = SIGMA OF BEST SEQUENCE OF DELTA) **
      16 DO 337 K=1,I
      337 MIEQ(K)=NEQ(K,1)
         NSIGMA=NSIG(1)
         III=1
         GO TO 17
C  ** (INVERT FIRST VERSION SEQUENCE AND TRY OPTIMIZATION
C  AGAIN) **
      17 DO 338 K=1,I
         L=I-K+1
      338 NEQ(K,1)=MIEQ(L)
         NTR=NTR+1
         M=0
         N=0
         IC=1
         GO TO 3
C  ** (SELECT BEST OF BOTH VERSIONS) **
      18 IF (NSIG(1)-NSIGMA) 19,20,20
      19 DO 339 K=1,I

```

TABLE IV (continued)

```

339 MIEQ(K)=NEQ(K,1)
    NSIGMA=NSIG(1)
    GO TO 20
21 NNR=1
    GO TO 3
22 DO 340 L=1,I
340 MIEQ(L)=NEQ(L,1)
    NSIGMA=NSIG(1)
    GO TO 20
23 DO 341 K=1,I
341 MIEQ(K)=NEQ(K,2)
    NSIGMA=NSIG(2)
    GO TO 20
C  ** (START CONVERGENCE CALCULATIONS OF RECYCLE PARAMETERS)
20 IF (NOUT) 612,612,613
613 PRINT 910
    PRINT 909,NSIGMA,(MIEQ(K),K=1,I)
    PRINT 914,(K,K=1,JKS)
    PRINT 911
    DO 614 LK=1,I
    KL=MIEQ(LK)
    PRINT 915,KL,(NP(KL,KXYZ),KXYZ=1,JKS)
614 CONTINUE
    PRINT 101,((VALUES(K,L),L=1,KC1),K=1,JKS)
    N123=2
    LEFT=34359738367-ITIMER(-1)
    X=LEFTT
    Y=LEFT
    X=(X-Y)/60.
    PRINT 260,N123,X
C  ** (COMPUTE, NUMBER OF RECYCLE STREAMS=NORC, NUMBER OF
C    RECYCLE PARAMETERS=MU ) **
C                                     OR
C  ** (ATTEMPT CONVERGENCE ON PRIMARY SEQUENCE) **
612 MU=0
    NORC=0
    DO 603 K=1,J
    DO 601 L=1,I
    KK=MIEQ(L)
    IF (NP(KK,K)) 603,601,600
600 NORC=NORC+1
    MINOR(NORC,KC1)=K
    MU=MU+NP(IP1,K)
    GO TO 603
601 CONTINUE

```

```

603 CONTINUE
  K1=0
C  ** (MINOR(K,L)= 1 IF PARAMETER IS RECYCLE, 0 IF NOT) **
  DO 616 K1=1,NORC
    K=MINOR(K1,KC1)
    DO 616 L=1,KC
      IF (VALUES(K,L)+1000000.) 618,618,619
618 MINOR(K1,L)=1
      GO TO 616
619 MINOR(K1,L)=0
616 CONTINUE
C  ** (CALCULATE ARBITRARY INITIAL RECYCLE COMPOSITIONS AND
C    FLOW RATES) **
  MP1=MU+1
  KKK=0
  STMTFR=0.
  DO 604 K=1,INSTM
    LL=K+J
604 STMTFR=STMTFR+VALUES(LL,KC1)
    DO 608 L=1,NORC
      K=MINOR(L,KC1)
      X=NP(IP1,K)
      DO 608 LL=1,KC
        IF (MINOR(L,LL)) 608,608,609
609 KKK=KKK+1
      PHI(KKK,1)=STMTFR/X
608 CONTINUE
C  ** (GENERATE THE FIRST PHI(MU,MU+1) MATRIX) **
  DO 710 L=1,MAXPAS
    NCOUNT=NCOUNT+1
    KK=1
    DO 703 K1=1,NORC
      K2=MINOR(K1,KC1)
      VALUES(K2,KC1)=0.
      DO 702 K=1,KC
        IF (MINOR(K1,K)) 702,702,701
701 VALUES(K2,K)=PHI(KK,1)
        KK=KK+1
702 VALUES(K2,KC1)=VALUES(K2,KC1)+VALUES(K2,K)
        DO 703 K=1,KC
          VALUES(K2,K)=VALUES(K2,K)/VALUES(K2,KC1)
703 CONTINUE
      CALL SELECT(NDTRED,MIEQ,IET,I,J,KS,JKS,KC,KC1,VALUES,S
1T,SP,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT,CFR)
      DO 705 KL=1,MU

```

```

705 PHI(KL,2)=PHI(KL,1)
    KK=1
    DO 707 K=1,NORC
    K1=MINOR(K,KC1)
    DO 707 K2=1,KC
    IF (MINOR(K,K2)) 707,707,706
706 PHI(KK,1)=VALUES(K1,K2)*VALUES(K1,KC1)
    KK=KK+1
707 CONTINUE
    IF (NOUT2) 207,207,208
208 LPONF=2
    PRINT 230,MU,LPONF
    DO 229 KTXN=1,MU
229 PRINT 101,(PHI(KTXN,KXT),KXT=1,LPONE)
    PRINT 228
C  ** (CHECK LAST SET OF PHI RECYCLE VALUES AGAINST
C  CONVERGENCE SPECIFICATIONS.) **
207 DO 709 K=1,MU
    X=(PHI(K,2)-PHI(K,1))/PHI(K,1)
    IF (NOUT2) 213,213,212
212 PRINT 101,X
213 IF (ABS(X)-CONCR1) 709,709,710
709 CONTINUE
    KENNY=0
    GO TO 800
710 CONTINUE
    IF (KENNY) 720,720,757
757 PRINT 119,NCOUNT
    GO TO 500
720 KK=1
    LRCMX=0
    NEG1=NEG+1
    GO TO (804,805),NEG1
805 PRINT 913
804 DO 811 L=1,NORC
    LK=MINOR(L,KC1)
    VALUES(LK,KC1)=0.
    DO 810 NK=1,KC
    IF (MINOR(L,NK)) 810,810,812
812 GO TO (807,806),NEG1
806 IF (PHI(KK,1)) 808,807,807
807 VALUES(LK,NK)=PHI(KK,1)
    GO TO 809
808 VALUES(LK,NK)=0.
809 KK=KK+1

```

```

      VALUES(LK,KC1)=VALUES(LK,KC1)+VALUES(LK,NK)
810 CONTINUE
      DO 811 K=1,KC
      VALUES(LK,K)=VALUES(LK,K)/VALUES(LK,KC1)
811 CONTINUE
C  ** (NO RECYCLE, CONVERGED RECYCLE VALUES, OR NO OPTIMIZED
C    SEQUENCE EXISTS AT THIS POINT) **
      2 IF (LRCMX-1) 800,800,612
C  ** (FINAL CALCULATIONS OF ALL COMPOSITIONS, FLOW RATES,
C    STREAM TEMPERATURES AND PRESSURES, AND EQUIPMENT HEAT
C    BALANCES) **
800 LCON=2
      IF (NOUT) 205,205,204
204 N123=3
      PRINT 118,NCOUNT
      LEFT=34359738367-ITIMER(-1)
      X=LEFTT
      Y=LEFT
      X=(X-Y)/60.
      PRINT 260,N123,X
205 CALL SELECT(NDTRED,MIEQ,IFT,I,J,KS,JKS,KC,KC1,VALUES,S
1T,SP,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT,CFR)
      DO 814 L=1,JKS
      SE(L)=0.
      DO 814 K=1,KC
814 SE(L)=SE(L)+(VALUES(L,K)*VALUES(L,KC1)*COMHC(K)*ST(L))
C  ** (FINAL OUTPUT OF SYSTEM ANALYSIS) **
      IF (NTYPE) 801,801,802
802 PUNCH 108,IDENT
      DO 819 L=1,JKS
      PUNCH 110,L,VALUES(L,KC1),ST(L)
      PUNCH 111,SP(L),SE(L)
      DO 821 K=1,KC
821 CFR(K)=VALUES(L,K)*VALUES(L,KC1)
      PUNCH 112
      DO 819 K=1,KC
819 PUNCH 113,(NAME(K,KK),KK=1,4),VALUES(L,K),CFR(K)
      DO 820 L=1,I
820 PUNCH 114,L,ENERGY(L)
      PUNCH 109
      DO 825 L=1,KC
      X=0.
      Y=0.
      DO 823 K=1,INSTM
      JPK=J+K

```

TABLE IV (continued)

```

823 X=X+(VALUES(JPK,L)*VALUES(JPK,KC1))
    DO 824 K=1,KOUT
      JPK=J+K+INSTM
824 Y=Y+(VALUES(JPK,L)*VALUES(JPK,KC1))
    PCE(L)=((Y-X)/X)*100.
825 PUNCH 117,(NAME(L,K1),K1=1,4),X,Y,PCE(L)
    Z=0.
    ZZ=0.
    DO 829 K=1,INSTM
      JPK=J+K
829 Z=Z+VALUES(JPK,KC1)
    DO 830 K=1,KOUT
      JPK=J+K+INSTM
830 ZZ=ZZ+VALUES(JPK,KC1)
    DELTA=((ZZ-Z)/Z)*100.
    PUNCH 131,Z,ZZ,DELTA
801 PRINT 103,IDENT
    DO 815 L=1,JKS
      PRINT 110,L,VALUES(L,KC1),ST(L)
      PRINT 111,SP(L),SE(L)
      DO 822 K=1,KC
622 CFR(K)=VALUES(L,K)*VALUES(L,KC1)
      PRINT 112
      DO 815 K=1,KC
815 PRINT 113,(NAME(K,KK),KK=1,4),VALUES(L,K),CFR(K)
      DO 816 L=1,I
816 PRINT 114,L,ENERGY(L)
      PRINT 109
      DO 828 L=1,KC
        X=0.
        Y=0.
        DO 826 K=1,INSTM
          JPK=J+K
826 X=X+(VALUES(JPK,L)*VALUES(JPK,KC1))
        DO 827 K=1,KOUT
          JPK=J+K+INSTM
827 Y=Y+(VALUES(JPK,L)*VALUES(JPK,KC1))
        PCE(L)=((Y-X)/X)*100.
828 PRINT 117,(NAME(L,K1),K1=1,4),X,Y,PCE(L)
        Z=0.
        ZZ=0.
        DO 831 K=1,INSTM
          JPK=J+K
831 Z=Z+VALUES(JPK,KC1)
        DO 832 K=1,KOUT

```

TABLE IV (continued)

40

```
      JPK=J+K+INSTM
832  ZZ=ZZ+VALUES(JPK,KC1)
      DELTA=((ZZ-Z)/Z)*100.
      PRINT 131,Z,ZZ,DELTA
818  IF (NEG1-1) 501,501,817
817  NEG=0
      GO TO 720
501  CONTINUE
      IF (NOUT) 500,500,211
211  LTIME=34359738367-ITIMER(-1)
      LEFT=LEFTT-LTIME
      X=LEFT
      Y=X/60.
      PRINT 259,Y
500  CONTINUE
      RETURN
      END
```

TABLE V

FORTRAN LISTING OF THE SEEK/HUNT PROGRAM SYSTEM DECK, PART A

```

C  ** THIS IS THE SEEK MASTER DECK
C  ** DIMENSION NEQ(I,2),NDM(I,1),NGM(I,1),NP(I+1,J+KS),MIEQ
C    1(I)
C  ** THE FOLLOWING CARD MUST BE ALTERED FOR EACH PROCESS **
      DIMENSION MIEQ(9),NDM(9,9),NGM(9,9),NEQ(9,2),NP(10,18)
100  FORMAT(14I5)
101  FORMAT(1H ,16HOPTIMUM SEQUENCE,20(13,2H**))
102  FORMAT(1H ,25I5)
210  FORMAT(1H1,20HORIENTATION MATRIX (13,3H BY13,1H))
211  FORMAT(1H ,4HMU =15)
212  FORMAT(1H ,6HSTREAM13,12H IS RECYCLE.)
      READ 100,I,J,KS,NOUT
      IP1=I+1
      JKS=J+KS
      READ 100,(NEQ(K,1),K=1,I)
      DO 120 KL=1,I
        K=NEQ(KL,1)
120  READ 100,(NP(K,L),L=1,JKS)
      READ 100,(NP(IP1,L),L=1,J)
      IF (NOUT) 300,300,302
300  PRINT 210,IP1,JKS
      DO 301 K=1,I
301  PRINT 102,(NP(K,L),L=1,JKS)
      PRINT 102,(NP(IP1,L),L=1,J)
302  CONTINUE
      CALL HUNT(I,J,KS,IP1,JKS,NEQ,NP,NDM,NGM,MIEQ,NOUT)
612  MU=0
      NORC=0
      DO 603 K=1,J
        DO 601 L=1,I
          KK=MIEQ(L)
          IF (NP(KK,K)) 603,601,600
600  NORC=NORC+1
          PRINT 212,K
          MU=MU+NP(IP1,K)
          GO TO 603
601  CONTINUE
603  CONTINUE
      PRINT 211,MU
      PRINT 101,(MIEQ(K),K=1,I)
      PUNCH 100,(MIEQ(K),K=1,I)
      CALL EXIT
      END

```

TABLE V (continued)

FORTRAN LISTING OF THE SEEK/HUNT PROGRAM SYSTEM DECK, PART B

```

      SUBROUTINE HUNT(I,J,KS,IP1,JKS,NEQ,NP,NDM,NGM,MIEQ,NOU
1T)
      DIMENSION NEQ(1,2),NDM(1,1),NGM(1,1),NP(IP1,JKS),MIEQ(
1I)
      DIMENSION IDENT(11),NSIG(2)
100 FORMAT(14I5)
103 FORMAT(1H .5X,11A6)
106 FORMAT(25I5)
107 FORMAT(1H1,11A6)
260 FORMAT(1H1,28HTOTAL COMPUTATIONAL TIME WAS,F10.5,9H SE
1CONDS.)
900 FORMAT(1H .60HERROR DETECTED IN STREAM ORIENTATION MAT
1RIX. PROGRAM DUMPED.)
901 FORMAT(1H .47HSYSTEM YIELDED NO MINIMUM EQUIPMENT SEQU
1UENCE IN,14.40H ATTEMPTS. BEST SEQUENCE WAS AS FOLLOWS
2.)
909 FORMAT(1H/,7HSIGMA =14.38H FOR THE OPTIMUM EQUIPMENT S
1EQUENCE OF13.19(1H,13))
910 FORMAT(1H/,59H***** OPTIONAL INTERNAL OUTPU
1T *****
914 FORMAT(1H/,20X,35HMATRIX OF SYSTEM STREAM ORIENTATION/
11H .9HEQP. NO./15X,10HSTREAM NO./1H,9X,25I5)
915 FORMAT(1H .16.3H /,25I5)
917 FORMAT(1H .60(1H-))
      LTIME=ITIMER(0)
      READ 103,IDENT
      1 IC=1
      IM1=1-1
      IM2=1-2
      III=0
      NTR=0
      M=0
      N=0
      NLIMIT=0
      NNR=0
C  ** (CALCULATE DELTA MATRIX) **
      DO 300 K=1,I
      DO 300 L=1,I
300 NDM(K,L)=0
      DO 312 K1=1,J
      DO 312 K2=1,I
      K=NEQ(K2,1)
      DO 312 L2=1,I
      L=NEQ(L2,1)
      IF (NP(K,K1)) 301,312,301

```

```

301 IF (NP(L,K1)) 302,312,302
302 IF (NP(K,K1)+NP(L,K1)) 312,303,312
303 IF (NP(L,K1)+IABS(NP(K,K1))) 312,304,305
304 NDM(K,L)=NP(IP1,K1)
    GO TO 306
305 NDM(K,L)=-NP(IP1,K1)
306 DO 311 KK=1,J
    IF (K1-KK) 307,311,307
307 IF (NP(K,KK)+NP(L,KK)) 311,308,311
308 IF (NP(K,KK)) 309,311,310
309 NDM(K,L)=NDM(K,L)-NP(IP1,KK)
    GO TO 311
310 NDM(K,L)=NDM(K,L)+NP(IP1,KK)
311 CONTINUE
312 CONTINUE
C  ** (MAXIMUM POSSIBLE SEQUENCES=(I) FACTORIAL) **
    NMATER=1
    DO 351 K=1,I
351 NMATER=NMATER*K
C  ** (CHECK DELTA CALCULATION.. NDM(K,L)=-NDM(L,K) )**
313 DO 314 K=1,I
    DO 314 L=1,I
        IF (NDM(K,L)+NDM(L,K)) 950,314,950
314 CONTINUE
C  ** (CALCULATE SIGMA(IC) OF NEQ(I,IC) ORDER OF DELTA) **
    3 NSIG(IC)=0
    DO 315 KK=1,IM1
        K=NEQ(KK,IC)
        KP1=KK+1
        DO 315 LL=KP1,I
            L=NEQ(LL,IC)
315 NSIG(IC)=NSIG(IC)+NDM(K,L)
    GO TO (4,5),IC
950 PRINT 900
    GO TO 500
C  ** (CALCULATE GAMMA UPPER TRIANGLE FROM NEQ(I,1) SEQUENCE
C    OF DELTA MATRIX) **
    4 CONTINUE
    DO 319 KK=1,IM1
        K=NEQ(KK,1)
        KL=KK+1
        DO 319 LL=KL,I
            LLL=NEQ(LL,1)
            NGM1=0
            NGM2=0

```

TABLE V (continued)

```

      DO 316 LK=KL,LL
      L=NEQ(LK,1)
316  NGM1=NGM1+NDM(K,L)
      LM1=LL-1
      DO 318 LK=KL,LM1
      IF (LL-KK-2) 319,317,317
317  CONTINUE
      L=NEQ(LK,1)
318  NGM2=NGM2+NDM(L,LLL)
319  NGM(KK,LL)=NGM1+NGM2
      GO TO 13
C  ** (COMPARE SIGMAS 1 AND 2 FOR MINIMUM) **
      5  IF (NSIG(2)-NSIG(1)) 7,6,6
      6  NTX=0
      NC=0
      GO TO 8
      7  NTX=1
      NC=1
      8  IF (NNR) 9,9,11
      9  IF (NTX) 10,10,12
     10  IF (NC) 322,322,320
     11  IF (III) 24,24,25
     24  IF (NTX) 22,22,23
     25  IF (NTX) 18,18,26
     26  NSIG(1)=NSIG(2)
      DO 342 K=1,I
342  NEQ(K,1)=NEQ(K,2)
      GO TO 18
C  ** (INITIALLY SET LOWER GAMMA = UPPER GAMMA TRIANGLE) **
320  CONTINUE
      DO 321 K=1,IM1
      KP1=K+1
      DO 321 L=KP1,I
321  NGM(L,K)=NGM(K,L)
C  ** (SET LOWER GAMMA(N,M)= -1000000) **
322  CONTINUE
      IF (M) 325,325,323
323  IF (N) 325,325,324
324  NGM(N,M)=-1000000
325  CONTINUE
C  ** (SELECT MAXIMUM ELEMENT OF LOWER GAMMA) **
      DO 350 K=1,IM1
      KP1=K+1
      DO 350 L=KP1,I
      IF (NGM(L,K)+1000000) 350,350,352

```

```

350 CONTINUE
  PRINT 901,NTR
  NNR=1
  NTX=0
  GO TO 11
352 CONTINUE
  L1=IM1
  K1=1
  DO 332 K=1,IM1
    L=I-K
    LP1=L+1
    DO 332 KK=LP1,I
      IF (NGM(K1,L1)) 327,327,328
327 IF (NGM(KK,L)) 329,329,330
328 IF (NGM(KK,L)) 331,331,329
329 CONTINUE
      IF (NGM(K1,L1)-NGM(KK,L)) 330,330,331
330 L1=L
      K1=KK
331 CONTINUE
332 CONTINUE
C  ** (M,N = COORDINATES OF MAXIMUM UNTRANSFORMED GAMMA) **
  M=L1
  N=K1
  NC=0
  NNR=0
  NTR=NTR+1
C  ** (IC= 2, NEQ(I,2)=TRANSFORMED SEQUENCE OF NEQ(I,1) ) **
  DO 333 K=1,I
333 NEQ(K,2)=NEQ(K,1)
    NEQ(M,2)=NEQ(N,1)
    NEQ(N,2)=NEQ(M,1)
    IC=2
C  ** (CHECK... NUMBER OF SEQUENCES NOT TO EXCEED NMATER) **
  IF (NTR-NMATER) 3,3,21
C  ** (IC= 1, NEQ(I,1)= BETTER SEQUENCE NEQ(I,2), WHEN
C  NSIG(2) WAS LESS THAN NSIG(1) ) **
  12 DO 334 K=1,I
334 NEQ(K,1)=NEQ(K,2)
    NSIG(1)=NSIG(2)
    IC=1
    NC=0
    N=0
    M=0
    GO TO 4

```

TABLE V (continued)

```

C  ** (SEARCH UPPER GAMMA FOR POSITIVE ELEMENTS) **
13  CONTINUE
    DO 335 K=1,IM1
      KP1=K+1
      DO 335 L=KP1,I
        IF (NGM(K,L)) 335,335,320
335  CONTINUE
      GO TO 14
C  ** (ALL GAMMA ELEMENTS=0 OR LESS, SEARCH INNER, UPPER
C  DELTA MATRIX FOR POSITIVE ELEMENTS.) **
14  DO 336 KK=2,IM2
      KP1=KK+1
      K=NEQ(KK,1)
      DO 336 LL=KP1,IM1
        L=NEQ(LL,1)
        IF (NDM(K,L)) 336,336,320
336  CONTINUE
      GO TO 15
C  ** (GAMMA AND DELTA ELEMENTS INDICATE A POSSIBLE SOLUTION
15  IF (III) 16,16,18
C  ** (III=0 FOR FIRST SEQUENCE, MIEQ(I)= NEQ(I,1) AND
C  NSIGMA = SIGMA OF BEST SEQUENCE OF DELTA.) **
16  DO 337 K=1,I
337  MIEQ(K)=NEQ(K,1)
      NSIGMA=NSIG(1)
      III=1
      GO TO 17
C  ** (INVERT FIRST VERSION SEQUENCE AND TRY OPTIMIZATION
C  AGAIN.) **
17  DO 338 K=1,I
      L=I-K+1
338  NEQ(K,1)=MIEQ(L)
      NTR=NTR+1
      M=0
      N=0
      IC=1
      GO TO 3
C  ** (SELECT BEST OF BOTH VERSIONS) **
18  IF (NSIG(1)-NSIGMA) 19,20,20
19  DO 339 K=1,I
339  MIEQ(K)=NEQ(K,1)
      NSIGMA=NSIG(1)
      GO TO 20
21  NNR=1
      GO TO 3

```

TABLE V (continued)

```
22 DO 340 L=1,I
340 MIEQ(L)=NEQ(L,1)
      NSIGMA=NSIG(1)
      GO TO 20
23 DO 341 K=1,I
341 MIEQ(K)=NEQ(K,2)
      NSIGMA=NSIG(2)
      GO TO 20
C  ** (START CONVERGENCE CALCULATIONS OF RECYCLE PARAMETERS)
20 IF (NOUT) 613,613,612
613 PRINT 910
      PRINT 909,NSIGMA,(MIEQ(K),K=1,I)
      PRINT 914,(K,K=1,JKS)
      PRINT 917
      DO 614 LK=1,I
      KL=MIEQ(LK)
      PRINT 915,KL,(NP(KL,KXYZ),KXYZ=1,JKS)
614 CONTINUE
612 CONTINUE
      LTIME=ITIMER(0)
      X=LTIME
      X=X/60.
      PRINT 260,X
      PRINT 107,IDENT
500 RETURN
END
```

TABLE VI

FORTRAN LISTING OF THE FIND PROGRAM DECK

