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OFFICE OF SALINE WATER

EVAPORATOR COMPONENT DEVELOPMENT PROGRAM

CONDENSER TUBE BUNDLE CONFIGURATIONS FOR 50-Mgd AND LARGER DESALINATION PLANTS

H. M. Noritake
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Evaporator Component Development Program

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H. M. Noritake
R. W. Browell

JUNE 1967

Final Report

OAK RIDGE NATIONAL LABORATORY
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CONDENSER TUBE BUNDLE CONFIGURATION

1. INTRODUCTION

Large desalination plants require tube bundles exceeding the size of those used in steam surface condensers of power plants and operating under different conditions. Tube arrangements and configurations are important factors in designing to obtain minimum pressure losses and maximum heat transfer without incurring excessive shell costs. In addition, consideration must be given to methods for removing noncondensables and for providing adequate flow velocities over the tubes in sections of the condenser where the tubes are liable to become air bound. To achieve minimum pressure drop, the designer must find the optimum tube spacing and maximum coil width.

Large desalination plants have many square feet of wall area; and, with major portions of it operating at pressures below atmospheric, inleakage of air is almost certain to occur. In addition, the makeup brine stream entering the plant contains dissolved gases which upon being heated are released; and, if the deaerator is not operating properly, they can enter the main evaporator plant and be drawn into the condenser tube banks. The deleterious effect of these relatively small amounts of noncondensables upon the condensing heat transfer coefficient is widely recognized, and they must be considered in the calculations. While the actual amount of noncondensables reaching the condenser tubes of a flash evaporator may be very small, estimated as being on the order of 0.002% to 0.02% weight percent even in the worst situations, the removal of water vapor from the flowing stream will lead to higher fractions of noncondensables as the gas passes through the tube bank.

The Office of Saline Water has had the Oak Ridge National Laboratory to study the problems of large condenser bundle design. This document presents the findings of this work. The main objectives of the study were as follows:

1. To identify design parameters and extract from the literature the most reliable information on heat transfer, steam pressure losses, tube spacing, tube length, tube diameter, bundle shape, venting, condensate rain, and other technical aspects of condenser design.

2. To review and briefly describe current design practices in industry.

3. To develop a computer program for general use and a graphical presentation of the data.

It is expected that this study will enable proper evaluation of designs for 50-Mgd and larger plants, as well as provide methods for design.

2. LITERATURE SURVEY

A literature survey was made to obtain reliable information on heat transfer, steam pressure losses, tube spacing, tube length, tube diameter, tube bundle shape, methods of removing noncondensables, condensate rain, and other aspects of condenser design. The reference list of condenser design reports consulted is included in Appendix F.

In our opinion, the most useful data on particular aspects of condenser design were found to be as follows:

a. Forced convection film coefficient, Reference 13.

b. Condensing coefficient, Reference 4.

c. Steam pressure loss, References 3, 6, 7, and 8.

d. Effect of noncondensables, References 14 and 17.

e. Method of removing noncondensables.

Discussions with industrial designers regarding current practice (see section below).

3. CURRENT CONDENSER DESIGN PRACTICES

Manufacturers of steam surface condensers were consulted to obtain general data for use in design of evaporator condenser coils. Design of tube sheet layout is considered proprietary information; therefore, no specific data were obtained on this item. The following data outline the current design practices used by three major manufacturers of power plant steam condensers.

3.1 Mechanical Design Features Associated with Condensers

3.1.1 Company A

Company A's method of handling noncondensable is to design the tube layout and the steam lanes to converge the noncondensables toward the bottom center of the condenser to an air cooler section. From this point they are continuously removed by a two-stage ejector. A downstream air meter detects any increase in flow. Dual, two-stage ejectors share common inter- and after-condensers. A "hogging" steam ejector evacuates the system before start-up.

Company A makes tube-to-tube-sheet seals by slipping rubber "O" rings over the tubes and then flaring the tube ends into the tube sheet, instead of using a rolled joint.

For seawater installations, Company A has found epoxy coatings over a fiberglass lay-up to be effective in protecting water boxes against corrosion.

3.1.2 Company B

The Company B method of coping with noncondensables is quite similar to that of Company A except that the convergence is more toward the center of the condenser tube bundle. Removal is effected by the apparently standard arrangement of paralleled two-stage steam ejectors with common inter- and after-condensers.

Company B also has used epoxy coatings to protect water boxes in salt-water service. The actual coating is a Dow-Corning mixture of epoxy and "flake" glass. They have previously experimented with epoxy-fiberglass but found the adhesion to be rather poor. In contrast, the epoxy-flake glass coatings are still giving good protection since their application six years ago.

Tubes are normally rolled into the tube sheet but are welded if requested. In the latter case, the tubes are fusion TIG welded with no filler metal being used. Considerable care must be exercised to avoid tube sheet warpage during welding.

3.2 Condenser Bundle Design

3.2.1 Company C

3.2.1.1 Tube Sheet Layout

1) Steam lanes are used to direct steam flow rather than baffles.

2) The tube rows between steam lanes are usually two or three rows deep, occasionally one row, and never more than four rows.

3) Toward the center of the tube bundle, the tubes are closely spaced with no regard to steam laning since velocities and pressure drops are quite low in this section.

3.2.1.2 Pressure Drop

1) Pressure drop in the bundle is the pressure drop encountered by the vapor flowing in the steam lanes, plus the pressure drop across the tubes.

2) Pressure drop is minimized by directing vapor flow essentially downward, parallel to the direction of condensate flow, rather than horizontally or upward.

3) Maximum velocity encountered in surface condensers ranges from 300 to 500 ft/sec coming from the turbine.

4) Experimental data from test sections of tube bundles are used to calculate pressure drop in Company C's surface condensers.

5) Company C has a computer program which will calculate pressure drop and heat transfer for a specified tube sheet layout. This program, however, does not determine optimum tube sheet layouts.

3.2.1.3 Noncondensables

1) The amount of noncondensables in surface condensers is normally on the order of 5 scfm per million lb/hr of steam flow.

2) For handling noncondensables, a cooler section is incorporated in the vicinity of the noncondensable removal pipe to remove most of the remainder of the water vapor from the noncondensable gas.

3) The noncondensables are directed longitudinally through the bundle from the higher pressure (warm) end to the lower pressure (cold) end and then fed to the ejector system.

4) This cooler section comprises approximately 2% of the total tubes in the bundle.

5) A minimum vapor velocity of 50 ft/sec within the bundle is desirable to keep tubes swept free of noncondensables.

3.2.1.4 Heat Transfer Coefficient

Coefficients in the HEI[1] Standards are used for condenser design.

3.2.2 Company D

3.2.2.1 Tube Sheet Layout

1) Steam lanes are used to direct steam flow; tapered bundles have been tried with little success.

2) Tube rows between steam lanes are usually just two rows deep.

3) Tubes are quite closely spaced at the center of the bundle.

3.2.2.2 Pressure Drop

1) Pressure drop to distribute the incoming steam around the periphery of the tube bundle and pressure drop for steam flow through the bundle should both be considered for optimum tube bundle design.

2) Direction of vapor flow within the bundle, i.e., up, down, or horizontal, does not make a noticeable difference in the pressure drop.

3) Condenser pressure drop calculations based on information published by Diehl[6] and Diehl and Unruh [7] give reasonable results.

3.2.2.3 Noncondensables

1) The amount of noncondensables are usually less than the maximum specificed in the HEI[1] Standards.

2) Minimum velocity of 40 ft/sec is necessary throughout the tube bundle to minimize noncondensable accumulations.

3) A gas cooler section is incorporated to remove most of the remainder of the water vapor from the noncondensables.

4) Noncondensables are removed from each section of the bundle by means of a central pipe, rather than allowed to flow longitudinally through the bundle.

3.2.2.4 Heat Transfer Coefficient

1) The Nusselt[2] condensing coefficient for five rows yields a satisfactory average value for use in bundle design.

2) To minimize flooding, a good design should probably have no more than twenty-five tubes in a row vertically, although this rule is not inviolate.

3) The optimum tube bundle orientation was calculated to be a 60-degree equilateral triangle laid out with the one side of the triangle 19 degrees from the vertical. With this tube orientation, the condensate drain from one tube strikes the tube below tangentially, leaving a larger portion of the lower tube surface dry for better condensing performance. However, other considerations, such as drilling the closely packed portion of the tube sheet at the center, may require some relief from this optimum 19-degree orientation.

4) Company D has a wealth of condenser data accumulated over years of testing.

5) Condensers are designed for 96% to 98% efficiency based on the following definition of efficiency:

$$\text{Eff} = \frac{\text{U actual}}{\text{U based on flange conditions*}}$$

*defined as inlet and outlet nozzle conditions.

3.2.3 Company E

3.2.3.1 Tube Sheet Layout

1) Condensers containing 30,000 square feet or less of surface area are considered to be small condensers, and no steam lanes are used in the tube sheet layouts of this size. No steam flow path through the tube bundle can be longer than 3 feet irrespective of the tube packing arrangement.

2) Larger condensers than those above are designed with steam lanes for every three rows of triangularly arrayed tubes. Condensate removal baffles are located carefully to avoid flooding.

3) Tube bundles are designed to insure that sufficient steam (approximately 20%) will enter the tube bundle from the bottom to serve as a reheat source and thus minimize subcooling of the condensate.

4) The tube sheet layout of a large TVA condenser was described as a unique design necessitated by the requirement of horizontal steam flow into the condenser. It represents a standard Company E design rotated 90 degrees from the vertical and is thus an untried modification.

5) Minimum web thickness on their tube sheets is 0.25 inches for 5/8-inch diameter tubes with somewhat thicker webs for larger tubes.

3.2.3.2 Pressure Drop

1) The steam velocity at the entering face of the tube bundle is a maximum of 150 ft/sec to minimize pressure drop losses.

2) The minimum design face velocity is 100 ft/sec in order to insure uniform distribution of the steam into all four faces of the tube bundle.

3) The design pressure drop for condensers operating at 1 inch Hg is around 0.1 inch Hg ΔP from plenum chamber to air removal pipe. (This corresponds to about $3^{o}F$ temperature drop at 1 inch Hg.)

4) No noticeable effect on pressure drop of direction of steam flow through the bundle (i.e., horizontal, up, or down) has been observed.

5) Flow of steam through the tube bundle is calculated with the assumption that all tubes in the bundle have the same heat duty.

3.2.3.3 Noncondensables

1) Approximately 5% of the steam is removed through the noncondensable system. Loss of steam, however, is minimized by utilizing a somewhat oversized condenser in the steam ejector system.

2) The proportion of noncondensables in the vapor stream removed through the noncondensable system is very small.

3) The vapor removed through the noncondensable system is at the saturation temperature corresponding to the pressure in the gas cooler section.

3.2.3.4 Heat Transfer Coefficient

1) Heat transfer coefficients are obtained by calculating an overall U based on a single tube coefficient for the condensing side and then multiplying this value by 0.85.

2) Dead spots of noncondensables are found to occur in the shadows of the condensate removal baffles.

3.2.3.5 Miscellaneous

The pressure drop correlations given in the HEI[1] Standards for water flow through tubes and through water boxes are much too high and are currently under revision.

4. COMPUTER PROGRAM FOR CALCULATING PERFORMANCE OF CONDENSER TUBE BUNDLES

4.1 Purpose of Program

The second phase of this study consists of developing a computer program for use in calculating pressure drop and heat transfer values for various types of tube bundle configurations. The purpose of this program is to enable the performance of condenser tube bundles to be predicted to the best extent possible with the current information available. The application of all available information through computerized designing of condenser bundles is a logical step since over-design and under-design of the tube bundles of an evaporator plant could cause considerable variation in plant capital cost.

Use of this program will enable detailed analysis of condenser tube bundles in each stage of a flash plant, thus allowing closer predictions of performance. Incorporated in this analysis will be the heat transfer performance of individual tubes as affected by their location within the bundle. Among the factors that must be considered are the following:

1. The amount of condensate flowing down from the upper rows of tubes.

2. The local saturation pressure and local saturation temperature at the internal tube rows as determined by pressure drops encountered by the vapor as it flows through the bundle.

3. The effect of small amounts of noncondensables in the vapor stream upon the heat transfer coefficient, particularly as the noncondensable concentration increases with passage through the bundle.

4. The effect of pressure level upon the heat transfer and the pressure drops within the bundle.

5. The effect of change of bundle geometry such as amount of face area presented to the flow, depth of the bundle, fraction of tubes that are shielded by baffles to form a gas cooler section, etc.

The preferred method of using this program is to incorporate it into an evaporator plant program as a subroutine which makes the initial estimates of the bundle geometry, performs the necessary thermal and hydraulic analysis, and returns an overall heat transfer coefficient to the main program for use in finalizing the plant design. Also included in these calculations could be such additional information as the amount of noncondensables present and the fraction of tubes in a baffled gas cooler section. Another use of this program could be as a separate program where information on bundle dimensions and vapor flow to the tube is inserted and bundle performance at various locations can be analyzed. This data may be used then to make modifications to the bundle geometry results of the evaporator plant program, thus obtaining an optimum bundle configuration.

As mentioned above, the condenser tube bundle codes described in this report use the input information on steam flows and temperatures, general bundle configuration, and tubing information and, from these, proceed to make row-by-row analyses in selected sections of the tube bundle. These analyses consist of pressure drop and heat transfer calculations for each row, performing thermal balances, adjusting the pressure and temperature conditions at the exit of each row to correspond to the calculated changes and then repeating the procedure for the next row encountered. Local conditions for temperature, pressure, heat transfer, condensation, presence of noncondensables, etc., are employed based upon the best correlations available for heat transfer and pressure drops. After following the vapor flow through the main portion of the tube bundle, the procedure is repeated for the gas cooler section to define pressure, temperature and flow conditions at the exit of the tube bundle.

In this fashion, the performance of the condenser bundle is evaluated, and an area-weighted overall heat transfer coefficient is obtained based upon the direction of vapor flow within the condenser, whether it be horizontal, vertical, or radial flow. At the same time, pressure drops and associated temperature losses are evaluated, thus defining the conditions of the exit stream from the tube bundle.

In addition, if a certain percentage steam loss at the bundle exit is specified, an iterative loop is available which will adjust the tubing length in the bundle in order to achieve the desired percentage condensation. Thus, the correct surface area required to perform a specific duty can be obtained through the use of either the rectangular or the circular condenser bundle code.

Descriptions of the heat transfer correlations employed in these codes are given in Section 4.8, and pressure drop correlations are given in Section 4.9. Descriptions of the condenser codes, including flow charts and listings of the codes, are presented in the Appendix.

4.2 Input Information

Input information to this code should be fairly specific in detailing the duty expected of the particular condenser. For desalination plants, most of these details are quite readily available so that the assembly of the input information should be relatively simple and straightforward. Among the information required by this code are the data normally presented on a flow sheet and the following:

1. Flows and Temperatures
   - a. Steam or vapor flow rate, lb/hr
   - b. Coolant flow rate, ft/sec
   - c. Brine concentration in the coolant, ppm
   - d. Noncondensable flow rate, lb/hr
   - e. Exit steam fraction
   - f. Inlet steam temperature, ^{o}F
   - g. Inlet coolant temperature, ^{o}F
2. Bundle Information
   - a. Number of tubes in the bundle
   - b. Percent of tubes allocated to the gas cooler
   - c. Ratio bundle height/bundle width
   - d. Bundle length, ft
   - e. Direction of steam flow, vertical or horizontal
   - f. Tube spacing in condenser
   - g. Tube spacing in the gas cooler
   - h. Half or full condenser
3. Tubing Information
   - a. Tube O.D., inch
   - b. Wall thickness, inch
   - c. Wall thermal conductivity, Btu/hr-ft^2-^{o}F/ft
   - d. Fouling factor

In specifying the input information, it must be borne in mind that the code is analyzing the performance of a single tube bundle. Consequently, if the tube bank is expected to consist of two or more separate bundles, it will be necessary to apportion the steam and noncondensable flow rates and the number of tubes accordingly.

The coolant for the condenser bundle is assumed to be either water or brine and the equations for physical properties, such as heat capacity, thermal conductivity, density, and viscosity that are incorporated into the code have been done with this in mind. Similarly, the noncondensable gas entering the bundle along with the steam is assumed to be air, and the physical properties for air are incorporated in this code.

Exit steam fraction is the fraction of the entering steam which remains uncondensed at the exit to the noncondensable removal system. This fraction may be specified if desired, in which case the stage length which is given as input information will be used only as a first estimate. Additional calculations are then performed by the code to arrive at a bundle length which will satisfy the exit fraction requirement. If the exit fraction value is given as 0.0, the code will consider the tube length as being specified and solve for the exit fraction of steam leaving the condenser.

The steam temperature given as input is assumed to be the saturation temperature, and the saturation pressure is calculated from this value. The total pressure of the system is found by adding the partial pressure of the noncondensables to this saturation pressure. Over the range of temperatures and pressures involved, it is assumed that the noncondensable gas can be treated as an ideal gas.

The specified coolant inlet temperature is assumed to be the same for all tubes in the bundle. The row-by-row calculation performed within the code, however, makes no such assumption concerning the exit temperature of the brine from the tubes in the different parts of the bundle and proceeds to solve for these local exit temperatures.

The number of tubes specified is the total number of tubes per bundle, including those in the gas cooler section.

The ratio of bundle height to bundle width refers to the approximate shape of the condenser portion of the bundle. When this ratio is specified as 1.0, the bundle height, h, will be equal to the bundle width, w (Figure 2); or, in other words, the bundle will have a square cross section exclusive of the gas cooler section. If the ratio is specified as 2.0, the vertical face dimension will be twice that of the horizontal face, etc.

Percent tubes in the gas cooler specifies the approximate number of tubes to be located in the gas cooler section. This specification undergoes a slight adjustment during the course of rounding off the number of horizontal and vertical rows to integers for the sake of indexing within the program, but the final value will be within a very small fraction of the specified percentage.

Bundle length is an input value which may be held constant during calculation or may be altered, depending upon the analysis desired. As mentioned above, if the exit fraction of steam is entered as 0.0, the condenser code will hold the bundle length inviolate and solve for the fraction of steam leaving the condenser as a dependent variable. If, however, the exit fraction is entered as some finite value greater than 0., the program will solve for a bundle length which will meet the specified exit steam fraction.

The S/D ratios, or tube spacing-to-tube diameter ratio (Figure 1) in the condenser and in the gas cooler section, are specified separately. This will allow larger spacings and lower pressure drops in the main or the condenser portion of the bundle if desired, and at the same time relatively close spacing and higher velocities in the gas cooler section where the uncondensed fraction is relatively small.

The direction of steam flow may be specified as vertical or horizontal for the condenser portion of the bundle. The vapor flow is assumed to follow only the specified orientation, with no cross flow or diagonal flow being considered. While this is admittedly a simplification of the true flow pattern, it is felt that the results should still present a reasonable characterization of the internal performance of the condenser. While shrouding or baffling may be necessary to obtain a vertical-only or a horizontal-only flow pattern, neither the presence nor the absence of such baffling is assumed by the code.

Vertical baffling is assumed around the gas cooler section to direct the vapor and gas mixture into entering this section at the bottom and then traveling upward through it to the noncondensable removal duct. Vapor flow in the gas cooler section is assumed to be upward in every case with the noncondensable removal duct located at the top as shown in Figure 1.

Another geometrical variation which may be specified is whether the bundle is symmetrically arranged on each side of the gas cooler section or whether the gas cooler section is located at the back of the bundle with all flow coming through the front face only for the horizontal flow, or the top face only in the case of the vertical condenser. The sketch in Figure 2 illustrates these two variations which are called as a "full" condenser or a "half" condenser within the program.

Tubing information to be inputted, such as outside diameter, wall thickness, wall thermal conductivity, and fouling factor, is standard information for condenser calculations and should present no difficulty to the user.

Calculations made for rectangular condensers of a representative multistage flash plant* indicate that the pressure drop for vapor

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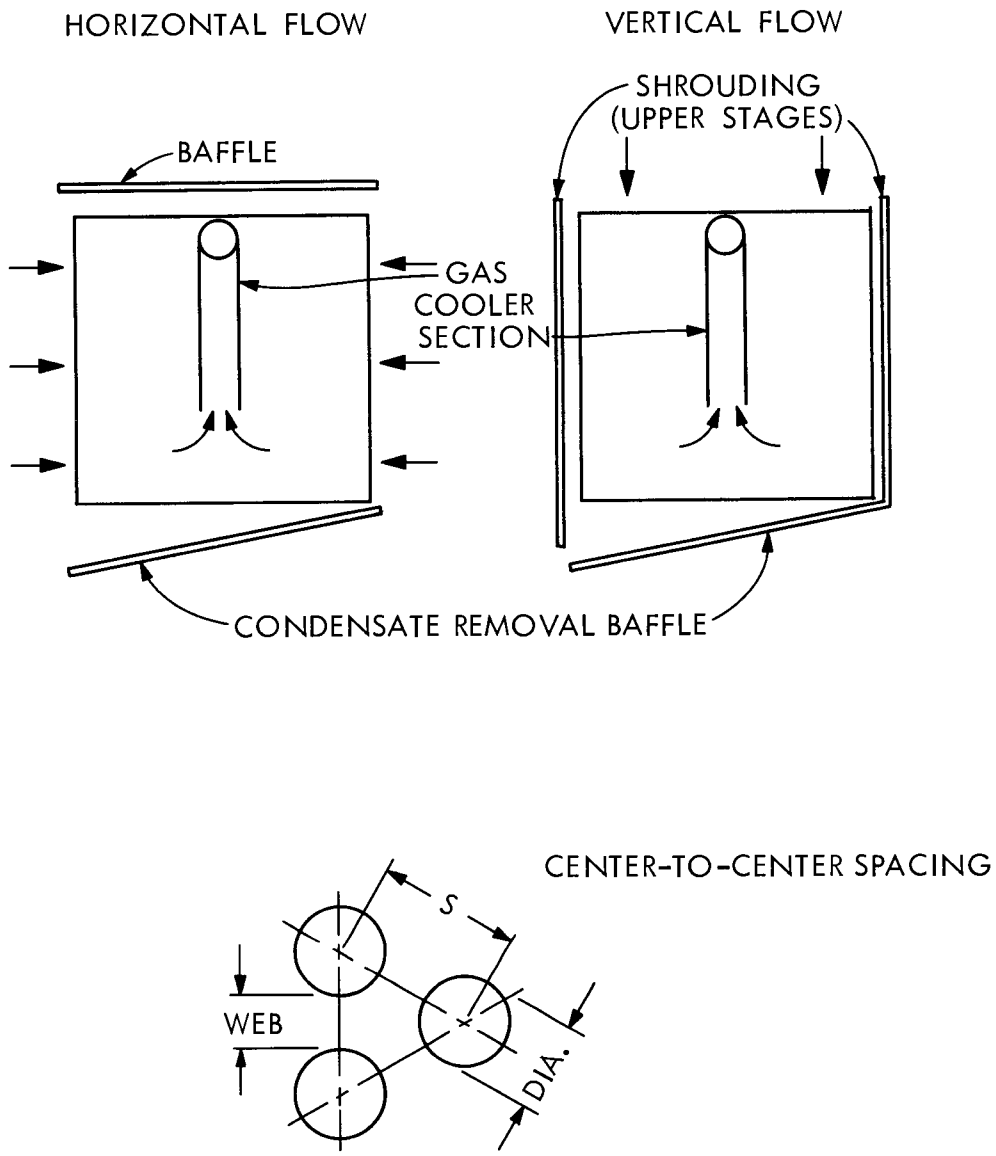
*A 50-Mgd multistage flash plant with 56 stages and maximum brine temperature of 250°F as calculated by the computer code ORSEF. There are 16 separate bundles in this design.

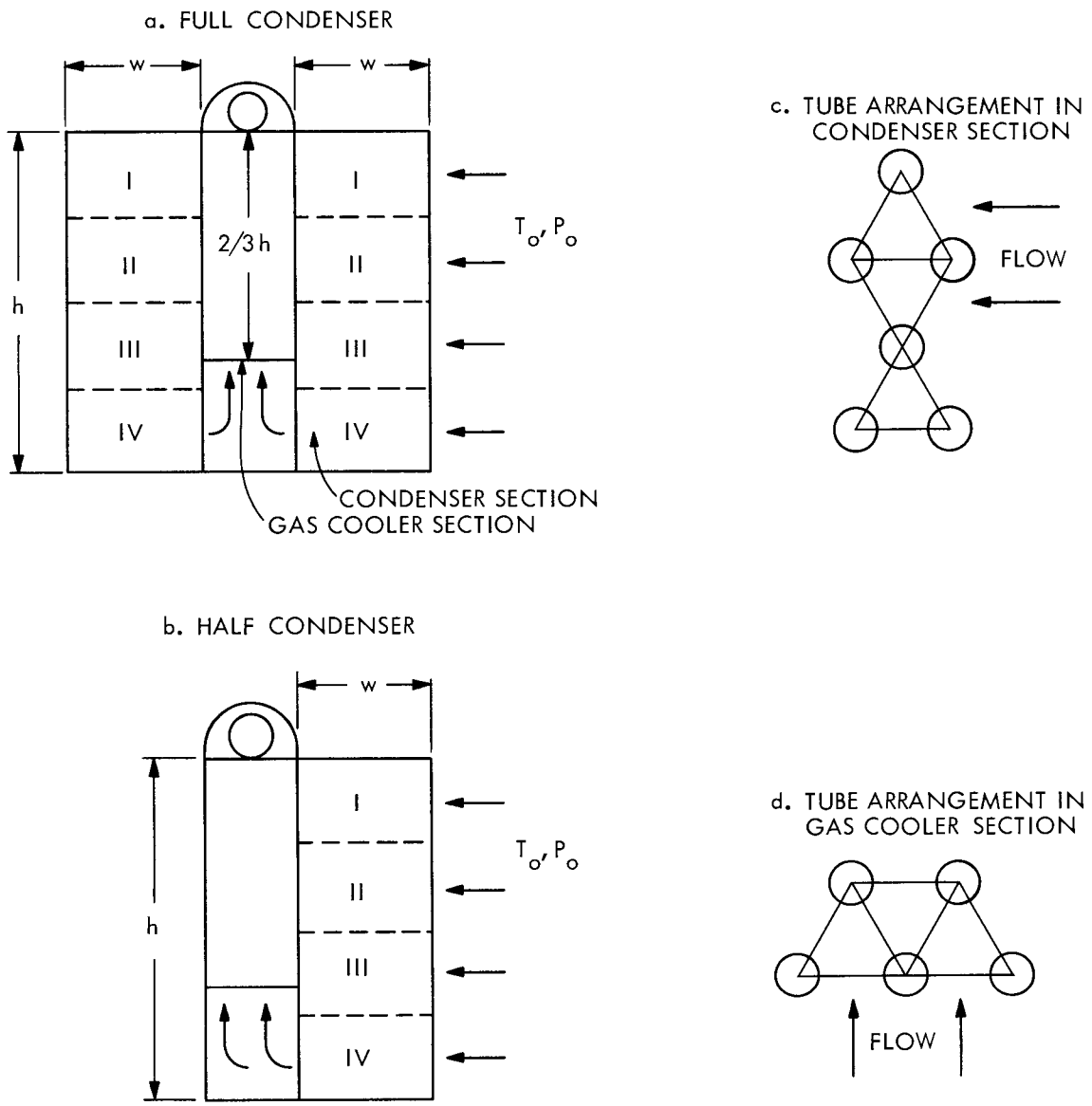
DWG. NO. G-67-226



SKETCH OF TUBE BUNDLE AND VAPOR FLOW PATHS

Figure 1

DWG. NO. G-67-225



RECTANGULAR CONDENSER BUNDLE

Figure 2

flowing through the condenser bank is very small over a major portion of the plant. (See Table I.) Since the majority of the tube and bundle sections will operate with very small pressure drops, it appears that the bundles for the condenser should be laid out with a minimum allowable web thickness. This can lead to relatively large temperature drops in the last two or three stages of a flash plant, but the overall penalty incurred due to these few stages will be very small. On the other hand, the closely spaced tube banks will provide more positive sweeping of noncondensables from the tube banks, and this should enhance the performance of those stages where noncondensable buildup is a problem.

Since the pressure drop is very low, steam lanes should not be required in the evaporator section condenser bundles. The heat reject section of a flash evaporator plant might use a more open tube spacing and/or steam lanes, since the vapor volumes to be handled are larger at this end of the plant.

4.3 Calculation of the Geometry for the Rectangular Tube Bundle

In the rectangular tube bundle code, the actual geometry of the bundle is calculated in the following fashion:

1. The fraction of tubes in the condenser portion of the bundle is obtained from the input information.

2. The tubes in the condenser are assumed to be arranged on a lattice of equilateral triangles with the base of the triangles oriented parallel to the horizontal flowing vapor (Figure 2). Consequently, the vertical face of the bundle will be equal to the quantity 0.866 x S/D x S x number of tubes in a vertical row, and the horizontal face of the bundle will be S/D x D x number of tubes in the horizontal row. Since the ratio of bundle height to bundle width is part of the input information, the number of tubes in a vertical row and in a horizontal row are quite readily determined. The number of tubes in the horizontal row is obtained first and rounded up to the nearest integer divisible by 2 in the case of the full condenser, since there will be two condensing sections. With the rounded number, the number of tubes in a vertical row is obtained and then also rounded up to the nearest integer.

3. Having determined the number of tubes in the condenser portion of the bundle, the number of tubes in the gas cooler section is redetermined as the difference between the total number of tubes specified and the number of tubes assigned to the condenser portion of the bundle by the code. A slight deviation in the fraction of tubes assigned to the gas cooler section from that specified in the input data will usually result.

4. The gas cooler section is assumed to have a vertical dimension equal to two-thirds the height of the condenser section. The equilateral triangles in this section are assumed to be oriented with the base normal to the vapor flow which means that the height of the gas cooler section is equal to 0.866 x S/D x D x number of tubes in a vertical row. The

TABLE I

CONDENSER BUNDLE DIMENSIONS AND PRESSURE DROP

Stage No.	Condenser Temp. °F	Tube Diameter, in.	S/D	Number of Rows		Bundle Dimension, ft		Product gpm	Pressure Drop		$\bar{U}$	Δt_m
				Horizontal	Vertical	Height	Width		psi	°F		
1	245.0	0.664	1.30	73.	44.	4.60	3.22	41.4	0.003	0.006	684.	11.5
5	234.5	0.664	1.30	73.	44.	4.60	3.22	40.6	0.003	0.007	671.	11.5
10	221.4	0.664	1.30	73.	44.	4.60	3.22	39.5	0.004	0.010	662.	11.6
15	208.2	0.664	1.30	73.	44.	4.60	3.22	38.6	0.004	0.015	645.	11.7
20	195.1	0.664	1.30	73.	44.	4.60	3.22	37.6	0.005	0.022	626.	11.8
25	182.0	0.664	1.30	73.	44.	4.60	3.22	36.7	0.006	0.033	613.	11.9
30	168.8	0.664	1.30	73.	44.	4.60	3.22	35.9	0.007	0.051	572.	12.0
35	155.6	0.664	1.30	73.	44.	4.60	3.22	35.0	0.008	0.080	555.	12.1
40	142.4	0.664	1.30	73.	44.	4.60	3.22	34.2	0.010	0.128	534.	12.1
45	129.1	0.664	1.30	73.	44.	4.60	3.22	34.4	0.012	0.208	496.	12.2
50	115.7	0.664	1.30	73.	44.	4.60	3.22	32.7	0.014	0.340	475.	12.1
54	104.9	0.664	1.30	73.	44.	4.60	3.22	32.1	0.017	0.511	440.	12.0
55	97.7	0.625	1.30	82.	27.	4.80	1.81	93.0	0.004	0.153	384.	11.1
56	89.8	0.625	1.30	82.	27.	4.80	1.81	53.3	0.007	0.313	340.	15.0

number of vertical rows arrived at in this fashion is rounded up to the nearest integer, and this value is used to obtain the number of horizontal rows required. The width of the horizontal section is equal to S/D x D x number of tubes in a horizontal row. These dimensions for the gas cooler section are subject to modification as will be explained later if the vapor velocity entering this portion were to exceed 150 ft/sec.

5. Calculations for the geometry for a vertical flow condenser are identical to those just described for a horizontal flow condenser.

4.4 Calculations for the Performance of the Rectangular Condenser Tube Bundle

With horizontal flow, as shown in Figure 2 for the full rectangular bundle, the vapor flow is assumed to approach the condenser horizontally from both sides, to undergo a contraction pressure drop into the tube side face of the bundle, and then to travel horizontally toward the center. Upon reaching the baffled section enclosing the gas cooler, the uncondensed portion travels downward until it reaches the entrance of the gas cooler section. Here, the remaining vapor is accelerated into the gas cooler section and then proceeds to travel upward to the noncondensable removal system. In the half bundle design shown in Figure 2b, the back face of the condenser is assumed to be blanked off by means of a baffle or a wall. Thus, flow is assumed to enter from a single face only. In all other respects, the flow path is similar to that described for the full condenser. Consequently, calculations involving the geometries in Figures 2a and 2b are essentially identical and only a flag in the input data is necessary to handle the required calculations for these two types.

The vertical face open to flow is divided into four equal horizontal sections with flow entering each section at identical temperatures and pressures. The overall heat transfer coefficient for the first row encountered in each section is calculated using the temperature and pressure conditions existing at that row. The forced convection coefficient inside the tube is based upon the Sieder-Tate correlation with the liquid coolant properties being calculated at the average coolant temperature, which in turn is dependent upon the amount of the heat transferred. This, of course, requires an iteration for the coolant exit temperature as a function of the calculated overall heat transfer coefficient. A fouling factor for the inside will also be considered in the calculation if entered as input data.

The average outside condensing coefficient is calculated using a modified Nusselt equation for the effect of the number of tubes in a vertical row. This equation is also a temperature dependent function and requires the same type of iteration as the inside coefficient calculation. The effect of the presence of noncondensables upon the condensing coefficient is treated by means of correlations based upon data available in the literature. The overall heat transfer coefficient based upon these individual resistances is then used to calculate the amount of water vapor condensed as the flow passes through the first row of tubes.

In addition, a second condensing coefficient is obtained for those tubes which are located above the mid-point of this section and which may thus be considered as contributing to the condensate rain falling through this section. A second overall heat transfer coefficient defined by using this condensing coefficient is used to calculate the amount of condensate falling in this section and contributing to the two-phase pressure drop encountered by the horizontally flowing vapor.

The two-phase pressure drop for the steam flow is calculated using this value and the Diehl-Unruh two-phase tube bank correlation for horizontal flow to derive the system pressure at the entrance to the next row of tubes. Since the amount of noncondensables (if present) is considered to remain the same, the fraction of noncondensables will increase after passing through each row, thus lowering the saturation pressure at the entrance to the next row of tubes. The assumption is made that the vapor is at its saturation temperature and pressure at all times; this leads to a decrease in the saturation temperature which is also the temperature of the vapor-noncondensable mixture. These conditions are then used as the entrance conditions for the next row of tubes, and the flow of the vapor is followed in this fashion until it emerges from the last row of the condenser section.

Similar calculations are performed for each of the four sections shown in Figure 2, resulting in four different exit conditions of temperatures and flows since each section will perform differently because of its relative position vertically within the bundle. Since the pressure drop encountered in each of these four sections should be identical, the entering vapor and gas flow to each section is adjusted (but not the entering temperature or pressure) and the procedure is repeated until the pressure drop encountered in each section has been balanced to within 1.0% of their numerical average.

After the performance through the condenser section has been satisfactorily determined, the remaining vapor and gas flow is assumed to be funneled into the bottom of the gas cooler section, where it then travels upward to the noncondensable removal exit. The geometry of the gas cooler section was determined as explained previously, but it may be altered at this point to insure that the entering vapor velocity does not exceed 150 ft/sec. If the quantity of material entering the gas cooler section is so large as to have an entering velocity greater than 150 ft/sec, the shape of the gas cooler section is revised to become wider and shorter in order not to exceed this maximum value. This is done to insure that excessive pressure drop and resultant poor heat transfer performance are not encountered in the gas cooler section.

A computational procedure for heat transfer and pressure drop similar to that described for the condenser section is then performed for vapor which is assumed to be engaged in upflow through the gas cooler section. While the fraction of noncondensables increases as the vapor travels upward through this portion, the flooding factor (i.e., the number of tubes in a vertical row) decreases so that in

some cases the heat transfer coefficient may reach a minimum at some point within this section and then increase slightly as it approaches the upper rows of the gas cooler. Since no pressure drop correlations could be found in the literature for vapor in upflow through a tube bundle, the pressure drop through this section is calculated as double the factor for horizontal flow through tube banks.

4.5 Calculations for the Performance of Rectangular Condenser Bundle with Vertical Flow

A sketch of the rectangular tube bundle with steam flowing vertically downward through it is shown in Figure 1. To insure that vertical flow is maintained in such a bundle, baffling of the two side faces to eliminate horizontal flow will be necessary.

The concept of a condenser with vertical flow is advanced particularly for incorporation in multistage flash plants where the range of system pressures may run from a few pounds per square inch absolute up to two atmospheres or more. At the low-pressure end of the plant, vapor velocities will become quite high and the resulting pressure drop within the tube bundles will detract from the expected heat transfer performance. On the other hand, the same bundle geometry installed in the high-pressure section of the plant will cause a considerably denser vapor to flow at a much lower velocity. In fact, the velocity in the high-pressure end may become so low as to detract from the heat transfer performance in still another fashion, namely, that of allowing noncondensables to build up because of lack of a sweeping action of the vapor. For a situation such as this, the rectangular tube bundle having the same dimensions as the bundle at the low-pressure end, but with baffling installed on the two side faces, will present a smaller face area to the incoming vapor. This, of course, will result in an increase in vapor velocity through the bundle, and thus a better sweeping action of the noncondensables. Because of the lack of experimental evidence, however, the effectiveness of this arrangement for high-pressure condensers can only be postulated at this time.

Inasmuch as the evaluation of the flooding factor is much simpler in the vertical-flow case, the condenser for vertical flow is not subdivided into smaller sections as it was in the calculation for horizontal flow. Calculations for the individual film coefficients inside and outside the tubes are performed in the same fashion as for the horizontal-flow case. For the vertical-flow condenser, however, the flow enters from the top face of the bundle so that, for the first row encountered, the condensing coefficient is very high, being that for a tube bank of one tube only. For the second row, the condensing coefficient is that for the second row only. Since the modified Nusselt condensing correlation gives the mean coefficient for a tube bank, the coefficient for the second row is derived as being the difference between the mean coefficient for a tube bank two rows deep and for one row deep. This process of obtaining individual row coefficients is repeated for each row as the calculation is performed vertically down through the bundle.

To ascertain the amount of condensate cascading down through the bundle and contributing to the two-phase pressure drop, the heat transfer coefficient for the tube bank above the particular row, n, being considered is obtained and used to calculate the amount of steam condensed by the (n - 1) rows above. The two-phase pressure drop for this vertical flow is then calculated using the correlation proposed by Diehl for pressure drop in downward flow through staggered tube banks. Since this analysis of vertical flow requires no subdivisions of the condenser, the process of adjusting flow in order to balance pressure drop is not required.

