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Packed column simulation

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PACKED COLUMN SIMULATION

BY

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ABSTRACT

The most difficult and time consuming aspect of the design of packed columns is the hydraulic part. If the designer wants to try many different conditions, many repetitive calculations will have to be performed. Also, some inaccuracy is incurred when trying to use the U.S. Stoneware curves. The graphs are hard to read and almost impossible to interpolate between the parametric lines. The purpose of the program is to give a more accurate calculation by using equations for the pressure drop lines, interpolating between them and correcting for gas density for each foot of packing. The program also allows changes in gas and liquid flow rates, gas density, packing type and size, bed height and column diameter which makes for easy comparison between many proposed columns.

Given the gas and liquid flow rates, gas and liquid densities, liquid viscosity, column pressure and temperature, type of packing, and whether the system is foaming or nonfoaming, the program will will develop the optimum column design based on the characteristics and restrictions of the program. The program will specify packing size, the maximum allowable bed height, total and incremental pressure

drop through the packing, superficial vapor velocity and percent of flooding. For each foot of packed height it will also interpolate between the pressure drop lines and correct for the effect of pressure on the gas density.

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INTRODUCTION

In almost all of our chemical processes today there is some area involving either absorption, stripping, scrubbing, distillation or extraction.

A common unit used in these operations is the packed tower. The usual purpose of the tower is to bring into contact a gas stream with a liquid stream. Almost all towers use counter current flow, the liquid entering the top, where it is distributed over the packing by some kind of distributor, and the gas enters the base of the column.

Packed columns lend themselves well to (a) a higher vapor-low liquid loading or low-vapor high liquid loading service; (b) where highly corrosive materials are to be handled; (c) where harmful contamination from metals might be encountered, such as in food and drug materials; and (d) where a small size would make the design of conventional fractionating plates difficult and the construction would be relatively more expensive.

Since the packing material (ceramic substances, porcelain, glass, clay tile, and carbon) is essentially inert, one of the most important applications is in the area of handling corrosive materials.

The most widely used design criteria used are those of the Norton Company, formerly U. S. Stoneware. There have been some modifications made with their data presented in "Design Information for Packed Towers", Bulletin DC-10, 1967. Most of these are in the packing factors listed. Some packing factors have been added where there are none and some have been corrected for the values $X=(L/G)(\rho_G/\rho_L)^{\frac{1}{2}}$. These may be seen in the Appendix.

Packed towers will be discussed in general in the following chapter. The method of operation, types of packing, and advantages to each, pressure drop and flooding will be discussed. After the basics have been discussed, the method of hand calculation, and computer calculation will be discussed.

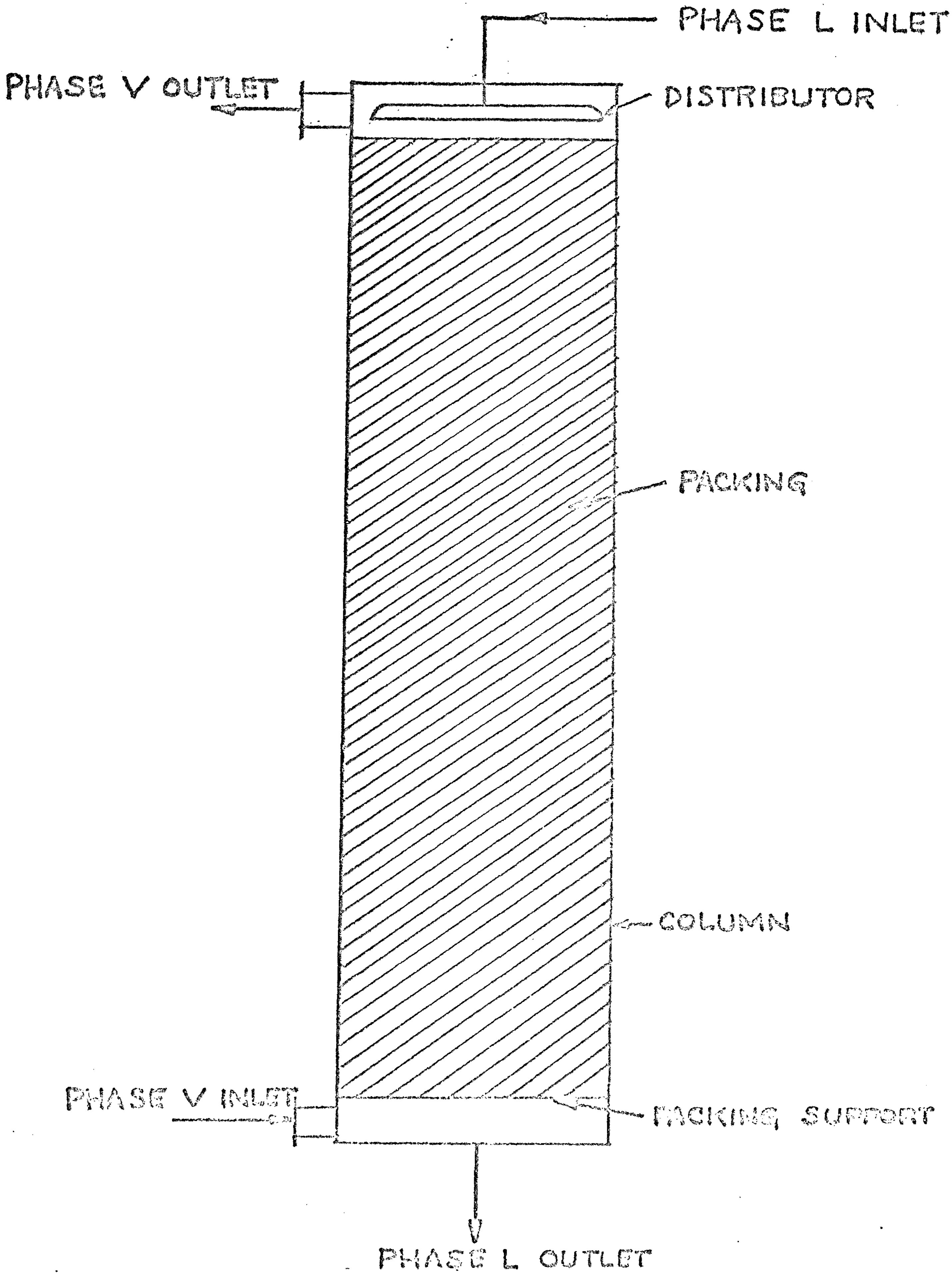
METHOD OF OPERATION OF A PACKED COLUMN

Faust[1] reference gives an excellent description of the way in which a packed column works. See Figure 1.

> Phase L enters the top of the column and is distributed over the surface of the packing either by nozzles or distributor plates. In most of the mass-transfer rate operations, phase L will be liquid. Thus the liquid, upon good initial distribution, will flow down through the packing by tortuous routes, thereby exposing a large surface area for contacting with the rising V phase. The V phase will enter the bottom of the tower and rise upward through a similar path. The V phase for absorption and distillation is a gas or vapor, and in extraction is a liquid.

Packed towers like all other phase contacting equipment, have limitations in their capacity to handle vapor and liquid loads. In distillation, the ratio of vapor and liquid is fixed by the reflux ratio. The operating limits, therefore, lie between the minimum reflux ratio and total reflux ratio and total reflux. For a given distillate rate the actual quantities of

Figure 1


PHASE L INLET
PHASE V OUTLET
DISTRIBUTOR
PACKING
COLUMN
PHASE V INLET
PACKING SUPPORT
PHASE L OUTLET

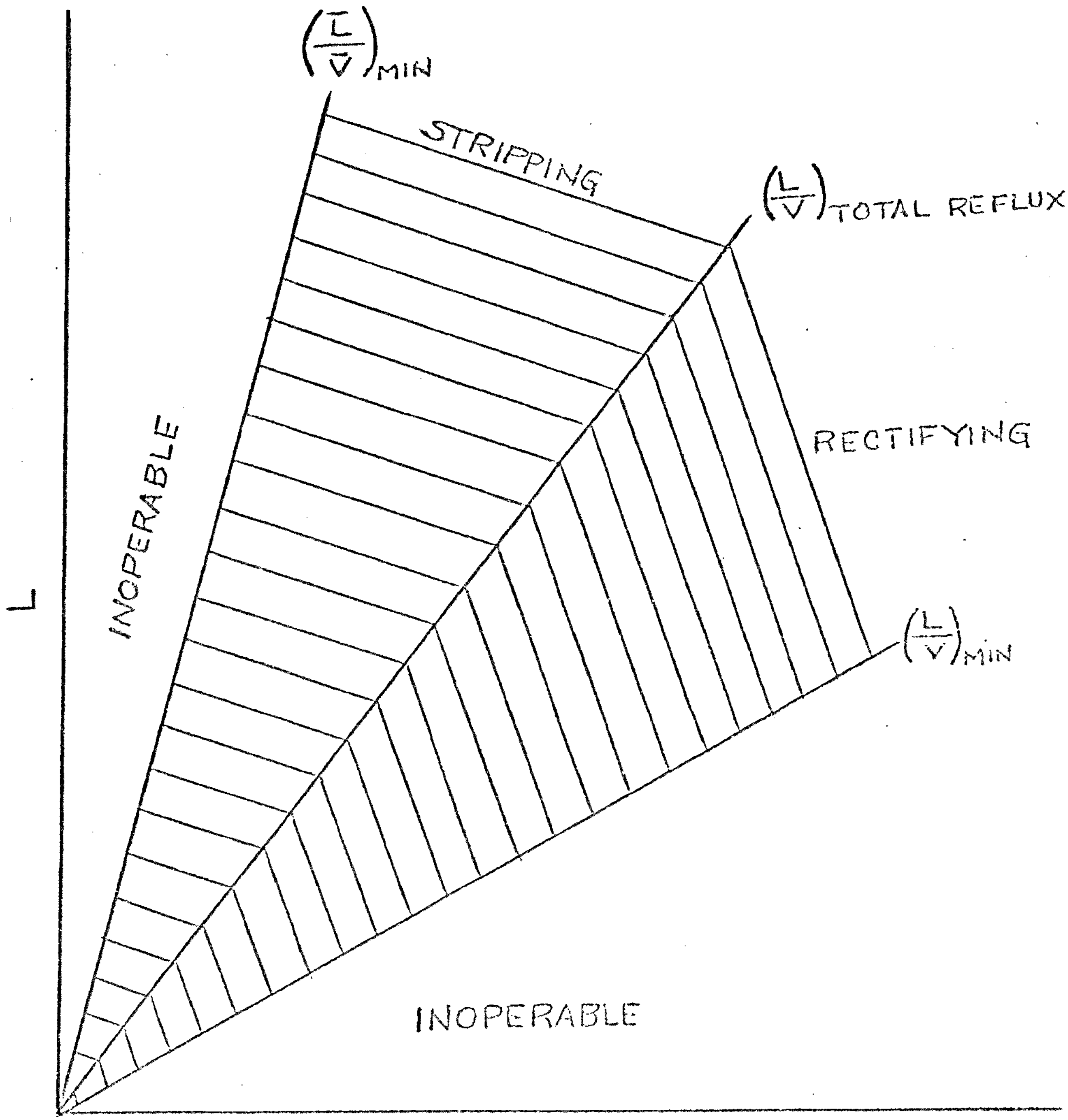
vapor and liquid are fixed in relation to the minimum or total reflux. The limitations are based on product specifications.

For a given column and packing, for a given system and separation, the limits may be shown in Figure 2.

In addition to the operating limits imposed by separation of the desired components, in terms of interrelated liquid and vapor quantities, there are other limits to capacity which must be realized. With high liquid and vapor rates the column will flood. When this happens, the liquid fills the column occupying the flow spaces between the packing. With low liquid and gas rates, or both, there is insufficient flow to cover the packing with liquid, and bypassing of liquid and vapor takes place with a very low efficiency of mass transfer. Including these limits Figure 3 shows the maximum and minimum operating range of any packed column.

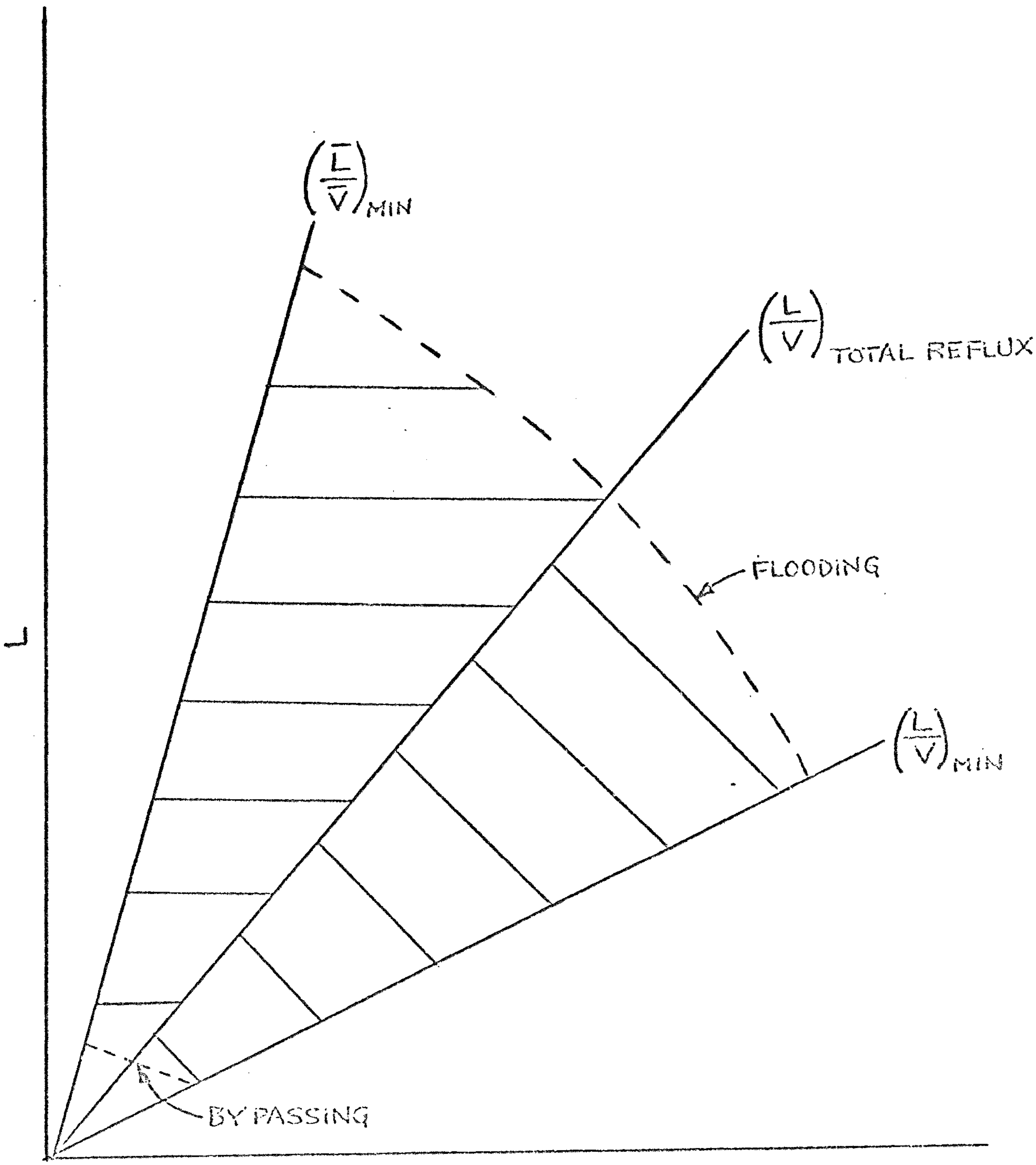
There are still further capacity limits imposed by poor efficiency of contact at low liquid and vapor rates and by excessive pressure drop at the high rates of flow. When these are plotted on a performance chart, the area A indicated on Figure 4 is the performance area.

