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DELAWARE
SHELL AND TUBE HEAT EXCHANGER RATING AND DESIGN

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DELAWARE
SHELL AND TUBE HEAT EXCHANGER
RATING AND DESIGN

INTRODUCTION

The microcomputer program, DELAWARE, is an interactive program intended to be of assistance to the user in the rating and design of shell and tube heat exchangers. Figure 1 is a sketch of such a unit.

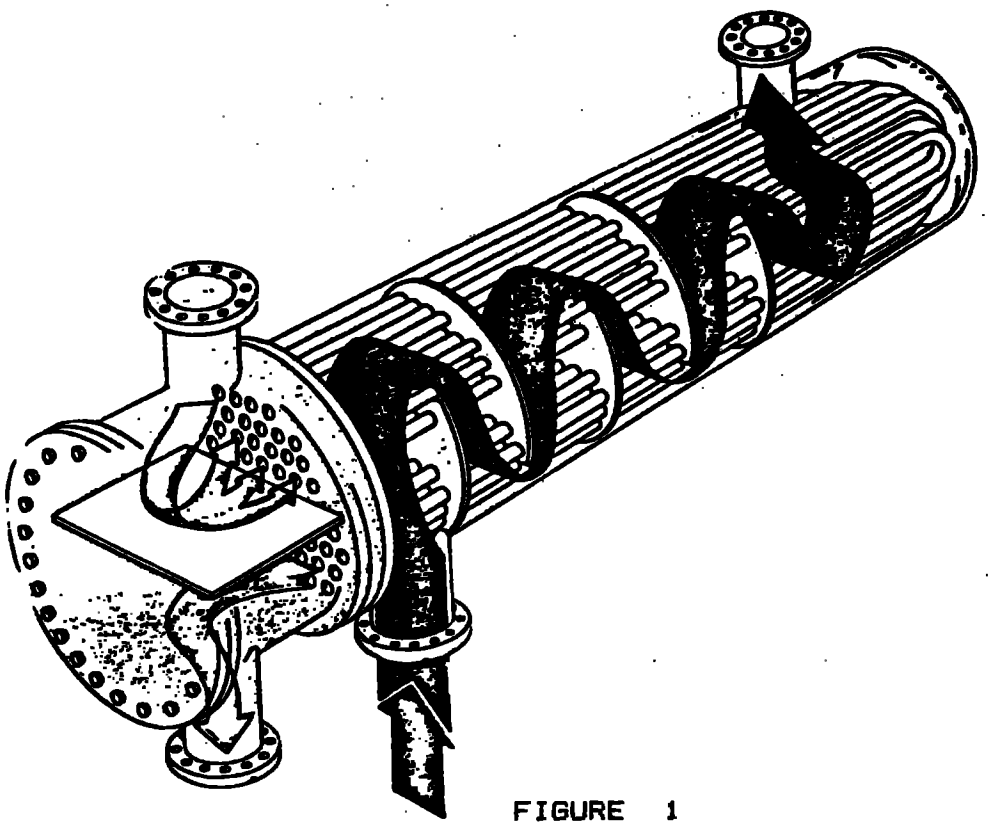

FIGURE 1

The user of the code is expected to have a background of heat transfer equivalent to a junior level course. Use of the software requires user response to prompts which ask for a variety of geometrical and fluid property information needed in the rating and design processes.

Appendix A of this document provides additional information specific to shell and tube exchangers which should be understood by the user before embarking on extended use of the program. However, to make it easier to get acquainted with the program, two sets of default data have been included in the program so that it may be used in a somewhat passive way for the first time. The first set of data present a rating problem whose solution is to be worked out while the second set provide a design problem for which an initial design is suggested. Use of the program on a particular design will require considerable preparation of the input data prior to using the computer.

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The program contains a reminder of some of the materials included in Appendix A to assist the user on the first few usages. There are also provisions to allow rapid movement to the data input portions without being hindered by these explanations.

As the program proceeds, some of the parametrs being calculated will be displayed on the CRT. At the conclusion of each rating run, an input data summary will be displayed and the major results will be shown on the monitor. Hardcopy output to a line printer is also an option at that point as shown in Figure 2.

The microcomputer program is written in MICROSOFT BASIC (1)) language. The graphics kernal was authored by Charles D. Hoover III(2) and the input routines were written by William J.Comfort(3).

The control of the processing of information resides in a main program"DELAWARE" which alternately merges and deletes subroutines needed for instruction to the user, input of data, calculations, and output of results.

The following is a list of the various routines used in the program:

NUMBER RANGE	ROUTINE	FUNCTION
1-1000	DELAWARE	Main program
1001-1500	DOUBIN	Provides background information
1501-2000	RASSIGN	Assigns symbols and prompts for rating variables
2001-2600	RVARB	Inputs default values for rating test or relates to the input system.
2901-3000	PAR	Sets up parameters used in rerunning data and making output.
3001-4000	CALC	Calc main rating parameters
4001-5000	IDELTUBE	Calc HT and PRESS DROP for ideal tube bank
5001-5500	SHELHTDP	Calc pred shell and tube results
7001-7300	MCIO	Input routine for multiple choice questions
8010-8560	MVWIO	Input routine for variable input and change
10001-11000	DELOUT	Line printer output of rating results
11001-12000	CRTOUT	CRT output of rating results
14001-14300	FLMTD	Calc corrections to log mean temp diff
15001-15300	DASSIGN	Assigns symbols and prompts for design var.
16001-16300	DVARB	Inputs default values to design test or relates to input system
17001-17700	DEOG	Makes initial design choices for design run

Appendix B provides a detailed listing of these routines.

EXECUTION OF THE PROGRAM

The MBASIC interpreter must be loaded, followed by the execution of DELAWARE. The specific steps which should be followed are:

1. Insert the proper diskette
2. Switch on the power
3. Load the BASIC interpreter:
   A>MBASIC
4. Execute the main program:
   RUN"DELAWARE"

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INPUT INFORMATION:

SYMBOL		VALUE	SYMBOL		VALUE	SYMBOL		VALUE
1	DS	591	2	DT	16	3	LTW	1.24
4	KTW	42	5	LTP	20.8	6	THETATP	30
7	LTO	2394	8	LTI	2276	9	BC	24
10	LBC	250	11	LBI	263	12	LBO	263
13	NTT	652	14	NTP	2	15	NSS	0
16	LTB	.5	17	LSB	5.5	18	LBB	10
19	TSI	89.8	20	TSO	147.3	21	TTI	178
22	TTO	178	23	MS	22.4	24	RHOS	740
25	KSF	.105	26	CPS	2407	27	MUS1	.0006
28	TSV1	90	29	MUS2	.0003	30	TSV2	190
31	RFO	0	32		0	33	MT	0
34	RHOT	0	35	KTF	0	36	CPT	0
37	MUT1	0	38	TTV1	0	39	MUT2	0
40	TTV2	0	41	RFI	0	42	ALPHAS	1000
43	ALPHAT	6000	44	PDMS	0	45	PDMT	0
46	VMAXT	0	47	VMINT	0	48		0

DELAWARE OUTPUT INFORMATION **********

SHELL SIDE HEAT TRANSFER COEF. PREDICT-W/M^2 K 1336.8
JC= 1.02282 JR= 1 JL= .66321
JS= .993077 JB= .864519 JTOT= .582382
TUBE SIDE HEAT TRANSFER COEF. PREDICT-W/M^2 K 6000

TOTAL SHELL SIDE PRESSURE DROP DPS ,KPa 12.9948
END ZONE PRESS DROP DPE ,KPa 2.97418
BAFFLE WINDOW PRESS DROP DPW ,KPa 6.37437
CROSSFLOW PRESS DROP DPC ,KPa 3.64629
RL= .426969 RB= .649909 RS2= 1.82558
TUBE SIDE PRESSURE DROP ,kPa 0

SHELL ID ,mm= 591 TUBE OD,mm= 16 TUBE LENGTH= 2394
C BAFFLE SPACE= 250 NO OF BAFFLES= 8 AREA= 74.5915

NO OF TUBES 652 PREDICTED NO OF TUBES FOR SHELL DIA 634
OVERALL TUBE LENGTH 2394 U(OVERALL)= 1057.87 W/M^K
SHELL SIDE REYNOLDS NO. 21116.5 RESIST SHELL SIDE= .791347 %
SHELL SIDE PRANDTL NO. 11.086 RESIST TUBE SIDE= 0 %
TUBE SIDE REYNOLDS NO. 0 RESIST TUBE WALL= .208653 %
TUBE SIDE PRANDTL NO. 0 RESIST TUBE FOUL= 0 %
LOG MEAN TEMP DIFF,C 54.4846 RESIST SHELL FOUL= 0 %

DESIGN LOAD= 0 WATTS PREDICTED LOAD= 4.29928E+06 WATTS
AREAS OF CAUTION: (Q=U*A*LMTD*FLMTD)

TUBE SIDE DATA ARE MEANINGLESS IN THIS TEST RUN

FIGURE 2

ACKNOWLEDGEMENT

The author is pleased to be able to take part in the project. Special thanks are due to W.J.Comfort for his support and guidance in the preparation of this material and for his leadership in developing the goals involved. This work has been supported by the Northwest College and University Association for Science (NORCUS).

REFERENCES

1.Microsoft, Inc., Microsoft BASIC User's Guide, Bellevue,WA,1981.

2.Comfort, William J. III. "Console Input-output Routines", Internal Publication of the Lawrence Livermore National Laboratory, 1982.

3.Kern, Donald Q.,"Process Heat Transfer"McGraw-Hill ,1950.

4.Engineering Sciences Data Unit #67016,68007 and 68008, 4.Hamilton Place, London, W.1.

5.Taborek,J."Shell-and-Tube Heat Exchangers:Single-Phase Flow" Section 3.3 of Heat Exchanger Design Handbook ,Hemisphere,1983.

APPENDIX A

INTRODUCTION

DELAWARE is designed to give the user an opportunity to learn some elementary facts about the construction,"rating" and design of a simple shell and tube heat exchanger similiar to that shown in Figure 1.

Many different shell and tube exchanger configurations are presently available as shown in the Tubular Exchanger Manufacturers Association(TEMA) notation definition in Figure 3. They may be used in a variety of different types of service. The user is cautioned that in its present form, DELAWARE is limited to a special, but common, class of shell and tube heat exchangers. Although extension to other cases is possible, it is considered outside the scope of this work. Briefly, DELAWARE may be used to "rate"single shell pass(TEMA Type E) heat exchangers with single phase flow in both the shell and tube passes. By iterative use of the "rating" approach it is possible to do the design of an exchanger of the type described above. This will involve careful changing of the various parameters to arrive at a design which has optimized the geometry for the desired duty.

A "rating" procedure is one that evaluates the heat transfer and pressure drop performance of a specified geometry of heat exchanger. To rate a given exchanger requires the complete specification of all of the geometrical properties of that exchanger. The problem of designing an exchanger is one of selecting the one exchanger which will have satisfactory heat transfer and pressure drop characteristics while optimizing the other variables including cost.

The software has built in warnings to the user when variables of the design depart greatly from what has become good practice. However, the user must still be alert to the variations which must be made to achieve an optimum design.

A typical shell and tube heat exchanger configuration is shown in Figure 1. This shows a single shell pass, U tube heat exchanger with five baffles. The tube fluid comes in the left end,entering through an upper nozzle into a chamber where it is forced to flow into the ends of half of the tubes in the exchanger. As the tube fluid reaches the right end of the exchanger the U tube configuration requires the tube fluid to return to the left end of the exchanger through the other half of the tubes and exit through a nozzle at the bottom of the left end of the exchanger. The tube fluid passes through the exchanger twice-- a two tube pass exchanger.

In the exchanger shown in Figure 1 the shell fluid enters the shell near the left end and is forced by baffles to flow across the tubes. The baffles are placed in the exchanger to support the tubes and make the shell side fluid move in this tortuous path. The shell fluid enters at one end of the shell and leaves at the other --one shell pass.

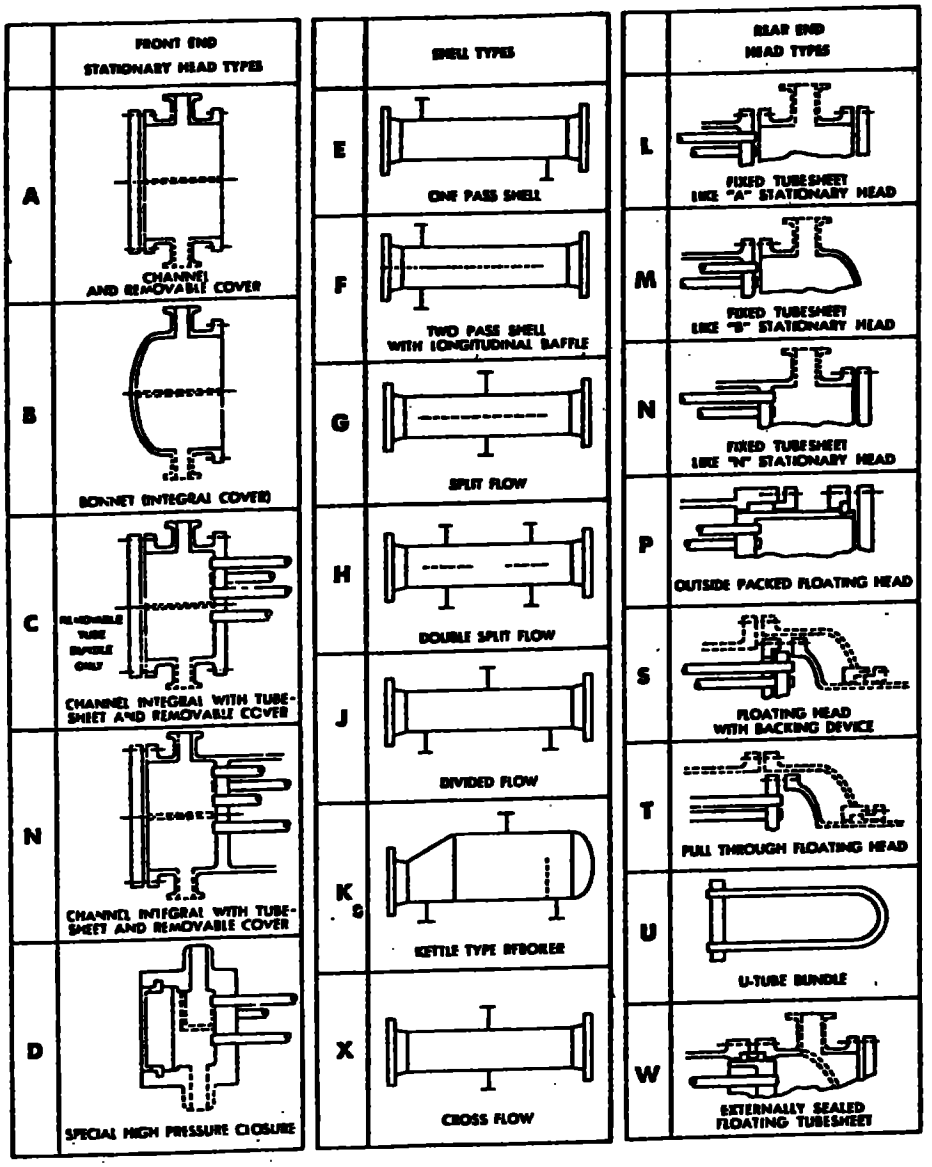


FIGURE 3 TEMA NOTATION FOR SHELL AND TUBE EXCHANGERS

Although moderate increase in contact area between the shell fluid and the tube surface may be accomplished by using fins on the outside of the tubes, the amount of this kind of improvement in area that may be obtained is relatively small. As a consequence, shell and tube exchangers are best used in applications where the shell side and the tube side resistances are of approximately the same magnitude.