```

C      THE FIND MASTER DECK   LNK
C      DIMENSION MIEQ(1),IET(1),ENERGY(1),NAME(KC,4),CFR(KC),
C      1VALUES(JKS,KC1),ST(JKS),SP(JKS),SE(JKS),MINOR(NORC,KC1
C      2),PHI(MU,2),COMMW(KC),COMHC(KC),COMHV(KC),PCE(KC)
      DIMENSION IDENT(11)
100  FORMAT(14I5)
101  FORMAT(5E15.6)
102  FORMAT(5F15.6)
103  FORMAT(1H1,5X,11A6)
104  FORMAT(7I15)
105  FORMAT(1H ,4A6,F7.2,F17.3,F16.2)
107  FORMAT(1H ,4A6,F10.3,F10.5,F10.2)
108  FORMAT(1H ,5X,11A6)
109  FORMAT(1H ,8X,9HCOMPONENT,11X,8HTOTAL IN,10X,9HTOTAL O
      1UT)
110  FORMAT(1H ,6HSTREAM,14,1H,,5H FLOW,E14.6,14H LBS. PER
      1HOUR,1H,,F6.1,7H F DEG.,1H,)
111  FORMAT(1H ,F6.1,5H PSIA,1H,E15.6,12H BTU PER HR.)
112  FORMAT(1H ,58HMASS FRACTION STREAM COMPOSITIONS AND CO
      1MPONENT FLOW RATES)
113  FORMAT(1H ,4A6,1X,2E17.6)
114  FORMAT (1H ,29HHEAT BALANCE ON EQUIPMENT NO.,13,1X,3HW
      1AS,E16.8,1X,3HBTU)
116  FORMAT(1H ,112,2F15.3)
117  FORMAT(1H ,4A6,E14.6,E18./1H ,21HCOMP. PER CENT CHANGE
      1F12.6)
118  FORMAT(1H ,31HCONVERGENCE WAS REALIZED IN THE15,10HTH.
      1 TRIAL.)
119  FORMAT(1H ,5HAFTER15,37H TRIALS CONVERGENCE WAS NOT OB
      1TAINED.)
131  FORMAT(1H ,3X,21HENTIRE SYSTEM BALANCE,E14.6,E18.6/1H
      1,13HPROCESS ERRORF12.6,5H PCT.)
228  FORMAT(1H ,36HINPUT-OUTPUT FRACTION DIFFERENCES OF/1H
      1,33HTHE RECYCLE COMPONENT FLOW RATES.)
902  FORMAT(1H ,51HOPTIONAL OUTPUT OF INPUT DATA. CHECK AGA
      1INST SYSTEM,8H VALUES.)
903  FORMAT(1H ,11HTOT. EQP. =I3,13H UNK. STMS. =I3,12H TOT
      1,COMP. =I3,14H KNOWN STMS.=I3,14H INLET STMS. =I3,20H
      2RECYCLE INDICATOR =I2)
904  FORMAT(1H ,20X,7HVALUES(I3,1H,I3,1H))
905  FORMAT(1H ,23HSTM. ORIENTATION MTX. (I3,1H,I3,1H))
906  FORMAT(1H ,9X,8HEQP. NO.,7X,9HEQP. TYPE)
907  FORMAT(1H ,9X,9HCOMPONENT,7X,9HMOLE. WT.,6X,9HHEAT CAP
      1.,4X,11HLATENT HEAT)
908  FORMAT(1H ,5X,10HINLET STM.,4X,11HTEMPERATURE,7X,8HPRE

```

```

ISSURE)
910 FORMAT(1H/,59H***** OPTIONAL INTERNAL OUTPUT
1T ***** )
911 FORMAT(1H ,30X)
912 FORMAT(1H0,14HENERGY BAL. ON,13,8H EQPS. =/10E12.5)
913 FORMAT(1H ,60H** (NEGATIVE VALUES OF RECYCLE PARAMETE
1RS RESULTED FROM THE/1H ,60H CONVERGENCE METHODS. TWO
2SETS OF RESULTS ARE PRESENTED. THE/1H ,60H LAST SET IS
3 THE RESULT OF SETTING ALL NEGATIVE VALUES=ZERO))
230 FORMAT(1H ,5HPhi (13,3H BY,13,1H))
259 FORMAT(1H1,29HACTUAL COMPUTATIONAL TIME WASF11.6,23H S
1SECONDS TO COMPLETION.)
260 FORMAT(1H1,52HTOTAL COMPUTING TIME TO COMPLETE ANALYSI
1S THRU PHASE12,4H WASF11.6,9H SECONDS.)
261 FORMAT(1H1,30HTIME LEFT TO RUN FROM START IS,F12.5,9H
1SECONDS.)
C ** (READ INPUT DATA) **
  READ 100,I,J,KC,KS,INSTM,LRC,LCON,IDTV,NOUT,NOUT2,NTYP
1E,NORC,MU
  IP1=I+1
  JKS=J+KS
  KC1=KC+1
  KOUT=JKS-(J+INSTM)
  MU1=MU+1
  IF (NOUT) 140,140,139
139 LEFTT=34359738367-ITIMER(-1)
  X=LEFTT
  X=X/60.
  PRINT 261,X
140 IM1=I-1
  IM2=I-2
  MP1=MU+1
  KENNY=1
  JINSTM=J+INSTM
  READ 108,IDENT
  READ 100,(IET(K),K=1,I)
  IF (LRC) 120,120,121
121 READ 101,CONCRI
  READ 100,MAXPAS
120 DO 122 L=1,JINSTM
122 READ 101,(VALUES(L,K),K=1,KC1)
  DO 128 K=1,KC
128 READ 107,(NAME(K,K1),K1=1,4),COMMW(K),COMHC(K),COMHV(K
1)
125 DO 127 L=1,INSTM

```

TABLE VI (continued)

```

      J1=J+L
127 READ 102,ST(J1),SP(J1)
      READ 101,(ENERGY(K),K=1,I)
      READ 100,((MINOR(K,L),L=1,KC1),K=1,NORC)
      READ 100,(MIEQ(K),K=1,I)
C  ** (OPTIONAL OUTPUT OF INPUT DATA) **
      IF (NOUT) 401,401,400
400 PRINT 902
      PRINT 103,I,DENT
      PRINT 910
      PRINT 903,I,J,KC,KS,INSTM,LRC
      PRINT 904,JKS,KC1
      DO 402 K=1,JKS
402 PRINT 101,(VALUES(K,L),L=1,KC1)
405 PRINT 906
      DO 406 K=1,I
406 PRINT 104,MIEQ(K),IET(K)
      PRINT 907
      DO 407 K=1,KC
407 PRINT 105,(NAME(K,K1),K1=1,4),COMMW(K),COMHC(K),COMHV(
1K)
      PRINT 908
      DO 408 K=1,INSTM
      J1=J+K
408 PRINT 116,J1,ST(J1),SP(J1)
      PRINT 912,I,(ENERGY(K),K=1,I)
      PRINT 911
401 NDTRED=0
C  ** (READ INPUT DATA IN SUBROUTINES) **
746 CONTINUE
      CALL SELECT(NDTRED,MIEQ,IET,I,J,KS,JKS,KC,KC1,VALUES,S
1T,SP,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT,CFR)
      IF (IDTV) 750,750,752
750 DO 751 K=1,INSTM
      KPJ=K+J
      DO 751 L=1,KC
751 VALUES(KPJ,L)=VALUES(KPJ,L)/VALUES(KPJ,KC1)
752 NDTRED=100
      IF (NOUT) 201,201,200
200 N123=1
      LEFT=34359738367-1TIMER(-1)
      X=LEFTT
      Y=LEFT
      X=(X-Y)/60.
      PRINT 260,N123,X

```

TABLE VI (continued)

```

201 IF (LRC) 2,2,1
  1 CONTINUE
  NCOUNT=0
  NEG=0
C  ** (ATTEMPT CONVERGENCE ON PRIMARY SEQUENCE) **
C  ** (MINOR(K,L)= 1 IF PARAMETER IS RECYCLE, 0 IF NOT) **
612 CONTINUE
  KK=0
  DO 614 K=1,NORC
    K1=MINOR(K,KC1)
    RATE=VALUES(K1,KC1)
    DO 614 K2=1,KC
      VALUES(K1,K2)=VALUES(K1,K2)/RATE
      IF (MINOR(K,K2)) 613,614,613
613 KK=KK+1
    PHI(KK,1)=VALUES(K1,K2)*RATE
614 CONTINUE
C  ** (START CONVERGENCE ITERATIVE PROCEDURE) **
  DO 710 L=1,MAXPAS
    NCOUNT=NCOUNT+1
    KK=1
    DO 703 K1=1,NORC
      K2=MINOR(K1,KC1)
      VALUES(K2,KC1)=0.
    DO 702 K=1,KC
      IF (MINOR(K1,K)) 702,702,701
701 VALUES(K2,K)=PHI(KK,1)
      KK=KK+1
702 VALUES(K2,KC1)=VALUES(K2,KC1)+VALUES(K2,K)
      DO 703 K=1,KC
        VALUES(K2,K)=VALUES(K2,K)/VALUES(K2,KC1)
703 CONTINUE
      CALL SELECT(NDTRED,MIEQ,IET,1,J,KS,JKS,KC,KC1,VALUES,S
1T,SP,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT,CFR)
      DO 705 KL=1,MU
705 PHI(KL,2)=PHI(KL,1)
      KK=1
      DO 707 K=1,NORC
        K1=MINOR(K,KC1)
        DO 707 K2=1,KC
          IF (MINOR(K,K2)) 707,707,706
706 PHI(KK,1)=VALUES(K1,K2)*VALUES(K1,KC1)
          KK=KK+1
707 CONTINUE
          IF (NOUT2) 209,209,208

```

TABLE VI (continued)

```

208 LPONE=2
  PRINT 230,MU,LPONE
  DO 229 KTXN=1,MU
229 PRINT 101,(PHI(KTXN,KXT),KXT=1,LPONE)
  PRINT 228
C  ** (CHECK LAST SET OF PHI RECYCLE VALUES AGAINST
C    CONVERGENCE CRITERION.) **
209 DO 709 K=1,MU
  X=(PHI(K,2)-PHI(K,1))/PHI(K,1)
  IF (NOUT2) 213,213,212
212 PRINT 101,X
213 IF (ABS(X)-CONCR1) 709,709,710
709 CONTINUE
  KENNY=0
  GO TO 2
710 CONTINUE
  IF (KENNY) 756,756,757
757 PRINT 119,NCOUNT
  GO TO 500
756 NCOUNT=0
720 KK=1
  NEG1=NEG+1
  GO TO (804,805),NEG1
805 PRINT 913
804 DO 811 L=1,NORC
  LK=MINOR(L,KC1)
  VALUES(LK,KC1)=0.
  DO 810 NK=1,KC
  IF (MINOR(L,NK)) 810,810,812
812 GO TO (807,806),NEG1
806 IF (PHI(KK,1)) 808,807,807
807 VALUES(LK,NK)=PHI(KK,1)
  GO TO 809
808 VALUES(LK,NK)=0.
809 KK=KK+1
  VALUES(LK,KC1)=VALUES(LK,KC1)+VALUES(LK,NK)
810 CONTINUE
  DO 811 K=1,KC
  VALUES(LK,K)=VALUES(LK,K)/VALUES(LK,KC1)
811 CONTINUE
C  ** (FINAL CALCULATIONS OF ALL COMPOSITIONS, FLOW RATES,
C    STREAM TEMPERATURES AND PRESSURES, AND EQUIPMENT HEAT
C    BALANCES) **
  2 LCON=100
  IF (NOUT) 206,206,205

```

TABLE VI (continued)

```

205 N123=3
   PRINT 118,NCOUNT
   LEFT=34359738367-ITIMER(-1)
   X=LEFTT
   Y=LEFT
   X=(X-Y)/60.
   PRINT 260,N123,X
206 CALL SELECT(NDTRED,MIEQ,IET,I,J,KS,JKS,KC,KC1,VALUES,S
  1T,SP,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT,CFR)
   DO 814 L=1,JKS
     SE(L)=0.
     DO 814 K=1,KC
       814 SE(L)=SE(L)+(VALUES(L,K)*VALUES(L,KC1)*COMHC(K)*ST(L))
C  ** (FINAL OUTPUT OF SYSTEM ANALYSIS) **
     IF (NTYPE) 801,801,802
802 PUNCH 108,IDENT
     DO 819 L=1,JKS
       PUNCH 110,L,VALUES(L,KC1),ST(L)
       PUNCH 111,SP(L),SE(L)
       DO 821 K=1,KC
         821 CFR(K)=VALUES(L,K)*VALUES(L,KC1)
       PUNCH 112
       DO 819 K=1,KC
         819 PUNCH 113,(NAME(K,KK),KK=1,4),VALUES(L,K),CFR(K)
       DO 820 L=1,I
         820 PUNCH 114,L,ENERGY(L)
       PUNCH 109
       DO 825 L=1,KC
         X=0.
         Y=0.
         DO 823 K=1,INSTM
           JPK=J+K
           823 X=X+(VALUES(JPK,L)*VALUES(JPK,KC1))
           DO 824 K=1,KOUT
             JPK=J+K+INSTM
           824 Y=Y+(VALUES(JPK,L)*VALUES(JPK,KC1))
           PCE(L)=((Y-X)/X)*100.
         825 PUNCH 117,(NAME(L,K1),K1=1,4),X,Y,PCE(L)
         Z=0.
         ZZ=0.
         DO 829 K=1,INSTM
           JPK=J+K
           829 Z=Z+VALUES(JPK,KC1)
         DO 830 K=1,KOUT
           JPK=J+K+INSTM

```

TABLE VI (continued)

```

830 ZZ=ZZ+VALUES(JPK,KC1)
   DELTA=((ZZ-Z)/Z)*100.
   PUNCH 131,Z,ZZ,DELTA
801 PRINT 103,IDENT
   DO 815 L=1,JKS
   PRINT 110,L,VALUES(L,KC1),ST(L)
   PRINT 111,SP(L),SE(L)
   DO 822 K=1,KC
822 CFR(K)=VALUES(L,K)*VALUES(L,KC1)
   PRINT 112
   DO 815 K=1,KC
815 PRINT 113,(NAME(K,KK),KK=1,4),VALUES(L,K),CFR(K)
   DO 816 L=1,I
816 PRINT 114,L,ENERGY(L)
   PRINT 109
   DO 828 L=1,KC
   X=0.
   Y=0.
   DO 826 K=1,INSTM
   JPK=J+K
826 X=X+(VALUES(JPK,L)*VALUES(JPK,KC1))
   DO 827 K=1,KOUT
   JPK=J+K+INSTM
827 Y=Y+(VALUES(JPK,L)*VALUES(JPK,KC1))
   PCE(L)=((Y-X)/X)*100.
828 PRINT 117,(NAME(L,K1),K1=1,4),X,Y,PCE(L)
   Z=0.
   ZZ=0.
   DO 831 K=1,INSTM
   JPK=J+K
831 Z=Z+VALUES(JPK,KC1)
   DO 832 K=1,KOUT
   JPK=J+K+INSTM
832 ZZ=ZZ+VALUES(JPK,KC1)
   DELTA=((ZZ-Z)/Z)*100.
   PRINT 131,Z,ZZ,DELTA
818 IF (NEG1-1) 501,501,817
817 NEG=0
   GO TO 720
501 CONTINUE
   IF (NOUT) 500,500,202
202 LTIME=34359738367-ITIMER(-1)
   LEFT=LEFTT-LTIME
   X=LEFT
   Y=X/60.

```

TABLE VI (continued)