Figure 2



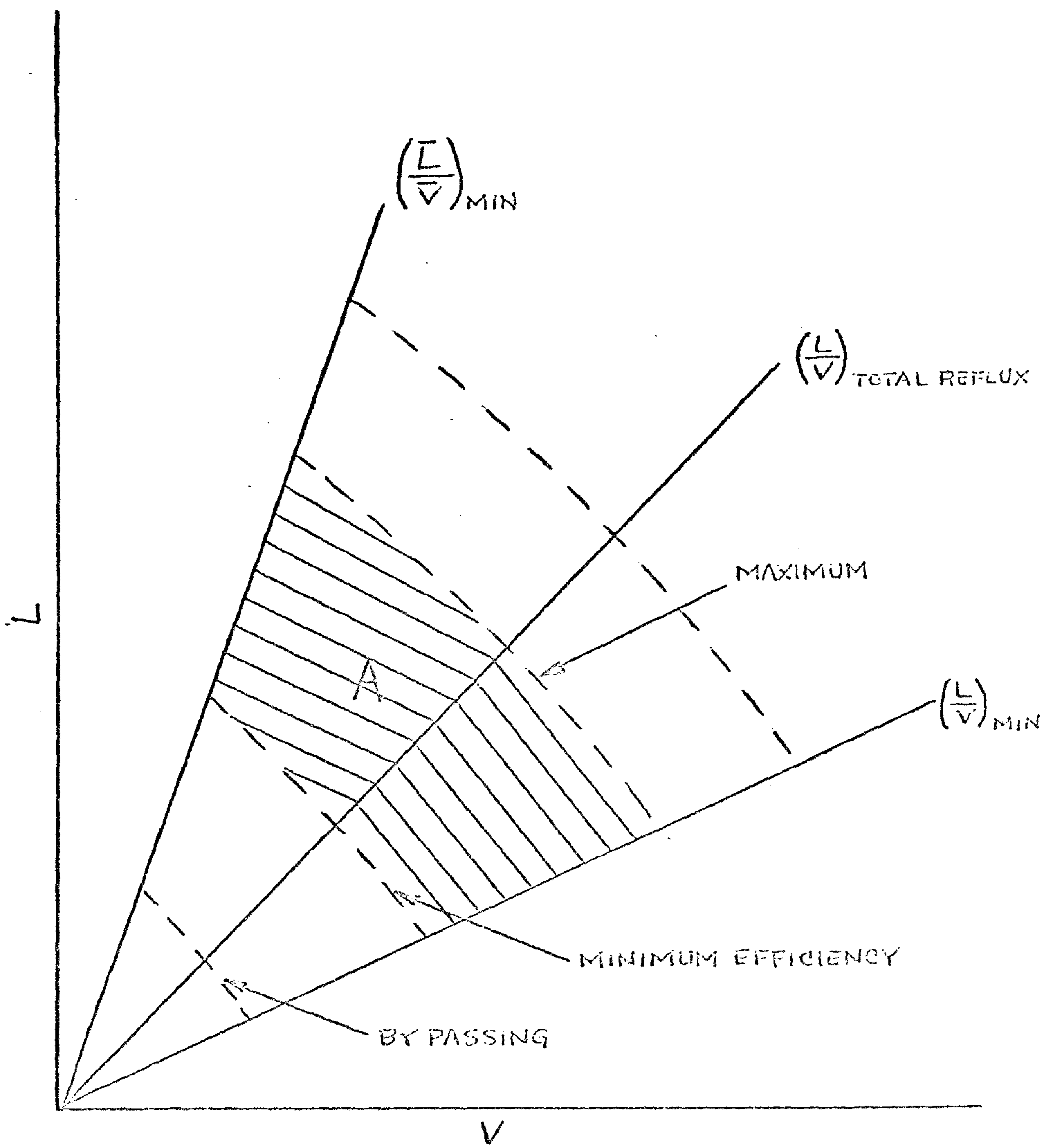
LIMITS OF OPERABILITY SHOWN BY REFLUX RATIO

Figure 3



LIMITS OF OPERABILITY BASED ON FLOODING AND BYPASSING

Figure 4



PERFORMANCE CHART FOR PACKED COLUMNS

STEPWISE PROCEDURE FOR DESIGNING A PACKED COLUMN

1. There are many methods which are acceptable in the design of a packed column. The most widely used, however, is that of U. S. Stoneware. Since their packing is the most widely used at present I have decided to use their method of hand calculations, packing factors, etc.

2. The following procedure is that which is outlined in Bulletin DC-10, 1967 "Design Information for Packed Towers", by the U. S. Stoneware Corporation.

3. Calculate the value of X, the abscissa on Figure 5 of the U. S. Stoneware pressure drop graph.

$$X = \frac{L}{G}\left(\frac{\rho_G}{\rho_L - \rho_G}\right)^{0.5} \qquad (1)$$

where: L = liquid flow rate, #/hr.

G = gas flow rate, #/hr.

ρ_G = gas density at the top of the column, #/cu. ft.

ρ_L = liquid density, #/cu. ft.

If X = 0.5 or less, go to the pressure drop line of P = 0.75.

X = between 0.5 and 3.75, go to P = 0.50

X = is greater than 3.75, go to P = 0.25

4. Calculate the vapor rate from the equation on the ordinate of the graph.

$$G = \left(\frac{Y \rho_G \rho_L g_c}{F \psi \mu^n} \right)^{0.5} \qquad (2)$$

where: G = vapor rate, #/hr sq. ft. (for this packing size)

Y = ordinate on Figure 5

gc= 32.2

$\psi = \frac{62.4}{\rho_L}$

ρ_g = gas density at the top of the column, #/cu. ft.

ρ_L = liquid density, #/cu. ft.

F = packing factor (see Table 1)

μ = viscosity of liquid in centipoise

As a starting point, assume an F factor for a 1" packing size.

If F is less than 150, $n = 0.1$

F is greater than 150, $n = 0.2$

5. Calculate a rough column diameter:

$$D = 1.13 \left(\frac{G' \text{(Acutal Rate in \#/Hr)}}{G \text{ (From Step 2)}} \right)^{0.5} \qquad (3)$$

6. Calculate a packing size and substitute for the value assumed above:

Using Raschig Rings: Packing size = D/30

Saddles: Packing size = D/15

Pall Rings: Packing size $\leq$ D/10 but $\geq$ D/15

7. Obtain a new value for G, using the corrected packing factor, and recalculate the column diameter.

8. Calculate the actual velocity (based on conditions at top of column):

$$V = \frac{G}{3600 \rho_G} \qquad (4)$$

9. Calculate the flooding velocity:

Repeat the above procedure using the flooding line (the 1.5" line for Raschig Rings) and calculate the value of G_F at flooding.

$$V = \frac{G_F}{3600 \rho_G} \qquad (5)$$

where: V_F = the flooding velocity, FEET/SEC.

10. Calculate the percent flooding:

$$\% \text{ Flooding} = \frac{V}{V_F} \times 100 \qquad (6)$$

Some types of packing flood at a higher pressure drop than others, thus a Pall Ring or a Saddle packed bed will ordinarily not flood below a pressure drop of 2" H_2O/ft. A Raschig Ring packed bed will flood at a pressure drop of $1\frac{1}{2}$" H_2O/ft.

or less. If a foaming system is being considered, the column should be operated at less than 50% of the calculated flooding point.

11. Establish the maximum allowable bed height:

For Raschig Rings: 2.5 to 3 Diameters

Saddles: 5 to 8 Diameters

Pall Rings: 5 to 10 Diameters

Bed heights should never exceed 20 feet.

12. Calculate the total bed pressure drop:

For columns operating at or above atmospheric pressures, the total pressure drop for a given column can be obtained by multiplying the pressure loss per foot of packing by the total bed height. The pressure drop for columns operating at subatmospheric pressures must be established by calculating and summing the individual pressure drops across incremental sections of the bed as outlined below.

a) Starting at the top, calculate the pressure drop for the first increment of packing and add it to the column head pressure.

b) Correct the gas density for the newly calculated pressure below the first increment.

c) Re-evaluate X and Y get a new ΔP from the graph.

d) Establish the pressure at the bottom of the second increment by additing the newly calculated ΔP to the pressure at the top of this increment.

e) Continue the pressure drop calculations for each increment of column height until the pressure at the bottom of the bed has been established.

f) Establish the total bed pressure drop by subtracting the top pressure from the calculated bottom pressure.

COMPUTER CALCULATION METHOD

The method of calculation described in the previous chapter may be used for individual cases but this method is far from adequate for optimization work. If limits such as bed height or pressure drop are imposed, one may easily change the column height, diameter, etc. to meet these specifications. As was stated before, many columns may be calculated in a relatively short time. The average time per calculation is less than one minute on the IBM 1130. It is much shorter on the IBM 360 and perhaps a little longer on the G.E. Timeshare. This program has been used on all three systems. Although the 1130 is the slowest, it is also the most convenient because the sense switches are the easiest and fastest method to make a change in the column conditions. For example, if you wish to change the column diameter, you flip up switch 2 and type in the new column diameter (See Program Options).

The calculation method is generally based on that used by the Norton Company (formerly U. S. Stoneware), as outlined in Bulletin DC-10 titled "Design Information for Packed Towers," 1967. The data contained in this manual was developed by Eckert, Frote, and Walter.

The program consists of a main program, sub-programs, and data files. The data fed into the programs are: liquid flow rate (#/hr.), gas flow rate (#/hr.), liquid and gas densities (#/ft.^{3}), liquid viscosity (centipoise), operating temperature (degrees Kelvin), operating pressure (pounds per square inch), type of packing, and whether it is a foaming or non-foaming system.

The equations of the pressure drop curves were found by multiple regression analysis. The equations included in the program are those in the Stoneware Bulletin plus others. The values of the pressure drops included are Delta P = 0.05, 0.07, 0.10, 0.15, 0.25, 0.35, 0.50, 0.75, 1.00, 1.50, in H_2O/ft. and the flooding line. The equations may be seen in Table 2. They are plotted on Figure 5. The additional curves plotted are for the values of Delta P = 0.07, 0.15, 0.35, and 0.75, in H_2O/ft. These additions make for greater ease of interpolation and greater accuracy in the values for the pressure drop. The main program, which will be discussed later, executes the main calculations. The sub-programs consist of one for the options after the optimum column is obtained, some logarithmic transformations, and interpolation. The data files include packing factors, packing sizes, round-off values for the column diameter and pressure drop values.

The method of calculation will now be discussed:

1. The values of the gas and liquid flow rates, gas and liquid densities, the temperature, liquid viscosity, pressure, foaming or non-foaming, and packing type are read from the data card and printed out.

2. An abscissa value is assigned on the data files for the packing type. (See data file arrangement)

3. The value of X, the abscissa on Figure 5 is calculated from the following equation:

   X = (WLF/WGR) * (RHOG/RHOL) * * 0.5 (7)

   If X = 0:5, an initial pressure drop line of 0.75 inches of H_2O/ft. is chosen.
   If X = 3.75, an initial pressure drop line of 0.05 inches of H_2O/ft. is chosen.
   If X = 3.75, an initial pressure drop line of 0.25 inches of H_2O/ft. is chosen.

4. A value of Y is calculated from the X value on the chosen equation from:

$$Y = EXP\ (C_1 + C_2 * XLN + C_3\ XLN * * 2 + C_4 * XLN * * 3) \quad (8)$$

5. An initial packing factor is determined. A 1" packing size is used to start.

6. Depending on the packing factor, a value for the exponent is determined.

   If $F \leqq 150$ $\quad \mu^n = .1$

   $F > 150$ $\quad \mu^n = .2$

7. A crude value of G is calculated:

$$G = SQRT\ (Y * RHOG * RHOL * GC)/(F * PSI * VISCL * * UM) \quad (9)$$

8. A crude value for the diameter is calculated:

$$DIAM = 1.13 * (WGR/G) * * 0.5 \quad (10)$$

   The value calculated is rounded up to the nearest 2" if the column diameter is less than 3 feet and 6" if the column diameter is more than 3 feet.

9. Having obtained a diameter, a packing size is calculated.

   If the type of packing is

   Raschig Rings: PAKSZ = DIAM/30

   Saddles: PAKSZ = DIAM/15

   Pall Rings: PAKSZ = DIAM/12

10. A new packing factor is obtained and G and the diameter are recalculated.

11. The flooding conditions at the calculated value of X are now determined.

$$VF = EXP(C_1 + C_2 * XLN + C_3 * XLN * * 2 + C_4 * XLN * * 3) \quad (11)$$

$$GF = SQRT\ (YF * RHOG * RHOL * GC)/(F * PSI * VISCL * UM) \quad (12)$$

The cross-sectional area based on the diameter is given by:

$$AREA = 3.1416 * (DIAM/2) * * 2 \quad (13)$$

$$VF = GF/(3600 * RHOG) \quad (14)$$

$$V = (WGR/3600)/(RHOG * AREA) \quad (15)$$

$$PERFL = (V/VF) * 100. \quad (16)$$

Where: YF = the value of the ordinate at the flooding conditions.

GF = the value of G at the flooding conditions.

V = the actual vapor velocity.

PERFL = the percent of flooding.

12. A bed height is now calculated based on the packing type and column diameter.

If the bed height is less than 20 feet, the bed height is rounded up to the next foot and printed out.

If the bed height is more than 20 feet, the bed height is set equal to 20 feet and printed out.

13. The program now goes through a series of trial and error calculations until the value of Y at the given X value falls between two Y values obtained from two pressure drop equations. A linear interpolation is done to get a value for the pressure drop in the first foot of packing.

ALPHA = (Y - YX)/(PYX - YX) (17)

DELTP = DPRES (M - 1) + ALPHA * (DPRES(M)
DPRES(M - 1)) (18)

The pressure drop calculated for this interval is then added to the original pressure at the top of the column.

The gas density is then corrected for the change in pressure and a new Y value is calculated. A new pressure drop is calculated and so on for each foot of packing, until the sum of the feet of packing is equal to the bed height. The absolute values for the pressures at each foot are printed out as is the total pressure drop across the column.

14. A final vapor velocity and percent of flooding is calculated and printed out.

$$V = (WGR/3600)/(RHOGA * AREA) \qquad (19)$$

$$PERFL = (G/GF) * 100. \qquad (20)$$

15. The program now goes into the option program which is discussed in the next chapter.

PROGRAM OPTIONS

After the final printout and before termination of the program, the following options are available to the designer:

1. Rerun the program using a different column diameter.
2. Rerun the program using a different bed height.
3. Rerun the program using a different type of packing.
4. Rerun the program using a different packing size.
5. Rerun the program using a different gas or liquid flow rate.
6. Rerun the program using a different column pressure and temperature.

If any change made in the optional portion of the program gives performance values above the flooding line, the program will suggest a change of the column diameter or packing size. If the calculated be height exceeds 20 feet, the printout from the main program will limit the permissable height to 20 feet. If a bed height greater than the macimum allowable bed height is obtained, the program will offer the following choices:

1. The designer may use this bed height regardless of the limit.
2. The designer may use the maximum allowable bed height.
3. The designer may type in any bed height he wishes.

PROGRAM CHARACTERISTICS AND RESTRICTIONS

The following section suggests the characteristics and restrictions set up in the program. Any of these may be altered by a few changes in the program. These characteristics are suggested by the U. S. Stoneware and the writer's design experience.

1. An arbitrary limit of 20 feet for the bed height has been set. If, on the basis of the packing size and column diameter a bed height greater than 20 feet is calculated, the program will type out that the limit has been exceeded. It has been suggested by the U. S. Stoneware Corporation that 20 feet be the limit. If more feet of packing is required, it should be broken down into smaller beds. For example, if 45 feet of packing are required, it may be broken down into 3 - 15 foot beds, 60 feet 3 - 20 foot beds, etc.

2. Packing sizes are limited to 1/4, 3/8, 1/2, 3/4, 1, 1 1/2, 2, and 3 inches. An additional type of packing (see #3) or packing size may be added to the data files. All that is needed for the addition is the packing factor. An even easier way is to find a packing size listed in the

appendix which has the packing factor for the desired packing. This eliminates changing the data files.

3. Types of packings are restricted to ceramic or plastic Intalox saddles, ceramic Raschig Rings, metal and plastic Pall Rings. Any additional types of packing may also be used with some changes in the data files (see #2).

4. Calculated diameters below 3 feet are rounded up by 2 inches and those equal to or above 3 feet are founded up by 6 inches. Example: (4.15 feet is rounded to 4 feet 6 inches).

5. Packing sizes are calculated as follows. If the type of packing is:

   Raschig Rings, the packing size is equal to the diameter of the column (in.) divided by 30.
   Saddles, the packing size is equal to the diameter of the column (in.) divided by 15.
   Pall Rings, the packing size is equal to the diameter of the column (in.) divided by 12.

   They are rounded down to the next smallest size.

6. The bed height is calculated as follows. If the type of packing is:

Raschig Rings, the bed height is equal to 2.6 diameters.

Saddles, the bed height is equal to 6.0 diameters.

Pall Rings, the bed height is equal to 7.0 diameters.

The bed height is rounded up to the next largest foot.

7. An option change in diameter does not affect the packing size, but may change the bed height.

COMPARISON OF EQUATIONS OBTAINED FROM REGRESSION ANALYSIS

VS.

ESTABLISHED VALUES FROM U. S. STONEWARE

Equation for the parametric lines on Figure 5 were obtained by regression analysis. The deviations of these equations may be seen in Table 2. The regression analysis program gave equations which were all within 2%.

Values at 6 different values of X were obtained for each curve for comparison purposes. The comparison's may be seen on the following pages. Due to the very close values of the curves and equations, a graph of any kind proved to be inadequate for comparison. A table comparing the values proved to be more effective.

Comparison of established values of U. S. Stoneware curves vs. values calculated from equations obtained by regression analysis.

FLOODING LINE

X	Y Stoneware	Y Equation
0.01	0.208	0.208
0.04	0.195	0.193
0.20	0.090	0.091
1.0	0.022	0.022

FLOODING LINE

(CON'T)

X	Y Stoneware	Y Equation
4.0	0.004	0.004
10.0	0.001	0.001

1.5 in. H_2O/ft. Packing

X	Y Stoneware	Y Equation
0.01	0.137	0.139
0.04	0.087	0.092
0.20	0.054	0.054
1.0	0.018	0.018
4.0	NA	0.003
10.0	NA	NR

1.0 in. H_2O/ft. Packing

X	Y Stoneware	Y Equation
0.01	0.107	0.107
0.04	0.087	0.092
0.20	0.054	0.054
1.0	0.018	0.018
4.0	NA	0.003
10.0	NA	NR

X	Y Stoneware	Y Equation
	0.75 in. H_2O/ft. Packing	
0.01	0.084	0.087
0.04	0.073	0.073
0.20	0.047	0.047
1.0	0.015	0.015
4.0	NA	0.002
10.0	NA	NR
	0.50 in. H_2O/ft. Packing	
0.01	0.062	0.061
0.04	0.058	0.058
0.20	0.040	0.039
1.0	0.013	0.013
4.0	0.002	0.002
10.0	NA	NR
	0.35 in. H_2O/ft. Packing	
0.01	0.051	0.048
0.04	0.043	0.043
0.20	0.032	0.028
1.0	0.010	0.010
4.0	NA	0.002
10.0	NA	NR

X	Y Stoneware	Y Equation
	0.25 in. H_2O/ft. Packing	
0.01	0.038	0.038
0.04	0.032	0.033
0.20	0.021	0.020
1.0	0.007	0.007
4.0	0.002	0.002
10.0	NA	NR
	0.15 in. H_2O/ft. Packing	
0.01	0.025	0.025
0.04	0.022	0.022
0.20	0.013	0.012
1.0	0.005	0.005
4.0	NA	0.001
10.0	NA	NR
	0.10 in. H_2O/ft. Packing	
0.01	0.018	0.018
0.04	0.016	0.016
0.20	0.010	0.010
1.0	0.004	0.004
4.0	0.001	0.001
10.0	NA	NR

X		
	0.07 in. H_2O/ft. Packing	
0.01	0.011	0.011
0.04	0.010	0.010
0.20	0.007	0.007
1.0	0.003	0.003
4.0	NA	NR
10.0	NA	NR
	0.05 in. H_2O/ft. Packing	
0.01	0.006	0.006
0.04	0.005	0.005
0.20	0.004	0.004
1.0	0.002	0.002
4.0	NA	NR
10.0	NA	NR

OPERATING INSTRUCTIONS

If the IBM 1130 or 360 is used, only one data card is needed. If the G.E. Timeshare is used, the input information is transmitted to the computer by a series of questions and answers.