Major problems related to the use of shell and tube exchangers are:

a) selection of which fluid should be used in the shell,
b) methods of allowing for thermal expansion of the parts,
c) methods of cleaning the surfaces, and
d) methods of protecting the tubes from erosion at the inlet.

Discussion of some of these factors will be carried out in the following sections.

If all other factors are equal, it will be advantageous to put a high pressure fluid inside the tubes rather than in the shell because the resulting stresses can be handled more cheaply in the relatively thin walled tubes than in the thicker walled shell.

If a fluid is corrosive and requires a special material to contain it, it will usually be cheaper to place the corrosive material inside of the tubes because a smaller amount of the more expensive material may be used this way.

If fouling is a problem with one fluid but not the other, that fluid which will cause fouling should probably be placed inside the tubes because of the greater ease of cleaning the inside of the tubes.

Shell side cleaning may be either chemical or mechanical. Especially if mechanical methods are to be used for shell side cleaning, it is necessary that the tube layout be such that access to the interior of the bundle can be made with cleaning rods etc. from the shell side. This usually requires an "in line" tube arrangement which has poorer heat transfer characteristics than staggered arrangements, and larger spacing of the tubes (which allows for fewer tubes in a given volume). See Figure 4

Generally the higher viscosity fluid would be used on the shell side unless that will cause laminar flow on the shell side.

The simplest type of shell and tube exchanger makes use of fixed tube sheets which hold the two ends of the tubes used in the exchanger. This tube arrangement is as if a tube sheet similar to that shown on the left end of Figure 1 were used on the right end as well. This approach may be used only if the differential expansion is kept low by the selection of materials and the temperature ranges of operation or if shell side expansion is provided.

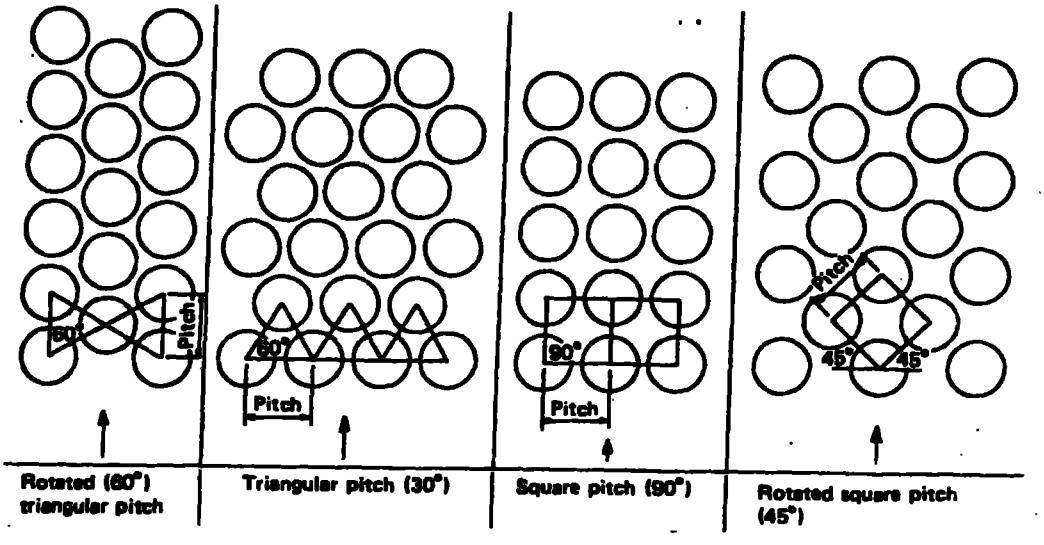


FIGURE 4

A U tube exchanger is probably the simplest means of solving the expansion problem. This uses tubes which are fixed to only one tube sheet by using a U bend at one end of the exchanger as shown in Figure 1. A variety of other expansion schemes are possible usually requiring special packing and/or sealing techniques as shown in Figure 3.

Erosion of the material of the tubes may occur at the inlet nozzle location if no provision is made to prevent it. Figure 5 shows a cross section of an exchanger. In the region just in front of the inlet nozzle, a plate has been placed to slow the fluid which would otherwise impact the tubes. In other cases a series of rods may be placed where the tubes would otherwise be. In either case the number of tubes within the shell will be less than if these steps were not taken. It will be necessary to make an allowance for this in selecting the number of tubes to be used in a given shell.

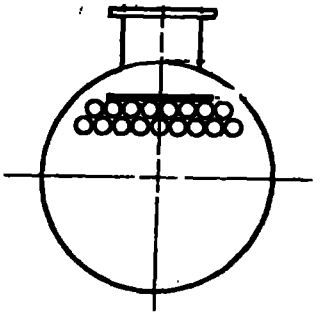


FIGURE 5

PREDICTION OF PERFORMANCE

The prediction of the performance of a shell and tube heat exchanger may be broken into the prediction of the heat transfer and pressure drop of the shell side and the tube side. These predictions for the tube side are relatively simple because the flow is little more than a set of parallel flows through straight tubes. On the shell side, however, the flow is not as clearly defined and does not lend itself to modeling as simply as the tube side.

After considerable testing a research group at the University of Delaware has proposed a rating method for the shell side which has its basis in the concept of an ideal tube bank together with corrections which allow for leakage and bypass around some of the heat transfer surfaces.

Imagine, for the moment, a heat exchanger such as the one in Figure 1 in which all of the shell fluid is forced to flow in the sinuous path shown by the heavy line on the shell side. In this path the fluid flows alternately normal to the tubes and then through the "window" in the baffles. In such an ideal tube bank all fluid should be effective from a heat transfer standpoint.

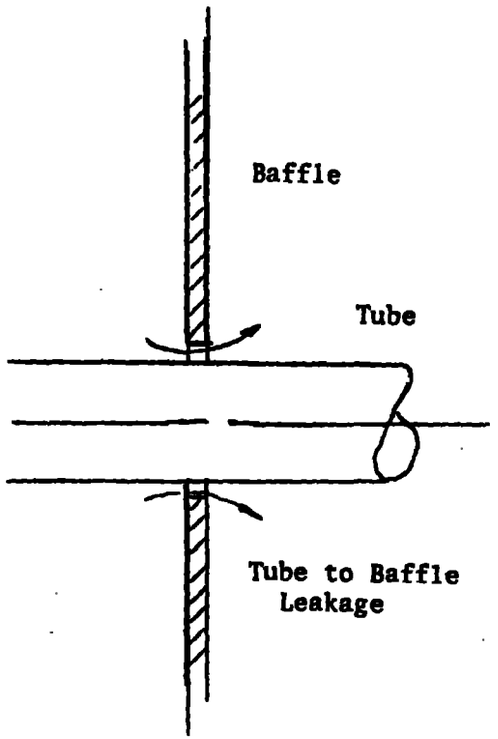
In an actual heat exchanger of this type there are several bypass and leakage paths which allow the shell fluid to get from one end of the shell to the other with decreased effectiveness. For example:

a) In order to put the tubes through the holes in the baffles, a small amount of clearance must exist. That is, the hole in the baffle must be larger than the tube which fits through it-- so that the tube may be put in. See Figure 6A .When this occurs the heat transfer will tend to be high at these points because of the high velocity, but there is a net loss because the fluid short circuits around the normal flow over the tubes.

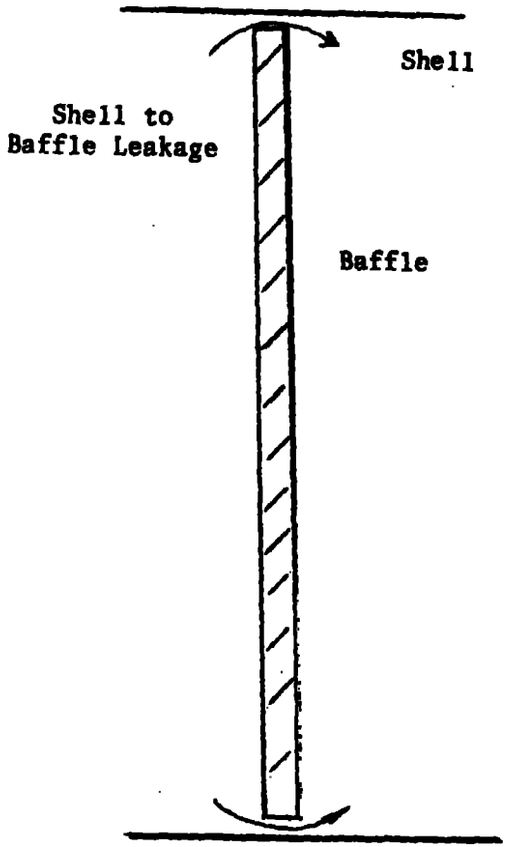
b) In order that the baffles may be slid into the shell, the baffles must have a smaller diameter than the inside of the shell. Leakage of fluid through this area is not as effective as that which leaks between the tubes and the baffle because the velocity associated with this flow is not effective on a boundary layer on a heat exchange surface. See Figure 6B.

c) Because the tubes may not be placed as closely near the shell surface as they are in the interior of the bundle, fliud may bypass around the tube bundle near the shell and not be active in heat exchange with the tubes. This bypass also represents a loss compared to the ideal heat exchanger. See Figure 6C.

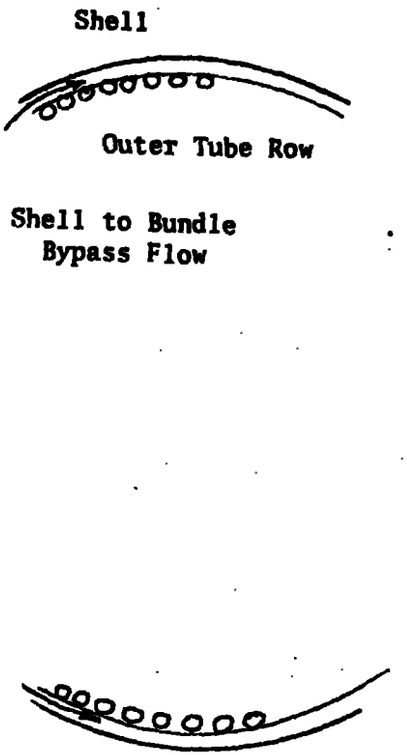
The Delaware method calculates a predicted heat transfer and pressure drop through an ideal tube bank and uses correction factors to allow for leakage and bypass as described.



6A



6B



6C

FIGURE 6 LEAKAGE AND BYPASS FLOWS

RATING AN EXCHANGER

The input variables needed to "rate" a specific shell and tube heat exchanger are shown in Figure 7. Some of these variables relate to the tube side flow or are input as an indication of a possible design limitation to be used in comparison at the completion of the rating run and need not be fixed for a rating run. It is recommended that all other variables be clearly established before attempting to start a rating procedure. (In order to allow the user to get familiar with the program as soon as possible, the rating portion of the program may be run with default input values. These input values have been taken from an example calculated by Jerry Taborek in the Heat Exchanger Design Handbook(5),section 3.3.9 and have been used to test the rating program. Output of this rating program which includes the values of the input variables, is shown in Figure 2. The tube side variables are set to zero in this test.
The rating input requests two values of the viscosity for each fluid so that when the temperature range is high enough to cause property variations with temperature, there may be a means of estimating that variation. If the user puts in the same value for the two temperatures requested, it will be assumed that the viscosity is constant.

Because the computer does so many calculations without the awareness of the user, it is possible(in fact probable) that the user will have difficulty in obtaining a clear vision of the physical relationships. Do not lose sight of the fact that changes that are made must be consistent. For example, as the size of the shell changes it is logical that the number of tubes within it will change. As the overall tube length changes so will the baffled length. If the tube pitch is increased for a fixed shell size, the number of tubes will need to change.
The program does have warnings about some of these things, but the user should continue to be alert to these possibilities.

The angle THETATP is selected early in the process. It describes the tube layout pattern as seen in Figure 4.
A value of 30 deg provides the most compact arrangement of tubes and a high heat transfer effectiveness, but does not allow for mechanical shell side cleaning. The 45 deg arrangement is not as compact, has high effectiveness and has good mechanical cleaning properties. A 90 deg arrangement is poor in laminar flow but ok in turbulent flow and has good mechanical cleaning characteristics. a 60 deg arrangement is not recommended.