The vapor emerging from the bottom of the condenser section is then fed to the bottom of the gas cooler section for travel upward through it to the noncondensable removal system. The calculation in the gas cooler portion is identical to that previously described for the horizontal flow condenser.

4.6 Calculation of the Geometry for a Circular Tube Bundle

For the circular tube bundle code, the geometry of the bundle is calculated in the following fashion:

1. The fraction of tubes assigned to the condenser section is derived from the input information.

2. The remaining number of tubes is assumed to be arranged in a lattice of equilateral triangles. The amount of tube sheet area required for these tubes is then considered to be represented by the equation

$$A_{TS} = 0.866\ (S/D \times D)^2 \times N_T$$

The radius for the circular tube sheet is calculated to be the radius for this area increased by a slight factor (of 2%) to avoid pinching of the flow as it converges towards the center of the bundle.

3. The vapor flow is assumed to be parallel to the base of the equilateral triangle. The number of tubes in the outer face of the circular condenser is calculated by assuming that the tubes are spaced S/D x D distance apart along the outer circumference of the circle described by the outer radius.

4. The next radius is calculated to be 0.866 x S/D x D less than the first radius, and the number of tubes in this row is calculated as in (3). The procedure is repeated until the number of tubes assigned to the condenser portion has been reached or exceeded.

5. The number of tubes in the gas cooler section is then recalculated as the difference between the total number of tubes and the number of tubes in the condenser section. The calculation for the geometry of the gas cooler section is identical to that for the gas cooler section of a rectangular bundle.

4.7 Calculations for the Performance of a Circular Condenser Tube Bundle

The circular condenser is assumed to be divided into twelve equal sectors, each of which may be analyzed separately as indicated in Figure 3. The two semicircular bundles, one on each side of the gas cooler, are assumed to operate in identical fashion so that only six sections in one of the semicircles is analyzed by the stepwise procedure used in this program. Many of the assumptions and computational procedures used for the circular bundle are identical to those which have been explained in detail for the rectangular condenser. Thus, it is assumed that the temperature and the pressure of the vapor stream at the outer surface of the tube bundle are equal at every point along its periphery.

The flow is assumed to enter the circular bundle normal to the circumference for each of the 30-degree sectors shown in Figure 3.

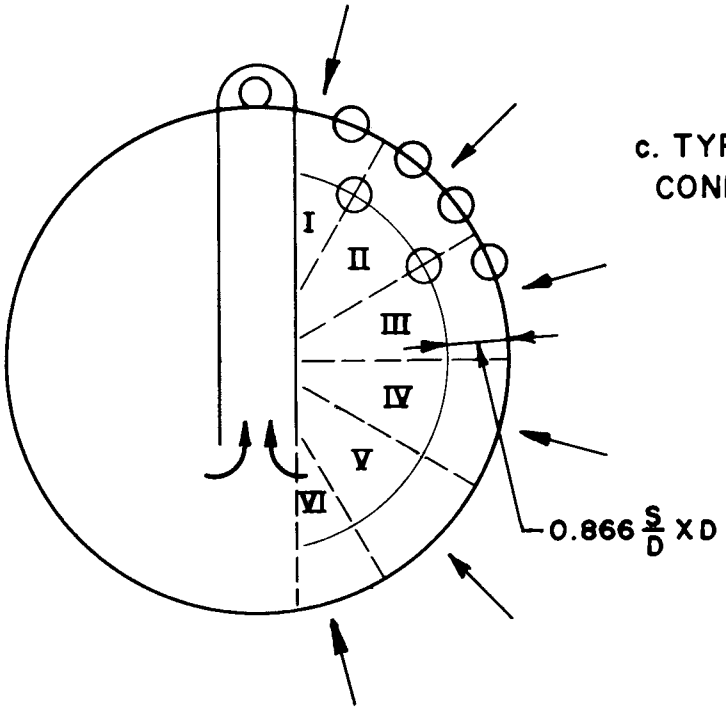
The overall heat transfer coefficient is calculated for the tubes in the outer row, assuming that all of these tubes along an arc perform identically within any given section. The inside coefficient is calculated by using the Sieder-Tate correlation with the fluid properties being based on the fluid temperatures, as was explained previously. The outside condensing coefficient is calculated using the modified Nusselt equation for a "typical" tube which is assumed to be the one located along the center line of the sector. The flooding factor for the "typical" tube is calculated by measuring the vertical distance from this tube to the outer edge of the bundle in the condensing coefficient and by finding out how many tubes are located along this vertical line. The overall coefficient for the first row, based upon these individual film coefficients, is then used to obtain tube-side and condensing-side temperatures from which the fluid properties are reevaluated and a more precise heat transfer coefficient is obtained. This iterative procedure and the subsequent two-phase pressure drop calculations are essentially identical to those described for the rectangular tube bundle.

After undergoing condensation and pressure drop in flowing past the first row of tubes, the vapor stream (plus noncondensables if present) encounters the next row of tubes arranged along an arc of somewhat shorter length because of the decreased radius. Flow of the vapor past this decreased radius is calculated in the same fashion as for the first row, and the procedure is repeated until the vapor emerges from the last row of tubes in the 30-degree sector.

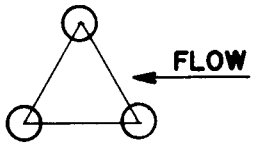
Similar calculations are performed for each of the six sectors in the semicircular bundle, and the vapor flow to each of the sectors is adjusted in order that the pressure drop encountered in each sector will be essentially the same. At the same time, of course, the sum of the individual flows to the six sectors must equal one-half of the total flow rate specified as input information (or all of the total flow value for the half condenser case).

DWG. NO. G-67-227

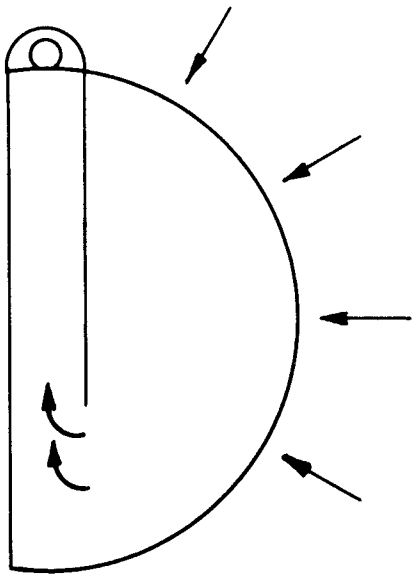
a. FULL CIRCULAR CONDENSER



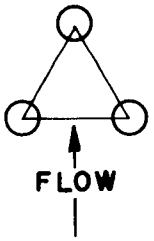
c. TYPICAL FLOW PATH IN CONDENSER SECTION



b. HALF CIRCULAR CONDENSER



d. TYPICAL FLOW PATH IN GAS COOLER SECTION



CIRCULAR CONDENSER BUNDLE

Figure 3

After flow rates and pressure drop calculations in the condenser section have been completed, the calculation of performance of the gas cooler section is conducted in the same fashion as described previously.

4.8 Heat Transfer Equations

Calculation of the heat transfer performance within the bundle is performed on a row-by-row basis using the following correlations:

Steam Side - Condensing Coefficient (Film Type)

$$h_m = 0.725 \left(\frac{k_f^3 \, \rho_f^2 \, H_{FG} \, g_c}{\mu_f \, D_o \, (t_{sat} - t_w) n} \right)^{0.25} \times C \times F \quad \text{(Ref. 4)} \qquad (1)$$

where h_m = mean condensing coefficient, Btu/hr-ft^2-^{o}F

k_f = thermal conductivity of the condensate at the film temperature, Btu/hr-ft^2-^{o}F/ft

ρ_f = density of the condensate at the film temperature, lb/ft^3

H_{FG} = heat vaporization at the film temperature, Btu/lb

μ_f = viscosity of the condensate film, lb/ft-hr

D_o = outside diameter of the tube, ft

t_{sat} = saturation temperature of the vapor, ^{o}F

t_w = outside wall temperature, ^{o}F

t_f = film temperature, ^{o}F = $t_{sat} - 0.5\,(t_{sat} - t_w)$

n = number of tubes in vertical row

C = correction factor for n

F = correction factor for the presence of noncondensables

g_c = gravitational constant, ft/hr^2.

The factor C for the effect of number of tubes is calculated as a function of n, number of tubes in a vertical row, as follows:

$$C = 1.310 \quad \text{for} \quad n = 1.0 \tag{2a}$$

$$= 1.2379 + 3.5361 \times 10^{-2} n - 1.5703 \times 10^{-3} n^2 \tag{2b}$$

$$\text{for} \quad 2 \leq n \leq 16$$

$$= 1.4017 \quad \text{for} \quad n > 16 \tag{2c}$$

The effect of noncondensables, when less than 4% by weight, is calculated as a function of the amount of noncondensables present as follows:

$$F = 1.0 - 3.4313 \times 10^{1} X + 1.2268 \times 10^{3} X^2 - 1.4923 \times 10^{4} X^3 \quad \text{(Ref. 14)} \tag{3}$$

where X = weight fraction of noncondensables.

4.8.1 Brine Side - Forced Convection Coefficient

$$\frac{hD}{k} = 0.027\, N_{Re}^{0.8}\, N_{Pr}^{0.333} \left(\frac{\mu_{ave}}{\mu_w}\right)^{0.14} \quad \text{(Ref. 13)} \tag{4}$$

where h = forced convection coefficient, Btu/hr-ft^2-^{o}F

D = inside diameter of the tube, ft

k = thermal conductivity of the brine, Btu/hr-ft^2-^{o}F/ft

N_{Re} = Reynolds number for brine flow, dimensionless

N_{Pr} = Prandtl number for brine side, dimensionless

μ_{ave} = viscosity of the brine at average bulk temperature, lb/ft-hr

μ_w = viscosity of the brine at wall temperature, lb/ft-hr.

Iterations are performed to determine t_{wi}, the wall temperature on the brine side and the t_{wo}, the wall temperature on the steam side, in order to define the heat transfer coefficients for both inside and outside surfaces.

When the amount of noncondensables becomes greater than 4% by weight, a weighted gas-vapor coefficient is calculated as follows:

$$\frac{1}{h_{cg}} = \frac{Q_G}{Q_T\, h_g} + \frac{1}{h_m} \quad \text{(Ref. 17)} \tag{5}$$

where h_{cg} = condensing coefficient with noncondensables present

h_g = gas coefficient based on properties of the non-condensable

Q_G = sensible heat removed from gas

Q_T = total heat removed from gas and vapor

h_m = condensing coefficient with no noncondensables.

The gas coefficient is calculated by the correlation

$$\frac{h_g D}{k} = 0.33\ N_{Pr}^{0.33}\ N_{Re}^{0.6} \qquad \text{(Ref. 13)} \qquad (6)$$

where h_g = forced convection coefficient, Btu/hr-ft^2-^{o}F

D = outside diameter, ft

k = thermal conductivity of gas, Btu/hr-ft^2-^{o}F/ft

N_{Re} = Reynolds number for the gas, dimensionless

N_{Pr} = Prandtl number for the gas, dimensionless.

4.9 Pressure Drop Equations

Pressure drop calculations within the tube bundle use two-phase flow correlations as a multiplier for the friction factor data on tube banks. Since the friction factors for tube banks as a function of Reynolds number, longitudinal pitch and transverse pitch, as correlated by Grimison[4], have resulted in curves of such complicated shapes, they have been incorporated into the program as a table rather than as equations. A subroutine is used to perform an interpolation between points of this table.

The two-phase flow correlation of Diehl and Unruh[7] for horizontal flow through tube banks is used as a multiplier to modify the single-phase pressure drop data and has been correlated as a series of equations as follows:

For $X \leq 0.15$

$$\left(\frac{\Delta P_{TP}}{\Delta P_G}\right) = 1.0 \qquad \text{(Ref. 7)} \qquad (6a)$$

For $0.15 < X \leq 2.0$

$$\left(\frac{\Delta P_{TP}}{\Delta P_G}\right) = \exp\left[-0.93213 - 0.74257\,\ell nX - 0.13174(\ell nX)^2\right] \tag{6b}$$

For $X > 2.0$

$$\left(\frac{\Delta P_{TP}}{\Delta P_G}\right) = \exp\left[-0.85714 - 0.94972\,\ell nX - 0.015453(\ell nX)^2\right] \tag{6c}$$

where

$$X = LVF \Big/ \left(\frac{\rho_g}{\rho_L}\right)$$

ΔP_{TP} = pressure drop calculated for two-phase flow

ΔP_G = pressure drop calculated for total flow occurring in gas

LVF = liquid volume fraction.

For pressure drop in vertical downflow through tube banks, the two phase correlation developed by Diehl (Ref. 6) has been fitted over several ranges as follows:

For $X_D \leq 0.001$

$$\left(\frac{\Delta P_{TP}}{\Delta P_G}\right) = 1.0 \tag{7a}$$

For $0.001 < X \leq 0.02$

$$\left(\frac{\Delta P_{TP}}{\Delta P_G}\right) = \exp\left[-4.0317 + 0.54538\,\ell n\,X_D + 0.39108\,(\ell n\,X_D)^2 + 1.0329\,(\ell n\,X_D)^3\right] \tag{7b}$$

for $0.001 < X \leq 0.02$

For $X > 0.02$

$$\left(\frac{\Delta P_{TP}}{\Delta P_G}\right) = 0.0225\,X_D^{-1.02} \tag{7c}$$

where

$$X_D = \frac{LVF \Big/ \left(\frac{\rho_g}{\rho_L}\right)}{N_{Re}^{0.5}}$$

4.10 Overall U Value and Log Mean Temperature Difference

The overall U value reported by this code is an area weighted U derived as follows:

$$\bar{U} = \frac{\sum_{i=1}^{n} U_i A_i}{\sum_{i=1}^{n} A_i} \tag{8}$$

where

$\bar{U}$ = an average overall heat transfer coefficient, Btu/hr-ft^2-^{o}F

U_i = overall heat transfer coefficient for row i, Btu/hr-ft^2-^{o}F

A_i = heat transfer surface of row i, ft^2

n = total number of rows under analysis (condenser section or gas cooler section).

These weighted U values are obtained separately for the condenser section, for the gas cooler section, and for the entire bundle.

The effective log mean temperature difference is calculated using these weighted U values as follows:

$$\Delta t_m = \frac{\sum_{i=1}^{n} Q_i}{\bar{U} \sum_{i=1}^{n} A_i} \tag{9}$$

where

Δt_m = effective log mean temperature difference, ^{o}F

Q_i = amount of heat transferred at row i, Btu/hr

i = tube row number.

Values of effective Δt_m are reported for the condenser section, for the gas cooler section, and for the total bundle for each case.

5. EXAMPLES OF PROGRAM CALCULATIONS

5.1 Description of Base Cases

Two sets of conditions considered as being typical of multistage flash evaporator operations were used to perform sample calculations with the condenser codes. These conditions are shown in Table II.

Case A may be considered representative of a stage condenser in the high-temperature end of a multistage flash plant, operating at maximum brine temperature of 250°F. A single bundle is assumed to consist of 3,302 tubes made of 70-30 copper-nickel, whose thermal conductivity is 16.7 Btu/hr-ft^2-°F/ft. Sixteen such bundles will be required in each stage of a 50-Mgd flash plant.

Case B is for conditions representative of the reject end of a multistage flash plant or of the deaerator section. Pressures and temperatures are very low, making the condenser bundles in this section very sensitive to losses sustained through unwarranted pressure drops, etc. A higher fouling resistance of .0005 is assumed for the tubes in this section, as well as a thermal conductivity of 9.4 Btu/hr-ft^2-°F/ft, corresponding to stainless steel. As in Case A above, sixteen of these bundles will be required in each stage of the reject section of a 50-Mgd flash plant.

As mentioned above, the conditions shown in Table II were considered as being merely typical of flash plant operation and should not be construed as recommendations for operating conditions of flash plants in general.

Although the reference bundles are useful for very large desalting plants, they might be classed as "small" bundles relative to those of power plant condensers (see page 5).

Calculations performed with this code have indicated that there are no major advantages or disadvantages of the rectangular-shaped bundle over the circular bundle. Consequently, the shape of the condenser bundle used, whether rectangular or circular, will be dictated primarily by the design of the shell containing the bundles and by the shape of the vapor flow path to the condenser. Aside from these considerations, it appears that, for high-pressure stages where vapor velocities are low and pressure losses small, a shrouded bundle design such as the rectangular condenser with vertical flow may be desirable from the standpoint of increasing vapor velocity for the purposes of sweeping out noncondensables. On the other hand, for a very low-pressure operation where velocities become high and pressure losses become significant, a bundle design presenting a larger face area such as the circular layout would appear to be preferable.

TABLE II

DESCRIPTION OF BASE CASES USED
FOR SAMPLE CALCULATIONS

	Case A	Case B
Saturation temperature, ^{o}F	244.6	85.2
Brine temperature in, ^{o}F	231.8	65.0
Steam flow rate, lb/hr	27620.	21685.
Brine velocity, ft/sec	6.0	6.0
Brine concentration, solids fraction	0.0576	0.0336
Noncondensable flow rate, lb/hr	50.	50.
Number of tubes	3302.	2134.
Tube O.D., in.	0.6637	0.625
Tube wall thickness, in.	0.042	0.035
Tube wall conductivity	16.7	9.4
Tube spacing, condenser section	1.30	1.30
Tube spacing, gas cooler section	1.30	1.30
Fouling resistance	0.0003	0.0005
Reference length per stage, ft	5.20	9.00
Reference area per stage, ft^2	2984.	3143.

5.2 Row-by-Row Performance

Calculations for heat transfer and pressure drop within tube bundles are performed on a row-by-row basis. A typical set of results for temperature, pressure, and flow profile within a rectangular bundle (horizontal flow) is shown in Figure 4. The entering conditions for this particular case were those corresponding to Case B (of Table II). Ten percent of the total tubes were assumed to be located in the gas cooler portion of the bundle. As shown in this figure, a pressure drop of 0.06 psi was incurred in passing through the condenser portion of the bundle, and a further loss of 0.03 psi was incurred in the gas cooler section. At a pressure level corresponding to 85°F, these pressure losses correspond to temperature losses of 3.5°F in the condenser section and to an additional 2°F loss in the gas cooler section, resulting in a total drop of 5.5°F. The sharper decreases in temperature and pressure in the gas cooler section are due to two factors, namely, the higher gas velocity achieved in this section and the conservative pressure loss correlation assumed for two-phase flow moving vertically upward.

The overall heat transfer coefficient in the condenser section on an area-weighted basis was 435.6 Btu/hr-ft^2-°F and 382.8 in the gas cooler section portion with a combined overall coefficient of 430.9 Btu/hr-ft^2-°F.

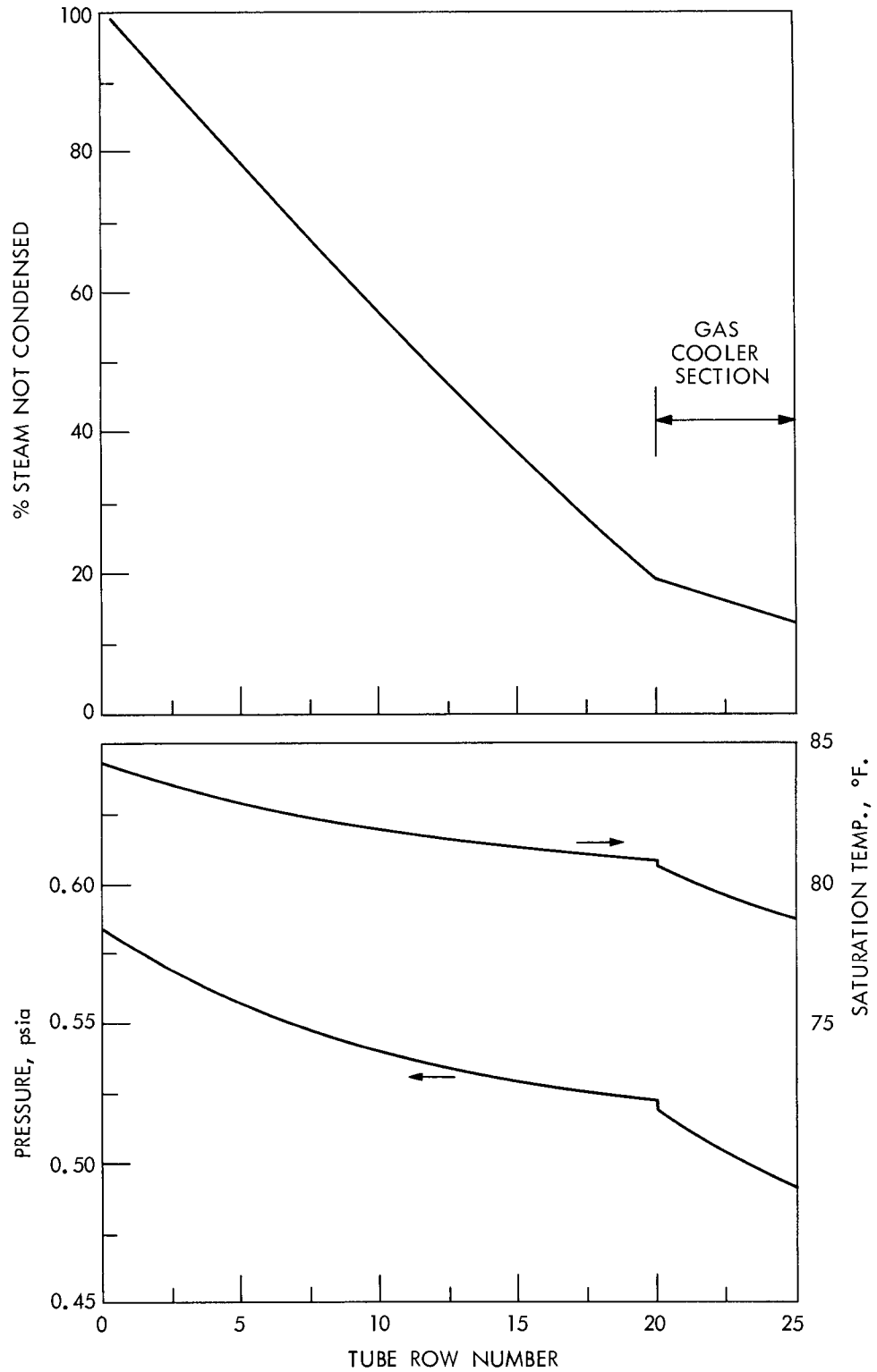
The upper line in Figure 4 shows the decreasing percentage of steam remaining uncondensed as the vapor passes through the bundle. In this calculation, 13% of the entering steam was vented from the top of the air cooler section. If desired, the code could be used to resize the bundle to give some other desired exit steam fraction.

5.3 Effect of Noncondensables on Condenser Performance

The effect of the amount of noncondensables in the vapor stream upon the overall heat transfer coefficient of a rectangular condenser is shown in Figure 5. The base case used in preparing this graph was Case A of Table II, and the tube length was assumed to be constant at 5.20 ft. With zero noncondensables entering, the overall heat transfer coefficient was 760.8 Btu/hr-ft^2-°F for the entire tube bundle, with an average coefficient of 760.7 for the condenser section and with 761.9 for the gas cooler section. Approximately 4% of the entering steam remained uncondensed at the exit end of the gas cooler section for the assumed condenser and driving force.

Shown plotted in Figure 5 is the ratio of the overall U with noncondensables to the overall U with zero noncondensables (760.8 Btu/hr-ft^2-°F) as a function of the entering amount of noncondensables. The overall U value decreases quite rapidly to about 75% of the original value when the entering noncondensables increase to 0.7% (by volume). As a result of this decrease in heat transfer performance, the uncondensed steam passing through to the noncondensable vent system increases from 4% to 28% over the same range, indicating a sizable loss to the vent system due to the increase in noncondensables within the bundle.

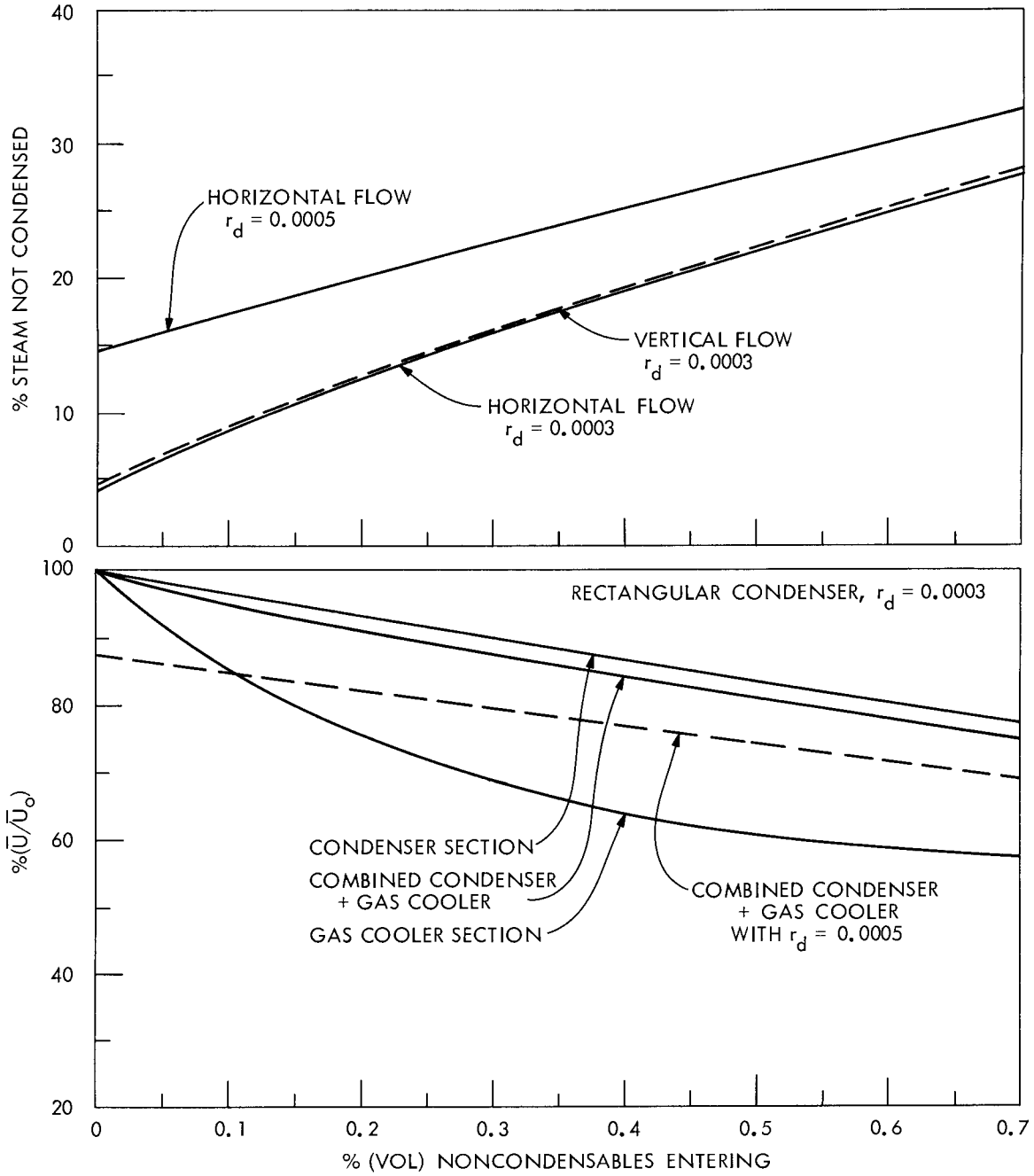
DWG. NO. G-67-233



TEMPERATURE, PRESSURE AND FLOW PROFILE IN
A RECTANGULAR CONDENSER
CASE B CONDITIONS

Figure 4

DWG. NO. G-67-230



EFFECT OF NONCONDENSABLES AND TUBE SIDE FOULING UPON CONDENSER PERFORMANCE AT CONSTANT GEOMETRY (RECTANGULAR)

CASE A CONDITIONS

Figure 5

Also shown in Figure 5 is the loss in heat transfer performance due to an increase in the dirt fouling resistance from .0003 to .0005. The overall U value is decreased between 6% and 12% because of this increased resistance, and the fraction of uncondensed steam loss to the vent removal system increases proportionately.

As shown in Figure 5, just above the line for the overall U ratio for the entire bundle is a line indicating the U value ratio for only the condenser section of this bundle compared to the U value of 760.8 for the total bundle. The U value for the condenser section ranges from 0 to about 3% higher than the U value for the whole bundle over this range of noncondensables. The lower solid line is the U value ratio for the gas cooler portion, and here the large effect of the increasing concentration of noncondensables in this portion of the bundle becomes quite apparent. The overall U value in the gas cooler section is decreased to about 60% of the original value when the entering amount of noncondensables is 0.7%

Because of the extreme similiarity of the performance for the vertical flow condenser and the horizontal flow condenser, it was not possible to show a separate line for the heat transfer coefficients for this case. They were essentially identical to the results just described for the horizontal flow condenser. In fact, the very slight difference in the performance of the vertical flow condenser can be shown graphically only when comparing the much more sensitive parameter, the uncondensed fraction leaving the condenser. Here, as indicated by the dashed line in the upper portion of Figure 5, a slightly higher loss amounting to the .05% of the entering steam is indicated for the vertical flow case. This is attributable to the slightly higher velocity and to the slightly greater pressure drop prevailing in this type of bundle. While these pressure losses are almost insignificantly small at the pressure levels prevailing in Case A, it may be of interest to note that the pressure losses in the vertical flow bundle become impossibly large under the conditions of Case B, and the calculations were automatically terminated before reaching a solution.

5.4 Comparison of the Rectangular Versus the Circular Condenser

A comparison of the relative performances of rectangular (horizontal flow) and circular condensers is shown in Figure 6. The entering conditions for steam and noncondensables are those corresponding to Case B in Table II.

System pressure, saturation temperature, and the uncondensed fraction of steam are shown plotted in this figure versus percent of area traversed. A slight difference in system pressure is encountered immediately (0% area) because of the difference in contraction loss suffered at the entrance face of the tube bundle, with the circular bundle presenting a greater face area for vapor entry than the rectangular design. The higher vapor velocity prevailing in the rectangular bundle design results in a larger pressure drop with an associated larger loss in the thermal driving force as shown by the lower levels for both

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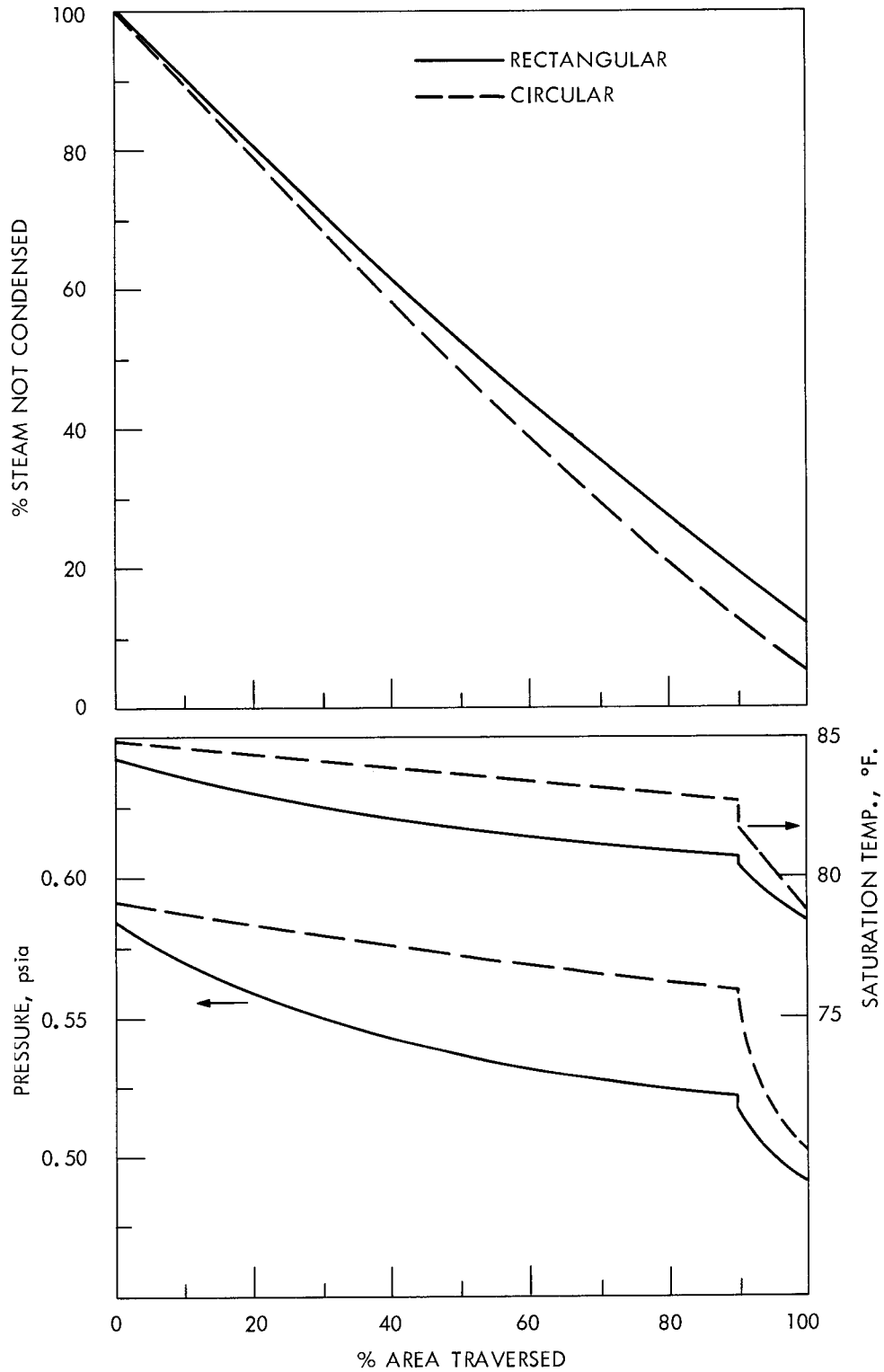

COMPARISON OF INTERNAL PERFORMANCES OF RECTANGULAR AND CIRCULAR TUBE BUNDLES CASE B CONDITIONS

Figure 6

pressure and temperature in the rectangular bundle. This loss in thermal driving force results in decreased condensation as indicated by the upper pair of lines with the net effect being that 94.0% of the entering steam is condensed in the circular bundle compared to 86.7% in the rectangular bundle when both have the same heat transfer area. In terms of heat transfer coefficients, however, the rectangular bundle had a slightly higher overall U value of 430.9 Btu/ft^2-^{o}F-hr versus 417.1 for the circular, because of the noncondensables being less concentrated at the exit of the less effective bundle. However, the improved coefficient is overshadowed by the loss in thermal driving force. This advantage of the circular over the rectangular bundle is accentuated in the case of the low-pressure condenser cited in this example. At higher pressures, this advantage was found to be much smaller.

The following discussion shows that a rectangular bundle with more open spacing could perform as well as the circular bundle.

5.5 Effect of Tube Spacing upon Condenser Performance

Figure 7 is a plot showing the effect of tube spacing upon condenser (rectangular bundle) performance. The base case used here is Case B of Table II, the low-temperature condenser with 50 lbs/hr of noncondensables added. Under these conditions, the overall U value is 430.9 Btu/hr-ft^2-^{o}F, and the log mean temperature difference is 14.7^{o}F with 13.2% of the entering steam leaving uncondensed. If the tube spacing were increased, thus decreasing the pressure drop within the bundle, the gain in thermal driving force or the log mean Δt improves the performance of the condenser and is shown in Figure 7 to reduce the uncondensed fraction of steam from 13% down to 3% as the tube spacing-to-tube diameter ratio is increased from 1.3 to 2.0. A substantial part of this gain, however, is seen to be achieved by increasing the spacing from 1.3 to 1.5.

Actually, all of the gain in performance is achieved through an improvement in thermal driving force since the overall heat transfer coefficient actually decreases as the spacing is increased, because the percent noncondensables is increasing as more of the water vapor is condensed and thus adversely affecting the heat transfer performance. However, as seen in Figure 7, a substantial net gain is achieved through the use of wider spacings for condensers operating in low-pressure regions.

In practical design situations, the higher shell and tube-sheet cost of bundles with wide spacing must be balanced against the higher tubing cost of close-spaced bundles to perform the same job.

As may be surmised, the value of wide tube spacing is significant only for lower pressure operations where vapor velocities are high and pressure drop losses are an appreciable factor. Under these conditions, steam lanes are frequently used by condenser manufacturers.