An important step for a successful design is the proper setup data card. The following form should be used when using the 1130:

1)

DATA	UNITS	SPACES	FORMAT
Liquid Flow Rate	Pounds Per Hour	1-10	F10.2
Gas Flow Rate	Pounds Per Hour	11-20	F10.2
Liquid Density	Pounds Per Cubic Ft.	21-27	F 7.3
Gas Density (top of column)	Pound Per Cubic Ft.	28-34	F 7.5
Temperature	Degress Kelvin	35-41	F 7.2
Liquid Viscostiy	Centipoise	42-47	F 6.3
Pressure (top of column)	PSIA	48-53	F 6.2
Non-Foaming	0	54-56	I 3
Foaming	1	54-56	
Packing Type	None	57-59	I 3

The following numbers should be used to represent the respective types of packing:

1. Intalox Saddles - Ceramic
2. Intalox Saddles - Plastic
3. Raschig Rings - Ceramic
4. Raschig Rings - Metal (1/16" Wall)
5. Raschig Rings - Metal (1/32" Wall)
6. Pall Rings - Plastic
7. Pall Fings - Metal

2) Arrange cards in the following manner:

1. // XEQ PKTW 3
2. * Local PKTW, MIRE, JUDI
3. I Files (11, SINTC) (12, SINTO)---
4. * Files (17, PACRM) (IP,---)

3) Execute program.

4) After the typewriter has written out several options, turn on switch 5 plus any other swith for the desired change. Push program "Start" and with the "Keyboard Select" light on, press the "Numeric" button and type in the desired value.

NOMENCLATURE

ABCS	Abscissa value for data file, integer
AREA	Cross sectional area of the tower, $ft.^2$
BEDH	Height of packed bed, ft.
BOTBP	Column pressure at points in the packed bed PSIA
DELTP	Pressure drop, inches H_2O/ft. packing
DIAM	Diameter of tower, ft.
DPRES	Variable refers to data file material
DPH_2O	Total pressure drop, inches of H_2O
F	Packing factor
FOAM	Indicates foaming system
G	Mass flow rate, lb./hr.-$ft.^2$
GF	Mass flow rate at flooding, lb/hr.-$ft.^2$
GC	0.47×10^9 (constant)
NORDI	Ordinate value for data files, integer
PAKSI	Packing size, in.
PERFL	Percent of flooding, %
PRTP	Type of packing, integer
PSIA	Column pressure, PSIA
RHOG	Gas density, at top of column, lb/$ft.^3$
RHOGA	Corrected gas density, lb/$ft.^3$
RHOL	Liquid density, lb/$ft.^3$

SUM	Operating pressure, inches of water
TEMP	Operating temperature, degrees kelvin
UM	Exponent
V	Superficial velocity, ft./sec.
VF	Superficial velocity at flooding, ft./sec.
VISCL	Viscosity of liquid, centipoise
WGR	Gas flow rate, lb./hr.
WLF	Liquid flow rate, lb./hr.

Table 1

SHERWOOD ABCISSA (From Bulletin DC-10, U.S. Stoneware)	Packing Factors		
RSRM 6 14 RASCHIG RINGS, METAL 1/16" WALL	X = 3.75	0.5-3.75	0.5
1/4 - in.	0	0	0
3/8 - in.	0	0	0
1/2 - in.	0	0	0
3/4 - in.	220	220	220
1 - in.	77	122	144
1 1/2 - in.	43	65	85
2 - in.	38	54	71
3 - in.	32	32	32

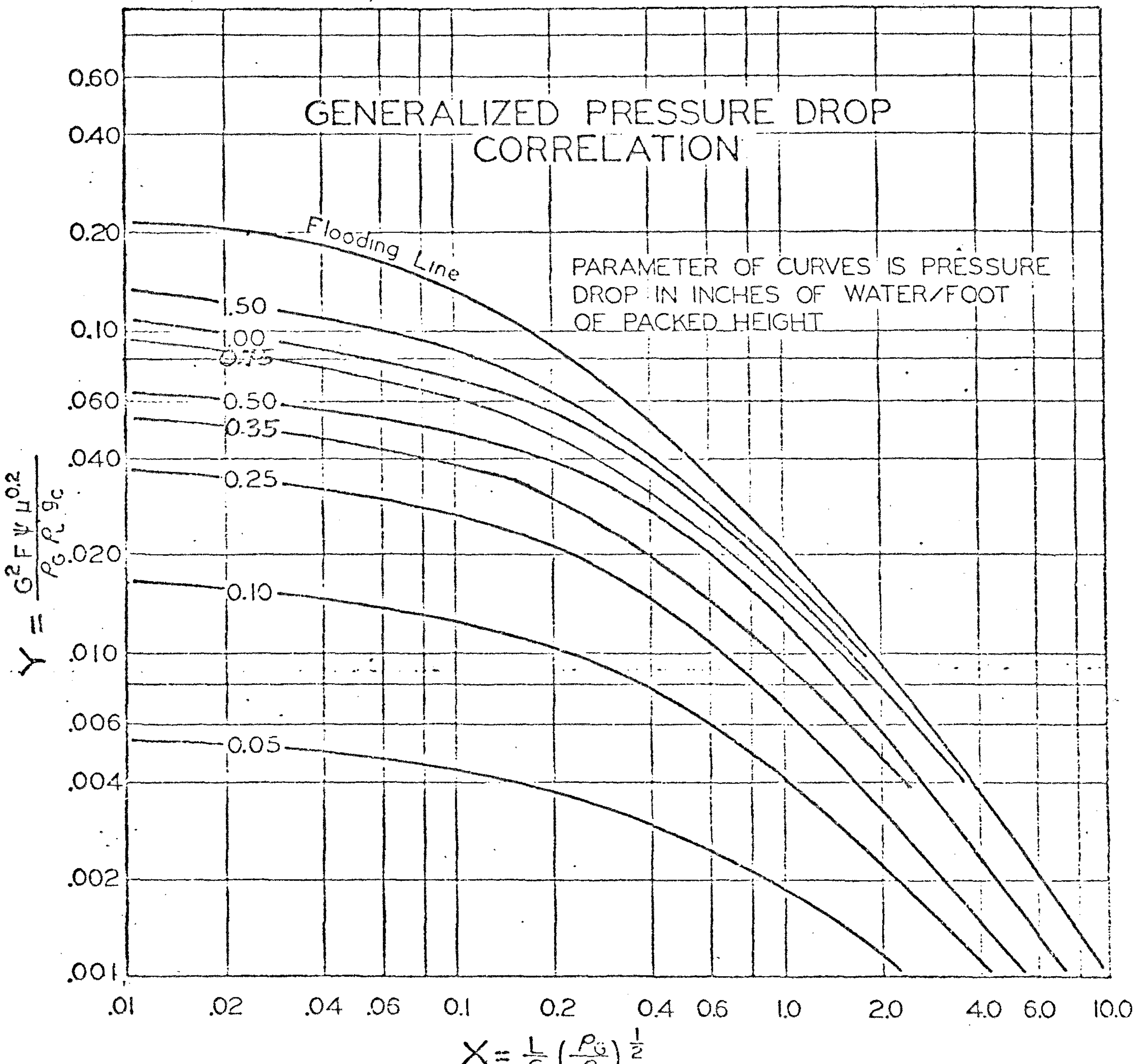
FILE NO. 18 PACKING SIZE D	FILE NO. 19 ROUND OFF VALUES FOR DIAMETER ARRAY L	FILE NO. 20 PRESSURE DROP CURVES ARRAY DPRES
D (1) = .25		
D (2) = .375		
D (3) = .5	L (1) = 2	DPRES(1)=.05
D (4) = .75	L (2) = 4	DPRES(2)=.07
D (5) = 1	L (3) = 6	DPRES(3)=.1
D (6) = 1.5	L (4) = 8	DPRES(4)=.15
D (7) = 2	L (5) = 10	DPRES(5)=.25
D (8) = 3	L (6) = 12	DPRES(6)=.35
		DPRES(7)=.50
		DPRES(8)=.75
		DPRES(9)=1.00
		DPRES(10)=1.50
		DPRES(11)= FLOODING=2

SHERWOOD ABCISSA	Packing Factors		
	X = 3.75	0.5-3.75	0.5
PALRM 17 - PALL RINGS, METAL			
1/4 - in.	0	0	0
3/8 - in.	0	0	0
1/2 - in.	0	0	0
5/8 - in.	70	70	70
1 - in.	42	42	52
1 1/2 - in.	31	36	28
2 - in.	20	25	25
3 - in.	0	0	0
PALRP 16 - PALL RINGS, PLASTIC			
1/4 - in.	0	0	0
3/8 - in.	0	0	0
5/8 - in.	97	97	97
3/4 - in.	0	0	0
1 - in. 0.024 Wall	52	52	52
1 1/2 - in. 0.030 Wall	32	32	32
2 - in. 0.036 Wall	25	25	25
3 - in.	0	0	0
RSRM 3 15 RASCHIG RINGS, METAL 1/32" Wall			
1/4 - in.	0	0	0
3/8 - in.	390	390	390
1/2 - in.	300	300	300
3/4 - in.	170	170	179
1 - in.	115	115	115
1 1/2 - in.	0	0	0
2 - in.	0	0	0
3 - in.	0	0	0

SHERWOOD ABCISSA	Packing Factors		
SINTC 11 - INTALOX, CERAMIC	X = 3.75	0.5-3.75	0.5
1/4 - in.			
3/8 - in.	330	330	330
1/2 - in	200	200	200
3/4 - in.	130	135	145
1 - in.	84	91	98
1 1/2 - in.	39	449	52
2 - in.	31	34	40
3 - in.	20	20	22
SINTP 12 - INTALOX, PLASTIC			
1/4 - in.	0	0	0
3/8 - in.	0	0	0
1/2 - in.	0	0	0
3/4 - in.	0	0	0
1 - in.	32	32	32
1 1/2 - in.	0	0	0
2 - in.	21	21	21
3 - in.	14	14	14
RSRC 13 - RASCHIG RINGS, CERAMIC			
1/4 - in. 1/16 - in. Wall	1600	1600	1600
3/8 - in. 1/16 - in. Wall	1000	1000	1000
1/2 - in. 3/32 - in. Wall	580	580	580
3/4 - in. 3/32 - in. Wall	210	255	255
1 - in. 1/8 - in. Wall	120	155	160
1 1/2 - in. 3/16 - in. Wall	65	95	95
2 - in. 1/4 - in. Wall	50	65	65
3 - in. 3/8 - in. Wall	37	37	37

Curve	Equation
Inches of Water Per Foot of Packing	
Flooding Line	$Y = EXP(-3.827927-1.080819x-.1176425x^2 +.002296566x^3)$
1.50	$Y = EXP(-3.988496-.994090x-.1573365x^2 -.007954698x^3)$
1.00	$Y = EXP(-4.024600-.9219081x-.1583744x^2 -.009222639x^3)$
0.75	$Y = EXP(\ 4.168572-1.007839x-.2231154x^2 -.01959140x^3)$
0.50	$Y = EXP(-4.326525-.9312685x-.1820800x^2 -.01132091x^3)$
0.35	$Y = EXP(-4.624282-.9174872x-.1861755x^2 -.01339159x^3)$
0.25	$Y = EXP(-4.935951-.8675696x-.1522480x^2 -.009138094x^3)$
0.15	$Y = EXP(-5.265190-.8076304x-.1366381x^2 -.007560742x^3)$
0.10	$Y = EXP(-5.485292-.7693485x-.1346535x^2 -.007927142x^3)$
0.07	$Y = EXP(-5.872896-.7226284x-.1429932x^2 -.01049381x^3)$
0.05	$Y = EXP(-6.249128-.6162116x-.1397602x^2 -.01208522x3)$

Figure 5



L = LIQUID RATE, LBS./SEC., SQ. FT.

G = GAS RATE, LBS./SEC., SQ. FT.

ρ_L = LIQUID DENSITY, LBS./CU. FT.

ρ_G = GAS DENSITY, LBS./CU. FT.

F = PACKING FACTOR

μ = VISCOSITY OF LIQUID, CENTIPOISE

ψ = RATIO, $\frac{\text{DENSITY OF WATER}}{\text{DENSITY OF LIQUID}}$

g_c = GRAVITATIONAL CONSTANT = 32.2

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```
// XEQ
      I-TEGERA,C
      DIMENSIONB(3) ,D(8) ,L(6) ,DPRES(11)
      COMMONDIAM,BEDH,IPKTP,PAKSI,C,D,L,DPRES,RHOG,RHOL,WLF,WGR,VISCL,PS
     1IA,IFOAM,GC,PSI,X,Y,G,PERFL,UM,F,XLN,ND,IN,DPH2O,V,A,B,NORDI,IABCS
     2,IBEDH,RHOGA,AREA,CPSIA,K,KI,GF,DF,TEMP1,TEMP2,BEDH1,YONE,LL,IL,ID
     3,IR,IZ
      DEFINEFILE11(8,6,U,IJ) ,12(8,6,U,JI) ,13(8,6,U,IK) ,14(8,6,U,KI) ,
     115(8,6,U,JK) ,16(8,6,U,KJ) ,17(8,6,U,LM) ,18(8,2,U,ML) ,19(6,1,U,M
     2N) ,20(11,2,U,NI)
    5 FORMAT(1H1,40X,'DESIGN INFORMATION FOR PACKED TOWERS',30X,' F W SC
     1HMIDT'///)
      CALL DATSW(5,IS5)
      IF (IS5 - 2) 10,15,15
   10 GOTO(570,600,120,290,160,160,670),C
   15 WRITE(3,5)
   20 FORMAT(2F10.2,F7.3,F7.5,F7.2,F6.3,F6.2,2I3)
      READ(2,20)WLF,WGR,RHOL,RHOG,TEMP1,VISCL,PSIA,IFOAM,IPKTP
      CPSIA = PSIA
   25 FORMAT(' LIQUID FLOW RATE     =',F9.2,2X,' POUNDS PER HOUR'//' GAS
     1FLOW RATE        =',F9.2,2X,' POUNDS PER HOUR'//' GAS DENSITY',9X,
     1'=',F11.4,' POUNDS PER CUBIC FOOT'//' LIQUID DENSITY       =',F9.2,
     12X,' POUNDS PER CUBIC FOOT'//' LIQUID VISCOSITY     =',F9.2,2X,
     1' CENTIPOISE'//' COLUMN PRESSURE      =',F11.4,' PSIA'//' TEMPERATU
     1RE          =',F9.2,2X,' DEGREES KELVIN')
      WRITE(3,25)WLF,WGR,RHOG,RHOL,VISCL,PSIA,TEMP1
   30 FORMAT(1H0,'FOAMING SYSTEM')
   35 FORMAT(1H0,'NON-FOAMING SYSTEM')
   40 FORMAT(' THE BED HEIGHT IS GREATER THAN THE LIMIT OF 20 FEET, THER
     1EFORE TURN ON SWITCH 2 TO TYPE IN A NEW BED HEIGHT.',/,' PUSH STAR
     1T.')
   45 FORMAT(' COLUMN CONDITIONS HAVE CAUSED FLOODING.  THEREFORE INCREA
     1SE THE COLUMN DIAMETER OR PACKING SIZE')
   50 FORMAT(' THERE IF NO PACKING FACTOR LISTED FOR THIS PACKING SIZE A
     1ND TYPE.  THEREFORE TYPE IN A NEW SIZE OR TYPE.')
   55 FORMAT('THE PERCENT OF FLOODING IS EQUAL TO OR GREATER THAN 100,TH
     1EREFORE TURN ON SWITCH 1 TO TYPE IN NEW COLUMN DIAMETER.',/,' PUSH
     1START.')
      DO 60 I=1,8
   60 READ(18'I) D(I)
      DO 65 J=1,6
   65 READ(19'J) L(J)
      DO 70 M=1,11
   70 READ(20'M) DPRES(M)
      IL = 0
      IR = 0
      ID = 0
      IZ = 0
      IF (IFOAM) 80,80,75
   75 WRITE(3,30)
      GOTO 120
   80 WRITE(3,35)
   85 FORMAT(////////' TYPE OF PACKING              CERAMIC OR CARBON INTALO
     1X SADDLES'/)
   90 FORMAT(////////' TYPE OF PACKING              PLASTIC INTALOX SADDLES'
     1/)
   95 FORMAT(////////' TYPE OF PACKING              CERAMIC OR CARBON RASCHI
     1G RINGS'/)
  100 FORMAT(////////' TYPE OF PACKING              1/16 IN. WALL METAL RASC
```