ITEM	SYMBOL	NAME AND DIMEN.	SUGGESTIONS
1	DS	SHELL ID, mm	STD PIPE SHELLS:5-21 INCH NOM;LARGER ROLLED SHELLS
2	DT	TUBE OD, mm	TUBE OD: .25,.375,.50,.625,.75,.875,1.0,1.25,2.0 INCHES
3	LTK	TUBE WALL THICKNESS, mm	SEE TABLE OF RECOMMENDED TUBE DIMENSIONS
4	KTW	THERMAL COND OF TUBE , W/MK	CU=310; AL=180; ADMIRALTY=120; CARBON STEEL=38;,TI=18
5	LTP	TUBE LAYOUT PITCH,mm	1.25<(LTP/DT)<1.5; MECH CLEANING OF SHELL SIDE REQUIRES :LTP>6.3 mm
6	THETATP	TUBE LAYOUT ANGLE DEG	SEE WRITE UP FOR DISCUSSION
7	LTO	OVERALL TUBE LENGTH-NOMINAL,mm	FIXED BY THE TOTAL AREA NEEDED AND BY NO. OF TUBES--A VARIABLE OF THE DESIGN
8	LTI	BAFFLED TUBE LENGTH,mm	LTI=LTO-2LTS;SUGGEST LTI=LTO-.2*DS
9	BC	BAFFLE CUT % OF DS	FOR NON PHASE CHANGE BC=20+17*(LBC/DS-.2)/.6-----(LBC IS CENTRAL BAFFLE SPACING;
10	LBC	CENTRAL BAFFLE SPACING,mm	.3<(LBC/DS)<.6; NOTE;(NB-1)*LBC+LBI+LBO=LTO,NB,#BAFFLES WILL BE CALC LATER
11	LBI	INLET BAFFLE SPACING,mm	FOR PRELI WORK SET TO LBC
12	LBO	OUTLET BAFFLE SPACING,mm	FOR PRELI WORK SET TO LBC
13	NTT	TOTAL NO OF TUBES	(TOTAL NO OF HOLES IN TUBE SHEETS)/2---TUBE COUNT TABLES ARE AVAILABLE
14	NTP	NUMBER OF TUBE PASSES	SUGGEST MIN TUBES/PASS=8; A FUNC OF PRESS DROP
15	NSS	NO OF PAIRS OF SEALING STRIPS	CONSIDER IF LBB >30mm
16	LTB	TUBE TO BAFFLE CLEAR(DIA),mm	FOR DRILLED HOLES .4mm-.8mm
17	LSB	SHELL TO BAFFLE CLEAR(DIA),mm	TEMA AVERAGE:LSB=1.6+.004*DS FOR ADDED CLEARANCE:LSB=3.1+.004*DS
18	LBB	SHELL TO BUNDLE BYPASS CLR(DIA),mm	FIXED TUBESHEET:15-25mm OR SEE WRITEUP
19	TSI	SHELL SIDE INLET TEMP, DEG C	DESIGN INFORMATION
20	TSO	SHELL SIDE OUTLET TEMP, DEG C	DESIGN INFORMATION
21	TTI	TUBE SIDE INLET TEMP,DEG C	DESIGN INFORMATION
22	TTO	TUBE SIDE OUTLET TEMP,DEG C	DESIGN INFORMATION
23	MS	SHELL SIDE MASS FLOW RATE,KG/S	DESIGN INFORMATION
24	RHOS	SHELL FLUID DENSITY, KG/M**3	TABLES
25	KSF	SHELL FLUID THERM COND,W/M K	TABLES
26	CPS	SHELL FLUID SP HT ,J/KG K	TABLES
27	MUS1	SHELL FLUID VISC AT TSAV,Pa S	OBTAIN BEST SHELL FLUID VISC DATA NEAR TSAV
28	TSV1	TEMP FOR PREV VISC ,DEG C	TABLES
29	MUS2	SHELL FLUID VISCOSITY,Pa S	OBTAIN BEST VISC NEAR TSWALL
30	TSV2	TEMP FOR PREV VISC,DEG C	TABLES
31	RFO	SHELL SIDE FOUL RESIST, MK/W	SEE TEMA STDS FOR SUGGESTIONS-RUN WITH RFO=0 FOR COMPARISONS
32			
33	MT	TUBE SIDE MASS FLOW RATE,KG/S	DESIGN INFORMATION
34	RHOT	TUBE FLUID DENSITY, KG/M**3	TABLES
35	KTF	TUBE FLUID THERMAL COND,W/MK	TABLES
36	CPT	TUBE FLUID SP HT, J/KG K	TABLES
37	MUT1	TUBE FLUID VISC @TTAV, Pa S	TABLES
38	TTV1	TEMP FOR PREVIOUS VISC DATA, DEG C	TABLES
39	MUT2	TUBE FLUID VISC @ TSW,PaS	TABLES
40	TTV2	TEMP FOR PREV VISC ,DEG C	TABLES
41	RFI	TUBE SIDE FOUL RESIST , MK/W	SEE TEMA STDS FOR SUGGESTIONS-- RUN WITH RFI=0 FOR COMPARISONS
42	ALPHAS	PREL SHELL SIDE HT COEFF,W/M^2 K	MAKE YOUR BEST ESTIMATE NOW.
43	ALPHAT	PREL TUBE SIDE HT COEFF,W/M^2 K	MAKE YOUR BEST ESTIMATE NOW
44	PDMS	SHELL SIDE MAX PRESS DROP,KPa	DESIGN LIMITATION
45	PDMT	MAX TUBE SIDE PRESS DROP,KPa	DESIGN LIMITATION
46	VMAXT	MAX ACCEPT TUBE VELO,M/S	MAX VEL MAY BE SET FOR EROSION CONTROL TYPICAL VALUES 3-6 M/S DEPEND ON MATLS
47	VMINT	MIN ACCEPT TUBE VELO,M/S	MIN VEL MAY BE SET TO CONTROL FOULING ,COST ETC, APPROX 1-2 M/S FREQUENTLY

FIGURE 7 INPUT INFORMATION

DESIGN OF AN EXCHANGER

The input variables needed to "design" a shell and tube heat exchanger are listed in Figure 8. Note that considerably fewer values are input than in the rating process and the designer must select more of them. In the design portion of the program, reasonable values will be selected by the established technique, but the user may change any or all. The designer using this program must initially fix:

a) The tube impingement protection to be used.
b) The tube layout angle.
c) The type of tube bundle to be used.

In the design case a default set of input values has again been provided to acquaint the user more quickly with the program. This example is patterned after a problem in PROCESS HEAT TRANSFER by Kern(3). Input values for this case are shown on the right of Figure 8.

After the input of data a number of assumptions are made about the geometry of the exchanger. The resulting configuration is rated by the rating portion of the program. The result is then output to the user who may make as many changes after that as appear to be worthwhile. In each case the program will rerate the configuration which is input.

Particular care is needed to be certain that the configuration and fluid temperatures are such that an acceptable design may be achieved. If the outlet temperature of the cold fluid approaches or exceeds the outlet temperature of the hot fluid, it may be necessary to use more than one shell in series to complete the design. Selection of a design requiring that no individual shell and tube exchanger has its cold outlet temperature hotter than its outlet hot temperature, should assure that no problem exists. Low values(<.85) of the correction factor to the log mean temperature difference,FLMTD, are an indication that this is a problem.

As the user looks at each succeeding run of the rating program, the lower portion of the output sheet has an area entitled "AREAS OF CAUTION" which should be helpful in making changes. Under this heading will be printed those factors which appear to depart from usual design practice or which may be a concern. In addition, the following suggestions may be of help:

1) In general it is desireable to have the resistance of the exchanger more or less evenly distributed over the various series resistances (see the resistance distribution). Efforts to reduce small resistances will not have much effect on the overall performance.

2) If the crossflow pressure drop turns out small (less than 1/2 of the window pressure drop), it is likely that the shell diameter should be increased and the tube length shortened.

3) If the convection coefficient and pressure drop on the tube

ITEM	SYMBOL	NAME AND DIMEN.	
1	MS	SHELL SIDE FLOW RATE ,KG/SEC	22.05
2	MT	TUBE SIDE FLOW RATE ,KG/SEC	35.28
3	TSI	SHELL INLET TEMPERATURE, DEG C	33.88
4	TSO	SHELL OUTLET TEMP , DEG C	29.44
5	TTI	TUBE INLET TEMPERATURE, DEG C	23.88
6	TTO	TUBE OUTLET TEMP , DEG C	26.67
7	U1	EST OVERALL HT COEFF, W/M^2 K	3050
8	CPS	SP HT OF SHELL FLUID, J/KG K	4178
9	CPT	SP HT OF TUBE FLUID, J/KG K	4178
10	RHOS	DENSITY OF SHELL FLUID,KG/M^3	1000
11	RHOT	DENSITY OF TUBE FLUID,KG/M^3	1000
12	KSF	THERMAL COND OF SHELL FLUID,W/M K	.618
13	KTF	THERMAL COND OF TUBE FLUID ,W/M K	.618
14	MUS1	VISC OF SHELL FLUID NEAR TSAV TEMP,PA S	.0008
15	TSV1	TEMP OF PREV DATA DEG C	30
16	MUS2	VISC OF SHELL FLUID NEAR TWALL ,PA S	.0008
17	TSV2	TEMP OF PREV DATA DEG C	30
18	MUT1	VISC OF TUBE FLUID NEAR TTAV TEMP,PA S	.0008
19	TTV1	TEMP OF PREV DATA DEG C	30
20	MUT2	VISC OF TUBE FLUID AT TWALL, PA S	.0008
21	TTV2	TEMP OF PREV DATA DEG C	30

FIGURE 8

side are low, consider using two or more tube passes. Remember that halving the number of tubes through which the flow goes will increase the pressure drop by a factor of approximately four.

4) Because the sizes of the inlet and outlet nozzles of both the tube and shell fluids have not been fixed, an allowance for their pressure drop has not been made. It must be included in the overall figure eventually used.

ERRORS

Although this program has been tested in a number of ways, it is possible that errors are still present. The author would appreciate being informed of any errors that are found.