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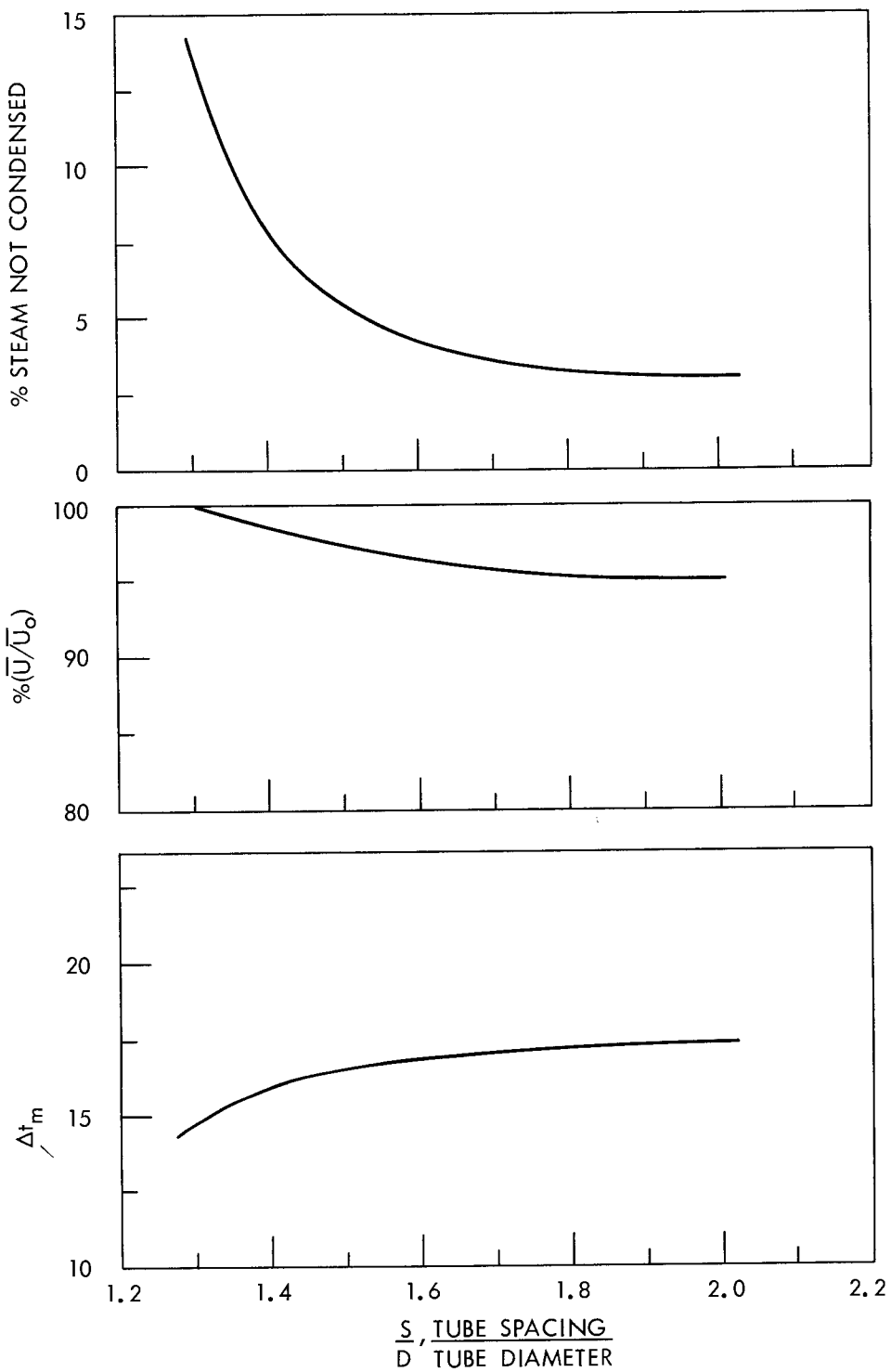

EFFECT OF TUBE SPACING RATIO
UPON CONDENSER PERFORMANCE
(RECTANGULAR BUNDLE)
CASE B CONDITIONS

Figure 7

5.6 Effect of Noncondensables on Condenser Area for Constant Fraction Condensed

Figure 8 is a modification of the cases computed for Figure 5. Here, over the same range of noncondensables entering the bundle, the condenser area is allowed to vary in order to condense 96% of the entering steam in each case. As the entering amount of noncondensables increases from 0 to 0.7% (volume), the required heat transfer area is seen to increase by almost 100%. The overall heat transfer coefficient in the condenser section decreases to 63% of its initial value, while the U value in the gas cooler section drops even faster to the vicinity of 20% of the initial value because of the increasing fraction of inerts. The combined condenser and gas cooler coefficient, thus, decreases to about 55% of its original value over this range of noncondensables.

Comparing these results with those in Figure 5, it becomes apparent that not only the entering concentration of noncondensables but also the concentration at the exit must be considered when deriving overall heat transfer coefficients for streams having noncondensables. Otherwise, the quantity of uncondensed steam lost to the vent system may become a significant fraction of the entering total.

5.7 Possibilities of Flooding

In the gas cooler section of the tube bundle, the vapor flow is assumed to travel upward countercurrent to the condensate rain from the tubes above. Since this is a situation which might result in flooding, some check calculations were performed with the results obtained for Cases A and B with zero noncondensables in the gas stream, i.e., the highest possible heat transfer coefficient. To approximate the geometry of the tube bundle, the flooding correlation line for stacked Raschig rings was employed in this calculation. (Reference 17) The results indicate that, for the conditions represented by these two cases, flooding in the gas cooler section would occur only if the volume of condensate rain were generated by gas cooler sections 40 feet high or more. Since the possibility of designing gas cooler sections of such a dimension would be very remote, the danger of bundle flooding does not appear to be a real problem. On the other hand, since the flooding correlation assumed was for stacked Raschig rings, it would appear that some data on flooding that would be more representative of tube bundle geometry would be of value in designing condenser tube bundles.

6. CONCLUSIONS

The results of these calculations indicate that there are not any major advantages of either rectangular or circular bundle configurations from the standpoint of condenser performance. Thus, the shape of the bundle will be determined by external factors such as shape of the housing for the condenser, orientation of the steam inlet, location of structural obstructions, etc.

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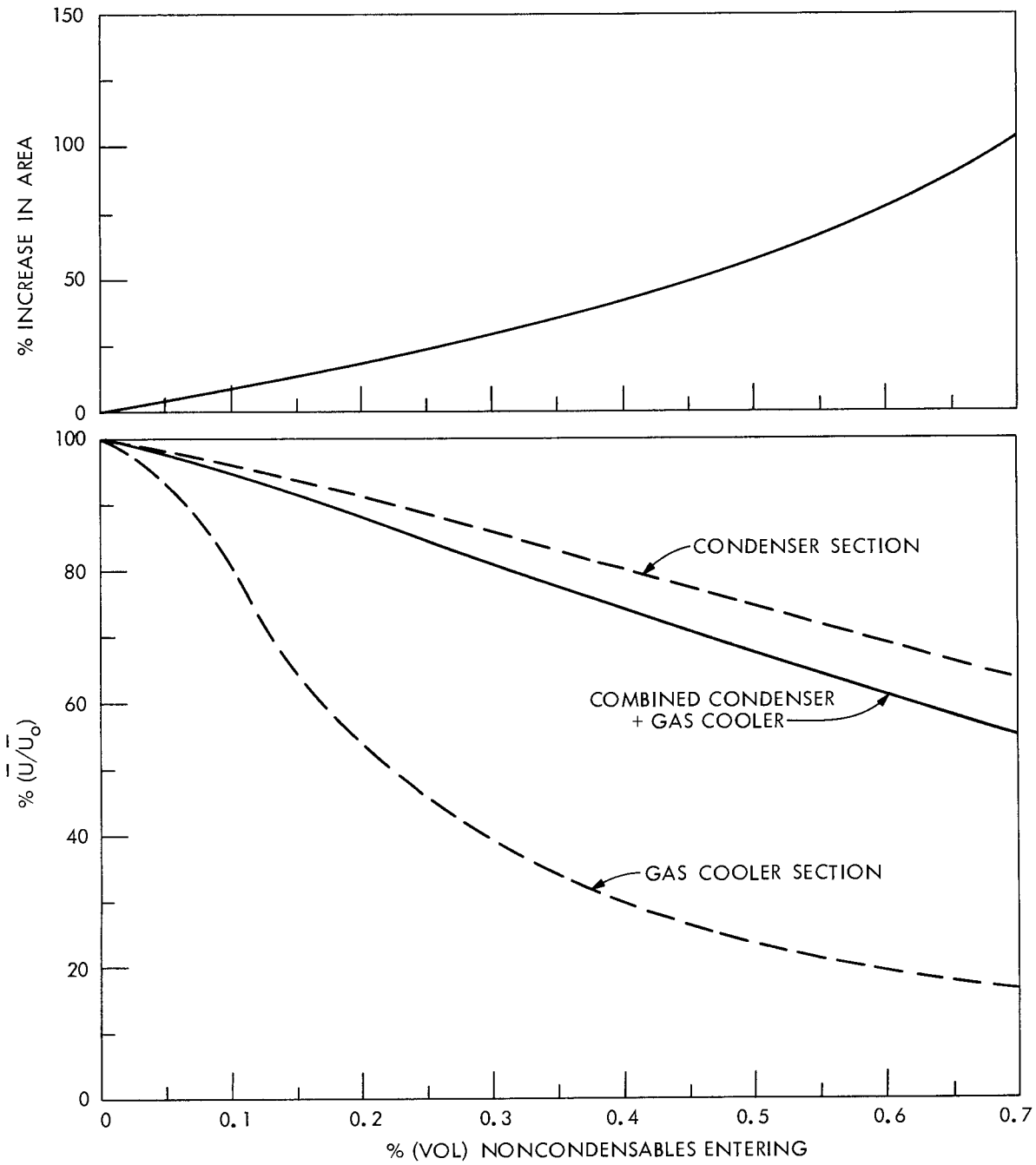

EFFECT OF NONCONDENSABLES UPON CONDENSER AREA REQUIREMENT FOR CONSTANT FRACTION CONDENSED (RECTANGULAR BUNDLE)

CASE A CONDITIONS

Figure 8

Other considerations such as maximum size of bundle and steam lanes are functions of the maximum allowable pressure drop, size and shape of inlet, etc., and are details which can be studied through the use of these codes. Evaluation of these details will be dependent on the circumstances for each case so that no firm criteria can be formulated concerning bundle size or steam laning requirements.

The effect of pressure drop on condenser performance becomes apparent when analyzing condensers operating at relatively low pressures, i.e., about 2 psia or less. Condenser performance at these lower operating pressures may be aided materially by increased tube spacing or steam lanes, thus minimizing the loss due to pressure drop.

Noncondensable venting is required to prevent gas-blanketing the condenser surface. The data from these studies indicate that relatively small amounts of noncondensables, on the order of 1% (volume) or less, can detract seriously from heat transfer performance of even a well-designed condenser.

The effect of condensate rain upon the condensing coefficient is sufficiently large to require that the tube orientation in a vertical row be given careful consideration in an effort to minimize the loss through flooding. In accordance with this, it is recommended that, for bundles with equilateral triangular tube lattices, the apex of the triangles be oriented toward the top of the bundle as shown in Figure 2 or that the rows be at an angle with the vertical.

7. ACKNOWLEDGMENT

The authors wish to acknowledge the support and suggestions of B. E. Mitchell and the assistance of R. A. Ebel in supplying consultation on the heat transfer calculations.

8. FUTURE WORK

The condenser code as described herein utilizes many of the correlations currently available from the literature on condensation heat transfer and two-phase pressure drop. Experimental verification of the results predicted here, of the losses and inefficiencies in large condenser tube bundles, would be the next logical step to obtain improved condenser bundle designs and more accurate predictions of their performance.

The types of information desired from such a test program would include the following:

A. Heat transfer information as functions of

1. individual tube location in bundle,

2. amount of noncondensables,

3. pressure level,

4. thermal driving force,

5. local gas velocity, and

6. local flooding.

B. Pressure drop information as functions of

1. local two-phase flow,

2. bundle configuration--tube spacing, tube orientation,

3. direction of vapor flow--up, down, horizontal, and

4. local vapor velocity.

C. Flow distribution as functions of

1. entrance configuration,

2. pressure level, and

3. local pressure gradients.

APPENDIX A

DESCRIPTION OF CONDENSER PROGRAM

APPENDIX A

DESCRIPTION OF CONDENSER PROGRAM

Flow Chart for the Rectangular Condenser Code

The flow chart for the rectangular condenser code is shown in Figure A-1.

After the input data is read in, the bundle geometry is calculated based upon the tube diameter, the tube spacing, the fraction of tubes in the gas cooler section, and the ratio of bundle height to bundle width. Depending upon whether the vapor flow is desired to be vertical or horizontal, indexes are then set up for either one or four sections, respectively.

After an entrance loss is calculated, treated simply as a sudden contraction loss into the first row of the bundle, the row-by-row calculation is begun. Heat transfer and pressure drop subroutines are called alternately until the end of the section has been reached. Four sections at four different levels (see Figure 2) are analyzed for horizontal flow condensers and one vertical section for a vertical flow type. In the case of the horizontal flow condenser, the pressure drops across the four sections are balanced by apportioning the flow to each section in accordance with a loss coefficient calculated for each following an initial row-by-row analysis. The row-by-row analysis is then repeated to confirm that the sectional pressure drops have been equalized.

After the pressure drops for the condenser section are satisfactorily balanced, the performance of the gas cooler section is analyzed, again on a row-by-row basis. Preliminary to performing this calculation, however, a check is made to see that the vapor velocity entering the gas cooler section does not exceed 150 ft/sec. If the velocity is found to exceed this value, the geometry of the gas cooler section is revised by increasing the width at the expense of the height in order to avoid an excessive pressure drop. While this is an expedient built into the code in order to avoid an unduly low performance of a condenser, this factor of reasonable vapor velocity should be given careful consideration in actual practice.

After the mixture passes through the gas cooler section and reaches its exit, a test is made to see if an exit steam fraction value has been specified. If this has not been specified, the calculation is concluded and the results are given at this point. If an exit feed fraction is desired, the tube bundle length is adjusted, and the entire calculation is repeated until the specified exit fraction is attained.

In the heat transfer subroutine (HETTRN) as shown in Figure A-2, the primary variables required are steam temperature, coolant temperature, steam flow rate, coolant flow rate, noncondensable flow rate, and an index to define the flooding factor. Film and wall temperatures are

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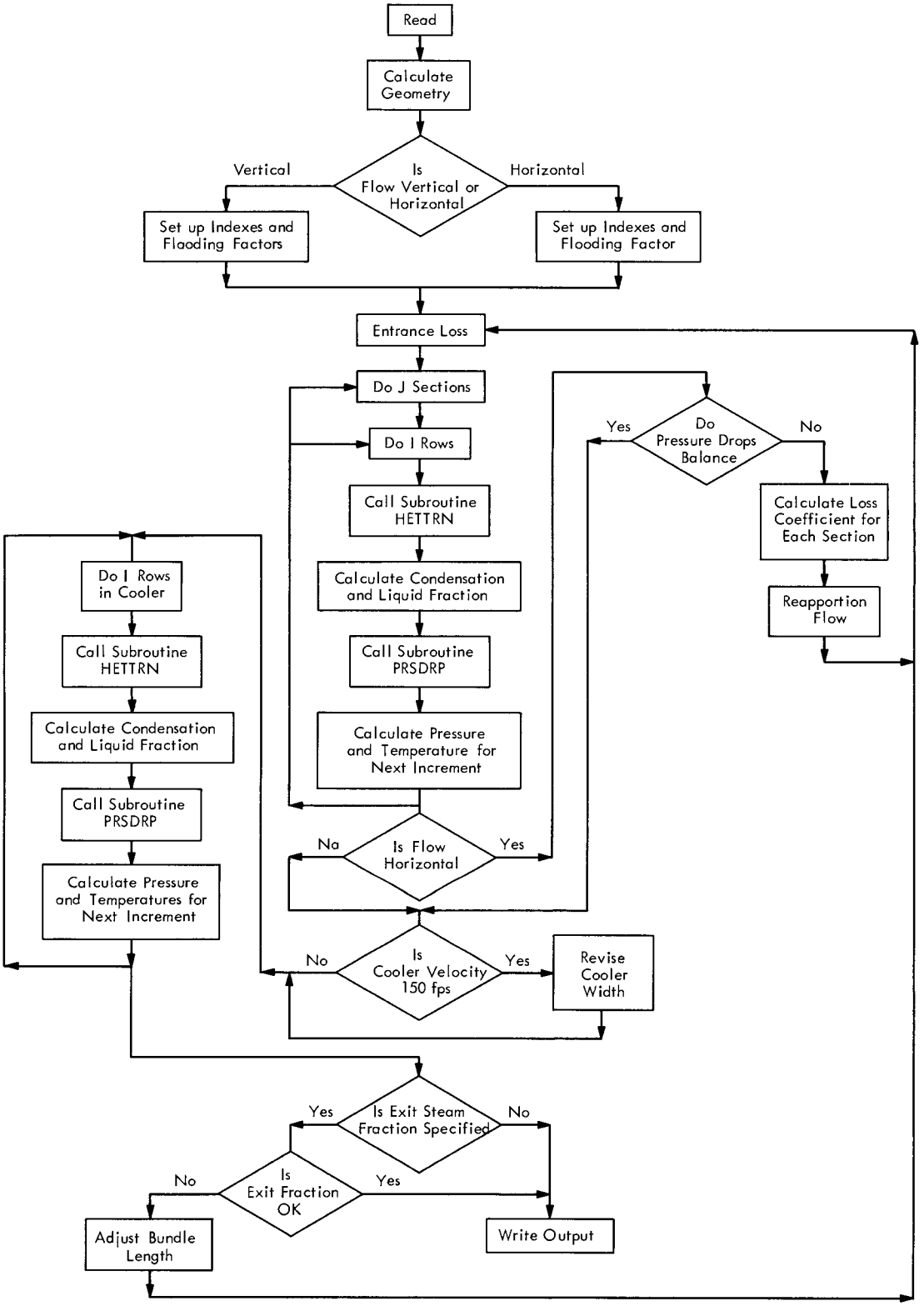
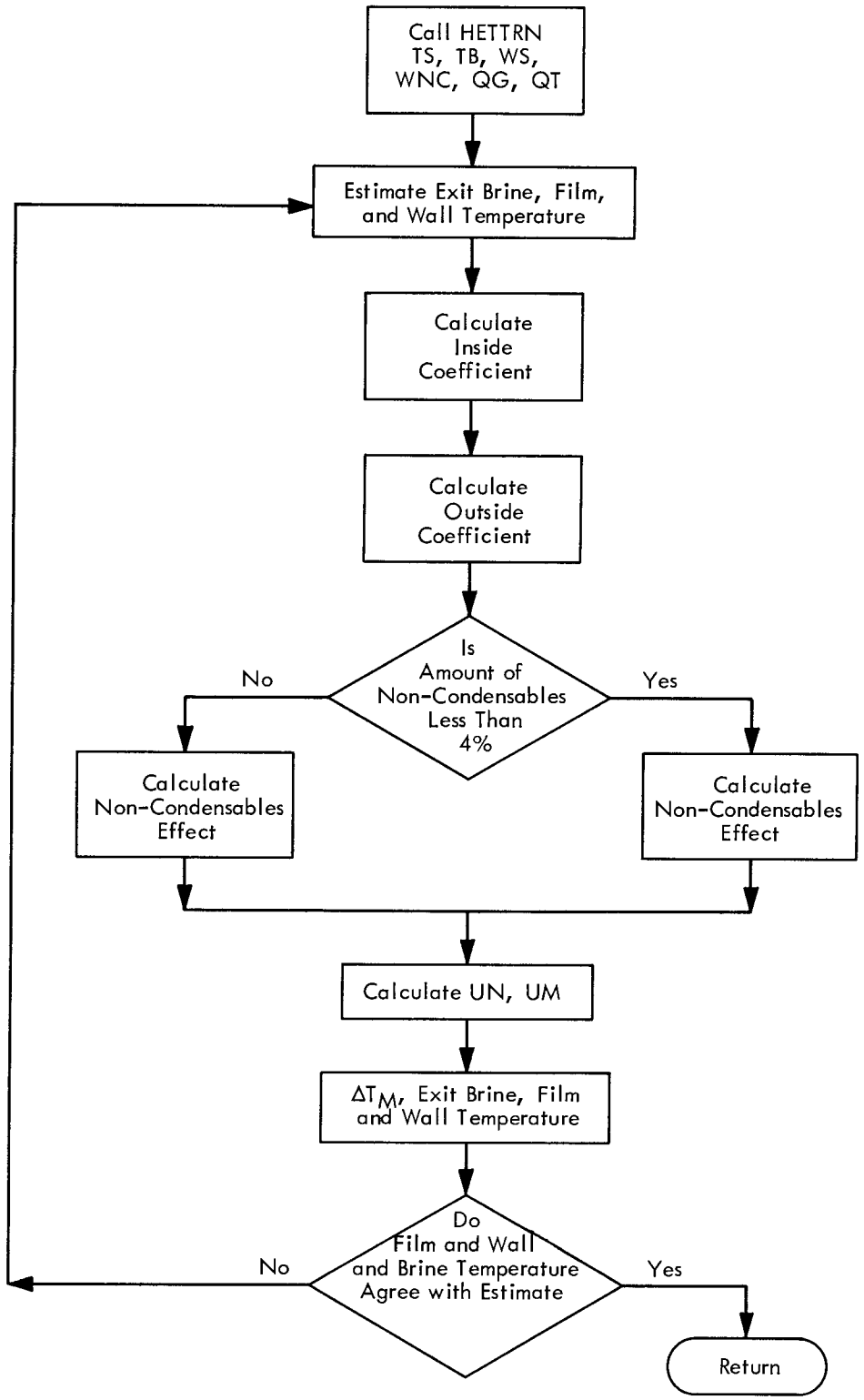


RECTANGULAR CONDENSER MAIN PROGRAM

Figure A-1

DWG. NO. G-67-229



SUBROUTINE HETTRN

Figure A-2

estimated; and from these, inside and outside coefficients are calculated. On the basis of the amount of noncondensables present, different correlations are used for calculating the effect of noncondensables upon the condensing coefficient.

After the overall heat transfer coefficient is obtained, a check is made to see if the resulting film temperatures and wall temperatures used for calculating fluid properties are in agreement with the original estimates. If not, the entire procedure is repeated until satisfactory convergence is obtained, and then the resulting overall heat transfer coefficient is returned to the main program.

In the pressure drop subroutine (PRSDRP) shown in Figure A-3, the information required is temperature, pressure, steam flow rate, noncondensable flow rate, and condensate rain flow rate. Fluid properties are calculated and a superficial Reynolds' number based upon steam plus noncondensable flow rate is obtained. With this Reynolds' number and the longitudinal and transverse spacing of the tubes, a table lookup subroutine is called which contains the Grimison friction factor values for staggered tube banks. With this friction factor and the two-phase pressure drop correlation for either horizontal or vertical flow in the tube banks, as the case might be, a pressure drop is calculated and returned to the main program.

Flow Chart for the Circular Condenser Code

The flow chart for the circular condenser code is essentially identical to that for the rectangular condenser code. The only significant differences between the two codes lie in the calculations of the bundle geometry and in the evaluation of the flooding factor for each point within the bundle. Heat transfer and pressure drop subroutines used are essentially same as those described for the rectangular bundle code with some minor modifications to account for the differences in geometry.

Condenser Code Output

Examples of the output page from the condenser code are shown in Table A-1 for the rectangular condenser with horizontal flows. The upper half of the first page is a listing of the input information to the program. In addition, on the rectangular flow condenser, an identification line is printed to indicate whether the vapor flow is assumed to be horizontal or vertical.

The results are summarized on the bottom half of this output page. Included in this output and listed separately according to whether it is for the condenser section, the cooler section, or the whole tube bundle are the following items:

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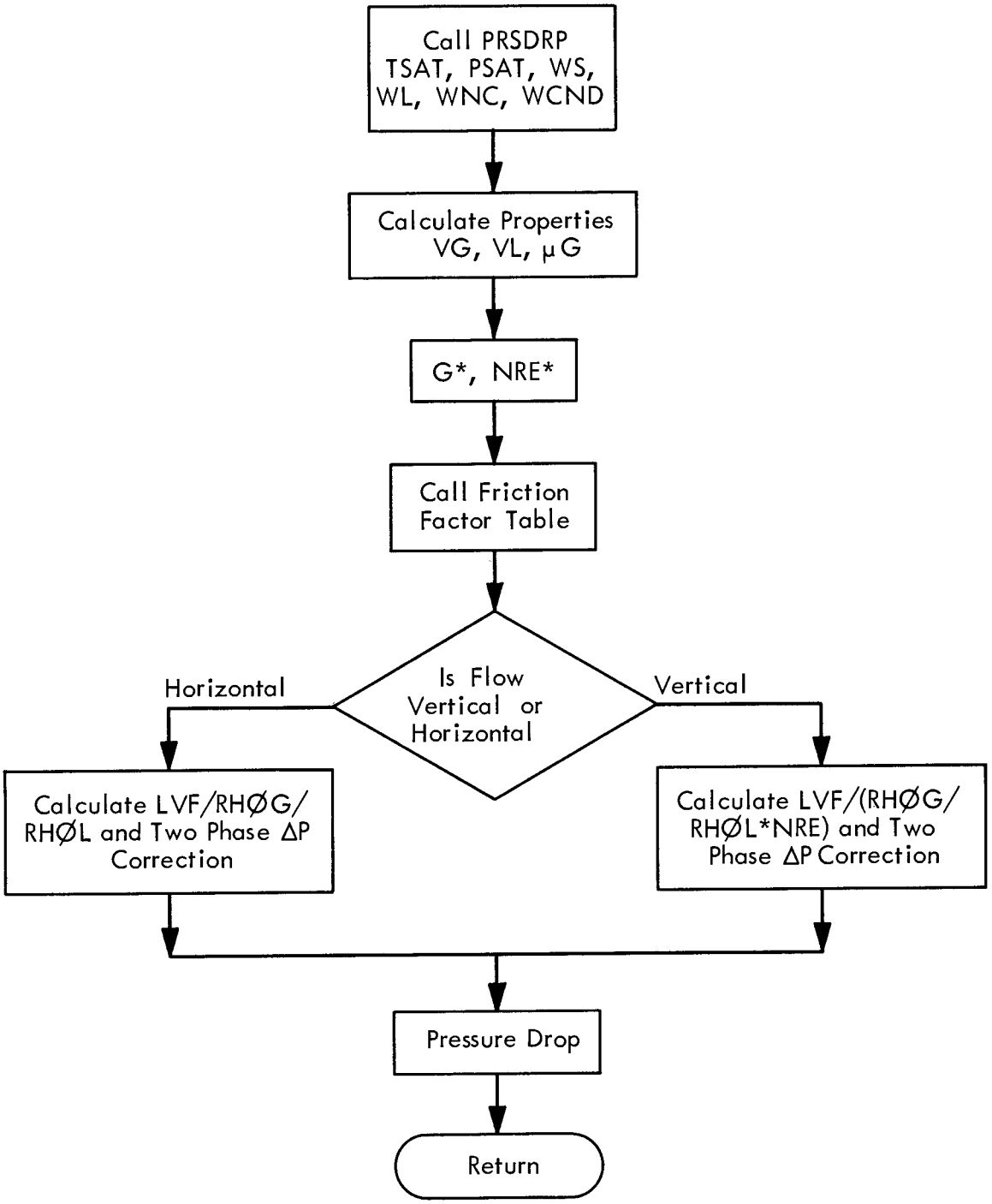


SUBROUTINE PRSDRP

Figure A-3

TABLE A-1

RECTANGULAR CONDENSER INPUT DATA

(HORIZONTAL FLOW)

CASE IDENTIFICATION AND NOTES **** REJECT TEST CASE CNDNSR IV - HORIZ. FLOW

GEOMETRY SPECIFICATION		TUBING SPECIFICATION		FLOW AND PROPERTIES SPECIFICATION	
NO. OF TUBES	2134.00	OUTSIDE DIAM., INCHES	0.6250	STEAM FLOW, LBS/HR.	21684.9
PCT. TUBES IN COOLER	10.00	WALL THICKNESS, INCHES	0.0350	NON-CONDENSIBLE FLOW, LBS/HR.	50.0
BUNDLE HGT/WIDTH RATIO	1.00	WALL COND.,BTU/HR/SQ.FT/DEG.F.	9.4000	COOLANT VELOCITY, FT/SEC.	6.0
LENGTH OF TUBES	8.90	FOULING FACTOR	0.0005	STEAM TEMP., DEG. F.	85.2
S/D, CONDENSER	1.30			COOLANT TEMP., DEG. F.	65.00
S/D, COOLER	1.30			WT. FRAC. OF NACL IN COOLANT	0.0336
				EXIT STEAM FRACTION, PCT. OF INPUT	0.

SUMMARY OF RESULTS

	U, BTU/HR/SQ.FT. /DEG. F.	LOG MEAN DELTA TEMP. DEG.F.	PRESSURE DROP LBS/SQ.IN.	TEMP. DROP DEG.F.	STEAM VELOCITY FT/SEC INLET	STEAM VELOCITY FT/SEC OUTLET	NUMBER OF TUBES HORIZ. ROWS	NUMBER OF TUBES VERTICAL ROWS	TUBE SPACING RATIO, S/D	TUBE FRACTION PERCENT
CONDENSER	434.69	14.87	0.0623	3.651	253.64	57.35	40.	48.	1.3	91.17
COOLER	427.16	12.71	0.0270	1.730	151.31	109.35	37.	5.	1.3	8.83
OVERALL	434.02	14.68	0.1098	6.49			40.	48.		

COOLER HEIGHT, FT. 0.35 COOLER WIDTH, FT. 2.54

BUNDLE HEIGHT, FT. 2.87 BUNDLE WIDTH, FT. 2.76 BUNDLE LENGTH, FT. 8.900

EXIT STEAM, PERCENT OF INPUT 14.04 EXIT NON-CONDENSIBLES, PERCENT OF TOTAL EXIT FLOW 1.62

REJECT TEST CASE CNDNSR IV - HORIZ. FLOW

ROW BY ROW OUTPUT, CONDENSER SECTION J = 1

STSAT	PMIX	WS	VEL	RC	UN	SHNF	SHI
0.84329151E 02	0.58317126E 00	0.23455309E 03	0.25364103E 03	0.23004551E-02	0.46409473E 03	0.22680965E 04	0.12728077E 04
0.83976627E 02	0.57662243E 00	0.22379273E 03	0.25090817E 03	0.24107985E-02	0.46399877E 03	0.22702332E 04	0.12715709E 04
0.83647617E 02	0.57057367E 00	0.21324348E 03	0.24149923E 03	0.25297599E-02	0.46388435E 03	0.22698093E 04	0.12709260E 04
0.83341801E 02	0.56500732E 00	0.20288125E 03	0.23192669E 03	0.26586248E-02	0.46369305E 03	0.22673559E 04	0.12703345E 04
0.83058811E 02	0.55990543E 00	0.19269422E 03	0.22220198E 03	0.27987832E-02	0.46344783E 03	0.22634741E 04	0.12697834E 04
0.82798138E 02	0.55524959E 00	0.18267040E 03	0.21233658E 03	0.29519098E-02	0.46314295E 03	0.22580434E 04	0.12692712E 04
0.82559193E 02	0.55102094E 00	0.17279818E 03	0.20234244E 03	0.31200305E-02	0.46277124E 03	0.22509150E 04	0.12687967E 04
0.82341305E 02	0.54720025E 00	0.16306643E 03	0.19223189E 03	0.33056175E-02	0.46232424E 03	0.22419225E 04	0.12683576E 04
0.82143696E 02	0.54376785E 00	0.15346447E 03	0.18201749E 03	0.35117167E-02	0.46179220E 03	0.22308779E 04	0.12679524E 04
0.81965511E 02	0.54070374E 00	0.14398228E 03	0.17171212E 03	0.37421213E-02	0.46116332E 03	0.22175637E 04	0.12675788E 04
0.81805782E 02	0.53798752E 00	0.13461046E 03	0.16132873E 03	0.40016120E-02	0.46042327E 03	0.22017272E 04	0.12672340E 04
0.81663456E 02	0.53559852E 00	0.12534040E 03	0.15088044E 03	0.42962960E-02	0.45955453E 03	0.21830675E 04	0.12669152E 04
0.81537395E 02	0.53351575E 00	0.11616438E 03	0.14038046E 03	0.46340948E-02	0.45853508E 03	0.21612233E 04	0.12666187E 04
0.81426723E 02	0.53172455E 00	0.10707569E 03	0.12984064E 03	0.50254649E-02	0.45733665E 03	0.21357433E 04	0.12663414E 04
0.81267124E 02	0.52911559E 00	0.98068555E 02	0.11950719E 03	0.54844985E-02	0.45602028E 03	0.21085292E 04	0.12659590E 04
0.81128124E 02	0.52690001E 00	0.89171761E 02	0.10913408E 03	0.60283960E-02	0.45442425E 03	0.20758973E 04	0.12656079E 04
0.81007526E 02	0.52504467E 00	0.80378109E 02	0.98739963E 02	0.66835160E-02	0.45251248E 03	0.20375647E 04	0.12652745E 04
0.80902851E 02	0.52351642E 00	0.71682276E 02	0.88343689E 02	0.74882273E-02	0.45008503E 03	0.19901811E 04	0.12649424E 04
0.80811169E 02	0.52228208E 00	0.63083593E 02	0.77967593E 02	0.85002427E-02	0.44731425E 03	0.19379853E 04	0.12646164E 04
0.80728863E 02	0.52130864E 00	0.54580143E 02	0.67630128E 02	0.98115656E-02	0.44396903E 03	0.18775652E 04	0.12642761E 04
0.80651066E 02	0.52056340E 00	0.46175789E 02	0.57354403E 02	0.	0.	0.	0.

REJECT TEST CASE CNDNSR IV - HORIZ. FLOW

ROW BY ROW OUTPUT, CONDENSER SECTION J = 2

STSAT	PMIX	WS	VEL	RC	UN	SHNF	SHI
0.84329151E 02	0.58317126E 00	0.22989373E 03	0.24860250E 03	0.23004601E-02	0.43264979E 03	0.16784228E 04	0.12703573E 04
0.83975880E 02	0.57660694E 00	0.21976423E 03	0.24639717E 03	0.24062392E-02	0.43252339E 03	0.16782899E 04	0.12694576E 04
0.83644711E 02	0.57051673E 00	0.20983354E 03	0.23765855E 03	0.25198311E-02	0.43244925E 03	0.16783697E 04	0.12688502E 04
0.83335278E 02	0.56488237E 00	0.20007950E 03	0.22876956E 03	0.26423504E-02	0.43229325E 03	0.16771303E 04	0.12682869E 04
0.83047970E 02	0.55970056E 00	0.19049189E 03	0.21973555E 03	0.27749729E-02	0.43207781E 03	0.16749272E 04	0.12677597E 04
0.82781269E 02	0.55493473E 00	0.18106001E 03	0.21057381E 03	0.29191064E-02	0.43179953E 03	0.16717203E 04	0.12672658E 04
0.82535229E 02	0.55057756E 00	0.17177398E 03	0.20129156E 03	0.30764265E-02	0.43145034E 03	0.16673976E 04	0.12668045E 04
0.82308338E 02	0.54659513E 00	0.16262403E 03	0.19190519E 03	0.32489576E-02	0.43102400E 03	0.16618840E 04	0.12663731E 04
0.82099987E 02	0.54297097E 00	0.15360125E 03	0.18242546E 03	0.34391500E-02	0.43051107E 03	0.16550598E 04	0.12659700E 04
0.81909511E 02	0.53968836E 00	0.14469724E 03	0.17286327E 03	0.36500074E-02	0.42990081E 03	0.16467939E 04	0.12655936E 04
0.81736164E 02	0.53673039E 00	0.13590407E 03	0.16322970E 03	0.38852500E-02	0.42918042E 03	0.16369357E 04	0.12652417E 04
0.81579136E 02	0.53408001E 00	0.12721445E 03	0.15353600E 03	0.41495379E-02	0.42833447E 03	0.16253100E 04	0.12649121E 04
0.81437534E 02	0.53172004E 00	0.11862174E 03	0.14379353E 03	0.44487843E-02	0.42734424E 03	0.16117105E 04	0.12646021E 04
0.81310406E 02	0.52963324E 00	0.11012010E 03	0.13401381E 03	0.47906000E-02	0.42618646E 03	0.15958917E 04	0.12643085E 04
0.81196728E 02	0.52780230E 00	0.10170457E 03	0.12420856E 03	0.51849427E-02	0.42483234E 03	0.15775597E 04	0.12640283E 04
0.81095341E 02	0.52620991E 00	0.93371179E 02	0.11438978E 03	0.56450871E-02	0.42324566E 03	0.15563638E 04	0.12637568E 04
0.81005024E 02	0.52483881E 00	0.85117205E 02	0.10456992E 03	0.61891138E-02	0.42138071E 03	0.15318826E 04	0.12634894E 04
0.80924343E 02	0.52367183E 00	0.76941303E 02	0.94762044E 02	0.68422786E-02	0.41917998E 03	0.15036216E 04	0.12632203E 04
0.80851688E 02	0.52269188E 00	0.68843844E 02	0.84980196E 02	0.76409226E-02	0.41657165E 03	0.14710161E 04	0.12629425E 04
0.80785229E 02	0.52188502E 00	0.60827225E 02	0.75239340E 02	0.86392449E-02	0.41346909E 03	0.14334718E 04	0.12626477E 04
0.80695095E 02	0.52076934E 00	0.52896223E 02	0.65612295E 02	0.	0.	0.	0.

REJECT TEST CASE CNDNSR IV - HORIZ. FLOW

ROW BY ROW OUTPUT, CONDENSER SECTION J = 3

STSAT	PMIX	WS	VEL	RC	UN	SHNF	SHI
0.84329151E 02	0.58317126E 00	0.22319958E 03	0.24136357E 03	0.23004555E-02	0.43264029E 03	0.16781522E 04	0.12704222E 04
0.83975864E 02	0.57660785E 00	0.21306777E 03	0.23888932E 03	0.24095833E-02	0.43250058E 03	0.16779440E 04	0.12694589E 04
0.83644543E 02	0.57051611E 00	0.20313750E 03	0.23007580E 03	0.25270769E-02	0.43241807E 03	0.16779047E 04	0.12688478E 04
0.83334759E 02	0.56487694E 00	0.19338415E 03	0.22111772E 03	0.26541920E-02	0.43224328E 03	0.16763869E 04	0.12682825E 04
0.83046108E 02	0.55967283E 00	0.18379777E 03	0.21202589E 03	0.27922406E-02	0.43200704E 03	0.16738800E 04	0.12677517E 04
0.82778110E 02	0.55488608E 00	0.17436822E 03	0.20281093E 03	0.29427962E-02	0.43170378E 03	0.16703098E 04	0.12672537E 04
0.82530224E 02	0.55049891E 00	0.16508564E 03	0.19348367E 03	0.31077520E-02	0.43132594E 03	0.16655743E 04	0.12667875E 04
0.82301830E 02	0.54649346E 00	0.15594061E 03	0.18405525E 03	0.32894046E-02	0.43086465E 03	0.16595598E 04	0.12663514E 04
0.82092838E 02	0.54286227E 00	0.14692415E 03	0.17453377E 03	0.34905646E-02	0.43030865E 03	0.16521208E 04	0.12659446E 04
0.81901783E 02	0.53957445E 00	0.13802750E 03	0.16493457E 03	0.37147150E-02	0.42964697E 03	0.16431309E 04	0.12655643E 04
0.81728275E 02	0.53661967E 00	0.12924290E 03	0.15526699E 03	0.39662021E-02	0.42886387E 03	0.16324030E 04	0.12652083E 04
0.81570789E 02	0.53396850E 00	0.12056296E 03	0.14554577E 03	0.42505356E-02	0.42794265E 03	0.16197542E 04	0.12648735E 04
0.81428455E 02	0.53160461E 00	0.11198141E 03	0.13578217E 03	0.45747792E-02	0.42686085E 03	0.16049386E 04	0.12645568E 04
0.81300342E 02	0.52951162E 00	0.10349284E 03	0.12598776E 03	0.49481500E-02	0.42559075E 03	0.15876652E 04	0.12642552E 04
0.81185428E 02	0.52767317E 00	0.95092725E 02	0.11617430E 03	0.53828970E-02	0.42409748E 03	0.15675840E 04	0.12639647E 04
0.81082561E 02	0.52607290E 00	0.86777693E 02	0.10635410E 03	0.58956448E-02	0.42233693E 03	0.15442743E 04	0.12636807E 04
0.80990452E 02	0.52469451E 00	0.78545693E 02	0.96540063E 02	0.65095171E-02	0.42025310E 03	0.15172334E 04	0.12633976E 04
0.80907596E 02	0.52352178E 00	0.70396283E 02	0.86746059E 02	0.72576207E-02	0.41777520E 03	0.14858752E 04	0.12631089E 04
0.80832172E 02	0.52253858E 00	0.62330974E 02	0.76987264E 02	0.81890294E-02	0.41481579E 03	0.14495545E 04	0.12628062E 04
0.80762470E 02	0.52173987E 00	0.54353672E 02	0.67279373E 02	0.93796320E-02	0.41127253E 03	0.14076453E 04	0.12624807E 04
0.80694523E 02	0.52109867E 00	0.46470855E 02	0.57643185E 02	0.	0.	0.	0.