```
     1HIG RINGS'/)
  105 FORMAT(////////' TYPE OF PACKING            1/32 IN. WALL METAL RASC
     1HIG RINGS'/)
  110 FORMAT(////////' TYPE OF PACKING            PLASTIC PALL RINGS'/)
  115 FORMAT(////////' TYPE OF PACKING            METAL PALL RINGS'/)
  120 GOTO(125,130,135,140,145,150,155),IPKTP
  125 WRITE(3,85)
      A = 1
      GOTO 160
  130 WRITE(3,90)
      A = 2
      GOTO 160
  135 WRITE(3,95)
      A = 3
      GOTO 160
  140 WRITE(3,100)
      A = 4
      GOTO 160
  145 WRITE(3,105)
      A = 5
      GOTO 160
  150 WRITE(3,110)
      A = 6
      GOTO 160
  155 WRITE(3,115)
      A = 7
  160 X = (WLF / WGR) * (RHOG / RHOL) * * .5
      IF (X - .5) 165,165,170
  165 XLN = ALOG(X)
      Y = EXP( - .4168572E01 - .1007839E01 * XLN - .2231154E00 * XLN * *
     12 - .1258140E - 01 * XLN * * 3)
      IABCS = 3
      GOTO 185
  170 IF (X - 3.75) 175,175,180
  175 XLN = ALOG(X)
      Y = EXP( - .4326525E01 - .9312685E00 * XLN - .1820800E00 * XLN * *
     12 - .1132091E - 01 * XLN * * 3)
      IABCS = 2
      GOTO 185
  180 XLN = ALOG(X)
      Y = EXP( - .4935951E01 - .8675696E00 * XLN - .1522480E00 * XLN * *
     12 - .9138094E - 02 * XLN * * 3)
      IABCS = 1
  185 GC = .417E09
      YONE = Y
      PSI = 62.4 / RHOL
      NORDI = 5
      GOTO(190,195,200,205,210,215,220),A
  190 READ(11'NORDI) B
      GOTO 225
  195 READ(12'NORDI) B
      GOTO 225
  200 READ(13'NORDI) B
      GOTO 225
  205 READ(14'NORDI) B
      GOTO 225
  210 READ(15'NORDI) B
      GOTO 225
```

```
215 READ(16'NORDI) B
    GOTO 225
220 READ(17'NORDI) B
225 F = B(IABCS)
    IF (F - 150.) 230,230,235
230 UM = .1
    GOTO 240
235 UM = .2
    GOTO 240
240 G = SQRT( (YONE * RHOG * RHOL * GC) / (F * PSI * VISCL * * UM))
    IF (IR) 245,245,280
245 DIAM = 1.13 * (WGR / G) * * .5
250 IF (IPKTP - 2) 255,255,260
255 PAKSZ = DIAM / 15.
    GOTO 275
260 IF (IPKTP - 5) 265,265,270
265 PAKSZ = DIAM / 30.
    GOTO 275
270 PAKSZ = DIAM / 12.
275 PAKSI = PAKSZ * 12.
280 IF (PAKSI - 3.) 290,285,285
285 PAKSI = 3.
    NORDI = 8
    GOTO 340
290 DO 295 I=1,8
    IF (PAKSI - D(I)) 300,300,295
295 CONTINUE
300 IF (IR) 305,305,310
305 IF (ID) 315,315,310
310 D(I) = PAKSI
    NORDI = I
    GOTO 340
315 IF (I - 1) 320,320,325
320 PAKSI = .25
    NORDI = 1
    GOTO 340
325 CALL DATSW(4,IS4)
    IF (IS4 - 2) 330,335,335
330 PAKSI = D(I)
    NORDI = I
    GOTO 340
335 PAKSI = D(I - 1)
    NORDI = (I - 1)
340 GOTO(345,350,355,360,365,370,375),A
345 READ(11'NORDI) B
    GOTO 380
350 READ(12'NORDI) B
    GOTO 380
355 READ(13'NORDI) B
    GOTO 380
360 READ(14'NORDI) B
    GOTO 380
365 READ(15'NORDI) B
    GOTO 380
370 READ(16'NORDI) B
    GOTO 380
375 READ(17'NORDI) B
380 F = B(IABCS)
```

```
      IF (F) 455,385,455
  385 IF (IR) 390,390,395
  390 IF (ID) 400,400,395
  395 WRITE(3,50)
      CALL LINK(OPT)
  400 IF (A - 7) 405,435,405
  405 IF (A - 6) 410,435,410
  410 IF (A - 5) 415,440,415
  415 IF (A - 4) 420,430,420
  420 IF (A - 3) 425,430,425
  425 IF (A - 2) 430,435,430
  430 IF (PAKSI - 3.) 445,450,450
  435 IF (PAKSI - 2.) 445,450,450
  440 IF (PAKSI - 1.) 445,450,450
  445 I = I + 1
      GOTO 330
  450 I = I - 1
      GOTO 330
  455 IF (F - 150.) 460,460,465
  460 UM = .1
      GOTO 470
  465 UM = .2
  470 G = SQRT( (Y * RHOG * RHOL * GC) / (F * PSI * VISCL * * UM))
      IF (IR) 475,475,540
  475 IF (ID) 480,480,540
  480 CALL DATSW(1,IS1)
      IF (IS1 - 2) 495,485,485
  485 CALL DATSW(4,IS4)
      IF (IS4 - 2) 495,490,490
  490 DIAM = 1.13 * (WGR / G) * * .5
  495 ND = DIAM
      FD = ND
      IN = (DIAM - FD) * 12.
      IF (DIAM - 3.) 500,500,515
  500 DO 505 J=1,6
      IF (IN - L(J)) 510,510,505
  505 CONTINUE
  510 IN = L(J)
      IF (IN - L(6)) 530,525,530
  515 IF (IN - 6) 520,520,525
  520 IN = 6
      GOTO 530
  525 IN = 0
      ND = ND + 1
  530 DIAM = ND + (IN / 12.)
      IF (IPKTP - 6) 535,540,540
  535 IF (IPKTP - 3) 540,540,545
  540 XLN = ALOG(X)
      YF = EXP( - .3827927E01 - .1080819E01 * XLN - .1176425E00 * XLN *
     1* 2 + .2295566E - 02 * XLN * * 3)
      GOTO 550
  545 XLN = ALOG(X)
      YF = EXP( - .3988496E01 - .9940904E00 * XLN - .1573365E00 * XLN *
     1* 2 - .7954698E - 02 * XLN * * 3)
  550 GF = SQRT( (YF * RHOG * RHOL * GC) / (F * PSI * VISCL * * UM))
      AREA = 3.1416 * (DIAM / 2.) * * 2
      VF = GF / (3600 * RHOG)
      V = (WGR / 3600.) / (RHOG * AREA)
```

```
      PERFL = (V / VF) * 100.
      K = 0
      IF (ID) 555,555,645
  555 IF (IFOAM) 565,565,560
  560 CALL MIKE
      GOTO 570
  565 KI = 0
      CALL JUDI
  570 IF (IPKTP - 2) 575,575,580
  575 BEDH = 6. * DIAM
      GOTO 595
  580 IF (IPKTP - 5) 585,585,590
  585 BEDH = 2.6 * DIAM
      GOTO 595
  590 BEDH = 7. * DIAM
      GOTO 595
  595 CONTINUE
  600 IBEDH = BEDH
  605 FORMAT(' LIQUID FLOW RATE      =',F9.2,2X,' POUNDS PER HOUR'//' GAS
     1FLOW RATE         =',F9.2,2X,' POUNDS PER HOUR'//' GAS DENSITY',9X,
     1'=',F11.4,' POUNDS PER CUBIC FOOT'//' LIQUID DENSITY       =',F9.2,
     12X,' POUNDS PER CUBIC FOOT'//' LIQUID VISCOSITY     =',F9.2,2X,
     1' CENTIPOISE'//' COLUMN PRESSURE      =',F11.4,' PSIA'//' TEMPERATU
     1RE          =',F9.2,2X,' DEGREES KELVIN'/)
  610 FORMAT(' PACKING SIZE         =',F9.2,2X,' INCHES'//' COLUMN DIAMET
     1ER      =',2X,I3,' FEET',2X,I3,' INCHES'/)
  615 FORMAT(      ' GAS DENSITY'9X,'=',  F11.4,' POUNDS PER CUBIC FOOT'/
     1/' PRESSURE DROP FOR RECCOMMENDED BED HEIGHT'/)
  620 FORMAT(' BED HEIGHT BASED ON ','=',F9.2,4X,'FEET'/' HYDRAULIC CONS
     1IDERATIONS'/)
  625 FORMAT(1H0,'TOTAL BED PRESSURE DROP THROUGH PACKING=',F7.3,2X,
     1'INCHES OF WATER')
  630 FORMAT(1H0,'SUPERFICIAL VAPOR VELOCITY',13X,'=',2X,F5.2,2X,'FEET/S
     1EC.')
  635 FORMAT(1H0,'PERCENT OF FLOODING',20X,'=',2X,F5.2,2X,'PERCENT')
  640 FORMAT(1H0,I3, 'FEET',2X,F8.3,2X,'INCHES OF WATER')
      TEMP2 = TEMP1
  645 WRITE(3,605)WLF,WGR,RHOG,RHOL,VISCL,PSIA,TEMP2
      WRITE(3,610)PAKSI,ND,IN
  650 IF (IZ) 655,655,665
  655 IF (BEDH - 20.) 665,665,660
  660 BEDH = 20.
  665 WRITE(3,620)BEDH
      LL = 0
  670 IF (LL) 680,680,675
  675 WRITE(3,605)WLF,WGR,RHOG,RHOL,VISCL,PSIA,TEMP2
      WRITE(3,610)PAKSI,ND,IN
      WRITE(3,620)BEDH
      LL = 0
  680 G = (WGR) / (DIAM / 1.13) * * 2
      AREA = 3.1416 * (DIAM / 2.) * * 2
  685 SUM = (PSIA / 14.696) * 407.14
      JD = 0
      KL = 0
      M = 0
      NL = 0
      ID = 0
      IR = 0
      RHOGA = RHOG
```

```
      TOP = PSIA
      BOTBP = PSIA
  690 NL = NL + 1
      RHOGA = RHOGA * (BOTBP / CPSIA) * (TEMP1 / TEMP2)
      IF (KL) 700,695,700
  695 WRITE(3,615)RHOGA
      KL = 1
  700 X = (WLF / WGR) * (RHOGA / RHOL) * * .5
      XLN = ALOG(X)
  705 Y = (G * * 2 * F * PSI * VISCL * * UM) / (RHOGA * RHOL * GC)
      YX = EXP( - .6249128E01 - .6162116E00 * XLN - .1397602E00 * XLN *
     1* 2 - .1208522E - 01 * XLN * * 3)
      DIFF = Y - YX
      SDIFF = ABS(DIFF)
  710 M = M + 1
      IF (M - 11) 715,715,815
  715 GOTO(720,725,730,735,740,745,750,755,760,765,770),M
  720 YX = EXP( - .6249128E01 - .6162116E00 * XLN - .1397602E00 * XLN *
     1* 2 - .1208522E - 01 * XLN * * 3)
      GOTO 775
  725 YX = EXP( - .5872896E01 - .7226284E00 * XLN - .1429932E00 * XLN *
     1* 2 - .1049381E - 01 * XLN * * 3)
      GOTO 775
  730 YX = EXP( - .5485292E01 - .7693485E00 * XLN - .1346535E00 * XLN *
     1* 2 - .7927142E - 02 * XLN * * 3)
      GOTO 775
  735 YX = EXP( - .5265190E01 - .8076304E00 * XLN - .1366381E00 * XLN *
     1* 2 - .7560742E - 02 * XLN * * 3)
      GOTO 775
  740 YX = EXP( - .4935951E01 - .8675696E00 * XLN - .1522480E00 * XLN *
     1* 2 - .9138094E - 02 * XLN * * 3)
      GOTO 775
  745 YX = EXP( - .4624282E01 - .9174872E00 * XLN - .1861755E00 * XLN *
     1* 2 - .1339159E - 01 * XLN * * 3)
      GOTO 775
  750 YX = EXP( - .4326525E01 - .9312685E00 * XLN - .1820800E00 * XLN *
     1* 2 - .1132091E - 01 * XLN * * 3)
      GOTO 775
  755 YX = EXP( - .4168572E01 - .1007839E01 * XLN - .2231154E00 * XLN *
     1* 2 - .1858140E - 01 * XLN * * 3)
      GOTO 775
  760 YX = EXP( - .4024600E01 - .9219081E00 * XLN - .1583744E00 * XLN *
     1* 2 - .9222639E - 02 * XLN * * 3)
      GOTO 775
  765 YX = EXP( - .3988496E01 - .9940904E00 * XLN - .1573365E00 * XLN *
     1* 2 - .7954698E - 02 * XLN * * 3)
      GOTO 775
  770 YX = EXP( - .3827927E01 - .1080819E01 * XLN - .1176425E00 * XLN *
     1* 2 + .2296566E - 02 * XLN * * 3)
  775 IF (JD) 815,780,810
  780 REM = Y - YX
      SREM = ABS(REM)
      SDIFF = SREM
      IF (REM) 790,790,785
  785 DELTP = DPRES(M)
      GOTO 710
  790 IF (M - 1) 710,795,800
  795 DELTP = DPRES(M)
      GOTO 815
```

```
800 IP = M - 1
    JD = 1
    PYX = YX
    IF (IP) 795,795,805
805 GOTO(720,725,730,735,740,745,750,755,760,765,770),IP
810 ALPHA = (Y - YX) / (PYX - YX)
    DELTP = DPRES(M - 1) + ALPHA * (DPRES(M) - DPRES(M - 1))
    JD = - 1
    GOTO 710
815 IF (DELTP - 2.0) 830,820,820
820 WRITE(1,45)
    CALL LINK(OPT)
825 WRITE(1,55)
    CALL LINK(OPT)
830 IF (IPKTP - 5) 835,835,840
835 YF = EXP( - .3827927E01 - .1080819E01 * XLN - .1176425E00 * XLN *
   1* 2 + .2296566E - 02 * XLN * * 3)
    GOTO 845
840 YF = EXP( - .3988496E01 - .9940904E00 * XLN - .1573365E00 * XLN *
   1* 2 - .7954698E - 02 * XLN * * 3)
845 GF = SQRT( (YF * RHOGA * RHOL * GC) / (F * PSI * VISCL * * UM))
    V = (WGR / 3600.) / (RHOGA * AREA)
    PERFL = (G / GF) * 100
    IF (PERFL - 100.) 850,825,825
850 SUM = SUM + DELTP
    WRITE(3,640)NL,SUM
    BOTBP = (SUM / 407.14) * 14.696
    RHOGA = RHOG * BOTBP / CPSIA
    JD = 0
    M = 0
    IF (BEDH - NL) 855,855,690
855 BEDPD = BOTBP - PSIA
    DPH2O = BEDPD / 14.696 * 407.14
    WRITE(3,625)DPH2O
    WRITE(3,630)V
    WRITE(3,635)PERFL
860 FORMAT(1H1)
    WRITE(3,860)
865 CALL LINK(OPT)
    END
*STORE
    INTEGERA,C
    DIMENSIONB(3) ,D(8) ,L(6) ,DPRES(11)
    COMMONDIAM,BEDH,IPKTP,PAKSI,C,D,L,DPRES,RHOG,RHOL,WLF,WGR,VISCL,PS
   1IA,IFOAM,GC,PSI,X,Y,G,PERFL,UM,F,XLN,ND,IN,DPH2O,V,A,B,NORDI,IABS,
   2IBEDH,RHOGA,AREA,CPSIA,K,KI,GF,DF,TEMP1,TEMP2,BEDH1,YONE,LL,IL,IJ,
   3IR,IZ
    DEFINEFILE11(8,6,U,IJ) ,12(8,6,U,JI) ,13(8,6,U,IK) ,14(8,6,U,KI) ,
   115(8,6,U,JK) ,16(8,6,U,KJ) ,17(8,6,U,LM) ,18(8,2,U,ML) ,19(6,1,U,M
   2N) ,20(11,2,U,NI)
  5 FORMAT(' TURN SWITCH 1 ON IF YOU WISH TO CHANGE THE COLUMN DIAMETE
   1R.',/,' TURN SWITCH 2 ON IF YOU WISH TO CHANGE THE BED HEIGHT.',/,
   1' TURN SWITCH 3 ON IF YOU WISH TO  CHANGE THE TYPE OF PACKING.')
 10 FORMAT(' THE INTEGER CONSTANTS FOR THE NEW PACKING TYPE ARE AS FOL
   1LOWS.')
 15 FORMAT(' 1 CERAMIC OR CARBON INTALOX SADDLES.',/,' 2 PLASTIC INTAL
   1OX SADDLES.',/,' 3 CERAMIC OR CARBON RASCHIG RINGS.',/,' 4 1/16 IN
   1. WALL METAL RASCHIG RINGS.',/,' 5 1/32 IN. WALL METAL RASCHIG RI.
```