APPENDIX B

```
1 PRINT"                                DELAWARE"
2 PRINT"                        LLNL MICRO--CAE  SOFTWARE"
3 PRINT"                          (C) COPYRIGHT  1983",
4 PRINT"                THE REGENTS OF THE UNIVERSITY OF CALIFORNIA"
5 PRINT"
6 PRINT"
7 REM ROUTINE DELAWARE 8/1/83 MBL  SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
8 PRINT" THIS PROGRAM IS DESIGNED TO ALLOW THE USER TO 'RATE' A SPECIFIED"
9 PRINT"GEOMETRY OF SHELL AND TUBE EXCHANGER. THIS METHOD IS INTENDED FOR"
10 PRINT "USE ON TEMA TYPE E (SINGLE SHELL PASS) EXCHANGERS WITH UNFINNED"
15 PRINT "TUBE BUNDLES. THIS PROGRAM MAY BE USED AS A COMPUTATIONAL ASSISTANT"
20 PRINT "BUT IT WILL NOT DESIGN BY ITSELF."
25 PRINT
30 INPUT"WHAT IS THE DATE?",DATE$
35 INPUT"WHAT IS THE TIME?",TIME$
40 TEST=0
45 REM
50 CHAIN MERGE "MCIO",55,ALL
55 DIM VNM$(48),VHELP$(48),NSYM$(48),PAR(48),VINPT(48)
60 PRINT "TO SKIP IMMEDIATELY  TO INPUT,TYPE  I"
65 QUEST$="                    TO CONTINUE,TYPE  C"
70 CHOIC$="IC"
75 GOSUB 7010
80 ON K GOTO 220,85
85 PRINT "THE RATING METHOD USED HERE IS BASED ON THE DISCUSSION PRESENTED"
90 PRINT "BY TABOREK IN THE HEAT EXCHANGER DESIGN HANDBOOK PART 3-REFERENCE"
95 PRINT "TO WHICH IS RECOMMENDED. REFERENCE TO PUBLICATIONS BY KJ BELL"
100 PRINT "ON THE DELAWARE (BELL DELAWARE) METHOD IS ALSO VERY APPROPRIATE"
105 PRINT
110 PRINT "A'RATING' PROGRAM IS ONE THAT PREDICTS THE HEAT TRANSFER AND"
115 PRINT "PRESSURE DROP PERFORMANCE OF A SPECIFIED GEOMETRY OF HEAT EXCHANGER"
120 PRINT
125 PRINT "A'DESIGN' PROGRAM WOULD USE A RATING PROGRAM TO EVALUATE THE "
130 PRINT "PERFORMANCE AND THEN ATTEMPT TO FIND AN OPTIMUM CONFIGURATION"
135 PRINT "(SUBJECT TO THE DESIRED CONSTRAINTS) BY REPEATED EVALUATION"
140 PRINT "OF A SERIES OF SUCH GEOMETRIES"
145 PRINT
150 PRINT " THE USER OF THE PRESENT PROGRAM SHOULD UNDERSTAND THAT, ALTHOUGH"
155 PRINT " THERE MAY BE SOME COMMENT ABOUT THE SELECTION OF THE VALUES OF"
160 PRINT " THE PARAMETERS CHOSEN, THIS PROGRAM IS PRIMARLY  A 'RATING' PROGRAM"
165 PRINT " AND THE SELECTION OF THE APPROPRIATE INPUT VALUES IS HIS JOB
170 PRINT
200 PRINT "SI UNITS WILL BE USED THROUGHOUT THE PROGRAM"
205 PRINT "EXCEPT THAT DIMENSIONS OF THE EXCHANGER WILL BE IN mm"
210 PRINT "PROMPTS WILL USUALLY SPECIFY THE INPUT UNITS REQUIRED"
215 PRINT
217 INPUT"Please push RETURN to continue";Q$
220 CHAIN MERGE "DELIN",225,ALL:REM INITIAL CHOICES OF CONFIGURATION
225 GOSUB 1010
230 PRINT
235 PRINT" CHOICES: (R) RUN-I HAVE THE DATA READY FOR A RATING RUN"
240 PRINT"          (I) INITIATE A DESIGN PROCEDURE "
245 PRINT"          (T) TEST RATING  WITH DEFAULT DATA-NO INPUT NEEDED"
250 PRINT"               (THIS WILL HELP TO LEARN THE PROCEDURE)"
260 PRINT"          (S) STOP-  I WANT TO GET OFF!"
265 QUEST$=" WHAT IS YOUR PREFERENCE?"
270 CHOIC$="RITS"
275 GOSUB 7010
280 ON K GOTO 300,610,295,290
290 END
```

```
295 TEST=1
296 REM
297 REM "                                   RATING" SEQUENCE BEGINS HERE!
298 REM
300 PRINT
302 CHAIN MERGE"ERASE",305,ALL,DELETE 7001-7300
305 IF RERUN=1 THEN 310 ELSE 315
310 CHAIN MERGE"RASSIGN",320,ALL
315 CHAIN MERGE"RASSIGN",320,ALL,DELETE 1-295
320 GOSUB 1510:REM                                  ASSIGN RATING VARIABLES
325 IF TEST=1 THEN 360
335 CHAIN MERGE "MVWIO",340,ALL
340  IF RERUN=1 THEN 350 ELSE 345
345 GOSUB 8010:REM                                  INPUT NEW DATA
350 GOSUB 8190:REM                                  CHANGE OLD DATA
355 CHAIN MERGE "ERASE",360,ALL,DELETE 8010-8560
360 CHAIN MERGE "RVARB",365,ALL,DELETE 1001-2000
365 GOSUB 2010:REM                                  SET VARIABLE VALUES
370 CHAIN MERGE "PAR",375,ALL,DELETE 2001-2600
375 GOSUB 2910:REM                                  SET PARAmeter VALUES
380 CHAIN MERGE "ERASE",385,ALL,DELETE 2901-3000
385 CHAIN MERGE "CALC", 390,ALL
390 GOSUB 3010:REM                                  RATING CALC
391 PRINT"PLEASE BE PATIENT,I'M WORKING ON IT!"
392 CHAIN MERGE"FLMTD",394,ALL,DELETE 3001-4000
394 GOSUB 14010:REM                                     OBTAIN FLMTD
395 CHAIN MERGE "IDELTUBE",400,ALL, DELETE 14001-14300
400 GOSUB 4010
405 CHAIN MERGE "SHELHTDP",410,ALL, DELETE 4001-5000
410 GOSUB 5010:REM                                  CALC ALPHA,DF,ETC
415 CHAIN MERGE "ERASE",420,ALL,DELETE 5001-5500
420 CHAIN MERGE "CRTOUT" ,425,ALL
425 GOSUB 11001:REM                             OUTPUT RESULTS TO CRT
430 CHAIN MERGE"ERASE",435,ALL,DELETE 11001-12000
435 PRINT:PRINT
440 CHAIN MERGE "MCIO",445,ALL
445 PRINT"YOU HAVE COMPLETED A RUN OF THE PROGRAM; AT THIS POINT"
450 PRINT"YOU MAY: "
455 PRINT"                  (P) PRINT THE SCREEN OUTPUT ON THE LINEPRINTER
460 PRINT"                  (R) REVISE THE PREVIOUS DATA AND RATE AGAIN
465 QUEST$="                  (S) STOP
470 CHOIC$="PRS"
475 GOSUB 7010
480 ON K GOTO 485,505,745
482 REM
483 REM THE NEXT FOUR LINES PROVIDE THE LINE PRINTER OUTPUT OPTION
484 REM
485 CHAIN MERGE"DELOUT",490,ALL,DELETE 7001-7300
490 GOSUB 10001:REM                             OUTPUT TO LINE PRINTER
495 CHAIN MERGE"ERASE",496,ALL,DELETE 10001-11000
496 GOTO 435
497 REM
498 REM THE NEXT TWO LINES PROVIDE THE BEGINNING OF NEW INPUT AND RECYCLE
505 TEST=0:CHAIN MERGE "PAR",515,ALL,DELETE 7001-7300
515  RERUN=1 :GOSUB 2901:REM                        TO REVISE EXISTING
520 FOR I=1 TO 47
525 VINPT(I)=PAR(I)
530 NEXT I
535 IF RERUN=1 THEN 540 ELSE 545
540 CHAIN MERGE"RASSIGN",550,ALL
```

```
545 CHAIN MERGE"RASSIGN",550,ALL,DELETE 1-290
550 GOSUB 1510:REM                                    ASSIGN RATING VARIABLES
555 IF TEST=1 THEN 585
560 CHAIN MERGE "MVWIO",565,ALL
565  IF RERUN=1 THEN 575 ELSE 570
570 GOSUB 8010:REM                                     TO INPUT NEW DATA
575 GOSUB 8190:REM                                     TO MODIFY OLD DATA
580 CHAIN MERGE "ERASE",585,ALL,DELETE 8010-8560
585 CHAIN MERGE "RVARB",590,ALL,DELETE 1501-2000
590 GOSUB 2010:REM                                     SET VARIABLE VALUES
595 CHAIN MERGE "PAR",600,ALL,DELETE 2001-2600
600 GOSUB 2910:REM                                     SET PARAMETER VALUES
605 CHAIN MERGE "ERASE",607,ALL,DELETE 2901-3000
607 GOTO 385
610 PRINT"THIS SECTION OF THE PROGRAM GOES THROUGH A PROCEDURE IN WHICH A "
615 PRINT "BALLPARK DESIGN OF AN EXCHANGER IS PROVIDED. FURTHER IMPROVEMENT"
620 PRINT "WILL THEN BE LEFT TO THE USER WHO , BY CHANGING THE DESIGN AND"
625 PRINT "RUNNING A RATING OF IT MAY BE ABLE TO IMPROVE IT FOR HIS USE."
630 REM
635 CHAIN MERGE"MCIO",640,ALL
640 PRINT"CHOICES: (O) OPT FOR A DEFAULT SET OF INPUT DATA VALUES"
645 PRINT"          (S) STOP,GO HOME AND REST"
650 QUEST$="          (U) UNDERTAKE MY OWN DESIGN--INPUT DATA ARE READY"
655 CHOIC$="OSU"
660 GOSUB 7010
665 ON K GOTO 690,290,670
666 REM
667 REM THE DESIGN SEQUENCE BEGINS HERE!
668 REM
670 CHAIN MERGE"DASSIGN",675,ALL,DELETE 7001-7300
675 GOSUB 15010:REM                                   ASSIGN DESIGN VARIABLES
680 CHAIN MERGE"MVWIO",685,ALL,DELETE 15001-15300
685 GOSUB 8010:GOSUB 8190:GOTO 700:REM                INPUT DESIGN VALUES
690 DTEST=1
695 CHAIN MERGE"DVARB",705,ALL
700 CHAIN MERGE"DVARB",705,ALL,DELETE 8001-8560
705 RUNNO=RUNNO+1:GOSUB 16010 :REM                    SET VARIABLE VALUES
706 PRINT "THIS MAY TAKE A LITTLE WHILE !"
707 CHAIN MERGE "FLMTD",708,ALL, DELETE 16001-16300
708 GOSUB 14010:REM                                     OBTAIN FLMTD
710 CHAIN MERGE"DGEO",715,ALL, DELETE 14001-14300
715  GOSUB 17010:REM                                 CALC GEOMETRY OF DESIGN
720 CHAIN MERGE"RASSIGN",725,ALL,DELETE 17001-17700
725 GOSUB 1510:REM                                  ASSIGN RATING VARIABLES
730 CHAIN MERGE"PAR",735,ALL,DELETE 1501-2000
735 GOSUB 2901:REM                                   SET PARAMETER VALUES
736 PRINT "YES, I'M STILL HERE!"
740 GOTO 385:REM                                    GOTO RATING PROCEDURE
745 END
```

```
1001 REM                          DELAWARE
1002 REM                   LLNL Micro--CAE  Software
1003 REM                     (C) COPYRIGHT  1983
1004 REM            The Regents of the University of California
1005 REM
1006 REM
1010 REM SUBROUTINE DELIN   6/23/83  MBL
1020 REM THIS PART OF THE PROGRAM STARTS THE INPUT OF DATA
1030 REM
1046 REM
1050 REM THE FIRST PORTION USES MCIO FOR RESPONSES ON THREE QUESTIONS
1060 REM TO ESTABLISH 1) SHELL SIDE NOZZLE PROTECTION;
1070 REM 2) THE BUNDLE TYPE; 3)TUBE LAYOUT ANGLE:PRINT:PRINT
1071 PRINT"AT THE INLET NOZZLE TO THE EXCHANGER HIGH VELOCITY FLUID MAY"
1072 PRINT"BE EROSIVE TO THE TUBES LOCATED BELOW IT. SOMETIMES THE VELOCITY"
1073 PRINT"WILL BE LOW ENOUGH SO THAT THERE IS NO PROBLEM. SOMETIMES A PLATE"
1074 PRINT"OR RODS ARE PLACED TO PROTECT THE TUBES. IF YOU USE PLATES OR TUBES"
1075 PRINT"YOU WILL NEED TO USE FEWER TUBES IN A GIVEN DIAMETER OF SHELL."
1076 PRINT"SOMETIMES AN ANNULAR DISTRIBUTER IS USED OUTSIDE THE MAIN SHELL."
1077 PRINT"THEN PROTECTION IS NOT NEEDED."
1080 PRINT"SHELL SIDE NOZZLE PROTECTION:   (N)NONE"
1081 PRINT"                                (P)PLATE"
1082 PRINT"                                (R)ROD"
1083 QUEST$="IF UNINFORMED USE N "
1084 PRINT "IF CHOICE IS P OR R YOU MUST DECREASE NO OF TUBES TO PROVIDE SPACE"
1090 CHOIC$="NPR"
1100 GOSUB 7010
1110 CN$=CHOIC$
1111 PRINT:PRINT"THE TYPE OF TUBE BUNDLE SELECTED WILL DEPEND UPON THE AMOUNT"
1112 PRINT"OF THERMAL EXPANSION WHICH MUST BE ALLOWED FOR. IF SUITABLE, THE
1113 PRINT"FIXED TUBE SHEET OR THE U TUBE BUNDLE WILL BE LEAST EXPENSIVE,"
1114 PRINT"HOWEVER, CLEANING MAY BE A PROBLEM":PRINT
1115 PRINT"SELECT TUBE BUNDLE TYPE:    (F) FX- FIXED TUBE PLATE"
1116 PRINT"                            (U) UT- U TUBE"
1117 PRINT"                            (S) SRFH-SPLIT RING FLOATING HEAD"
1118 PRINT"                            (P) PSH--PACKED FLOATING HEAD"
1119 QUEST$="                            (T) PTFH--PULL THRU FLOATING HEAD"
1130 CHOIC$="FUSPT"
1140 GOSUB 7010
1150 CB$=CHOIC$:PRINT:PRINT
1151 PRINT"TUBE LAYOUT SELECTION IS BASED ON:DENSITY OF TUBES IN SHELL,"
1152 PRINT"EFFECTIVENESS OF HEAT TRANSFER, AND EASE OF CLEANING."