```
      PRINT 259.Y  
500  CONTINUE  
      RETURN  
      END
```

CHAPTER IV

THE SEQUENCE SEARCHING METHOD FOR MINIMIZING THE NUMBER OF RECYCLE PARAMETERS INVOLVED IN THE PROCESS, PHASE II OF MAEBE

Phase II deals with the problem of reducing the number of recycle parameters involved in a process by altering the sequence in which the equipment nodes are calculated. The method used to accomplish this optimization is an empirical one which was presented by Rubin (9). The process depicted in Figure 1, page 16, is used as an example in the presentation of this method. A matrix, NDM, of net unknown values is calculated for each sequence of equipment under consideration. The elements of this matrix are calculated from the following relationships:

$$NDM_{k,n} = NP_{I+1,m} \quad \text{if stream "m" flows into} \\ \text{equipment "k" from equip- (1)} \\ \text{ment "n".}$$

$$NDM_{k,n} = -NP_{I+1,m} \quad \text{if stream "m" flows into} \\ \text{equipment "n" from equip- (2)} \\ \text{ment "k".}$$

$$NDM_{k,n} = NP_{I+1,j} - NP_{I+1,m} \quad \text{if stream "m"} \\ \text{flows into equip-} \\ \text{ment "n" from equipment "k" (3)} \\ \text{and stream "j" flows from} \\ \text{equipment "n" to "k".}$$

These equations allow for a maximum of two streams flowing

between any two pieces of equipment. In addition to the NDM matrix, a variable, sigma, is calculated for each equipment sequence as the sum of all of the NDM elements above the diagonal. It is an indication of the merit of the particular equipment order which produced the NDM matrix, and by comparing two sigmas, the sequence having the lesser number of recycle parameters may be selected.

Another matrix is computed from the NDM matrix, and is composed of "weighted" elements of NDM. The formula for computing the values in this matrix is as follows:

$$NGM_{k,m} = \sum_{n=k+1}^{n=m} NDM_{k,n} + \sum_{j=k+1}^{j=m-1} NDM_{j,m} \quad (4)$$

The values of these matrices and sigma are presented in Table VII for the process shown in Figure 1, pg. 16, along with versions of NDM and NGM computed from the equipment sequences examined in Phase II until an optimum sequence is determined.

When determining the best sequence for calculating the equipment in the process, all streams entering or leaving the process are ignored. A basic requirement for efficient convergence of the recycle calculations is that the recycle stream must enter the first equipment node to be calculated. This requirement means that the top row of the NDM matrix can have one or more positive elements.

TABLE VII

SIGMA, NDM AND NGM MATRICES VALUES FOR THE
PROCESS IN FIGURE 1

Equipment sequence	NDM matrix values	NGM matrix values	Sigma
1	0 -4 0 3	x -4 -8 -1	-5*
2	4 0 -4 4	x x -4 -4	
3	0 4 0 -4	x x x -4	
4	-3 -4 4 0	x x x x	
4	0 4 -4 -3	x 4 4 1	+5**
3	-4 0 4 0	x x 4 8	
2	-4 -4 0 4	x x x 4	
1	3 0 -4 0	x x x x	
4	0 -3 -4 4	x -3 -11 -7	-11***
1	3 0 -4 0	x x -4 -8	
2	4 4 0 -4	x x x -4	
3	-4 0 4 0	x x x x	

Final equipment order: 4, 1, 2, 3

* This sequence satisfied the non-positive elements test on the NDM and NGM matrices, so a possible equipment order has been found. This sequence is reversed to search for another, possibly better sequence. (see next page)

** This sequence did not satisfy the non-positive elements requirement; the maximum element of the NGM matrix was the $NGM_{2,4} = 8$ element. The second and fourth elements of the equipment series are interchanged for the next sequence to be examined.

*** The sequence producing a sigma = -11 satisfies the non-positive elements test and has a smaller value of sigma than the first sequence's sigma. Therefore, this sequence is the best one encountered in Phase II.

Since the recycle stream could easily originate in the last piece of equipment, the last column of this matrix can also have positive values. The magnitude of each element of the NDM matrix represents the net number of internal unknown parameters which need to be specified between the two equipment nodes represented by the indices of the NDM element. A negative element indicates that interchange of the two equipment nodes would not reduce the number of recycle parameters of the process; zero means no net benefit would result from the interchange of the two pieces of equipment, and a positive value has the magnitude of the number of recycle parameters which would be known if the represented equipment nodes were interchanged. When a possible sequence produces an NDM matrix having only non-positive elements above the diagonal, excluding the first row and last column, and the NGM matrix of that particular sequence has all non-positive elements above the diagonal, the sequence satisfies the requirements needed to start the convergence computations. These conditions are called the non-positive elements test.

Although the elements of NDM are calculated from the NP configuration matrix, the elements of NDM change with alterations in the equipment sequence vector, thus changing the NGM matrix values also due to its dependence on NDM. When the order of equipment is changed from the

consecutive sequence of 1 to I, the formula for arranging the elements is altered. If the "n" and "m" elements of the equipment vector are interchanged, the effect that this transformation has on the NDM matrix is that first the elements of the "n" and "m" rows of NDM are interchanged, and then the interchange of the "n" and "m" columns' elements is performed. The change in equipment order which would produce this alteration would be from a sequence of $NEQ_1, NEQ_2, \dots, NEQ_n, NEQ_{n+1}, \dots, NEQ_m, NEQ_{m+1}, \dots, NEQ_I$ to a new order of $NEQ_1, NEQ_2, \dots, NEQ_m, NEQ_{n+1}, \dots, NEQ_n, NEQ_{m+1}, \dots, NEQ_I$.

Using the non-positive elements test, the method presented in Table VIII is followed until the best sequence available to the execution of Phase II is determined. The criterion which determines which of two possible sequences is better (but not necessarily the final solution) is a minimum value of sigma, the sum of all NDM elements above the diagonal. The result of Phase II computations for the first recycle process is shown in Figure 3.

Although the method in Phase II of MAEBE is empirical, the resulting sequence will be as good or better than the original one used as NEQ input data. The final sequence will not necessarily be the true optimum in a theoretical sense as is demonstrated by the process presented in

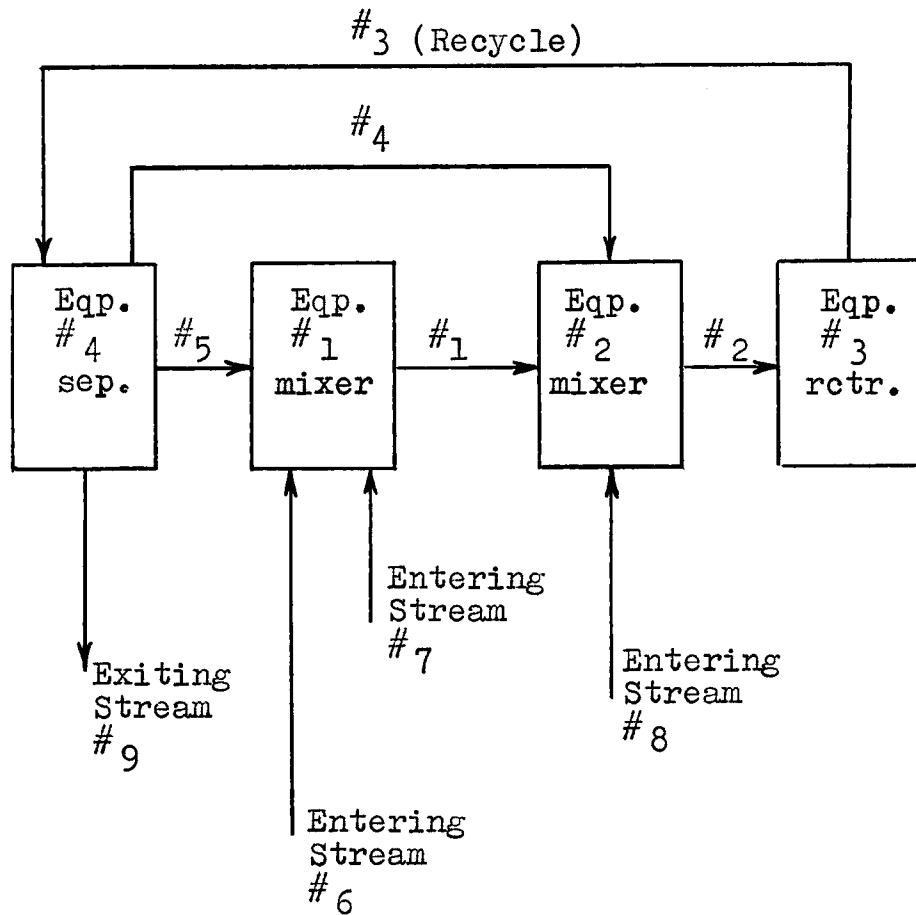
TABLE VIII

PHASE II OPTIMIZATION STEPS

-
-
1. Calculate the NDM matrix for the sequence of equipment; $IC = 1$ (or transform the rows and columns of the NDM matrix).
 2. Calculate the value of sigma for the sequence used in step 1.
 3. If $IC = 1$, go to step 4; if $IC = 2$, compare the two sigma values and assign the sequence that produced the minimum sigma to the $IC = 1$ equipment order.
 4. Calculate the NGM matrix for the $IC = 1$ sequence.
 5. Check the upper inner triangle values of the NDM matrix for positive values. If none exist, go to step 6; but if one or more element is positive, go to step 7.
 6. Check the upper triangle elements of the NGM matrix for (+) values. If none exist, the sequence is a possible solution; and if this is the first such sequence encountered, the sequence is inverted; set $IC = 1$; and return to step 1. If the second sequence, go to step 10. Otherwise continue to step 7.
 7. The number of different sequences examined at this point of computation is checked to insure that it does not exceed "I!", the maximum sets of variations possible; if this number is not exceeded, the program transfers to step 8. If the maximum number is reached, the program enters Phase III calculations with the best equipment sequence encountered to date.
 8. Examine the NGM matrix for the maximum element in the following way: scan the matrix row by row from the bottom row, starting with the element next to the diagonal for each row. Omit the element which produced the last transformation (if the sequence has been transformed prior to this scanning), and if more than one element has the maximum value, use the last one encountered as the next transformation.
-

TABLE VIII (continued)

-
-
9. The maximum element of the NGM matrix is $NGM_{n,m}$. Interchange the "n" and "m" nodes of the NEQ_1 to $I,1$ vector. $IC = 2$, go to step 1.
 10. Compare the sigmas of the two possible sequences to determine the better of the two, i. e., the one having the minimum sigma. If the two sigmas are equal, the first valid sequence encountered is used. Go to Phase III for the trial and error computation.
-
-



(This configuration has only 1 recycle stream, with only 4 unknowns.)

Figure 3. Optimized Sequence of the First Recycle Process.

Appendix E. Two different sequences were read into SEEK/HUNT for this process and no improvement was obtained, but one of these equipment sequences had one less recycle stream and three fewer parameters to be determined by trial and error. Use of these programs does not free the user from the necessity of following his common sense regarding the possible reduction of the number of unknown parameters.

The logic flow diagram of the SEEK/HUNT program system and Phases I and II of MAEBE is presented in combined form in Figure 4.

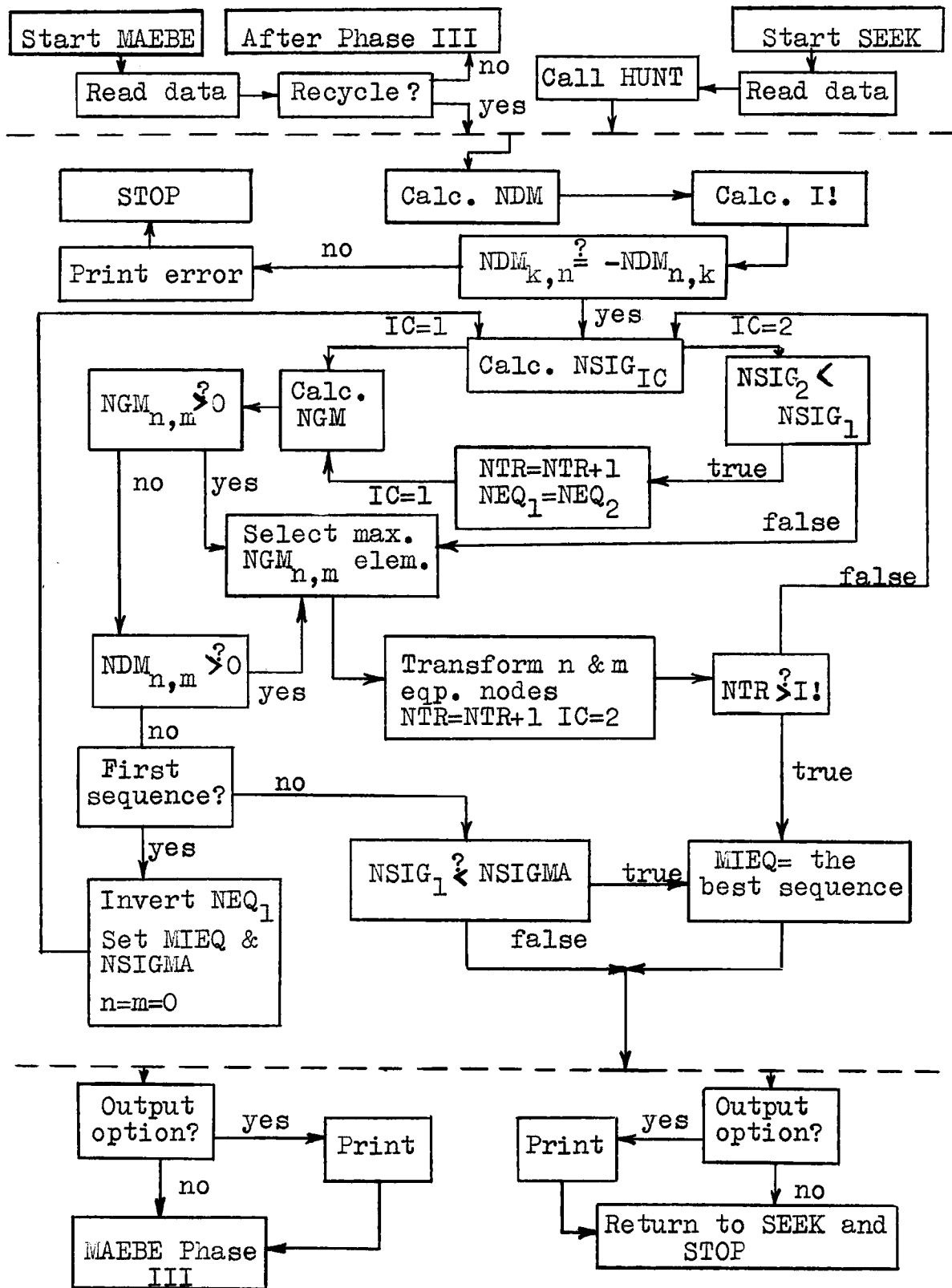


Figure 4. The Logic Diagram of SEEK/HUNT and Phases I and II of the MAEBE Program.

CHAPTER V

PHASE III, THE CONVERGENCE METHOD

When considering a general process having recycle streams, the problem of performing trial and error calculations becomes tenfold more difficult than that encountered for a specific process. The method must work for practically any number of unknown parameters, and for more than one recycle stream. With these requirements in mind, several methods were examined, and two were programmed into MAEBE. A convergence method presented by Rubin (9), based on a multi-dimensional false position calculation, could not be made to function reliably. It frequently produced computer overflows and underflows causing error termination of the execution, and reasonable adjustments of the convergence parameters did not remedy the difficulties.

The method that was finally incorporated into MAEBE as the Phase III portion is a simple direct-iteration operation on the recycle parameters; successive calculated values are used as new trial values of these parameters until the changes between successive trials are smaller than the specified convergence limit. In the MAEBE program the NP matrix is examined to determine the recycle stream designations for the equipment sequence, MIEQ (1 through I),

determined by Phase II; then the components which appear in each recycle stream are indicated by the values of the VALUES matrix. The total input flow rate for the entire process is selected as the flow rate of each recycle stream, and the components appearing in the stream are arbitrarily specified as having equal fractions of the total flow rate of the particular recycle stream. These component flow rates are also defined as the "MU" unknowns of the trial and error computations. These guessed values are assigned to the PHI (1 through MU, 1) vector elements. These PHI values are then placed into the recycle stream positions of the VALUES matrix in mass fraction form. Using these values, the equipment subroutines are entered in the appropriate sequence to evaluate the process. The new calculated values of the component flow rates of the recycle streams are found in the VALUES matrix after the evaluation of the process is completed. These values are assigned to the PHI (1 through MU, 1) vector locations after the guessed values are shifted to the PHI (1 through MU, 2) vector. The condition to be satisfied for convergence is the following equation:

$$\left| \frac{\text{PHI}_{k,1} - \text{PHI}_{k,2}}{\text{PHI}_{k,1}} \right| \leq \text{CONCRI} \quad (5)$$

where "k" represents all of the 1 through MU parameters. If this equation is not satisfied for all of the parameters, the PHI (1 through MU, 1) values are again placed in the appropriate locations of the VALUES matrix and the process is again evaluated. The only limitations on this repetitive procedure are the time allowed for computation by the computer system control and the value of MAXPAS, the maximum number of iterations to be performed, which is provided as input data by the user.

FIND works in exactly the same manner with one exception; the first values of the PHI (1 through MU, 1) vector are part of the VALUES matrix input data provided by the user.

To assist in conveying the necessary information to the user of this program, but in order to avoid the use of unnecessary computer time, two options for internal output of data, NOUT and NOUT2, have been provided. The use of NOUT prints component and total flow rates for each stream and any data desired from the equipment subroutines for each iteration of the Phase III computations. The data read into the main program are also printed out with this option. The utilization of NOUT2 will print out only the calculated and guessed values of the PHI matrix for each iteration and the relative change effected by that iteration for each parameter, until one is encountered which

does not satisfy the CONCRI value.

Although it is usually preferable for energy balance variables to be evaluated for each iteration, the user of either FIND or MAEBE may elect to not do so. In this event the energy values of the recycle streams will not be determined prior to the final evaluation of the process. If a material balance of the process is the only result desired by the programmer, considerable time may be saved by omitting the energy balance computations, depending on the nature of the equipment subroutines which the programmer provides.

After the convergence criterion is satisfied, the process is evaluated once more for two reasons; this will provide further improvement in the convergence of recycle calculations, and it is convenient to evaluate processes not containing recycle streams in this section of the program for both energy and material balance parameters. Figure 5 presents the logic flow diagram of the remaining portion of MAEBE and the entire FIND program.

During this final calculation a balance of the mass of each component entering and leaving the process is made and the percent difference is computed. Another balance is made for the entire process and the percent deviation in entering and leaving mass is a measure of the total error (from round-off, incomplete convergence, etc.) in the

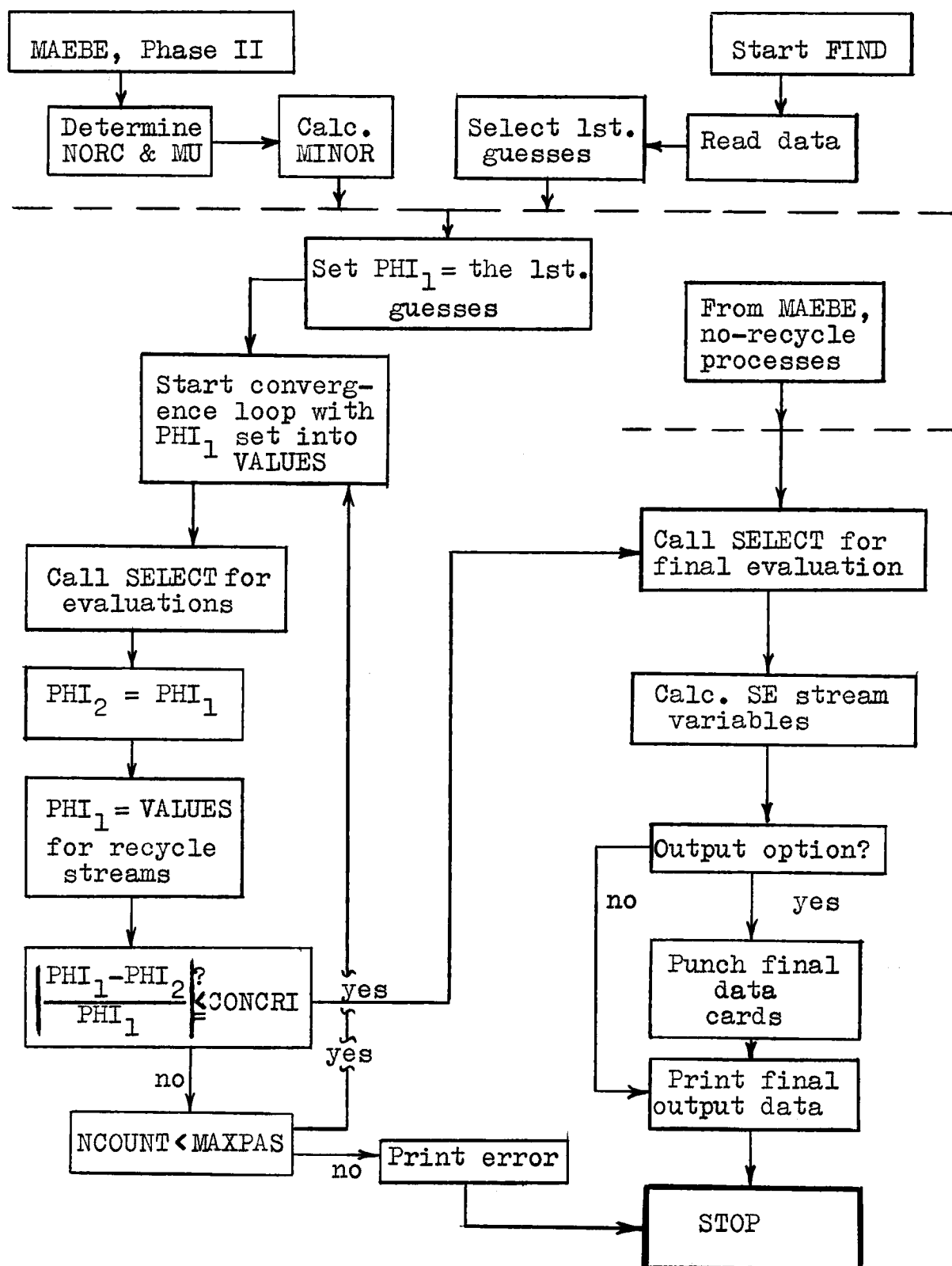


Figure 5. Logic Diagram of FIND and Remainder of MAEBE

evaluation of the process. All of these process balance values are presented in the final output of the program, along with the tabulated stream parameters and equipment energy balances.

CHAPTER VI

THE SUBROUTINES NEEDED BY PROGRAM SYSTEMS

Of the three program systems, only the SEEK/HUNT system requires no additional subroutines. HUNT is the only subroutine called by SEEK, and the discussion of its characteristics can be found in Chapter IV.

The use of both MAEBE and FIND require two subprograms which are presently available on sub-library tape in The University of Tennessee Computer Center. These subroutines require two control cards to make them available to the program system. Although these cards and subprograms may be altered or removed from the sub-library tape in the future, the action of these subroutines can be reproduced with little difficulty, or references to them may be deleted from the program systems. The first of these subprograms is the underflow over-rider. This subroutine, FPT, essentially reduces all values ranging between -10^{38} and $+10^{38}$ to a value of zero. The range of the 7040 IBM computer gives an underflow value to all computations resulting in a number falling within this range, and when ten of the underflows occur, the program is dumped if the FPT subroutine is not in effect.

The other sub-library routine is the ITIMER program which gives the computational time required to complete

various portions of the program and the entire computation. The control card which calls these subroutines has the following form: starting in card column 1, \$SBLIB; skip column 7; punch the name of the subroutine starting in column 8; and punch GENERAL USE in the card starting in column 40.

The remaining subroutines used by MAEBE and FIND are concerned with equipment operation. When reading data into the equipment subroutines or when calculating the operational effects of a piece of equipment on the process, both MAEBE and FIND first enter the SELECT subroutine. The purpose of this subroutine is to control the "selection" of the appropriate equipment subroutine at the correct time. Slight modifications must be made in the SELECT subroutine for an arrangement other than that used for testing purposes. The value of NEQPSR must be altered for more or less than four equipment subroutines; the call statements must be changed if these subroutines are not named as they were in the test program systems; and the number of call statements must be changed if the number of equipment subroutines is increased or decreased. If a subroutine is referred to anywhere in the program system, the subroutine must be present in the program deck or a "dump" will result. These modifications are indicated in the Fortran listing of SELECT, Table IX. The logic diagram of

FORTRAN LISTING OF THE SELECT SUBROUTINE

```

SUBROUTINE SELECT(M,MIEQ,IET,I,J,KS,JKS,KCMX,KCMX1,VAL
1UES,STMTEM,STMPRS,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT,C
2FR)
  DIMENSION VALUES(JKS,KCMX1),STMTEM(JKS),STMPRS(JKS),CO
1MMW(KCMX),COMHC(KCMX),COMHV(KCMX),ENERGY(1),MIEQ(1),IE
2T(1),CFR(KCMX1)
300 FORMAT(1H ,36HSTREAM COMP. AND TOTAL FLOW RATES (13,1
1H,13,1H))
400 FORMAT(1H ,9E14,6)
C ** CHANGE THE VALUE OF NEQPSR TO THE NUMBER OF EQUIPMENT
C SUBROUTINES PRESENT IN THE PROGRAM SYSTEM. **
  NEQPSR=4
  NDTRED=M
  IF (NOUT) 203,203,200
200 IF (M-100) 600,611,601
611 M=M+100
600 MM=KS
  NN=J+1
  GO TO 602
601 MM=JKS
  NN=1
602 PRINT 300,MM,KCMX1
  DO 202 K2=NN,JKS
  DO 201 K1=1,KCMX
201 CFR(K1)=VALUES(K2,K1)*VALUES(K2,KCMX1)
  CFR(KCMX1)=VALUES(K2,KCMX1)
202 PRINT 400,(CFR(K3),K3=1,KCMX1)
203 DO 100 NX=1,I
  IF (M) 96,96,97
  96 NRT=NX
  KNOW=NRT
  IF (NRT-NEQPSR) 98,98,100
  97 KNOW=MIEQ(NX)
  NRT=IET(KNOW)
  98 CONTINUE
  GO TO (1,2,3,4),NRT
  1 CALL EQP1(NDTRED,KNOW,I,J,KS,JKS,KCMX,KCMX1,VALUES,STM
1TEM,STMPRS,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT)
  GO TO 99
  2 CALL EQP2(NDTRED,KNOW,I,J,KS,JKS,KCMX,KCMX1,VALUES,STM
1TEM,STMPRS,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT)
  GO TO 99
  3 CALL EQP3(NDTRED,KNOW,I,J,KS,JKS,KCMX,KCMX1,VALUES,STM
1TEM,STMPRS,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT)
  GO TO 99

```