REJECT TEST CASE CNDNSR IV - HORIZ. FLOW

ROW BY ROW OUTPUT. CONDENSER SECTION J = 4

STSAT	PMIX	WS	VEL	RC	UN	SHNF	SHI
0.84329151E 02	0.58317126E 00	0.21618482E 03	0.23377795E 03	0.23004557E-02	0.43263930E 03	0.16781248E 04	0.12704286E 04
0.83976208E 02	0.57661550E 00	0.20605278E 03	0.23102177E 03	0.24133008E-02	0.43248320E 03	0.16776832E 04	0.12694585E 04
0.83642719E 02	0.57048552E 00	0.19612266E 03	0.22214306E 03	0.25351817E-02	0.43238598E 03	0.16774328E 04	0.12688422E 04
0.83330860E 02	0.56481054E 00	0.18637091E 03	0.21312410E 03	0.26674799E-02	0.43219184E 03	0.16756340E 04	0.12682720E 04
0.83040226E 02	0.55957311E 00	0.17678759E 03	0.20397584E 03	0.28116723E-02	0.43193239E 03	0.16727905E 04	0.12677361E 04
0.82770336E 02	0.55475562E 00	0.16736254E 03	0.19470895E 03	0.29695418E-02	0.43160138E 03	0.16688182E 04	0.12672330E 04
0.82520664E 02	0.55034035E 00	0.15808597E 03	0.18533441E 03	0.31432485E-02	0.43119021E 03	0.16636027E 04	0.12667615E 04
0.82290584E 02	0.54630958E 00	0.14894846E 03	0.17586339E 03	0.33354334E-02	0.43068883E 03	0.16570150E 04	0.12663200E 04
0.82079433E 02	0.54264558E 00	0.13994111E 03	0.16630723E 03	0.35493578E-02	0.43008535E 03	0.16489067E 04	0.12659066E 04
0.81886463E 02	0.53933067E 00	0.13105550E 03	0.15667746E 03	0.37890935E-02	0.42936547E 03	0.16391062E 04	0.12655194E 04
0.81710880E 02	0.53634723E 00	0.12228390E 03	0.14698567E 03	0.40597872E-02	0.42851178E 03	0.16274115E 04	0.12651556E 04
0.81551815E 02	0.53367775E 00	0.11361924E 03	0.13724361E 03	0.43680365E-02	0.42750294E 03	0.16135832E 04	0.12648132E 04
0.81408329E 02	0.53130482E 00	0.10505524E 03	0.12746323E 03	0.47224327E-02	0.42631223E 03	0.15973336E 04	0.12644882E 04
0.81279690E 02	0.52921651E 00	0.96586601E 02	0.11765556E 03	0.51343662E-02	0.42490559E 03	0.15783076E 04	0.12641778E 04
0.81164661E 02	0.52739366E 00	0.88208935E 02	0.10783370E 03	0.56192637E-02	0.42324050E 03	0.15560883E 04	0.12638773E 04
0.81062801E 02	0.52583352E 00	0.79919220E 02	0.98008302E 02	0.61985155E-02	0.42126079E 03	0.15301446E 04	0.12635827E 04
0.80971477E 02	0.52449886E 00	0.71715605E 02	0.88197008E 02	0.69026752E-02	0.41889882E 03	0.14999073E 04	0.12632852E 04
0.80888805E 02	0.52337104E 00	0.63598732E 02	0.78415355E 02	0.77767872E-02	0.41606641E 03	0.14646838E 04	0.12629766E 04
0.80812435E 02	0.52243195E 00	0.55571684E 02	0.68680551E 02	0.88901182E-02	0.41265737E 03	0.14237640E 04	0.12626465E 04
0.80739216E 02	0.52166401E 00	0.47640506E 02	0.59012191E 02	0.10354817E-01	0.40855987E 03	0.13766321E 04	0.12622830E 04
0.80664394E 02	0.52105013E 00	0.39814688E 02	0.49432813E 02	0.	0.	0.	0.

REJECT TEST CASE CNDNSR IV - HORIZ. FLOW

ROW BY ROW OUTPUT- GAS COOLER SECTION

STSATC	PMIXC	WSC	VELC	RCC	UNC	SHNFC	SHIC
0.80398594E 02	0.51612918E 00	0.44471356E 04	0.15130711E 03	0.11118188E-01	0.42994668E 03	0.16525634E 04	0.12629368E 04
0.79970753E 02	0.50919111E 00	0.41526720E 04	0.14318135E 03	0.11897193E-01	0.42445130E 03	0.15762268E 04	0.12617946E 04
0.79582325E 02	0.50301012E 00	0.38696936E 04	0.13504939E 03	0.12756099E-01	0.42988476E 03	0.16545715E 04	0.12614239E 04
0.79233936E 02	0.49758624E 00	0.35910417E 04	0.12669507E 03	0.13732334E-01	0.42333805E 03	0.15633335E 04	0.12604343E 04
0.78920086E 02	0.49281003E 00	0.33227072E 04	0.11838385E 03	0.14824886E-01	0.45175756E 03	0.20336026E 04	0.12613959E 04
0.78668514E 02	0.48915105E 00	0.30451458E 04	0.10935236E 03	0.	0.	0.	0.

Overall U, weighted on the basis of area, Btu/hr-ft^2-^{o}F

Log mean ΔT, a back calculated value from the total amount of heat transferred and the condenser surface area, ^{o}F

Pressure drop, lb/in.^{2}

Pressure drop expressed as equivalent temperature drop, ^{o}F

Vapor velocity at the inlet and outlet of each section, ft/sec

For the rectangular condenser, the number of tubes in a horizontal row and the number of tubes in a vertical row.

Tube spacing to tube diameter ratio, S/D

Percent of tubes calculated to be in the gas cooler section

Bundle dimensions, ft (height, width, and length)

Cooler dimensions, ft (height, width) (length assumed to be same as condenser section)

Exit steam percentage (as percent of input steam)

Exit composition (as percent noncondensables)

The output format for the circular condenser program is very similar, the only difference being in the description of the geometry.

Outside bundle diameter, ft

Inside bundle diameter, ft

Number of radial rows of tubes

In addition to the summarized values, an option is available for presenting the following information on a row-by-row basis:

STSAT - saturation temperature for row i, ^{o}F

PMIX - system pressure at row i, psi

UNC - overall heat transfer coefficient for row i, Btu/ft^2-hr-^{o}F

WS - weight flow of steam at row i, lb/hr

VEL - vapor velocity at row i, ft/sec

SHI - inside heat transfer coefficient, Btu/hr-ft^2-^{o}F

SHNF - condensing heat transfer coefficient including effect of flooding and of noncondensables, Btu/hr-ft^2-^{o}F

RC - weight fraction of noncondensables at row i, dimensionless

APPENDIX B

INPUT DATA SETUP

APPENDIX B

INPUT DATA SETUP

Data Setup

Figure B-1 illustrates the order in which the program accepts the input data for each case. Data cases, each consisting of the four input cards as shown, may be stacked and the program will compute the cases successively. The input variable names and required unit dimension can be identified from the nomenclature dictionary given in Appendix C. The necessity and result of inputting these variables are discussed fully in Section 4.2.

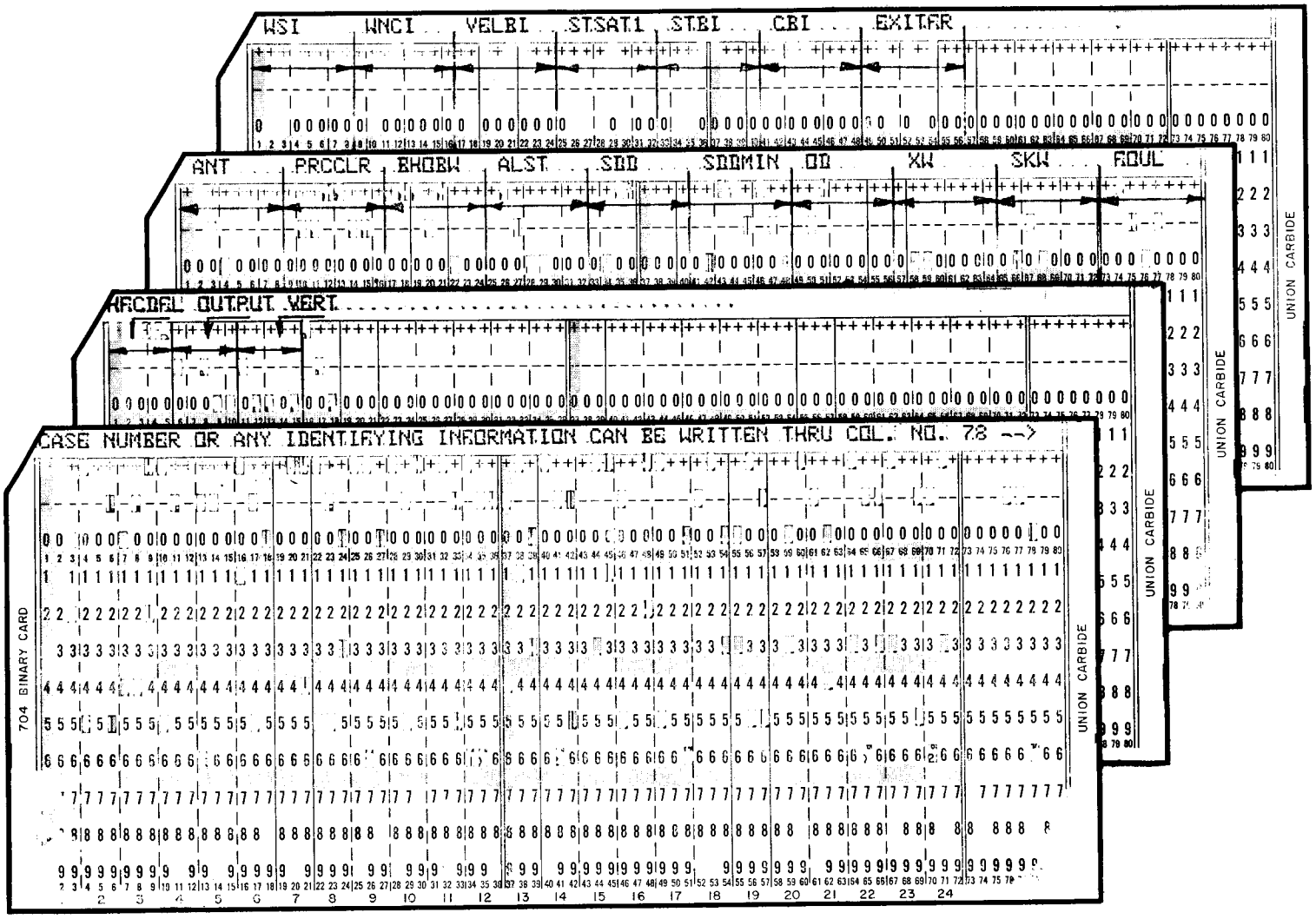
Card No. 2 of Figure B-1 is an option control card and operates as follows:

If HFCDFL = 1.0 (Columns 1-5), the code will compute the case as a "full"condenser (shown in Figure 2a). If HFCDFL = 0.0, the "half" condenser case will be computed as shown in Figure 2b.

If ØUTPUT = 1.0 (Columns 6-10), the program will provide all the output shown in Table A-1 of Appendix A. If ØUTPUT = 0.0, only the first page of Table A-1 will produce.

If VERT = 1.0 (Columns 11-15), the program will compute the case assuming vertical steam flow through the condenser, whereas setting VERT = 0.0 results in a horizontal steam flow path being assumed.

In the circular condenser model, only the ØUTPUT option is available and the 1.0 or 0.0 must be entered in Columns 1-5 on Card 2.



INPUT DATA SETUP (ONE CASE)

Figure B-1

APPENDIX C

NOMENCLATURE USED IN CONDENSER PROGRAMS

APPENDIX C

NOMENCLATURE USED IN CONDENSER PROGRAMS

Nomenclature - Condenser Main

ADTCLR - Average ΔT_m in the gas cooler section, ^oF

ADTCND - Average ΔT_m in the condenser section, ^oF

ADTOA - Average ΔT_m for the entire bundle, ^oF

AI - Inside heat transfer surface per tube, ft^2

ALMAX - Tube length at which steam flow reaches zero or negative value, ft

ALMTD - Log mean temperature difference for tube i in the condenser section, ^oF

ALMTDC - ALMTD in the gas cooler section, ^oF

ALST - Tube length, ft

AMOLS - Steam flow within the condenser section, moles per hr

AMLSCC - Flow rate of noncondensables in the gas cooler section, moles/hr

AMLSSC - Flow rate of steam in the gas cooler section, moles/hr

AMOLNC - Entering noncondensable flow, moles/hr

AMOLSC - Noncondensable flow rate within the condenser section, moles/hr

AMOLSS - Entering steam flow, moles/hr

AMOLST - Total molal flow entering, moles/hr

ANF - Number of tubes in a vertical row for calculating the flooding factor

ANT - Total number of tubes in the condenser bundle

AC - Outside heat transfer surface per tube, ft^2

AXI - Cross sectional area of tube, ft^2

AXO - Area open to flow in the condenser section, moles/ft^2

AXOC - Area open to flow in the gas cooler section, ft^2

BHOBW - Ratio of bundle height to bundle width

C - Loss coefficient, dimensionless

CBI - Salt concentration in coolant, lb/lb

CPB - Heat capacity of coolant, Btu/lb

DELP - Pressure drop per row in condenser section, psi

DELPC - Pressure drop per row in gas cooler section, psi

DELPCT - Pressure drop due to contraction into the gas cooler section, psi

DELPVE - Average pressure drop through the condenser section, psi

DELTP - Pressure drop due to two-phase flow in the condenser section, psi

DELTPC - Pressure drop due to two-phase flow in the gas cooler section, psi

EXITFR - Fraction of entering steam remaining uncondensed at the exit from the gas cooler section

FOUL - Tube resistance factor

GB - Mass flow rate of coolant, $lbs/hr\text{-}ft^2$

HBND - Bundle height, ft

HFG - Latent heat of vaporization, Btu/lb

HNO - Number of tubes in a horizontal row in condenser section

HNOC - Number of tubes in a horizontal row in the gas cooler section

HTCLR - Height of gas cooler section, ft

OD - Tube outside diameter, inches

PCTCLR - Percent of tubes assigned to the gas cooler section

PMIX - System pressure in condenser section, psia

PMIXC - System pressure in the gas cooler section, psia

PMXEXT - Average system pressure at the exit from the condenser section, psia

PSAT - Saturation pressure of water vapor, psia

PSATC - Saturation pressure in the gas cooler section, psia

QCND - Heat removed through condensation of steam, Btu/hr

QG - Sensible heat extracted in cooling the gas stream, Btu/hr

QGC - Q G in the gas cooler section, Btu/hr

QM - Heat removed above row i to form condensate rain, Btu/hr

QMC - Heat removed above row i in the gas cooler section to form condensate rain, Btu/hr

QT - Total of QG and QCND, Btu/hr

QTC - Q T in the gas cooler section, Btu/hr

RC - Weight fraction of noncondensables in the condenser section

RCC - Weight fraction of noncondensables in the gas cooler section

SDD - S/D, the tube spacing to tube diameter ratio in the condenser section

SDDMIN - S/D in the gas cooler section

SDI - Inside diameter, ft

SDO - Outside diameter, ft

SHDINV - Resistance factor for the fouling

SHG - Heat transfer coefficient for noncondensables only in the vapor stream, Btu/hr-^{o}F-ft^{2}

SHGC - S H G in the gas cooler section

SHI - Inside heat transfer coefficient, Btu/hr-ft^{2}-^{o}F

SHML - Average condensing coefficient for tubes above row i, Btu/hr-ft^{2}-^{o}F

SHN - Condensing coefficient for row i, Btu/hr-ft^{2}-^{o}F

SHWINV - Resistance factor for tube wall

SKW - Thermal conductivity of tubing wall, Btu/hr-ft^{2}-^{o}F/ft

STBI - Temperature of coolant entering condenser, ^{o}F

STSAT - Saturation temperature in the condenser section, ^{o}F

STSATC - STSAT in the gas cooler section

STSAEX - Saturation temperature at exit of condenser section, ^{o}F

STSAT1 - Saturation temperature of vapor entering the condenser, ^{o}F

SVNC - Specific volume of noncondensables, ft^3/lb

TNO - Number of tubes in the condenser section

TNOC - Number of tubes in the gas cooler section

TSAT - Saturation temperature, ^{o}R

TSATC - Saturation temperature in the gas cooler section, ^{o}R

TSATEX - Saturation temperature at end of condenser section, ^{o}R

UAVGW - Average overall heat transfer coefficient for the bundle, $Btu/hr\text{-}ft^2\text{-}^{o}F$

UBARW - Overall heat transfer coefficient averaged by area in the condenser section, $Btu/hr\text{-}ft^2\text{-}^{o}F$

UBARWC - UBARW in the gas cooler section

UM - Average overall heat transfer coefficient for tubes above row i in the condenser section, $Btu/hr\text{-}ft^2\text{-}^{o}F$

UMC - UM in the gas cooler section

UN - Overall heat transfer coefficient for row i in the condenser section, $Btu/hr\text{-}ft^2\text{-}^{o}F$

UNC - UN in the gas cooler section

VEL - Gas velocity in the condenser section, ft/sec

VELBI - Coolant velocity inside the tube, ft/sec

VELC - Velocity in the gas cooler section, ft/sec

VELEXT - Velocity at exit of condenser section, ft/sec

VERT - Flag for vertical flow in condenser

VG - Specific volume of steam, ft^3/lb

VMIX - Specific volume of vapor in noncondensable mixture, ft^3/lb

VNO - Number of tubes in a vertical row in the condenser section

VNOC - VNO in the gas cooler section

WB - Weight flow of coolant per tube, lb/hr

WBI - Total weight flow of coolant, lb/hr

WBND - Bundle width, ft

WCND - Amount of steam condensed on tube i in the condenser section, lb/hr

WCNDC - WCND in the gas cooler section

WL - Weight flow of condensate rain, lb/hr

WLC - WL in the gas cooler section

WNC - Weight flow of noncondensables, lb/hr

WNCC - WNC in the gas cooler section

WNCI - Weight flow of noncondensables entering the condenser, lb/hr

WP - Adjusted flow of steam and gas in the condenser section, lb/hr

WS - Weight flow of steam, lb/hr

WSC - WS in the gas cooler section, lb/hr

WSEXIT - Weight flow of steam entering gas cooler section, lb/hr

WSI - Weight flow of steam entering the condenser, lb/hr

WSP - Adjusted steam flow in the condenser section, lb/hr

XW - Wall thickness of tubing, in.

Nomenclature for Subroutine HETTRN

DELST - Temperature drop from steam side to coolant side, ^{o}F

DTFILM - Temperature drop across the outside film, ^{o}F

RIN - Inside resistance

RMA - Mole fraction of noncondensables

RMS - Mole fraction of steam

ROUT - Outside resistance

RTOT - Total resistance to heat transfer

SHCGM - Condensing coefficient including effect of noncondensables, Btu/hr-ft^2-^{o}F