1153 PRINT"     30 DEG MOST COMPACT ,HIGH EFFECTIVENESS"
1154 PRINT"     45 DEG LESS COMPACT ,HIGH EFFECTIVENESS,MECH SHELL SIDE CLEANING"
1155 PRINT"     90 DEG POOR IN LAMINAR FLOW,OK IN TURBULENT,GOOD MECH CLEANING"
1156 PRINT"     60 DEG NOT RECOMMENDED"
1160 PRINT"SELECT TUBE LAYOUT ARRANGEMENT: (A) 30 DEG STAGGERED"
1161 PRINT"                                (B) 45 DEG STAGGERED"
1162 PRINT"      PROBABLY LEAST CHOICE     (C) 90 DEG INLINE"
1163 PRINT"          NOT RECOMMENDED       (D) 60 DEG"
1165 QUEST$=" SEE REFERENCES IF NEEDED"
1190 PRINT "IF SUITABLE 30 AND 45 RECOMMENDED IN THAT ORDER"
1210 CHOIC$="ABCD"
1215 PRINT:PRINT
1220 GOSUB 7010
1230 ON K GOTO 1251,1261,1271,1281
1251 THETATP=30
1252 RETURN
1261 THETATP=45
1262 RETURN
```

```
1271 THETATP=90
1272 RETURN
1281 THETATP=60
1282 RETURN
1500 REM END OF DELIN
```

```
1501 REM                          DELAWARE
1502 REM                   LLNL Micro--CAE  Software
1503 REM                     (C) COPYRIGHT  1983
1504 REM            The Regents of the University of California
1505 REM
1506 REM
1510 REM SUBROUTINE RASSIGN   7/28/83 MBL
1515 IVMX=47
1517 REM THE FOLLOWING ASSIGN PROMPTS TO BE USED IN OBTAINING DESIRED INPUT DATA
1520 VNM$(1)="SHELL ID, mm": NSYM$(1)=" DS"
1525 VHELP$(1)="STD PIPE SHELLS:5-21 INCH NOM.;LARGER ROLLED SHELLS"
1530 VNM$(2)="TUBE OD, mm": NSYM$(2)=" DT"
1535 VHELP$(2)="TUBE OD: .25,.375,.50,.625,.75,.875,1.0,1.25,2.0 INCHES"
1540 VNM$(3)="TUBE WALL THICKNESS,  mm":NSYM$(3)=" LTW"
1545 VHELP$(3)="SEE TABLE OF RECOMMENDED TUBE DIMENSIONS"
1550 VNM$(4)="THERMAL CONDUCTIVITY OF TUBE , W/MK": NSYM$(4)=" KTW"
1555 VHELP$(4)=" CU=310; AL=180; ADMIRALTY=120;CARB.ST.=38;TI=18"
1560 VNM$(5)="TUBE LAYOUT PITCH,mm": NSYM$(5)=" LTP"
1565 VHELP$(5)="1.25<(LTP/DT)<1.5; MECH CLEAN OF SHELL SIDE REQ :LTP>6.3 mm"
1570 VNM$(6)="TUBE LAYOUT ANGLE DEG ":NSYM$(6)=" THETATP"
1580 VNM$(7)="OVERALL TUBE LENGTH-NOMINAL,mm":NSYM$(7)=" LTO"
1585 VHELP$(7)="FIXED BY AREA NEEDED AND BY NO. OF TUBES--A VARIABLE OF DESIGN"
1590 VNM$(8)="BAFFLED TUBE LENGTH,mm":NSYM$(8)=" LTI"
1595 VHELP$(8)="LTI=LTO-2LTS;SUGGEST LTI=LTO-.2*DS"
1600 VNM$(9)="BAFFLE CUT % OF DS":NSYM$(9)=" BC"
1605 VHELP$(9)="FOR NON PHASE CHANGE BC=20+17*(LBC/DS-.2)/.8"
1610 VNM$(10)="CENTRAL BAFFLE SPACING,mm":NSYM$(10)=" LBC"
1615 VHELP$(10)=".3<(LBC/DS)<.6; NOTE;(NB-1)*LBC+LBI+LBO=LTO"
1620 VNM$(11)="INLET BAFFLE SPACING,mm":NSYM$(11)=" LBI"
1625 VHELP$(11)="FOR PRELI WORK SET TO LBC"
1630 VNM$(12)="OUTLET BAFFLE SPACING,mm":NSYM$(12)=" LBO"
1635 VHELP$(12)="FOR PRELI WORK SET TO LBC"
1640 VNM$(13)="TOTAL NO OF TUBES":NSYM$(13)=" NTT"
1645 VHELP$(13)="TUBE COUNT TABLES ARE AVAILABLE"
1650 VNM$(14)="NUMBER OF TUBE PASSES":NSYM$(14)=" NTP"
1655 VHELP$(MIN OF 8 TUBES PER PASS-- FUNCT OF PRESS DROP AVAIL"
1660 VNM$(15)="NO OF PAIRS OF SEALING STRIPS":NSYM$(15)=" NSS"
1665 VHELP$(15)="CONSIDER USING THEM IF LBB>30mm "
1670 VNM$(16)="TUBE TO BAFFLE CLEAR(DIA),mm":NSYM$(16)=" LTB"
1675 VHELP$(16)="FOR DRILLED HOLES  :.4-.8mm"
1680 VNM$(17)="SHELL TO BAFFLE CLEAR(DIA),mm":NSYM$(17)=" LSB"
1685 VHELP$(17)="TEMA AVERAGE:LSB=1.6+.004*DS "
1690 VNM$(18)="SHELL TO BUNDLE BYPASS CLEAR(DIA),mm":NSYM$(18)=" LBB"
1695 VHELP$(18)="FIXED TUBESHEET:15-25mm FOR DS=200-2500"
1700 VNM$(19)="SHELL SIDE INLET TEMP, DEG C":NSYM$(19)=" TSI"
1705 VHELP$(19)="DESIGN INFORMATION"
1710 VNM$(20)="SHELL SIDE OUTLET TEMP, DEG C":NSYM$(20)=" TSO"
1715 VHELP$(20)="DESIGN INFORMATION"
1720 VNM$(21)="TUBE SIDE INLET TEMP,DEG C":NSYM$(21)=" TTI"
1725 VHELP$(21)="DESIGN INFORMATION"
1730 VNM$(22)="TUBE SIDE OUTLET TEMP,DEG C":NSYM$(22)=" TTO"
1735 VHELP$(22)="DESIGN INFORMATION"
1740 VNM$(23)="SHELL SIDE MASS FLOW RATE,KG/S":NSYM$(23)=" MS"
1745 VHELP$(23)="DESIGN INFORMATION"
1750 VNM$(24)="SHELL FLUID DENSITY, KG/M**3":NSYM$(24)=" RHOS"
1755 VHELP$(24)="TABLES"
1760 VNM$(25)="SHELL FLUID THERMAL CONDUCT,W/M K":NSYM$(25)=" KSF"
1765 VHELP$(25)="TABLES"
1770 VNM$(26)="SHELL FLUID SP HT ,J/KG K":NSYM$(26)=" CPS"
1775 VHELP$(26)="TABLES"
```

```
1780 VNM$(27)="SHELL FLUID VISCOSITY AT TSAV,Pa S":NSYM$(27)=" MUS1"
1785 VHELP$(27)="OBTAIN BEST SHELL FLUID VISC DATA NEAR TSAV"
1790 VNM$(28)="TEMP FOR PREVIOUS VISC DATA,DEG C":NSYM$(28)=" TSV1"
1795 VHELP$(28)="TABLES"
1800 VNM$(29)="SHELL FLUID VISCOSITY,Pa S":NSYM$(29)=" MUS2"
1805 VHELP$(29)="OBTAIN BEST VISC NEAR TSWALL"
1810 VNM$(30)="TEMP FOR PREVIOUS DATA,DEG C":NSYM$(30 )=" TSV2"
1815 VHELP$(30)="TABLES"
1820 VNM$(31)="SHELL SIDE FOUL RESIST, M^2K/W":NSYM$(31)=" RFO"
1825 VHELP$(31)="SEE TEMA STDS FOR SUGGESTIONS-RUN WITH RFO=0 FOR COMPARISONS"
1830 VNM$(32)=" "
1835 VNM$(33)="TUBE SIDE MASS FLOW RATE,KG/S":NSYM$(33)=" MT"
1840 VHELP$(33)="DESIGN INFORMATION"
1845 VNM$(34)="TUBE FLUID DENSITY, KG/M**3":NSYM$(34)=" RHOT"
1850 VHELP$(34)="TABLES"
1855 VNM$(35)="TUBE FLUID THERMAL CONDUCTIVITY,W/MK":NSYM$(35)=" KTF"
1860 VHELP$(35)="TABLES"
1865 VNM$(36)="TUBE FLUID SP HT, J/KG K":NSYM$(36)=" CPT"
1870 VHELP$(36)="TABLES"
1875 VNM$(37)="TUBE FLUID VISC @TTAV, Pa S":NSYM$(37)=" MUT1"
1880 VHELP$(37)="TABLES"
1885 VNM$(38)="TEMP FOR PREVIOUS VISC DATA, DEG C":NSYM$(38)=" TTV1"
1890 VHELP$(38)="TABLES"
1895 VNM$(39)="TUBE FLUID VISC @ TWALL,PaS":NSYM$(39)=" MUT2"
1900 VHELP$(39)="TABLES"
1905 VNM$(40)="TEMP FOR PREVIOUS VISC DATA,DEG C":NSYM$(40)=" TTV2"
1910 VHELP$(40)="TABLES"
1915 VNM$(41)="TUBE SIDE FOUL RESIST , MK/W":NSYM$(41 )=" RFI"
1920 VHELP$(41)="SEE TEMA STDS FOR SUGGESTIONS-- RUN WITH RFO=0 FOR COMPARISONS"
1925 VNM$(42)="PREL SHELL SIDE HT COEFF,W/M**2 K":NSYM$(42)=" ALPHAS"
1930 VHELP$(42)="THIS WILL BE CALC IN PROGRAM LATER MAKE BEST EST NOW."
1935 VNM$(43)="PREL  TUBE SIDE HT COEFF,W/M**2 K":NSYM$(43)=" ALPHAT"
1940 VHELP$(43)="THIS WILL NOT BE CALC IN PROGRAM SEE APPR REFS"
1945 VNM$(44)="SHELL SIDE MAX PRESS DROP,KPa":NSYM$(44)=" PDMS"
1950 VHELP$(44)="DESIGN LIMITATION"
1955 VNM$(45)="MAX TUBE SIDE PRESS DROP,KPa":NSYM$(45)=" PDMT"
1960 VHELP$(45)="DESIGN LIMITATION"
1965 VNM$(46)="MAX ACCEPTABLE TUBE  VELOCITY,M/S":NSYM$(46)=" VMAXT"
1970 VHELP$(46)="MAX VEL  SET FOR EROSION CONTROL TYP. VALUES 3-6M/S"
1975 VNM$(47)="MIN ACCEPTABLE TUBE  VELOCITY,M/S ":NSYM$(47)=" VMINT"
1980 VHELP$(47)=" MIN VEL  SET FOR FOULING,COST ETS,APPROX1-2 M/S"
1985 PRINT FRE("")
1999 REM END OF RASSIGN
2000 RETURN :REM RRRRRRRRRRRRRRRRRRRRRRRRR RETURN RRRRRRRRRRRRRRRRRRRRRRRRR
```

```
2001 REM                          DELAWARE
2002 REM                    LLNL Micro--CAE  Software
2003 REM                      (C) COPYRIGHT  1983
2004 REM             The Regents of the University of California
2005 REM
2006 REM
2010 REM SUBROUTINE RVARB2  7/29/83 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
2020 REM THIS PART OF THE PROGRAM ASSIGNS VALUES TO THE VARIABLES
2025 REM EITHER "TEST" OR INPUT VALUES MAY BE USED
2060 IF TEST=1 THEN DS=591                        ELSE DS=VINPT(1)
2070 IF TEST=1 THEN DT=16                         ELSE DT=VINPT(2)
2080 IF TEST=1 THEN LTW=1.24                      ELSE LTW=VINPT(3)
2090 IF TEST=1 THEN KTW=42                        ELSE KTW=VINPT(4)
2100 IF TEST=1 THEN LTP=20.8                      ELSE LTP=VINPT(5)
2110 IF TEST=1 THEN LTO=2394                      ELSE LTO=VINPT(7)
2120 IF TEST=1 THEN LTI=2276                      ELSE LTI=VINPT(8)
2130 IF TEST=1 THEN BC =24                        ELSE BC= VINPT(9)
2140 IF TEST=1 THEN LBC=250                       ELSE LBC=VINPT(10)
2150 IF TEST=1 THEN LBI=263                       ELSE LBI=VINPT(11)
2160 IF TEST=1 THEN LBO=263                       ELSE LBO=VINPT(12)
2170 IF TEST=1 THEN NTT=652                       ELSE NTT=VINPT(13)
2180 IF TEST=1 THEN NTP=2                         ELSE NTP=VINPT(14)
2190 IF TEST=1 THEN NSS=0                         ELSE NSS=VINPT(15)
2200 IF TEST=1 THEN LTB=.5                        ELSE LTB=VINPT(16)
2210 IF TEST=1 THEN LSB=5.5                       ELSE LSB=VINPT(17)
2220 IF TEST=1 THEN LBB=10                        ELSE LBB=VINPT(18)
2230 IF TEST=1 THEN TSI=89.8                      ELSE TSI=VINPT(19)
2240 IF TEST=1 THEN TSO=147.3                     ELSE TSO=VINPT(20)
2250 IF TEST=1 THEN TTI=178                       ELSE TTI=VINPT(21)
2260 IF TEST=1 THEN TTO=178                       ELSE TTO=VINPT(22)
2270 IF TEST=1 THEN MS=22.4                       ELSE MS =VINPT(23)
2280 IF TEST=1 THEN RHOS=740                      ELSE RHOS=VINPT(24)
2290 IF TEST=1 THEN KSF=.105                      ELSE KSF= VINPT(25)
2300 IF TEST=1 THEN CPS=2407                      ELSE CPS= VINPT(26)
2310 IF TEST=1 THEN MUS1=.0006                    ELSE MUS1=VINPT(27)
2320 IF TEST=1 THEN TSV1=90                       ELSE TSV1=VINPT(28)
2330 IF TEST=1 THEN MUS2=.0003                    ELSE MUS2=VINPT(29)
2340 IF TEST=1 THEN TSV2=190                      ELSE TSV2=VINPT(30)
2350 IF TEST=1 THEN RFO=0                         ELSE RFO= VINPT(31)
2360 IF TEST=1 THEN MT=0!                         ELSE MT=  VINPT(33)
2370 IF TEST=1 THEN RHOT=0!                       ELSE RHOT=VINPT(34)
2380 IF TEST=1 THEN KTF=0!                        ELSE KTF= VINPT(35)
2390 IF TEST=1 THEN CPT=0!                        ELSE CPT= VINPT(36)
2400 IF TEST=1 THEN MUT1=0!                       ELSE MUT1=VINPT(37)
2410 IF TEST=1 THEN TTV1=0!                       ELSE TTV1=VINPT(38)
2420 IF TEST=1 THEN MUT2=0!                       ELSE MUT2=VINPT(39)
2430 IF TEST=1 THEN TTV2=0!                       ELSE TTV2=VINPT(40)
2440 IF TEST=1 THEN RFI=0                         ELSE RFI =VINPT(41)
2450 IF TEST=1 THEN ALPHAS=1000                   ELSE ALPHAS=VINPT(42)
2460 IF TEST=1 THEN ALPHAT=6000                   ELSE ALPHAT=VINPT(43)
2470 IF TEST=1 THEN PDMS=0!                       ELSE PDMS=  VINPT(44)
2480 IF TEST=1 THEN PDMT=0!                       ELSE PDMT=  VINPT(45)
2490 IF TEST=1 THEN VMAXT=0!                      ELSE VMAXT= VINPT(46)
2500 IF TEST=1 THEN VMINT=0!                      ELSE VMINT= VINPT(47)
2510 RETURN
2600 REM END OF VARB
```

```
2901 REM                          DELAWARE