```
      4 CALL EQP4(NDTRED,KNOW,I,J,KS,JKS,KCMX,KCMX1,VALUES,STM
        1TEM,STMPRS,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT)
        GO TO 99
C   ** THE FOLLOWING CARDS ARE NEEDED IF MORE THAN 4 EQP.
C   SUBROUTINES ARE TO BE USED. **
C   5 CALL EQP5(NDTRED,KNOW,I,J,KS,JKS,KCMX,KCMX1,VALUES,STM
C   1TEM,STMPRS,COMMW,COMHC,COMHV,E5E9GY,LC05,N6UT)
C   GO TO 99
C   ** REPEAT THE ABOVE CARDS FOR EQP6, ETC. **
      99 CONTINUE
     100 CONTINUE
         IF (NOUT) 207,207,204
     204 IF (M) 603,603,604
     603 MM=KS
         NN=J+1
         GO TO 605
     604 MM=JKS
         NN=1
     605 PRINT 300,MM,KCMX1
         DO 206 K2=NN,JKS
         DO 205 K1=1,KCMX
     205 CFR(K1)=VALUES(K2,K1)*VALUES(K2,KCMX1)
         CFR(KCMX1)=VALUES(K2,KCMX1)
     206 PRINT 400,(CFR(K3),K3=1,KCMX1)
     207 RETURN
        END
```

this subroutine is presented in Figure 6.

The subroutines which simulate the operational effects of the various pieces of equipment have a minimum number of restrictions placed on them, in accordance with the principle of generalization of the program system. The call statement in the SELECT subroutine has an argument list of variables which restricts the order in which the arguments must appear in each equipment subroutine. These standard equipment subroutine arguments are defined and listed in Table X. This is followed by the logic diagram of the typical equipment subroutine, Figure 7.

A second restriction on the equipment subroutines is that a dimension statement must be included for any subscripted subroutine arguments. Since these variables are dimensioned in the main program, the varying size of the dimensions are accounted for by the use of the variable type of dimension statement in the SELECT and equipment subroutines. Although the variables in the subroutine argument list can be named any legal Fortran name, these variables should be used in accordance with the meaning listed in Table X.

The last main requirement in the development of equipment subroutines deals with the input of data. Each subroutine must be entered in the order of the type designations prior to any computations. The first fixed point

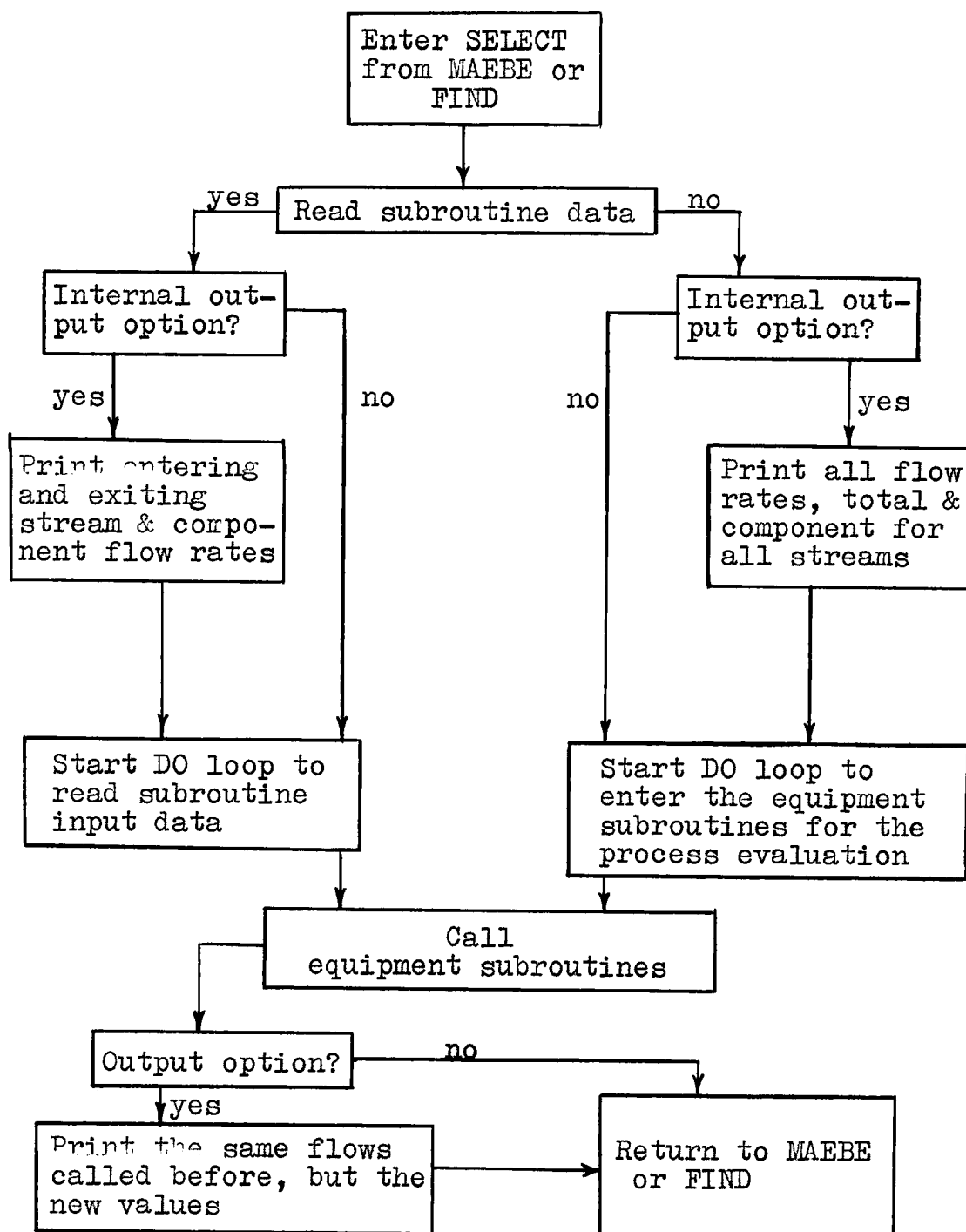


Figure 6. Logic Flow Diagram of SELECT Subroutine.

TABLE X

THE SUBROUTINE ARGUMENT LIST

The argument variable list sequence:

$(N_1, N_2, N_3, N_4, N_5, N_6, N_7, N_8, X_1, X_2, X_3, X_4, X_5, X_6, X_7, N_9, N_{10})$

where N_j is the "j"th. fixed point variable in the list,
and X_k is the "k"th. floating point variable in the list.

Variable in the Argument List	Corresponding Main Program Variable and a Brief Description of Its Use.
N_1	NDTRED, The read-in controller.
N_2	MIEQ _n , The designation of the equipment to be calculated.
N_3	I, The number of pieces of equipment in the process.
N_4	J, The number of internal streams in the process.
N_5	KS, The number of streams entering and leaving the process.
N_6	JKS, The total number of streams in the entire process.
N_7	KC, The number of components in the process' streams.
N_8	KC1, Equal to KC+1
X_1	VALUES, The mass fraction and stream flow rate matrix.
X_2	ST, The stream temperature vector.

TABLE X (continued)

X_3	SP, The stream pressure vector.
X_4	COMMW, The component molecular weight vector.
X_5	COMHC, The component heat capacity vector.
X_6	COMHV, The component latent heat vector.
X_7	ENERGY, The heat stream feed for each piece of equipment, a vector.
N_9	LCON, The heat or energy balance option control indicator.
N_{10}	NOUT, The internal output option control indicator.

Form of the Variable Dimension Statement Needed in Each Equipment-simulating Subroutine:

DIMENSION $X_1(N_6, N_8), X_2(N_6), X_3(N_6), X_4(N_8), X_5(N_8), X_6(N_8),$
 $X_7(N_3)$

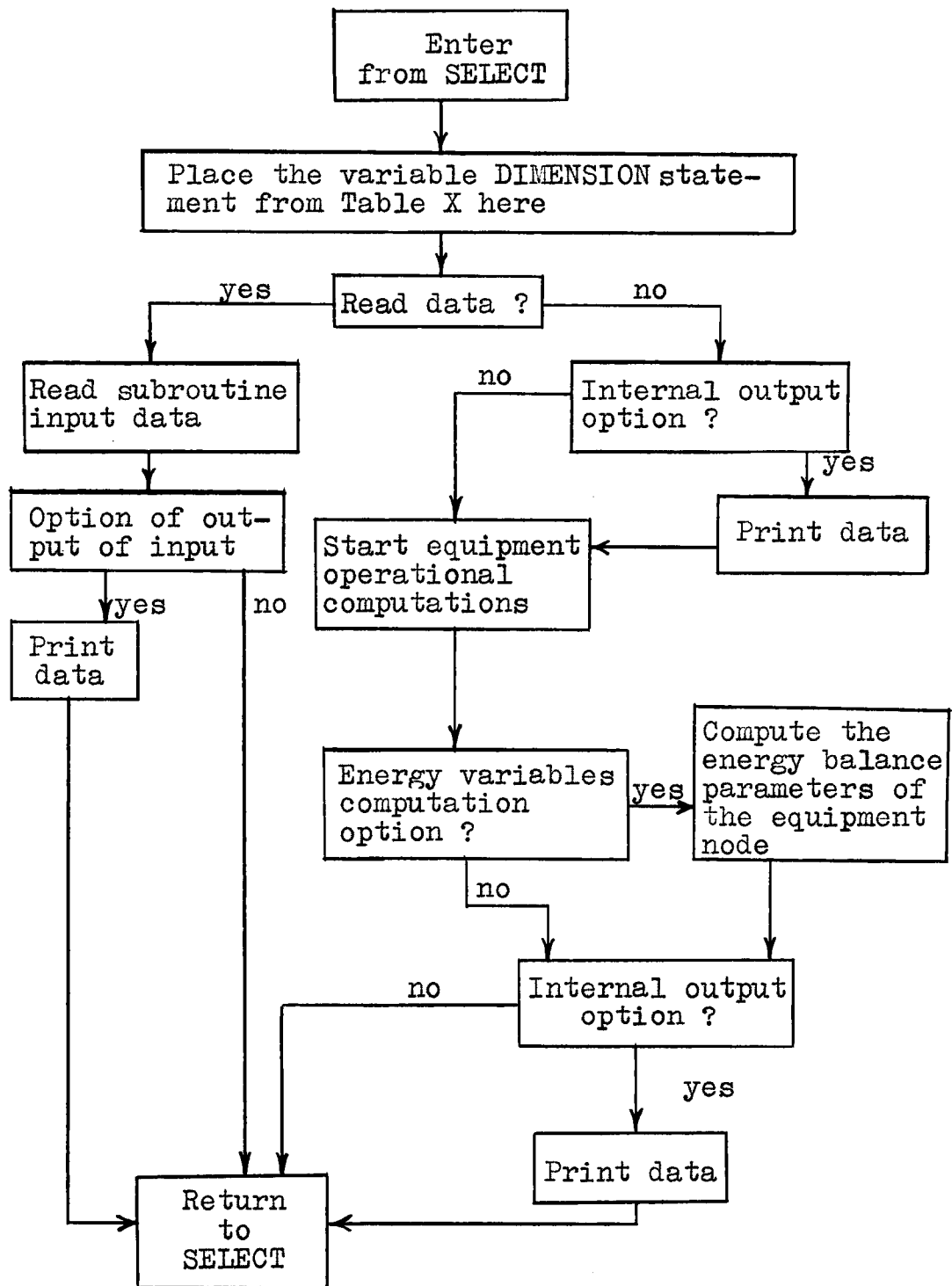


Figure 7. Logic Flow Diagram of a Typical Equipment Subroutine.

variable in the equipment argument list initially has a value of zero for the read-in portion of the subroutine and a value of 100 for computation. Every subroutine must be entered at the start of the program execution, even if no equipment of its type exists in the process. There is no provision for conveying the process configuration into the equipment subroutines, so the stream designations entering the various pieces of equipment and the output streams must be part of the input data for the subroutines. Any physical properties data for the components other than the molecular weight, heat capacity, and latent heat must also be read into the subroutines as needed. The Fortran listings of the four subroutines used to develop these programs are presented in Appendix B. Comparison of these programs and the flow diagram in Figure 7 should give any information concerning the equipment-simulating subroutines not conveyed herein.

CHAPTER VII

THE METHOD FOR UTILIZING THE PROGRAM SYSTEMS TO EVALUATE A PROCESS

Whether a programmer is using the SEEK/HUNT system to seek an optimum equipment sequence, or the MAEBE or FIND systems to evaluate a process; the basic approach to the problem is essentially the same. The steps to be taken by the user are listed in the following sequence:

1. Draw a sketch of the process, depicting all necessary streams and equipment nodes.
2. Inspect the process to find a configuration, disregarding the streams entering and leaving the process, which appears to require a minimum number of unknowns to be determined by trial and error if recycle streams exist.
3. Assign number designations to each of the "I" pieces of equipment, and assign the number which designates the type of each piece of equipment according to the appropriate subroutine.
4. Assign number designations to each of the streams in the process, starting with 1 through "J" for the "J" internal streams connecting the various pieces of equipment; the streams entering the process are numbered "J+1" through "J+INSTM", and the exiting streams are numbered

"J+INSTM+1" through "J+KS". This order of numbering the streams must be followed if any of the systems are to work correctly.

5. Determine the maximum number of chemical compounds and elements present in the entire process, and collect the physical data needed for these components by the program system.

6. Examine the process to determine, to the extent possible, what components do not appear in each of the internal streams. This determines the number of parameters which are required to specify the flow rate and composition of the stream, to be listed as the values of the last row of the NP configuration matrix.

7.* Specify all the properties of the entering streams; the component flow rates, total flow rates, temperatures, and pressures.

8.** Compose a configuration matrix of -1, 0, and +1 for the streams exiting, not connected with, and entering each piece of equipment; and the "I+1"th. row of stream parameters determined in step 6.

9.* Determine, where possible, the heat loads on each of the "I" pieces of equipment.

10.* Compose a matrix of mass fractions and total flow rates for each of the streams in the process; if a component appears in any unknown stream, the mass fraction value

should be initially be specified as -1×10^6 and the total flow rate set at -2×10^6 ; if the component does not appear in the stream, set the mass fraction value equal zero. For the entering streams, the total flow rate must be given and the component values may be specified in mass flow rates if IDTV is 0, or as mass fractions if IDTV is 1 or greater.

11. Based on the process arrangement selected in step 2, or on the output of the SEEK/HUNT system, determine the original sequence of equipment nodes.

12.* Evaluate all subroutine data required by the user's own equipment subroutines, and arrange the data in the ascending order of the equipment type designations: data for type 1 subroutine is read directly after the main program data, then type 2 data, etc.

13. Determine the appropriate dimension sizes for the subscripted variables in the comment cards at the first of the Fortran listings of the program system being used.

14.*** Prepare all data cards and insert all dimension statement cards into the programs.

15. Prepare all control cards required by the computer center's method for program executions.

* Steps 7, 9, 10, and 12 are not needed for SEEK/HUNT.

** This step is not needed for no-recycle processes.

*** See Tables I, II, and III for input instructions.

CHAPTER VIII

THE RESULTS OF TEST PROCESSES EVALUATED BY THE THREE PROGRAM SYSTEMS

The specific results of processes tested by these program systems are presented in Appendices C, D, and E. Three basic types of processes were tested, although a number of variations of these types were also tested. A process having no recycle streams was used to perfect the methods of transferring from the main programs to the equipment subroutines correctly. The basic no-recycle process is described together with a listing of input and printout data in Appendix C. Other than the fact that this type of process can only be evaluated by MAEBE, nothing of importance can be gained by further description of this type of process. The FIND program can also be altered to evaluate the no-recycle processes by using the LRC data read into the program, in the same manner that the transfer is accomplished in MAEBE.

The performance of the convergence method was perfected by the use of MAEBE on the process depicted in Figure 1, pg. 16, and the results of this evaluation are given in Appendix D. After the successful operation of the program was insured, a larger recycle process was then evaluated by the three program systems. The configuration

for this process was examined intuitively and two equipment sequences were tried on the SEEK/HUNT system. Neither of the sequences were improved by this system, illustrating that the empirical method in phase II does not insure that an optimum sequence in the theoretical sense will be found. However, the result of this method will never be worse than the initial sequence of equipment chosen. The types of processes tested, the actual computational time required to evaluate them, the number of recycle parameters, and the program system which evaluated the processes are presented in a condensed form in Table XI.

Satisfactory operation was demonstrated in performing material and energy balances for the hypothetical processes. The most fruitful direction for future work with this program is the development of more sophisticated subroutines to permit calculations to be performed for real processes.

TABLE XI
THE CONDENSED RESULTS OF PROCESS EVALUATIONS

Results Variable or designation of result	Process Designations			
	No Recycle	First Recycle	Second Recycle (sequence) Initial Improved	
I	4	4	9	9
J	3	5	14	14
KS	7	4	4	4
KC	5	4	5	5
Total no. of unknowns	15	19	62	62
No. of recycle streams	0	2	2	1
No. of recycle parameters	0	7	8	5
SEEK/HUNT seq. results	*	4,1-3	1-9	2-9,1
Time for MAEBE computations	2.8 sec.	3.6 sec.	8.4 sec.	4.8 sec.
Time for SEEK/ HUNT computations	*	0.36 sec.	2.19 sec.	2.35 sec.
Time for FIND computations	*	2.85 sec.	7.2 sec.	3.8 sec.
CONCRI	*	10^{-8}	10^{-5}	10^{-5}
Error	$10^{-5}\%$	$10^{-5}\%$	$5.X 10^{-4}\%$	$5.X 10^{-4}\%$

* Only the MAEBE program is applicable for this type of process, no-recycle.

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APPENDIX A

LIST OF VARIABLES AND THEIR DEFINITIONS

Part 1. Fixed Point Variables Used In All Main Programs.

I	The total number of pieces of equipment in the process.
IC	The control indicator used in Phase II computations to designate the two sequences being compared.
IDENT	The alphameric subscripted variable used in an A6 format field to identify the process, programmer, etc.
IDTV	The control indicator for the form of reading the mass flow values of the input streams; 0 for using mass flow rates of the components, and 1 for using mass fractions.
IET	The equipment type subscripted variable which controls the transfer into appropriate equipment subroutines.
III	The control indicator designating the number of possible equipment sequences satisfying recycle restrictions.
IM1	I minus 1
IM2	I minus 2
INSTM	The total number of streams entering the process.
IP1	I plus 1
J	The total number of internal streams connecting various pieces of equipment in the process.
JKS	The total number of streams involved in the process.
KC	The total number of components present in the process; chemical compounds and elements.

KC1	KC plus 1
KENNY	The convergence control indicator; 1 when convergence is not obtained, and 0 when it is obtained.
KOUT	The number of streams leaving the process.
KS	The total number of streams entering and leaving the process.
LCON	The energy balance computation option indicator; 0 for not performing energy balance calculations during the trial and error calculations of recycle processes, 1 for exercising the option to make such calculations during each iteration.
LEFT	Time left to execute the program in fixed point integers of 1/60 ths. of a second.
LEFTT	Time left to execute the program from the start of the program in 1/60 ths. of a second.
LRC	The recycle process control indicator; 0 for a no-recycle process, 1 if recycle streams exist in the process.
LRCMX	The Phase II option controller for the MAEBE program; 1 if Phase II computations are to be performed, 2 if not.
M	One of the coordinates of the maximum NGM matrix element which indicates the elements of the equipment sequence to be interchanged.
MAXPAS	The maximum number of iterations to be tried before the program's execution is terminated.
MIEQ	The possible sequence of equipment resulting from the first part of the Phase II computations, or the final order for calculating the process. The variable is subscripted for "I" elements.
MINOR	The control indicator subscripted variable which designates the components present in each recycle stream and the stream's designation number; 0 if the component is not present, 1 if it is present, and the integer designation of the recycle stream.

MP1	MU plus 1, see MU definition below.
MU	The total number of parameters involved in the mass flow rates of all of the recycle streams.
N123	The integer designation of the phase of MAEBE just completed by the program execution.
NAME	The alphameric component identification variable in an A6 format field.
NCOUNT	The number of iterations completed by Phase III of the program.
NDM	The matrix of variables used by Phase II to determine the relative desirability of interchanging any two equipment nodes.
NDTRED	The control indicator variable which designates whether the equipment subroutines are to read data or calculate operational effects; 0 for data input, 100 for computing.
NEG	One of the indicator variables controlling the presence of negative component flow rates in the recycle streams.
NEG1	The other negative recycle parameter indicator.
NEQ	The subscripted variable of the two equipment sequences being compared in Phase II.
NGM	The subscripted variable indicating the relative improvement to be accomplished by interchanging any two equipment nodes.
NMATER	The value of "I" which indicates the maximum number of different sequences which can be examined.
NMLKJI	The number of complete sets of data to be evaluated by the program.
NNR	The control indicator which specifies whether the number of different equipment sequences examined have exceeded the maximum value, NMATER; 0 if not exceeded, 1 if the number has been exceeded and a repetition is occurring.

- NORC The total number of recycle streams in the process as determined by the particular sequence.
- NOUT The control option for internal output of the input data, the component and total flow rates of each stream during each iteration, and any subroutine output desired by the user; 0 for no internal output, 1 for exercising the output options.
- NOUT2 The output option controlling the printing of all "MU" values of the guessed and calculated recycle parameters for each iteration and the relative change effected by the iteration; 0 for no output, 1 for output.
- NP The subscripted variable list of process configuration and total number of unknown flow rates in each internal stream; -1 for exiting streams, 0 for no connection, and +1 for a stream that enters the equipment node corresponding to the row index of the matrix (the column index is the stream designation). The last row has integer elements giving the number of components that appear, or may appear, in each of the internal streams.
- NSIG The sum of all of the elements of the NDM matrix positioned above the diagonal; there are two elements of this variable to allow different equipment sequences to be compared for a minimum NSIG value.
- NSIGMA The value of NSIG that results from the equipment sequence NEQ that is assigned to the MIEQ vector.
- NTR The number of different sequences examined.
- NTYPE The final output option indicator; 1 if the final data is desired in both punched card form and the normal computer output listing, 0 if normal output alone is needed.

Part 2. The Floating Point Variables Used In All Systems.

- CFR The subscripted variable used in output of component flow rates.

COMHC	The subscripted variable list of component heat capacities.
COMHV	The subscripted variable list of the components' latent heats.
COMMW	The subscripted variable list of component molecular weights.
DELTA	The variable used to compute the entire process' error in mass balance.
ENERGY	The subscripted variable list of the heat balance loads on each equipment node.
PCE	The subscripted variable used to compute the percent change in each component's entering and exiting mass flow rates for the entire process.
PHI	The subscripted variable list of the guessed and calculated values of the "MU" recycle parameters.
SE	The subscripted variable list of the energy properties of each stream, calculated from a relative zero value at 0.0 degrees F.
SP	The subscripted variable list of the pressures of each stream.
ST	The subscripted variable list of the temperatures of each stream.
VALUES	The subscripted variable array of the mass fraction of each component and the total flow rate of each stream in the process.

Part 3. The Variables and Their Definitions as Used in the Subroutines.

For the SELECT subroutine:

M	The NDTRED variable.
NEQPSR	The number of equipment subroutines called by the SELECT subroutine.
NRT	The equipment type designation used to select the correct subroutine.

For the EQP1 (mixer) subroutine:

AB	The COMMW vector.
AI	The total rate of heat addition to the equipment node including energy of inlet streams and heat added from external sources.
AMOL	The subscripted variable list of component flow rates for each entering stream of each mixer.
AO	The total energy leaving the mixer.
BC	The COMHC vector.
CD	The COMHV vector.
DPM	The difference in pressure caused by the mixer.
IN	The subscripted variable list of stream designations for the streams entering each mixer.
KCMX	The KC variable.
MAXIN	The maximum number of streams entering a single mixer.
NADIAB	The control indicator subscripted for each piece of equipment designating the heat load of the equipment as either 0 or finite; 0 if the equipment is adiabatic, 1 if there is a net addition or removal of heat.
NM	The subscripted variable list of equipment designations of each mixer.
NMIX	The total number of mixers in the process.
NSEM	The subscripted variable list of stream designations for the streams entering each mixer.
NSLM	The subscripted variable list of the designation of the stream leaving each mixer.

For the EQP2 (separator) subroutine: (except the previously defined variables)

AMOL	The subscripted variable list of the component flow rates leaving in each stream of the separator.
DPSEP	The subscripted variable list of pressure drops

of each exiting stream from the pressure of the stream entering each separator.

DTSEP The subscripted variable list of the temperature drops of each exiting stream from the temperature of the stream entering each separator.

FRACT The subscripted variable list of the fractions of each component which are diverted to each exit stream.

MAXOUT The maximum number of exiting streams involved with a single separator.

NMAX The subscripted variable list of the numbers of streams exiting from each separator.

NS The subscripted variable list of the designation number of each separator in the equipment list.

NSEP The total number of separators in the process.

NSES The subscripted variable list of the designation of the stream entering each separator.

NSLS The subscripted variable list of the designation numbers of the streams leaving each separator.

S The subscripted variable list of the total flow rates of the streams leaving a separator.

TMOL The subscripted variable list of the component flow rates entering a separator.

For EQP3 (reactor) subroutine: (except the variables previously defined)

A The subscripted variable list of component flow rates entering a reactor.

ALPHA The subscripted variable list of the stiochiometric ratios of components for each reaction.

AM The subscripted variable list of the component molar flow rates entering a reactor.

BC The computational variable equal to the RXNK variable up to the maximum fraction of reaction of the minimum reactant available.

DPR	The subscripted variable list of the pressure drop effected by each reactor.
HFM	The subscripted variable list of the heats of formation of one mole of each component.
INRX	The subscripted variable list of the designations of the streams entering the reactors.
MAXRXN	The maximum number of reactions occurring in a single reactor.
NOUTr	The subscripted variable list of the designations of the streams leaving reactors.
NR	The subscripted variable list of the equipment designations of the reactors.
NRCT	The number of reactors in the process.
NRXK	The subscripted variable list of the number of separate reactions to occur in any single reactor simultaneously.
PMC	The maximum fraction of any reactant able to react in each reaction.
RXNK	The subscripted variable list of the number of times the basic ratios of reactants and products are to be involved in each reaction.

For the EQP4 (heat exchanger) subroutine: (except the variables previously defined)

A	The subscripted variable list of component flow rates in the shell side stream.
DPH	The subscripted variable list of pressure drops across each side of an exchanger.
INHE	The subscripted variable list of the designations of the streams entering a single exchanger.
NHE	The number of heat exchangers present in the process.
NOUthe	The subscripted variable list of the designations of the streams leaving a single exchanger.

TA The subscripted variable list of the component
 flow rates in the tube side stream of a single
 heat exchanger.

APPENDIX B

EQUIPMENT SUBROUTINE FORTRAN LISTINGS

The Fortran listings of the four basic equipment subroutines are presented in Tables XII through XV. The mixer subroutine, EQP1, is Table XII; the separator subroutine, EQP2, is Table XIII; the reactor subroutine, EQP3, is Table XIV, and Table XV is the listing of the heat exchanger subroutine, EQP4.

TABLE XII

FORTRAN LISTING OF THE EQP1, MIXER SUBROUTINE

```

      SUBROUTINE EQP1(M,N,I,J,KS,JKS,KCMX,KCMX1,VALUES,STMTE
1M,STMPRS,AB,BC,CD,ENERGY,LCON,NOUT)
C  ** THIS IS A MIXER SIMULATION.  **
C  ** DIMENSION NM(NMIX),IN(NMIX),NSLM(NMIX),NSEM(MAXIN,NMIX
C  1),DPM(NMIX),T(KCMX),A(KCMX,MAXIN),S(MAXIN),TMOL(KCMX),
C  2AMOL(KCMX,MAXIN),NADIAB(1),COMMW(KCMX),COMHC(KCMX),COM
C  3HV(KCMX)
C  ** THE NEXT CARD CHANGES WITH DIFFERENT PROCESSES.  **
      DIMENSION NM(2),IN(2),NSLM(2),NSEM(4,2),DPM(2),T(5),A(
15,4),S(4),TMOL(5),AMOL(5,4),NADIAB(9),COMMW(5),COMHC(5
2),COMHV(5)
      DIMENSION VALUES(JKS,KCMX1),STMTEM(JKS),STMPRS(JKS),AB
1(KCMX),BC(KCMX),CD(KCMX),ENERGY(1)
101 FORMAT(10E12,4)
200 FORMAT(14I5)
201 FORMAT(7F10,5)
202 FORMAT (5F14,5)
900 FORMAT(1H ,36HOPTIONAL OUTPUT OF INPUT DATA ** EQP11)
901 FORMAT(1H ,25X,8HVALUES (I2,1H,I2,6H) MTX.)
902 FORMAT(1H ,9E14,7)
903 FORMAT(1H ,6X,9HCOMPONENT,6X,9HMOLE. WT.,6X,9HHEAT CAP
1.,4X,11HLATENT HEAT)
904 FORMAT(I12,F19,3,F15,5,F15,4)
905 FORMAT(1H ,15HNO. OF MIXERS =I3,3X,25HMAX. NO. OF INLE
1T STMS. =I3)
906 FORMAT(1H ,9HMIXER NO.I2,12H IS EQP. NO.I2)
907 FORMAT(1H ,7HNADIAB=I2,2X,16HNO. INLET STMS.=I3,2X,16H
1EXIT STM. IS NO.I3,2X,9HDELTA P =F10,5)
908 FORMAT(1H/,3HTHEI2,24H ENTERING STMS. ARE NOS.,5I5)
909 FORMAT(1H ,24HCALCULATING FOR EQP. NO.I2)
910 FORMAT(1H ,26HFINISHED CALC. ON EQP. NO.I2)
      IF (M) 1,1,5
1  READ 200,NMIX,MAXIN
      IF (NMIX) 50,50,2
2  READ 200,((NM(L),IN(L),NSLM(L)),L=1,NMIX)
      DO 3 L=1,NMIX
        KK=NM(L)
        LL=IN(L)
3  READ 200,NADIAB(KK),(NSEM(LK,L),LK=1,LL)
      READ 201,(DPM(L),L=1,NMIX)
      DO 4 K=1,KCMX
        COMMW(K)=AB(K)
        COMHC(K)=BC(K)
4  COMHV(K)=CD(K)
      IF (NOUT) 401,401,400

```

```

400 PRINT 900,N
    PRINT 901,JKS,KCMX1
    DO 402 K=1,KCMX1
402 PRINT 902,(VALUES(L,K),L=1,JKS)
    PRINT 903
    DO 403 K=1,KCMX
403 PRINT 904,K,COMMW(K),COMHC(K),COMHV(K)
    PRINT 905,NMIX,MAXIN
    DO 405 K=1,NMIX
        LL=IN(K)
        KK=NM(K)
        PRINT 906,K,NM(K)
        PRINT 907,NADIAB(KK),IN(K),NSLM(K),DPM(K)
405 PRINT 908,LL,(NSEM(LK,K),LK=1,LL)
401 CONTINUE
    GO TO 50
5 ST=0.
    IF (NOUT) 408,408,406
406 PRINT 909,N
    PRINT 901,JKS,KCMX1
    DO 407 K=1,KCMX1
407 PRINT 902,(VALUES(KIX,K),KIX=1,JKS)
408 CONTINUE
    DO 6 L=1,NMIX
        IF (NM(L)-N) 6,7,6
6 CONTINUE
7 KK=IN(L)
  B=KK
  NC1=NSLM(L)
  DO 8 K=1,KK
    LNK=NSEM(K,L)
    S(K)=VALUES(LNK,KCMX1)
    DO 8 N1=1,KCMX
      A(N1,K)=VALUES(LNK,N1)*S(K)
8 AMOL(N1,K)=A(N1,K)/COMMW(N1)
    DO 9 K=1,KK
      DO 9 KKK=1,KCMX
        ST=ST+A(KKK,K)
9 CONTINUE
    DO 10 N2=1,KCMX
10 T(N2)=0.
    DO 12 IXX=1,KCMX
      DO 11 K=1,KK
11 T(IXX)=T(IXX)+A(IXX,K)
12 VALUES(NC1,IXX)=T(IXX)/ST

```

TABLE XII (continued)

```
      IF (LCON-1) 20,20,13
13  IF (NADIAB(N)) 14,14,15
14  AI=0.
      GO TO 16
15  AI=ENERGY(N)
16  AO=0.
      DO 18 N4=1,KCMX
      DO 17 K=1,KK
      LNK=NSEM(K,L)
17  AI=AI+(A(N4,K)*COMHC(N4)*STMTEM(LNK))
18  AO=AO+(T(N4)*COMHC(N4))
      TOUT=AI/AO
      AVPR=0.
      DO 19 K=1,KK
      LNK=NSEM(K,L)
19  AVPR=AVPR+STMPRS(LNK)
      AVPR=AVPR/B
      STMPRS(NC1)=AVPR+DPM(L)
      STMTEM(NC1)=TOUT
20  VALUES(NC1,KCMX1)=ST
      IF (NOUT) 411,411,409
409  PRINT 910,N
      PRINT 901,JKS,KCMX1
      DO 410 K=1,KCMX1
410  PRINT 902,(VALUES(KXZ,K),KXZ=1,JKS)
411  CONTINUE
50  CONTINUE
      RETURN
      END
```

TABLE XIII

FORTRAN LISTING OF THE EQP2, SEPARATOR SUBROUTINE

```

      SUBROUTINE EQP2(M,N,I,J,KS,JKS,KCMX,KCMX1,VALUES,STMTE
1M,STMPRS,AB,BC,CD,ENERGY,LCON,NOUT)
C  ** THIS IS A SEPARATOR SIMULATION. **
C  ** DIMENSION NS(NSEP),NMAX(NSEP),NSES(NSEP),NSLS(MAXOUT,N
C  1SEP),DPSEP(MAXOUT,NSEP),DTSEP(MAXOUT,NSEP),FRACT(NSEP,
C  2MAXOUT,KCMX),NADIAB(I),A(KCMX,MAXOUT),T(KCMX),AMOL(KCM
C  3X,MAXOUT),TMOL(KCMX),S(MAXOUT),COMMW(KCMX),COMHC(KCMX)
C  4,COMHV(KCMX)
C  ** THE NEXT CARD CHANGES WITH DIFFERENT PROCESSES. **
      DIMENSION NS(4),NMAX(4),NSES(4),NSLS(3,4),DPSEP(3,4),D
1TSEP(3,4),FRACT4(3,5),NADIAB(9),A(5,3),T(5),AMOL(5,3),
2TMOL(5),S(3),COMMW(5),COMHC(5),COMHV(5)
      DIMENSION VALUES(JKS,KCMX1),STMTEM(JKS),STMPRS(JKS),AB
1(KCMX),BC(KCMX),CD(KCMX),ENERGY(I)
101 FORMAT(10E12.4)
200 FORMAT(14I5)
201 FORMAT(7F10.5)
202 FORMAT (5F14.5)
900 FORMAT(1H ,36HOPTIONAL OUTPUT OF INPUT DATA ** EQP11)
901 FORMAT(1H ,25X,8HVALUES (12,1H,12,6H) MTX.)
902 FORMAT(1H ,9E14.7)
903 FORMAT(1H ,6X,9HCOMPONENT,6X,9HMOLE. WT.,6X,9HHEAT CAP
1.,4X,11HLATENT HEAT)
904 FORMAT(112,F19.3,F15.5,F15.4)
905 FORMAT(1H ,19HNO. OF SEPARATORS =13,3X,24HMAX. NO. OF
1EXIT STMS. =13)
906 FORMAT(1H ,13HSEPARATOR NO.12,12H 1S EQP. NO.12)
907 FORMAT(1H ,7HNADIAB=12,2X,18HNO. OF EXIT STMS.=13,2X,1
17HINLET STM. 1S NO.12)
908 FORMAT(1H ,9HDELTA P =F10.5,2X,9HDELTA T =F10.5)
909 FORMAT(1H ,24HCALCULATING FOR EQP. NO.12)
910 FORMAT(1H ,26HFINISHED CALC. ON EQP. NO.12)
912 FORMAT(1H ,14HFRACT SPLITS =,5E14.6)
      IF (M) 1,1,6
1 READ 200,NSEP,MAXOUT
  IF (NSEP) 50,50,2
2 READ 200,((NS(K),NMAX(K),NSES(K)),K=1,NSEP)
  DO 3 L=1,NSEP
    LNK=NS(L)
    LN=NMAX(L)
    READ 200,NADIAB(LNK)
    READ 200,(NSLS(K1,L),K1=1,LN)
3 READ 201,(DPSEP(K,L),DTSEP(K,L),(FRACT(L,K,MN),MN=1,KC
1MX),K=1,LN)
  DO 5 L=1,KCMX

```