SHM - Mean condensing coefficient for i rows, Btu/hr-ft^2-^{o}F

SHML - Mean condensing coefficient for the tubes above row i, Btu/hr-ft^2-^{o}F

SHNF - Condensing coefficient for row i, Btu/hr-ft^2-^{o}F

STBAVE - Average coolant temperature, ^{o}F

STFI - Inside film temperature, ^{o}F

STFO - Outside film temperature, ^{o}F

STWI - Inside wall temperature, ^{o}F

STWO - Outside wall temperature, ^{o}F

TB2 - Exit temperature of coolant, ^{o}F

XNC - Correction term to condensing coefficient for effect of noncondensables

XNF - Correction term to the condensing coefficient for effect of flooding

Nomenclature for Subroutine PRSDRP

ALVF - Liquid volume fraction factor for two-phase horizontal flow correlation

ALVFD - Liquid volume fraction factor for two-phase downflow correlation

ANRE - Reynolds number, dimensionless

DELPFS - Frictional pressure drop assuming gas flow, psi

DELPTP - Two-phase pressure drop, psi

GSTAR - Mass flow rate based on total flow of vapor and liquid, lb/hr-ft^2

SF - Friction factor

TPOG - Two-phase pressure drop factor

UNC - Viscosity of noncondensables, lb/ft-sec

APPENDIX D

RECTANGULAR CONDENSER CODE

```
$IBFTC COND     DECK                                                    COND0000
C       CNDNSR - HORIZ. OR VERT. FLOW                                   COND0005
C       CONDENSER MAIN                                                  COND0010
C** THIS DECK CALLS FOR HETTRN WITH Q GAS CORRELATION                   COND0015
C** THIS DECK CALLS FOR PRSDRP WITH EXTENDED TABLE                      COND0020
C** DECK NO. 2   INPUT MUST INCLUDE SDD                                 COND0025
C**  INPUT MUST INCLUDE AMWNC  11/12/65                                 COND0030
C**   OUTPUT OPTION REVISED 10/25/66                                    COND0035
      DIMENSION IDENT(13),DELP(4),WP(4),WGAS(4),AMOLS(100,4),AMLSSC(100)COND0040
      DIMENSION  PMIX (100,4),  PSAT (100,4),  TSAT (100,4),            COND0045
     1 STSAT (100,4) , VEL (100,4),  WS (100, 4) ,  ALMTD (100,4),      COND0050
     2 WL(100,4),  WCND (100, 4),  UN (100, 4),                         COND0055
     3 SHI (100, 4),  SHN (100, 4),   C(4),        RC (100, 4),         COND0060
     4 DELPTP (100, 4)                                                  COND0065
      DIMENSION   VELC (100),   PMIXC (100),  PSATC (100), TSATC (100), COND0070
     1 STSATC (100),  WSC (100),  ANFC (100),  ALMTDC (100),            COND0075
     2 WLC (100),   WCNDC (100),  UNC (100),  WSP (100),  DELTPC (100), COND0080
     3SHIC (100),  SHNFC (100),  RCC (100)                              COND0085
      DIMENSION ANFIP(100)                                              COND0090
      DIMENSION COOR(3)                                                 COND0095
      DIMENSION ANF1 (4), ANF2 (4), ANF3 (4)                            COND0100
      COMMON  SDO    , STBI   , AI     , AO     , AW     , SHWINV       COND0105
      COMMON  FOUL   , CBI    , SDI    , AXI    , WB     , HFG          COND0110
      COMMON  SDD    , STB2ES , GB     , VG     , AMWNC  , STFO         COND0115
      COMMON  TB2    , STBAVE , VNO    , J      , XNC    , SF           COND0120
      COMMON  COOR   , JRC    , VERT                                    COND0125
  100 READ  (5,8000)IDENT                                               COND0130
 8000 FORMAT(13A6)                                                      COND0135
      READ (5,8005) HFCDFL, OUTPUT, VERT                                COND0140
 8005 FORMAT(4F5.2)                                                     COND0145
      READ(5,8010)   ANT, PRCCLR,  BHOBW,   ALST,   SDD,                COND0150
     1            SDDMIN,     OD,     XW,    SKW,  FOUL,                COND0155
     2               WSI,   WNCI,  VELBI, STSATI,  STBI,                COND0160
     3               CBI, EXITFR                                        COND0165
 8010 FORMAT(8E10.5)                                                    COND0170
      WRITE(6,8015)                                                     COND0175
 8015 FORMAT(1H1,48X, 32HRECTANGULAR CONDENSER INPUT DATA )             COND0180
      IF(VERT) 105, 110, 105                                            COND0185
  105 WRITE(6,8020)                                                     COND0190
 8020 FORMAT(1H0,56X, 15H(VERTICAL FLOW) )                              COND0195
      GO TO 115                                                         COND0200
  110 WRITE(6,8025)                                                     COND0205
 8025 FORMAT(1H0,55X, 17H(HORIZONTAL FLOW) )                            COND0210
  115 WRITE(6,8030) IDENT                                               COND0215
 8030 FORMAT(1H0, 35HCASE IDENTIFICATION AND NOTES ****  , 13A6 )       COND0220
      WRITE(6,8035)                                                     COND0225
 8035 FORMAT(1H0, 22HGEOMETRY SPECIFICATION ,9X, 20HTUBING SPECIFICATIONCOND0230
     1 ,25X, 33HFLOW AND PROPERTIES SPECIFICATION )                     COND0235
      WRITE(6,8040) ANT, OD, WSI, PRCCLR, XW, WNCI, BHOBW, SKW, VELBI,  COND0240
     1 ALST, FOUL, STSATI, SDD, STBI, SDDMIN, CBI, EXITFR               COND0245
 8040 FORMAT(1H0, 14H  NO. OF TUBES,9X,F8.2,4X, 21HOUTSIDE DIAM., INCHESCOND0250
     1,13X, F6.4,5X, 19HSTEAM FLOW, LBS/HR., 13X, F8.1/1X22H  PCT. TUBESCOND0255
     2 IN COOLER ,3X, F6.2,4X, 22HWALL THICKNESS, INCHES ,12X,F6.4,5X, 2COND0260
     39HNON-CONDENSIBLE FLOW, LBS/HR. ,5X, F6.1/1X24H  BUNDLE HGT/WIDTH COND0265
     4RATIO ,   3X, F4.2,4X, 32HWALL COND.,BTU/HR/SQ.FT/DEG.F.   ,F8.4, COND0270
     55X, 25HCOOLANT VELOCITY, FT/SEC. ,11X, F4.1/1X17H  LENGTH OF TUBESCOND0275
     6 ,8X, F6.2,4X, 14HFOULING FACTOR ,20X, F6.4,5X, 20HSTEAM TEMP., DECOND0280
     7G. F. ,15X, F5.1/1X16H  S/D, CONDENSER ,11X, F4.2, 49X, 22HCOOLANTCOND0285
     8 TEMP., DEG. F. ,13X, F6.2/1X13H  S/D, COOLER ,14X,F4.2,49X,34HWT.COND0290
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     9 FRAC. OF NACL IN COOLANT        ,3X, F6.4 /81X, 35HEXIT STEAM FRACCOND0295
     1TION, PCT. OF INPUT   , F6.2   )                                   COND0300
      AMWNC # 28.965                                                     COND0305
      ILNG # 0                                                           COND0310
      ALMIN # 0.0                                                        COND0315
      IFSTRY # 0                                                         COND0320
      SG#32.174                                                          COND0325
      JRC # 0                                                            COND0330
      VLCMAX#150.0                                                       COND0335
      SDO#OD/12.0                                                        COND0340
      SDO#SDO                                                            COND0345
      SDI#(OD-2.0*XW)/12.0                                               COND0350
      TSATI#STSATI+459.69                                                COND0355
      PSATI#PSATFN(TSATI)                                                COND0360
      AMOLSS#WSI/18.016                                                  COND0365
      AMOLNC#WNCI/AMWNC                                                  COND0370
      AMOLST#AMOLSS+AMOLNC                                               COND0375
      PMIXI#PSATI*(AMOLST/AMOLSS)                                        COND0380
      VGI#VGFN(TSATI,PMIXI)                                              COND0385
      PI#3.1417416                                                       COND0390
      AXI#(PI*SDI**2)/4.0                                                COND0395
      SDW#(SDO-SDI)/ALOG(SDO/SDI)                                        COND0400
      HFG#HFGFN(STSATI)                                                  COND0405
      CPB#CPFN(CBI,STBI)                                                 COND0410
      SVNCI#10.729*TSATI/(AMWNC  *PMIXI        )                         COND0415
      SVMIXI # 1.0/  (AMOLSS / (AMOLST * VGI) + AMOLNC/                  COND0420
     1 (SVNCI * AMOLST))                                                 COND0425
      WBI # 3600.0* ANT * AXI * ROEFN ( CBI, STBI) * VELBI               COND0430
      WB#WBI/ANT                                                         COND0435
      GB#WB/(3600.0*AXI)                                                 COND0440
      STB2ES#(WSI*HFG)/(    WBI*CPB)+STBI                                COND0445
C   INITIAL ESTIMATE OF GEOMETRY ( FOR SQUARE BUNDLE)                    COND0450
C     CONDENSER SECTION                                                  COND0455
      TNO#ANT*(1.0-PRCCLR/100.0)                                         COND0460
      IF(HFCDFL)120,125,120                                              COND0465
  120 IHNO # SQRT(0.866 * TNO/ BHOBW ) * 0.5 + 0.5                       COND0470
      HNO # FLOAT(IHNO ) * 2.0                                           COND0475
      GO TO 130                                                          COND0480
  125 IHNO # SQRT(0.866 * TNO/ BHOBW )        + 0.5                      COND0485
      HNO # FLOAT(IHNO)                                                  COND0490
  130 IVNO # TNO/HNO + 0.5                                               COND0495
      VNO # FLOAT(IVNO)                                                  COND0500
      TNO # HNO*VNO                                                      COND0505
      HBND # 0.866 * SDD * SDO * VNO + SDO                               COND0510
      WBND # SDD * SDO * HNO + SDO                                       COND0515
C     COOLER SECTION                                                     COND0520
      TNOC#ANT-TNO                                                       COND0525
      HTCLR#2.0*HBND/3.0                                                 COND0530
      IVNOC # (HTCLR-SDO)/(SDDMIN*SDO*0.866)                             COND0535
      VNOC#FLOAT(IVNOC)                                                  COND0540
      IHNOC#TNOC/VNOC                                                    COND0545
      HNOC#FLOAT(IHNOC)                                                  COND0550
      TNOC # VNOC*HNOC                                                   COND0555
      PCTCLR#VNOC*HNOC/ANT*100.0                                         COND0560
      IF (VERT ) 140, 135, 140                                           COND0565
  135 JK # 4                                                             COND0570
      IK # IHNO                                                          COND0575
      GO TO 145                                                          COND0580
  140 JK # 1                                                             COND0585
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      IK # IVNO                                                         COND0590
      ANF1P(I) # 1.0                                                    COND0595
      ANF2P#0.                                                          COND0600
      ANF3P#16.0                                                        COND0605
      GO TO 165                                                         COND0610
  145 ANF1 (1) # VNO * 0.125                                            COND0615
      ANF2 (1) # VNO * 0.0625                                           COND0620
      ANF3 (1) # VNO * 0.0                                              COND0625
  150 ANF1 (2) # VNO * 0.25                                             COND0630
      ANF2 (2) # VNO * 0.1875                                           COND0635
      ANF3 (2) # VNO * 0.125                                            COND0640
  155 ANF1 (3) # VNO * 0.375                                            COND0645
      ANF2 (3) # VNO * 0.3125                                           COND0650
      ANF3 (3) # VNO * 0.25                                             COND0655
  160 ANF1 (4) # VNO * 0.50                                             COND0660
      ANF2 (4) # VNO * 0.4375                                           COND0665
      ANF3 (4) # VNO * 0.375                                            COND0670
CCCCCC                                                                  COND0675
C     INITIALIZATION                                                    COND0680
CCCCCC                                                                  COND0685
  165 CONTINUE                                                          COND0690
      ALS1 # ALST                                                       COND0695
      AI#PI*SDI*ALST                                                    COND0700
      AO#PI*SDO*ALST                                                    COND0705
      AO # AO                                                           COND0710
      AW#PI*SDW*ALST                                                    COND0715
      SHWINV#(AO*XW)/(12.0*SKW*AW)                                      COND0720
      SHDINV#FOUL                                                       COND0725
      DO 175 I#1,50                                                     COND0730
      DO 170 J#1,4                                                      COND0735
      PMIX  (I,J)#0.0                                                   COND0740
      PSAT  (I,J)#0.0                                                   COND0745
      STSAT (I,J)#0.0                                                   COND0750
      VEL   (I,J)#0.0                                                   COND0755
      UN    (I,J)#0.0                                                   COND0760
      WCND  (I,J)#0.0                                                   COND0765
      WS    (I,J)#0.0                                                   COND0770
      ALMTD (I,J)#0.0                                                   COND0775
      SHI   (I,J)#0.0                                                   COND0780
      SHN   (I,J)#0.0                                                   COND0785
  170 RC    (I,J)#0.0                                                   COND0790
      PMIXC (I)#0.0                                                     COND0795
      PSATC (I)#0.0                                                     COND0800
      STSATC(I)#0.0                                                     COND0805
      VELC  (I)#0.0                                                     COND0810
      UNC   (I)#0.0                                                     COND0815
      WCNDC (I)#0.0                                                     COND0820
      WSC   (I)#0.0                                                     COND0825
      ALMTDC(I)#0.0                                                     COND0830
      SHIC  (I)#0.0                                                     COND0835
      SHNFC (I)#0.0                                                     COND0840
  175 RCC   (I)#0.0                                                     COND0845
  180 IFSTRY#IFSTRY+1                                                   COND0850
  185 IF (VERT ) 205, 190, 205                                          COND0855
  190 IF(HFCDFL)195,200,195                                             COND0860
  195 AENT#2.0*ALST*(SDD-1.0)*SDO* VNO                                  COND0865
      AREA1 # HBND*ALST          * 2.0                                  COND0870
      GOTO210                                                           COND0875
  200 AENT#ALST*(SDD-1.0)*SDO*  VNO                                     COND0880
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      AREAI # HBND*ALST                                                 COND0885
      GO TO 210                                                         COND0890
  205 AENT#     ALST*(SDD-1.0)*SDO* HNO                                 COND0895
      AREAI # WBND * ALST                                               COND0900
  210 AXO#ALST*(SDD-1.0)*SDO                                            COND0905
      G2#288.0*SG*SVMIXI                                                COND0910
      VELI#((WSI+WNCI)*SVMIXI)/(3600.0*AREAI)                           COND0915
      AXO#AXO                                                           COND0920
      IF(AENT-AREAI)  220,  220,  215                                   COND0925
  215 ARATIO#AREAI/AENT                                                 COND0930
      DELPI2#(1.0-ARATIO)*VELI**2/G2                                    COND0935
      VEL2#ARATIO*VELI                                                  COND0940
      GO TO 235                                                         COND0945
  220 ARATIO#AENT/AREAI                                                 COND0950
      VEL2#VELI/ARATIO                                                  COND0955
      IF(ARATIO-0.715)  225,  225,  230                                 COND0960
  225 DELPI2#0.4*(1.25-ARATIO)*VEL2**2/G2                               COND0965
      GO TO 235                                                         COND0970
  230 DELPI2 # 0.75*(1.0-ARATIO)*VEL2**2/G2                             COND0975
  235 DELP23#(VEL2**2-VELI**2)/G2                                       COND0980
      IF (VERT ) 240, 245, 240                                          COND0985
  240 A # 1.0                                                           COND0990
      GO TO 250                                                         COND0995
  245 A # 1.15                                                          COND1000
  250 DO 255 J#1,JK                                                     COND1005
      WGAS(J)#(WNCI/AENT)*(SDD-1.0)*SDO*ALST                            COND1010
      WS(1,J)#(WSI/AENT)*(SDD-1.0)*SDO*ALST                             COND1015
      WS(1,J)#A*WS(1,J)                                                 COND1020
  255 A#A-0.10                                                          COND1025
      WSAVE#WGAS(1)+(WSI/AENT)*(SDD-1.0)*SDO*ALST                       COND1030
C     FOR THE FIRST PASS THROUGH THE CONDENSER , (J#1)                  COND1035
C     SET UP FOR CALCULATION THRU CONDENSER USE DOUBLE SUBSCRIPTS, (I,J)COND1040
CCCCCC                                                                  COND1045
C     I---TUBE ROWS, 1 TO IK                                            COND1050
C     J---PASS NO  , 1 TO JK                                            COND1055
      IPLOOP#0                                                          COND1060
  260 DO415J#1,JK                                                       COND1065
  265 PMIX(1,J) # PMIXI - DELPI2 - DELP23                               COND1070
      PSAT(1,J)#PMIX(1,J)*(AMOLSS/AMOLST)                               COND1075
      PAL#PSAT(1,J)                                                     COND1080
      TSAT(1,J)#TSATFN(PAL)                                             COND1085
      STSAT(1,J)#TSAT(1,J)-459.69                                       COND1090
      TAL#TSAT(1,J)                                                     COND1095
      VG#VGFN(TAL,PMIX(1,J))                                            COND1100
      VNC#(10.729*TSAT(1,J))/(AMWNC *(PMIX(1,J)))                       COND1105
      VMIX#1.0/((AMOLSS/(VG*AMOLST))+(AMOLNC/(VNC*AMOLST)))             COND1110
      VEL(1,J)#((WSI+WNCI)*VMIX)/(3600.0*AENT)                          COND1115
      QG#0.0                                                            COND1120
      QGP#0.0                                                           COND1125
      DO410IL#1,IK                                                      COND1130
      I#IL                                                              COND1135
      LQ#0                                                              COND1140
      IF(WNCI) 270, 270, 275                                            COND1145
  270 WGAS(J) # 0.0                                                     COND1150
  275 WNC # WGAS(J)                                                     COND1155
      STSAT(I+1,J)#STSAT(I,J)                                           COND1160
      IF ( VERT ) 280, 300, 280                                         COND1165
  280 IF ( MOD( I,2) ) 290, 285, 290                                    COND1170
  285 ANFIP( I + 1) # ANFIP(I) + 1.0                                    COND1175
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      ANF1 (J) # ANF1P (I)                                              COND1180
      GO TO 295                                                         COND1185
  290 ANF1P(I+1) # ANF1P (I )                                           COND1190
      ANF1 (J) # ANF1P (I)                                              COND1195
  295 ANF2P    # ANF1P(I) - 1.0                                         COND1200
      ANF2 (J) # ANF2P                                                  COND1205
      ANF3 (J) # ANF3P                                                  COND1210
  300 STAVG#(STSAT(I+1,J)+STSAT(I,J))*0.5                               COND1215
      CALL HETTRN(STAVG      ,          WS(I,J),WNC,UM      ,UN(I,J),  COND1220
     1ALMTD(I,J),ASS,QG,QT,QCND,SHI(I,J),SHML      ,SHN (I,J),SHG      ,  COND1225
     2SHCGM      ,ALST,RC(I,J),SHCGN      ,LQ,STSAT(I,J),STSAT(I+1,J) ,  COND1230
     3 ANF1 (J), ANF2 (J), ANF3 (J) )                                   COND1235
      IF(ASS)545,305,545                                                COND1240
  305 QM      #UM      *A0* ANF2(J) *ALMTD(I,J)                         COND1245
      HFG#HFGFN(STSAT(I,J))                                             COND1250
      WL(I,J)#QM      /HFG                                              COND1255
      WCND(I,J)#UN(I,J)*A0*ALMTD(I,J)/HFG                               COND1260
      AMOLS(I,J)#WS(I,J)/18.015                                         COND1265
      AMOLSC#WNC/AMWNC                                                  COND1270
      L # 4                                                             COND1275
      CALL PRSDRP(TSAT(I,J),PSAT(I,J),PMIX(I,J),WS(I,J),WL(I,J),WNC,AXO,COND1280
     1AMOLS(I,J),AMOLSC,NERR,DELPTP(I,J),WCND(I,J),TPOG      ,ALV      ,L)COND1285
      JX # 0                                                            COND1290
      IF(NERR)555,310,555                                               COND1295
  310 WS(I+1,J)#WS(I,J)-WCND(I,J)                                       COND1300
      IF(WS(I+1,J))315,345,345                                          COND1305
  315 IF (EXITFR) 330, 330, 320                                         COND1310
  320 ALMAX # ALST                                                      COND1315
      ALST # ALST * 0.9 ** ( 1.0 /(FLOAT(ILNG)+ 1.0 ) )                 COND1320
      IF (ALST - ALMIN ) 325, 325, 165                                  COND1325
  325 ALST # ALMIN + (ALMAX - ALMIN) * 0.1                              COND1330
      GO TO 165                                                         COND1335
  330 STSAT(I+1,J)#STFO                                                 COND1340
      TSATMN#STSAT(I+1,J)+459.69                                        COND1345
      PMIN#PSATFN(TSATMN)                                               COND1350
      WCND(I,J)#WS(I,J)*(PSAT(I,J)-PMIN)/PSAT(I,J)                      COND1355
      WS(I+1,J)#WS(I,J)-WCND(I,J)                                       COND1360
      QG#(WS(I,J)*CPSFN(TSAT(I,J))/18.105+WNC*CPAFN(TSAT(I,J))/AMWNC )* COND1365
     1(TSAT(I,J)-TSATMN)                                                COND1370
      QT#QG+WCND(I,J)*HFG                                               COND1375
      IF(STSAT(I,J)-TB2) 335, 335, 340                                  COND1380
  335 TB2 # STSAT(I,J) - 0.1                                            COND1385
  340 ALMTD(I,J)#((STSAT(I+1,J)-STB1)-(STSAT(I,J)-TB2))/ALOG((STSAT(I+1,COND1390
     1J)-STB1)/(STSAT(I,J)-TB2))                                        COND1395
      UN(I,J)#QT/(A0*ALMTD(I,J))                                        COND1400
      AMOLS(I+1,J)#WS(I+1,J)/18.015                                     COND1405
      PMIX(I+1,J)#PMIX(I,J)-DELPTP(I,J)                                 COND1410
      PSAT(I+1,J)#PMIX(I+1,J)*AMOLS(I+1,J)/(AMOLS(I+1,J)+AMOLSC)        COND1415
      TSAT(I+1,J)#TSATMN                                                COND1420
      GO TO 405                                                         COND1425
  345 AMOLS(I+1,J)#WS(I+1,J)/18.015                                     COND1430
      PMIX(I+1,J)#PMIX(I,J)-DELPTP(I,J)                                 COND1435
      PSAT(I+1,J)#PMIX(I+1,J)*AMOLS(I+1,J)/(AMOLS(I+1,J)+AMOLSC)        COND1440
      PAL#PSAT(I+1,J)                                                   COND1445
      TSAT(I+1,J)#TSATFN(PAL)                                           COND1450
      STSAT(I+1,J)#TSAT(I+1,J)-459.69                                   COND1455
      TAL#TSAT(I+1,J)                                                   COND1460
      WCNDP#(UN(I,J)*A0*ALMTD(I,J)-(WS(I   ,J)*CPSFN(TSAT(I+1,J))/18.105 COND1465
     1+WNC*CPAFN(TSAT(I+1,J))/AMWNC )*(TSAT(I,J)-TSAT(I+1,J)))/HFG      COND1470
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      IF(ABS(WCNDP/WCND(I,J)-1.0)-.005)365,350,350                      COND1475
  350 JX#JX+1                                                           COND1480
      IF(JX-50)360,360,355                                              COND1485
  355 WRITE (6,8045)IDENT,I,J,I,J                                       COND1490
 8045 FORMAT(1H1,13A6/1H0,5X,2HI#,I2,5X,2HJ#,I1/1H0,24HNO CONVERGENCE FOCOND1495
     1R WCND(I2,1H,I1,1H))                                              COND1500
      GO TO 745                                                         COND1505
  360 WCND(I,J)#WCNDP                                                   COND1510
      GOTO310                                                           COND1515
  365 QG#(WS(I,J)*CPSFN(TSAT(I,J))/18.105+WNC*CPAFN(TSAT(I,J))/AMWNC )* COND1520
     1(TSAT(I,J)-TSAT(I+1,J))                                           COND1525
      WCND(I,J)#WCNDP                                                   COND1530
      QT#QG+WCND(I,J)*HFG                                               COND1535
C     WRITE OUTPUT TAPE 6, 3000, I, J, RC(I,J),QG, QT, QGP,UN(I,J)      COND1540
C3000 FORMAT(2I5, 5E16.8)                                               COND1545
      IF(RC(I,J)-0.040)405,405,370                                      COND1550
  370 IF(ABS(QGP/QG -1.0)-0.10 )405,375,375                             COND1555
  375 IF(LQ)380,380,385                                                 COND1560
  380 QGP#QG                                                            COND1565
      LQ#LQ+1                                                           COND1570
      GOTO 300                                                          COND1575
  385 IF(LQ- 5)390,390,395                                              COND1580
  390 QGP#QGP-0.5*(QGP-QG)                                              COND1585
      QG#QGP                                                            COND1590
      LQ#LQ+1                                                           COND1595
      GOTO 300                                                          COND1600
  395 QGP#QGP-0.1*(QGP-QG)                                              COND1605
      QG#QGP                                                            COND1610
      LQ#LQ+1                                                           COND1615
      IF(LQ-10)300,400,400                                              COND1620
  400 WRITE (6,8050)IDENT,I,J,I,J                                       COND1625
 8050 FORMAT(1H1,13A6/1H0,5X,2HI#,I2,5X,2HJ#,I1/1H0,22HNO CONVERGENCE FOCOND1630
     1R QG(I2,1H,I1,1H))                                                COND1635
  405 VG#VGFN(TSAT(I+1,J),PMIX(I+1,J))                                  COND1640
      QGP#QG                                                            COND1645
      VNC#(10.729*TSAT(I+1,J))/(AMWNC *(PMIX(I+1,J)))                   COND1650
      VMIX#1.0/((AMOLS(I+1,J)/(VG*(AMOLS(I+1,J)+AMOLSC)))+(AMOLSC/      COND1655
     1(VNC*(AMOLS(I+1,J)+AMOLSC))))                                     COND1660
      VEL(I+1,J)#(WS(I+1,J)+WNC)/AXO*VMIX/3600.0                        COND1665
  410 CONTINUE                                                          COND1670
      GI#288.00*SG*SVMIXI                                               COND1675
      VEL(I,J)#SVMIXI*(WS(I,J)+WGAS(J))/(3600.0*AXO)                    COND1680
      C(J)#(PMIX(I,J)-PMIX(IHNO+1,J))*GI/VEL(I,J)**2                    COND1685
  415 CONTINUE                                                          COND1690
      PMXEXT#0.0                                                        COND1695
      DO425J#1,JK                                                       COND1700
  420 DELP(J)#PMIX(I,J)-PMIX( IK +1,J)                                  COND1705
  425 PMXEXT#PMXEXT+PMIX( IK +1,J)                                      COND1710
      PMXEXT#PMXEXT/ FLOAT (JK)                                         COND1715
      DELPVE#PMIX(I,1)-PMXEXT                                           COND1720
      WPT#0.0                                                           COND1725
      IF (VERT) 470, 430,  470                                          COND1730
  430 DO 435 J#1,JK                                                     COND1735
      IF (ABS(DELP(J) / DELPVE - 1.0) - 0.01) 435, 435, 440             COND1740
  435 CONTINUE                                                          COND1745
      GO TO 470                                                         COND1750
  440 DO445J#1,4                                                        COND1755
      WP(J)#(DELPVE*GI/C(J))**0.5 *3600.0* AXO              /SVMIXI     COND1760
      WSP(J)#WP(J)*WSI/(WNCI+WSI)                                       COND1765
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      WGAS(J)#WP(J)-WSP(J)                                              COND1770
  445 WPT#WPT+WP(J)                                                     COND1775
      IF(ABS(WPT/(4.0*WSAVE)-1.0)-0.0005) 455,455, 450                  COND1780
  450 DELPVE # (WSAVE * 4.0 / WPT )      * DELPVE                       COND1785
      WPT#0.0                                                           COND1790
      GOTO440                                                           COND1795
  455 IPLOOP#IPLOOP + 1                                                 COND1800
      DO 460 J#1,4                                                      COND1805
  460 WS(1,J)#WSP(J)                                                    COND1810
      IF(IPLOOP-10) 260, 260,465                                        COND1815
  465 WRITE (6,8055)IDENT                                               COND1820
 8055 FORMAT(1H1,13A6,40HNO CONVERGENCE IN COND. DELTA P (IPLOOP) )     COND1825
      GOTO745                                                           COND1830
C     AVERAGE CONDITION AFTER CONDENSER SECTION AND BEFORE COOLER       COND1835
C     SECTION.                                                          COND1840
  470 PMXEXT#PMIX(1,1)-DELPVE                                           COND1845
      WSUME#0.0                                                         COND1850
      WSUMX#0.0                                                         COND1855
      DO 475 J#1,JK                                                     COND1860
      WSUMX#WSUMX + WS( IK +1,J)                                        COND1865
  475 WSUME#WSUME + WS(1,J)                                             COND1870
      WSEXIT#WSUMX/WSUME*WSI                                            COND1875
      WSFR # WSEXIT / WSI                                               COND1880
      TNOFR # TNOC / (TNOC + TNO)          *100.0                       COND1885
      AMLSEX#WSEXIT/18.015                                              COND1890
      PSATEX#PMXEXT* AMLSEX / (AMLSEX + AMOLNC)                         COND1895
      WNCC#WNCI                                                         COND1900
      TSATEX#TSATFN(PSATEX)                                             COND1905
      STSAEX#TSATEX-459.69                                              COND1910
      VELEXT#0.0                                                        COND1915
      DO480J#1,JK                                                       COND1920
  480 VELEXT#VELEXT+VEL( IK  + 1, J)                                    COND1925
      VELEXT#VELEXT/FLOAT(JK)                                           COND1930
C     CALCULATION THROUGH COOLER                                        COND1935
  485 AXOC#        SDO*HNOC*ALST * (SDDMIN - 1.0)                       COND1940
      SVGEXT#VGFN(TSATEX,PMXEXT)                                        COND1945
      SVNCEX#10.729*TSATEX/( AMWNC*(PMXEXT))                            COND1950
      AMLT # AMLSEX + AMOLNC                                            COND1955
      SVMXEX # 1.0 / (AMLSEX / (AMLT * SVGEXT) + AMOLNC /               COND1960
     1 (AMLT * SVNCEX ))                                                COND1965
      VELC(1)#(WSEXIT+WNCC)*SVMXEX/(AXOC*3600.0)                        COND1970
  490 IF(VELC(1)-VLCMAX)500,500,495                                     COND1975
  495 AXOC#(WSEXIT+WNCC)*SVMXEX/(VLCMAX*3600.0)                         COND1980
      HNOC#AXOC/(        SDO*ALST * (SDDMIN - 1.0 ))                    COND1985
      VNOC#TNOC/HNOC                                                    COND1990
      IVNOC # VNOC + 0.1                                                COND1995
      VELC(1)#VLCMAX                                                    COND2000
  500 G2#288.0*SG*SVMXEX                                                COND2005
      IF(VELC(1)-VELEXT)505,505,510                                     COND2010
  505 A2DAI#VELC(1)/VELEXT                                              COND2015
      DELPCT#((1.0-A2DAI)*VELEXT**2)/G2                                 COND2020
      GOTO525                                                           COND2025
  510 A2DAI#VELEXT/VELC(1)                                              COND2030
      IF(A2DAI-0.715)520,520,515                                        COND2035
  515 DELPCT#(0.75*(1.0-A2DAI)*VELC(1)**2)/G2                           COND2040
      GOTO525                                                           COND2045
  520 DELPCT#(0.4*(1.25-A2DAI)*VELC(1)**2)/G2                           COND2050
  525 PMIXC(1)#PMXEXT-DELPCT    -(VELC(1)**2 -VELEXT**2)/G2             COND2055
      PSATC(1)#PMIXC(1)*AMLSEX/(AMLSEX+AMOLNC)                          COND2060
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      PAL#PSATC(I)
      TSATC(I)#TSATFN(PAL)                                              COND2065
      STSATC(I)#TSATC(I)-459.69                                         COND2070
      WSC(I)#WSEXIT                                                     COND2075
      TAL#TSATC(I)                                                      COND2080
      VG#VGFN(TAL,PMIXC(I))                                             COND2085
      AMLSSC(I)#WSC(I)/18.015                                           COND2090
      AMLSCC#AMOLNC                                                     COND2095
      VNC#10.729*TSATC(I)/(AMWNC *(PMIXC(I)))                           COND2100
      VMIX#1.0/((AMLSSC(I)/(VG*(AMLSSC(I)+AMLSCC)))                     COND2105
     1+(AMLSCC/(VNC*(AMLSSC(I)+AMLSCC))))                               COND2110
      VELC(I)#(WSC(I)+WNCC)*VMIX/(AXOC*3600.0)                          COND2115
      ANFC(I)#(VNOC+1.0)/2.0                                            COND2120
      QGC#0.0                                                           COND2125
      QGPC#0.0                                                          COND2130
      DO650 KKK#1,IVNOC                                                 COND2135
      I # KKK                                                           COND2140
      J # 4                                                             COND2145
      LQC#0                                                             COND2150
      STSATC(I+1)#STSATC(I)                                             COND2155
      IF (MOD(I,2) ) 535, 530, 535                                      COND2160
  530 ANFC (I+1) # ANFC (I) - 1.0                                       COND2165
      GO TO 540                                                         COND2170
  535 ANFC (I+1) # ANFC (I)                                             COND2175
  540 STAVG#(STSATC(I+1) + STSATC(I))*0.5                               COND2180
      ANFC2      # ANFC (I) - 1.0                                       COND2185
      CALL HETTRN(STAVG     ,          WSC(I),WNCC    ,UMC    ,UNC(I),  COND2190
     1ALMTDC(I),ASS,QGC,QTC,QCNDC,SHIC(I),SHMLC    ,SHNFC(I),SHGC    ,  COND2195
     2SHCGCM    ,ALST,RCC(I),SHCGCN    ,LQC,STSATC(I),STSATC(I+1) ,     COND2200
     3 ANFC (I), ANFC2     , ANFC2      )                                COND2205
      IF(ASS) 545,550, 545                                              COND2210
  545 WRITE (6,8060)IDENT                                               COND2215
 8060 FORMAT(1H1,13A6/48HONO CONVERGENCE FOR TB2 IN HEAT TRANSFER ROUTINCOND2220
     1E)                                                                COND2225
      GO TO 745                                                         COND2230
  550 QMC    #UMC    *AO*ANFC2    *ALMTDC(I)                            COND2235
      HFG#HFGFN(STSATC(I))                                              COND2240
      WLC(I)#QMC    *HNOC/HFG                                           COND2245
      WCNDC(I)#UNC(I)*AO*HNOC*ALMTDC(I)/HFG                             COND2250
      LJ # 5                                                            COND2255
      CALL PRSDRP(TSATC(I),PSATC(I),PMIXC(I),WSC(I),WLC(I),WNCC,AXOC,   COND2260
     1AMLSSC(I),AMLSCC,NERR,DELTPC(I),WCNDC(I),TPOGC    ,ALVC    ,LJ)   COND2265
      DELTPC (I) # 2.0 * DELTPC (I)                                     COND2270
      JY # 0                                                            COND2275
      IF(NERR)555,560,555                                               COND2280
  555 WRITE (6,8065)IDENT                                               COND2285
 8065 FORMAT(1H1,13A6,42HERROR IN INTPL2 WHICH IS CALLED BY PRSDRP.)    COND2290
      GO TO 745                                                         COND2295
  560 WSC(I+1)#WSC(I)-WCNDC(I)                                          COND2300
      IF(WSC(I+1))565,595,595                                           COND2305
  565 IF (EXITFR) 580, 580, 570                                         COND2310
  570 ALMAX # ALST                                                      COND2315
      ALST # ALST *0.98 ** ( 1.0 /(FLOAT  (ILNG)+ 1.0 ) )               COND2320
      IF (ALST - ALMIN ) 575, 575, 165                                  COND2325
  575 ALST # ALMIN + (ALMAX - ALMIN) * 0.1                              COND2330
      GO TO 165                                                         COND2335
  580 STSATC(I+1) # STFO                                                COND2340
      TSATMN#STSATC(I+1)+459.69                                         COND2345
      PMIN#PSATFN(TSATMN)                                               COND2350
                                                                        COND2355
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      WCNDC(I)#WSC(I)*(PSATC(I)-PMIN)/PSATC(I)                          COND2360
      WSC(I+1)#WSC(I)-WCNDC(I)                                          COND2365
      QGC#(WSC(I)*CPSFN(TSATC(I))/18.015+WNCC*CPAFN(TSATC(I))/AMWNC)*   COND2370
     1(TSATC(I)-TSATMN)                                                 COND2375
      QTC#QGC+WCNDC(I)*HFG                                              COND2380
      IF(STSATC(I)-TB2) 585, 585, 590                                   COND2385
  585 TB2 # STSATC(I) - 0.1                                             COND2390
  590 ALMTDC(I)#((STSATC(I+1)-STBI)-(STSATC(I)-TB2))/ALOG((STSATC(I+1)- COND2395
     1STBI)/(STSATC(I)-TB2))                                            COND2400
      UNC(I)#QTC/(AO*HNOC*ALMTDC(I))                                    COND2405
      AMLSSC(I+1)#WSC(I+1)/18.015                                       COND2410
      PMIXC(I+1)#PMIXC(I)-DELTPC(I)                                     COND2415
      PSATC(I+1)#(PMIXC(I+1)*AMLSSC(I+1))/(AMLSSC(I+1)+AMLSCC)          COND2420
      TSATC(I+1)#TSATMN                                                 COND2425
      GO TO 635                                                         COND2430
  595 AMLSSC(I+1)#WSC(I+1)/18.015                                       COND2435
      PMIXC(I+1)#PMIXC(I)-DELTPC(I)                                     COND2440
      PSATC(I+1)#(PMIXC(I+1)*AMLSSC(I+1))/(AMLSSC(I+1)+AMLSCC)          COND2445
      PAL#PSATC(I+1)                                                    COND2450
      TSATC(I+1)#TSATFN(PAL)                                            COND2455
      STSATC(I+1)#TSATC(I+1)-459.69                                     COND2460
      TAL#TSATC(I+1)                                                    COND2465
      WCNDP#(UNC(I)*AO*HNOC*ALMTDC(I)-(WSC(I  )*CPSFN(TSATC(I+1))/18.105COND2470
     1+WNCC*CPAFN(TSATC(I+1)))/AMWNC )*(TSATC(I)-TSATC(I+1))))/HFG      COND2475
  600 IF(ABS(WCNDP/WCNDC(I)-1.0)-.005)615,605,605                       COND2480
  605 WCNDC(I)#WCNDP                                                    COND2485
      JY # JY + 1                                                       COND2490
      IF(JY-50) 560, 560, 610                                           COND2495
  610 WRITE (6,8070)I                                                   COND2500
 8070 FORMAT(1H0, 25HNO CONVERGENCE FOR WCNDC(, 12, 2H).  )             COND2505
      GO TO 745                                                         COND2510
  615 QGC#(AMLSSC(I)*CPSFN(TSATC(I))+AMLSCC*CPAFN(TSATC(I)))*(TSATC(I)- COND2515
     1TSATC(I+1))                                                       COND2520
      WCNDC(I)#WCNDP                                                    COND2525
      QTC#QGC+WCNDC(I)*HFG                                              COND2530
C     WRITE OUTPUT TAPE 6, 3001, I, RCC(I), QGC, QTC, QGPC, UNC(I)      COND2535
C3001 FORMAT(I5, 5E16.8)                                                COND2540
      IF(RCC( I)-0.040)635,635,620                                      COND2545
  620 IF(ABS(QGPC/QGC-1.0)-0.10)635,625,625                             COND2550
  625 QGPC#(QGPC + QGC)*0.5                                             COND2555
      LQC#LQC+1                                                         COND2560
      IF(LQC-50)540,630,630                                             COND2565
  630 WRITE (6,8075)IDENT,I                                             COND2570
 8075 FORMAT(1H1,13A6/1H0,5X,2HI#,I2/1H0,25HNO CONVERGENCE FOR QGC(I))  COND2575
      GO TO 745                                                         COND2580
  635 VG#VGFN(TSATC(I+1),PMIXC(I+1))                                    COND2585
      QGPC#QGC                                                          COND2590
      VNC#10.729*TSATC(I+1)/(AMWNC *(PMIXC(I+1)))                       COND2595
      VMIX#1.0/((AMLSSC(I+1)/(VG*(AMLSSC(I+1)+AMLSCC)))+(AMLSCC/(VNC*   COND2600
     1(AMLSSC(I+1)+AMLSCC))))                                           COND2605
      VELC(I+1)#(WSC(I+1)+WNCC)*VMIX/(AXOC *3600.0)                     COND2610
      IF(MOD(I,2))640,645,640                                           COND2615
  640 ANFC(I+1)#ANFC(I)                                                 COND2620
      GOTO650                                                           COND2625
  645 ANFC(I+1)#ANFC(I)-1.0                                             COND2630
  650 CONTINUE                                                          COND2635
      DELPC#PMIXC(1)-PMIXC(IVNOC+1)                                     COND2640
      CLC#DELPC*488.0*SG*SVMXEX/VELC(1)**2                              COND2645
      XTFR1 # WSC (IVNOC + 1) / WSI                                     COND2650
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      IF (EXITFR) 720, 720, 655                                         COND2655
  655 IF (ABS(XTFRI - EXITFR) - 0.25 * EXITFR) 720, 720, 660            COND2660
  660 IF ( ILNG -  5) 670, 670, 665                                     COND2665
  665 WRITE (6,8080)                                                    COND2670
 8080 FORMAT (1H0 44H NO CONVERGENCE FOR EXITFR AFTER  5 TRIES        )  COND2675
      GO TO 720                                                         COND2680
  670 IF (XTFRI - EXITFR ) 675,  675, 700                               COND2685
  675 ALMAX # ALST                                                      COND2690
      IF ( ILNG - 2) 680, 685, 685                                      COND2695
  680 ALST # ALST *(( 1.0 + XTFRI) / ( 1.0 + EXITFR ) )                 COND2700
      GO TO 695                                                         COND2705
  685 ALST #     ALST + (ALSI - ALS2) / (XTFRI - XTFR2)                 COND2710
     1 * (EXITFR - XTFRI )                                              COND2715
      IF (ALST - ALMIN ) 690, 690, 695                                  COND2720
  690 ALST # ALMIN +(ALMAX - ALMIN ) * 0.1                              COND2725
  695 ALS2 # ALSI                                                       COND2730
      XTFR2 # XTFRI                                                     COND2735
      ILNG # ILNG + 1                                                   COND2740
      GO TO 165                                                         COND2745
  700 ALMIN # ALST                                                      COND2750
      IF (ILNG - 2) 705, 710, 710                                       COND2755
  705 ALST # ALST *(( 1.0 + XTFRI) / ( 1.0 + EXITFR ) )                 COND2760
      GO TO 695                                                         COND2765
  710 ALST #     ALST + (ALSI - ALS2) / (XTFRI - XTFR2)                 COND2770
     1 * (EXITFR - XTFRI )                                              COND2775
      IF (ALMAX - ALST) 715, 715, 695                                   COND2780
  715 ALST # ALMAX - (ALMAX - ALMIN) * 0.1                              COND2785
      GO TO 695                                                         COND2790
  720 CONTINUE                                                          COND2795
  725 ARCOND#A0*(ANT-TNOC)                                              COND2800
      WCNDT#WSI-WSC(1)                                                  COND2805
      QTCOND#WCNDT*HFGFN(STSATC(1))                                     COND2810
     1+((WSI+WSC(1))*0.5*CPSFN(TSATC(1))/18.015                         COND2815
     2+AMOLNC*CPAFN(TSATC(1)))*(STSAT(1,1)-STSATC(1))                   COND2820
      STB2CD#QTCOND/(WB*(ANT-TNOC)*CPFN(CBI,STBI)) + STBI               COND2825
      DTCOND#((STSATC(1)-STBI)-(STSAT(1,1)-STB2CD))/                    COND2830
     1ALOG((STSATC(1)-STBI)/(STSAT(1,1)-STB2CD))                        COND2835
      UCOND#QTCOND/(ARCOND*DTCOND)                                      COND2840
      ARCOOL#A0*TNOC                                                    COND2845
      WCNDCT#WSC(1)-WSC(IVNOC+1)                                        COND2850
      QTCOOL#WCNDCT*HFGFN(STSATC(1))                                    COND2855
     1+((WSC(1)+WSC(IVNOC+1))*0.5*CPSFN(TSATC(1))/18.015                COND2860
     2+AMOLNC*CPAFN(TSATC(1)))*(STSATC(1)-STSATC(IVNOC+1))              COND2865
      STB2CL#QTCOOL/(WB*(TNOC)*CPFN(CBI,STBI)) + STBI                   COND2870
      DTCOOL#((STSATC(IVNOC+1)-STBI)-(STSATC(1)-STB2CL))/               COND2875
     1        ALOG((STSATC(IVNOC+1)-STBI)/(STSATC(1)-STB2CL))           COND2880
      UCOOL#QTCOOL/(ARCOOL*DTCOOL)                                      COND2885
      STB2T#(QTCOND+QTCOOL)/(WBI*CPFN(CBI,STBI)) + STBI                 COND2890
      DELTOT#((STSATC(IVNOC+1)-STBI)-(STSAT(1,1)-STB2T))/               COND2895
     1ALOG((STSATC(IVNOC+1)-STBI)/(STSAT(1,1)-STB2T))                   COND2900
      UAVG#(QTCOND + QTCOOL)/(A0*ANT*DELTOT)                            COND2905
      DTCND2# (STB2CD- STBI) / ALOG(( STSAT(1,1)- STBI) /            ( STCOND2910
     1SAT(1,1) - STB2CD))                                               COND2915
      UPCOND # QTCOND / (ARCOND * DTCND2)                               COND2920
      DTCOL2# (STB2CL- STBI) / ALOG(( STSATC(1) - STBI) /            (STCOND2925
     1SATC(1 ) - STB2CL))                                               COND2930
      UPCOOL # QTCOOL / (ARCOOL * DTCOL2 )                              COND2935
      DLTOT2# (STB2T- STBI) / ALOG((STSAT(1,1) - STBI) /            (STSACOND2940
     1T(1,1) - STB2T))                                                  COND2945
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      UPAVG # (QTCOND + QTCOOL) / (AO * ANT * DLTOT2)                   COND2950
      UBARW # 0.0                                                       COND2955
      UBARWC # 0.0                                                      COND2960
      HNO2 # FLOAT(IHNO)                                                COND2965
      DO  735 J#1,JK                                                    COND2970
      DO  730 I#1,IK                                                    COND2975
  730 UBARW # UBARW + UN(I,J)                                           COND2980
  735 CONTINUE                                                          COND2985
      UBARW # UBARW/ ( FLOAT(JK) * FLOAT(IK) )                          COND2990
      DO  740 I#1,IVNOC                                                 COND2995
  740 UBARWC # UBARWC + UNC(I)                                          COND3000
      UBARWC # UBARWC/VNOC                                              COND3005
      UAVGW #(UBARW*TNO + UBARWC*TNOC)/(TNO + TNOC)                     COND3010
      ADTCLR # QTCOOL/(UBARWC*ARCOOL)                                   COND3015
      ADTCND # QTCOND/(UBARW*AO*TNO)                                    COND3020
      ADTOA # (QTCOOL+QTCOND)/(UAVGW*(TNO+TNOC)*AO)                     COND3025
      TDROP1 # STSAT(1,1) - STSAEX                                      COND3030
      TDROP2 # STSATC(1) - STSATC(IVNOC+1)                              COND3035
      TDROP3 # STSAT1 - STSATC(IVNOC+1)                                 COND3040
      THOFR # TNO/(TNO + TNOC) *100.0                                   COND3045
      DELPOA # PMIX1 - PMIXC(IVNOC+1)                                   COND3050
      HBNDC # 0.866*VNOC*SDD*SDO + SDO                                  COND3055
      WBNDC # HNOC*SDD*SDO + SDO                                        COND3060
      EXSTFR # WSC(IVNOC+1)/WSI * 100.0                                 COND3065
      EXNCFR# WNCI/(WNCI+WSC(IVNOC+1))*100.0                            COND3070
C  REGULAR OUTPUT PKG                                                   COND3075
      WRITE(6,8085)                                                     COND3080
 8085 FORMAT(1HK,52X, 18HSUMMARY OF RESULTS /1H0,16X, 2HU,8X, 8HLOG MEANCOND3085
     1 ,4X, 79HPRESSURE   TEMP.   STEAM VELOCITY  NUMBER OF TUBES  TUBE COND3090
     2SPACING  TUBE FRACTION /12X, 88HBTU/HR/SQ.FT. DELTA TEMP,    DROP COND3095
     3    DROP        FT/SEC      HORIZ. VERTICAL     RATIO,/14X,99H/DEGCOND3100
     4. F.       DEG.F.    LBS/SQ.IN.  DEG.F.  INLET   OUTLET   ROWS    RCOND3105
     5OWS         S/D        PERCENT )                                 COND3110
      WRITE(6,8090) UBARW, ADTCND, DELPVE, TDROP1, VEL(1,1), VEL(IHNO+1,COND3115
     11), HNO, VNO, SDD, THOFR, UBARWC, ADTCLR, DELPC, TDROP2, VELC(1), COND3120
     2VELC(IVNOC+1), HNOC,  VNOC, SDDMIN, TNOFR, UAVGW, ADTOA, DELPOA,  COND3125
     3TDROP3, HNO, VNO                                                  COND3130
 8090 FORMAT(1H0, 11HCONDENSER    , F8.2,6X,F6.2,7X,F7.4,3X,F6.3,2X,F6.2,COND3135
     12X,F6.2,3X,F6.0,3X,F6.0,8X,F3.1,8X,F6.2/1X,  6HCOOLER ,5X,F8.2,6X,COND3140
     2F6.2,7X,F7.4,3X,F6.3,2X,F6.2,2X,F6.2,3X,F6.0,3X,F6.0,8X ,F3.1,8X, COND3145
     3F6.2/1X,  7HOVERALL ,4X,F8.2,6X,F6.2,7X,F7.4,3X,F6.2,19X,F6.0,3X, COND3150
     4F6.0 )                                                            COND3155
      WRITE(6, 8095) HBNDC, WBNDC                                       COND3160
 8095 FORMAT(1H0, 18HCOOLER HEIGHT, FT. ,F6.2,5X,17HCOOLER WIDTH, FT. , COND3165
     1F6.2)                                                             COND3170
      WRITE(6, 8100) HBND, WBND, ALST, EXSTFR, EXNCFR                   COND3175
 8100 FORMAT(1H0, 18HBUNDLE HEIGHT, FT. ,F6.2,5X,17HBUNDLE WIDTH, FT. , COND3180
     1F6.2,5X, 18HBUNDLE LENGTH, FT. ,F7.3/1H0, 28HEXIT STEAM, PERCENT OCOND3185
     2F INPUT ,5X,F6.2,9X, 49HEXIT NON-CONDENSIBLES, PERCENT OF TOTAL EXCOND3190
     3IT FLOW ,5X, F6.2 )                                               COND3195
      IF(OUTPUT) 745, 100, 745                                          COND3200
C  FULL OUTPUT PKG                                                      COND3205
  745 IVNOC#IVNOC+1                                                     COND3210
      IHNO# IK +1                                                       COND3215
      DO 750 J # 1, JK                                                  COND3220
      WRITE (6,8105)IDENT                                               COND3225
 8105 FORMAT(1H1,13A6)                                                  COND3230
      WRITE (6, 8110 ) J                                                COND3235
 8110 FORMAT(1H0 20X 41H ROW BY ROW OUTPUT, CONDENSER SECTION J #   , I2)COND3240
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      WRITE (6,8125)                                                    COND3245
      WRITE(6,8130) (STSAT(I,J),PMIX(I,J),WS(I,J),VEL(I,J),RC(I,J),     COND3250
     1UN(I,J),SHN (I,J),SHI(I,J), I#1,IHNO)                             COND3255
  750 CONTINUE                                                          COND3260
      WRITE (6,8105)IDENT                                               COND3265
      WRITE (6, 8115 )                                                  COND3270
 8115 FORMAT (1H0 20X 39H ROW BY ROW OUTPUT, GAS COOLER SECTION    )    COND3275
      WRITE (6,8120)                                                    COND3280
      WRITE(6,8130)(STSATC(I),PMIXC(I),WSC(I),VELC(I),RCC(I),UNC(I),    COND3285
     1SHNFC(I),SHIC(I),I#1,IVNOC)                                       COND3290
      IVNOC#IVNOC-1                                                     COND3295
      IHNO# IK -1                                                       COND3300
 8120 FORMAT(1H0,5X,6HSTSATC,10X,5HPMIXC,11X,3HWSC,13X,4HVELC,12X,3HRCC,COND3305
     113X,3HUNC,13X,5HSHNFC,11X,4HSHIC )                                COND3310
 8125 FORMAT(1H0,5X,5HSTSAT,11X,4HPMIX,12X,2HWS,14X,3HVEL,13X,2HRC,14X, COND3315
     12HUN,14X,4HSHNF,12X,3HSHI )                                       COND3320
 8130 FORMAT(1H ,8E16.8)                                                COND3325
      GOTO100                                                           COND3330
      END                                                               COND3335
```