2902 REM                   LLNL Micro--CAE  Software
2903 REM                     (C) COPYRIGHT  1983
2904 REM            The Regents of the University of California
2905 PRINT
2906 REM
2910 REM SUBROUTINE PAR 7/29/83 MBL
2950 PAR(1)=DS
2951 PAR(2)=DT
2952 PAR(3)=LTW
2953 PAR(4)=KTW
2954 PAR(5)=LTP
2955 PAR(6)=THETATP
2956 PAR(7)=LTO
2957 PAR(8)=LTI
2958 PAR(9)=BC
2959 PAR(10)=LBC
2960 PAR(11)=LBI
2961 PAR(12)=LBO
2962 PAR(13)=NTT
2963 PAR(14)=NTP
2964 PAR(15)=NSS
2965 PAR(16)=LTB
2966 PAR(17)=LSB
2967 PAR(18)=LBB
2968 PAR(19)=TSI
2969 PAR(20)=TSO
2970 PAR(21)=TTI
2971 PAR(22)=TTO
2972 PAR(23)=MS
2973 PAR(24)=RHOS
2974 PAR(25)=KSF
2975 PAR(26)=CPS
2976 PAR(27)=MUS1
2977 PAR(28)=TSV1
2978 PAR(29)=MUS2
2979 PAR(30)=TSV2
2980 PAR(31)=RFO
2981 PAR(32)=0
2982 PAR(33)=MT
2983 PAR(34)=RHOT
2984 PAR(35)=KTF
2985 PAR(36)=CPT
2986 PAR(37)=MUT1
2987 PAR(38)=TTV1
2988 PAR(39)=MUT2
2989 PAR(40)=TTV2
2990 PAR(41)=RFI
2991 PAR(42)=ALPHAS
2992 PAR(43)=ALPHAT
2993 PAR(44)=PDMS
2994 PAR(45)=PDMT
2995 PAR(46)=VMAXT
2996 PAR(47)=VMINT
2999 REM END OF PAR
3000 RETURN :REM RRRRRRRRRRRRRRRRRRRRRRRRRRRRRR RETURN RRRRRRRRRRRRRRRR
```

```
3001 REM                          DELAWARE
3002 REM                    LLNL Micro--CAE  Software
3003 REM                      (C) COPYRIGHT  1983
3004 REM            The Regents of the University of California
3005 REM
3006 REM
3010 REM SUBROUTINE CALC 7/29/83  MBL
3015 DTI=DT-2*LTW
3020 IF(LTP/DT)<1.25                        THEN PRINT "LTP/DT<1.25"
3025 IF(LTP/DT)>1.5                         THEN PRINT "LTP/DT>1.5"
3030 IF (THETATP=90)                        THEN PRINT"THETATP=90DEG"
3035 IF (THETATP=60)                        THEN PRINT"THETATP= 60DEG"
3040 IF (BC<20)                             THEN PRINT "BC<20%"
3045 IF (BC>37)                             THEN PRINT "BC>37%"
3050 LBMAX=LBC+LBI
3055 IF (LBC+LBO)>LBMAX                     THEN LBMAX=LBC+LBO
3060 IF (2*LBC>LBMAX)                       THEN LBMAX=2*LBC
3065 IF (LBC<.2*DS)                         THEN PRINT "LBC TOO SMALL"
3070 IF (LBC>DS )                           THEN PRINT "LBC TOO LARGE"
3075 IF DT<19  THEN GOTO 3080 ELSE GOTO 3095
3080 IF (LBMAX>68*DT+228) THEN PRINT "BAFFLE SPACE TOO LARGE FOR GROUP A MATLS"
3085 IF(LBMAX>60*DT+177) THEN PRINT"BAFFLE SPACE TOO LARGE FOR GROUP B MATLS"
3090 GOTO 3105
3095 IF(LBMAX>52*DT+532) THEN PRINT "BAFFLE SPACE TOO LARGE FOR GROUP A MATLS"
3100 IF(LBMAX>46*DT+436) THEN PRINT "BAFFLE SPACE TOO LARGE FOR GROUP B MATLS"
3105 REM
3110 DCTL=DS-LBB-DT
3115 IF(THETATP=30)                         THEN  C1=.866
3120 IF(THETATP=45)                         THEN  C1=1!
3125 IF(THETATP=90)                         THEN  C1=1!
3130 IF(THETATP=60)                   THEN PRINT"THETATP=60DEG IS NOT RECOMMENDED"
3135 NTT1=.78*((DCTL)^2)/(C1*(LTP)^2)
3140 IF NTP>1                               THEN GOTO 3180
3145 NTTE=NTT1:REM                          EST OF TOTAL NO OF TUBES
3150 REM THE FOLLOWING ARE TO BE USED FOR IMPINGEMENT CORRECTIONS LATER:
3155 REM C=(DS/DCTL)*(1-2*BC/100)
3160 REM THETACTL=2*57.2958*(1.5708-2*ATN(C/(1+SQR(1-C*C))))
3165 REM PSIC=(THETACTL/360-SIN(THETACTL)/(2*3.14159))
3170 REM NTTE=NTT1*(1-PSIC)
3175 GOTO 3195
3180 IF DCTL<500                            THEN C7=2.2 ELSE C7=1.95
3185 PSIN=(27/DCTL)*(NTP-1)-(1.5/DCTL)*(NTP-1)^C7
3190 NTTE=INT(NTT1*(1-PSIN))
3195 IF(NTT<.92*NTTE)                       THEN PRINT"NTT SEEMS SMALL CF";NTTE
3200 IF(NTT>1.08*NTTE)                      THEN PRINT"NTT SEEMS LARGE CF":NTTE
3205 REM LATER CHECK ON ITEMS 19,20,21????????????????????????????
3210 DCTL=DS-LBB
3215 PRINT
3220 REM THIS ROUTINE CALCULATESPARAMETERS:SM,TSAV,TTAV,RES,PRS,TLMTD,
3225 REM TMTD ETC. THE PARAMETER ms=MS/SM IS DEFINED AS MSM
3230 REM ALSO CALCULATED ARE JC--JL--JB--JR--JS
3235 IF THETATP=30                          THEN LTPE=LTP
3240 IF THETATP=90                          THEN LTPE=LTP
3245 IF THETATP=45                          THEN LTPE=.707*LTP
3250 SM=LBC*(LBB+DCTL*(LTP-DT)/LTPE):REM            CROSS FLOW AREA
3255 TSAV=.5*(TSI+TSO):REM                          AVE SHELL TEMPERATURE
3260 TTAV=.5*(TTI+TTO):REM                          AVE TUBE TEMPERATURE
3265 MSM=(MS/SM)*10^6:REM                   SHELL SIDE CROSSFLOW MASS VELOCITY
3270 IF MUS2/MUS1=1                         THEN  GOTO 3290
3275 MUSB=(LOG(MUS2/MUS1))/(LOG((TSV2+273)/(TSV1+273)))
```

```
3280 MUSA=MUS1/(TSV1+273)^MUSB
3285 MUS=MUSA*(TSAV+273)^MUSB: GOTO 3295
3290 MUS=MUS1:REM                                VISC OF SHELL FLIUD AT TSAV
3295 RES=DT*MSM/(MUS*1000):REM                   SHELL SIDE REYNOLDS NUMBER
3300 PRS=(CPS*MUS/KSF):REM                 SHELL SIDE PRANDTL NUMBER
3305 IF TSAV>TTAV                           THEN 3310 ELSE 3325
3310 TDIF1=TSI-TTO
3315 TDIF2=TSO-TTI
3320 GOTO 3335
3325 TDIF1=TTI-TSO
3330 TDIF2=TTO-TSI
3335 TLMTD=(TDIF1-TDIF2)/LOG(TDIF1/TDIF2):REM    LOG MEAN TEMP DIFF
3340 IF CB$="U"                            THEN LTA=LTI+.3*DOTL ELSE LTA=LTI
3345 AO=3.14159*DT*LTA*NTT/10^6:REM                AREA of EXCHANGER
3350 REM THE FOLLOWING ARE 'AUX' CALC
3355 C=(1-2*BC/100)
3360 THETADS=2*57.2958*(1.5708-2*ATN(C/(1+SQR(1-C*C))))
3365 C=C*DS/DCTL
3370 THETACTL=2*57.2958*(1.5708-2*ATN(C/(1+SQR(1-C*C))))
3375 SWG=3.14159*DS*DS*.25*(THETADS/360-SIN(THETADS/57.2958)/(2*3.14159))
3380 FW=THETACTL/360-SIN(THETACTL/57.2958)/(2*3.14159)
3385 FC=1-2*FW
3390 SWT=NTT*FW*DT*DT*.25*3.14159
3395 NTW=NTT*FW
3400 SW=SWG-SWT
3405 DW=4*SW/(3.14159*(DT*NTW+DS*THETADS/360))
3410 IF THETATP=30                         THEN LPP=.866*LTP
3415 IF THETATP=45                         THEN LPP=.707*LTP
3420 IF THETATP=90                         THEN LPP=LTP
3425 NTCC=DS*(1-2*BC/100)/LPP
3430 NTCW=.8*(DS*BC/100-(DS-DCTL)/2)/LPP
3435 NB=INT(LTI/LBC-1):REM                                NO OF BAFFLES
3440 IF NB<5          THEN PRINT "NO OF BAFFLES<5--POOR DESIGN"
3445 REM LPL= BYPASS LANE DIMENSION IN mm COULD EST AS .5DT....??????
3450 LPL=.5*DT : IF TEST=1 THEN LPL=6.35
3455 SB=LBC*((DS-DOTL)+LPL):REM                    BYPASS AREA / BAFFLE
3460 FSBP=SB/SM
3465 SSB=.00436*DS*LSB*(360-THETADS)
3470 STB1=.25*3.14159*((DT+LTB)^2-DT^2)
3475 STB=STB1*NTT*(1-FW):REM                 TUBE TO BAFFLE LEAKAGE AREA
3480 JC=.55+.72*FC
3485 RS=SSB/(SSB+STB)
3490 RLM=(SSB+STB)/SM
3495 P=.8-.15*(1+RS)
3500 RL=EXP(-1.33*(1+RS)*(RLM^P)):REM                              RL
3505 JL=.44*(1-RS)+((1-.44*(1-RS))*EXP(-2.2*RLM)):REM              JL
3510 RSS=NSS/NTCC
3515 REM CALC JB&RB BUNDLE BYPASS COEF
3520 IF RES<100                            THEN CBH=1.35 ELSE CBH=1.25
3525 JB=EXP(-CBH*FSBP*(1-(2*RSS)^.3333)):REM                       JB
3530 IF JB>1                               THEN JB=1
3535 IF RES<100                            THEN CBP=4.5 ELSE CBP=3.7
3540 RB=EXP(-CBP*FSBP*(1-(2*RSS)^.3333)):REM                       RB
3545 IF RB>1                               THEN RB=1
3550 NC=(NTCC+NTCW)*(NB+1)
3555 JRR=1.51/(NC^.18)
3560 JR=JRR+(20-RES)*(JRR-1)/80:REM                                JR
3565 IF RES>100                            THEN JR=1
3570 IF RES<20                             THEN JR=JRR
3575 IF JR<.4                              THEN PRINT"JR<.4"
```

```
3580 LSTAR=(LBI/LBC+LBO/LBC)/2:REM                                    LSTAR
3585 JS=((NB-1)+2*LSTAR^.4)/((NB-1)+2*LSTAR):REM                      JS
3590 IF LSTAR>2                          THEN PRINT "LSTAR>2---POOR DESIGN"
3595 IF RES<100                          THEN JS=(1+JS)/2
3600 IF RES<100                          THEN NZ=1 ELSE NZ=.2
3605 RS2=(LBC/LBO)^(2-NZ)+(LBC/LBI)^(2-NZ)
3999 RETURN
4000 REM END OF CALC
```

```
4550 GOTO 4660
4560 IF RES<10000 THEN 4570 ELSE 4590
4570 A1=.107:A2=-.266:B1=.0815:B2=.022
4580 GOTO 4660
4590 IF RES<100000! THEN 4600 ELSE 4620
4600 A1=.37:A2=-.395: B1=.391: B2=-.148
4610 GOTO 4660
4620 IF RES>100000! THEN PRINT"RES>100000"
4630 GOTO 4660
4640 REM ***********************************************************
4650 REM
4660 A=A3/(1+.14*(RES)^A4)
4670 JI=A1*((1.33/(LTP/DT))^A)*(RES)^A2
4680 B=B3/(1+.14*(RES)^B4)
4690 FI=B1*((1.33/(LTP/DT))^B)*(RES)^B2
4700 REM THESE VALUES OF JI&FI WILL BE USED TO CALC VALUES OF ALPHAI&DPI.
4710 REM THEN CORRECTION FACTORS(J'S & R'S WILL BE APPLIED TO THEM
4720 REM
4730 REM IF PRS<1 CONCLUDE FLUID IS A GAS& EVAL PHISR
4740 TW=TTAV+(TSAV-TTAV)/(1+(ALPHAT/ALPHAS))
4750 IF PRS<1 THEN 4760 ELSE 4790
4760 IF TSAV>TTAV THEN PHISR=1 :REM            SHELL FLUID BEING COOLED
4770 IF TSAV<TTAV THEN PHSIR=((TSAV+273)/(TW+273)^.25 :REM         HEATED
4780 GOTO 4800
4790 PHISR=(MUS1/MUS2)^.14
4800 ALPHAI=JI*CPS*MSM*(PRS^(-.667))*PHISR
4810 DPBI=2*FI*NTCC*(MSM^2/(RHOS*PHISR))/1000
4999 REM END OF IDELTUBE:PRINT"AT 4999"
5000 RETURN:REM RRRRRRRRRRRRRRRRRRRRRRRRRRRR RETURN RRRRRRRRRRRRRRRRRRRRRRRRR
```

```
5001 REM                          DELAWARE
5002 REM                    LLNL Micro--CAE  Software
5003 REM                      (C) COPYRIGHT  1983
5004 REM            The Regents of the University of California
5005 REM
5006 REM
5010 REM SUBROUTINE SHELHTDP   6/26/83  MBL SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
5020 REM THIS SUBROUTINE PUTS TOGETHER THE IDEAL CALC& THE CORRECTIONS TO
5030 REM PREDICT THE SHELL SIDE HT AND PRESS DROP AND CALC TUBE SIDE VALUES.
5040 JTOT= JC*JL*JB*JR*JS
5070 REM
5080 ALPHAS=ALPHAI*JTOT
5090 DPC=DPBI*(NB-1)*RB*RL
5100 MWM=(MS/(SM*SW)^.5)*10^6
5110 IF RES<100 THEN 5120 ELSE 5150
5120 DPW=(26*MWM*MUS1*(NTCW/(LTP-DT)+LBC/(DW*DW)) +MWM^2/(RHOS)*10^3)*RL*NB
5140 GOTO 5170
5150 DPW=NB*RL*(2+.6*NTCW)*MWM^2/((2*RHOS)*10^3)
5170 DPE=DPBI*(1+NTCW/NTCC)*RB*RS2
5180 DPS=DPC+DPW+DPE
5190 IF TEST=1 THEN GOTO 5340
5200 REM                                                CALC TUBE HT &PRESS DROP
5201 IF MUT2/MUT1=1 THEN GOTO 5205
5202 MUTB=(LOG(MUT2/MUT1))/(LOG((TTV2+273)/(TTV1+273)))
5203 MUTA=MUT1/(TTV1+273)^MUTB
5204 MUT=MUTA*(TTAV+273)^MUTB: GOTO 5210
5205 MUT=MUT1:REM                                       VISC OF TUBE FLUID AT TTAV
5210 RET=4000*MT*NTP/(3.14159*NTT*DTI*MUT)