```
     1GS.',/,' 6 PLASTIC PALL RINGS.',/,' 7 METAL PALL RINGS.')
  20 FORMAT(' TURN SWITCH 4 ON IF YOU WISH TO CHANGE THE PACKING SIZE.'
     1)
  25 FORMAT(' TURN SWITCH 6 ON IF YOU WISH TO CHANGE THE LIQUID FLOW RA
     1TE.',/,' TURN SWITCH 7 ON IF YOU WISH TO CHANGE THE GAS FLOW RATE.
     1',/,' TURN SWITCH 8 ON IF YOU WISH TO CHANGE THE COLUMN PRESSURE A
     1ND TEMPERATURE.',/,' TURN SWITCH 10 ON IF YOU WISH TO TERMINATE TH
     1E PROGRAM.')
  30 FORMAT(' TURN ON SWITCH 5 AND PUSH START.')
  35 FORMAT(' THE BED HEIGHT PROPOSED IS GREATER THAN THE MAXIMUM ALLOW
     1ABLE BED HEIGHT',/,' IF YOU WISH TO USE THIS BED HEIGHT TURN ON SW
     1ITCH 11',/,' IF YOU WISH TO USE THE MAXIMUM ALLOWABLE BED HEIGHT T
     1URN ON SWITCH 12',/,' IF YOU WISH TO GO BELOW THE ALLOWABLE BED HE
     1IGHT TURN ON SWITCH 13')
  40 FORMAT(' PUSH START')
  45 WRITE(1,5)
     WRITE(1,20)
     WRITE(1,25)
     WRITE(1,30)
     PAUSE
     CALL DATSW(1,IS1)
     IF (IS1 - 2) 100,50,50
  50 CALL DATSW(2,IS2)
     IF (IS2 - 2) 115,55,55
  55 CALL DATSW(3,IS3)
     IF (IS3 - 2) 180,60,60
  60 CALL DATSW(4,IS4)
     IF (IS4 - 2) 200,65,65
  65 CALL DATSW(6,IS6)
     IF (IS6 - 2) 220,70,70
  70 CALL DATSW(7,IS7)
     IF (IS7 - 2) 235,75,75
  75 CALL DATSW(8,IS8)
     IF (IS8 - 2) 260,80,80
  80 CALL DATSW(10,IS10)
     IF (IS10 - 2) 265,45,45
  85 FORMAT(' TYPE THE NEW COLUMN DIAMETER IN F4.1 FORMAT.')
  90 FORMAT(F4.1)
  95 FORMAT(' DIAM =',F4.1,' FEET'///)
 100 WRITE(1,85)
     READ(6,90)DIAM
     WRITE(3,95)DIAM
     ND = DIAM
     FD = ND
     IN = (DIAM - FD) * 12.
     LL = 1
     C = 1
     ID = 0
     IR = 0
     CALL LINK(PKTW)
 105 FORMAT(' TYPE THE NEW BED HEIGHT IN F4.1 FORMAT')
 110 FORMAT(' BEDH =',F4.1,' FEET'///)
 115 BEDH1 = BEDH
     WRITE(1,105)
     READ(6,90)BEDH
     IF (BEDH - BEDH1) 160,160,120
 120 WRITE(1,35)
     WRITE(1,40)
```

```
      PAUSE
  125 CALL DATSW(11,IS11)
      IF (IS11 - 2) 160,130,130
  130 CALL DATSW(12,IS12)
      IF (IS12 - 2) 140,135,135
  135 CALL DATSW(13,IS13)
      IF (IS13 - 2) 155,120,120
  140 BEDH = BEDH1
      GOTO 160
  145 FORMAT(' TYPE THE NEW BED HEIGHT IN F4.1 FORMAT')
  150 FORMAT(F4.1)
  155 WRITE(1,145)
      READ(6,150)BEDH
  160 WRITE(3,110)BEDH
      LL = 0
      C = 2
      ID = 0
      IR = 0
      IZ = 1
      CALL LINK(PKTW)
  165 FORMAT(' TYPE THE NEW PACKING TYPE NUMBER IN I1 FORMAT')
  170 FORMAT(I1)
  175 FORMAT(' IPKTP =',I2,///)
  180 WRITE(1,10)
      WRITE(1,15)
      WRITE(1,165)
      READ(6,170)IPKTP
      WRITE(3,175)IPKTP
      LL = 0
      C = 3
      ID = 0
      IR = 1
      CALL LINK(PKTW)
  185 FORMAT(' TYPE THE NEW PACKING SIZE IN F6.3 FORMAT')
  190 FORMAT(F6.3)
  195 FORMAT(' PAKSI =',F6.3,'INCHES'///)
  200 WRITE(1,185)
      READ(6,190)PAKSI
      WRITE(3,195)PAKSI
      LL = 0
      C = 4
      ID = 1
      IR = 0
      CALL LINK(PKTW)
  205 FORMAT(' TYPE THE NEW LIQUID FLOW RATE IN F10.2 FORMAT')
  210 FORMAT(F10.2)
  215 FORMAT(' WLF=',F10.2,' LBS./HR.')
  220 WRITE(1,205)
      READ(6,210)WLF
      WRITE(3,215)WLF
      LL = 0
      C = 5
      ID = 0
      IR = 0
      CALL LINK(PKTW)
  225 FORMAT(' TYPE THE NEW GAS FLOW RATE IN F10.2 FORMAT')
  230 FORMAT(' WGR=',F10.2,' LBS./HR. ')
  235 WRITE(1,225)
```

```
      READ(6,210)WGR
      WRITE(3,230)WGR
      LL = 0
      C = 6
      ID = 0
      IR = 0
      CALL LINK(PKTW)
  240 FORMAT(' TYPE THE NEW COLUMN PRESSURE AND TEMPERATURE IN F FORMAT'
     1,/,'(PRESSURE)(TEMPERATURE)')
  245 FORMAT(1X,F8.3,2X,F11.3)
  250 FORMAT(' NEW TEMP=',F11.4,' DEGREES KELVIN'///)
  255 FORMAT(' PSIA=',F11.4,' LBS./SQ.IN.'/)
  260 WRITE(1,240)
      READ(6,245)PSIA,TEMP2
      WRITE(3,255)PSIA
      WRITE(3,250)TEMP2
      LL = 1
      C = 7
      ID = 0
      IR = 0
      CALL LINK(PKTW)
  265 CALL EXIT
      END
```

```
// XEQ
      SUBROUTINETRAN
      COMMONICR,ICP,IPR,ITW,IT1,IT2,IPROB,N,NF,CASES,NPAGE,INMD,IPRED,IS
     1TEP,ICNST,IREAR,KX(1) ,MX(20) ,NCD(3) ,ISEQ,NCASE,NX(10) ,EFOUT,EF
     2IN,TOL,FLVB(2) ,KNN
      COMMONTITLE(18) ,VNAME(30) ,SUMY(30) ,SD(30) ,X(30) ,R(30,30)
      COMMONHIGH(30) ,HLOW(30) ,MF(50,3)
      X(1) = ALOG(X(1))
      X(2) = ALOG(X(2))
      X(3) = X(1) * * 2
      X(4) = X(1) * * 3
      RETURN
```

```
// XEQ
      DIMENSIONXCOL(13) ,XLN(13) ,YLN(13) ,YCOL(13)
    5 FORMAT(4F4.2,9F4.1)
   10 FORMAT(1H ,F7.5,10X,F4.2)
   15 FORMAT(1H0,'CHART OF VALUES FOR GRAPHING FLOODING LINE')
   20 FORMAT(1H0,1X,'YCOL',11X,'XCOL')
      READ(2,5)XCOL
      WRITE(3,15)
      WRITE(3,20)
      DO 25 I=1,13
      XLN(I) = ALOG(XCOL(I))
      YLN(I) = - 3.827927 - 1.080819 * XLN(I) - .1176425 * XLN(I) * * 2
      YCOL(I) = EXP(YLN(I))
   25 WRITE(3,10)YCOL(I),XCOL(I)
      CALL EXIT
```

```
// XEQ
      SUBROUTINEJUDI
      DIMENSIONB(3) ,D(8) ,L(6) ,DPRES(11)
      COMMONDIAM,BEDH,IPKTP,PAKSI,C,D,L,DPRES,RHOG,RHOL,WLF,WGR,VISCL,PS
     1IA,IFOAM,GC,PSI,X,Y,G,PERFL,UM,F,XLN,ND,IN,DPH2O,V,A,B,NORDI,IABCS
     2,IBEDH,RHOGA,AREA,CPSIA,K,KI,GF,DF
    5 IF (PERFL - 20.) 10,70,70
   10 KI = KI + 1
      GOTO(15,20,25,30,35,40,45,50,55,60),KI
   15 Y = EXP( - .6249128E01 - .6162116E00 * XLN - .1397602E00 * XLN * *
     12 - .1208522E - 01 * XLN * * 3)
      GOTO 65
   20 Y = EXP( - .5872896E01 - .7226284E00 * XLN - .1429932E00 * XLN * *
     12 - .1049381E - 01 * XLN * * 3)
      GOTO 65
   25 Y = EXP( - .5485292E01 - .7693485E00 * XLN - .1346535E00 * XLN * *
     12 - .7927142E - 02 * XLN * * 3)
      GOTO 65
   30 Y = EXP( - .5265190E01 - .8076304E00 * XLN - .1366381E00 * XLN * *
     12 - .7560742E - 02 * XLN * * 3)
      GOTO 65
   35 Y = EXP( - .4935951E01 - .8675696E00 * XLN - .1522480E00 * XLN * *
     12 - .9138094E - 02 * XLN * * 3)
      GOTO 65
   40 Y = EXP( - .4624282E01 - .9174872E00 * XLN - .1861755E00 * XLN * *
     12 - .1339159E - 01 * XLN * * 3)
      GOTO 65
   45 Y = EXP( - .4326525E01 - .9312685E00 * XLN - .1820800E00 * XLN * *
     12 - .1132091E - 01 * XLN * * 3)
      GOTO 65
   50 Y = EXP( - .4168572E01 - .1007839E01 * XLN - .2231154E00 * XLN * *
     12 - .1858140E - 01 * XLN * * 3)
      GOTO 65
   55 Y = EXP( - .4024600E01 - .9219031E00 * XLN - .1583744E00 * XLN * *
     12 - .9222639E - 02 * XLN * * 3)
      GOTO 65
   60 Y = EXP( - .3988496E01 - .9940904E00 * XLN - .1573365E00 * XLN * *
     12 - .79954698E - 02 * XLN * * 3)
   65 G = SQRT( (Y * RHOG * RHOL * GC) / (F * PSI * VISCL * * UM))
      PERFL = (G / GF) * 100.
      GOTO 5
   70 RETURN
```

```
// XEQ
      SUBROUTINEMIKE
      DIMENSIONB(3) ,D(8) ,L(6) ,DPRES(11)
      COMMONDIAM,BEDH,IPKTP,PAKSI,C,D,L,DPRES,RHOG,RHOL,WLF,WGR,VISCL,PS
     1IA,IFOAM,GC,PSI,X,Y,G,PERFL,UM,F,XLN,ND,IN,DPH2O,V,A,B,NORDI,IABCS
     2,IBEDH,RHOGA,AREA,CPSIA,K,KI,GF,DF
    5 IF (PERFL - 50.) 70,10,10
   10 XLN = ALOG(X)
      K = K + 1
      GOTO(15,20,25,30,35,40,45,50,55,60),K
   15 Y = EXP( - .3988496E01 - .9940904E00 * XLN - .1573365E00 * XLN * *
     12 - .7954698E - 02 * XLN * * 3)
      GOTO 65
   20 Y = EXP( - .4024600E01 - .9219081E00 * XLN - .1583744E00 * XLN * *
     12 - .9222639E - 02 * XLN * * 3)
      GOTO 65
   25 Y = EXP( - .4168572E01 - .1007839E01 * XLN - .2231154E00 * XLN * *
     12 - .1858140E - 01 * XLN * * 3)
      GOTO 65
   30 Y = EXP( - .4326525E01 - .9312685E00 * XLN - .1820800E00 * XLN * *
     12 - .1132091E - 01 * XLN * * 3)
      GOTO 65
   35 Y = EXP( - .4624282E01 - .9174872E00 * XLN - .1861755E00 * XLN * *
     12 - .1339159E - 01 * XLN * * 3)
      GOTO 65
   40 Y = EXP( - .4935951E01 - .8675696E00 * XLN - .1522480E00 * XLN * *
     12 - .9138094E - 02 * XLN * * 3)
      GOTO 65
   45 Y = EXP( - .5265190E01 - .8076304E00 * XLN - .1366381E00 * XLN * *
     12 - .7560742E - 02 * XLN * * 3)
      GOTO 65
   50 Y = EXP( - .5485292E01 - .7693485E00 * XLN - .1346535E00 * XLN * *
     12 - .7927142E - 02 * XLN * * 3)
      GOTO 65
   55 Y = EXP( - .5872896E01 - .7226284E00 * XLN - .1429932E00 * XLN * *
     12 - .1049381E - 01 * XLN * * 3)
      GOTO 65
   60 Y = EXP( - .6249128E01 - .6162116E00 * XLN - .1397602E00 * XLN * *
     12 - .1208522E - 01 * XLN * * 3)
   65 G = SQRT( (Y * RHOG * RHOL * GC) / (F * PSI * VISCL * * UM))
      PERFL = (G / GF) * 100.
      GOTO 5
   70 RETURN
```

```
// XEQ
      DIMENSION DATA1(3)
      DEFINE FILE 11 (8,6,U,IJ)
      DO 5 I=1,8
      READ(2,100)DATA1
  100 FORMAT(3F5.0)
      WRITE(11'I)DATA1
    5 CONTINUE
      CALL EXIT
      END
// XEQ          1
*FILES(11,SINTC)
   0.   0.   0.
 330. 330. 330.
 200. 200. 200.
 130. 135. 145.
  84.  91.  98.
  39.  49.  52.
  31.  34.  40.
  20.  20.  22.
```

```
// JOB
// DUP
*STOREDATA  WS  UA  SINTP     1
// JOB
// FOR
*IOCS(CARD,TYPEWRITER,1132PRINTER,DISK)
*ONE WORD INTEGERS
      DIMENSION DATA2(3)
      DEFINE FILE 12 (8,6,U,JI)
      DO 5 I=1,8
      READ(2,100)DATA2
  100 FORMAT(3F5.0)
      WRITE(12'I)DATA2
    5 CONTINUE
      CALL EXIT
      END
// XEQ          1
*FILES(12,SINTP)
   0.   0.   0.
   0.   0.   0.
   0.   0.   0.
   0.   0.   0.
  32.  32.  32.
   0.   0.   0.
  21.  21.  21.
  14.  14.  14.
```

```
// JOB
// DUP
*STOREDATA  WS  UA  RSRC     1
// JOB
// FOR
*IOCS(CARD,TYPEWRITER,1132PRINTER,DISK)
*ONE WORD INTEGERS
```

```
      DIMENSION DATA3(3)
      DEFINE FILE 13 (8,6,U,IK)
      DO 5 I=1,8
      READ(2,100)DATA3
  100 FORMAT(3F5.0)
      WRITE(13'I)DATA3
    5 CONTINUE
      CALL EXIT
      END
// XEQ                1
*FILES(13,RSRC)
1600.1600.1600.
1000.1000.1000.
 580. 580. 580.
 210. 255. 255.
 120. 155. 160.
  65.  95.  95.
  50.  65.  65.
  37.  37.  37.
```

```
// JOB
// DUP
*STOREDATA   WS   UA   RSRM6      1
// JOB
// FOR
*IOCS(CARD,TYPEWRITER,1132PRINTER,DISK)
*ONE WORD INTEGERS
      DIMENSION DATA4(3)
      DEFINE FILE 14 (8,6,U,KI)
      DO 5 I=1,8
      READ(2,100)DATA4
  100 FORMAT(3F5.0)
      WRITE(14'I)DATA4
    5 CONTINUE
      CALL EXIT
      END
// XEQ                1
*FILES(14,RSRM6)
   0.   0.   0.
   0.   0.   0.
   0.   0.   0.
 220. 220. 220.
  77. 122. 144.
  43.  65.  85.
  38.  54.  71.
  32.  32.  32.
```

```
// JOB
// DUP
*STOREDATA   WS   UA   RSRM3      1
// JOB
// FOR
*IOCS(CARD,TYPEWRITER,1132PRINTER,DISK)
*ONE WORD INTEGERS
```

```
      CALL EXIT
      END
// XEQ             1
*FILES(19,L)
  2
  4
  6
  8
 10
 12

// JOB
// DUP
*STOREDATA  WS  UA  DPRES     1
// JOB
// FOR
*IOCS(CARD,TYPEWRITER,1132PRINTER,DISK)
*ONE WORD INTEGERS
      DEFINE FILE 20 (11,2,U,NI)
      DO 5 I=1,11
      READ(2,100)DATA0
  100 FORMAT(F5.2)
      WRITE(20'I)DATA0
    5 CONTINUE
      CALL EXIT
      END
// XEQ             1
*FILES(20,DPRES)

  .05
  .07
  .1
  .15
  .25
  .35
  .50
  .75
 1.00
 1.50
 2.00
```

```
      DIMENSION DATA5(3)
      DEFINE FILE 15 (8,6,U,JK)
      DO 5 I=1,8
      READ(2,100)DATA5
  100 FORMAT(3F5.0)
      WRITE(15'I)DATA5
    5 CONTINUE
      CALL EXIT
      END
// XEQ           1
*FILES(15,RSRM3)
   0.   0.   0.
 390. 390. 390.
 300. 300. 300.
 170. 170. 170.
 115. 115. 115.
   0.   0.   0.
   0.   0.   0.
   0.   0.   0.

// JOB
// DUP
*STOREDATA  WS  UA  PALRP    1
// JOB
// FOR
*IOCS(CARD,TYPEWRITER,1132PRINTER,DISK)
*ONE WORD INTEGERS
      DIMENSION DATA6(3)
      DEFINE FILE 16 (8,6,U,KJ)
      DO 5 I=1,8
      READ(2,100)DATA6
  100 FORMAT(3F5.0)
      WRITE(16'I)DATA6
    5 CONTINUE
      CALL EXIT
      END
// XEQ           1
*FILES(16,PALRP)
   0.   0.   0.
   0.   0.   0.
  97.  97.  97.
   0.   0.   0.
  52.  52.  52.
  32.  32.  32.
  25.  25.  25.
   0.   0.   0.