```

      COMMW(L)=AB(L)
      COMHC(L)=BC(L)
5     COMHV(L)=CD(L)
      IF (NOUT) 401,401,400
400   PRINT 900,N
      PRINT 901,JKS,KCMX1
      DO 402 K=1,KCMX1
402   PRINT 902,(VALUES(L,K),L=1,JKS)
      PRINT 903
      DO 403 K=1,KCMX
403   PRINT 904,K,COMMW(K),COMHC(K),COMHV(K)
      PRINT 905,NSEP,MAXOUT
      DO 413 K=1,NSEP
      LL=NMAX(K)
      KK=NS(K)
      PRINT 906,K,NS(K)
      PRINT 907,NADIAB(KK),NMAX(K),NSES(K)
      DO 405 L=1,LL
405   PRINT 908,DPSEP(L,K),DTSEP(L,K)
      LN1=NMAX(K)
      DO 412 L=1,LN1
      PRINT 200,K,L
412   PRINT 912,(FRACTUK,L,LKX),LKX=1,KCMX)
413   CONTINUE
401   CONTINUE
      GO TO 50
      6 CONTINUE
      IF (NOUT) 408,408,406
406   PRINT 909,N
      PRINT 901,JKS,KCMX1
      DO 407 K=1,KCMX1
407   PRINT 902,(VALUES(K1X,K),K1X=1,JKS)
408   CONTINUE
      DO 7 L=1,NSEP
      IF (NS(L)-N) 7,8,7
      7 CONTINUE
      8 KST=NSES(L)
      ST=VALUES(KST,KCMX1)
      DO 9 K=1,KCMX
      9 T(K)=VALUES(KST,K)*ST
      KK=NMAX(L)
      DO 10 K=1,KK
10    S(K)=0.
      DO 11 K=1,KK
      DO 11 MO=1,KCMX

```

```
      A(MO,K)=T(MO)*FRACT(L,K,MO)
11  S(K)=S(K)+A(MO,K)
      IF (LCON-1) 20,20,12
12  IF (NADIAB(N)) 14,14,13
13  AI=ENERGY(N)
      GO TO 15
14  AI=0.
15  AO=0.
16  DO 18 MO=1,KCMX
      DO 17 K=1,KK
17  AO=AO+A(MO,K)*COMHC(MO)*(DTSEP(K,L)+STMTEM(KST))
18  AI=AI+T(MO)*COMHC(MO)*STMTEM(KST)
      ENERGY(N)=AO-AI+ENERGY(N)
      DO 19 K=1,KK
      LNK=NSLS(K,L)
      STMTEM(LNK)=STMTEM(KST)+DTSEP(K,L)
19  STMPRS(LNK)=STMPRS(KST)+DPSEP(K,L)
20  DO 21 K=1,KK
      LNK=NSLS(K,L)
      VALUES(LNK,KCMX1)=S(K)
      DO 21 MO=1,KCMX
21  VALUES(LNK,MO)=A(MO,K)/S(K)
      IF (NOUT) 411,411,409
409 PRINT 910,N
      PRINT 901,JKS,KCMX1
      DO 410 K=1,KCMX1
410 PRINT 902,(VALUES(KXZ,K),KXZ=1,JKS)
411 CONTINUE
50  CONTINUE
      RETURN
      END
```

TABLE XIV

FORTRAN LISTING OF THE EQP3, REACTOR SUBROUTINE

```

SUBROUTINE EQP3(M,N,I,J,KS,JKS,KCMX,KCMX1,VALUES,STMTE
1M,STMPRS,AB,CD,DE,ENERGY,LCON,NOUT)
C  ** THIS IS A REACTOR SIMULATION. **
C  ** DIMENSION NR(NRCT),INRX(NRCT),NOUTR(NRCT),RXNK(NRCT,MA
C 1RXN),NRXN(NRCT),ALPHA(NRCT,MAXRXN,KCMX),DPR(NRCT),NAD
C 2IAB(1),A(KCMX),AM(KCMX),T(KCMX),TM(KCMX),BC(NRCT,MAXRX
C 3N),HFM(KCMX),PMC(MAXRXN),COMMW(KCMX),COMHC(KCMX),COMHV
C 4(KCMX)
C  ** THE FOLLOWING CARD CHANGES WITH DIFFERENT PROCESSES.
    DIMENSION NR(1),INRX(1),NOUTR(1),NRXN(1),RXNK(1,2),ALP
1HA(1,2,5),DPR(1),NADIAB(9),A(5),AM(5),T(5),TM(5),BC(1,
22),HFM(5),COMMW(5),COMHC(5),COMHV(5),PMC(2)
    DIMENSION VALUES(JKS,KCMX1),STMTEM(JKS),STMPRS(JKS),AB
1(KCMX),CD(KCMX),DE(KCMX),ENERGY(1)
100 FORMAT(14I5)
101 FORMAT(7F10,3)
102 FORMAT(4E13,6)
900 FORMAT(1H ,36HOPTIONAL OUTPUT OF INPUT DATA ** EQP11)
901 FORMAT(1H ,25X,8HVALUES (12,1H,12,6H) MTX.)
902 FORMAT(1H ,9E14,7)
903 FORMAT(1H ,6X,9HCOMPONENT,6X,9HMOLE. WT.,6X,9HHEAT CAP
1.,4X,11HLATENT HEAT)
904 FORMAT(1I2,F19,3,F15,5,F15,4)
905 FORMAT(1H ,17HNO. OF REACTORS =13,2X,19HMAX. NO. OF RX
1NS. =13)
906 FORMAT(1H ,11HREACTOR NO.12,13H IS EQP. NO. 13)
907 FORMAT(1H ,7HNADIAB=12,2X,14HNO. OF RXNS. =12,2X,17HIN
1LET STM. NO. 13,2X,16HEXIT STM. NO. 13,2X,9HDELTA
2P =F10,5)
908 FORMAT(1H ,9HRXNK(1 TO,12,2H)=5E14,6)
909 FORMAT(1H ,24HCALCULATING FOR EQP. NO.12)
910 FORMAT(1H ,26HFINISHED CALC. ON EQP. NO.12)
911 FORMAT(1H ,11HHEAT/MOLE.=E14,6,2X,7HALPHA =,5F10,4)
    IF (M) 1,1,5
      1 READ 100,NRCT,MAXRXN
        IF (NRCT) 50,50,2
      2 DO 30 K=1,NRCT
30 READ 100,NR(K),INRX(K),NOUTR(K),NRXN(K)
    READ 101,(DPR(K),K=1,NRCT)
    DO 3 K=1,NRCT
      LK=NR(K)
      READ 100,NADIAB(LK)
      LK=NRXN(K)
      DO 3 L=1,LK
        READ 101,RXNK(K,L)

```

```

3 READ 101,(ALPHA(K,L,KL),KL=1,KCMX)
  READ 102,(HFM(K),K=1,KCMX)
  READ 101,(PMC(K),K=1,MAXRXN)
  DO 4 K=1,KCMX
    COMMW(K)=AB(K)
    COMHC(K)=CD(K)
4 COMHV(K)=DE(K)
  IF (NOUT) 401,401,400
400 PRINT 900,N
  PRINT 901,JKS,KCMX1
  DO 402 K=1,KCMX1
402 PRINT 02,(VALUES(L,K),L=1,JKS)
  PRINT 903
  DO 403 K=1,KCMX
403 PRINT 904,K,COMMW(K),COMHC(K),COMHV(K)
  PRINT 905,NRCT,MAXRXN
  DO 405 K=1,NRCT
    KK=NR(K)
    LL=NRXN(K)
    PRINT 906,K,KK
    PRINT 907,NADIAB(KK),NRXN(K),INRX(K),NOUTR(K),DPR(K)
    PRINT 908,LL,(RXNK(K,L),L=1,LL)
    DO 405 LK=1,KCMX
405 PRINT 911,HFM(LK),(ALPHA(K,L,LK),L=1,LL)
  PRINT 101,(PMC(K),K=1,MAXRXN)
401 CONTINUE
  GO TO 50
5 CONTINUE
  IF (NOUT) 408,408,406
406 PRINT 909,N
  PRINT 01,JKS,KCMX1
  DO 407 K=1,KCMX1
407 PRINT 902,(VALUES(K1X,K),K1X=1,JKS)
408 CONTINUE
  DO 6 L=1,NRCT
    IF (NR(L)-N) 6,7,6
6 CONTINUE
7 LK=NRXN(L)
  IN=INRX(L)
  NOTR=NOUTR(L)
  DO 8 IJ=1,NRCT
    DO 8 IK=1,LK
8 BC(IJ,IK)=RXNK(IJ,IK)
  S=VALUES(IN,KCMX1)
  DO 9 IJ=1,KCMX

```

```

  9 A(IJ)=VALUES(IN,IJ)*S
    DO 10 IK=1,KCMX
10  AM(IK)=A(IK)/COMMW(IK)
11  DO 12 IK=1,KCMX
12  TM(IK)=0.
    DO 16 K=1,KCMX
    DO 13 II=1,LK
13  TM(K)=TM(K)+ALPHA(L,II,K)*BC(L,II)
    IF((PMC(LK)*AM(K))+TM(K)) 14,16,16
14  B=-(AM(K)/TM(K))*PMC(LK)
    DO 15 IJ=1,LK
15  BC(L,IJ)=BC(L,IJ)*B
    GO TO 11
16  CONTINUE
    DO 17 K=1,KCMX
17  TM(K)=TM(K)+AM(K)
    DO 18 K=1,KCMX
18  T(K)=TM(K)*COMMW(K)
    ST=0.
    DO 19 IX=1,KCMX
19  ST=ST+T(IX)
    VALUES(NOTR,KCMX1)=ST
    DO 20 IY=1,KCMX
20  VALUES(NOTR,IY)=T(IY)/ST
    IF (LCON-1) 50,50,21
21  STMPRS(NOTR)=STMPRS(IN)+DPR(L)
    IF (NADIAB(N)) 23,23,22
22  HEAT=ENERGY(N)
    GO TO 24
23  HEAT=0.
24  DO 25 IJ=1,KCMX
25  HEAT=HEAT+(HFM(IJ)*(TM(IJ)-AM(IJ)))
    AI=HEAT
    AO=0.
    DO 26 IK=1,KCMX
    AI=AI+(STMTEM(IN)*COMHC(IK)*A(IK))
    AO=AO+(COMHC(IK)*T(IK))
26  CONTINUE
    STMTEM(NOTR)=AI/AO
    IF (NOUT) 411,411,409
409 PRINT 910,N
    PRINT 901,JKS,KCMX1
    DO 410 K=1,KCMX1
410 PRINT 902,(VALUES(KXZ,K),KXZ=1,JKS)
411 CONTINUE

```

TABLE XIV (continued)

109

50 CONTINUE
RETURN
END

TABLE XV

FORTRAN LISTING OF THE EQP4, HEAT EXCHANGER SUBROUTINE

```

      SUBROUTINE EQP4(M,N,I,J,KS,JKS,KCMX,KCMX1,VALUES,STMTE
1M,STMPRS,COMMW,COMHC,COMHV,ENERGY,LCON,NOUT)
C  ** THIS IS A HEAT EXCHANGER SIMULATION. **
C  ** DIMENSION NH(NHE),INHE(2,NHE),NOUTHE(2,NHE),DPH(2,NHE)
C 1,A(KCMX),TA(KCMX)
C  ** THE NEXT CARD CHANGES WITH DIFFERENT PROCESSES. **
      DIMENSION NH(2),INHE(2,2),NOUTHE(2,2),DPH(2,2),A(5),TA
1(5),NADIAB(9)
      DIMENSION VALUES(JKS,KCMX1),STMTEM(JKS),STMPRS(JKS),CO
1MMW(KCMX),COMHC(KCMX),COMHV(KCMX),ENERGY(I)
104 FORMAT(1H ,50HNO HT. EXCH. SHOULD HAVE A ZERO HEAT LOA
1D. NADIAB(,I2,10H)=1. NOT 0)
105 FORMAT(1H ,31H BOTH INLET TEMPERATURES OF EQP.,I3,4H AR
1E,F10.3,33H ...NO HEAT TRANSFER IS POSSIBLE.)
200 FORMAT(14I5)
201 FORMAT(7F10.5)
202 FO-MAT(1H9,+2,2X,F5.1,5X,F8.3,5X,F10.3)
900 FORMAT(1H ,36H OPTIONAL OUTPUT OF INPUT DATA ** EQP11)
901 FORMAT(1H ,25X,8HVALUES (I2,1H,I2,6H) MTX.)
902 FORMAT(1H ,9E14.7)
903 FORMAT(1H ,6X,9HCOMPONENT,6X,9HMOLE. WT.,6X,9HHEAT CAP
1.,4X,11H LATENT HEAT)
904 FORMAT(I12,F19.3,F15.5,F15.4)
905 FORMAT(1H ,19HNO. OF HT. EXCHS. =I3)
906 FORMAT(1H ,13HHT. EXCH. NO.I3,12H IS EQP. NO.I3)
907 FORMAT(1H ,2(14HINLET STM. NO.I3,18H EXITS AS STM. NO.
1I3,3X))
908 FORMAT(1H/,10HDELTA P1 =F10.5,11H DELTA P2 =F10.5,8H N
1ADIAB=I2,12H HEAT LOAD =E14.6)
909 FORMAT(1H ,24H CALCULATING FOR EQP. NO.I2)
910 FORMAT(1H ,26H FINISHED CALC. ON EQP. NO.I2)
      IF (M) 1,1,4
1 READ 200,NHE
      IF (NHE) 50,50,2
2 READ 200,((INHE(1,L),NOUTHE(1,L),INHE(2,L),NOUTHE(2,L)
1,NH(L)),L=1,NHE)
      READ 201,((DPH(K,L),L=1,NHE),K=1,2)
      DO 3 L=1,NHE
        LK=NH(L)
3 READ 200,NADIAB(LK)
      IF (NOUT) 401,401,400
400 PRINT 900,N
      PRINT 901,JKS,KCMX1
      DO 402 K=1,KCMX1
402 PRINT 902,(VALUES(L,K),L=1,JKS)

```

```
      PRINT 903
      DO 403 K=1,KCMX
403  PRINT 904,K,COMMW(K),COMHC(K),COMHV(K)
      PRINT 905,NHE
      DO 405 K=1,NHE
      PRINT 906,K,NH(K)
      PRINT 907,((INHE(KX,K),NOUTHE(KX,K)),KX=1,2)
      KK=NH(K)
405  PRINT 908,DPH(1,K),DPH(2,K),NADIAB(KK),ENERGY(KK)
401  CONTINUE
      GO TO 50
      4 CONTINUE
      IF (NOUT) 408,408,406
406  PRINT 909,N
      PRINT 901,JKS,KCMX1
      DO 407 K=1,KCMX1
407  PRINT 902,(VALUES(K1X,K),K1X=1,JKS)
408  CONTINUE
      DO 5 L=1,NHE
      IF (NH(L)-N) 5,6,5
      5 CONTINUE
      6 CONTINUE
      LK1=INHE(1,L)
      LK2=INHE(2,L)
      LNK1=NOUTHE(1,L)
      LNK2=NOUTHE(2,L)
      DO 7 LL=1,KCMX1
      VALUES(LNK1,LL)=VALUES(LK1,LL)
      7  VALUES(LNK2,LL)=VALUES(LK2,LL)
      IF (LCON-1) 50,50,8
      8 DO 9 LK3=1,KCMX
      A(LK3)=VALUES(LK1,LK3)*VALUES(LK1,KCMX1)
      9  TA(LK3)=VALUES(LK2,LK3)*VALUES(LK2,KCMX1)
      B=0.
      C=0.
      DO 10 K=1,KCMX
      B=B+(COMHC(K)*A(K))
      10 C=C+(COMHC(K)*TA(K))
      IF (NADIAB(N)) 11,11,12
      11 PRINT 104,N
      12 IF (STMTEM(LK1)-STMTEM(LK2)) 14,13,15
      13 PRINT 105,N,STMTEM(LK1)
      HEAT=0.
      GO TO 16
      14 HEAT=ENERGY(N)
```

TABLE XV (continued)