5220 PRT=CPT*MUT/KTF
5230 VELT=4*MT*NTP/(RHOT*NTT*3.14159*(DTI/1000)^2)
5240 IF RET<2300 THEN FT=64/RET  ELSE GOTO 5260
5245 REM NOTE THAT THE FOREGOING USES THE "LARGE"FRICTION FACTOR!
5250 GOTO 5270
5260 FT=(1.82*(.4343)*LOG(RET)-1.64)^(-2)
5270 DPTOT=FT*(LTO/(NTP*DTI))*RHOT*(VELT)^2/2 +(1.5/2)*NTP*RHOT*(VELT)^2
5280 IF RET<2300 THEN NUT=((3.66^3+1.61^3)*RET*PRT*DTI/LTO)^.333
5290 IF(RET>2300 AND PRT<1.5 AND PRT>.5) THEN 5295 ELSE 5299
5295 NUT=.0214*(RET^.8-100)*PRT^.4*(1+DTI*NTP/LTO)^.667)
5299 IF(RET>2300 AND PRT>1.5 AND PRT<500) THEN 5300 ELSE 5310
5300  NUT=.012*(RET^.87-280)*PRT^.4*(1+(DTI*NTP/LTO)^.667)
5310 IF(RET>2300 AND PRT>500 OR PRT<.5)THEN  PRINT"PRT OUT OF RANGE ?"
5320 ALPHAT= NUT*KTF/(DTI/1000)
5330 RESISTT=(1/ALPHAT)*DT/DTI
5340 RESISTS=1/ALPHAS
5350 RESISTW=DT/(ALPHAT*DTI)
5360 TOTRES=RFO+RFI*(DT/DTI)+RESISTS+RESISTT+RESISTW
5370 PERS=RESISTS/TOTRES:REM                          % RESIST--SHELL
5380 PERT=RESISTT/TOTRES:REM                          % RESIST--TUBE
5390 PERW=RESISTW/TOTRES:REM                          % RESIST--WALL
5400 PERSF=RFO/TOTRES:REM                             % SHELL FOUL
5410 PERTF=RFI*(DT/DTI)/TOTRES:REM                            % TUBE FOUL
5420 UO=1/TOTRES
5425 QPRED=AO*UO*FLMTD*TLMTD
5430 RETURN
5500 REM END OF SHELHTDP
```

```
7001 REM                          DELAWARE
7002 REM                    LLNL Micro--CAE  Software
7003 REM                      (C) COPYRIGHT  1983
7004 REM            The Regents of the University of California
7005 REM
7006 REM
7010 REM SUBROUTINE MCIO   SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
7020 REM Subroutine displays question string QUEST$ and returns a single letter
7030 REM response in CHOIC$ which the user selects from the possible responses
7040 REM initially set in CHOIC$.
7050 REM Variables used:  External:  QUEST$, CHOIC$;  Internal:  LTR$, LTR$,
7060 REM K, I%
7070 PRINT QUEST$
7080 PRINT
7090 INPUT "          Please type your single letter response:  ", RESP$
7100 LTRS$=""
7110 I%=LEN(CHOIC$)
7120 FOR K=1 TO I%
7130 LTR$=MID$(CHOIC$,K,1)
7140 IF LTR$=RESP$ THEN 7280
7150 LTRS$=LTRS$+", "+LTR$
7160 IF K=1 THEN LTRS$=LTR$
7170 LTR$=CHR$(ASC(LTR$)+32)
7180 IF LTR$=RESP$ THEN 7280
7190 LTRS$=LTRS$+", "+LTR$
7200 NEXT K
7210 PRINT
7220 PRINT TAB(5) "************************INPUT ERROR************************"
7230 PRINT TAB(5) "Please type one of the listed letters shown in parentheses:"
7240 PRINT TAB((60-6*I%)/2)LTRS$"...try again:"
7250 PRINT TAB(5) "*************************************************************"
7260 PRINT
7270 GOTO 7070
7280 CHOIC$=MID$(CHOIC$,K,1)
7290 RETURN:REM RRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRR RETURN RRRRRRRRRRRRR
7300 REM END OF MCIO
```

```
8010 REM SUBROUTINE MVWIO    SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
8020 REM Subroutine displays a list of variable names, one at a time, accepts
8030 REM user responses and stores them in vector form in VINPT(I).
8040 REM Variables used:  External:  VNM$, VINPT, IVMX;
8050 REM Internal:  DSPLA$, I
8060 PRINT TAB(12) "Please type the value of each variable as it is"
8070 PRINT TAB(25) "identified on the screen: IF YOU NEED HELP TYPE' HELP'"
8080 PRINT
8090 FOR I=1 TO IVMX
8100 DSPLA$=VNM$(I)+"....................................."
8110 PRINT
8120 PRINT TAB(5) MID$(DSPLA$,1,45);
8130 INPUT VINPT$
8140 IF VINPT$="HELP" THEN PRINT VHELP$(I) ELSE VINPT(I)=VAL(VINPT$)
8150 IF VINPT$="HELP" THEN GOTO 8120
8160 NEXT I
8170 PRINT
8180 RETURN:REM RRRRRRRRRRRRRRRRRRRRRRRR RETURN RRRRRRRRRRRRRRRRRRRRRRRR
8190 REM Section displays variables and their values vertically.
8200 FOR I=1 TO IVMX
8210 DSPLA$="("+STR$(I)+")  "+VNM$(I)+"............................."
8220 PRINT TAB(5) MID$(DSPLA$,1,45);
8230 IF VINPT(I)>500 THEN PRINT USING"######.#";VINPT(I)
8240 IF VINPT(I)=0   THEN PRINT USING"######.#";VINPT(I)
8250 IF VINPT(I)>500 THEN GOTO 8320
8260 IF VINPT(I)=0 THEN GOTO 8320
8270 PRINT SPC(2)
8280 IF VINPT(I)>1 THEN PRINT USING"####.###";VINPT(I)
8290 IF VINPT(I)>1 THEN GOTO 8320
8300 PRINT SPC(4)
8310 PRINT USING".#######";VINPT(I)
8320 IF I=15 THEN GOSUB 8370
8330 IF I=30 THEN GOSUB 8370
8340 IF I=47 THEN GOSUB 8370
8350 NEXT I
8355 IF I<15 THEN GOSUB 8370
8360 RETURN:REM RRRRRRRRRRRRRRRRRRRRRRRR RETURN RRRRRRRRRRRRRRRRRRRRRRRR
8370 REM Section allows user to make changes in any member of variable list
8380 PRINT
8390 PRINT"                    type 'NONE' if no changes"
8400 INPUT "          Type line index of variable to be changed: "; I$
8410 IF I$="NONE" THEN RETURN
8420 J=VAL(I$)
8430 IF J<=IVMX THEN 8500
8440 PRINT
8450 PRINT TAB(10) "*********************INPUT ERROR*********************"
8460 PRINT TAB(11) "The line index must be less than: "IVMX+1"...try again:"
8470 PRINT TAB(10) "*****************************************************"
8480 PRINT
8490 GOTO 8400
8500 DSPLA$=VNM$(J)+"............................."
8510 PRINT
8520 PRINT TAB(5) MID$(DSPLA$,1,45);
8530 INPUT VINPT(J)
8540 GOTO 8380
8550 PRINT
8560 RETURN: REM RRRRRRRRRRRRRRRRRRRRRRRR RETURN RRRRRRRRRRRRRRRRRRRRRRRR
```

```
10001 LPRINT"                          DELAWARE                          ";DATE$
10002 LPRINT"                  LLNL MICRO--CAE  SOFTWARE                  ";TIME$
10003 LPRINT"                    (C) COPYRIGHT  1983                      ";RUNNO
10004 LPRINT"          THE REGENTS OF THE UNIVERSITY OF CALIFORNIA"
10005 LPRINT
10006 LPRINT
10010 REM SUBROUTINE DELOUT  7/14/83 MBL SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
10020 REM THIS SUBROUTINE PROVIDES THE OUTPUT FROM THE RATING
10030 REM CALCULATIONS WHICH HAVE BEEN PERFORMED.
10032 LPRINT"INPUT INFORMATION;"
10034 LPRINT"SYMBOL"TAB(13)"VALUE"TAB(26);
10040 LPRINT "SYMBOL"TAB(39)"VALUE"TAB(50)"SYMBOL"TAB(61)"VALUE"
10050 FOR I=1 TO 48 STEP 3
10060 LPRINT  I TAB(6);NSYM$(I);TAB(13);PAR(I);
10070 LPRINT TAB(26);I+1 TAB(31)NSYM$(I+1)TAB(39)PAR(I+1);
10080 LPRINT TAB(50)I+2 TAB(54)NSYM$(I+2)TAB(62)PAR(I+2)
10090 NEXT I
10120 LPRINT "DELAWARE OUTPUT INFORMATION ***********************************"
10130 LPRINT
10140 LPRINT"SHELL SIDE HEAT TRANSFER COEF. PREDICT-W/M^2 K   ",ALPHAS
10150 LPRINT"   JC=";JC;"   JR=";JR;"   JL=";JL
10160 LPRINT"   JS=";JS;"   JB=";JB;"   JTOT=";JTOT
10170 LPRINT "TUBE SIDE HEAT TRANSFER COEF. PREDICT-W/M^2 K   ",ALPHAT
10180 LPRINT
10190 LPRINT "TOTAL SHELL SIDE PRESSURE DROP  DPS    ,KPa",DPS
10200 LPRINT "END ZONE PRESS DROP             DPE   ,KPa",DPE
10210 LPRINT "BAFFLE WINDOW PRESS DROP        DPW   ,KPa",DPW
10220 LPRINT "CROSSFLOW PRESS DROP            DPC   ,KPa",DPC
10230 LPRINT "   RL=";RL;"    RB=";RB;"     RS2=";RS2
10240 LPRINT"TUBE SIDE PRESSURE DROP                    ,kPa",DPTOT/1000
10250 LPRINT
10260 LPRINT"SHELL ID  ,mm=";DS;"    TUBE OD,mm=";DT;"      TUBE LENGTH=";LTO
10270 LPRINT"C BAFFLE SPACE="; LBC;"    NO OF BAFFLES=";NB;"    AREA=";AO
10280 LPRINT
10290 LPRINT
10300 LPRINT"NO OF TUBES  ",NTT "  PREDICTED NO OF TUBES FOR SHELL DIA  "  ;NTTE
10310 LPRINT"OVERALL TUBE LENGTH      "; LTO;"    U(OVERALL)= ";UO;  " W/M^K"
10320 LPRINT"SHELL SIDE REYNOLDS NO. ";RES;"     RESIST SHELL SIDE=  ";PERS;"%"
10330 LPRINT"SHELL SIDE PRANDTL NO.  ";PRS;"      RESIST TUBE SIDE= ";PERT;"%"
10340 LPRINT"TUBE SIDE REYNOLDS NO.  ";RET;"     RESIST TUBE WALL=  ";PERW;"%"
10350 LPRINT"TUBE SIDE PRANDTL NO.   ";PRT;"     RESIST TUBE FOUL=  ";PERTF;"%"
10360 LPRINT"LOG MEAN TEMP DIFF,C    ";TLMTD;"     RESIST SHELL FOUL=  ";PERSF;"%"
10370 LPRINT
10380 LPRINT"DESIGN LOAD=   ";Q;"WATTS     PREDICTED LOAD=   ";QPRED;"WATTS"
10390 LPRINT"AREAS OF CAUTION:                    (Q=U*A*LMTD*FLMTD)
10395 LPRINT
10400 IF LTP/DT<1.25 THEN LPRINT "LTP/DT=",LTP/DT
10410 IF LTP/DT>1.5  THEN LPRINT "LTP/DT=",LTP/DT
10420 IF THETATP= 90 THEN LPRINT "THETATP=",THETATP
10430 IF THETATP= 60 THEN LPRINT "THETATP=",THETATP
10440 IF BC<20  THEN LPRINT "BC=", BC
10450 IF BC>37  THEN LPRINT "BC=", BC
10460 IF LBC<.2*DS  THEN LPRINT "LBC TOO SMALL"
10470 IF LBC> DS THEN LPRINT "LBC TOO LARGE"
10480 IF NTT<.92*NTTE THEN LPRINT "NTT SEEMS SMALL CF";NTTE
10490 IF NTT>1.08*NTTE THEN LPRINT "NTT SEEMS LARGE CF";NTTE
10500 IF JL<.6 THEN LPRINT"JL<.6"
10510 IF NB<5 THEN LPRINT "NO. OF BAFFLES<5--- POOR!"
10520 IF JR<.4 THEN LPRINT "JR<.4"
10530 IF JTOT<.5 THEN LPRINT "JTOT<.5"
```

```
10540 IF LSTAR> 2 THEN LPRINT"LSTAR>2-- POOR!
10550 IF DPW/DPC>2 THEN LPRINT"WINDOW PRES DROP HIGH COMPARED TO CROSSFLOW DP"
10560 IF DT<19 THEN GOTO 10570 ELSE 10600
10570 IF (LBMAX>68*DT) THEN LPRINT"BAFFLE SPACE TOO LARGE FOR GRP 'A' MATLS"
10580 IF (LBMAX>60*DT+177) THEN LPRINT"BAFFLE SPACE TOO LARGE FOR GRP 'B' MATLS"
10590 GOTO 10630
10600 IF (LBMAX>52*DT+532) THEN LPRINT"BAFFLE SPACE TOO LARGE FOR GRP 'A'MATLS"
10610 IF (LBMAX>46*DT+436) THEN LPRINT"BAFFLE SPACE TOO LARGE FOR GRP 'B' MATLS"
10630 IF(Q>QPRED)THEN LPRINT "PREDICTED LOAD LESS THAN DESIGN LOAD"
10632 IF TEST=1 THEN LPRINT"TUBE SIDE DATA ARE MEANINGLESS IN THIS TEST RUN"
10633 IF FLMTD<.8 THEN LPRINT"FLMTD SEEMS LOW-CK OUTLET TEMP VALUES"
10635 LPRINT CHR$(12)
10650 RETURN
11000 REM END OF DELOUT
```

```
11001 REM                          DELAWARE
11002 REM                    LLNL Micro--CAE  Software
11003 REM                      (C) COPYRIGHT  1983
11004 REM            The Regents of the University of California
11005 REM
11006 REM
11010 REM SUBROUTINE CRTOUT  7/14/83 MBL SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
11020 REM THIS SUBROUTINE PROVIDES THE OUTPUT FROM THE RATING
11030 REM CALCULATIONS WHICH HAVE BEEN PERFORMED.
11035 PRINT"SYMBOL"TAB(13)"VALUE"TAB(26);
11040 PRINT "SYMBOL"TAB(39)"VALUE"TAB(50)"SYMBOL"TAB(61)"VALUE"
11050 FOR I=1 TO 48 STEP 3
11060 PRINT  I TAB(6);NSYM$(I);TAB(13);PAR(I);
11070 PRINT TAB(26);I+1 TAB(31)NSYM$(I+1)TAB(39)PAR(I+1);
11080 PRINT TAB(50)I+2 TAB(54)NSYM$(I+2)TAB(62)PAR(I+2)
11090 NEXT I
11110 PRINT "DELAWARE OUTPUT INFORMATION ************************************"
11120 PRINT
11130 PRINT"SHELL SIDE HEAT TRANSFER COEF. PREDICT-W/M^2 K   ",ALPHAS