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$IBFTC HTTR     DECK                                                    HTTR0000
C       SUBROUTINE HETTRN SANS-0 UPDATE 9/21/66                         HTTR0005
C** THIS HETTRN USES QGAS CORRELATION                                   HTTR0010
        SUBROUTINE HETTRN(STSAT,     WS,WNC,VML,VNF,ALMTD,ASS,QG,QT,QCND,  )TTR0015
       1SHI,SHML,SHNF,SHG,SHCGM,ALST,RC,SHCGN,LQ,STSAT1,STSAT2,         HTTR0020
       2 AA1, AA2, AA3)                                                 HTTR0025
        DIMENSION COOR (3)                                              HTTR0030
        COMMON  SDO     , STBI    , AI      , AO      , AW      , SHWINV HTTR0035
        COMMON  FOUL    , CBI     , SDI     , AXI     , WB      , HFG   HTTR0040
        COMMON  SDD     , STB2ES  , GB      , VG      , AMWNC   , STFO  HTTR0045
        COMMON  TB2     , STBAVE  , VNO     , J       , XNC     , SF    HTTR0050
        COMMON  COOR    , JRC     , VERT                              HTTR0055
C       COMMON SDO,STBI,AI,AO,AW,SHWINV,FOUL,CBI,SDI,AXI,WB,HFG,SDD,STB2ESHTTR0060
C      1,GB,VG, AMWNC,STFO,TB2, STBAVE, VNO, J, XNC                     HTTR0065
C       COMMON SF, COOR, JRC ,  VERT                                    HTTR0070
C       DIMENSION COOR (3)                                              HTTR0075
        RC#WNC/(WS+WNC)                                                 HTTR0080
        ASS#0                                                           HTTR0085
        TSAT#STSAT+459.69                                               HTTR0090
        ANF # AA1                                                       HTTR0095
        ANF2 # AA2                                                      HTTR0100
        ANF3 # AA3                                                      HTTR0105
        BNFM # 16.0                                                     HTTR0110
        IF(TB2) 100, 100, 105                                           HTTR0115
  100   STBAVE#( STBI+STB2ES) / 2.0                                     HTTR0120
        TB2 # STB2ES                                                    HTTR0125
CCCCC                                                                   HTTR0130
C      CALC. BRINE PROPERTIES AT STBAVE,(CBI,MUW,TW,CBI)                HTTR0135
C                                .8        0.33            0.14         HTTR0140
C      SHI#0.027*( K )(SDI*GB)  (CP*BMU)    (BMU(AVG T) )                HTTR0145
C                (SDI)( BMU  )  (  K   )    (BMU(WALL T))                HTTR0150
CCCC                                                                    HTTR0155
  105   BB#GB*3600.0                                                    HTTR0160
        STBAVE # (STBI + TB2)*0.5                                       HTTR0165
        STWI#(STBAVE+STSAT)/2.0                                         HTTR0170
        STWO#(STBAVE+ STSAT)/2.0                                        HTTR0175
        STFI#(STBAVE+STWI)/2.0                                          HTTR0180
        STFO#(STSAT+STWO)/2.0                                           HTTR0185
        K # 0                                                           HTTR0190
        KK # 0                                                          HTTR0195
 8000   FORMAT(1H0, 8H IDIV # , I4 )                                    HTTR0200
        CALL DVCHK (K000FX)                                             HTTR0205
         GO TO(110,115),K000FX                                          HTTR0210
  110   IDIV # 8051                                                     HTTR0215
        WRITE (6,8000)IDIV                                              HTTR0220
  115   CONTINUE                                                        HTTR0225
  120   SHI#.027*SKBFN(CBI,STBAVE)/SDI*(SDI*BB/BMUFN(CBI,STBAVE))**0.  HTTR0230
       18*(CPFN(CBI,STBAVE)*BMUFN(CBI,STBAVE)/SKBFN(CBI,STBAVE))**.333*(BMHTTR0235
       2UFN(CBI,STBAVE)/BMUFN(CBI,STWI))**.14                           HTTR0240
        RIN#AO/(SHI*AI)                                                 HTTR0245
CCCCC                                                                   HTTR0250
C       CALCULATE STEAM PROPERTIES (K,ROE,HFG,MU) AT TFO                HTTR0255
CCCCC                                                                   HTTR0260
        AMOLSS#WS/18.015                                                HTTR0265
        AMOLNC#WNC/AMWNC                                                HTTR0270
        RMS#AMOLSS/(AMOLSS+AMOLNC)                                      HTTR0275
        RMA #AMOLNC/(AMOLNC+AMOLSS)                                     HTTR0280
        IF(RC-0.040)130,130,125                                         HTTR0285
  125   XNC # 1.0                                                       HTTR0290
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      GO TO 135                                                         HTTR0295
  130 XNC#1.0-0.34316E2*RC+0.12268E4*RC**2-0.14923E5*RC**3              HTTR0300
  135 IF(ANF-1.0)140,140,145                                            HTTR0305
  140 XNF#1.310                                                         HTTR0310
      BNF# 1.0                                                          HTTR0315
      BNF2 # 1.0                                                        HTTR0316
      GOTO195                                                           HTTR0320
  145  IF (ANF - 16.0) 150, 150, 155                                    HTTR0325
  150 BNF # ANF                                                         HTTR0330
      BNF2 # ANF2                                                       HTTR0335
      IF(BNF2) 152, 152, 153                                            HTTR0338
  152 BNF2 # 1.0                                                        HTTR0339
  153 BNF3 # ANF3                                                       HTTR0340
      GO TO 190                                                         HTTR0345
  155 BNF # 16.0                                                        HTTR0350
      IF (BNF2 - 16.0 ) 160, 160, 165                                   HTTR0355
  160 BNF2 # ANF2                                                       HTTR0360
      BNF3 # ANF3                                                       HTTR0365
      GO TO 190                                                         HTTR0370
  165 BNF2 # 16.0                                                       HTTR0375
      IF (BNF3 - 16.0 ) 170, 170, 175                                   HTTR0380
  170 BNF3 # ANF3                                                       HTTR0385
      GO TO 190                                                         HTTR0390
  175 BNF3 # 16.0                                                       HTTR0395
      CALL DVCHK (KOOOFX)                                               HTTR0400
       GO TO(180,185),KOOOFX                                            HTTR0405
  180 IDIV # 8053                                                       HTTR0410
      WRITE (6,8000)IDIV                                                HTTR0415
  185 CONTINUE                                                          HTTR0420
  190 XNF#1.2379476+.35360826E-1*BNF-.15703466E-2*BNF**2                HTTR0425
      XNF2 #1.2379476+.35360826E-1*BNF2 -.15703466E-2*BNF2 **2          HTTR0430
      XNF3 #1.2379476+.35360826E-1*BNF3 -.15703466E-2*BNF3 **2          HTTR0435
      XNFMIN#1.2379476+.35360826E-1*BNFM -.15703466E-2*BNFM **2         HTTR0440
  195 A#XNF*XNC                                                         HTTR0445
      KSTFO#0                                                           HTTR0450
CCCCC                                                                   HTTR0455
C        CALC. AVG. HEAT TRF COEFF AT BRINE CONC.#0                     HTTR0460
C                   3    2              8 0.25                          HTTR0465
C     SHM#0.725*( K *ROE *HVAP*4.17*10 )     *A                         HTTR0470
C                ( BMU*SDO*DELTA T*BNF   )                              HTTR0475
CCCC                                                                    HTTR0480
      IF ( RC - 0.040) 200, 200, 205                                    HTTR0485
  200 XNC2 # (100.0*RMA + 0.6) ** (-1.50 /(ABS(STSAT-STWO))**0.17)      HTTR0490
      XNC# AMIN1(XNC, XNC2)                                             HTTR0495
  205 A # XNC * XNF                                                     HTTR0500
      A # XNC * XNF                                                     HTTR0505
      SHMK#0.725*(SKBFN(0,STFO)**3*ROEFN(0.0,STFO)**2*HFGFN(STFO)*      HTTR0510
     1416975040.0/(BMUFN(0,STFO)*SDO*ABS(STSAT-STWO)     ))**.25        HTTR0515
      SHM # SHMK * XNC * XNF / BNF ** 0.25                              HTTR0520
      SHML# SHMK * XNC * XNF2/ BNF2** 0.25                              HTTR0525
      SHMIN # SHMK * XNC * XNFMIN / BNFM **0.25                         HTTR0530
      CALL DVCHK (KOOOFX)                                               HTTR0535
       GO TO(210,215),KOOOFX                                            HTTR0540
  210 IDIV # 8055                                                       HTTR0545
      WRITE (6,8000)IDIV                                                HTTR0550
  215 CONTINUE                                                          HTTR0555
      IF (VERT) 220, 255, 220                                           HTTR0560
  220 IF (ANF - 1.0) 225, 225, 230                                      HTTR0565
  225 SHNF # SHM                                                        HTTR0570
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      SHML # 1.0 E15                                                    HTTR0575
      GO TO 300                                                         HTTR0580
  230 IF (ANF - 16.0) 240, 235, 235                                     HTTR0585
  235 SHNF # SHM                                                        HTTR0590
      GO TO 300                                                         HTTR0595
  240 SHNFP # (ANF * SHM - ANF2 * SHML) / (ANF - ANF2)                  HTTR0600
      SHMIN # SHMK * XNC * XNF3 / BNF3 **0.25                           HTTR0605
      SHNF# AMAX1(SHNFP, SHMIN)                                         HTTR0610
      CALL DVCHK (K000FX)                                               HTTR0615
       GO TO(245,250),K000FX                                            HTTR0620
  245 IDIV # 8057                                                       HTTR0625
      WRITE (6,8000)IDIV                                                HTTR0630
  250 CONTINUE                                                          HTTR0635
      GO TO 300                                                         HTTR0640
  255 IF (J - 1) 260, 260, 265                                          HTTR0645
  260 SHNF # SHM                                                        HTTR0650
      GO TO 300                                                         HTTR0655
  265 IF (ANF3 - 16.0) 275, 270, 270                                    HTTR0660
  270 SHNF # SHM                                                        HTTR0665
      SHML # SHM                                                        HTTR0670
      GO TO 300                                                         HTTR0675
  275 SHM3 # SHMK * XNC * XNF3 / BNF3 ** 0.25                           HTTR0680
      SHM3AV # (BNF * SHM - ANF3 * SHM3) / (BNF - ANF3)                 HTTR0685
      IF (SHM3AV - SHMIN)  280, 285, 285                                HTTR0690
  280 SHM3AV # SHMIN                                                    HTTR0695
  285 IF (ANF - 16. ) 290, 290, 295                                     HTTR0700
  290 SHNF # SHM3AV                                                     HTTR0705
      GO TO 300                                                         HTTR0710
  295 SHNF # (SHM3AV * (16.0 - ANF3) + SHM * (ANF - 16.0)) / (ANF-ANF3) HTTR0715
  300 CPMIX#CPAFN(TSAT)/AMWNC                                           HTTR0720
      AKMIX#AKAFN(TSAT)                                                 HTTR0725
      AMUMIX# AMUFN(TSAT)                                               HTTR0730
CCCC                                                                    HTTR0735
C     CALCULATE STEAM-AIR MIXTURE HEAT TRF COEFF., SHG                  HTTR0740
C                    0.33       0.6                                     HTTR0745
C     SHG#0.33(CP*MU)    (SDO*G)   ( K )                               HTTR0750
C              (  K  )    ( MU  )   (SDO)                              HTTR0755
CCCC                                                                    HTTR0760
      SHG#0.33*(CPMIX*AMUMIX*3600.0/AKMIX)**0.33*(SDO*(WS+WNC)/         HTTR0765
     1 (3600.0*ALST*SDO*(SDD-1.0)*AMUMIX))**0.6*AKMIX/SDO               HTTR0770
      CALL DVCHK (K000FX)                                               HTTR0775
       GO TO(305,310),K000FX                                            HTTR0780
  305 IDIV # 8059                                                       HTTR0785
      WRITE (6,8000)IDIV                                                HTTR0790
  310 CONTINUE                                                          HTTR0795
      IF(RC-0.040)330,330,315                                           HTTR0800
  315 SHCGM#1.0/(QG/(QT*SHG)+1.0/SHML)                                  HTTR0805
      CALL DVCHK (K000FX)                                               HTTR0810
       GO TO(320,325),K000FX                                            HTTR0815
  320 WRITE (6,8005)SHML                                                HTTR0820
 8005 FORMAT(1H0, 20X, 21H DIV CHECK ON, SHML # , F5.2  )               HTTR0825
  325 CONTINUE                                                          HTTR0830
      SHCGN#1.0/(QG/(QT*SHG)+1.0/SHNF)                                  HTTR0835
      ROUT#1.0/SHCGN                                                    HTTR0840
      RTOT#RIN+ROUT+SHWINV+FOUL                                         HTTR0845
      VNF#1.0/RTOT                                                      HTTR0850
      VML#1.0/(RIN+1.0/SHCGM+SHWINV+FOUL)                               HTTR0855
      IF(SHML)335,335,345                                               HTTR0860
  330 ROUT#1.0/SHNF                                                     HTTR0865
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      RTOT#RIN+ROUT+SHWINV+FOUL                                         HTTR0870
      VNF#(1.0/RTOT)                                                    HTTR0875
      IF(SHML)335,335,340                                               HTTR0880
  335 VML#0.0                                                           HTTR0885
      GOTO345                                                           HTTR0890
  340 VML#(1.0/(RIN+1.0/SHML+SHWINV+FOUL))                              HTTR0895
  345 CONTINUE                                                          HTTR0900
      IF(STSAT1-TB2)350,350,355                                         HTTR0905
  350 ALMTD#ALMTD                                                       HTTR0910
      GOTO370                                                           HTTR0915
  355 IF(STSAT2-STBI)360,360,365                                        HTTR0920
  360 ALMTD#ALMTD                                                       HTTR0925
      GOTO370                                                           HTTR0930
  365 ALMTD#((STSAT2-STBI)-(STSAT1-TB2))/ALOG((STSAT2-STBI)/(STSAT1-TB2)HTTR0935
     1)                                                                 HTTR0940
  370 DTFILM # VNF * ALMTD * ROUT                                       HTTR0945
      STWOP # STSAT - DTFILM                                            HTTR0950
      IF((ABS(STWOP-STWO)/(STSAT-STWO))-0.005)385,375,375               HTTR0955
  375 STWO # STWOP                                                      HTTR0960
      STFO # STSAT - (STSAT - STWO)* 0.5                                HTTR0965
      KSTFO#KSTFO + 1                                                   HTTR0970
      IF (KSTFO - 20) 200, 380, 380                                     HTTR0975
  380 ASS # 2.0                                                         HTTR0980
      WRITE (6,8010)KSTFO, KK                                           HTTR0985
 8010 FORMAT(1H0, 8H KSTFO #, I3, 4H KK#, I3, 28H FILM TEMPS. NOT CONVERHTTR0990
     1GING.  )                                                          HTTR0995
      GO TO 450                                                         HTTR1000
  385 QCND#VNF*AO*ALMTD                                                 HTTR1005
      TB2P #QCND/(WB*CPFN(CBI,STBAVE))+STBI                             HTTR1010
      IF (K - 20) 395, 395, 390                                         HTTR1015
  390 ASS#1.0                                                           HTTR1020
      GO TO 450                                                         HTTR1025
  395 IF(ABS((TB2P  -STBI)/(TB2-STBI)-1.0)-.010)415,415,400             HTTR1030
  400 TB2 # TB2P + (TB2 - TB2P) * 0.15                                  HTTR1035
      IF (STSAT- TB2) 405, 405, 410                                     HTTR1040
  405 TB2 # STSAT- 0.5                                                  HTTR1045
  410 K # K +1                                                          HTTR1050
      STBAVE#(TB2+STBI)*0.5                                             HTTR1055
      STWI#STBAVE+VNF*ALMTD*RIN                                         HTTR1060
      GOTO120                                                           HTTR1065
  415 STBAVE#(TB2+STBI)/2.0                                             HTTR1070
      DELST#STSAT-STBAVE                                                HTTR1075
      TWIPM#STBAVE+(RIN+FOUL)/RTOT*DELST                                HTTR1080
      TFIPM#(STBAVE+TWIPM)/2.0                                          HTTR1085
      TWOPM#STSAT-ROUT/RTOT*DELST                                       HTTR1090
      TFOPM#(STSAT+TWOPM)/2.0                                           HTTR1095
      IF(ABS(TWIPM-STWI)-1.0)425,420,420                                HTTR1100
  420 STWI#TWIPM                                                        HTTR1105
  425 IF(ABS(TFOPM-STFO)-1.0)435,430,430                                HTTR1110
  430 STFO#TFOPM                                                        HTTR1115
      KK # KK + 1                                                       HTTR1120
      IF(KK-20) 120, 120, 380                                           HTTR1125
  435 CONTINUE                                                          HTTR1130
      CALL DVCHK (KOOUFX)                                               HTTR1135
       GO TO(440,445),KOOUFX                                            HTTR1140
  440 IDIV # 8061                                                       HTTR1145
      WRITE (6,8000)IDIV                                                HTTR1150
  445 CONTINUE                                                          HTTR1155
  450 RETURN                                                            HTTR1160
```

END HTTR1165

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$IBFTC PDRP     DECK                                                    PDRP0000
C       SUBROUTINE PRSDRP                                               PDRP0005
C** THIS PRSDRP CALLS FOR EXTENDED TABLE                                PDRP0010
        SUBROUTINE PRSDRP(TSAT,PSAT,PMIX,WS,WL,WNC,AXO,AMOLS,AMOLSC,    PDRP0015
       1NERR,DELPTP,WCND,TPOG,ALVF,LJ)                                  PDRP0020
        DIMENSION COOR(3)                                               PDRP0025
        COMMON  SDO     , STBI    , AI      , AO      , AW      , SHWINV PDRP0030
        COMMON  FOUL    , CBI     , SDI     , AXI     , WB      , HFG   PDRP0035
        COMMON  SDD     , STB2ES  , GB      , VG      , AMWNC   , STFO  PDRP0040
        COMMON  TB2     , STBAVE  , VNO     , J       , XNC     , SF    PDRP0045
        COMMON  COOR    , JRC     , VERT                                PDRP0050
C       DIMENSION COOR(3)                                               PDRP0055
C       COMMON SDO,STBI,AI,AO,AW,SHWINV,FOUL,CBI,SDI,AXI,WB,HFG,SDD,STB2ESPDRP0060
C      1,GB,VG, AMWNC,STFO,TB2, STBAVE, VNO, J, XNC                     PDRP0065
C       COMMON SF, COOR, JRC ,  VERT                                    PDRP0070
CCCCC                                                                   PDRP0075
C       CALCULATES STEAM PROPERTIESUS,VS, AT TSAT(I),PSAT(I)            PDRP0080
C       CALCULATE WATER PROPERTY VR AT TSAT(I)                          PDRP0085
        STSAT#TSAT - 459.69                                             PDRP0090
        SG#32.174                                                       PDRP0095
        IF (WNC ) 105, 105, 100                                         PDRP0100
  100   AMNC# AMWNC                                                     PDRP0105
        VNC#10.729*TSAT/((PMIX-PSAT)*AMNC)                              PDRP0110
        UNC#AMUFN(TSAT)                                                 PDRP0115
        VMIX#1.0/(((AMOLSC/(VNC*(AMOLSC+AMOLS)))+(AMOLS/(VG*(AMOLSC+AMOLS))PDRP0120
       1))                                                              PDRP0125
        GO TO 110                                                       PDRP0130
  105   VMIX # VG                                                       PDRP0135
  110   GSTAR#(WL+WS+WNC)/(AXO*3600.0)                                  PDRP0140
        ANRE#(SDO*GSTAR)/SMUFN(TSAT)                                    PDRP0145
        COOR(1) # ANRE                                                  PDRP0150
        IF(ANRE-2000.0)115,130,130                                      PDRP0155
  115   IF(ANRE-100.0) 120, 125, 125                                    PDRP0160
C  LAMINAR FLOW FRICTION FACTOR, SF                                     PDRP0165
  120   SF # 70.0*(1.0/SDD)**1.6/ANRE                                   PDRP0170
        GO TO 210                                                       PDRP0175
C  TRANSITION FLOW FRICTION FACTOR, SF                                  PDRP0180
  125   SF # (1.0/SDD)**2/ALOG10(ANRE - 81.0)                           PDRP0185
        GO TO 210                                                       PDRP0190
  130   COOR(1)#ANRE                                                    PDRP0195
  135   IF(COOR(1)-80000.0) 145, 145, 140                               PDRP0200
  140   COOR(1)#80000.0                                                 PDRP0205
        IF (VERT ) 155, 145, 155                                        PDRP0210
  145   IF (LJ - 4) 150, 150, 155                                       PDRP0215
  150   COOR (2)# 0.50 * SDD                                            PDRP0220
        COOR (3) # SDD * 1.732                                          PDRP0225
        GO TO 160                                                       PDRP0230
  155   COOR (2) # SDD * 0.866                                          PDRP0235
        COOR (3) # SDD                                                  PDRP0240
  160   IF(COOR(3)-1.15)170,165,165                                     PDRP0245
  165   IF(COOR(3)-3.5)180,180,175                                      PDRP0250
  170   COOR(3)#1.15                                                    PDRP0255
        GOTO180                                                         PDRP0260
  175   COOR(3)#3.5                                                     PDRP0265
  180   IF(COOR(2)-.7)190,185,185                                       PDRP0270
  185   IF(COOR(2)-1.2)200,200,195                                      PDRP0275
  190   COOR(2)#.7                                                      PDRP0280
        GOTO200                                                         PDRP0285
  195   COOR(2)#1.2                                                     PDRP0290
```

```
200 CALLINTPL2(COOR(1),SF,NERR,JRC)                                PDRP0295
205 IF(NERR)230,210,230                                            PDRP0300
210 ALVF#1.0/(VLFN(0.0,STSAT)/VMIX+(WS+WNC)/(WL+WCND))             PDRP0305
    IF (VERT) 215, 220, 215                                        PDRP0310
215 ALVFD # ALVF / ANRE **0.5                                      PDRP0315
    TPOG # TPDNFN (  ALVFD )                                       PDRP0320
    GO TO 225                                                      PDRP0325
220 TPOG#TPOGFN(ALVF)                                              PDRP0330
225 DELPFS#4.0*SF*GSTAR**2*VMIX/(2.0*SG*144.0)                     PDRP0335
    DELPTP#DELPFS*TPOG                                             PDRP0340
230 CONTINUE                                                       PDRP0345
    RETURN                                                         PDRP0350
    END                                                            PDRP0355
```

```
$IBFTC FC2      DECK
      FUNCTION PSATFN(T)
      PSATFN#2.718**(14.150119-(6452.5621/T)-(837533.21/T**2))
      RETURN
      END
$IBFTC FC3      DECK
      FUNCTION TSATFN(P)
      AA#(ALOG(P)-14.150119)
      DET#6452.5621**2-(4.0*AA*837533.21)
      IF(DET)1,2,2
    1 WRITE (6,3)
    3 FORMAT(1H1,37HSUBROUTINE TSATFN FINDS COMPLEX ROOTS)
      CALL EXIT
    2 X#(-6452.5621+SQRT(DET))/(2.0*AA)
      Y#(-6452.5621-SQRT(DET))/(2.0*AA)
      IF(X-Y)4,5,5
    4 TSATFN#Y
      GOTO6
    5 TSATFN#X
    6 CONTINUE
      RETURN
      END
$IBFTC FC4      DECK
      FUNCTION HFGFN(T)
      HFGFN#1093.88-0.5703*T+.00012819*T**2-.0000008824*T**3
      RETURN
      END
$IBFTC FC5      DECK
      FUNCTION CPSFN(T)
C*****EQUATION SPECIFIC HEAT FOR PURE WATER
      CPSFN# 1.0121559 +(-0.24618473E-3 + 0.10282155E-5*T)*T
      RETURN
      END
$IBFTC FC6      DECK
      FUNCTION SMUFN(T)
      SMUFN#1.0E-5*(0.122+(1.001E-3)*T+(2.892E-7)*T**2-(7.693E-11)*T**3)
      RETURN
      END
$IBFTC FC7      DECK
      FUNCTION VGFN(T,P)
       X#ALOG(T/P)
       VGFN#EXP(((.00103758*X-.0177861)*X+1.10267)*X-.72240)
      RETURN
      END
$IBFTC FC8      DECK
      FUNCTION SKSFN(T)
      X#T+459.69
      SKSFN#.01*(0.448+1.591E-3*X+1.421E-6*X**2-2.087E-10*X**3)
      RETURN
      END
$IBFTC FC9      DECK
      FUNCTION CPFN(C,T)
  100 IF(C-0.005)101,101,102
C*****EQUATION SPECIFIC HEAT FOR PURE WATER
  101 CP# 1.0121559 +(-0.24618473E-3 + 0.10282155E-5*T)*T
      GO TO 103
C*****EQUATION SPECIFIC HEAT FOR BRINE
  102 CP#.96946859+(2.*(0.00010404965)*T)-(.91199294*C)
     1+(2.*(-.00064829659)*C*T)+(-1.555779*(C**2))+
     2(2.*(.0076721469)*(C**2)*T)+(6.7981008*(C**3))+
     3(2.*(-.01261 0354)*(C**3)*T)
```

```
  103 CPFN#CP
      RETURN
      END
$IBFTC FC10     DECK
      FUNCTION VLFN(C,T)
      VLFN#1.0/(62.717753-.32152986E-2*T+.44315006E2*C-.11647394E-1*C*T-
     1.48932777E-4*T**2+.16449945E2*C**2+.13761984E-1*C**2*T+.34231326E-
     25*C*T**2-.92275301E-4*C**2*T**2)
      RETURN
      END
$IBFTC FC11     DECK
      FUNCTION SKBFN(C,T)
C             THERMAL CONDUCTIVITY OF SALINE SOLUTION.  RANGE OF DATA
C             0 - 24 PERCENT CONCENTRATION AND 40 - 300 DEGREES FARENHEIT
      SKBFN#(.30157913+.697989E-3*T-.12506E-5*T**2
     1-.2072E-10*T**3)*(-.1687109*C+1.)
      RETURN
      END
$IBFTC FC12     DECK
      FUNCTION BMUFN(C,T)
C     VISCOSITY OF SALINE SOLUTION.  RANGE OF DATA WAS 0 - 24 PERCENT
C     CONCENTRATION AND 40 - 210 DEGREES FARENHEIT.
      R#T+459.69
      BMUFN#EXP (-10.592566+.4606532E-2*R-11.591155*C
     1+.12602329E-1*C*R+4759.5941/R+3863.7378*C/R)
      RETURN
      END
$IBFTC FC13     DECK
      FUNCTION ROEFN(C,T)
C     DENSITY OF SALINE SOLUTION.  RANGE OF DATA WAS 0 - 26 PERCENT
C     CONCENTRATION AND 40 - 300 DEGREES FARENHEIT.
      ROEFN#62.707172+49.364088*C-.43955304E-2*T
     1-.32554667E-1*C*T-.46076921E-4*T**2+.63240299E-4
     2*T**2*C
      RETURN
      END
$IBFTC FC14     DECK
      FUNCTION TPOGFN(A)
      IF(A-0.15)1,1,2
    1 TPOGFN#1.0
      GOTO10
    2 X#ALOG(A)
      IF(A-2.0)3,3,4
    3 TPOGFN#EXP(-0.93213315-0.74256993*X- (0.13174182)*X**2)
      GOTO10
    4 TPOGFN#EXP( -0.85714256-0.94971689*X-(.15453488E-01)*X**2)
   10 CONTINUE
      RETURN
      END
$IBFTC FC15     DECK
      FUNCTION AMUFN(T)
      AMUFN#1.0E-5*(0.1490+(0.238E-2)*T-(.7209E-6)*T**2+(.1184E-9)*T**2)
      RETURN
      END
$IBFTC FC16     DECK
      FUNCTION CPAFN(T)
C AIR CP, BTU / LB MOLE-DEGREE RANKIN
      CPAFN#7.139-0.9884E-3*T +0.1393E-5*T**2 -0.3367E-9*T**3
      RETURN
      END
$IBFTC FC17     DECK
```

```
      FUNCTION AKAFN(T)
C AIR K, BTU / FT-HR-DEGREE RANKIN
      AKAFN#0.01*(-0.026+0.3266E-2*T -0.8271E-6*T**2 +0.1251E-9*T**3)
      RETURN
      END
$IBFTC FC25     DECK
      FUNCTION TPDNFN(A)
      IF (A - 0.001) 5, 5, 10
    5 TPDNFN # 1.0
      GO TO 25
   10 X # ALOG(A)
      IF ( A - 0.02) 15, 15, 20
   15 TPDNFN # EXP( -4.031725 + (0.5453815 + (0.3910848 +              0
     1.0229413 * X) *X) *X)
      GO TO 25
   20 TPDNFN # 0.0225 / A **1.02
   25 RETURN
      END
```

```
$IBFTC SUBI     DECK
C  INTPL2 UPDATE - 9/30/66  TABLE I EXPANSION - TABLE 3 OUT
      SUBROUTINE INTPL2(COOR,AVER,NERR,JRC)
       DIMENSION Z(10),X(10),Y(10),W(10,10,10),COOR(3),CORN(6)
C      DIMENSION Z(10),X(10),Y(10),W(10,10,10),COOR(3),CORN(6)
      IF (JRC) 100, 100, 300
  100 Z(1)#2000.0
      Z(2)#4000.0
      Z(3)#8000.0
      Z(4)#20000.0
      Z(5)#40000.0
      Z(6)#80000.0
      X(1)#0.7
      X(2)#0.8
      X(3)#0.9
      X(4)#1.0
      X(5)#1.2
      Y(1)#1.15
      Y(2)#1.20
      Y(3)#1.25
      Y(4)#1.40
      Y(5)#1.60
      Y(6)#2.0
      Y(7)#2.5
      Y(8)#3.0
      Y(9)#3.5
      W(1,1,1)#.370
      W(1,1,2)#.250
      W(1,1,3)#.205
      W(1,1,4)#.150
      W(1,1,5)#.128
      W(1,1,6)#.114
      W(1,1,7)#.098
      W(1,1,8)#.083
      W(1,1,9)#.065
      W(1,2,1)#.360
      W(1,2,2)#.250
      W(1,2,3)#.205
      W(1,2,4)#.154
      W(1,2,5)#.133
      W(1,2,6)#.118
      W(1,2,7)#.102
      W(1,2,8)#.088
      W(1,2,9)#.072
      W(1,3,1)#.321
      W(1,3,2)#.245
      W(1,3,3)#.200
      W(1,3,4)#.155
      W(1,3,5)#.136
      W(1,3,6)#.124
      W(1,3,7)#.107
      W(1,3,8)#.091
      W(1,3,9)#.075
      W(1,4,1)#.320
      W(1,4,2)#.240
      W(1,4,3)#.200
      W(1,4,4)#.157
      W(1,4,5)#.142
      W(1,4,6)#.135
      W(1,4,7)#.122
      W(1,4,8)#.100
```

```
W(1,4,9)#.084                                                    IN0610
W(1,5,1)#.325                                                    IN0620
W(1,5,2)#.240                                                    IN0630
W(1,5,3)#.200                                                    IN0640
W(1,5,4)#.156                                                    IN0650
W(1,5,5)#.140                                                    IN0660
W(1,5,6)#.130                                                    IN0670
W(1,5,7)#.122                                                    IN0680
W(1,5,8)#.112                                                    IN0690
W(1,5,9)#.100                                                    IN0700
W(2,1,1)#.305                                                    IN0710
W(2,1,2)#.232                                                    IN0720
W(2,1,3)#.180                                                    IN0730
W(2,1,4)#.138                                                    IN0740
W(2,1,5)#.120                                                    IN0750
W(2,1,6)#.108                                                    IN0760
W(2,1,7)#.093                                                    IN0770
W(2,1,8)#.0785                                                   IN0780
W(2,1,9)#.062                                                    IN0790
W(2,2,1)#.295                                                    IN0800
W(2,2,2)#.215                                                    IN0810
W(2,2,3)#.179                                                    IN0820
W(2,2,4)#.137                                                    IN0830
W(2,2,5)#.121                                                    IN0840
W(2,2,6)#.108                                                    IN0850
W(2,2,7)#.094                                                    IN0860
W(2,2,8)#.081                                                    IN0870
W(2,2,9)#.0665                                                   IN0880
W(2,3,1)#.280                                                    IN0890
W(2,3,2)#.211                                                    IN0900
W(2,3,3)#.178                                                    IN0910
W(2,3,4)#.136                                                    IN0920
W(2,3,5)#.121                                                    IN0930
W(2,3,6)#.110                                                    IN0940
W(2,3,7)#.096                                                    IN0950
W(2,3,8)#.083                                                    IN0960
W(2,3,9)#.069                                                    IN0970
W(2,4,1)#.262                                                    IN0980
W(2,4,2)#.200                                                    IN0990
W(2,4,3)#.170                                                    IN1000
W(2,4,4)#.136                                                    IN1010
W(2,4,5)#.123                                                    IN1020
W(2,4,6)#.116                                                    IN1030
W(2,4,7)#.105                                                    IN1040
W(2,4,8)#.090                                                    IN1050
W(2,4,9)#.076                                                    IN1060
W(2,5,1)#.283                                                    IN1070
W(2,5,2)#.211                                                    IN1080
W(2,5,3)#.178                                                    IN1090
W(2,5,4)#.140                                                    IN1100
W(2,5,5)#.126                                                    IN1110
W(2,5,6)#.116                                                    IN1120
W(2,5,7)#.109                                                    IN1130
W(2,5,8)#.100                                                    IN1140
W(2,5,9)#.0915                                                   IN1150
W(3,1,1)#.250                                                    IN1160
W(3,1,2)#.135                                                    IN1170
W(3,1,3)#.158                                                    IN1180
W(3,1,4)#.125                                                    IN1190
W(3,1,5)#.111                                                    IN1200
W(3,1,6)#.100                                                    IN1210
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w(3,1,7)#.088                                                    IN1220
w(3,1,8)#.073                                                    IN1230
w(3,1,9)#.0385                                                   IN1240
w(3,2,1)#.245                                                    IN1250
w(3,2,2)#.183                                                    IN1260
w(3,2,3)#.155                                                    IN1270
w(3,2,4)#.122                                                    IN1280
w(3,2,5)#.109                                                    IN1290
w(3,2,6)#.0985                                                   IN1300
w(3,2,7)#.086                                                    IN1310
w(3,2,8)#.074                                                    IN1320
w(3,2,9)#.060                                                    IN1330
w(3,3,1)#.242                                                    IN1340
w(3,3,2)#.182                                                    IN1350
w(3,3,3)#.155                                                    IN1360
w(3,3,4)#.119                                                    IN1370
w(3,3,5)#.107                                                    IN1380
w(3,3,6)#.098                                                    IN1390
w(3,3,7)#.086                                                    IN1400
w(3,3,8)#.074                                                    IN1410
w(3,3,9)#.062                                                    IN1420
w(3,4,1)#.214                                                    IN1430
w(3,4,2)#.166                                                    IN1440
w(3,4,3)#.142                                                    IN1450
w(3,4,4)#.117                                                    IN1460
w(3,4,5)#.105                                                    IN1470
w(3,4,6)#.100                                                    IN1480
w(3,4,7)#.092                                                    IN1490
W(3,4,8)#.080                                                    IN1500
w(3,4,9)#.068                                                    IN1510
W(3,5,1)#.240                                                    IN1520
w(3,5,2)#.181                                                    IN1530
W(3,5,3)#.155                                                    IN1540
W(3,5,4)#.124                                                    IN1550
W(3,5,5)#.111                                                    IN1560
w(3,5,6)#.102                                                    IN1570
W(3,5,7)#.096                                                    IN1580
w(3,5,8)#.089                                                    IN1590
W(3,5,9)#.081                                                    IN1600
W(4,1,1)#.188                                                    IN1610
W(4,1,2)#.146                                                    IN1620
W(4,1,3)#.128                                                    IN1630
W(4,1,4)#.106                                                    IN1640
w(4,1,5)#.098                                                    IN1650
w(4,1,6)#.089                                                    IN1660
W(4,1,7)#.078                                                    IN1670
w(4,1,8)#.065                                                    IN1680
W(4,1,9)#.051                                                    IN1690
W(4,2,1)#.185                                                    IN1700
w(4,2,2)#.145                                                    IN1710
w(4,2,3)#.125                                                    IN1720
w(4,2,4)#.102                                                    IN1730
w(4,2,5)#.093                                                    IN1740
w(4,2,6)#.085                                                    IN1750
w(4,2,7)#.0725                                                   IN1760
W(4,2,8)#.063                                                    IN1770
w(4,2,9)#.051                                                    IN1780
W(4,3,1)#.195                                                    IN1790
w(4,3,2)#.146                                                    IN1800
w(4,3,3)#.125                                                    IN1810
W(4,3,4)#.097                                                    IN1820
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W(4,3,5)#.087                                                    IN1830
W(4,3,6)#.080                                                    IN1840
W(4,3,7)#.071                                                    IN1850
W(4,3,8)#.062                                                    IN1860
W(4,3,9)#.052                                                    IN1870
W(4,4,1)#.157                                                    IN1880
W(4,4,2)#.126                                                    IN1890
W(4,4,3)#.110                                                    IN1900
W(4,4,4)#.092                                                    IN1910
W(4,4,5)#.083                                                    IN1920
W(4,4,6)#.079                                                    IN1930
W(4,4,7)#.0725                                                   IN1940
W(4,4,8)#.065                                                    IN1950
W(4,4,9)#.057                                                    IN1960
W(4,5,1)#.186                                                    IN1970
W(4,5,2)#.140                                                    IN1980
W(4,5,3)#.120                                                    IN1990
W(4,5,4)#.098                                                    IN2000
W(4,5,5)#.089                                                    IN2010
W(4,5,6)#.082                                                    IN2020
W(4,5,7)#.077                                                    IN2030
W(4,5,8)#.072                                                    IN2040
W(4,5,9)#.066                                                    IN2050
W(5,1,1)#.150                                                    IN2060
W(5,1,2)#.120                                                    IN2070
W(5,1,3)#.106                                                    IN2080
W(5,1,4)#.090                                                    IN2090
W(5,1,5)#.085                                                    IN2100
W(5,1,6)#.079                                                    IN2110
W(5,1,7)#.069                                                    IN2120
W(5,1,8)#.057                                                    IN2130
W(5,1,9)#.047                                                    IN2140
W(5,2,1)#.145                                                    IN2150
W(5,2,2)#.116                                                    IN2160
W(5,2,3)#.103                                                    IN2170
W(5,2,4)#.086                                                    IN2180
W(5,2,5)#.080                                                    IN2190
W(5,2,6)#.073                                                    IN2200
W(5,2,7)#.062                                                    IN2210
W(5,2,8)#.057                                                    IN2220
W(5,2,9)#.0433                                                   IN2230
W(5,3,1)#.157                                                    IN2240
W(5,3,2)#.120                                                    IN2250
W(5,3,3)#.102                                                    IN2260
W(5,3,4)#.080                                                    IN2270
W(5,3,5)#.072                                                    IN2280
W(5,3,6)#.066                                                    IN2290
W(5,3,7)#.059                                                    IN2300
W(5,3,8)#.0515                                                   IN2310
W(5,3,9)#.043                                                    IN2320
W(5,4,1)#.120                                                    IN2330
W(5,4,2)#.098                                                    IN2340
W(5,4,3)#.087                                                    IN2350
W(5,4,4)#.073                                                    IN2360
W(5,4,5)#.067                                                    IN2370
W(5,4,6)#.063                                                    IN2380
W(5,4,7)#.058                                                    IN2390
W(5,4,8)#.0535                                                   IN2400
W(5,4,9)#.0485                                                   IN2410
W(5,5,1)#.132                                                    IN2420
W(5,5,2)#.105                                                    IN2430
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      W(5,5,3)#.092                                                     IN2440
      W(5,5,4)#.076                                                     IN2450
      W(5,5,5)#.070                                                     IN2460
      W(5,5,6)#.066                                                     IN2470
      W(5,5,7)#.062                                                     IN2480
      W(5,5,8)#.058                                                     IN2490
      W(5,5,9)#.0535                                                    IN2500
      W(6,1,1)#.111                                                     IN2510
      W(6,1,2)#.093                                                     IN2520
      W(6,1,3)#.083                                                     IN2530
      W(6,1,4)#.074                                                     IN2540
      W(6,1,5)#.070                                                     IN2550
      W(6,1,6)#.066                                                     IN2560
      W(6,1,7)#.0575                                                    IN2570
      W(6,1,8)#.047                                                     IN2580
      W(6,1,9)#.034                                                     IN2590
      W(6,2,1)#.110                                                     IN2600
      W(6,2,2)#.0905                                                    IN2610
      W(6,2,3)#.082                                                     IN2620
      W(6,2,4)#.070                                                     IN2630
      W(6,2,5)#.066                                                     IN2640
      W(6,2,6)#.060                                                     IN2650
      W(6,2,7)#.050                                                     IN2660
      W(6,2,8)#.046                                                     IN2670
      W(6,2,9)#.0345                                                    IN2680
      W(6,3,1)#.121                                                     IN2690
      W(6,3,2)#.094                                                     IN2700
      W(6,3,3)#.078                                                     IN2710
      W(6,3,4)#.063                                                     IN2720
      W(6,3,5)#.056                                                     IN2730
      W(6,3,6)#.051                                                     IN2740
      W(6,3,7)#.046                                                     IN2750
      W(6,3,8)#.0393                                                    IN2760
      W(6,3,9)#.033                                                     IN2770
      W(6,4,1)#.088                                                     IN2780
      W(6,4,2)#.072                                                     IN2790
      W(6,4,3)#.065                                                     IN2800
      W(6,4,4)#.054                                                     IN2810
      W(6,4,5)#.0505                                                    IN2820
      W(6,4,6)#.0475                                                    IN2830
      W(6,4,7)#.044                                                     IN2840
      W(6,4,8)#.041                                                     IN2850
      W(6,4,9)#.039                                                     IN2860
      W(6,5,1)#.083                                                     IN2870
      W(6,5,2)#.069                                                     IN2880
      W(6,5,3)#.061                                                     IN2890
      W(6,5,4)#.0525                                                    IN2900
      W(6,5,5)#.050                                                     IN2910
      W(6,5,6)#.0480                                                    IN2920
      W(6,5,7)#.045                                                     IN2930
      W(6,5,8)#.043                                                     IN2940
      W(6,5,9)#.040                                                     IN2950
      NZ#6                                                              IN2960
      NX#5                                                              IN2970
      NY#9                                                              IN2980
      JRC # 1                                                           IN2990
30    NERR#0                                                            IN3000
      ZPT#COOR(1)                                                       IN3010
      XPT # COOR(2)                                                     IN3020
      YPT#COOR(3)                                                       IN3030
      IF(ZPT-Z(1))21,30,30                                              IN3040
```

```
   30 IF(XPT-X(I))21,31,31                                              IN3050
   31 IF(YPT-Y(I))21,32,32                                              IN3060
   32 DO 1 I#2,NZ                                                       IN3070
      IF (ZPT-Z(I))2,2,1                                                IN3080
    2 CORN(1)#Z(I-1)                                                    IN3090
      CORN(2)#Z(I)                                                      IN3100
      IND1#I-1                                                          IN3110
      IND2#I                                                            IN3120
      GO TO 3                                                           IN3130
    1 CONTINUE                                                          IN3140
    3 DO 4 I#2,NX                                                       IN3150
      IF (XPT-X(I))5,5,4                                                IN3160
    5 CORN(3)#X(I-1)                                                    IN3170
      CORN(4)#X(I)                                                      IN3180
      IND3#I-1                                                          IN3190
      IND4 #I                                                           IN3200
      GO TO 6                                                           IN3210
    4 CONTINUE                                                          IN3220
    6 DO 7 I#2,NY                                                       IN3230
      IF (YPT-Y(I))8,8,7                                                IN3240
    8 CORN(5)#Y(I-1)                                                    IN3250
      CORN(6)#Y(I)                                                      IN3260
      IND5 #I-1                                                         IN3270
      IND6#I                                                            IN3280
      GO TO 9                                                           IN3290
    7 CONTINUE                                                          IN3300
    9 SLOPE#(CORN(6)-CORN(5))/(CORN(4)-CORN(3))                         IN3310
C     DETERMINE HALF OF CUBE TO ELIMINATE                               IN3320
      COOR(1)#ZPT                                                       IN3330
      COOR(2)#XPT                                                       IN3340
      COOR(3)#YPT                                                       IN3350
      IF(YPT-(CORN(6)+SLOPE*(XPT-CORN(4))))10,10,12                     IN3360
C     ELIMINATE UPPER HALF                                              IN3370
   10 JJ#0                                                              IN3380
      CALL APPROX(CORN(1),IND1,IND2,IND3,IND4,IND5,IND6,AVER,JJ,COOR(1), IN3390
     1Z(1),X(1),Y(1),W(1,1,1),NZ,NX,NY)                                 IN3400
      GO TO 22                                                          IN3410
C     ELIMINATE LOWER HALF                                              IN3420
   12 JJ#1                                                              IN3430
      CALL APPROX(CORN(1),IND1,IND2,IND3,IND4,IND5,IND6,AVER,JJ,COOR(1), IN3440
     1Z(1),X(1),Y(1),W(1,1,1),NZ,NX,NY)                                 IN3450
      GO TO 22                                                          IN3460
   21 NERR#1                                                            IN3470
   22 RETURN                                                            IN3480
      END                                                               IN3490
```

```
$IBFTC SUB2     DECK
      SUBROUTINE APPROX(C,IND1,IND2,IND3,IND4,IND5,IND6,AVER,JJ,COOR,Z,X
     1,Y,W,NZ,NX,NY)
      DIMENSION A(4,4),C(6),W(10,10,10),F(4),VAL(6),COOR(3)
      DIMENSION Z(10),X(10),Y(10)
C     SET UP FIRST BASE
      K#0
      KK#0
      IVAL#1
   10 DO 1 I#1,3
      A(I,1)#C(2)
      A(I,2)#C(4)
      A(I,3)#C(5)
    1 A(I,4)#1.0
      IF (KK)7,7,8
    8 DO 9 I#1,3
    9 A(I,1)#TEMP
    7 A(1,2)#C(3)
       A(3,3)#C(6)
      A(4,4)#1.0
       F(1)#W(IND2,IND3,IND5)
      F(2)#W(IND2,IND4,IND5)
      F(3)#W(IND2,IND4,IND6)
      IF (JJ) 30,30,31
   31 A(2,2)#C(3)
      A(2,3)#C(6)
      F(2)#W(IND2,IND3,IND6)
C      SET UP FIRST TETRAHEDRON
   30 A(4,1)#C(1)
      IF(K)4,3,6
    3 A(4,2)#C(3)
      A(4,3)#C(5)
      F(4)#W(IND1,IND3,IND5)
      CALL AMATQ2(A(1,1),F(1),D,4,1)
      VAL(IVAL)#EVAL(COOR(1),F(1))
      IVAL #IVAL+1
      K#-1
      GO TO 10
C     SET UP SECOND TETRADRON
    4 A(4,2)#C(4)
      A(4,3)#C(5)
      F(4)#W(IND1,IND4,IND5)
      IF (JJ) 40,40,41
   41 A(4,2)#C(3)
      A(4,3)#C(6)
      F(4)#W(IND1,IND3,IND6)
   40 CALL AMATQ2(A(1,1),F(1),D,4,1)
      VAL(IVAL)#EVAL(COOR(1),F(1))
      IVAL#IVAL+1
      K#1
      GO TO 10
C     SET UP THIRD TETRADRON
    6 A(4,2)#C(4)
      A(4,3)#C(6)
      F(4)#W(IND1,IND4,IND6)
      CALL AMATQ2(A(1,1),F(1),D,4,1)
      VAL(IVAL)#EVAL(COOR(1),F(1))
      IVAL#IVAL+1
      IF (KK)11,11,15
   11 KK#1
      K#0
```

```
      TEMP#IND1
      IND1#IND2
      IND2#TEMP
      TEMP#C(1)
      C(1)#C(2)
      GO TO 15
   15 K#0
      DO 50 J#1,6
      JM1#J-1
      DO 50 I#JM1,6
      IF(I-J)51,50,51
   51 IF(ABS((VAL(J)-VAL(I))/VAL(J))-1.E-03)52,52,50
   52 K#K+1
      IF(K-3)50,53,53
   53 AVER#VAL(J)
      GO TO 100
   50 CONTINUE
      AVER#0.0
      DO 20 I#1,6
   20 AVER#AVER+VAL(I)
      AVER#AVER/6.0
  100 RETURN
      END
$IBFTC SUB3     DECK
      SUBROUTINE AMATQ2(A,B,D,III,JJJ)
      DIMENSION A(4,4),B(4,1)
      KK#III
      NV#JJJ
      KKM#KK-1
      D#1.0
      DO20I#1,KKM
      S#0.0
      DO2J#I,KK
      R#ABS(A(J,I))
      IF(R-S)2,1,1
    1 S#R
      L#J
    2 CONTINUE
      IF(L-I)3,8,3
    3 DO4J#I,KK
      S#A(I,J)
      A(I,J)#A(L,J)
    4 A(L,J)#S
      IF(NV)7,7,5
    5 DO6J#1,NV
      S#B(I,J)
      B(I,J)#B(L,J)
    6 B(L,J)#S
    7 D#-D
    8 IF(A(I,I))9,20,9
    9 IPO#I+1
      DO14J#IPO,KK
      IF(A(J,I))10,14,10
   10 S#A(J,I)/A(I,I)
      A(J,I)#0.0
      DO11K#IPO,KK
   11 A(J,K)#A(J,K)-A(I,K)*S
      IF(NV)14,14,12
   12 DO13K#1,NV
   13 B(J,K)#B(J,K)-B(I,K)*S
   14 CONTINUE
```

```
   20 CONTINUE                                                          400
      DO15I#1,KK                                                        410
   15 D#D*A(I,I)                                                        420
      IF(NV)19,19,16                                                    430
   16 KMO#KK-1                                                          440
      DO18K#1,NV                                                        450
      B(KK,K)#B(KK,K)/A(KK,KK)                                          460
      DO18I#1,KMO                                                       470
      N#KK-I                                                            480
      DO17J#N,KMO                                                       490
   17 B(N,K)#B(N,K)-A(N,J+1)*B(J+1,K)                                   0500
   18 B(N,K)#B(N,K)/A(N,N)                                              510
   19 RETURN                                                            520
       END                                                              530
$IBFTC FCT      DECK
      FUNCTION EVAL(COOR,F)                                              10
      DIMENSION F(4),COOR(3)                                             20
       EVAL#0.0                                                          40
      DO 1 I#1,3                                                         50
    1 EVAL#EVAL + F(I) * COOR(I)                                         60
      EVAL # EVAL + F(4)                                                 70
C     WRITE OUTPUT TAPE 6,400,EVAL,(F(I),I#1,4)                         080
  400 FORMAT(1H0,4HEVAL,5(E16.8,5X))                                     90
      RETURN                                                            100
      END                                                               110
```