// JOB
// DUP
*STOREDATA  WS  UA  PALRM    1
// JOB
// FOR
*IOCS(CARD,TYPEWRITER,1132PRINTER,DISK)
*ONE WORD INTEGERS
      DIMENSION DATA7(3)
      DEFINE FILE 17 (8,6,U,LM)
```

```
      DO 5 I=1,8
      READ(2,100)DATA7
  100 FORMAT(3F5.0)
      WRITE(17'I)DATA7
    5 CONTINUE
      CALL EXIT
      END
// XEQ          1
*FILES(17,PALRM)
   0.   0.   0.
   0.   0.   0.
   0.   0.   0.
  70.  70.  70.
  42.  52.  52.
  31.  36.  28.
  20.  25.  25.
   0.   0.   0.

// JOB
// DUP
*STOREDATA   WS   UA   D          1
// JOB
// FOR
*IOCS(CARD,TYPEWRITER,1132PRINTER,DISK)
*ONE WORD INTEGERS
      DEFINE FILE 18 (8,2,U,ML)
      DO 5 I=1,8
      READ(2,100)DATA8
  100 FORMAT(F6.3)
      WRITE(18'I)DATA8
    5 CONTINUE
      CALL EXIT
      END
// XEQ          1
*FILES(18,D)
  .25
  .375
  .5
  .75
 1.
 1.5
 2.
 3.

// JOB
// DUP
*STOREDATA   WS   UA   L          1
// JOB
// FOR
*IOCS(CARD,TYPEWRITER,1132PRINTER,DISK)
*ONE WORD INTEGERS
      DEFINE FILE 19 (6,1,U,MN)
      DO 5 I=1,6
      READ(2,100)NDAT9
  100 FORMAT(I3)
      WRITE(19'I)NDAT9
    5 CONTINUE
```

Sample Problem

Given: Liquid Flow Rate = 20,000 #/hr.

Gas Flow Rate = 10,000 #/hr.

Gas Density = 0.01 #/ft^3.

Liquid Density = 62.4 #/ft^3

Liquid Viscosity = 1.0 Cp

Column Pressure = 14.7 psia

Temperature = 300°K

For this case the optimum design was calculated. For each of the following changes in design criteria the column characteristics were simulated.

1. Change in diameter
2. Change in bed height
3. Change in packing type
4. Change in packing size
5. Change in liquid flow rate
6. Change in gas flow rate
7. Change in column temperature and pressure

DESIGN INFORMATION FOR PACKE

LIQUID FLOW RATE	=	20000.00	POUNDS PER HOUR
GAS FLOW RATE	=	10000.00	POUNDS PER HOUR
GAS DENSITY	=	0.0100	POUNDS PER CUBIC FOOT
LIQUID DENSITY	=	62.40	POUNDS PER CUBIC FOOT
LIQUID VISCOSITY	=	1.00	CENTIPOISE
COLUMN PRESSURE	=	14.7000	PSIA
TEMPERATURE	=	300.00	DEGREES KELVIN

NON-FOAMING SYSTEM

TYPE OF PACKING METAL PALL RINGS

LIQUID FLOW RATE	=	20000.00	POUNDS PER HOUR
GAS FLOW RATE	=	10000.00	POUNDS PER HOUR
GAS DENSITY	=	0.0100	POUNDS PER CUBIC FOOT
LIQUID DENSITY	=	62.40	POUNDS PER CUBIC FOOT
LIQUID VISCOSITY	=	1.00	CENTIPOISE
COLUMN PRESSURE	=	14.7000	PSIA
TEMPERATURE	=	300.00	DEGREES KELVIN
PACKING SIZE	=	2.00	INCHES
COLUMN DIAMETER	=	4 FEET	0 INCHES
BED HEIGHT BASED ON HYDRAULIC CONSIDERATIONS	=	20.00	FEET
GAS DENSITY	=	0.0100	POUNDS PER CUBIC FOOT

PRESSURE DROP FOR RECCOMMENDED BED HEIGHT

1FEET	407.757	INCHES OF WATER
2FEET	408.262	INCHES OF WATER
3FEET	408.764	INCHES OF WATER

4FEET	409.264	INCHES OF WATER
5FEET	409.763	INCHES OF WATER
6FEET	410.260	INCHES OF WATER
7FEET	410.756	INCHES OF WATER
8FEET	411.251	INCHES OF WATER
9FEET	411.744	INCHES OF WATER
10FEET	412.237	INCHES OF WATER
11FEET	412.727	INCHES OF WATER
12FEET	413.217	INCHES OF WATER
13FEET	413.705	INCHES OF WATER
14FEET	414.192	INCHES OF WATER
15FEET	414.677	INCHES OF WATER
16FEET	415.161	INCHES OF WATER
17FEET	415.644	INCHES OF WATER
18FEET	416.126	INCHES OF WATER
19FEET	416.606	INCHES OF WATER
20FEET	417.086	INCHES OF WATER

TOTAL BED PRESSURE DROP THROUGH PACKING= 9.835 INCHES OF WATER

SUPERFICIAL VAPOR VELOCITY = 21.12 FEET/SEC.

PERCENT OF FLOODING = 68.03 PERCENT

DIAM = 4.5 FEET

LIQUID FLOW RATE	=	20000.00	POUNDS PER HOUR
GAS FLOW RATE	=	10000.00	POUNDS PER HOUR
GAS DENSITY	=	0.0100	POUNDS PER CUBIC FOOT
LIQUID DENSITY	=	62.40	POUNDS PER CUBIC FOOT
LIQUID VISCOSITY	=	1.00	CENTIPOISE
COLUMN PRESSURE	=	14.7000	PSIA
TEMPERATURE	=	300.00	DEGREES KELVIN
PACKING SIZE	=	2.00	INCHES
COLUMN DIAMETER	=	4 FEET	6 INCHES
BED HEIGHT BASED ON HYDRAULIC CONSIDERATIONS	=	20.00	FEET
GAS DENSITY	=	0.0100	POUNDS PER CUBIC FOOT

PRESSURE DROP FOR RECCOMMENDED BED HEIGHT

1FEET	407.532	INCHES OF WATER
2FEET	407.813	INCHES OF WATER
3FEET	408.094	INCHES OF WATER
4FEET	408.374	INCHES OF WATER
5FEET	408.653	INCHES OF WATER
6FEET	408.932	INCHES OF WATER
7FEET	409.211	INCHES OF WATER
8FEET	409.489	INCHES OF WATER
9FEET	409.767	INCHES OF WATER
10FEET	410.044	INCHES OF WATER
11FEET	410.320	INCHES OF WATER
12FEET	410.596	INCHES OF WATER
13FEET	410.872	INCHES OF WATER
14FEET	411.147	INCHES OF WATER
15FEET	411.422	INCHES OF WATER

16FEET 411.696 INCHES OF WATER
17FEET 411.970 INCHES OF WATER
18FEET 412.243 INCHES OF WATER
19FEET 412.516 INCHES OF WATER
20FEET 412.788 INCHES OF WATER

TOTAL BED PRESSURE DROP THROUGH PACKING= 5.537 INCHES OF WATER
SUPERFICIAL VAPOR VELOCITY = 17.02 FEET/SEC.
PERCENT OF FLOODING = 54.24 PERCENT

BEDH =30.0 FEET

LIQUID FLOW RATE = 20000.00 POUNDS PER HOUR

GAS FLOW RATE = 10000.00 POUNDS PER HOUR

GAS DENSITY = 0.0100 POUNDS PER CUBIC FOOT

LIQUID DENSITY = 62.40 POUNDS PER CUBIC FOOT

LIQUID VISCOSITY = 1.00 CENTIPOISE

COLUMN PRESSURE = 14.7000 PSIA

TEMPERATURE = 300.00 DEGREES KELVIN

PACKING SIZE = 2.00 INCHES

COLUMN DIAMETER = 4 FEET 6 INCHES

BED HEIGHT BASED ON = 30.00 FEET
HYDRAULIC CONSIDERATIONS

GAS DENSITY = 0.0100 POUNDS PER CUBIC FOOT

PRESSURE DROP FOR RECCOMMENDED BED HEIGHT

1FEET	407.532	INCHES OF WATER
2FEET	407.813	INCHES OF WATER
3FEET	408.094	INCHES OF WATER
4FEET	408.374	INCHES OF WATER
5FEET	408.653	INCHES OF WATER
6FEET	408.932	INCHES OF WATER
7FEET	409.211	INCHES OF WATER
8FEET	409.489	INCHES OF WATER
9FEET	409.767	INCHES OF WATER
10FEET	410.044	INCHES OF WATER
11FEET	410.320	INCHES OF WATER
12FEET	410.596	INCHES OF WATER
13FEET	410.872	INCHES OF WATER
14FEET	411.147	INCHES OF WATER
15FEET	411.422	INCHES OF WATER