11140 PRINT"   JC=";JC;"   JR=";JR;"   JL=";JL
11150 PRINT"   JS=";JS;"   JB=";JB;"   JTOT=";JTOT
11160 PRINT "TUBE SIDE HEAT TRANSFER COEF. PREDICT-W/M^2 K   ",ALPHAT
11165 INPUT"Push RETURN to continue";Q$
11170 PRINT
11180 PRINT "TOTAL SHELL SIDE PRESSURE DROP  DPS    ,KPa",DPS
11190 PRINT "END ZONE PRESS DROP             DPE   ,KPa",DPE
11200 PRINT "BAFFLE WINDOW PRESS DROP        DPW   ,KPa",DPW
11210 PRINT "CROSSFLOW PRESS DROP            DPC   ,KPa",DPC
11220 PRINT "   RL=";RL;"    RB=";RB;"     RS2=";RS2
11230 PRINT"TUBE SIDE PRESSURE DROP                    ,kPa",DPTOT/1000
11235 INPUT"Push RETURN to continue";Q$
11240 PRINT
11250 PRINT"SHELL ID  ,mm=";DS;"    TUBE OD,mm=";DT;"      TUBE LENGTH=";LTO
11260 PRINT"C BAFFLE SPACE="; LBC;"    NO OF BAFFLES=";NB;"    AREA=";AO
11270 PRINT
11280 PRINT
11290 PRINT"NO OF TUBES  ",NTT "  PREDICTED NO OF TUBES FOR SHELL DIA",NTTE
11300 PRINT"OVERALL TUBE LENGTH     "; LTO;"    U(OVERALL)= ";UO;   " W/M^K"
11310 PRINT"SHELL SIDE REYNOLDS NO. ";RES;"     RESIST SHELL SIDE=  ";PERS;"%"
11320 PRINT"SHELL SIDE PRANDTL NO.  ";PRS;"      RESIST TUBE SIDE= ";PERT;"%"
11330 PRINT"TUBE SIDE REYNOLDS NO.  ";RET;"     RESIST TUBE WALL=  ";PERW;"%"
11340 PRINT"TUBE SIDE PRANDTL NO.   ";PRT;"     RESIST TUBE FOUL=  ";PERTF;"%"
11350 PRINT"LOG MEAN TEMP DIFF,C    ";TLMTD;"     RESIST SHELL FOUL=  ";PERSF;"%"
11360 PRINT
11370 PRINT"DESIGN LOAD=   ";Q;"WATTS     PREDICTED LOAD=   ";QPRED;"WATTS"
11380 PRINT"AREAS OF CAUTION:                    (Q=U*A*LMTD*FLMTD)
11385 PRINT
11390 IF LTP/DT<1.25 THEN PRINT "LTP/DT=",LTP/DT
11400 IF LTP/DT>1.5  THEN PRINT "LTP/DT=",LTP/DT
11410 IF THETATP= 90 THEN PRINT "THETATP=",THETATP
11420 IF THETATP= 60 THEN PRINT "THETATP=",THETATP
11430 IF BC<20  THEN PRINT "BC=", BC
11440 IF BC>37  THEN PRINT "BC=", BC
11450 IF LBC<.2*DS  THEN PRINT "LBC TOO SMALL"
11460 IF LBC> DS THEN PRINT "LBC TOO LARGE"
11470 IF NTT<.92*NTTE THEN PRINT "NTT SEEMS SMALL CF";NTTE
11480 IF NTT>1.08*NTTE THEN PRINT "NTT SEEMS LARGE CF";NTTE
11490 IF JL<.6 THEN PRINT"JL<.6"
11500 IF NB<5 THEN PRINT "NO. OF BAFFLES<5--- POOR!"
11510 IF JR<.4 THEN PRINT "JR<.4"
```

```
11520 IF JTOT<.5 THEN PRINT "JTOT<.5"
11530 IF LSTAR> 2 THEN PRINT"LSTAR>2-- POOR!
11540 IF DPW/DPC>2 THEN PRINT"WINDOW PRES DROP HIGH COMPARED TO CROSSFLOW DP"
11550 IF DT<19 THEN GOTO 11560 ELSE 11590
11560 IF (LBMAX>68*DT) THEN PRINT"BAFFLE SPACE TOO LARGE FOR GRP 'A' MATLS"
11570 IF (LBMAX>60*DT+177) THEN PRINT"BAFFLE SPACE TOO LARGE FOR GRP 'B' MATLS"
11580 GOTO 11620
11590 IF (LBMAX>52*DT+532) THEN PRINT"BAFFLE SPACE TOO LARGE FOR GRP 'A'MATLS"
11600 IF (LBMAX>46*DT+436) THEN PRINT"BAFFLE SPACE TOO LARGE FOR GRP 'B' MATLS"
11610 IF TEST=1 THEN PRINT" TUBE SIDE DATA ARE MEANINGLESS IN THIS TEST RUN"
11620 IF(Q>QPRED)THEN PRINT "PREDICTED LOAD LESS THAN DESIGN LOAD"
11622 IF TEST=1 THEN PRINT"TUBE SIDE DATA MEANINGLESS FOR THIS TEST RUN"
11630 IF FLMTD<.8 THEN PRINT"FLMTD SEEMS LOW-CK OUTLET TEMP VALUES"
11640 IF JB<.82 THEN PRINT"JB<.82 (IMPLIES LARGE BUNDLE BYPASS FLOW)"
11650 RETURN
12000 REM END OF CRTOUT
```

```
14001 REM                          DELAWARE
14002 REM                   LLNL Micro--CAE  Software
14003 REM                     (C) COPYRIGHT  1983
14004 REM            The Regents of the University of California
14005 REM
14006 REM
14010 REM SUBROUTINE FLMTD    7/15/83   MBL
14020 REM  THIS ROUTINE WILL CALCULATE A CORRECTION FACTOR TO THE LMTD
14030 REM  FOR A TEMA TYPE E SHELL AND TUBE EXCHANGER.
14035 IF TEST=1 THEN GOTO 14140
14040 R14=MS*CPS/(MT*CPT)
14045 IF TS1=TS2 THEN  14140 ELSE 14050
14050 P14=(TS1-TS2)/(TS1-TT1)
14060 IF R14=0 THEN GOTO 14100
14070 DELTA=(R14-1)/(LOG((1-P14)/(1-P14*R14)))
14080 GOTO 14110
14100 DELTA=(1-P14)/P14
14110 ETA=SQR(R14^2+1)
14120 FLMTD=ETA/(DELTA*LOG((2-P14*(1+R14-ETA))/(2-P14*(1+R14+ETA))))
14130 RETURN
14140 FLMTD=1
14150 RETURN
14300 REM END OF FLMTD
```

```
15001 REM                          DELAWARE
15002 REM                   LLNL Micro--CAE  Software
15003 REM                     (C) COPYRIGHT  1983
15004 REM .          The Regents of the University of California
15005 REM .
15006 REM
15010 REM SUBROUTINE DASSIGN 7/29/83 MBL
15020 VNM$(1)="SHELL SIDE FLOW RATE    ,KG/SEC":NSYM$(1)="MS"
15030 VNM$(2)="TUBE SIDE FLOW RATE     ,KG/SEC":NSYM$(2)="MT"
15040 VNM$(3)="SHELL INLET TEMPERATURE, DEG C":NSYM$(3)="TSI"
15050 VNM$(4)="SHELL OUTLET TEMP       , DEG C":NSYM$(4)="TSO"
15060 VNM$(5)="TUBE INLET TEMPERATURE,  DEG C":NSYM$(5)="TTI"
15070 VNM$(6)="TUBE OUTLET TEMP        , DEG C":NSYM$(6)="TTO"
15080 VNM$(7)="EST OVERALL HT COEFF, W/M^2 K ":NSYM$(7)="U1"
15090 VNM$(8)="SP HT OF SHELL FLUID, J/KG K ":NSYM$(8)="CPS"
15100 VNM$(9)="SP HT OF TUBE  FLUID, J/KG K ":NSYM$(9)="CPT"
15110 VNM$(10)="DENSITY OF SHELL FLUID,KG/M^3":NSYM$(10)="RHOS"
15120 VNM$(11)="DENSITY OF TUBE FLUID,KG/M^3 ":NSYM$(11)="RHOT"
15130 VNM$(12)="THERMAL COND OF SHELL FLUID,W/M K":NSYM$(12)="KSF"
15140 VNM$(13)="THERMAL COND OF TUBE FLUID ,W/M K":NSYM$(13)="KTF"
15150 VNM$(14)="VISC OF SHELL FLUID NEAR TSAV TEMP,PA S":NSYM$(14)="MUS1"
15160 VNM$(15)="TEMP OF PREV DATA DEG C":NSYM$(15)="TSV1"
15170 VNM$(16)="VISC OF SHELL FLUID NEAR  TWALL  ,PA S":NSYM$(16)="MUS2"
15180 VNM$(17)="TEMP OF PREV DATA DEG C":NSYM$(17)="TSV2"
15190 VNM$(18)="VISC OF TUBE FLUID NEAR TTAV TEMP,PA S":NSYM$(18)="MUT1"
15200 VNM$(19)="TEMP OF PREV DATA DEG C":NSYM$(19)="TTV1"
15210 VNM$(20)="VISC OF TUBE FLUID AT TWALL, PA S":NSYM$(20)="MUT2"
15220 VNM$(21)="TEMP OF PREV DATA DEG C":NSYM$(21)="TTV2"
15230 IVMX=21
15260 RETURN
15300 REM END OF DASSIGN
```

```
16001 REM                          DELAWARE
16002 REM                   LLNL Micro--CAE  Software
16003 REM                     (C) COPYRIGHT  1983
16004 REM            The Regents of the University of California
16005 REM
16006 REM
16010 REM SUBROUTINE DVARB  7/29/83 MBL
16020 IF DTEST=1 THEN MS=22.05          ELSE MS=  VINPT(1)
16030 IF DTEST=1 THEN MT=35.28          ELSE MT= VINPT(2)
16040 IF DTEST=1 THEN TSI=33.88         ELSE TSI=VINPT(3)
16050 IF DTEST=1 THEN TSO=29.44         ELSE TSO=VINPT(4)
16060 IF DTEST=1 THEN TTI=23.88         ELSE TTI=VINPT(5)
16070 IF DTEST=1 THEN TTO=26.67         ELSE TTO=VINPT(6)
16080 IF DTEST=1 THEN U1=3050           ELSE U1= VINPT(7)
16090 IF DTEST=1 THEN CPS=4178          ELSE CPS=VINPT(8)
16100 IF DTEST=1 THEN CPT=4178          ELSE CPT=VINPT(9)
16110 IF DTEST=1 THEN RHOS=1000         ELSE RHOS=VINPT(10)
16120 IF DTEST=1 THEN RHOT=1000         ELSE RHOT=VINPT(11)
16130 IF DTEST=1 THEN KSF=.618          ELSE KSF=VINPT(12)
16140 IF DTEST=1 THEN KTF=.618          ELSE KTF=VINPT(13)
16150 IF DTEST=1 THEN MUS1=.0008        ELSE MUS1=VINPT(14)
16160 IF DTEST=1 THEN TSV1=30           ELSE TSV1=VINPT(15)
16170 IF DTEST=1 THEN MUS2=.0008        ELSE MUS2=VINPT(16)
16180 IF DTEST=1 THEN TSV2=30           ELSE TSV2=VINPT(17)
16190 IF DTEST=1 THEN MUT1=.0008        ELSE MUT1=VINPT(18)
16200 IF DTEST=1 THEN TTV1=30           ELSE TTV1=VINPT(19)
16210 IF DTEST=1 THEN MUT2=.0008        ELSE MUT2=VINPT(20)
16220 IF DTEST=1 THEN TTV2=30           ELSE TTV2=VINPT(21)
16230 REM
16240 RETURN
16300 REM END OF DVARB
```

```
17001 REM                          DELAWARE
17002 REM                    LLNL Micro--CAE  Software
17003 REM                      (C) COPYRIGHT  1983
17004 REM            The Regents of the University of California
17005 REM
17006 REM
17010 REM SUBROUTINE DGEO  7/29/83 MBL
17015 DIM DT(17),DS(17),LTW(17),LTP(17),NTT(17)
17020 Q=ABS( MS*CPS*(TSI-TSO))
17050 TSAV=.5*(TSI+TSO)
17060 TTAV=.5*(TTI+TTO)
17070 IF TSAV>TTAV THEN 17080 ELSE 17100
17080 TDIF1=TSI-TTO:TDIF2=TSO-TTI
17090 GOTO 17110
17100 TDIF1=TTI-TSO:TDIF2=TTO-TSI
17110 TLMTD=(TDIF1-TDIF2)/LOG(TDIF1/TDIF2)
17115 PRINT"TEMPERATURE INPUTS IMPLY:  LMTD=  ";TLMTD;"K"
17120 ANEED= Q/(U1*TLMTD*FLMTD)
17125 PRINT"FOR THE 'U' VALUE ESTIMATED THIS REQUIRES AN AREA OF";ANEED;"M^2"
17130 DS1=SQR(ANEED*1E+06/190)
17140 FOR I=1 TO 17
17150 READ DT(I)
17160 READ DS(I)
17170 READ LTW(I)
17180 READ LTP(I)
17190 NTT(I)=.85*(DS(I)-DT(I))^2/(LTP(I))^2
17200 DATA 6.350,  203,  .559,  7.938:REM                Table of suggested
17210 DATA 9.525,  254,  .889, 12.700:REM              shell-tube-spacing
17220 DATA 12.700,  305,  .889, 16.669:REM                  combinations
17230 DATA 12.700,  337,  .889, 16.669
17240 DATA 12.700,  387,  .889, 16.669
17250 DATA 12.770,  438,  .889, 16.669
17260 DATA 12.700,  489,  .889, 16.669
17270 DATA 15.875,  540,  .889, 20.638
17280 DATA 15.875,  591,  .889, 20.638
17290 DATA 15.875,  635,  .889, 20.638
17300 DATA 19.050,  686, 1.245, 25.400
17310 DATA 19.050,  737, 1.245, 25.400
17320 DATA 19.050,  787, 1.245, 25.400
17330 DATA 22.225,  838, 1.651, 28.890
17340 DATA 22.225,  889, 1.651, 28.890
17350 DATA 22.225,  940, 1.651, 28.890
17360 DATA 25.400,  991, 2.108, 33.338
17380 IF DS1<1.15*DS(I)  THEN GOTO 17400
17390 NEXT I
17400 DS=DS(I)
17410 DT=DT(I)
17420 NTT=NTT(I)
17425 NTT=INT(NTT)
17430 LTW=LTW(I)
17440 LTP=LTP(I)
17450 LBC=.6*DS
17460 LTO=ANEED*1E+06/(3.14159*DT*NTT):PRINT"LTO=",LTO
17470 IF LTO/DS<6 THEN 17500
17480 IF LTO/DS>9 THEN 17390
17490 GOTO 17510
17500 I=I-1:GOTO 17400
17510 IF LTO/LBC -1<5  THEN LBC=LTO/6
17520 THETATP=30
17521 PRINT"LET'S TRY:SHELL DIA OF   ";DS;"mm"
```

```
17522 PRINT"            TUBE DIA OF     ";DT;"mm"
17523 PRINT"            NO OF TUBES     ";NTT
17524 PRINT"     OVERALL TUBE LENGTH    ";LTO;"mm"
17530 LTI=LTO-.2*DS
17540 LBI=LBC
17550 LBO=LBC
17560 KTW=42
17570 IF DT<32 THEN LTB=.4 ELSE LTB=.8
17580 LSB=3.1+.004*DS
17590 IF ((CB$="F" OR CB$="U") AND DT<500) THEN LBB=15
17600 IF ((CB$="F" OR CB$="U") AND DT>500) THEN LBB=15+10*(DS-500)/2000
17610 IF (CB$="S" OR CB$="P") THEN  LBB=30+(DS-200)*34/2300
17620 IF(CB$="T") THEN LBB=88(1+(DS/2900)^1.5)
17630 NB=INT(LTO/LBC-1)
17640 NSS=0
17650 NTP=1
17660 BC=20+21.2*(LBC/DS-.2)
17662 ALPHAS=1.4*U1
17664 ALPHAT=1.4*U1
17670 RETURN
17690 PRINT:PRINT"REMEMBER THESE ARE JUST FIRST ITERATION VALUES!"
17700 REM ENDOF DGEO
```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