APPENDIX E

CIRCULAR CONDENSER CODE

```
$IBFTC CIRC     DECK
C  CIRCND 12 SECTOR CIRCULAR CONDENSER
      DIMENSION IDENT(13),DELP(6),WP(6),WGAS(6),AMOLS(100,6),AMLSSC(100)
      DIMENSION  PMIX (100,6),  PSAT (100,6),  TSAT (100,6),
     1 STSAT (100,6) , VEL (100,6),  WS (100, 6) ,  ALMTD (100,6),
     2 WL(100,6),  WCND (100, 6),  UN (100, 6),
     3 SHI (100, 6),  SHN (100, 6), ANF(100,6),RC(100,6),C(6),
     4 DELPTP (100, 6),  QTS (100, 6)
      DIMENSION   VELC (100),   PMIXC (100),  PSATC (100), TSATC (100),
     1 STSATC (100),  WSC (100),  ANFC (100),  ALMTDC (100),
     2 WLC (100),   WCNDC (100),  UNC (100),  WSP (100),  DELTPC (100),
     3SHIC (100),  SHNFC (100),  RCC (100),  QTCS (100)
      DIMENSION RADIUS(100),TBNPR(100),AOTFLW(100)
      DIMENSION COOR (3)
      DIMENSION C1(6), C2(6)
      COMMON  SDO     , STBI    , AI      , AO      , AW      , SHWINV
      COMMON  FOUL    , CBI     , SDI     , AXI     , WB      , HFG
      COMMON  SDD     , STB2ES  , GB      , VG      , AMWNC   , STFO
      COMMON  TB2     , STBAVE  , VNO     , J       , XNC     , SF
      COMMON  COOR    , JRC
  100 READ  (5,8000)IDENT
 8000 FORMAT(13A6)
      READ  (5,8005)OUTPUT
 8005 FORMAT(2F5.2)
      READ(5,8010)   ANT, PRCCLR,  BHOBW,   ALST,   SDD,
     1             SDDMIN,     OD,     XW,    SKW,  FOUL,
     2                WSI,   WNCI,  VELBI, STSATI,  STBI,
     3                CBI, EXITFR
 8010 FORMAT(8F10.2)
      WRITE(6,8015)
 8015 FORMAT(1H1,47X,    29HCIRCULAR CONDENSER INPUT DATA )
  105 WRITE(6,8020) IDENT
 8020 FORMAT(1H0, 35HCASE IDENTIFICATION AND NOTES ****  , 13A6 )
      WRITE(6,8025)
 8025 FORMAT(1H0, 22HGEOMETRY SPECIFICATION ,9X, 20HTUBING SPECIFICATION
     1 ,25X, 33HFLOW AND PROPERTIES SPECIFICATION )
      WRITE(6,8030) ANT, OD, WSI, PRCCLR, XW, WNCI, BHOBW, SKW, VELBI,
     1 ALST, FOUL, STSATI, SDD, STBI, SDDMIN, CBI, EXITFR
 8030 FORMAT(1H0, 14H  NO. OF TUBES,9X,F8.2,4X, 21HOUTSIDE DIAM., INCHES
     1,13X, F6.4,5X, 19HSTEAM FLOW, LBS/HR., 13X, F8.1/1X22H  PCT. TUBES
     2 IN COOLER ,3X, F6.2,4X, 22HWALL THICKNESS, INCHES ,12X,F6.4,5X, 2
     39HNON-CONDENSIBLE FLOW, LBS/HR. ,5X, F6.1/1X24H  BUNDLE HGT/WIDTH
     4RATIO ,   3X, F4.2,4X, 32HWALL COND.,BTU/HR/SQ.FT/DEG.F.   ,F8.4,
     55X, 25HCOOLANT VELOCITY, FT/SEC. ,11X, F4.1/1X17H  LENGTH OF TUBES
     6 ,8X, F6.2,4X, 14HFOULING FACTOR ,20X, F6.4,5X, 20HSTEAM TEMP., DEC
     7G. F. ,15X, F5.1/1X16H  S/D, CONDENSER ,11X, F4.2, 49X, 22HCOOLANT
     8 TEMP., DEG. F. ,13X, F6.2/1X13H  S/D, COOLER ,14X,F4.2,49X,34HWT.
     9 FRAC. OF NACL IN COOLANT        ,3X, F6.4 /81X, 35HEXIT STEAM FRAC
     1TION, PCT. OF INPUT  , F6.2  )
      AMWNC # 28.965
      PI # 3.1416
      SDO#OD/12.0
C          COMPUTE BUNDLE GEOMETRY
C     CONDENSER SECTION
      TNO#ANT*(1.0-PRCCLR/100.0)
      NOROWS#((TNO*1.1035)**0.5/2.0)*1.02
      BNDRAD#FLOAT(NOROWS)*SDD*SDO
C  CALCULATE TUBE SHEET AREA, ARTS
      ARTS # PI * (BNDRAD + SDD*SDO/2.0)**2
```

```
C  CALC. TUBE DENSITY, TUBDEN                                          CIRC0295
      TUBDEN # TNO / ARTS                                              CIRC0300
C  CALC. FOR EACH ROW(I), RADIUS AND  NO. OF TUBES                     CIRC0305
      RADIUS(I)#BNDRAD                                                 CIRC0310
      GMFCTR # 2.0*PI/(SDD*SDO*12.0)                                   CIRC0315
      RADSQ # BNDRAD**2                                                CIRC0320
      SPFCTR # 1.732*SDD*SDO                                           CIRC0325
      SUMTUB # 0.0                                                     CIRC0330
      DO 125 I#1,NOROWS                                                CIRC0335
      TBNPR(I)#RADIUS(I)*GMFCTR                                        CIRC0340
C  ESTIMATE NO. TUBES ABOVE ROW(I) FOR THE 6 SECTOR GEOM. CONCEPT      CIRC0345
      ALN1#0.96593*RADIUS(I)                                           CIRC0350
      ALN5#0.25882*RADIUS(I)                                           CIRC0355
      ALN2#(RADSQ-ALN5**2)**0.5                                        CIRC0360
      ANF(I,1)#(ALN2-ALN1)/SPFCTR                                      CIRC0365
      ANF(I,6)#(ALN2+ALN1)/SPFCTR                                      CIRC0370
      ALN3#0.70711*RADIUS(I)                                           CIRC0375
      ALN4#(RADSQ-ALN3**2)**0.5                                        CIRC0380
      ANF(I,2)#(ALN4-ALN3)/SPFCTR                                      CIRC0385
      ANF(I,5)#(ALN4+ALN3)/SPFCTR                                      CIRC0390
      ALN6#(RADSQ-ALN1**2)**0.5                                        CIRC0395
      ANF(I,3)#(ALN6-ALN5)/SPFCTR                                      CIRC0400
      ANF(I,4)#(ALN6+ALN5)/SPFCTR                                      CIRC0405
      DO 115 JJ#1,6                                                    CIRC0410
      IF(ANF(I,JJ)-1.0) 110, 110, 115                                  CIRC0415
  110 ANF(I,JJ) # 1.0                                                  CIRC0420
  115 CONTINUE                                                         CIRC0425
      SUMTUB # TBNPR (I) *12.0 + SUMTUB                                CIRC0430
      IF (SUMTUB - TNO) 125, 120, 120                                  CIRC0435
  120 IHNO # I - 1                                                     CIRC0440
      SUMTUB # SUMTUB - TBNPR (I) * 12.0                               CIRC0445
      TNOC # ANT - SUMTUB                                              CIRC0450
      RADINS # RADIUS (I - 1) - SDD * SDO / 2.0                        CIRC0455
      GO TO 130                                                        CIRC0460
  125 RADIUS (I + 1) # RADIUS (I) - 0.866 * SDD * SDO                  CIRC0465
  130 CONTINUE                                                         CIRC0470
CCCCCC                                                                 CIRC0475
C     INITIALIZATION                                                   CIRC0480
CCCCCC                                                                 CIRC0485
      JRC # 0                                                          CIRC0490
      ILNG # 0                                                         CIRC0495
      ALMIN # 0.0                                                      CIRC0500
  135 CONTINUE                                                         CIRC0505
      ALS1 # ALST                                                      CIRC0510
      C2(1) # 0.0                                                      CIRC0515
      DO 145 I#1,100                                                   CIRC0520
      DO 140 J#1,6                                                     CIRC0525
      PMIX  (I,J)#0.0                                                  CIRC0530
      PSAT  (I,J)#0.0                                                  CIRC0535
      STSAT (I,J)#0.0                                                  CIRC0540
      VEL   (I,J)#0.0                                                  CIRC0545
      UN    (I,J)#0.0                                                  CIRC0550
      WCND  (I,J)#0.0                                                  CIRC0555
      WS    (I,J)#0.0                                                  CIRC0560
      ALMTD (I,J)#0.0                                                  CIRC0565
      SHI   (I,J)#0.0                                                  CIRC0570
      SHN   (I,J)#0.0                                                  CIRC0575
  140 RC    (I,J)#0.0                                                  CIRC0580
      AOTFLW(I)#0.0                                                    CIRC0585
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      PMIXC (I)#0.0                                                     CIRC0590
      PSATC (I)#0.0                                                     CIRC0595
      STSATC(I)#0.0                                                     CIRC0600
      VELC  (I)#0.0                                                     CIRC0605
      UNC   (I)#0.0                                                     CIRC0610
      WCNDC (I)#0.0                                                     CIRC0615
      WSC   (I)#0.0                                                     CIRC0620
      ALMTDC(I)#0.0                                                     CIRC0625
      SHIC  (I)#0.0                                                     CIRC0630
      SHNFC (I)#0.0                                                     CIRC0635
  145 RCC   (I)#0.0                                                     CIRC0640
      SG#32.174                                                         CIRC0645
      VLCMAX#150.0                                                      CIRC0650
      SDI#(OD-2.0*XW)/12.0                                              CIRC0655
      TSATI#STSATI+459.69                                               CIRC0660
      PSATI#PSATFN(TSATI)                                               CIRC0665
      AMOLSS#WSI/18.016                                                 CIRC0670
      AMOLNC#WNCI/AMWNC                                                 CIRC0675
      AMOLST#AMOLSS+AMOLNC                                              CIRC0680
      PMIXI#PSATI*(AMOLST/AMOLSS)                                       CIRC0685
      VGI#VGFN(TSATI,PMIXI)                                             CIRC0690
      AXI#(PI*SDI**2)/4.0                                               CIRC0695
      WBI # 3600.0* ANT * AXI * ROEFN ( CBI, STBI) * VELBI              CIRC0700
      WB#WBI/ANT                                                        CIRC0705
      AI#PI*SDI*ALST                                                    CIRC0710
      AO#PI*SDO*ALST                                                    CIRC0715
      SDW#(SDO-SDI)/ALOG(SDO/SDI)                                       CIRC0720
      AW#PI*SDW*ALST                                                    CIRC0725
      SHWINV#(AO*XW)/(12.0*SKW*AW)                                      CIRC0730
      GB#WB/(3600.0*AXI)                                                CIRC0735
      HFG#HFGFN(STSATI)                                                 CIRC0740
      CPB#CPFN(CBI,STBI)                                                CIRC0745
      STB2ES#(WSI*HFG)/(     WBI*CPB)+STBI                              CIRC0750
      SVNCI#10.729*TSATI/(AMWNC  *PMIXI        )                        CIRC0755
      SVMIXI # 1.0/  (AMOLSS / (AMOLST * VGI) + AMOLNC/                 CIRC0760
     1 (SVNCI * AMOLST))                                                CIRC0765
C  CALC. BUNDLE FACE AREA                                               CIRC0770
      BNDFAR # 2.0*PI*(BNDRAD + SDO/2.0)*ALST                           CIRC0775
C  CALC. FOR EACH ROW(I), THE AREA OPEN TO FLOW                         CIRC0780
      PATHAR # (SDD-1.0)*SDO*ALST                                       CIRC0785
      DO 150 I#1,NOROWS                                                 CIRC0790
  150 AOTFLW(I) # PATHAR * TBNPR(I)                                     CIRC0795
      VEL1#((WSI+WNCI)*SVMIXI)/(3600.0*BNDFAR)                          CIRC0800
      G2#288.0*SG*SVMIXI                                                CIRC0805
      BNDIAM # 2.0*(BNDRAD + SDD*SDO/2.0)                               CIRC0810
C     COOLER SECTION                                                    CIRC0815
      HTCLR # 2.0*BNDIAM/3.0                                            CIRC0820
      VNOC#(HTCLR-SDO)/( SDDMIN *SDO)                                   CIRC0825
      IHNOC#TNOC/VNOC                                                   CIRC0830
      HNOC#FLOAT(IHNOC)                                                 CIRC0835
      VNOC#TNOC/HNOC                                                    CIRC0840
      IVNOC#VNOC + .5                                                   CIRC0845
      VNOC#FLOAT(IVNOC)                                                 CIRC0850
      PCTCLR#VNOC*HNOC/ANT*100.0                                        CIRC0855
      AENT #12.0 * AOTFLW(I)                                            CIRC0860
      IF(AENT-BNDFAR)  160,  160,  155                                  CIRC0865
  155 ARATIO#BNDFAR/AENT                                                CIRC0870
      DELPI2# (1.0-ARATIO)*VEL1**2/G2                                   CIRC0875
      VEL2#ARATIO*VEL1                                                  CIRC0880
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      GO TO 175                                                         CIRC0885
  160 ARATIO#AENT/BNDFAR                                                CIRC0890
      VEL2#VEL1/ARATIO                                                  CIRC0895
      IF(ARATIO-0.715)  165,  165,  170                                 CIRC0900
  165 DELP12#0.4*(1.25-ARATIO)*VEL2**2/G2                               CIRC0905
      GO TO 175                                                         CIRC0910
  170 DELP12#0.75*(1.0-ARATIO)*VEL2**2/G2                               CIRC0915
  175 DELP23#(VEL2**2-VEL1**2)/G2                                       CIRC0920
      A#1.15                                                            CIRC0925
      DO 180 J#1,6                                                      CIRC0930
      WGAS (J) # WNCI / 12.0                                            CHRC0935
      WS (I,J) # WSI / 12.0                                             CIRC0940
      WGAS(J)# A*WGAS(J)                                                CIRC0945
      WS(I,J)#A*WS(I,J)                                                 CIRC0950
  180 A#A-0.075                                                         CIRC0955
      WSAVE # (WNCI + WSI)/12.0                                         CIRC0960
C     FOR THE FIRST PASS THROUGH THE CONDENSER , (J#1)                  CIRC0965
C     SET UP FOR CALCULATION THRU CONDENSER USE DOUBLE SUBSCRIPTS, (I,J)CIRC0970
CCCCCC                                                                  CIRC0975
C     I---TUBE ROWS, 1 TO IHNO                                          CIRC0980
C     J---PASS NO  , 1 TO 6                                             CIRC0985
      IPLOOP#0                                                          CIRC0990
  185 DO 325 J#1,6                                                      CIRC0995
      PMIX(I,J) # PMIX1 - DELP12 - DELP23                               CIRC1000
      PSAT(I,J)#PMIX(I,J)*(AMOLSS/AMOLST)                               CIRC1005
      PAL#PSAT(I,J)                                                     CIRC1010
      TSAT(I,J)#TSATFN(PAL)                                             CIRC1015
      STSAT(I,J)#TSAT(I,J)-459.69                                       CIRC1020
      TAL#TSAT(I,J)                                                     CIRC1025
      VG#VGFN(TAL,PMIX(I,J))                                            CIRC1030
      VNC#(10.729*TSAT(I,J))/(AMWNC *(PMIX(I,J)))                       CIRC1035
      VMIX#1.0/((AMOLSS/(VG*AMOLST))+(AMOLNC/(VNC*AMOLST)))             CIRC1040
      VEL (I, J) # ( WS (I,J) + WGAS (J) ) * VMIX  / (3600.0* AOTFLW(I))CIRC1045
      IF(WNCI) 190, 190, 195                                            CIRC1050
  190 WGAS(J) # 0.0                                                     CIRC1055
  195 WNC # WGAS(J)                                                     CIRC1060
      AMOLSC#WNC/AMWNC                                                  CIRC1065
      TB2 # 0.0                                                         CIRC1070
      QG#0.0                                                            CIRC1075
      QGP#0.0                                                           CIRC1080
      DO320IL#1,IHNO                                                    CIRC1085
      I#IL                                                              CIRC1090
      LQ#0                                                              CIRC1095
      STSAT(I+1,J)#STSAT(I,J)                                           CIRC1100
  200 STAVG#(STSAT(I+1,J)+STSAT(I,J))*0.5                               CIRC1105
      CALL HETTRN(STAVG      ,ANF(I,J),WS(I,J),WNC,UM      ,UN(I,J),    CIRC1110
     1ALMTD(I,J),ASS,QG,QT,QCND,SHI(I,J),SHML      ,SHN (I,J),SHG      ,CIRC1115
     2SHCGM      ,ALST,RC(I,J),SHCGN      ,LQ,STSAT(I,J),STSAT(I+1,J) )CIRC1120
      IF(ASS)455,205,455                                                CIRC1125
  205 QM      #UM      *AO*ANF(I,J)*ALMTD(I,J) *TBNPR(I)                CIRC1130
      HFG#HFGFN(STSAT(I,J))                                             CIRC1135
      WL(I,J)#QM      /HFG                                              CIRC1140
      WCND(I,J)#UN(I,J)*AO*ALMTD(I,J)/HFG * TBNPR (I)                   CIRC1145
      AMOLS(I,J)#WS(I,J)/18.015                                         CIRC1150
      L # 4                                                             CIRC1155
      AXO # AOTFLW(I)                                                   CIRC1160
      CALL PRSDRP(TSAT(I,J),PSAT(I,J),PMIX(I,J),WS(I,J),WL(I,J),WNC,AXO,CIRC1165
     1AMOLS(I,J),AMOLSC,NERR,DELPTP(I,J),WCND(I,J),TPOG      ,ALV      ,L)CIRC1170
      JX#0                                                              CIRC1175
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      IF(NERR)465,210,465                                               CIRC1180
  210 WS(I+1,J)# WS(I,J)-WCND(I,J)                                      CIRC1185
      IF(WS(I+1,J))215,235,235                                          CIRC1190
  215 IF (EXITFR) 230, 230, 220                                         CIRC1195
  220 ALMAX # ALST                                                      CIRC1200
      ALST # ALST * 0.9 ** ( 1.0 /(FLOAT(ILNG)+ 1.0 ) )                 CIRC1205
      IF (ALST - ALMIN ) 225, 225, 135                                  CIRC1210
  225 ALST # ALMIN + (ALMAX - ALMIN) * 0.1                              CIRC1215
      GO TO 135                                                         CIRC1220
  230 WCND(I,J) # 0.5*WS(I,J)                                           CIRC1225
      WS(I+1,J)# WS(I,J)-WCND(I,J)                                      CIRC1230
      AMOLS(I+1,J)#WS(I+1,J)/18.015                                     CIRC1235
      PMIX(I+1,J)#PMIX(I,J)-DELPTP(I,J)                                 CIRC1240
      PSAT(I+1,J)#PMIX(I+1,J)*AMOLS(I+1,J)/(AMOLS(I+1,J)+WNC /AMWNC)    CIRC1245
      TSAT(I+1,J) # TSATFN(PSAT(I+1,J))                                 CIRC1250
      STSAT(I+1,J)#TSAT(I+1,J)-459.69                                   CIRC1255
      QG#(WS(I,J)*CPSFN(TSAT(I,J))/18.105+WNC*CPAFN(TSAT(I,J))/AMWNC )* CIRC1260
     1(TSAT(I,J)-TSAT(I+1,J))                                           CIRC1265
      QT#QG+WCND(I,J)*HFG                                               CIRC1270
      ALMTD(I,J) # WCND(I,J) *HFG/(UN(I,J)*AO * TBNPR (I) )             CIRC1275
      TB2 # QT/(WB*CPFN(CBI,STBAVE)*TBNPR(I) ) + STBI                   CIRC1280
      GO TO 315                                                         CIRC1285
  235 AMOLS(I+1,J)#WS(I+1,J)/18.015                                     CIRC1290
      PMIX(I+1,J)#PMIX(I,J)-DELPTP(I,J)                                 CIRC1295
      PSAT(I+1,J)#PMIX(I+1,J)*AMOLS(I+1,J)/(AMOLS(I+1,J)+WNC /AMWNC)    CIRC1300
      PAL#PSAT(I+1,J)                                                   CIRC1305
      IF(PAL) 240, 240, 245                                             CIRC1310
  240 WRITE(6,8035) I, PMIX(I+1,J)                                      CIRC1315
 8035 FORMAT(1H0, 22HPAL IS NEGATIVE, PMIX( , I2, 6H+1) #   , E16.8 )   CIRC1320
      GO TO 655                                                         CIRC1325
  245 TSAT(I+1,J)#TSATFN(PAL)                                           CIRC1330
      STSAT(I+1,J)#TSAT(I+1,J)-459.69                                   CIRC1335
      IF(STSAT(I+1,J)-STFO) 250, 250, 255                               CIRC1340
  250 STSAT(I+1,J) # STFO                                               CIRC1345
      TSAT(I+1,J) # STSAT(I+1,J) + 459.69                               CIRC1350
  255 TAL # TSAT(I+1,J)                                                 CIRC1355
      WCNDP#(UN(I,J)*AO*ALMTD(I,J) * TBNPR (I)                          CIRC1360
     1                          -(WS(I  ,J)*CPSFN(TSAT(I+1,J))/18.105 CIRC1365
     2+WNC*CPAFN(TSAT(I+1,J))/AMWNC )*(TSAT(I,J)-TSAT(I+1,J)))/HFG      CIRC1370
      IF(ABS(WCND P/WCND(I,J)-1.0)-.005)275,260,260                     CIRC1375
  260 JX#JX+1                                                           CIRC1380
      IF(JX-50)270,270,265                                              CIRC1385
  265 WRITE (6,8040)IDENT,I,J,I,J                                       CIRC1390
 8040 FORMAT(1H1,13A6/1H0,5X,2HI#,I2,5X,2HJ#,I1/1H0,24HNO CONVERGENCE FOCIRC1395
     1R WCND(I2,1H,I1,1H))                                              CIRC1400
      GO TO 655                                                         CIRC1405
  270 WCND(I,J)#WCNDP                                                   CIRC1410
      GOTO210                                                           CIRC1415
  275 QG#(WS(I,J)*CPSFN(TSAT(I,J))/18.105+WNC*CPAFN(TSAT(I,J))/AMWNC )* CIRC1420
     1(TSAT(I,J)-TSAT(I+1,J))                                           CIRC1425
      WCND(I,J)#WCNDP                                                   CIRC1430
      QT#QG+WCND(I,J)*HFG                                               CIRC1435
C     WRITE OUTPUT TAPE 6, 3000, I, J, RC(I,J),QG, QT, QGP,UN(I,J)      CIRC1440
C3000 FORMAT(2I5, 5E16.8)                                               CIRC1445
      IF(RC(I,J)-0.040)315,315,280                                      CIRC1450
  280 IF(ABS(QGP/QG -1.0)-0.10 )315,285,285                             CIRC1455
  285 IF(LQ)290,290,295                                                 CIRC1460
  290 QGP#QG                                                            CIRC1465
      LQ#LQ+1                                                           CIRC1470
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      GOTO 200                                                          CIRC1475
  295 IF(LQ- 5)300,300,305                                              CIRC1480
  300 QGP#QGP-0.5*(QGP-QG)                                              CIRC1485
      QG#QGP                                                            CIRC1490
      LQ#LQ+1                                                           CIRC1495
      GOTO 200                                                          CIRC1500
  305 QGP#QGP-0.1*(QGP-QG)                                              CIRC1505
      QG#QGP                                                            CIRC1510
      LQ#LQ+1                                                           CIRC1515
      IF(LQ-10)200,310,310                                              CIRC1520
  310 WRITE (6,8045)IDENT,I,J,I,J                                       CIRC1525
 8045 FORMAT(1H1,13A6/1H0,5X,2HI#,I2,5X,2HJ#,I1/1H0,22HNO CONVERGENCE FOCIRC1530
     1R QG(I2,1H,I1,1H))                                                CIRC1535
  315 VG#VGFN(TSAT(I+1,J),PMIX(I+1,J))                                  CIRC1540
      QGP#QG                                                            CIRC1545
      AMOLSC # WNC/AMWNC                                                CIRC1550
      VNC#(10.729*TSAT(I+1,J))/(AMWNC *(PMIX(I+1,J)))                   CIRC1555
      VMIX#1.0/((AMOLS(I+1,J)/(VG*(AMOLS(I+1,J)+AMOLSC)))+(AMOLSC/      CIRC1560
     1(VNC*(AMOLS(I+1,J)+AMOLSC))))                                     CIRC1565
      VEL(I+1,J)#(WS(I+1,J)+WNC)/(AOTFLW (I+1)          )*VMIX/3600.0   CIRC1570
C     WRITE OUTPUT TAPE 6, 8004, STB2ES, TB2, STFO                      CIRC1575
 8050 FORMAT(1H0, 3F10.5)                                               CIRC1580
  320 CONTINUE                                                          CIRC1585
      G1#288.00*SG*SVMIX1                                               CIRC1590
      VEL(1,J)#SVMIX1*(WS(1,J)+WGAS(J))/(3600.0*AOTFLW(1) )             CIRC1595
      C1(J)#(PMIX(1,J)-PMIX(1HNO+1,J))*G1/VEL(1,J)**3                   CIRC1600
  325 CONTINUE                                                          CIRC1605
      PMXEXT#0.0                                                        CIRC1610
      IF(C2(1))330, 330, 340                                            CIRC1615
  330 DO 335 J#1,6                                                      CIRC1620
  335 C2(J) # C1(J)                                                     CIRC1625
  340 DO 350 J#1,6                                                      CIRC1630
      C(J) # (C1(J) + C2(J)) * 0.5                                      CIRC1635
      C2(J) # C(J)                                                      CIRC1640
  345 DELP(J)#PMIX(1,J)-PMIX(1HNO+1,J)                                  CIRC1645
  350 PMXEXT#PMXEXT+PMIX(1HNO+1,J)                                      CIRC1650
      PMXEXT # PMXEXT/6.0                                               CIRC1655
      DELPVE#PMIX(1,1)-PMXEXT                                           CIRC1660
      TNOFR # TNOC / (TNOC + TNO)          *100.0                       CIRC1665
      WPT#0.0                                                           CIRC1670
  355 DO 360 J#1,6                                                      CIRC1675
      IF (ABS(DELP(J) / DELPVE - 1.0) - 0.01) 360, 360, 365             CIRC1680
  360 CONTINUE                                                          CIRC1685
      GO TO 395                                                         CIRC1690
  365 DO370J#1,6                                                        CIRC1695
      WP(J)#(DELPVE*G1/C(J))**0.3333*3600.0* AOTFLW (1)        /SVMIX1  CIRC1700
      WSP(J)#WP(J)*WS1/(WNC1+WS1)                                       CIRC1705
      WGAS(J)#WP(J)-WSP(J)                                              CIRC1710
  370 WPT#WPT+WP(J)                                                     CIRC1715
      IF(ABS(WPT/(6.0*WSAVE)-1.0)-0.0005)380,380, 375                   CIRC1720
  375 DELPVE#DELPVE*(WSAVE*6.0/WPT)**2                                  CIRC1725
      WPT#0.0                                                           CIRC1730
      GOTO365                                                           CIRC1735
  380 IPLOOP#IPLOOP + 1                                                 CIRC1740
      DO 385 J#1,6                                                      CIRC1745
  385 WS(1,J)#WSP(J)                                                    CIRC1750
      IF(IPLOOP-10) 185, 185,390                                        CIRC1755
  390 WRITE (6,8055)IDENT                                               CIRC1760
 8055 FORMAT(1H1,13A6,40HNO CONVERGENCE IN COND. DELTA P (IPLOOP) )     CIRC1765
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      GOTO655                                                           CIRC1770
C     AVERAGE CONDITION AFTER CONDENSER SECTION AND BEFORE COOLER       CIRC1775
C     SECTION.                                                          CIRC1780
  395 PMXEXT#PMIX(I,I)-DELPVE                                           CIRC1785
      WSUMX#0.0                                                         CIRC1790
      DO 400 J#1,6                                                      CIRC1795
  400 WSUMX#WSUMX + WS(IHNO+I,J)                                        CIRC1800
      WSEXIT#WSUMX*2.0                                                  CIRC1805
      AMLSEX#WSEXIT/18.015                                              CIRC1810
      PSATEX#PMXEXT* AMLSEX / (AMLSEX + AMOLNC)                         CIRC1815
      WNCC#WNCI                                                         CIRC1820
      TSATEX#TSATFN(PSATEX)                                             CIRC1825
      STSAEX#TSATEX-459.69                                              CIRC1830
      VELEXT#0.0                                                        CIRC1835
      DO405J#1,6                                                        CIRC1840
  405 VELEXT#VELEXT+VEL(IHNO + I, J)                                    CIRC1845
      VELEXT#VELEXT/6.0                                                 CIRC1850
C     CALCULATION THROUGH COOLER                                        CIRC1855
  410 AXOC#        SDO*HNOC*ALST * (SDDMIN - 1.0)                       CIRC1860
      SVGEXT#VGFN(TSATEX,PMXEXT)                                        CIRC1865
      SVNCEX#10.729*TSATEX/( AMWNC*(PMXEXT))                            CIRC1870
      AMLT # AMLSEX + AMOLNC                                            CIRC1875
      SVMXEX # 1.0 / (AMLSEX / (AMLT * SVGEXT) + AMOLNC /               CIRC1880
     1 (AMLT * SVNCEX ))                                                CIRC1885
      VELC(I)#(WSEXIT+WNCC)*SVMXEX/(AXOC*3600.0)                        CIRC1890
      IF(VELC(I)-VLCMAX)420,420,415                                     CIRC1895
  415 AXOC#(WSEXIT+WNCC)*SVMXEX/(VLCMAX*3600.0)                         CIRC1900
      HNOC#AXOC/(        SDO*ALST * (SDDMIN - 1.0 ))                    CIRC1905
      VNOC#TNOC/HNOC                                                    CIRC1910
      IVNOC # VNOC + 0.1                                                CIRC1915
      VELC(I)#VLCMAX                                                    CIRC1920
  420 G2#288.0*SG*SVMXEX                                                CIRC1925
      IF(VELC(I)-VELEXT)425,425,430                                     CIRC1930
  425 A2DAI#VELC(I)/VELEXT                                              CIRC1935
      DELPCT#((1.0-A2DAI)*VELEXT**2)/G2                                 CIRC1940
      GOTO445                                                           CIRC1945
  430 A2DAI#VELEXT/VELC(I)                                              CIRC1950
      IF(A2DAI-0.715)440,440,435                                        CIRC1955
  435 DELPCT#(0.75*(1.0-A2DAI)*VELC(I)**2)/G2                           CIRC1960
      GOTO445                                                           CIRC1965
  440 DELPCT#(0.4*(1.25-A2DAI)*VELC(I)**2)/G2                           CIRC1970
  445 PMIXC(I)#PMXEXT-DELPCT   -(VELC(I)**2 -VELEXT**2)/G2              CIRC1975
      PSATC(I)#PMIXC(I)*AMLSEX/(AMLSEX+AMOLNC)                          CIRC1980
      PAL#PSATC(I)                                                      CIRC1985
      TSATC(I)#TSATFN(PAL)                                              CIRC1990
      STSATC(I)#TSATC(I)-459.69                                         CIRC1995
      WSC(I)#WSEXIT                                                     CIRC2000
      TAL#TSATC(I)                                                      CIRC2005
      VG#VGFN(TAL,PMIXC(I))                                             CIRC2010
      AMLSSC(I)#WSC(I)/18.015                                           CIRC2015
      AMLSCC#AMOLNC                                                     CIRC2020
      VNC#10.729*TSATC(I)/(AMWNC *(PMIXC(I)))                           CIRC2025
      VMIX#1.0/((AMLSSC(I)/(VG*(AMLSSC(I)+AMLSCC)))                     CIRC2030
     1+(AMLSCC/(VNC*(AMLSSC(I)+AMLSCC))))                               CIRC2035
      VELC(I)#(WSC(I)+WNCC)*VMIX/(AXOC*3600.0)                          CIRC2040
      ANFC(I)#(VNOC+1.0)/2.0                                            CIRC2045
      QGC#0.0                                                           CIRC2050
      QGPC#0.0                                                          CIRC2055
      DO565IK#1,IVNOC                                                   CIRC2060
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      I#IK                                                              CIRC2065
      L # 7                                                             CIRC2070
      LQC#0                                                             CIRC2075
      STSATC(I+1)#STSATC(I)                                             CIRC2080
  450 STAVG#(STSATC(I+1) + STSATC(I))*0.5                               CIRC2085
      CALL HETTRN(STAVG    ,ANFC(I),WSC(I),WNCC    ,UMC    ,UNC(I),    CIRC2090
     1ALMTDC(I),ASS,QGC,QTC,QCNDC,SHIC(I),SHMLC    ,SHNFC(I),SHGC    ,  CIRC2095
     2SHCGCM    ,ALST,RCC(I),SHCGCN    ,LCC,STSATC(I),STSATC(I+1) )     CIRC2100
      IF(ASS)455,460,455                                                CIRC2105
  455 WRITE (6,8060)IDENT                                               CIRC2110
 8060 FORMAT(1H1,13A6/48HONO CONVERGENCE FOR TB2 IN HEAT TRANSFER ROUTINCIRC2115
     1E)                                                                CIRC2120
      GO TO 655                                                         CIRC2125
  460 QMC    #UMC    *AO*ANFC(I)*ALMTDC(I                               CIRC2130
      HFG#HFGFN(STSATC(I))                                              CIRC2135
      WLC(I)#QMC    *HNOC/HFG                                           CIRC2140
      WCNDC(I)#UNC(I)*AO*HNOC*ALMTDC(I)*HFG                             CIRC2145
      CALL PRSDRP(TSATC(I),PSATC(I),PMIXC(I),WSC(I),WLC(I),WNCC,AXOC,   CIRC2150
     1AMLSSC(I),AMLSCC,NERR,DELTPC(I),WCNDC(I),TPOGC    ,ALVC    ,LJ)  CIRC2155
      DELTPC (I) # 2.0 * DELTPC (I)                                     CIRC2160
      JY # 0                                                            CIRC2165
      IF(NERR)465,470,465                                               CIRC2170
  465 WRITE (6,8065)IDENT                                               CIRC2175
 8065 FORMAT(1H1,13A6,42HERROR IN INTPL2 WHICH IS CALLED BY PRSDRP.)    CIRC2180
      GO TO 655                                                         CIRC2185
  470 WSC(I+1)#WSC(I)-WCNDC(I)                                          CIRC2190
      IF(WSC(I+1))475,505,505                                           CIRC2195
  475 IF (EXITFR) 490, 490, 480                                         CIRC2200
  480 ALMAX # ALST                                                      CIRC2205
      ALST # ALST *0.98 ** ( 1.0 /(FLOAT(ILNG)+ 1.0 ) )                 CIRC2210
      IF (ALST - ALMIN ) 485, 485, 135                                  CIRC2215
  485 ALST # ALMIN + (ALMAX - ALMIN) * 0.1                              CIRC2220
      GO TO 135                                                         CIRC2225
  490 STSATC(I+1) # STFO                                                CIRC2230
      TSATMN#STSATC(I+1)+459.69                                         CIRC2235
      PMIN#PSATFN(TSATMN)                                               CIRC2240
      WCNDC(I)#WSC(I)*(PSATC(I)-PMIN)/PSATC(I)                          CIRC2245
      WSC(I+1)#WSC(I)-WCNDC(I)                                          CIRC2250
      QGC#(WSC(I)*CPSFN(TSATC(I))/18.015+WNCC*CPAFN(TSATC(I))/AMWNC)*   CIRC2255
     1(TSATC(I)-TSATMN)                                                 CIRC2260
      QTC#QGC+WCNDC(I)*HFG                                              CIRC2265
      IF(STSATC(I)-TB2) 495, 495, 500                                   CIRC2270
  495 TB2 # STSATC(I) - 0.1                                             CIRC2275
  500 ALMTDC(I)#((STSATC(I+1)-STBI)-(STSATC(I)-TB2))/ALOG((STSATC(I+1)- CIRC2280
     1STBI)/(STSATC(I)-TB2))                                            CIRC2285
      UNC(I)#QTC/(AO*HNOC*ALMTDC(I))                                    CIRC2290
      AMLSSC(I+1)#WSC(I+1)/18.015                                       CIRC2295
      PMIXC(I+1)#PMIXC(I)-DELTPC(I)                                     CIRC2300
      PSATC(I+1)#(PMIXC(I+1)*AMLSSC(I+1))/(AMLSSC(I+1)+AMLSCC)          CIRC2305
      TSATC(I+1)#TSATMN                                                 CIRC2310
      GO TO 550                                                         CIRC2315
  505 AMLSSC(I+1)#WSC(I+1)/18.015                                       CIRC2320
      PMIXC(I+1)#PMIXC(I)-DELTPC(I)                                     CIRC2325
      PSATC(I+1)#(PMIXC(I+1)*AMLSSC(I+1))/(AMLSSC(I+1)+AMLSCC)          CIRC2330
      PAL#PSATC(I+1)                                                    CIRC2335
      TSATC(I+1)#TSATFN(PAL)                                            CIRC2340
      STSATC(I+1)#TSATC(I+1)-459.69                                     CIRC2345
      TAL#TSATC(I+1)                                                    CIRC2350
      WCNDP#(UNC(I)*AO*HNOC*ALMTDC(I)-(WSC(I   )*CPSFN(TSATC(I+1))/18.105CIRC2355
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     1+WNCC*CPAFN(TSATC(I+1))/AMWNC )*(TSATC(I)-TSATC(I+1)))/HFG
  510 IF(ABS(WCNDP/WCNDC(I)-1.0)-.005)525,515,515
  515 WCNDC(I)#WCNDP
      JY # JY + 1
      IF(JY-50) 470, 470, 520
  520 WRITE (6,8070)I
 8070 FORMAT(1H0, 25HNO CONVERGENCE FOR WCNDC(, I2, 2H).   )
      GO TO 545
  525 QGC#(AMLSSC(I)*CPSFN(TSATC(I))+AMLSCC*CPAFN(TSATC(I)))*(TSATC(I)-
     1TSATC(I+1))
      WCNDC(I)#WCNDP
      QTC#QGC+WCNDC(I)*HFG
C     WRITE OUTPUT TAPE 6, 3001, I, RCC(I), QGC, QTC, QGPC, UNC(I)
C3001 FORMAT(I5, 5E16.8)
      IF(RCC( I)-0.040)550,550,530
  530 IF(ABS(QGPC/QGC-1.0)-0.10)550,535,535
  535 QGPC#(QGPC + QGC)*0.5
      LQC#LQC+1
      IF(LQC-50)450,540,540
  540 WRITE (6,8075)IDENT,I
 8075 FORMAT(1H1,13A6/1H0,5X,2HI#,I2/1H0,25HNO CONVERGENCE FOR QGC(I))
  545 CONTINUE
      GO TO 655
  550 VG#VGFN(TSATC(I+1),PMIXC(I+1))
      QGPC#QGC
      VNC#10.729*TSATC(I+1)/(AMWNC *(PMIXC(I+1)))
      VMIX#1.0/((AMLSSC(I+1)/(VG*(AMLSSC(I+1)+AMLSCC)))+(AMLSCC/(VNC*
     1(AMLSSC(I+1)+AMLSCC))))
      VELC(I+1)#(WSC(I+1)+WNCC)*VMIX/(AXOC *3600.0)
C     WRITE OUTPUT TAPE 6, 8004, STB2ES, TB2, STFO
      IF(MOD(I,2))555,560,555
  555 ANFC(I+1)#ANFC(I)
      GOTO565
  560 ANFC(I+1)#ANFC(I)-1.0
  565 CONTINUE
      DELPC#PMIXC(1)-PMIXC(IVNOC+1)
      CLC#DELPC*488.0*SG*SVMXEX/VELC(1)**2
      XTFR1 # WSC (IVNOC + 1) / WSI
      IF (EXITFR) 635, 635, 570
  570 IF (ABS(XTFR1 - EXITFR) - 0.25 * EXITF*) 635, 635, 575
  575 IF ( ILNG -  5) 585, 585, 580
  580 WRITE (6,8080)
 8080 FORMAT (1H0 44H NO CONVERGENCE FOR EXITFR AFTER  5 TRIES        )
      GO TO 635
  585 IF (XTFR1 - EXITFR ) 590,  590, 615
  590 ALMAX # ALST
      IF ( ILNG - 2) 595, 600, 600
  595 ALST # ALST * ( 1.0 + XTFR1) / ( 1.0 + EXITFR )
      GO TO 610
  600 ALST #     ALST + (ALS1 - ALS2) / (XTFR1 - XTFR2)
     1 * (EXITFR - XTFR1 )
      IF (ALST - ALMIN ) 605, 605, 610
  605 ALST # ALMIN +(ALMAX - ALMIN ) * 0.1
  610 WRITE (6,8085)ALST, ALS1, ALS2, XTFR1, XTFR2          , ALMAX, ALM
     1IN
 8085 FORMAT (1H0 6H 4002   7E16.8)
      ALS2 # ALS1
      XTFR2 # XTFR1
      ILNG # ILNG + 1
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      GO TO 135
  615 ALMIN # ALST
      IF (ILNG - 2) 620, 625, 625
  620 ALST # ALST * ( 1.0 + XTFR1) / ( 1.0 + EXITFR )
      GO TO 610
  625 ALST #     ALST + (ALS1 - ALS2) / (XTFR1 - XTFR2)
     1 * (EXITFR - XTFR1 )
      IF (ALMAX - ALST) 630, 630, 610
  630 ALST # ALMAX - (ALMAX - ALMIN) * 0.1
      GO TO 610
  635 CONTINUE
      ARCOND#AO*(ANT-TNOC)
      WCNDT#WSI-WSC(I)
      QTCOND#WCNDT*HFGFN(STSATC(I))
     1+((WSI+WSC(I))*0.5*CPSFN(TSATC(I))/18.015
     2+AMOLNC*CPAFN(TSATC(I)))*(STSAT(I,I)-STSATC(I))
      STB2CD#QTCOND/(WB*(ANT-TNOC)*CPFN(CBI,STBI)) + STBI
      DTCOND#((STSATC(I)-STBI)-(STSAT(I,I)-STB2CD))/
     1ALOG((STSATC(I)-STBI)/(STSAT(I,I)-STB2CD))
      UCOND#QTCOND/(ARCOND*DTCOND)
      ARCOOL#AO*TNOC
      WCNDCT#WSC(I)-WSC(IVNOC+1)
      QTCOOL#WCNDCT*HFGFN(STSATC(I))
     1+((WSC(I)+WSC(IVNOC+1))*0.5*CPSFN(TSATC(I))/18.015
     2+AMOLNC*CPAFN(TSATC(I)))*(STSATC(I)-STSATC(IVNOC+1))
      STB2CL#QTCOOL/(WB*(TNOC)*CPFN(CBI,STBI)) + STBI
      DTCOOL#((STSATC(IVNOC+1)-STBI)-(STSATC(I)-STB2CL))/
     1        ALOG((STSATC(IVNOC+1)-STBI)/(STSATC(I)-STB2CL))
      UCOOL#QTCOOL/(ARCOOL*DTCOOL)
      STB2T#(QTCOND+QTCOOL)/(WBI*CPFN(CBI,STBI)) + STBI
      DELTOT#((STSATC(IVNOC+1)-STBI)-(STSAT(I,I)-STB2T))/
     1ALOG((STSATC(IVNOC+1)-STBI)/(STSAT(I,I)-STB2T))
      UAVG#(QTCOND + QTCOOL)/(AO*ANT*DELTOT)
      DTCND2# (STB2CD- STBI) / ALOG(( STSAT(I,I)- STBI) /
     1SAT(I,I) - STB2CD))
      UPCOND # QTCOND / (ARCOND * DTCND2)
      DTCOL2 # (STB2CL- STBI) / ALOG(( STSATC(I) - STBI) /
     1TSATC(I ) - STB2CL))
      UPCOOL # QTCOOL / (ARCOOL * DTCOL2 )
      DLTOT2# (STB2T- STBI) / ALOG((STSAT(I,I) - STBI) /
     1T(I,I) - STB2T))
      UPAVG # (QTCOND + QTCOOL) / (AO * ANT * DLTOT2)
      VNOC # FLOAT(IVNOC)
      UBARW # 0.0
      UBARWC # 0.0
      DO  645 J#1,6
      DO  640 I#1,IHNO
  640 UBARW# UBARW + UN(I,J)*TBNPR(I)*2.0
  645 CONTINUE
      UBARW # UBARW/TNO
      DO  650 I#1,IVNOC
  650 UBARWC # UBARWC + UNC(I)
      UBARWC # UBARWC/VNOC
      UAVGW #(UBARW*TNO + UBARWC*TNOC)/(TNO + TNOC)
      ADTCLR # QTCOOL/(UBARWC*ARCOOL)
      ADTCND # QTCOND/(UBARW*AO*TNO)
      ADTOA # (QTCOOL+QTCOND)/(UAVGW*(TNO+TNOC)*AO)
 REGULAR OUTPUT PKG
      TDROP1 # STSAT(I,I) - STSAEX
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      THOFR # TNO/(TNO + TNOC) *100.0                                   CIRC2950
      TDROP2 # STSATC(1) - STSATC(IVNOC+1)                              CIRC2955
      DELPOA # PMIX1 - PMIXC(IVNOC+1)                                   CIRC2960
      TDROP3 # STSAT1 - STSATC(IVNOC+1)                                 CIRC2965
      VOIDID # 2.0*RADINS                                               CIRC2970
      HNO # FLOAT(IHNO)                                                 CIRC2975
      HBNDC # 0.866*VNOC*SDD*SDO + SDO                                  CIRC2980
      WBNDC # HNOC*SDD*SDO + SDO                                        CIRC2985
      EXSTFR # WSC(IVNOC+1)/WSI * 100.0                                 CIRC2990
      EXNCFR# WNCI/(WNCI+WSC(IVNOC+1))*100.0                            CIRC2995
      WRITE(6,8090)                                                     CIRC3000
 8090 FORMAT(1HK,52X, 18HSUMMARY OF RESULTS /1H0,16X, 2HU,8X, 8HLOG MEANCIRC3005
     1 ,4X, 33HPRESSURE   TEMP.   STEAM VELOCITY ,            29H  TUBE CIRC3010
     2SPACING  TUBE FRACTION /12X, 56HBTU/HR/SQ.FT. DELTA TEMP,    DROP CIRC3015
     3    DROP        FT/SEC , 8X,                 6HRATIO, /14X, 58H/DEGCIRC3020
     4. F.      DEG.F.    LBS/SQ.IN.  DEG.F.  INLET   OUTLET ,         CIRC3025
     5   6X,  18HS/D        PERCENT )                                  CIRC3030
      WRITE(6,8095) UBARW, ADTCND, DELPVE, TDROP1, VEL(1,1), VEL(IHNO+1,CIRC3035
     11),            SDD, THOFR, UBARWC, ADTCLR, DELPC, TDROP2, VELC(1), CIRC3040
     2VELC(IVNOC+1),              SDDMIN, TNOFR, UAVGW, ADTOA, DELPOA,  CIRC3045
     3TDROP3                                                            CIRC3050
 8095 FORMAT(1H0, 11HCONDENSER    , F8.2,6X,F6.2,7X,F7.4,3X,F6.3,2X,F6.2,CIRC3055
     12X,F6.2,                 7X,F3.1,8X,F6.2/1X,  6HCOOLER ,5X,F8.2,6X,CIRC3060
     2F6.2,7X,F7.4,3X,F6.3,2X,F6.2,2X,F6.2,                 7X ,F3.1,8X, CIRC3065
     3F6.2/1X,  7HOVERALL ,4X,F8.2,6X,F6.2,7X,F7.4,3X,F6.3 )            CIRC3070
      WRITE(6,8100) BNDIAM, VOIDID, HNO                                 CIRC3075
 8100 FORMAT(1H0, 25HOUTSIDE BUNDLE DIAM., FT. , F6.2,4X, 22HINSIDE VOIDCHRC3080
     1 DIAM., FT. , F6.2,4X, 26HNUMBER OF RADIAL TUBE ROWS , F4.0 )    CIRC3085
      WRITE(6, 8105) HBNDC, WBNDC, ALST, EXSTFR, EXNCFR                 CIRC3090
 8105 FORMAT(1H0, 18HCOOLER HEIGHT, FT. ,F6.2,5X,17HCOOLER WIDTH, FT. , CIRC3095
     1F6.2,5X, 18HBUNDLE LENGTH, FT. ,F7.3/1H0, 28HEXIT STEAM, PERCENT OCIRC3100
     2F INPUT ,5X,F6.2,9X, 49HEXIT NON-CONDENSIBLES, PERCENT OF TOTAL EXCIRC3105
     3IT FLOW ,5X, F6.2 )                                               CIRC3110
      IF(OUTPUT) 655, 100, 655                                          CIRC3115
C  FULL OUTPUT PKG                                                      CIRC3120
  655 IVNOC#IVNOC+1                                                     CIRC3125
      IHNO # IHNO + 1                                                   CIRC3130
      DO 665 J#1,6                                                      CIRC3135
      WRITE(6,8110) IDENT, J                                            CIRC3140
      WRITE (6,8125)                                                    CIRC3145
      DO 660 I#1,IHNO                                                   CIRC3150
      WRITE(6,8130)  STSAT(I,J),PMIX(I,J),WS(I,J),VEL(I,J),RC(I,J),     CIRC3155
     1UN(I,J),SHN (I,J),SHI(I,J)                                        CIRC3160
  660 CONTINUE                                                          CIRC3165
  665 CONTINUE                                                          CIRC3170
      WRITE(6,8115) IDENT                                               CIRC3175
      WRITE (6,8120)                                                    CIRC3180
      WRITE(6,8130)(STSATC(I),PMIXC(I),WSC(I),VELC(I),RCC(I),UNC(I),    CIRC3185
     1SHNFC(I),SHIC(I),I#1,IVNOC)                                       CIRC3190
      IVNOC#IVNOC-1                                                     CIRC3195
      IHNO # IHNO - 1                                                   CIRC3200
 8110 FORMAT(1H1,13A6, 7H   J # , I2 )                                  CIRC3205
 8115 FORMAT(1H1, 13A6, 17H   COOLER SECTION  )                         CIRC3210
 8120 FORMAT(1H0,5X,6HSTSATC,10X,5HPMIXC,11X,3HWSC,13X,4HVELC,12X,3HRCC,CIRC3215
     113X,3HUNC,13X,5HSHNFC,11X,4HSHIC )                                CIRC3220
 8125 FORMAT(1H0,5X,5HSTSAT,11X,4HPMIX,12X,2HWS,14X,3HVEL,13X,2HRC,14X, CIRC3225
     12HUN,14X,4HSHNF,12X,3HSHI )                                       CIRC3230
 8130 FORMAT(1H ,8E16.8)                                                CIRC3235
      GOTO100                                                           CIRC3240
```