```
16FEET   411.696  INCHES OF WATER
17FEET   411.970  INCHES OF WATER
18FEET   412.243  INCHES OF WATER
19FEET   412.516  INCHES OF WATER
20FEET   412.788  INCHES OF WATER
21FEET   413.060  INCHES OF WATER
22FEET   413.331  INCHES OF WATER
23FEET   413.602  INCHES OF WATER
24FEET   413.873  INCHES OF WATER
25FEET   414.143  INCHES OF WATER
26FEET   414.412  INCHES OF WATER
27FEET   414.682  INCHES OF WATER
28FEET   414.950  INCHES OF WATER
29FEET   415.213  INCHES OF WATER
30FEET   415.486  INCHES OF WATER
TOTAL BED PRESSURE DROP THROUGH PACKING=  8.235  INCHES OF WATER
SUPERFICIAL VAPOR VELOCITY             =  16.80  FEET/SEC.
PERCENT OF FLOODING                    =  53.91  PERCENT
```

IPKTP = 4

TYPE OF PACKING		1/16 IN. WALL METAL RASCHIG RINGS
LIQUID FLOW RATE	= 20000.00	POUNDS PER HOUR
GAS FLOW RATE	= 10000.00	POUNDS PER HOUR
GAS DENSITY	= 0.0100	POUNDS PER CUBIC FOOT
LIQUID DENSITY	= 62.40	POUNDS PER CUBIC FOOT
LIQUID VISCOSITY	= 1.00	CENTIPOISE
COLUMN PRESSURE	= 14.7000	PSIA
TEMPERATURE	= 300.00	DEGREES KELVIN
PACKING SIZE	= 2.00	INCHES
COLUMN DIAMETER	= 4 FEET	6 INCHES
BED HEIGHT BASED ON HYDRAULIC CONSIDERATIONS	= 11.70	FEET
GAS DENSITY	= 0.0100	POUNDS PER CUBIC FOOT

PRESSURE DROP FOR RECCOMMENDED BED HEIGHT

1FEET	408.427	INCHES OF WATER
2FEET	409.593	INCHES OF WATER
3FEET	410.749	INCHES OF WATER
4FEET	411.895	INCHES OF WATER
5FEET	413.032	INCHES OF WATER
6FEET	414.158	INCHES OF WATER
7FEET	415.276	INCHES OF WATER
8FEET	416.384	INCHES OF WATER
9FEET	417.483	INCHES OF WATER
10FEET	418.573	INCHES OF WATER

11FEET 419.654 INCHES OF WATER
12FEET 420.726 INCHES OF WATER
TOTAL BED PRESSURE DROP THROUGH PACKING= 13.475 INCHES OF WATER
SUPERFICIAL VAPOR VELOCITY = 16.44 FEET/SEC.
PERCENT OF FLOODING = 69.81 PERCENT

PAKSI = 2.500INCHES

LIQUID FLOW RATE	= 20000.00	POUNDS PER HOUR
GAS FLOW RATE	= 10000.00	POUNDS PER HOUR
GAS DENSITY	= 0.0100	POUNDS PER CUBIC FOOT
LIQUID DENSITY	= 62.40	POUNDS PER CUBIC FOOT
LIQUID VISCOSITY	= 1.00	CENTIPOISE
COLUMN PRESSURE	= 14.7000	PSIA
TEMPERATURE	= 300.00	DEGREES KELVIN
PACKING SIZE	= 2.50	INCHES
COLUMN DIAMETER	= 4 FEET	6 INCHES
BED HEIGHT BASED ON HYDRAULIC CONSIDERATIONS	= 11.70	FEET
GAS DENSITY	= 0.0100	POUNDS PER CUBIC FOOT

PRESSURE DROP FOR RECCOMMENDED BED HEIGHT

1FEET	407.638	INCHES OF WATER
2FEET	408.024	INCHES OF WATER
3FEET	408.410	INCHES OF WATER
4FEET	408.795	INCHES OF WATER
5FEET	409.179	INCHES OF WATER
6FEET	409.563	INCHES OF WATER
7FEET	409.945	INCHES OF WATER
8FEET	410.327	INCHES OF WATER
9FEET	410.707	INCHES OF WATER
10FEET	411.087	INCHES OF WATER
11FEET	411.467	INCHES OF WATER
12FEET	411.845	INCHES OF WATER

TOTAL BED PRESSURE DROP THROUGH PACKING= 4.594 INCHES OF WATER

SUPERFICIAL VAPOR VELOCITY = 17.10 FEET/SEC.

PERCENT OF FLOODING = 47.74 PERCENT

WLF= 22000.00 LBS./HR.
LIQUID FLOW RATE = 22000.00 POUNDS PER HOUR

GAS FLOW RATE = 10000.00 POUNDS PER HOUR

GAS DENSITY = 0.0100 POUNDS PER CUBIC FOOT

LIQUID DENSITY = 62.40 POUNDS PER CUBIC FOOT

LIQUID VISCOSITY = 1.00 CENTIPOISE

COLUMN PRESSURE = 14.7000 PSIA

TEMPERATURE = 300.00 DEGREES KELVIN

PACKING SIZE = 2.00 INCHES

COLUMN DIAMETER = 5 FEET 0 INCHES

BED HEIGHT BASED ON = 13.00 FEET
HYDRAULIC CONSIDERATIONS

GAS DENSITY = 0.0100 POUNDS PER CUBIC FOOT

PRESSURE DROP FOR RECCOMMENDED BED HEIGHT

1FEET	407.915	INCHES OF WATER
2FEET	408.577	INCHES OF WATER
3FEET	409.235	INCHES OF WATER
4FEET	409.890	INCHES OF WATER
5FEET	410.542	INCHES OF WATER
6FEET	411.190	INCHES OF WATER
7FEET	411.835	INCHES OF WATER
8FEET	412.477	INCHES OF WATER
9FEET	413.116	INCHES OF WATER
10FEET	413.752	INCHES OF WATER
11FEET	414.385	INCHES OF WATER
12FEET	415.014	INCHES OF WATER
13FEET	415.641	INCHES OF WATER

TOTAL BED PRESSURE DROP THROUGH PACKING= 8.390 INCHES OF WATER

SUPERFICIAL VAPOR VELOCITY = 13.62 FEET/SEC.

PERCENT OF FLOODING = 57.52 PERCENT

WGR= 12000.00 LBS./HR.

LIQUID FLOW RATE = 22000.00 POUNDS PER HOUR

GAS FLOW RATE = 12000.00 POUNDS PER HOUR

GAS DENSITY = 0.0100 POUNDS PER CUBIC FOOT

LIQUID DENSITY = 62.40 POUNDS PER CUBIC FOOT

LIQUID VISCOSITY = 1.00 CENTIPOISE

COLUMN PRESSURE = 14.7000 PSIA

TEMPERATURE = 300.00 DEGREES KELVIN

PACKING SIZE = 2.50 INCHES

COLUMN DIAMETER = 4 FEET 6 INCHES

BED HEIGHT BASED ON = 11.70 FEET
HYDRAULIC CONSIDERATIONS

GAS DENSITY = 0.0100 POUNDS PER CUBIC FOOT

PRESSURE DROP FOR RECCOMMENDED BED HEIGHT

1FEET	407.885	INCHES OF WATER
2FEET	408.517	INCHES OF WATER
3FEET	409.146	INCHES OF WATER
4FEET	409.772	INCHES OF WATER
5FEET	410.395	INCHES OF WATER
6FEET	411.016	INCHES OF WATER
7FEET	411.633	INCHES OF WATER
8FEET	412.247	INCHES OF WATER
9FEET	412.859	INCHES OF WATER
10FEET	413.468	INCHES OF WATER
11FEET	414.074	INCHES OF WATER
12FEET	414.677	INCHES OF WATER

TOTAL BED PRESSURE DROP THROUGH PACKING= 7.426 INCHES OF WATER

SUPERFICIAL VAPOR VELOCITY = 20.27 FEET/SEC.

PERCENT OF FLOODING = 56.66 PERCENT

PSIA= 20.0000 LBS./SQ.IN.

NEW TEMP= 350.0000 DEGREES KELVIN

LIQUID FLOW RATE	= 22000.00	POUNDS PER HOUR
GAS FLOW RATE	= 12000.00	POUNDS PER HOUR
GAS DENSITY	= 0.0100	POUNDS PER CUBIC FOOT
LIQUID DENSITY	= 62.40	POUNDS PER CUBIC FOOT
LIQUID VISCOSITY	= 1.00	CENTIPOISE
COLUMN PRESSURE	= 20.0000	PSIA
TEMPERATURE	= 350.00	DEGREES KELVIN
PACKING SIZE	= 2.50	INCHES
COLUMN DIAMETER	= 4 FEET	6 INCHES
BED HEIGHT BASED ON HYDRAULIC CONSIDERATIONS	= 11.70	FEET
GAS DENSITY	= 0.0116	POUNDS PER CUBIC FOOT

PRESSURE DROP FOR RECCOMMENDED BED HEIGHT

1FEET	554.578	INCHES OF WATER
2FEET	554.928	INCHES OF WATER
3FEET	555.277	INCHES OF WATER
4FEET	555.626	INCHES OF WATER
5FEET	555.974	INCHES OF WATER
6FEET	556.322	INCHES OF WATER
7FEET	556.669	INCHES OF WATER
8FEET	557.015	INCHES OF WATER
9FEET	557.361	INCHES OF WATER
10FEET	557.707	INCHES OF WATER
11FEET	558.052	INCHES OF WATER
12FEET	558.396	INCHES OF WATER

TOTAL BED PRESSURE DROP THROUGH PACKING= 4.313 INCHES OF WATER

SUPERFICIAL VAPOR VELOCITY = 13.02 FEET/SEC.

PERCENT OF FLOODING = 46.09 PERCENT

Program Language

The language used for the programs on the 1130, 360, and timeshare is Fortran IV. The only difference in programming technique is the use of data switches for the 1130 and keyboard input for the G.E. Timeshare. The data switches were used in the regular manner, i.e., checking to see which switches are on for the various design options (see program). For the timeshare program, keyboard input is used. The terminal will print out, "If you wish to change column diameter, etc. type in a 1 in column 1." It is essentially the same theory as is used on the 1130 with the exception that the data is typed right on the terminal instead of the keyboard.

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212-425-6568

GE MARK II  T/S FROM NEW JERSEY 005
TERMINAL 003 ON AT 14:06  03/11/70
USER NUMBER--TAJ03010,CENG
PROJECT ID--91500
SYSTEM--FOR
NEW OR OLD--OLD
ENTER FILE NAME-N41
READY
KEY

READY
LISTNH


01*XLN*06120&-.1208522E-01*XLN**3)
00100*   ALLIED CHEMICAL CORP ENGINEERING PROGRAM  N41
00110 INTEGERA,C
00120 DIMENSIONB(3) ,O(8) ,L(6) ,DPRES(11)
00130 COMMON DIAM,BEDH,IPKTP,PAKSI,C,D,L,DPRES,RHOG,RHOL,VLF,
00140&WGR,VISCL,PS
00150&IA,IFOAM,GC,PSI,X,Y,G,PERFL,UM,F,XLN,ND,IN,DPH2O,V,A,B,
00160&NOROI,IABCS
00170&,IBEDH,RHOGA,AREA,CPSIA,K,KI,GF,DF,TEMP1,TEMP2,BEDH1,YONE,
00180& LL,IL,ID
00190&IR,IZ,IS1,IS4
00210  FILENAME  IN2,OUT3,IN11,IN12,IN13,IN14,IN15,IN16,IN17,IN18,
00220&IN19,IN20
00230 IN11="N41SINTP";IN12="N41SINTR";IN13="N41RSRC";IN14="N41RSRM6";
00250&IN15="N41RSRM3";IN16="N41PALRP";IN17="N41PALRM";
00251&IN18="N41O";
00260&IN19="N41L";IN20="N41DPRES";IN2="     ";OUT3="
00270 WRITE(OUT3,1)
00280 1 FORMAT(" ENTER 1 TO CONTINUE OLD PROBLEM OR 2 TO RUN NEW",
00290&//)
00300 READ(IN2,2)ISS
00310 2 FORMAT(V)
00320 IF (ISS - 2) 10,15,15
00330 10 GOTO(570,600,120,290,160,160,670),C
00340 15 WRITE(OUT3,5)
00341  IS1= 2
00342  IS4= 2
00350 5 FORMAT(" CORPORATE ENGINEERING,ALLIED CHEMICAL",/" PROGRAM
00360& N41  DESIGN INFORMATION FOR PACKED TOWERS",/"  O.F./F.W.S.
00370&   TIMESHARE VERSION  1  MOD 0  NOV. 1969",//" INSTRUCTIONS",
00380&//" ENTER ALL DATA THROUGH KEYBOARD",//)
00390 WRITE(OUT3,3)
00391 3 FORMAT(" TYPE FOLLOWING INPUT DATA:",//)
00400 WRITE(OUT3,987)
00401 987 FORMAT(" TYPE LIQUID FLOW RATE,LBS/HR")
00402 READ(IN2,2)VLF
00420 WRITE(OUT3,4)
00430 4 FORMAT(" GAS FLOW RATE, LBS/HR ")
00440 READ(IN2,2) WGR
00450 WRITE(OUT3,6)
00460 6 FORMAT(" GAS DENSITY, LBS/CUFT ")
00470 READ(IN2,2) RHOG
```

```
WRITE(OUT3,7)
7 FORMAT(" LIQUID DENSITY, LBS/CUFT ")
READ (IN2,2) RHØL
WRITE(ØUT3,8)
8 FØRMAT(" LIQUID VISCØSITY, CENTIPØISE ")
READ(IN2,2) VISCL
WRITE(OUT3,9)
9 FØRMAT(" CØLUMN PRESSURE, PSIA" )
READ(IN2,2) PSIA
WRITE(OUT3,11)
11 FØRMAT(" TEMPERATURE, DEGK" )
READ(IN2,2) TEMP1
WRITE(ØUT3,12)
12FØRMAT(" ENTER 1 FOR FOAMING SYSTEM, ØR 2 FØR NØN-FØAMING ")
READ(IN2,2) IFØAM
WRITE(ØUT3,13)
13 FØRMAT(" ENTER PACKING TYPE - SEE MANUAL FØR CØDE ")
14 FØRMAT(7X,V)
READ(IN2,2) IPKTP
CPSIA = PSIA
30 FØRMAT(" FØAMING SYSTEM ")
35 FØRMAT(" NON-FØAMING SYSTEM")
40 FØRMAT(" THE BED HEIGHT IS GREATER THAN THE LIMIT OF 20
& FEET",/" NEW BED HEIGHT SUGGESTED."/)
45 FØRMAT(" COLUMN CØNDITIONS HAVE CAUSED FLØODING.  THEREFØRE
& INCREASE THE COLUMN DIAMETER OR PACKING SIZE")
50 FØRMAT(" THERE IF NØ PACKING FACTØR LISTED FOR THIS PACKING
&SIZE AND TYPE.  THEREFØRE TYPE IN A NEW SIZE ØR TYPE.")
55 FØRMAT("THE PERCENT ØF FLØØDING IS EQUAL TØ OR GREATER THAN
& 100",/" NEW CØLUMN DIAMETER SUGGESTED.",/)
DØ 60 I=1,8
60 READ(IN18,14)D(I)
DØ 65 J=1,6
65 READ(IN19,14)L(J)
DØ 70 M=1,11
70 READ(IN20,14)DPRES(M)
IL = 0
IR = 0
ID = 0
IZ = 0
IF (IFØAM) 80,80,75
75 WRITE(ØUT3,30)
GOTØ 120
80 WRITE(ØUT3,35)
85 FØRMAT(//" TYPE ØF PACKING   CERAMIC ØR CARBØN INTALØ
&X SADDLES"/)
90 FØRMAT(//" TYPE OF PACKING   PLASTIC INTALØX SADDLES"
&/)
95 FØRMAT(//" TYPE ØF PACKING   CERAMIC ØR CARBØN RASCHI
&G RINGS"/)
100 FØRMAT(//" TYPE ØF PACKING  1/16 IN. WALL METAL RASC
&HIG RINGS"/)
105 FØRMAT(//" TYPE ØF PACKING   1/32 IN. WALL METAL RASC
&HIG RINGS"/)
110 FØRMAT(//" TYPE ØF PACKING   PLASTIC PALL RINGS"/)
115 FØRMAT(//" TYPE OF PACKING   METAL PALL RINGS"/)
120 GØTØ(125,130,135,140,145,150,155),IPKTP
125 WRITE(ØUT3,85)
A = 1
GOTØ 160
130 WRITE(ØUT3,90)
A = 2
GOTØ 160
135 WRITE(ØUT3,95)
A = 3
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GØTØ 160
140 WRITE(ØUT3,100)
A = 4
GØTØ 160
145 WRITE(ØUT3,105)
A = 5
GØTØ 160
150 WRITE(ØUT3,110)
A = 6
GØTØ 160
155 WRITE(ØUT3,115)
A = 7
160 X=(WLF/WGR) * (RHØG/RHØL) ** .5
IF(X-.5)165,165,170
165 XLW=ALØG(X)
Y=EXP(-.4168572E01-.1007839E01*XLN-.2231154E00*XLN**
&2-.1858140E-01*XLN**3)
IABCS=3
GO TO 185
170 IF(X-3.75)175,175,180
175 XLN=ALØG(X)
Y=EXP(-.4326525E01-.9312685E00*XLN-.1820800E00*XLN**2
&-.1132091E-01*XLN**3)
IABCS=2
GO TO 185
180 XLN=ALØG(X)
Y=EXP(-.4935951E01-.867569E00*XLN-.1522480E00*XLN**2
&-.9138094E-02*XLN**3)
IABCS = 1
185 GC = .417E09
YØNE = Y
PSI = 62.4/RHØL
NØRDI = 5
DØ 225 IFIL=1,NØRDI
 GØTØ(190,195,200,205,210,215,220),A
190 READ(IN11,14)(B(J),J=1,3)
GØTØ 225
195 READ(IN12,14)(B(J),J=1,3)
GØTØ 225
200 READ(IN13,14)(B(J),J=1,3)
GØTØ 225
205 READ(IN14,14)(B(J),J=1,3)
GØTØ 225
210 READ(IN15,14)(B(J),J=1,3)
GØTØ 225
215 READ(IN16,14)(B(J),J=1,3)
GØTØ 225
220 READ(IN17,14)(B(J),J=1,3)
225 CONTINUE
REWIND IN11
REWIND IN12
REWIND IN13
REWIND IN14
REWIND IN15
REWIND IN16
REWIND IN17
IF (IF-150.)230,230,235
230 UM = .1
GØTØ 240
235 UM = .2
GØTØ 240
 240 G = SQRT((YØNE*RHØG*RHØL*GC)/(F*PSI*VISCL**UM))
IF(IR)245,245,280
245 DIAM=1.13*(WGR/G)**.5
250 IF(IPKTP - 2)255,255,260
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255 PAKSZ=DIAM/15.
GØTØ 275
260 IF(IPKTP - 5)265,265,270
265 PAKSZ = DIAM/30.
GØTØ 275
270 PAKSZ = DIAM/12.
275 PAKSI = PAKSZ*12.
280 IF(PAKSI - 3.)290,285,285
285 PAKSI = 3.
NØRDI = 8
GØTØ 340
290 DØ 295 I=1,8
IF(PAKSI - D(I))300,300,295
295 CONTINUE
300 IF(IR)305,305,310
305 IF(ID)315,315,310
310 D(I) = PAKSI
NØRDI = I
GØTØ 340
315 IF(I - 1)320,320,325
320 PAKSI = .25
NØRDI= I
GØTØ 340
325 IF(IS4 - 2)330,335,335
330 PAKSI=D(I)
NØRDI=I
GØTØ 340
335 PAKSI = D(I - 1)
NØRDI = (I - 1)
340 DØ 380 IFIL=1,NØRDI
GO TO(345,350,355,360,365,370,375),A
345 READ(IN11,14)(B(J),J=1,3)
GØTØ 380
350 READ(IN12,14)(B(J),J=1,3)
GØTØ 380
355 READ(IN13,14)(B(J),J=1,3)
GØTØ 380
360 READ(IN14,14)(B(J),J=1,3)
GØTØ 380
365 READ(IN15,14)(B(J),J=1,3)
GØTØ 380
370 READ(IN16,14)(B(J),J=1,3)
GØTØ 380
375 READ(IN17,14)(B(J),J=1,3)
380 CONTINUE
REWIND IN11
REWIND IN12
REWIND IN13
REWIND IN14
REWIND IN15
REWIND IN16
REWIND IN17
F=B(IABCS)
IF (F) 455,385,455
385 IF(IR)390,390,395
390 IF(ID)400,400,395
395 WRITE(OUT3,50)
CHAIN"N41OPT"
400 IF(A - 7)405,435,405
405 IF(A - 6)410,435,410
410 IF(A - 5)415,440,415
415 IF(A - 4)420,430,420
420 IF(A - 3)425,430,425
425 IF(A - 2)430,435,430
430 IF(PAKSI - 3.)445,450,450
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435 IF(PAKSI - 2.)445,450,450
440 IF(PAKSI - 1.)445,450,450
445 I = I + 1
GOTØ 330
450 I = I - 1
GØTØ 330
455 IF(F - 150.)460,460,465
460 UM = .1
GØTØ 470
465 UM = .2
470 G=SQRT((Y*RHØG*RHØL*GC)/(IF*PSI*VISCL**UM))
IF(IR)475,475,540
475 IF(ID)480,480,540
480 IF(IS1 - 2)495,485,485
485 IF(IS4 - 2)495,490,490
490 DIAM = 1.13*(WGR/G)**.5
495 ND=DIAM
FD=ND
IN=(DIAM - FD)*12.
IF (DIAM - 3.)500,500,515
500 DØ 505 J=1,6
IF (IN - L(J))510,510,505
505 CØNTINUE
510 IN=L(J)
IF (IN - L(6))530,525,530
515 IF (IN - 6)520,520,525