```
      GO TO 16
15  HEAT=-ENERGY(N)
16  STMTEM(LNK1)=STMTEM(LK1)+(HEAT/B)
      STMTEM(LNK2)=STMTEM(LK2)-(HEAT/C)
      STMPRS(LNK1)=STMPRS(LK1)+DPH(1,L)
      STMPRS(LNK2)=STMPRS(LK2)+DPH(2,L)
      IF (NOUT) 411,411,409
409  PRINT 910,N
      PRINT 901,JKS,KCMX1
      DO 410 K=1,KCMX1
410  PRINT 902,(VALUES(KXZ,K),KXZ=1,JKS)
411  CONTINUE
      50  CONTINUE
      RETURN
      END
```

APPENDIX C

THE NO-RECYCLE PROCESS

The basic no-recycle process used in testing the basic transfer patterns of MAEBE is presented in Figure 8. The input data for the evaluation of this process by MAEBE is listed in Table XVI. Each data card is represented by two lines in the table. The vertical divisions are 10 column width fields, and columns 1 through 40 are listed first, followed by 41 through 80 on the second line. The results obtained by MAEBE's execution are presented in Table XVII.

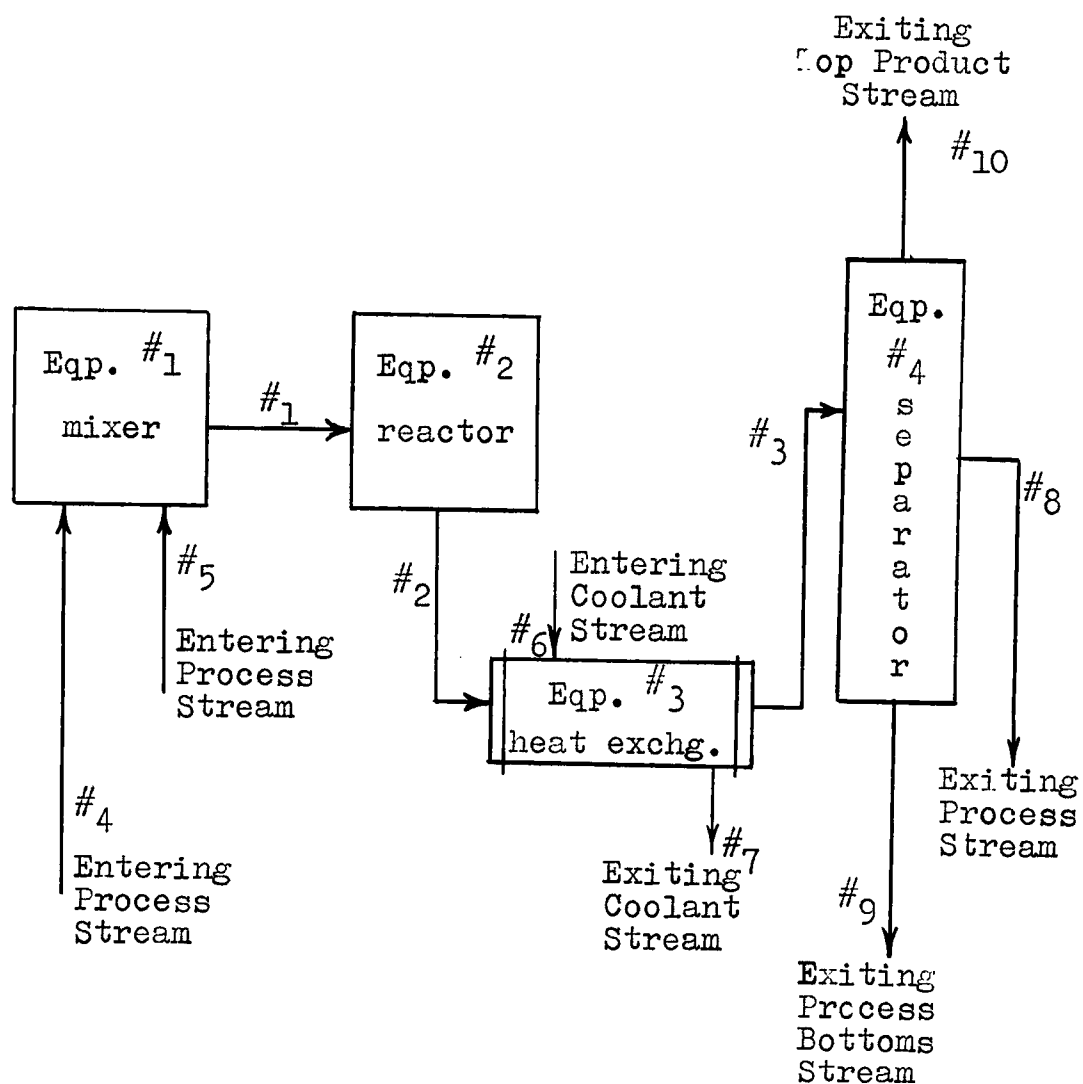


Figure 8. Configuration of the Basic No-recycle Process.

TABLE XVI

THE MAEBE INPUT DATA FOR THE NO-RECYCLE PROCESS

NMLKJI	1							
I,J,KC,KS,INSTM,LRC, LCON,...,NTYPE	4 1	3 0	5 1	7	3	0	0	0
IDENT(1-11)	TEST OF MAEBE, NO RECYCLE PROCESS							
VALUES(1,1-5)*		-1.E+06			0.E+00		-1.E+	
06		-1.E+06			-1.E+06			
VALUES(1,6)*		-2.E+06						
VALUES(2,1-5)*		-1.E+06			0.E+00		-1.E+	
06		-1.E+06			-1.E+06			
VALUES(2,6)*		-2.E+06						
VALUES(3,1-5)*		-1.E+06			0.E+00		-1.E+	
06		-1.E+06			-1.E+06			
VALUES(3,6)*		-2.E+06						
VALUES(4,1-5)*		1.E+01			0.E+00		4.E+	
04		3.E+04			1.E+02			
VALUES(4,6)*		7.011E+04						
VALUES(5,1-5)*		0.E+00			0.E+00		2.E+	
04		5.E+02			3.E+03			
VALUES(5,6)*		2.35E+04						
VALUES(6,1-5)*		5.E+04			0.E+00		0.E+	
00		0.E+00			0.E+00			
VALUES(6,6)*		5.E+04						

TABLE XVI (continued)

116

NAME(1,1-4),COMMW(1), COMHC(1),COMHV(1)	880.	WATER	18.	1.
NAME(2,1-4),COMMW(2), COMHC(2),COMHV(2)	700.	COMPOUND A	40.	.9
NAME(3,1-4),COMMW(3), COMHC(3),COMHV(3)	600.	COMPOUND B	20.	.8
NAME(4,1-4),COMMW(4), COMHC(4),COMHV(4)	500.	COMPOUND C	10.	.7
NAME(5,1-4),COMMW(5), COMHC(5),COMHV(5)	400.	COMPOUND D	5.	.6
NEQ(1-4,1)	1	2 3 4		
IET(1-4)	1	3 4 2		
ST(4),SP(4)	100.	25.		
ST(5),SP(5)	70.	15.		
ST(6),SP(6)	39.	40.		
ENERGY(1-4)*	05	1.E+06 -9.E+04	0.E+00	2.5E+
INPUT DATA FOR THE EQP1, MIXER SUBROUTINE				
NMIX,MAXIN	1	2		
NM(1),IN(1),NSLM(1)	1	2 1		
NADIAB(1),NSEM(1,1), NSEM(2,1)	1	4 5		

TABLE XVI (continued)

117

DPM(1)	-1.				
INPUT DATA FOR THE EQP2, SEPARATOR SUBROUTINE					
NSEP,MAXOUT	1	3			
NS(1),NMAX(1), NSES(1)	4	3	3		
NADIAB(4)	1				
NSLS(1-3,1)	8	9	10		
DPSEP(1,1),DTSEP (1,1),FRACT(1,1,15)	-0.5 .9	12.5 .8	1. .7	0.	
DPSEP(2,1),DTSEP (2,1),FRACT(1,2,15)	-0.1 .1	-1. .2	0. .3	0.	
DPSEP(3,1),DTSEP (3,1),FRACT(1,3,15)	2. 0.	-5. 0.	0. 0.	1.	
INPUT DATA FOR THE EQP3, REACTOR SUBROUTINE					
NRCT,MAXRXN	1	1			
NR(1),INRX(1),NOUTR (1),NRXN(1)	2	1	2	1	
DPR(1)	-2.				
NADIAB(2)	1				
RXNK(1,1)	100.				

TABLE XVI (continued)

118

ALPHA(1,1,1-5)	0. -12.	5.	-2.	-10.
HFM(1-4)	.E+02	1.E+01 -4 E+02	E+02	-5
HFM(5)		-2.E+02		
PMC(1)	.95			
INPUT DATA FOR THE EQP4, HEAT EXCHANGER SUBR.				
NHE				
INHE(1,1), NOUTHE(1,1), ..., NH(1)	2	3	6	7
DPH(1-2,1)	-4.	-5		
NADIAE(3)	1			

*

These sets of data were originally read on a 5E14.6 format, but this has since been changed to a 5E15.6 format for data coding purposes.

TABLE XVII

MAEBE OUTPUT OF THE NO-RECYCLE PROCESS TEST

TEST OF MAEBE, NO RECYCLE PROCESS		
STREAM 1, FLOW	0.936100E 05 LBS. PER HOUR,	106.4 F DEG.,
19.0 PSIA,	0.757750E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
WATER	0.106826E-03	0.100000E 02
COMPOUND A	0.	0.
COMPOUND B	0.640957E 00	0.600000E 05
COMPOUND C	0.325820E 00	0.305000E 05
COMPOUND D	0.331161E-01	0.310000E 04
STREAM 2, FLOW	0.936100E 05 LBS. PER HOUR,	111.4 F DEG.,
17.0 PSIA,	0.816159E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
WATER	0.106826E-03	0.100000E 02
COMPOUND A	0.104868E 00	0.981667E 04
COMPOUND B	0.619984E 00	0.580367E 05
COMPOUND C	0.273386E 00	0.255917E 05
COMPOUND D	0.165581E-02	0.155000E 03
STREAM 3, FLOW	0.936100E 05 LBS. PER HOUR,	108.0 F DEG.,
13.0 PSIA,	0.791159E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
WATER	0.106826E-03	0.100000E 02
COMPOUND A	0.104868E 00	0.981667E 04
COMPOUND B	0.619984E 00	0.580367E 05
COMPOUND C	0.273386E 00	0.255917E 05
COMPOUND D	0.165581E-02	0.155000E 03
STREAM 4, FLOW	0.701100E 05 LBS. PER HOUR,	100.0 F DEG.,
25.0 PSIA,	0.530700E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
WATER	0.142633E-03	0.100000E 02
COMPOUND A	0.	0.
COMPOUND B	0.570532E 00	0.400000E 05
COMPOUND C	0.427899E 00	0.300000E 05
COMPOUND D	0.142633E-02	0.100000E 03
STREAM 5, FLOW	0.235000E 05 LBS. PER HOUR,	70.0 F DEG.,
15.0 PSIA,	0.127050E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
WATER	0.	0.
COMPOUND A	0.	0.
COMPOUND B	0.851064E 00	0.200000E 05
COMPOUND C	0.212766E-01	0.500000E 03
COMPOUND D	0.127660E 00	0.300000E 04
STREAM 6, FLOW	0.500000E 05 LBS. PER HOUR,	39.0 F DEG.,
40.0 PSIA,	0.195000E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
WATER	0.100000E 01	0.500000E 05

TABLE XVII (continued)

120

COMPOUND A	0.	0.
COMPOUND B	0.	0.
COMPOUND C	0.	0.
COMPOUND D	0.	0.
STREAM 7, FLOW 0.500000E 05 LBS. PER HOUR, 44.0 F DEG.,		
39.5 PSIA, 0.220000E 07 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
WATER	0.100000E 01	0.500000E 05
COMPOUND A	0.	0.
COMPOUND B	0.	0.
COMPOUND C	0.	0.
COMPOUND D	0.	0.
STREAM 8, FLOW 0.728248E 05 LBS. PER HOUR, 120.5 F DEG.,		
12.5 PSIA, 0.676908E 07 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
WATER	0.137316E-03	0.100000E 02
COMPOUND A	0.	0.
COMPOUND B	0.717242E 00	0.522330E 05
COMPOUND C	0.281131E 00	0.204733E 05
COMPOUND D	0.148988E-02	0.108500E 03
STREAM 9, FLOW 0.109685E 05 LBS. PER HOUR, 107.0 F DEG.,		
12.9 PSIA, 0.882826E 06 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
WATER	0.	0.
COMPOUND A	0.	0.
COMPOUND B	0.529121E 00	0.580367E 04
COMPOUND C	0.466639E 00	0.511833E 04
COMPOUND D	0.423941E-02	0.465000E 02
STREAM 10, FLOW 0.981667E 04 LBS. PER HOUR, 103.0 F DEG.,		
15.0 PSIA, 0.909666E 06 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
WATER	0.	0.
COMPOUND A	0.100000E 01	0.981667E 04
COMPOUND B	0.	0.
COMPOUND C	0.	0.
COMPOUND D	0.	0.
HEAT BALANCE ON EQUIPMENT NO. 1 WAS 0.10000000E 07 BTU		
HEAT BALANCE ON EQUIPMENT NO. 2 WAS 0. BTU		
HEAT BALANCE ON EQUIPMENT NO. 3 WAS 0.25000000E 06 BTU		
HEAT BALANCE ON EQUIPMENT NO. 4 WAS 0.64998156E 06 BTU		
COMPONENT	TOTAL IN	TOTAL OUT
WATER	0.500100E 05	0.500100E 05
COMP. PER CENT CHANGE	0.000000	
COMPOUND A	0.	0.981667E 04
COMP. PER CENT CHANGE	0.000000	

TABLE XVII (continued)

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COMPOUND B	.600000E 05	0.580367E 05
COMP. PER CENT CHANGE	-3.272200	
COMPOUND C	0.305000E 05	0.255917E 05
COMP. PER CENT CHANGE	-16.092900	
COMPOUND D	0.310000E 04	0.155000E 03
COMP. PER CENT CHANGE	-95.000000	
ENTIRE SYSTEM BALANCE	0.143610E 06	0.143610E 06
PROCESS ERROR	0.000000 PCT.	

APPENDIX D

THE FIRST RECYCLE PROCESS

The first recycle process, depicted in Figure 1, page 16, was evaluated by the three program systems. The necessary input data and the programs' results are presented in Tables XVIII through XXII. The tables which list input data are arranged so that each data card will be represented by two lines in the table; columns 1 through 40 are listed first, followed by 41 through 80 on the second line. The vertical divisions represent 10 column width fields.

TABLE XVIII

INPUT AND OUTPUT FOR THE FIRST RECYCLE
PROCESS AS A TEST OF THE SEEK/HUNT SYSTEM

I,J,KS,NOUT	4	5	4	1				
NEQ(1-4,1)	1	2	3	4				
NP(1,1-9)	-1 0	0	0	0	1	1	1	0
NP(2,1-9)	1 0	-1	0	1	0	0	0	1
NP(3,1-9)	0 0	1	-1	0	0	0	0	0
NP(4,1-9)	0 -1	0	1	-1	-1	0	0	0
NP(5,1-9)	4 0	4	4	4	3	0	0	0
IDENT(1-11)	SEEK/HUNT TEST OF FIRST RECYCLE PROCESS							
OUTPUT FROM THE FIRST RECYCLE PROCESS TEST OF THE SEEK/HUNT SYSTEM								
OPTIMUM SEQUENCE	4**	1**	2**	3**				

TABLE XIX

THE FIND INPUT DATA FOR THE FIRST RECYCLE PROCESS

I,J,KC,KS,INSTM, LRC,....,NORC,MU *** IET(1-4)	4 0	5 0	4 0	4 1	3 4	1 1	1 1
CONCRI *	.100000E-07						
MAXPAS	100						
VALUES(1,1-5) *	-1.000000E+06 -1.000000E+06 -1.000000E+06 06 -1.000000E+06 -1.000010E+06						
VALUES(2,1-5) *	-1.000000E+06 -1.000000E+06 -1.000000E+06 06 -1.000000E+06 -1.000010E+06						
VALUES(3,1-5) *	-1.000000E+06 -1.000000E+06 -1.000000E+06 06 -1.000000E+06 -1.000010E+06						
VALUES(4,1-5) *	03	1.E+03 1.E+03		1.E+03 4.E+03		1.E+	
VALUES(5,1-5) *	-1.000000E+06 0.000000E+00 -1.000000E+06 06 -1.000000E+06 -1.000010E+06						
VALUES(6,1-5) *	00	.250000E+00 .250000E+00	.250000E+00 1.000000E+05			.250000E+	
VALUES(7,1-5) *	00	.500000E+00 .500000E+00	0.000000E+00 2.000000E+04			0.000000E+	
VALUES(8,1-5) *	00	0.000000E+00 0.000000E+00	1.000000E+00 1.000000E+02			0.000000E+	
NAME(1,1-4),COMMW (1),....,COMHV(1)	0.1	COMPONENT A 100.0				10.0	
NAME(2,1-4),COMMW (2),....,COMHV(2)	0.2	COMPONENT B 200.0				20.0	
NAME(3,1-4),COMMW (3),....,COMHV(3)	0.3	COMPONENT C 300.0				30.0	

TABLE XIX (continued)

NAME(4,1-4), COMMW (4), ..., COMHV(4)	0.4	COMPONENT 400.0	D	40.0
ST(6), SP(6)	100.000000	1000.000000		
ST(7), SP(7)	200.000000	2000.000000		
ST(8), SP(8)	50.000000	25.000000		
ENERGY(1-4)	0.000000E+00 05 0.100000E+07	0.100000E+04		0.600000E+
MINOR(1,1-5)	1	1	1	3
NEQ(1-4,1)	4	1	2	3

INPUT DATA FOR THE EQP1, MIXER SUBROUTINE

NMIX, MAXIN	2	3			
NM(1), IN(1), NSLM(1), NM(2), IN(2), NSLM(2)	1	3	1	2	3
NADIAB(1), NSEM(1-3,1)	0	6	7	5	
NADIAB(3), NSEM(1-3,1)	1	4	8	1	
DPM(1-2)	-50.00000	-10.00000			

INPUT DATA FOR THE EQP2, SEPARATOR SUBROUTINE

NSEP, MAXOUT	1	3			
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TABLE XIX (continued)

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NS(1),NMAX(1), NSES(1)	4	3	3		
NADIAB(4)	1				
NSLS(1-3,1)	4	5	9		
DPSEP(1,1),DTSEP (1,1),FRACT(1,1,1-4), DPSEP(2,1)	-10.0		20.15	.2	.20
DTSEP(2,1),FRACT(1, 2,1-4),DPSEP(3,1), DTSEP(3,1)	.41		.15	-2.15	
FRACT(1,3,1-4)	.1		.2	0.0	.05
	.10		1.0	-20.0	
	.6		.8	.54	.75

INPUT DATA FOR THE EQP3, REACTOR SUBROUTINE

NRCT,MAXRXN	1	1			
NR(1),INRX(1), NOUTR(1),NRXN(1)	3	2	3	1	
DPR(1)	-10.000				
NADIAB(3)	1				
RXNK(1,1)	1000.000				
ALPHA(1,1,1-4)	3.000	2.000	-1.000	-1.000	
HFM(1-4)	1.000000E+03 0E+03	-2.000000E+03 4.000000E+03		-3.000000	
PMC(1)	.905				

TABLE XIX (continued)

INPUT DATA FOR THE EQP4, HEAT EXCHANGER SUBR.

NHE	0			
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* These sets of data were originally read on a 5E14.6 format, but this has since been changed to a 5E15.6 format for data coding purposes.

*** The identification variable array was not used at the time that this process was evaluated; it has since been introduced into the data list at the location indicated.

TABLE XX

FIND OUTPUT OF THE FIRST RECYCLE PROCESS

STREAM 1, FLOW	0.127379E 06 LBS. PER HOUR,	116.5 F DEG.,	
	1130.1 PSIA,	0.358495E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT 1	0.331330E 00	0.422045E 05	
COMPONENT 2	0.196265E 00	0.250000E 05	
COMPONENT 3	0.197252E 00	0.251258E 05	
COMPONENT 4	0.275153E 00	0.350487E 05	
STREAM 2, FLOW	0.148534E 06 LBS. PER HOUR,	117.8 F DEG.,	
	552.6 PSIA,	0.403868E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT 1	0.332645E 00	0.494090E 05	
COMPONENT 2	0.262030E 00	0.389203E 05	
COMPONENT 3	0.169328E 00	0.251509E 05	
COMPONENT 4	0.235998E 00	0.350536E 05	
STREAM 3, FLOW	0.148534E 06 LBS. PER HOUR,	109.1 F DEG.,	
	542.6 PSIA,	0.258962E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT 1	0.485040E 00	0.720448E 05	
COMPONENT 2	0.465223E 00	0.691014E 05	
COMPONENT 3	0.169328E-01	0.251509E 04	
COMPONENT 4	0.328041E-01	0.487251E 04	
STREAM 4, FLOW	0.210548E 05 LBS. PER HOUR,	129.3 F DEG.,	
	532.6 PSIA,	0.451726E 06 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT 1	0.342178E 00	0.720448E 04	
COMPONENT 2	0.656396E 00	0.138203E 05	
COMPONENT 3	0.119455E-02	0.251509E 02	
COMPONENT 4	0.231421E-03	0.487251E 01	
STREAM 5, FLOW	0.737896E 04 LBS. PER HOUR,	109.2 F DEG.,	
	540.4 PSIA,	0.849493E 05 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT 1	0.976354E 00	0.720448E 04	
COMPONENT 2	0.	0.	
COMPONENT 3	0.170423E-01	0.125755E 03	
COMPONENT 4	0.660325E-02	0.487251E 02	
STREAM 6, FLOW	0.100000E 06 LBS. PER HOUR,	100.0 F DEG.,	
	1000.0 PSIA,	0.250000E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT 1	0.250000E 00	0.250000E 05	
COMPONENT 2	0.250000E 00	0.250000E 05	
COMPONENT 3	0.250000E 00	0.250000E 05	
COMPONENT 4	0.250000E 00	0.250000E 05	
STREAM 7, FLOW	0.200000E 05 LBS. PER HOUR,	200.0 F DEG.,	
	2000.0 PSIA,	0.100000E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			

TABLE XX (continued)

COMPONENT 1	0.500000E 00	0.100000E 05
COMPONENT 2	0.	0.
COMPONENT 3	0.	0.
COMPONENT 4	0.500000E 00	0.100000E 05
STREAM 8, FLOW 0.100000E 03 LBS. PER HOUR, 50.0 F DEG.,		
25.0 PSIA, 0.100000E 04 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
COMPONENT 1	0.	0.
COMPONENT 2	0.100000E 01	0.100000E 03
COMPONENT 3	0.	0.
COMPONENT 4	0.	0.
STREAM 9, FLOW 0.120100E 06 LBS. PER HOUR, 89.1 F DEG.,		
544.5 PSIA, 0.173429E 07 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES		
COMPONENT 1	0.479899E 00	0.576358E 05
COMPONENT 2	0.460292E 00	0.552811E 05
COMPONENT 3	0.196851E-01	0.236419E 04
COMPONENT 4	0.401242E-01	0.481891E 04
HEAT BALANCE ON EQUIPMENT NO. 1 WAS 0. BTU		
HEAT BALANCE ON EQUIPMENT NO. 2 WAS 0.10000000E 04 BTU		
HEAT BALANCE ON EQUIPMENT NO. 3 WAS 0.59999999E 05 BTU		
HEAT BALANCE ON EQUIPMENT NO. 4 WAS -0.10608397E 07 BTU		
COMPONENT	TOTAL IN	TOTAL OUT
COMPONENT 1	0.350000E 05	0.576358E 05
COMP. PER CENT CHANGE	64.673700	
COMPONENT 2	0.251000E 05	0.552811E 05
COMP. PER CENT CHANGE	120.243333	
COMPONENT 3	0.250000E 05	0.236419E 04
COMP. PER CENT CHANGE	-90.543333	
COMPONENT 4	0.350000E 05	0.481891E 04
COMP. PER CENT CHANGE	-86.231700	
ENTIRE SYSTEM BALANCE 0.120100E 06		0.120100E 06
PROCESS ERROR 0.000000 PCT.		

**** The IDENT variable has been introduced into the list of output of the FIND program system as the heading of the listing.

TABLE XXI

THE MAEBE INPUT DATA FOR THE FIRST RECYCLE PROCESS

NMLKJI	1							
I,J,KC,KS,INSTM, LRC,...,NTYPE	4 0	5 0	4 0	4	3	1	1	1
IDENT(1-11)	TEST OF SMALL RECYCLE PROCESS ALL SYSTEMS A-OK LNK							
CONCRI *	.100000E-05							
LRCMX	0							
MAXPAS	100							
VALUES(1,1-5) *	-1.000000E+06 -1.000000E+06 -1.000000E+06 06 -1.000000E+06 -1.000010E+06							
VALUES(2,1-5) *	-1.000000E+06 -1.000000E+06 -1.000000E+06 06 -1.000000E+06 -1.000010E+06							
VALUES(3,1-5) *	-1.000000E+06 -1.000000E+06 -1.000000E+06 06 -1.000000E+06 -1.000010E+06							
VALUES(4,1-5) *	-1.000000E+06 -1.000000E+06 -1.000000E+06 06 -1.000000E+06 -1.000010E+06							
VALUES(5,1-5) *	-1.000000E+06 0.000000E+00 -1.000000E+06 06 -1.000000E+06 -1.000010E+06							
VALUES(6,1-5) *	.250000E+00 .250000E+00 .250000E+00 00 .250000E+00 1.000000E+05							
VALUES(7,1-5) *	.500000E+00 0.000000E+00 0.000000E+00 00 .500000E+00 2.000000E+04							
VALUES(8,1-5) *	0.000000E+00 1.000000E+00 0.000000E+00 00 0.000000E+00 1.000000E+02							
NAME(1,1-4),COMMW (1),...,COMHV(1)	0.1	COMPONENT		1	10.0			
		100.0						

TABLE XXI (continued)

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NAME(2,1-4),COMMW (2),...,COMHV(2)	0.2	COMPONENT 200.0	II	20.0
NAME(3,1-4),COMMW (3),...,COMHV(3)	0.3	COMPONENT 300.0	III	30.0
NAME(4,1-4),COMMW (4),...,COMHV(4)	0.4	COMPONENT 400.0	IV	40.0
NEQ(1-4,1)	1	2 3 4		
IET(1-4)	1	1 3 2		
NP(1,1-9)	-1 0	0 0 0	1 1	1 0
NP(2,1-9)	1 0	-1 0 1	0 0	0 1
NP(3,1-9)	0 0	1 -1 0	0 0	0 0
NP(4,1-9)	0 -1	0 1 -1	-1 0	0 0
NP(5,1-5)	4	4 4 4	3	
ST(6),SP(6)	100.000000	1000.000000		
ST(7),SP(7)	200.000000	2000.000000		
ST(8),SP(8)	50.000000	25.000000		
ENERGY(1-4)*	0.000000E+00 05 0.100000E+07	0.100000E+04	0.600000E+	

TABLE XXI (continued)

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INPUT DATA FOR THE EQP1, MIXER SUBROUTINE

NMIX, MAXIN	2	3				
NM(1), IN(1), NSLM(1),	1	3	1	2	3	2
NM(2), IN(2), NSLM(2)						
NADIAB(1), NSEM(1-3,1)	0	6	7	5		
NADIAB(2), NSEM(1-3,1)	1	4	8	1		
DPM(1-2)	-50.00000	-10.00000				

INPUT DATA FOR THE EQP2, SEPARATOR SUBROUTINE

NSEP, MAXOUT	1	3				
NS(1), NMAX(1), NSES (1)	4	3	3			
NADIAB(4)	1					
NSLS(1-3,1)	4	5	9			
DPSEP(1,1), DTSEP (1,1), FRACT(1,1,1-4),	-10.0	20.15	.2	.20		
	.41	.15	-2.15			
DPSEP(2,1), DTSEP (2,1), FRACT(1,2,1-4),	.1	.2	0.0	.05		
	.10	1.9	-20.0			
DPSEP(3,1), DTSEP (3,1), FRACT(1,3,1-4)	.6	.8	.54	.75		

INPUT FOR THE EQP3, REACTOR SUBROUTINE

NRCT, MAXRXN	1	1				
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TABLE XXI (continued)

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NR(1), INRX(1), NOU (1), NRXN(1)	3	2	3	1		
DPR(1)	-10.000					
NADIAB(3)	1					
RXNK(1,1)	300.000					
ALPHA(1,1,1-4)	3.000		2.000	-1.000	-1.000	
HFM(1-4)	1.000000E+03 0E+03	4.000000E+03	-2.000000E+03	-3.000000E+03		
PMC(1)	.950					
INPUT DATA FOR THE EQP4, HEAT EXCHANGER SUBR.						
NHE	0					

* These sets of data were originally read on a 5E14.6 format, but this has since been changed to a 5E15.6 format for coding purposes.