520 IN=6
GØTØ 530
525 IN = 0
ND = ND + 1
530 DIAM=ND+(IN/12.)
IF(IPKTP - 6)535,540,540
535 IF(IPKTP - 3)540,540,545
540 XLN = ALØG(X)
YF=EXP(-.3827927E01-.1080819E01*XLN-.1176425E00*XLN*
&1*2+.2296566E-02*XLN**3)
GOTO 550
545 XLN = ALØG(X)
YF=EXP(-.3988496E01-.9940904E00*XLN-.1573365E00*XLN*
&*2-.7954698E-02*XLN**3)
550 GF=SQRT((YF*RHØG*RHØL*GC)/(F*PSI*VISCL**UM))
AREA=3.1416*(DIAM/2.)**2
VF=GF/(3600 * RHØG)
V=(WGR/3600.)/(RHØG*AREA)
PERFL=(V/VF)*100.
K = 0
IF(ID)555,555,645
555 IF(IFØAM)565,565,560
560 CALL MIKE
GØTØ 570
565 KI = 0
CALL JUDI
570 IF(IPKTP - 2)575,575,580
575 BEDH=6.*DIAM
GØTØ 595
580 IF(IPKTP - 5)585,585,590
585 BEDH = 2.6*DIAM
GØTØ 595
590 BEDH=7.*DIAM
GØTØ 595
595 CØNTINUE
600 IBEDH=BEDH
605 FØRMAT(" LIQUID FLOW RATE    =",F9.2,2X," PØUNDS PER
&HØUR"//" GAS
&FLOW RATE    =",F9.2,2X," PØUNDS PER HOUR"//" GAS DENSITY",9X,
```

```
&"=",F11.4," PØUNDS PER CUBIC FØØT"//" LIQUID DENSITY  =",F9.2,
&2X," PØUNDS PER CUBIC FOOT"//" LIQUID VISCØSITY  =",F9.2,2X,
&" CENTIPØISE"//" COLUMN PRESSURE  =",F11.4," PSIA"//" TEMPERATU
&RE   =",F9.2,2X," DEGREES KELVIN"/)
610 FØRMAT(" PACKING SIZE   =",F9.2,2X," INCHES"//" CØLUMN
&DIAMETER   =",2X,I3," FEET",2X,I3," INCHES"/)
615 FØRMAT(  "GAS DENSITY"9X,"=", F11.4," PØUNDS PER CUBIC
&FØØT"//" PRESSURE DRØP FØR RECCØMMENDED BED HEIGHT"/)
620 FØRMAT(" BED HEIGHT BASED ØN ","=",F9.2,4X,"FEET"/"
&HYDRAULIC CØNSIDERATIØNS"/)
625 FØRMAT(1H0,"TØTAL BED PRESSURE DRØP THRØUGH PACKING=",
&F7.3,2X,"INCHES ØF WATER")
630 FØRMAT(1H0,"SUPERFICIAL VAPØR VELØCITY",13X,"=",2X,F5.2,
&2X,"FEET/SEC.")
635 FØRMAT(1H0,"PERCENT ØF FLØØDING",20X,"=",2X,F5.2,2X,"
&PERCENT")
640 FØRMAT(1H0,I3, "FEET",2X,F8.3,2X,"INCHES ØF WATER")
TEMP2 = TEMP1
645 WRITE(ØUT3,605)WLF,WGR,RHØG,RHØL,VISCL,PSIA,TEMP2
WRITE(ØUT3,610)PAKSI,ND,IN
650 IF(IZ)655,655,665
655 IF(BEDH - 20.)665,665,660
660 BEDH = 20.
665 WRITE(ØUT3,620)BEDH
LL = 0
670 IF(LL)680,680,675
675 WRITE(ØUT3,605)WLF,WGR,RHØG,RHØL,VISCL,PSIA,TEMP2
WRITE(ØUT3,610)PAKSI,ND,IN
WRITE(ØUT3,620)BEDH
LL = 0
680 G=(WGR)/(DIAM/1.13)**2
AREA=3.1416*(DIAM/2.)**2
685 SUM=(PSIA/14.696)*407.14
JD = 0
KL = 0
M = 0
NL = 0
ID = 0
IR = 0
RHØGA = RHØG
TØP = PSIA
BØTBP = PSIA
690 NL = NL + 1
RHØGA=RHØGA*(BØTBP/(PSIA)*(TEMP1/TEMP2)
IF(KL)700,695,700
695 WRITE(ØUT3,615)RHØGA
KL = 1
700 X=(WLF/WGR)*(RHØGA/RHØL)**.5
XLN = ALØG(X)
705 Y=(G**2*F*PSI*VISCL**UM)/(RHØGA*RHØL*GC)
YX=EXP(-.6249128E01-.6162116E00*XLN-.1397602E00*XLN*
&*2-.1208522E-01*XLN**3)
DIFF = Y-YX
SDIFF = ABS(DIFF)
710 M = M + 1
IF(M - 11)715,715,815
715 GØTØ(720,725,730,735,740,745,750,755,760,765,770),M
720 YX=EXP(-.6249128E01-.6162116E00*XLN-.1397602E00*XLN*
&*2-.1208522E-01*XLN**3)
GØTØ 775
725 YX=EXP(-.5872896E01-.7226284E00*XLN-.1429932E00*XLN*
&*2-.1049381E-01*XLN**3)
GØTØ 775
730 YX=EXP(-.5485292E01-.7693485E00*XLN-.1346535E00*XLN*
&*2-.7927142E-02*XLN**3)
```

```
GØTØ 775
735 YX=EXP(-.5265190E01-.8076304E00*XLN-.1366381E00*XLN*
&*2-.7560742E-02*XLN**3)
GØTØ 775
740 YX=EXP(-.4935951E01-.8675696E00*XLN-.1522480E00*XLN*
&*2-.9138094E-02*XLN**3)
GØTØ 775
745 YX=EXP(-.4624282E01-.9174872E00*XLN-.1861755E00*XLN*
&*2-.1339159E-01*XLN**3)
GØTØ 775
750 YX=EXP(-.4326525E01-.9312685E00*XLN-.1820800E00*XLN*
&*2-.1132091E-01*XLN**3)
GØTØ 775
755 YX=EXP(-.4168572E01-.1007839E01*XLN-.2231154E00*XLN*
&*2-.1858140E-01*XLN**3)
GØTØ 775
760 YX=EXP(-.4024600E01-.9219081E00*XLN-.1583744E00*XLN*
&*2-.9222639E-02*XLN**3)
GØTØ 775
765 YX=EXP(-.3958496E01-.9940904E00*XLN-.1573365E00*XLN*
&*2-.7954698E-02*XLN**3)
GØTØ 775
770 YX=EXP(-.3827927E01-.1080819E01*XLN-.1176425E00*XLN*
&*2+.2296566E-02*XLN**3)
775 IF(JD)815,780,810
780 REM=Y-YX
SREM=ABS(REM)
SDIFF = SREM
IF(REM)790,790,785
785 DELTP = DPRES(M)
GØTØ 710
790 IF(M - 1)710,795,800
795 DELTP = DPRES(M)
GØTØ 815
800 IP = M - 1
JD = 1
PYX = YX
IF(IP)795,795,805
805 GO TO(720,725,730,735,740,745,750,755,760,765,770),IP
810 ALPHA=(Y - YX)/(PYX-YX)
DELTP=DPRES(M - 1)+ALPHA*(DPRES(M)-DPRES(M - 1))
JD = - 1
GØTØ 710
815 IF(DELTP - 2.01)830,820,820
820 WRITE(OUT3,45)
CHAIN "N41OPT"
825 WRITE(OUT3,55)
CHAIN "N41OPT"
830 IF(IPKTP - 5)835,835,840
835 YF=EXP(-.3827927E01-.1080819E01*XLN-.1176425E00*XLN*
&*2+.2296566E-02*XLN**3)
GØTØ 845
840 YF=EXP(-.3988496E01-.9940904E00*XLN-.1573365E00*XLN*
&*2-.7954698-02*XLN**3)
845 GF=SQRT((YF*RHØGA*RHOL*GC)/(F*PSI*VISCL**UM))
V=(WGR/3600.)/(RHØGA*AREA)
PERFL=(G/GF)*100
IF(PERFL - 100.)850,825,825
850 SUM=SUM+DELTP
WRITE(OUT3,640)NL,SUM
 BOTBP=(SUM/407.14)*14.696
RHØGA=RHØG*BOTBP/CPSIA
JD = 0
M = 0
IF(BEDH - NL)855,855,690
```

```
855 BEDPD = BØTBP - PSIA
DPH20=BEDPD/14.696*407.14
WRITE(ØUT3,625)DPH20
WRITE(ØUT3,630)V
WRITE(ØUT3,635)PERFL
860 FØRMAT(1H1)
WRITE(ØUT3,860)
865 CHAIN "N41ØPT"
STØP
END
*
SUBRØUTINE MIKE
INTEGER A,C
DIMENSIØN  B(3),D(8),L(6),DPRES(11)
CØMMØN DIAM,BEDH,IPKTP,PAKSI,C,D,L,DPRES,RHØG,RHØL,WLF,WGR,VISCL
&,PSIA,IFØAM,GC,PSI,X,Y,G,PERFL,UM,F,XLN,ND,IN,DPH20,V,A,B,NØRDI,
&IABCS,IBEDH,RHØGA,AREA,CPSIA,K,KI,GF,DF,TEMP1,TEMP2,BEDH1,YØNE,
&LL,IL,ID,IR,IZ,IS1,IS4
5 IF(PERFL-50.)70,10,10
10 XLN=ALØG(X)
K=K+1
GØ TO (15,20,25,30,35,40,45,50,55,60),K
15 Y=EXP(-.3988496E01-.9940904E00*XLN-.1573365E00*XLN**2
&-.7954698E-02*XLN**3)
GØ TØ 65
20 Y=EXP(-.4024600E01-.9219081E00*XLN-.1583744E00*XLN**2
&-.9222639E-02*XLN**3)
GØ TØ 65
25 Y= EXP(-.4168572E01-.1007839E01*XLN-.2231154E00*XLN**2
&-.185140E-01*XLN**3)
GØ TØ 65
30 Y=EXP(-.4326525E01-.9312685E00*XLN-.1820800E00*XLN**2
&-.1132091E-01*XLN**3)
GØ TØ 65
35 Y=EXP(-.4624282E01-.9174872E00*XLN-.1861755E00*XLN**2
&-.1339159E-01*XLN**3)
GØ TØ 65
40 Y=EXP(-.4935951E01-.8675696E00*XLN-.1522480E00*XLN**2
&-.9138094E-02*XLN**3)
GØ TØ 65
45 Y=EXP(-.5265190E01-.8076304E00*XLN-.1366381E00*XLN**2
&-.7560742E-02*XLN**3)
GØ TØ 65
50 Y=EXP(-.5485292E01-.7693485E00*XLN-.1346535E00*XLN**2
&-.7927142E-02*XLN**3)
GØ TØ 65
55 Y=EXP(-.5872896E01-.7226284E00*XLN-.1429932E00*XLN**2
&-.1049381E-01*XLN**3)
GØ TØ 65
60 Y=EXP(-.6249128E-01-.6162116E00*XLN-.1397602E00*XLN**2
&-.1208522E-01*XLN**3)
65 G=SQRT((Y*RHØG*RHØL*GC)/(F*PSI*VISCL**UM))
PERFL=(G/GF)*100.
GØ TØ 5
70 RETURN
END
*
SUBRØUTINE JUDI
INTEGER A,C
DIMENSIØN B(3),D(8),L(6),DPRES(11)
CØMMØN DIAM,BEDH,IPKTP,PAKSI,C,D,L,DPRES,RHØG,RHØL,WLF,WGR,VISCL
&,PSIA,IFØAM,GC,PSI,X,Y,G,PERFL,UM,F,XLN,ND,IN,DPH20,V,A,B,NØRDI,
&IABCS,IBEDH,RHØGA,AREA,CPSIA,K,KI,GF,DF,TEMP1,TEMP2,BEDH1,YØNE,
&LL,IL,ID,IR,IZ,IS1,IS4
5 IF(PERFL-20.)10,70,70
10 KI=KI+1
```

```
GØ TØ (15,20,25,30,35,40,45,50,55,60),KI
15 Y=EXP(-.6249128E01-.6162116E00*XLN-.1397602E00*XLN**2
&-.1208522E-01*XLN**3)
GØ TØ 65
20 Y=EXP(-.5872896E01-.7226284E00*XLN-.1429932E00*XLN**2
&-.1049381E-01*XLN**3)
GØ TØ 65
25 Y=EXP(-.5485292E01-.7693485E00*XLN-.1346535E00*XLN**2
&-.7927142E-02*XLN**3)
GØ TØ 65
30 Y=EXP(-.5265190E01-.8076304E00*XLN-.1366381E00*XLN**2
&-.7560742E-02*XLN**3)
GØ TØ 65
35 Y=EXP(-.4935951E01-.8675696E00*XLN-.1522480E00*XLN**2
&-.9138094E-02*XLN**3)
GØ TØ 65
40 Y=EXP(-.4624282E01-.9174872E00*XLN-.1861755E00*XLN**2
&-.1339159E-01*XLN**3)
GØ TØ 65
45 Y=EXP(-.4326525E01-.9312685E00*XLN-.1820800E00*XLN**2
&-.1132091E-01*XLN**3)
GØ TØ 65
50 Y=EXP(-.4168572E01-.1007839E01*XLN-.2231554E00*XLN**2
&-.1858148E-01*XLN**3)
GØ TØ 65
55 Y=EXP(-.4024600E01-.9219081E00*XLN-.1583744E00*XLN**2
&-.9222639E-02*XLN**3)
GØ TØ 65
60 Y=EXP(-.3988496E01-.9940904E00*XLN-.1573365E00*XLN**2
&-.7954698E-02*XLN**3)
65 G=SQRT((Y*RHØG*RHØL*GC)/(F*PSI*VISCL**UM))
PERFL=(G/GF)*100.
GØ TØ 5
70 RETURN
END
```

```
WHAT?
ØLD
ENTER FILE NAME-N41OPT
READY
LISTNH

10000* N41OPT      CONTIANS OPTION BRANCHES FOR PROGRAM N41
10010 INTEGER A,C
10020 DIMENSION B(3),D(8),L(6),DPRES(11)
10030 COMMON DIAM,BEDH,IPKTP,PAKSI,C,D,L,DPRES,RHOG,RHOL,WLF,WGR,VISCL
10040&,PSIA,IFOAM,GC,PSI,X,Y,G,PERFL,UM,F,XLN,ND,IN,DPH2O,V,A,B,NORDI,
10050&IABCS,IBEDH,RHOGA,AREA,CPSIA,K,KI,GF,DF,TEMP1,TEMP2,BEDH1,YONE,
10060&LL,IL,ID,IR,IZ,IS1,IS4
10080 FILENAME IN2,OUT3
10120 IN2="      ";OUT3="
10130 WRITE(OUT3,5)
10140 5 FORMAT(" TYPE 1 TO CHANGE COLUMN DIAMETER",/" TYPE 2 TO CHANGE
10150& BED HEIGHT",/" TYPE 3 TO CHANGE TYPE OF PACKING",/" TYPE 4 TO
10160& CHANGE PACKING SIZE",/" TYPE 5 TO CHANGE LIQUID FLOW RATE",/"
10170& TYPE 6 TO CHANGE GAS FLOW RATE",/" TYPE 7 TO CHANGE TEMPERATURE
10180& AND PRESSURE",/" TYPE 8 TO TERMINATE PROGRAM",//)
10190 READ(IN2,10)IJK
10200 10 FORMAT(V)
10210 GO TO(100,115,180,200,220,235,260,265),IJK
10220 100 WRITE(OUT3,35)
10230 35 FORMAT(" TYPE COLUMN DIAMETER. USE DECIMAL POINT",/)
10240 READ(IN2,10)DIAM
10250 ND=DIAM
10260 FD=ND
10270 IN=(DIAM-FD)*12.
10280 LL=1
10290 C=1
10300 ID=0
10310 IR=0
10315 IS1=1
10320 CHAIN "N41"
10330 115 BEDH1=BEDH
10340 WRITE(OUT3,105)
10350 105 FORMAT(" TYPE BED HEIGHT. USE A DECIMAL POINT",/)
10360 READ(IN2,10)BEDH
10370 IF(BEDH-BEDH1)160,160,120
10380 120 WRITE(OUT3,35)
10390 35 FORMAT(" THE  BED HEIGHT PROPOSED IS GREATER THAN THE MAXIMUM
10400&",/" ALLOWABLE BED HEIGHT. TYPE 1 IF YOU WISH TO USE THIS BED
10410& HEIGHT",/" TYPE 2 TO USE MAXIMUM BED HEIGHT. TYPE 3 TO GO BELOW
10420& MAXIMUM",/" BED HEIGHT",/)
10430 READ(IN2,10)IJK
10440 GO TO(160,140,155),IJK
10450 140 BEDH=BEDH1
10460 GO TO 160
10470 160 LL=0
10480 C=Z
10490 ID=0
10500 IR=0
10510 IZ=1
10520 CHAIN "N41"
10530 155 WRITE(OUT3,145)
```

```
145 FØRMAT(TYPE NEW BED HEIGHT. USE A DECIMAL PØINT",/)
READ(IN2,10)BEDH
GØ TØ 160
180 WRITE(ØUT3,11)
11 FØRMAT(" THE INTEGER CØNSTNATS FØR THE PACKING TYPES ARE:",/
&" 1 CERAMIC ØR CARBØN INTALØX SADDLES",/" 2 PLASTIC INTALØX SADD
&LES",/" 3 CERAMIC ØR CARBØN RASCHIG RINGS",/" 4 1/16 IN WALL MET
&AL RASCHIG RINGS",/" 5 1/32 IN WALL METAL RASCHIG RINGS",/" 6
&PLASTIC PALL RINGS",/" 7 METAL PALL RINGS",//" TYPE THE INTEGER
&FØR THE DESIRED PACKING",//)
READ(IN2,10)IPKTP
LL=0
C=3
ID=0
IR=1
CHAIN "N41"
200 WRITE(ØUT3,185)
185 FØRMAT(" TYPE PACKING SIZE. USE A DECIMAL PØINT",/)
READ(IN2,10)PAKSI
LL=0
C=4
ID=1
IR=0
IS4=1
CHAIN "N41"
220 WRITE(ØUT3,205)
205 FØRMAT(" TYPE  LIQUID FLØW RATE. USE A DECIMAL PØINT",/)
READ(IN2,10)WLF
LL=0
C=5
ID=0
IR=0
CHAIN "N41"
235 WRITE(ØUT3,225)
225 FØRMAT(" TYPE GAS FLØW RATE. USE A DECIMAL PØINT",/)
READ(IN2,10)WGR
LL=0
C=6
ID=0
IR=0
CHAIN "N41"
260 WRITE(ØUT3,240)
240 FØRMAT(" TYPE CØLUMN PRESSURE. USE A DECIMAL PØINT",/)
READ(IN2,10)PSIA
WRITE(ØUT3,241)
241 FØRMAT(" TYPE CØLUMN TEMPERATURE. USE A DECIMAL PØINT",/)
READ(IN2,10)TEMP2
LL=1
C=7
ID=0
IR=0
CHAIN "N41"
265 STØP
END


WHAT?
OLD
ENTER FILE NAME-N41SINTP
READY
LISTNH
SERVICE TEMPORARILY INTERRUPTED.  PLEASE CALL BACK IN 5 MINUTES.
```

```
212-425-6568

GE MARK II  T/S FROM NEW JERSEY 005
TERMINAL 007 ON AT 14:56  03/11/70
USER NUMBER--TAJ03010,CENG
PROJECT ID--91500
SYSTEM--FOR
NEW OR OLD--OLD
ENTER FILE NAME-N41SINTP
READY
KEY

READY
LISTNH


10000          0.,0.,0.
10010          330.,330.,330.
10020          200.,200.,200.
10030          130.,135.,145.
10040          84.,91.,98.
10050          39.,49.,52.
10060          31.,34.,40.
10070          20.,20.,22.
OLD
ENTER FILE NAME-N41SINTR
READY
LISTNH


10000          0.,0.,0.
10010          0.,0.,0.
10020          0.,0.,0.
10030          0.,0.,0.
10040          32.,32.,32.
10050          0.,0.,0.
10060          21.,21.,21.
10070          14.,14.,14.
OLD
ENTER FILE NAME-N41RSRC
READY
LISTNH


10000          1600.,1600.,1600.
10010          1000.,1000.,1000.
10020          580.,580.,580.
10030          210.,255.,255.
10040          120.,155.,160.
10050          65.,95.,95.
10060          50.,65.,65.
10070          37.,37.,37.
```

```
ENTER FILE NAME-N41D
READY
LISTNH


10000     .25
10010     .375
10020     .5
10030     .75
10040     1.0
10050     1.5
10060     2.0
10070     3.0
ØLD
ENTER FILE NAME-N41PALRP
READY
LISTNH


10000               0.,0.,0.
10010               0.,0.,0.
10020               97.,97.,97.
10030               0.,0.,0.
10040               52.,52.,52.
10050               32.,32.,32.
10060               25.,25.,25.
10070               0.,0.,0.
ØLS←D
ENTER FILE NAME-N41RSRM6
FILE NOT SAVED
READY
ØLD
ENTER FILE NAME-RSR
FILE NOT SAVED
READY
OLDD
ENTER FILE NAME-N41RSRM3
READY
LISTNH


10000               0.,0.,0.
10010               390.,390.,390.
10020               300.,300.,300.
10030               170.,170.,170.
10040               115.,115.,115.
10050               0.,0.,0.
10060                0.,0.,0.
10070               0.,0.,0.
OLD
ENTER FILE NAME-N41PALRP
READY
LISTNH


10000               0.,0.,0.
10010               0.,0.,0.
10020               97.,97.,97.
10030               0.,0.,0.
10040               52.,52.,52.
10050               32.,32.,32.
10060               25.,25.,25.
10070               0.,0.,0.
```

```
ØLD
ENTER FILE NAME-N41PALRM
READY
LISTNJ-H


10000              0.,0.,0.
100020
10010              0.,0.,0.
10020              0.,0.,0.
10030              70.,70.,70.
10040              42.,52.,52.
10050              31.,36.,28.
10060              20.,25.,25.
10070              0.,0.,0.
OLD
ENTER FILE NAME-N41L
READY
LISTM-NH


10000       2
10010       4
10030       6
10040       8
10050       10
10060       12
OLD
ENTER FILE NAME-N41DPRES
READY
LISTNH


10000        .05
10010        .07
10020        .10
10030        .15
10040        .25
10050        .35
10060        .50
10070        .75
10080        1.0
10090        1.5
10100        2.0
BYE
0000.33   CRU     0000.20   TCH     0003.33   KC

OFF AT 15:08  03/11/70
```

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