TABLE XXII

MAEBE OUTPUT OF THE FIRST RECYCLE PROCESS TEST

TEST OF SMALL RECYCLE PROCESS ALL SYSTEMS A-OK LNK			
STREAM 1, FLOW	0.139215E 06 LBS. PER HOUR,	105.6 F DEG.,	
	949.3 PSIA,	0.350031E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT I	0.356763E 00	0.496667E 05	
COMPONENT II	0.179579E 00	0.250000E 05	
COMPONENT III	0.190220E 00	0.264815E 05	
COMPONENT IV	0.273438E 00	0.380667E 05	
STREAM 2, FLOW	0.180005E 06 LBS. PER HOUR,	87.7 F DEG.,	
	311.4 PSIA,	0.367976E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT I	0.357398E 00	0.643333E 05	
COMPONENT II	0.190967E 00	0.343750E 05	
COMPONENT III	0.214604E 00	0.386296E 05	
COMPONENT IV	0.237031E 00	0.426667E 05	
STREAM 3, FLOW	0.180005E 06 LBS. PER HOUR,	83.1 F DEG.,	
	301.4 PSIA,	0.313976E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT I	0.407397E 00	0.733333E 05	
COMPONENT II	0.257632E 00	0.463750E 05	
COMPONENT III	0.164605E 00	0.296296E 05	
COMPONENT IV	0.170366E 00	0.306667E 05	
STREAM 4, FLOW	0.406898E 05 LBS. PER HOUR,	20.2 F DEG.,	
	-10.0 PSIA,	0.177443E 06 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT I	0.360450E 00	0.146667E 05	
COMPONENT II	0.227944E 00	0.927500E 04	
COMPONENT III	0.298555E 00	0.121481E 05	
COMPONENT IV	0.113050E 00	0.460000E 04	
STREAM 5, FLOW	0.192148E 05 LBS. PER HOUR,	0.1 F DEG.,	
	-2.2 PSIA,	0.313778E 03 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT I	0.763300E 00	0.146667E 05	
COMPONENT II	0.	0.	
COMPONENT III	0.771010E-01	0.148148E 04	
COMPONENT IV	0.159599E 00	0.306667E 04	
STREAM 6, FLOW	0.100000E 06 LBS. PER HOUR,	100.0 F DEG.,	
	1000.0 PSIA,	0.250000E 07 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT I	0.250000E 00	0.250000E 05	
COMPONENT II	0.250000E 00	0.250000E 05	
COMPONENT III	0.250000E 00	0.250000E 05	
COMPONENT IV	0.250000E 00	0.250000E 05	
STREAM 7, FLOW	0.200000E 05 LBS. PER HOUR,	200.0 F DEG.,	
	2000.0 PSIA,	0.100000E 07 BTU PER HR.	

TABLE XXII (continued)

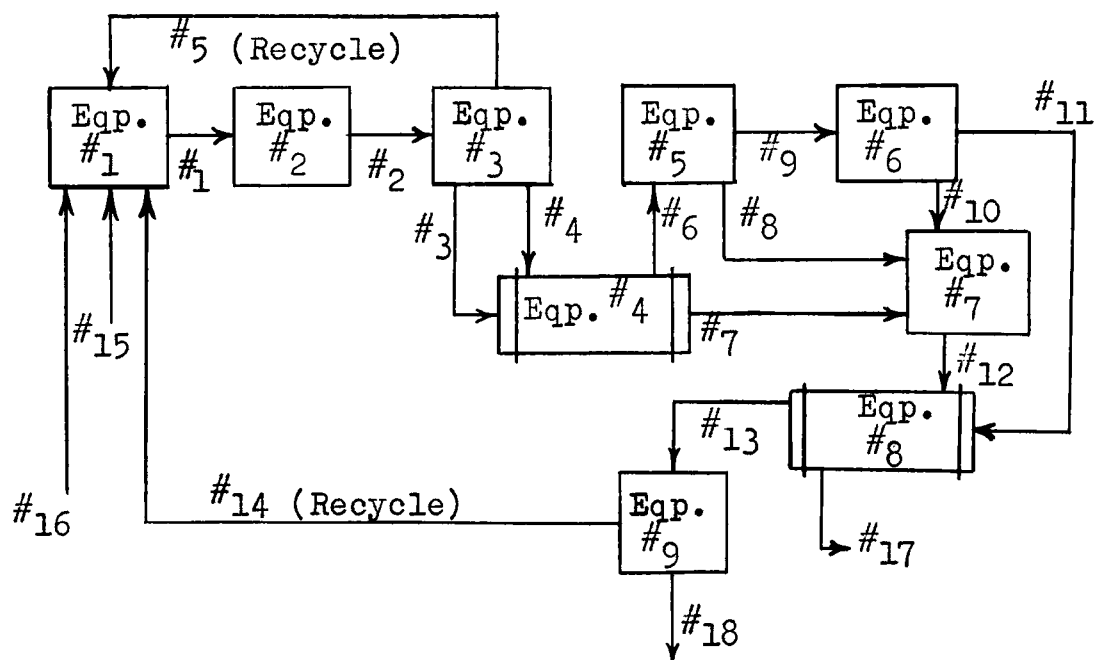
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT	I	0.500000E 00	0.100000E 05
COMPONENT	II	0.	0.
COMPONENT	III	0.	0.
COMPONENT	IV	0.500000E 00	0.100000E 05
STREAM	8, FLOW	0.100000E 03 LBS. PER HOUR,	50.0 F DEG.,
	25.0 PSIA,	0.100000E 04 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT	I	0.	0.
COMPONENT	II	0.100000E 01	0.100000E 03
COMPONENT	III	0.	0.
COMPONENT	IV	0.	0.
STREAM	9, FLOW	0.120100E 06 LBS. PER HOUR,	-20.0 F DEG.,
	1.9 PSIA,	-0.516400E 06 BTU PER HR.	
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMPONENT	I	0.366361E 00	0.440000E 05
COMPONENT	II	0.308909E 00	0.371000E 05
COMPONENT	III	0.133222E 00	0.160000E 05
COMPONENT	IV	0.191507E 00	0.230000E 05
HEAT BALANCE ON EQUIPMENT NO. 1 WAS 0. BTU			
HEAT BALANCE ON EQUIPMENT NO. 2 WAS 0.10000000E 04 BTU			
HEAT BALANCE ON EQUIPMENT NO. 3 WAS 0.59999999E 05 BTU			
HEAT BALANCE ON EQUIPMENT NO. 4 WAS -0.13386430E 07 BTU			
COMPONENT		TOTAL IN	TOTAL OUT
COMPONENT	I	0.350000E 05	0.440000E 05
COMP. PER CENT CHANGE		25.714200 PCT.	
COMPONENT	II	0.251000E 05	0.371000E 05
COMP. PER CENT CHANGE		47.808800	
COMPONENT	III	0.250000E 05	0.160000E 05
COMP. PER CENT CHANGE		-36.000000	
COMPONENT	IV	0.350000E 05	0.230000E 05
COMP. PER CENT CHANGE		-34.285700	
ENTIRE SYSTEM BALANCE		0.120100E 06	0.120100E 06
PROCESS ERROR		0.000000 PCT.	

APPENDIX E

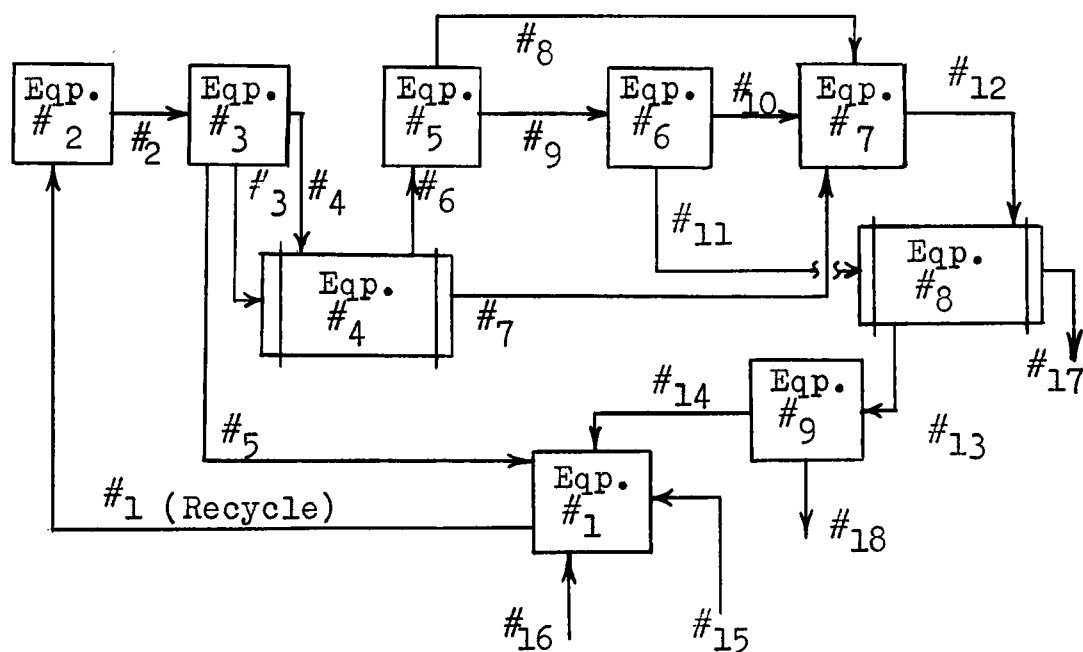
THE SECOND RECYCLE PROCESS

The second recycle process was evaluated by the three program systems in two configurations. These are designated as Second Recycle¹ and Second Recycle², and are presented in Figure 9.

Tables XXIII through XXIX are the listed input data and results utilized in the evaluation of the two versions of this process by the program systems.



Initial Configuration: 1, 2, 3, 4, 5, 6, 7, 8, 9 = MIEQ



Improved Configuration: 2, 3, 4, 5, 6, 7, 8, 9, 1 = MIEQ

Figure 9. The Two Versions of the Second Recycle Process.

TABLE XXIII
 INPUT AND OUTPUT FOR THE SECOND RECYCLE¹ PROCESS
 TEST OF THE SEEK/HUNT SYSTEM

I, J, KS, NOUT	9	14	4	0				
NEQ(1-9,1)	1 9	2	3	4	5	6	7	8
NP(1,1-14)	-1 0	0 0	0 0	0 0	1 0	0 1	0	0
NP(1,15-18)	1	1	0	0				
NP(2,1-14)	1 0	-1 0	0 0	0 0	0 0	0 0	0	0
NP(2,15-18)	0	0	0	0				
NP(3,1-14)	0 0	1 0	-1 0	-1 0	-1 0	0 0	0	0
NP(3,15-18)	0	0	0	0				
NP(4,1-14)	0 0	0 0	1 0	1 0	0 0	-1 0	-1	0
NP(4,15-18)	0	0	0	0				
NP(5,1-14)	0 -1	0 0	0 0	0 0	0 0	1 0	0	-1
NP(5,15-18)	0	0	0	0				
NP(6,1-14)	0 1	0 -1	0 -1	0 0	0 0	0 0	0	0
NP(6,15-18)	0	0	0	0				
NP(7,1-14)	0 0	0 1	0 0	0 -1	0 0	0 0	1	1

TABLE XXIII (continued)

NP(7,15-18)	0	0	0	0				
NP(8,1-14)	0	0	0	0	0	0	0	0
	0	0	1	1	-1	0		
NP(8,15-18)	0	0	-1	0				
NP(9,1-14)	0	0	0	0	0	0	0	0
	0	0	0	0	1	-1		
NP(9,15-18)	0	0	0	-1				
NP(10,1-14)	5	5	5	4	4	4	4	4
	4	4	5	5	5	4		
IDENT(1-11)	TEST OF PHASE II TEST BIG RECYCLE							
SEEK/HUNT OUTPUT FOR THE SECOND RECYCLE PROCESS								
NO IMPROVEMENT OBTAINED. BEST SEQUENCE IS	1**	2**	3**	4				
** 5** 6** 7** 8** 9**								

* This data is for the original sequence of 1-9 equipment designation numbers.

TABLE XXIV

INPUT AND OUTPUT OF THE SECOND RECYCLE² PROCESS
TEST OF THE SEEK/HUNT SYSTEM *

I, J, KS, NOUT	9	14	4	0				
NEQ(1-9,1)	2 1	3	4	5	6	7	8	9
NP(2,1-14)	1 0	-1 0	0 0	0 0	0 0	0 0	0	0
NP(2,15-18)	0	0	0	0				
NP(3,1-14)	0 0	1 0	-1 0	-1 0	-1 0	0 0	0	0
NP(3,15-18)	0	0	0	0				
NP(4,1-14)	0 0	0 0	1 0	1 0	0 0	-1 0	-1	0
NP(4,15-18)	0	0	0	0				
NP(5,1-14)	0 -1	0 0	0 0	0 0	0 0	1 0	0	-1
NP(5,15-18)	0	0	0	0				
NP(6,1-14)	0 1	0 -1	0 -1	0 0	0 0	0 0	0	0
NP(6,15-18)	0	0	0	0				
NP(7,1-14)	0 0	0 1	0 0	0 -1	0 0	0 0	1	1
NP(7,15-18)	0	0	0	0				
NP(8,1-14)	0 0	0 0	0 1	0 1	0 -1	0 0	0	0

TABLE XXIV (continued)

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NP(8,15-18)	0	0	-1	0				
NP(9,1-14)	0	0	0	0	0	0	0	0
	0	0	0	0	1	-1		
NP(9,15-18)	0	0	0	-1				
NP(1,1-14)	-1	0	0	0	1	0	0	0
	0	0	0	0	0	1		
NP(1,15-18)	1	1	0	0				
NP(10,1-14)	5	5	5	4	4	4	4	4
	4	4	5	5	5	4		
IDENT(1-11)	TEST OF PHASE II TEST BIG RECYCLE							
SEEK/HUNT OUTPUT FOR THE SECOND RECYCLE PROCESS								
NO IMPROVEMENT OBTAINED, BEST SEQUENCE IS 2** 3** 4** 5								
** 6** 7** 8** 9** 1**								

* This data is for the improved equipment sequence of 2-9,1 designation numbers.

TABLE XXV

THE FIND INPUT DATA FOR THE SECOND RECYCLE PROCESS*

I,J,KC,KS,...,MU	9 0	14 1	5 1	4 2	2 8	2	2	0
IDENT(1,1-11)	TEST OF FIND ESS LNK				SECOND RECYCLE PROC			
IET(1-9)	1 2	3	2	4	2	2	1	4
CONCRI **	1.E-08							
MAXPAS	200							
VALUES(1,1-5) **	06	-1.E+06			-1.E+06			-1.E+
		-1.E+06			-1.E+06			
VALUES(1,6) **	-1.00001E+06							
VALUES(2,1-5) **	06	-1.E+06			-1.E+06			-1.E+
		-1.E+06			-1.E+06			
VALUES(2,6) **	-1.00001E+06							
VALUES(3,1-5) **	06	-1.E+06			-1.E+06			-1.E+
		-1.E+06			-1.E+06			
VALUES(3,6) **	-1.00001E+06							
VALUES(4,1-5) **	06	-1.E+06			-1.E+06			-1.E+
		-1.E+06			0.E+00			
VALUES(4,6) **	-1.00001E+06							
VALUES(5,1-5) **	03	0.E+00			1.E+03			1.E+
		1.E+03			1.E+03			
VALUES(5,6) **	4.E+03							

TABLE XXV (continued)

VALUES(6,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(6,6)**		-1.00001E+06		
VALUES(7,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(7,6)**		-1.00001E+06		
VALUES(8,1-5)**	06	0.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(8,6)**		-1.00001E+06		
VALUES(9,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 0.E+00	-1.E+
VALUES(9,6)**		-1.00001E+06		
VALUES(10,1-5)**	06	0.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(10,6)**		-1.00001E+06		
VALUES(11,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(11,6)**		-1.00001E+06		
VALUES(12,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(12,6)**		-1.00001E+06		
VALUES(13,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+

TABLE XXV (continued)

VALUES(13,6)**		-1.00001E+06			
VALUES(14,1-5)**	03	0.E+00 1.E+03	1.E+03 1.E+03	1.E+	
VALUES(14,6)**		4.E+03			
VALUES(15,1-5)**	04	1.E+01 6.7E+02	2.E+03 1.E+01	5.E+	
VALUES(15,6)**		5.269E+04			
VALUES(16,1-5)**	03	0.E+00 0.E+00	0.E+00 0.E+00	2.1E+	
VALUES(16,6)**		2.1E+03			
NAME(1,1-4),COMMW (1),...,COMHV(1)		COMP. X-1000 .75 1000.	(1111)	100.	
NAME(2,1-4),COMMW (2),...,COMHV(2)		COMP. X-2000 .90 800.	(XXXX)	10.	
NAME(3,1-4),COMMW (3),...,COMHV(3)		COMP. X-427 .95 750.	(YYYY)	20.	
NAME(4,1-4),COMMW (4),...,COMHV(4)		COMP. 954 .80 500.	(YYYY)	30.	
NAME(5,1-4),COMMW (5),...,COMHV(5)		COMP. -1 .99 880.	(ZZZ)	.15	
ST(15),SP(15)		767.	914.7		
ST(16),SP(16)		172.	342.2		
ENERGY(1-5)**	04	0.E+00 - .E+04	-1.E+03 2.E+06	1.E+	

TABLE XXV (continued)

ENERGY(6-9)**	05	3.E+04 1.E+05	-8.E+05		5.9F+	
MINOR(1,1-6),	0	1	1	1	1	5
MINOR(2,1-6)	1	1	1	14	0	1
NEQ(1-9,1)	1	2	3	4	5	6
	9				7	8

INPUT DATA FOR THE EQP1, MIXER SUBROUTINE

NMIX,MAXIN	2	4				
NM(1),IN(1),NSLM(1), NM(2),...,NSLM(2)	1	4	1	7	3	12
NADIAB(1),NSEM(1-4,1)	0	15	16	5	14	
NADIAB(7),NSEM(1-3,1)	1	7	8	10		
DPM(1-2)	-10.		-2.5			

INPUT DATA FOR THE EQP2, SEPARATOR SUBROUTINE

NSEP,MAXOUT	4	3				
NS(1),NMAX(1),NSES (1),...,NSES(4)	3	3	2	5	2	6
	9	9	2	13		6
NADIAB(3)	1					
NSLS(1-3,1)	3	4	5			
DISEP(1,1)..., FRACT(1,1,1-5)	-5.		12.		.1	.05
	.5		.5		.95	

TABLE XXV (continued)

DPSEP(2,1),...., FRACT(1,2,1-5)	-39. .4	-1. .49	.9 0.	.75
DPSEP(3,1),...., FRACT(1,3,1-5)	20. .1	13. .01	0. .05	.2
NADIAB(5)	1			
NSLS(1-2,2)	8	9		
DPSEP(1,2),...., FRACT(2,1,1-5)	-2.5 .6	15. .5	0. 1.	.01
DPSEP(2,2),...., FRACT(2,2,1-5)	-10. .4	-3.1 .5	1. 0.	.99
NADIAB(6)	1			
NSLS(1-2,3)	10	11		
DPSEP(1,3),...., FRACT(3,1,1-5)	-5. .88	20. .75	0. .995	.75
DPSEP(2,3),...., FRACT(3,2,1-5)	-22. .12	-9. .25	1. .005	.25
NADIAB(9)	1			
NSLS(1-2,4)	14	18		
DPSEP(1,4),...., FRACT(4,1,1-5)	-1. .9	37. 1.	0. 1.	.95
DPSEP(2,4),...., FRACT(4,2,1-5)	-31. .1	-8.2 0.	1. 0.	.05

TABLE XXV (continued)

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INPUT DATA FOR THE EQP3, REACTOR SUBROUTINE									
NRCT, MAXRXN	1	2							
NR(1), INRX(1), NOUTR (1), NRXN(1)	2	1	2	2					
DPR(1)		-43.							
NADIAB(2)	1								
RXNK(1,1)		1.							
ALPHA(1,1,1-5)		1.68 0.		-3.		-3.9		-2.	
RXNK(1,2)		.01							
ALPHA(1,2,1-5)		-.2 -2.		5.		0.		0.	
HFM(1-4)		1.E+05 5E+04		1.6E+04		-2.E+03		-2.	
HFM(5)		3.E+04							
PMC(1-2)		.95		.9					

INPUT DATA FOR THE EQP4, HEAT EXCHANGER SUBR.

NHE	2								
INHE(1,1), NOUTHE(1,1), INHE(2,1), ... NH(2)	3 17	7 8	4	6	4	11	13	12	
DFH(1-2,1), DPH(1-2,2)		-10.		-20.		-2.		-4.	

TABLE XXV (continued)

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NADIAB(4)	1			
NADIAB(8)	1			

* This data is for the original equipment sequence, 1-9.

** These sets of data were originally read on a 5E14.6 format, but this has since been changed to a 5E15.6 format for coding purposes.

I,J,KC,KS,...,MU	9	14	5	4	2	2	2	0
	0	1	1	1	5			
IDENT(1-11)	TEST OF FIND				SECOND RECYCLE PROC			
	ESS	LNK						
IET(1-9)	1	3	2	4	2	2	1	4
	2							
CONCRI**	1.E-08							
MAXPAS	200							
VALUES(1,1-5)**	0.139450E+05		0.139450E+05		0.139450E+05			
	05	0.139450E+05	0.139450E+05					
VALUES(1,6)**	0.697250E+05							
VALUES(2,1-5)**	-1.E+06		-1.E+06		-1.E+06			
	06	-1.E+06	-1.E+06					
VALUES(2,6)**	-1.00001E+06							
VALUES(3,1-5)**	-1.E+06		-1.E+06		-1.E+06			
	06	-1.E+06	-1.E+06					
VALUES(3,6)**	-1.00001E+06							
VALUES(4,1-5)**	-1.E+06		-1.E+06		-1.E+06			
	06	-1.E+06	0.E+00					
VALUES(4,6)**	-1.00001E+06							
VALUES(5,1-5)**	0.E+00		-1.E+06		-1.E+06			
	06	-1.E+06	-1.E+06					
VALUES(5,6)**	-1.00001E+06							

TABLE XXVI (continued)

VALUES(6,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(6,6)**		-1.00001E+06		
VALUES(7,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(7,6)**		-1.00001E+06		
VALUES(8,1-5)**	06	0.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(8,6)**		-1.00001E+06		
VALUES(9,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 0.E+00	-1.E+
VALUES(9,6)**		-1.00001E+06		
VALUES(10,1-5)**	06	0.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(10,6)**		-1.00001E+06		
VALUES(11,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(11,6)**		-1.00001E+06		
VALUES(12,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(12,6)**		-1.00001E+06		
VALUES(13,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+

TABLE XXVI (continued)

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VALUES(13,6)**		-1.00001E+06		
VALUES(14,1-5)**	06	0.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(14,6)**		-1.00001E+06		
VALUES(15,1-5)**	04	1.E+01 6.7E+02	2.E+03 1.E+01	5.E+
VALUES(15,6)**		5.269E+04		
VALUES(16,1-5)**	03	0.E+00 0.E+00	0.E+00 0.E+00	2.1E+
VALUES(16,6)**		2.1E+03		
NAME(1,1-4),COMMW (1),...,COMHV(1)	COMP. X .75	-1000 1000.	(111)	100.
NAME(2,1-4),COMMW (2),...,COMHV(2)	COMP. X .90	-2000 800.	(XXX)	10.
NAME(3,1-4),COMMW (3),...,COMHV(3)	COMP. X .95	-427 750.	(YYY)	20.
NAME(4,1-4),COMMW (4),...,COMHV(4)	COMP. X .80	-954 500.	(YYY)	30.
NAME(5,1-4),COMMW (5),...,COMHV(5)	COMP. Z .99	-1 880.	(ZZZ)	.15
ST(15),SP(15)		967.	914.7	
ST(16),SP(16)		872.	342.2	
ENERGY(1-5)**	04	0.E+00 -1.E+04	-1.E+03 2.E+06	1.E+

TABLE XXVI (continued)

ENERGY(6-9)**	05	3.E+04 1.E+05			-8.E+05		5.9E+
MINOR(1,1-6)	1	1	1	1	1	1	
NEQ(1-9,1)	2 1	3	4	5	6	7	8 9

All of the data required by the equipment subroutines will be identical to that presented in Table XXV.

* This set of input data is for the improved sequence of the second recycle process, 2-9,1.

** These sets of data were originally read on a 5E14.6 format, but this has since been changed to a 5E15.6 format for coding purposes.

THE OUTPUT OF THE FIND PROGRAM , SECOND RECYCLE PROCESS

TEST OF FIND SECOND RECYCLE PROCESS LNK

STREAM 1, FLOW 0.629382E 05 LBS. PER HOUR, 976.0 F DEG.,
528.4 PSIA, 0.580913E 08 BTU PER HR.

MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES

COMP. X-1000	(III)	0.158886E-03	0.100000E 02
COMP. X-2000	(XXX)	0.506703E-01	0.318909E 04
COMP. X-427	(YYY)	0.937615E 00	0.590117E 05
COMP. X-954	(YYY)	0.113889E-01	0.716797E 03
COMP. Z-1	(ZZZ)	0.167246E-03	0.105262E 02

STREAM 2, FLOW 0.629385E 05 LBS. PER HOUR, 980.3 F DEG.,
485.4 PSIA, 0.583289E 08 BTU PER HR.

MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES

COMP. X-1000	(III)	0.282498E-02	0.177800E 03
COMP. X-2000	(XXX)	0.502013E-01	0.315959E 04
COMP. X-427	(YYY)	0.936371E 00	0.589337E 05
COMP. X-954	(YYY)	0.104355E-01	0.656797E 03
COMP. Z-1	(ZZZ)	0.167198E-03	0.105232E 02

STREAM 3, FLOW 0.299810E 05 LBS. PER HOUR, 992.3 F DEG.,
480.4 PSIA, 0.282034E 08 BTU PER HR.

MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES

COMP. X-1000	(III)	0.593042E-03	0.177800E 02
COMP. X-2000	(XXX)	0.526932E-02	0.157980E 03
COMP. X-427	(YYY)	0.982851E 00	0.294669E 05
COMP. X-954	(YYY)	0.109535E-01	0.328398E 03
COMP. Z-1	(ZZZ)	0.333444E-03	0.999700E 01

STREAM 4, FLOW 0.264250E 05 LBS. PER HOUR, 979.3 F DEG.,
446.4 PSIA, 0.243900E 08 BTU PER HR.

MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES

COMP. X-1000	(III)	0.605562E-02	0.160020E 03
COMP. X-2000	(XXX)	0.896761E-01	0.236969E 04
COMP. X-427	(YYY)	0.892089E 00	0.235735E 05
COMP. X-954	(YYY)	0.121790E-01	0.321830E 03
COMP. Z-1	(ZZZ)	0.	0.

STREAM 5, FLOW 0.653239E 04 LBS. PER HOUR, 993.3 F DEG.,
505.4 PSIA, 0.613197E 07 BTU PER HR.

MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES

COMP. X-1000	(III)	0.	0.
COMP. X-2000	(XXX)	0.967362E-01	0.631919E 03
COMP. X-427	(YYY)	0.902178E 00	0.589337E 04
COMP. X-954	(YYY)	0.100545E-02	0.656797E 01
COMP. Z-1	(ZZZ)	0.805460E-04	0.526158E 00

STREAM 6, FLOW 0.264250E 05 LBS. PER HOUR, 978.9 F DEG.,
444.4 PSIA, 0.243800E 08 BTU PER HR.

MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES

COMP. X-1000	(III)	0.605562E-02	0.160020E 03
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TABLE XXVII (continued)

COMP. X-2000	(XXX)	0.896761E-01	0.236969E 04
COMP. X-427	(YYY)	0.892089E 00	0.235735E 05
COMP. X-954	(YYY)	0.121790E-01	0.321830E 03
COMP. Z-1	(ZZZ)	0.	0.
STREAM 7. FLOW 0.299810E 05 LBS. PER HOUR, 992.7 F DEG.,			
470.4 PSIA, 0.282134E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.593042E-03	0.177800E 02
COMP. X-2000	(XXX)	0.526932E-02	0.157980E 03
COMP. X-427	(YYY)	0.982851E 00	0.294669E 05
COMP. X-954	(YYY)	0.109535E-01	0.328398E 03
COMP. Z-1	(ZZZ)	0.333444E-03	0.999700E 01
STREAM 8. FLOW 0.143287E 05 LBS. PER HOUR, 993.9 F DEG.,			
441.9 PSIA, 0.135043E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.	0.
COMP. X-2000	(XXX)	0.165381E-02	0.236969E 02
COMP. X-427	(YYY)	0.987116E 00	0.141441E 05
COMP. X-954	(YYY)	0.112303E-01	0.160915E 03
COMP. Z-1	(ZZZ)	0.	0.
STREAM 9. FLOW 0.120963E 05 LBS. PER HOUR, 975.8 F DEG.,			
434.4 PSIA, 0.110444E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.132288E-01	0.160020E 03
COMP. X-2000	(XXX)	0.193943E 00	0.234600E 04
COMP. X-427	(YYY)	0.779525E 00	0.942940E 04
COMP. X-954	(YYY)	0.133028E-01	0.160915E 03
COMP. Z-1	(ZZZ)	0.	0.
STREAM 10. FLOW 0.101781E 05 LBS. PER HOUR, 995.8 F DEG.,			
433.9 PSIA, 0.952308E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.	0.
COMP. X-2000	(XXX)	0.172872E 00	0.175950E 04
COMP. X-427	(YYY)	0.815271E 00	0.829787E 04
COMP. X-954	(YYY)	0.118575E-01	0.120686E 03
COMP. Z-1	(ZZZ)	0.	0.
STREAM 11. FLOW 0.191828E 04 LBS. PER HOUR, 966.8 F DEG.,			
412.4 PSIA, 0.169676E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.834186E-01	0.160020E 03
COMP. X-2000	(XXX)	0.305743E 00	0.586499E 03
COMP. X-427	(YYY)	0.589867E 00	0.113153E 04
COMP. X-954	(YYY)	0.209713E-01	0.402288E 02
COMP. Z-1	(ZZZ)	0.	0.
STREAM 12. FLOW 0.544878E 05 LBS. PER HOUR, 978.1 F DEG.,			

446.3 PSIA, 0.504408E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.326312E-03	0.177800E 02
COMP. X-2000	(XXX)	0.356259E-01	0.194117E 04
COMP. X-427	(YYY)	0.952669E 00	0.519088E 05
COMP. X-954	(YYY)	0.111952E-01	0.610000E 03
COMP. Z-1	(ZZZ)	0.183472E-03	0.999700E 01
STREAM 13, FLOW 0.191828E 04 LBS. PER HOUR, 1303.0 F DEG.,			
392.4 PSIA, 0.228676E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.834186E-01	0.160020E 03
COMP. X-2000	(XXX)	0.305743E 00	0.586499E 03
COMP. X-427	(YYY)	0.589867E 00	0.113153E 04
COMP. X-954	(YYY)	0.209713E-01	0.402288E 02
COMP. Z-1	(ZZZ)	0.	0.
STREAM 14, FLOW 0.161578E 04 LBS. PER HOUR, 1340.0 F DEG.,			
391.4 PSIA, 0.201147E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.	0.
COMP. X-2000	(XXX)	0.344833E 00	0.557174E 03
COMP. X-427	(YYY)	0.630269E 00	0.101838E 04
COMP. X-954	(YYY)	0.248975E-01	0.402288E 02
COMP. Z-1	(ZZZ)	0.	0.
STREAM 15, FLOW 0.526900E 05 LBS. PER HOUR, 967.0 F DEG.,			
914.7 PSIA, 0.482082E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.189789E-03	0.100000E 02
COMP. X-2000	(XXX)	0.379579E-01	0.200000E 04
COMP. X-427	(YYY)	0.948947E 00	0.500000E 05
COMP. X-954	(YYY)	0.127159E-01	0.670000E 03
COMP. Z-1	(ZZZ)	0.189789E-03	0.100000E 02
STREAM 16, FLOW 0.210000E 04 LBS. PER HOUR, 872.0 F DEG.,			
342.2 PSIA, 0.173964E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.	0.
COMP. X-2000	(XXX)	0.	0.
COMP. X-427	(YYY)	0.100000E 01	0.210000E 04
COMP. X-954	(YYY)	0.	0.
COMP. Z-1	(ZZZ)	0.	0.
STREAM 17, FLOW 0.544878E 05 LBS. PER HOUR, 966.6 F DEG.,			
442.3 PSIA, 0.498508E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.326312E-03	0.177800E 02
COMP. X-2000	(XXX)	0.356259E-01	0.194117E 04
COMP. X-427	(YYY)	0.952669E 00	0.519088E 05

TABLE XXVII (continued)

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COMP. X-954	(YYY)	0.111952E-01	0.610000E 03
COMP. Z-1	(ZZZ)	0.183472E-03	0.999700E 01
STREAM 18. FLOW 0.302498E 03 LBS. PER HOUR. 1294.8 F DEG.,			
361.4 PSIA. 0.328753E 06 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.528996E 00	0.160020E 03
COMP. X-2000	(XXX)	0.969428E-01	0.293250E 02
COMP. X-427	(YYY)	0.374062E 00	0.113153E 03
COMP. X-954	(YYY)	0.	0.
COMP. Z-1	(ZZZ)	0.	0.
HEAT BALANCE ON EQUIPMENT NO. 1 WAS 0. BTU			
HEAT BALANCE ON EQUIPMENT NO. 2 WAS -0.10000000E 04 BTU			
HEAT BALANCE ON EQUIPMENT NO. 3 WAS 0.39640466E 06 BTU			
HEAT BALANCE ON EQUIPMENT NO. 4 WAS -0.10000000E 05 BTU			
HEAT BALANCE ON EQUIPMENT NO. 5 WAS 0.16871783E 06 BTU			
HEAT BALANCE ON EQUIPMENT NO. 6 WAS 0.17546635E 06 BTU			
HEAT BALANCE ON EQUIPMENT NO. 7 WAS -0.79999999E 06 BTU			
HEAT BALANCE ON EQUIPMENT NO. 8 WAS 0.59000000E 06 BTU			
HEAT BALANCE ON EQUIPMENT NO. 9 WAS 0.53458523E 05 BTU			
COMPONENT		TOTAL IN	TOTAL OUT
COMP. X-1000	(III)	0.100000E 02	0.177800E 03
COMP. PER CENT CHANGE 1677.999999			
COMP. X-2000	(XXX)	0.200000E 04	0.197050E 04
COMP. PER CENT CHANGE -1.4750000			
COMP. X-427	(YYY)	0.521000E 05	0.520220E 05
COMP. PER CENT CHANGE -0.149700			
COMP. X-954	(YYY)	0.670000E 03	0.610000E 03
COMP. PER CENT CHANGE -8.955200			
COMP. Z-1	(ZZZ)	0.100000E 02	0.999700E 01
COMP. PER CENT CHANGE -0.030000			
ENTIRE SYSTEM BALANCE		0.547900E 05	0.547903E 05
PROCESS ERROR 0.000500 PCT.			

This output listing applies to both equipment sequence sets of data for the FIND program system.

TABLE XXVIII

THE MAEBE INPUT DATA FOR THE SECOND RECYCLE PROCESS*

NMLKJI	1							
I,J,KC,KS,...,NTYPE	9 0	14 0	5 0	4	2	2	2	0
IDENT(1-11)	TEST OF LARGE RECYCLE PROCESS ALL SYSTEMS A-OK LNK							
CONCRI**		1.E-06						
LRCMX	0							
MAXPAS	1000							
VALUES(1,1-5)**		-1.E+06			-1.E+06		-1.E+	
	06	-1.E+06			-1.E+06			
VALUES(1,6)**		-1.00001E+06						
VALUES(2,1-5)**		-1.E+06			-1.E+06		-1.E+	
	06	-1.E+06			-1.E+06			
VALUES(2,6)**		-1.00001E+06						
VALUES(3,1-5)**		-1.E+00			-1.E+06		-1.E+	
	06	-1.E+06			-1.E+06			
VALUES(3,6)**		-1.00001E+06						
VALUES(4,1-5)**		-1.E+06			-1.E+06		-1.E+	
	06	-1.E+06			0.E+00			
VALUES(4,6)**		-1.00001E+06						
VALUES(5,1-5)**		0.E+00			-1.E+06		-1.E+	
	06	-1.E+06			-1.E+06			

TABLE XXVIII (continued)

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VALUES(5,6)**		-1.00001E+06		
VALUES(6,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(6,6)**		-1.00001E+06		
VALUES(7,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(7,6)**		-1.00001E+06		
VALUES(8,1-5)**	06	0.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(8,6)**		-1.00001E+06		
VALUES(9,1-5)**	06	-1.E+06 -1.E+06	-1.E+06 0.E+00	-1.E+
VALUES(9,6)**		-1.00001E+06		
VALUES(10,1-5)**	06	0.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(10,6)**		-1.00001E+06		
VALUES(11,1-5)**	06	-1.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(11,6)**		-1.00001E+06		
VALUES(12,1-5)**	06	-1.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(12,6)**		-1.00001E+06		

TABLE XXVIII (continued)

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VALUES(13,1-5)**	06	-1.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(13,6)**		-1.00001E+06		
VALUES(14,1-5)**	06	0.E+00 -1.E+06	-1.E+06 -1.E+06	-1.E+
VALUES(14,6)**		-1.00001E+06		
VALUES(15,1-5)**	04	1.E+01 *** 6.7E+02	2.E+03 1.E+01	5.E+
VALUES(15,6)**		5.269E+04 ****		
VALUES(16,1-5)**	03	0.E+00 0.E+00	0.E+00 0.E+00	2.1E+
VALUES(16,6)**		2.1E+03		
NAME(1,1-4), COMMW (1),..., COMHV(1)	COMP. X .75	-1000 1000.	(111)	100.
NAME(2,1-4), COMMW (1),..., COMHV(1)	COMP. X .90	-2000 800.	(XXX)	10.
NAME(3,1-4), COMMW (3),..., COMHV(3)	COMP. X .95	-427 750.	(YYY)	20.
NAME(4,1-4), COMMW (4),..., COMHV(4)	COMP. X .80	-954 500.	(YYY)	30.
NAME(5,1-4), COMMW (5),..., COMHV(5)	COMP. Z .99	-1 880.	(ZZZ)	15.
NEQ(1-9,1)	1 9	2 3	4 5	6 7 8
IET(1-9)	1 2	3 2	4 4	2 2 1 4

TABLE XXVIII (continued)

NP(1,1-14)	-1 0	0 0	0 0	0 0	1 0	0 1	0 0	0 0
NP(1,15-18)	1	1	0	0				
NP(2,1-14)	1 0	-1 0	0 0	0 0	0 0	0 0	0 0	0 0
NP(2,15-18)	0	0	0	0				
NP(3,1-14)	0 0	1 0	-1 0	-1 0	-1 0	0 0	0 0	0 0
NP(3,15-18)	0	0	0	0				
NP(4,1-14)	0 0	0 0	1 0	1 0	0 0	-1 0	-1 0	0 0
NP(4,15-18)	0	0	0	0				
NP(5,1-14)	0 -1	0 0	0 0	0 0	0 0	1 0	0 0	-1 0
NP(5,15-18)	0	0	0	0				
NP(6,1-14)	0 1	0 -1	0 -1	0 0	0 0	0 0	0 0	0 0
NP(6,15-18)	0	0	0	0				
NP(7,1-14)	0 0	0 1	0 0	0 -1	0 0	0 0	1 0	1 0
NP(7,15-18)	0	0	0	0				
NP(8,1-14)	0 0	0 0	0 1	0 1	0 -1	0 0	0 0	0 0

TABLE XXVIII (continued)

NP(8,15-18)	0	0	-1	0				
NP(9,1-14)	0	0	0	0	0	0	0	0
	0	0	0	0	1	-1		
NP(9,15-18)	0	0	0	-1				
NP(10,1-14)	5	5	5	4	4	4	4	4
	4	4	5	5	5	4		
ST(15),SP(15)			967.		914.7			
ST(16),SP(16)			872.		342.2			
ENERGY(1-5)**			0.E+00		-1.E+03		1.E+	
04			-1.E+04		2.E+06			
ENERGY(6-9)**			3.E+04		-8.E+05		5.9E+	
05			1.E+05					

INPUT DATA FOR THE EQP1, MIXER SUBROUTINE

NMIX,MAXIN	2	4						
NM(1),IN(1),NSLM(1), ...,NSLM(2)	1	4	1	7	3	12		
NADIAB(1),NSEM(14,1)	0	15	16	5	14			
NADIAB(7),NSEM(13,2)	1	7	8	10				
DPM(1-2)	-10.		-2.5					

INPUT DATA FOR THE EQP2, SEPARATOR SUBROUTINE
(next page)

TABLE XXVIII (continued)

NSEP, MAXOUT	4	3					
NS(1), NMAX(1), NSES (1), ..., NSES(4)	3 9	3 9	2 2	5 13	2	6	6 2
NADIAB(3)	1						
NSLS(1-3,1)	3	4	5				
DTSEP(1,1), ..., FRACT(1,1,1-5)	-5. .5		12. .9		.1 .95		.05
DTSEP(2,1), ..., FRACT(1,2,1-5)	-39. .4		-1. .01		.9 0.		.75
DTSEP(3,1), ..., FRACT(1,3,1-5)	20. .1		13. .09		0. .05		.2
NADIAB(5)	1						
NSLS(1-2,2)	8	9					
DTSEP(1,2), ..., FRACT(2,1,1-5)	-2.5 .6		15. .95		0. 1.		.01
DTSEP(2,2), ..., FRACT(2,2,1-5)	-10. .4		-3.1 .05		1. 0.		.99
NADIAB(6)	1						
NSLS(1-2,3)	10	11					
DTSEP(1,3), ..., FRACT(3,1,1-5)	-.5 .88		20. .99		0. .995		.75
DTSEP(2,3), ..., FRACT(3,2,1-5)	-22. .12		-9. .01		1. .005		.25

TABLE XXVIII (continued)

NADIAB(9)	1				
NSLS(1-2,4)	14	18			
DTSEP(1,4),..., FRACT(4,1,1-5)	-1. .9	37. 1.	0. 1.		.95
DTSEP(2,4),..., FRACT(4,2,1-5)	-31. .1	-8.2 0.	1. 0.		.05

INPUT DATA FOR THE EQP3, REACTOR SUBROUTINE

NRCT,MAXRXN	1	2			
NR(1),INFX(1),NOUTR (1),NRXN(1)	2	1	2	2	
DPR(1)	-43.				
NADIAB(2)	1				
RXNK(1,1)	10.				
ALPHA(1,1,1-5)	1.68 0.	-3.	-3.9		-2.
RXNK(1,2)	.5				
ALPHA(1,2,1-5)	-.2 -2.	5.	0.		0.
HFM(1-4)	5E+04	1.E+05 1.6E+04	-2.E+03		-2.
HFM(5)		3.E+03			

TABLE XXVIII (continued)

PMC(1-2)	.95	.9						
INPUT DATA FOR THE EQP4, HEAT EXCHANGER SUBR.								
NHE	2							
INHE(1,1),NOUTHE(1,1), ...,NOUTHE(2,2),NH(2)	3 7 17 8	4	6	4	11	13	12	
DPH(1-2,1),DPH(1-2,2)	-10.	-20.		-2.			-4.	
NADIAB(4)	1							
NADIAB(8)	1							

* This set of data is for the original equipment sequence of 1-9.

** These sets of data were originally read on a 5E14.6 format, but this has since been changed to a 5E15.6 format for coding purposes.

*** The correct value of VALUES(15,1) is 1.E+03.

**** The correct value of VALUES(15,6) is 5.368E+04.

TABLE XXIX

THE OUTPUT OF THE MAEBE PROGRAM, SECOND RECYCLE PROCESS

TEST OF MAEBE SECOND RECYCLE PROCESS A-OK LNK			
STREAM 1, FLOW	0.637770E 05 LBS. PER HOUR,	974.8 F DEG.,	
528.4 PSIA,	0.586121E 08 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.156796E-01	0.100000E 04
COMP. X-2000	(XXX)	0.487139E-01	0.310683E 04
COMP. X-427	(YYY)	0.924466E 00	0.589596E 05
COMP. X-954	(YYY)	0.109833E-01	0.700482E 03
COMP. Z-1	(ZZZ)	0.157584E-03	0.100503E 02
STREAM 2, FLOW	0.637770E 05 LBS. PER HOUR,	1000.9 F DEG.,	
485.4 PSIA,	0.600444E 08 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.314696E-01	0.200704E 04
COMP. X-2000	(XXX)	0.461138E-01	0.294100E 04
COMP. X-427	(YYY)	0.917091E 00	0.584893E 05
COMP. X-954	(YYY)	0.531027E-02	0.338673E 03
COMP. Z-1	(ZZZ)	0.157584E-04	0.100503E 01
STREAM 3, FLOW	0.298981E 05 LBS. PER HOUR,	1012.9 F DEG.,	
480.4 PSIA,	0.286760E 08 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.671291E-02	0.200703E 03
COMP. X-2000	(XXX)	0.491836E-02	0.147050E 03
COMP. X-427	(YYY)	0.978142E 00	0.292446E 05
COMP. X-954	(YYY)	0.101948E-01	0.304806E 03
COMP. Z-1	(ZZZ)	0.319342E-04	0.954774E 00
STREAM 4, FLOW	0.274112E 05 LBS. PER HOUR,	999.9 F DEG.,	
446.4 PSIA,	0.255666E 08 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.658976E-01	0.180633E 04
COMP. X-2000	(XXX)	0.804689E-01	0.220575E 04
COMP. X-427	(YYY)	0.853510E 00	0.233957E 05
COMP. X-954	(YYY)	0.123553E-03	0.338673E 01
COMP. Z-1	(ZZZ)	0.	0.
STREAM 5, FLOW	0.646766E 04 LBS. PER HOUR,	1013.9 F DEG.,	
505.4 PSIA,	0.619538E 07 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.	0.
COMP. X-2000	(XXX)	0.909447E-01	0.588199E 03
COMP. X-427	(YYY)	0.904335E 00	0.584893E 04
COMP. X-954	(YYY)	0.471277E-02	0.304806E 02
COMP. Z-1	(ZZZ)	0.776962E-05	0.502513E-01
STREAM 6, FLOW	0.274112E 05 LBS. PER HOUR,	999.5 F DEG.,	
444.4 PSIA,	0.255566E 08 BTU PER HR.		
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.658976E-01	0.180633E 04

TABLE XXIX (continued)

COMP. X-2000	(XXX)	0.804689E-01	0.220575E 04
COMP. X-427	(YYY)	0.853510E 00	0.233957E 05
COMP. X-954	(YYY)	0.123553E-03	0.338673E 01
COMP. Z-1	(ZZZ)	0.	0.
STREAM 7, FLOW 0.298981E 05 LBS. PER HOUR, 1013.3 F DEG.,			
470.4 PSIA, 0.286860E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.671291E-02	0.200703E 03
COMP. X-2000	(XXX)	0.491836E-02	0.147050E 03
COMP. X-427	(YYY)	0.978142E 00	0.292446E 05
COMP. X-954	(YYY)	0.101948E-01	0.304806E 03
COMP. Z-1	(ZZZ)	0.319342E-04	0.954774E 00
STREAM 8, FLOW 0.140627E 05 LBS. PER HOUR, 1014.5 F DEG.,			
441.9 PSIA, 0.135521E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.	0.
COMP. X-2000	(XXX)	0.156851E-02	0.220575E 02
COMP. X-427	(YYY)	0.998203E 00	0.140374E 05
COMP. X-954	(YYY)	0.228789E-03	0.321740E 01
COMP. Z-1	(ZZZ)	0.	0.
STREAM 9, FLOW 0.133485E 05 LBS. PER HOUR, 996.4 F DEG.,			
434.4 PSIA, 0.121670E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.135321E 00	0.180633E 04
COMP. X-2000	(XXX)	0.163591E 00	0.218369E 04
COMP. X-427	(YYY)	0.701075E 00	0.935828E 04
COMP. X-954	(YYY)	0.126858E-04	0.169337E 00
COMP. Z-1	(ZZZ)	0.	0.
STREAM 10, FLOW 0.987322E 04 LBS. PER HOUR, 1016.4 F DEG.,			
433.9 PSIA, 0.945045E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.	0.
COMP. X-2000	(XXX)	0.165880E 00	0.163777E 04
COMP. X-427	(YYY)	0.834103E 00	0.823529E 04
COMP. X-954	(YYY)	0.169796E-04	0.167643E 00
COMP. Z-1	(ZZZ)	0.	0.
STREAM 11, FLOW 0.347525E 04 LBS. PER HOUR, 987.4 F DEG.,			
412.4 PSIA, 0.287632E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.519770E 00	0.180633E 04
COMP. X-2000	(XXX)	0.157089E 00	0.545922E 03
COMP. X-427	(YYY)	0.323140E 00	0.112299E 04
COMP. X-954	(YYY)	0.487265E-06	0.169337E-02
COMP. Z-1	(ZZZ)	0.	0.
STREAM 12, FLOW 0.538341E 05 LBS. PER HOUR, 998.5 F DEG.,			

TABLE XXIX (continued)

446.3 PSIA, 0.508886E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.372819E-02	0.200703E 03
COMP. X-2000	(XXX)	0.335638E-01	0.180687E 04
COMP. X-427	(YYY)	0.956965E 00	0.515173E 05
COMP. X-954	(YYY)	0.572483E-02	0.308191E 03
COMP. Z-1	(ZZZ)	0.177355E-04	0.954774E 00
STREAM 13, FLOW 0.347525E 04 LBS. PER HOUR, 1190.0 F DEG.,			
392.4 PSIA, 0.346632E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.519770E 00	0.180633E 04
COMP. X-2000	(XXX)	0.157089E 00	0.545922E 03
COMP. X-427	(YYY)	0.323140E 00	0.112299E 04
COMP. X-954	(YYY)	0.487265E-06	0.169337E-02
COMP. Z-1	(ZZZ)	0.	0.
STREAM 14, FLOW 0.152932E 04 LBS. PER HOUR, 1227.0 F DEG.,			
391.4 PSIA, 0.175081E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.	0.
COMP. X-2000	(XXX)	0.339122E 00	0.518626E 03
COMP. X-427	(YYY)	0.660877E 00	0.101069E 04
COMP. X-954	(YYY)	0.110727E-05	0.169337E-02
COMP. Z-1	(ZZZ)	0.	0.
STREAM 15, FLOW 0.536800E 05 LBS. PER HOUR, 967.0 F DEG.,			
914.7 PSIA, 0.489262E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.186289E-01	0.100000E 04
COMP. X-2000	(XXX)	0.372578E-01	0.200000E 04
COMP. X-427	(YYY)	0.931446E 00	0.500000E 05
COMP. X-954	(YYY)	0.124814E-01	0.670000E 03
COMP. Z-1	(ZZZ)	0.186289E-03	0.100000E 02
STREAM 16, FLOW 0.210000E 04 LBS. PER HOUR, 872.0 F DEG.,			
342.2 PSIA, 0.173964E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.	0.
COMP. X-2000	(XXX)	0.	0.
COMP. X-427	(YYY)	0.100000E 01	0.210000E 04
COMP. X-954	(YYY)	0.	0.
COMP. Z-1	(ZZZ)	0.	0.
STREAM 17, FLOW 0.538341E 05 LBS. PER HOUR, 986.9 F DEG.,			
442.3 PSIA, 0.502986E 08 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.372819E-02	0.200703E 03
COMP. X-2000	(XXX)	0.335638E-01	0.180687E 04
COMP. X-427	(YYY)	0.956965E 00	0.515173E 05

TABLE XXIX (continued)

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COMP. X-954	(YYY)	0.572483E-02	0.308191E 03
COMP. Z-1	(ZZZ)	0.177355E-04	0.954774E 00
STREAM 18. FLOW 0.194593E 04 LBS. PER HOUR, 1181.8 F DEG.,			
361.4 PSIA, 0.175612E 07 BTU PER HR.			
MASS FRACTION STREAM COMPOSITIONS AND COMPONENT FLOW RATES			
COMP. X-1000	(III)	0.928263E 00	0.180633E 04
COMP. X-2000	(XXX)	0.140273E-01	0.272961E 02
COMP. X-427	(YYY)	0.577100E-01	0.112299E 03
COMP. X-954	(YYY)	0.	0.
COMP. Z-1	(ZZZ)	0.	0.
HEAT BALANCE ON EQUIPMENT NO. 1 WAS 0. BTU			
HEAT BALANCE ON EQUIPMENT NO. 2 WAS -0.10000000E 04 BTU			
HEAT BALANCE ON EQUIPMENT NO. 3 WAS 0.39358500E 06 BTU			
HEAT BALANCE ON EQUIPMENT NO. 4 WAS -0.10000000E 05 BTU			
HEAT BALANCE ON EQUIPMENT NO. 5 WAS 0.16251650E 06 BTU			
HEAT BALANCE ON EQUIPMENT NO. 6 WAS 0.15973662E 06 BTU			
HEAT BALANCE ON EQUIPMENT NO. 7 WAS -0.79999999E 06 BTU			
HEAT BALANCE ON EQUIPMENT NO. 8 WAS 0.59000000E 06 BTU			
HEAT BALANCE ON EQUIPMENT NO. 9 WAS 0.40611000E 05 BTU			
COMPONENT		TOTAL IN	TOTAL OUT
COMP. X-1000	(III)	0.100000E 04	0.200703E 04
COMP. PER CENT CHANGE 1677.999999			
COMP. X-2000	(XXX)	0.200000E 04	0.183417E 04
COMP. PER CENT CHANGE -1.4750000			
COMP. X-427	(YYY)	0.521000E 05	0.516296E 05
COMP. PER CENT CHANGE -0.149700			
COMP. X-954	(YYY)	0.670000E 03	0.3081 1E 03
COMP. PER CENT CHANGE -8.955200			
COMP. Z-1	(ZZZ)	0.100000E 02	0.954774E 00
COMP. PER CENT CHANGE -0.030000			
ENTIRE SYSTEM BALANCE		0.557800E 05	0.557800E 05
PROCESS ERROR		0.000500 PCT.	

VITA

Landon Nelson Kenny was born on January 2, 1942 in Bristol, Virginia. After completing grammar and high school education in Kingsport, Tennessee, the author entered the University of Tennessee in September of 1959. During the next five years he completed the requirements for a B. S. degree in Chemical Engineering and participated in the Cooperative Engineering program with Tennessee Eastman Company. After an additional summer of employment with Tennessee Eastman, he entered the Graduate School of the University of Tennessee with the goal in mind of obtaining a Master of Science degree in Chemical Engineering.

The author has accepted a position in the Engineering Division of Tennessee Eastman Company, and may be reached through this firm for consultation concerning this thesis, if the need shall arise.