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8135 FORMAT(1H0, 8H IDIV # , I4 )                                  CIRC3245
     END                                                           CIRC3250
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$IBFTC HTTR    DECK                                                     HTTR0000
C      SUBROUTINE HETTRN SANS-0 UPDATE 10/5/66                          HTTR0005
       SUBROUTINE HETTRN(STSAT,ANF,WS,WNC,VML,VNF,ALMTD,ASS,QG,QT,QCND,  HTTR0010
      1SHI,SHML,SHNF,SHG,SHCGM,ALST,RC,SHCGN,LQ,STSAT1,STSAT2)          HTTR0015
       DIMENSION COOR (3)                                               HTTR0020
       COMMON  SDO    , STBI   , AI     , AO     , AW     , SHWINV       HTTR0025
       COMMON  FOUL   , CBI    , SDI    , AXI    , WB     , HFG          HTTR0030
       COMMON  SDD    , STB2ES , GB     , VG     , AMWNC  , STFO         HTTR0035
       COMMON  TB2    , STBAVE , VNO    , J      , XNC    , SF           HTTR0040
       COMMON  COOR   , JRC                                             HTTR0045
C      DIMENSION COOR (3)                                               HTTR0050
C      COMMON SDO,STBI,AI,AO,AW,SHWINV,FOUL,CBI,SDI,AXI,WB,HFG,SDD,STB2ESHTTR0055
C     1,GB,VG, AMWNC,STFO,TB2, STBAVE, VNO, J, XNC                      HTTR0060
C      COMMON SF, COOR, JRC                                             HTTR0065
       BNF3 # 16.0                                                      HTTR0070
       XNF3 #1.2379476+.35360826E-1*BNF3 -.15703466E-2*BNF3 **2         HTTR0075
       RC#WNC/(WS+WNC)                                                  HTTR0080
       ASS#0                                                            HTTR0085
       TSAT#STSAT+459.69                                                HTTR0090
       IF(TB2) 100, 100, 105                                            HTTR0095
  100  STBAVE#( STBI+STB2ES) / 2.0                                      HTTR0100
       TB2 # STB2ES                                                     HTTR0105
CCCCC                                                                   HTTR0110
C     CALC. BRINE PROPERTIES AT STBAVE,(CBI,MUW,TW,CBI)                 HTTR0115
C                                .8        0.33            0.14         HTTR0120
C     SHI#0.027*( K )(SDI*GS)  (CP*BMU)    (BMU(AVG T) )                HTTR0125
C                (SDI)( BMU  )  (  K   )    (BMU(WALL T))               HTTR0130
CCCC                                                                    HTTR0135
  105  BB#GB*3600.0                                                     HTTR0140
       STBAVE # (STBI + TB2)*0.5                                        HTTR0145
       STWI#(STBAVE+STSAT)/2.0                                          HTTR0150
       STWO#(STBAVE+ STSAT)/2.0                                         HTTR0155
       STFI#(STBAVE+STWI)/2.0                                           HTTR0160
       STFO#(STSAT+STWO)/2.0                                            HTTR0165
       K # 0                                                            HTTR0170
       KK # 0                                                           HTTR0175
  110  SHI#.027*SKBFN(CBI,STBAVE)/SDI*(SDI*BB/BMUFN(CBI,STBAVE))**0.    HTTR0180
      18*(CPFN(CBI,STBAVE)*BMUFN(CBI,STBAVE)/SKBFN(CBI,STBAVE))**.333*(BMHTTR0185
      2UFN(CBI,STBAVE)/BMUFN(CBI,STWI))**.14                            HTTR0190
       RIN#AO/(SHI*AI)                                                  HTTR0195
CCCCC                                                                   HTTR0200
C      CALCULATE STEAM PROPERTIES (K,ROE,HFG,MU) AT TFO                 HTTR0205
CCCCC                                                                   HTTR0210
       AMOLSS#WS/18.015                                                 HTTR0215
       AMOLNC#WNC/AMWNC                                                 HTTR0220
       RMS#AMOLSS/(AMOLSS+AMOLNC)                                       HTTR0225
       RMA #AMOLNC/(AMOLNC+AMOLSS)                                      HTTR0230
       IF(RC-0.040)120,120,115                                          HTTR0235
  115  XNC # 1.0                                                        HTTR0240
       GO TO 125                                                        HTTR0245
  120  XNC#1.0-0.34316E2*RC+0.12268E4*RC**2-0.14923E5*RC**3             HTTR0250
  125  IF(ANF-1.0)130,130,135                                           HTTR0255
  130  XNF#1.310                                                        HTTR0260
       BNF# 1.0                                                         HTTR0265
       GOTO150                                                          HTTR0270
  135  IF(ANF-16.0)140,140,145                                          HTTR0275
  140  XNF#1.2379476+.35360826E-1*ANF-.15703466E-2*ANF**2               HTTR0280
       XNFP#1.2379476+.35360826E-01*(ANF-1.0)-.15703466E-02*(ANF-1.0)**2 HTTR0285
       BNF#ANF                                                          HTTR0290
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      GOTO150                                                           HTTR0295
  145 XNF#1.2379476+.3536U826E-1*16.0-.15703466E-2*16.0**2              HTTR0300
      XNFP # XNF                                                        HTTR0305
      BNF#16.0                                                          HTTR0310
  150 A#XNF*XNC                                                         HTTR0315
      KSTFO#0                                                           HTTR0320
CCCCC                                                                   HTTR0325
C        CALC. AVG. HEAT TRF COEFF AT BRINE CONC.#0                     HTTR0330
C                  3    2              8 0.25                           HTTR0335
C     SHM#0.725*( K *ROE *HVAP*4.17*10 )·    *A                        HTTR0340
C               ( BMU*SDO*DELTA T*BNF   )                               HTTR0345
CCCC                                                                    HTTR0350
  155 XNC2 # (100.0*RMA + 0.6) ** (-1.50 /(ABS(STSAT-STWO))**0.17)      HTTR0355
      XNC# AMIN1(XNC, XNC2)                                             HTTR0360
      A # XNC * XNF                                                     HTTR0365
      SHM#0.725*(SKBFN(0,STFO)**3*ROEFN(0.0,STFO)**2*HFGFN(STFO)*       HTTR0370
     1416975040.0/(BMUFN(0,STFO)*SDO*ABS(STSAT-STWO)*BNF))**.25*A       HTTR0375
      SHMK#0.725*(SKBFN(0,STFO)**3*ROEFN(0.0,STFO)**2*HFGFN(STFO)*      HTTR0380
     1416975040.0/(BMUFN(0,STFO)*SDO*ABS(STSAT-STWO)     ))**.25        HTTR0385
      SHMIN # SHMK * XNC * XNF3/ BNF3** 0.25                            HTTR0390
      IF(ANF-1.0)160,160,165                                            HTTR0395
  160 SHML#0.0                                                          HTTR0400
      GOTO170                                                           HTTR0405
  165 SHML # SHM*(BNF/(BNF-1.0))**0.25*XNFP/XNF                         HTTR0410
  170 SHNF # BNF*SHM-(BNF-1.0) * SHML                                   HTTR0415
      SHNF# AMAX1(SHNF, SHMIN)                                          HTTR0420
      CPMIX#CPAFN(TSAT)/AMWNC                                           HTTR0425
      AKMIX#AKAFN(TSAT)                                                 HTTR0430
      AMUMIX# AMUFN(TSAT)                                               HTTR0435
CCCC                                                                    HTTR0440
C     CALCULATE STEAM-AIR MIXTURE HEAT TRF COEFF., SHG                  HTTR0445
C                     0.33       0.6
C     SHG#0.33(CP*MU)    (SDO*G)   ( K )                                HTTR0455
C              (  K  )    ( MU  )   (SDO)                              HTTR0460
CCCC                                                                    HTTR0465
      SHG#0.33*(CPMIX*AMUMIX*3600.0/AKMIX)**0.33*(SDO*(WS+WNC)/         HTTR0470
     1 (3600.0*ALST*SDO*(SDD-1.0)*AMUMIX))**0.6*AKMIX/SDO               HTTR0475
      IF(SHM - SHG)  175,  180, 180                                     HTTR0480
  175 SHM # SHG                                                         HTTR0485
      SHML # SHG                                                        HTTR0490
      SHNF # SHG                                                        )TTR0495
  180 CONTINUE                                                          HTTR0500
      IF(RC-0.999)200,200,185                                           HTTR0505
  185 SHCGM#1.0/(QG/(QT*SHG)+1.0/SHML)                                  HTTR0510
      CALL DVCHK (KOOOFX)                                               HTTR0515
       GO TO(190,195),KOOOFX                                            HTTR0520
  190 WRITE (6,8000)SHML                                                HTTR0525
 8000 FORMAT(1H0, 20X, 21H DIV CHECK ON, SHML # , F5.2  )               HTTR0530
  195 CONTINUE                                                          HTTR0535
      SHCGN#1.0/(QG/(QT*SHG)+1.0/SHNF)                                  HTTR0540
      ROUT#1.0/SHCGN                                                    HTTR0545
      RTOT#RIN+ROUT+SHWINV+FOUL                                         HTTR0550
      VNF#1.0/RTOT                                                      HTTR0555
      VML#1.0/(RIN+1.0/SHCGM+SHWINV+FOUL)                               HTTR0560
      IF(SHML)205,205,215                                               HTTR0565
  200 ROUT#1.0/SHNF                                                     HTTR0570
      RTOT#RIN+ROUT+SHWINV+FOUL                                         HTTR0575
      VNF#(1.0/RTOT)                                                    HTTR0580
      IF(SHML)205,205,210                                               HTTR0585
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205 VML#0.0                                                          HTTR0590
    GOTO215                                                          HTTR0595
210 VML#(1.0/(RIN+1.0/SHML+SHWINV+FOUL))                             HTTR0600
215 CONTINUE                                                         HTTR0605
    IF(STSAT1-TB2)220,220,225                                        HTTR0610
220 ALMTD#ALMTD                                                      HTTR0615
    GOTO240                                                          HTTR0620
225 IF(STSAT2-STBI)230,230,235                                       HTTR0625
230 ALMTD#ALMTD                                                      HTTR0630
    GOTO240                                                          HTTR0635
235 ALMTD#((STSAT2-STBI)-(STSAT1-TB2))/ALOG((STSAT2-STBI)/(STSAT1-TB2)HTTR0640
   1)                                                                HTTR0645
240 DTFILM # VNF * ALMTD * ROUT                                      HTTR0650
    STWOP # STSAT - DTFILM                                           HTTR0655
    IF((ABS(STWOP-STWO)/(STSAT-STWO))-0.005)255,245,245              HTTR0660
245 STWO # STWOP                                                     HTTR0665
    STFO # STSAT - (STSAT - STWO)* 0.5                               HTTR0670
    KSTFO#KSTFO + 1                                                  HTTR0675
    IF (KSTFO - 20) 155, 250, 250                                    HTTR0680
250 ASS # 2.0                                                        HTTR0685
    WRITE (6,8005)KSTFO, KK                                          HTTR0690
8005 FORMAT(1H0, 8H KSTFO #, I3, 4H KK#, I3, 28H FILM TEMPS. NOT CONVERHTTR0695
   1GING.  )                                                         HTTR0700
    GO TO 310                                                        HTTR0705
255 QCND#VNF*AO*ALMTD                                                HTTR0710
    TB2P #QCND/(WB*CPFN(CBI,STBAVE))+STBI                            HTTR0715
    IF (K - 20) 265, 265, 260                                        HTTR0720
260 ASS#1.0                                                          HTTR0725
    GO TO 310                                                        HTTR0730
265 IF(ABS((TB2P  -STBI)/(TB2-STBI)-1.0)-.010)285,285,270            HTTR0735
270 TB2 # TB2P + (TB2 - TB2P) * 0.15                                 HTTR0740
    IF (STSAT- TB2) 275, 275, 280                                    HTTR0745
275 TB2 # STSAT- 0.5                                                 HTTR0750
280 K # K +1                                                         HTTR0755
    STBAVE#(TB2+STBI)*0.5                                            HTTR0760
    STWI#STBAVE+VNF*ALMTD*RIN                                        HTTR0765
    GOTO110                                                          HTTR0770
285 STBAVE#(TB2+STBI)/2.0                                            HTTR0775
    DELST#STSAT-STBAVE                                               HTTR0780
    TWIPM#STBAVE+(RIN+FOUL)/RTOT*DELST                               HTTR0785
    TFIPM#(STBAVE+TWIPM)/2.0                                         HTTR0790
    TWOPM#STSAT-ROUT/RTOT*DELST                                      HTTR0795
    TFOPM#(STSAT+TWOPM)/2.0                                          HTTR0800
    IF(ABS(TWIPM-STWI)-1.0)295,290,290                               HTTR0805
290 STWI#TWIPM                                                       HTTR0810
295 IF(ABS(TFOPM-STFO)-1.0)305,300,300                               HTTR0815
300 STFO#TFOPM                                                       HTTR0820
    KK # KK + 1                                                      HTTR0825
    IF(KK-20) 110, 110, 250                                          HTTR0830
305 CONTINUE                                                         HTTR0835
310 RETURN                                                           HTTR0840
    END                                                              HTTR0845
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$IBFTC PDRP     DECK                                                    PDRP0000
C** THIS PRSDRP CALLS FOR EXTENDED TABLE                                PDRP0005
C       SUBROUTINE PRSDRP                                               PDRP0010
        SUBROUTINE PRSDRP(TSAT,PSAT,PMIX,WS,WL,WNC,AXO,AMOLS,AMOLSC,    PDRP0015
       1NERR,DELPTP,WCND,TPOG,ALVF,LJ)                                  PDRP0020
        DIMENSION COOR(3)                                               PDRP0025
        COMMON  SDO     , STBI    , AI      , AO      , AW      , SHWINV PDRP0030
        COMMON  FOUL    , CBI     , SDI     , AXI     , WB      , HFG   PDRP0035
        COMMON  SDD     , STB2ES  , GB      , VG      , AMWNC   , STFO  PDRP0040
        COMMON  TB2     , STBAVE  , VNO     , J       , XNC     , SF    PDRP0045
        COMMON  COOR    , JRC                                           PDRP0050
C       DIMENSION COOR(3)                                               PDRP0055
C       COMMON SDO,STBI,AI,AO,AW,SHWINV,FOUL,CBI,SDI,AXI,WB,HFG,SDD,STB2ESPDRP0060
C      1,GB,VG, AMWNC,STFO,TB2, STBAVE, VNO, J, XNC                     PDRP0065
C       COMMON SF, COOR, JRC                                            PDRP0070
CCCCC                                                                   PDRP0075
C       CALCULATES STEAM PROPERTIESUS,VS, AT TSAT(I),PSAT(I)            PDRP0080
C       CALCULATE WATER PROPERTY VR AT TSAT(I)                          PDRP0085
        STSAT#TSAT - 459.69                                             PDRP0090
        SG#32.174                                                       PDRP0095
        IF (WNC ) 105, 105, 100                                         PDRP0100
  100   AMNC# AMWNC                                                     PDRP0105
        VNC#10.729*TSAT/((PMIX-PSAT)*AMNC)                              PDRP0110
        UNC#AMUFN(TSAT)                                                 PDRP0115
        VMIX#1.0/(((AMOLSC/(VNC*(AMOLSC+AMOLS)))+(AMOLS/(VG*(AMOLSC+AMOLS))PDRP0120
       1))                                                              PDRP0125
        GO TO 110                                                       PDRP0130
  105   VMIX # VG                                                       PDRP0135
  110   GSTAR#(WL+WS+WNC)/(AXO*3600.0)                                  PDRP0140
        ANRE#(SDO*GSTAR)/SMUFN(TSAT)                                    PDRP0145
        COOR(1) # ANRE                                                  PDRP0150
        IF(ANRE-2000.0)115,130,130                                      PDRP0155
  115   IF(ANRE-100.0) 120, 125, 125                                    PDRP0160
C  LAMINAR FLOW FRICTION FACTOR, SF                                     PDRP0165
  120   SF # 70.0*(1.0/SDD)**1.6/ANRE                                   PDRP0170
        GO TO 210                                                       PDRP0175
C  TRANSITION FLOW FRICTION FACTOR, SF                                  PDRP0180
  125   SF # (1.0/SDD)**2/ALOG10(ANRE - 81.0)                           PDRP0185
        GO TO 210                                                       PDRP0190
  130   COOR(1)#ANRE                                                    PDRP0195
  135   IF(COOR(1)-80000.0) 145, 145, 140                               PDRP0200
  140   COOR(1)#80000.0                                                 PDRP0205
  145   IF (LJ - 6) 150, 150, 155                                       PDRP0210
  150   COOR (2)# 0.50 * SDD                                            PDRP0215
        COOR (3) # SDD * 1.732                                          PDRP0220
        GO TO 160                                                       PDRP0225
  155   COOR (2) # SDD * 0.866                                          PDRP0230
        COOR (3) # SDD                                                  PDRP0235
  160   IF(COOR(3)-1.15)170,165,165                                     PDRP0240
  165   IF(COOR(3)-3.5)180,180,175                                      PDRP0245
  170   COOR(3)#1.15                                                    PDRP0250
        GOTO180                                                         PDRP0255
  175   COOR(3)#3.5                                                     PDRP0260
  180   IF(COOR(2)-.7)190,185,185                                       PDRP0265
  185   IF(COOR(2)-1.2)200,200,195                                      PDRP0270
  190   COOR(2)#.7                                                      PDRP0275
        GOTO200                                                         PDRP0280
  195   COOR(2)#1.2                                                     PDRP0285
  200   CALLINTPL2(COOR(1),SF,NERR,JRC)                                 PDRP0290
```

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205 IF(NERR)215,210,215                                          PDRP0295
210 ALVF#1.0/(VLFN(0.0,STSAT)/VMIX+(WS+WNC)/(WL+WCND))           PDRP0300
    TPOG#TPOGFN(ALVF)                                            PDRP0305
    DELPFS#4.0*SF*GSTAR**2*VMIX/(2.0*SG*144.0)                   PDRP0310
    DELPTP#DELPFS*TPOG                                           PDRP0315
215 CONTINUE                                                     PDRP0320
    RETURN                                                       PDRP0325
    END                                                          PDRP0330
```

APPENDIX F

REFERENCE LIST OF CONDENSER DESIGN REPORTS

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REFERENCE LIST OF CONDENSER DESIGN REPORTS

1. American Heat Exchange Institute.

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APPENDIX G

COMPUTER PROGRAM DIAGNOSTIC STATEMENTS

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COMPUTER PROGRAM DIAGNOSTIC STATEMENTS

Most programmers, during the writing of a computer code, will insert diagnostic checks in locations where the computations could logically cause trouble. Examples might be where division by zero could occur or where iterative calculations could repeat endlessly. Since there are several iteration type calculations imbedded in the steam condenser codes, several diagnostic messages were inserted to assist in the location of trouble spots.

The source of most errors will probably be faulty input data, and the exercise of due care in this area cannot be overemphasized.

The following compendiums of diagnostic messages do not define error sources, but do indicate the area of the program where an error has begun to cause trouble. Under normal circumstances these messages will rarely be encountered.

CNDNSR (MAIN RØUTINE)

1. (Case Identification) - NO CONVERGENCE FOR WCND (I,J) - The iterative computation for the weight of condensate in the condenser from the Ith tube row of the Jth sector did not converge to within the required 0.5 percent after 50 iterations. Execution concludes with a printout of the computations made up to this point. This error message is located near program statement number 355.

2. (Case Identification) - NO CONVERGENCE FOR QG (I,J) - The iterative computation for balancing the heat transferred from the noncondensable gases at the Ith tube row of the Jth sector did not converge to within the required ten percent after 10 iterations. This is located near statement number 400. Computation will continue but the results will be unreliable.

3. (Case Identification) - NO CONVERGENCE IN COND. DELTA P (IPLOOP) - The iterative computation to balance the pressure drop between the representative flow sectors did not converge to within the required one percent after 10 iterations. Execution concludes with a printout of the computations made to this point. This message is located near statement number 465.

4. (Case Identification) - NO CONVERGENCE FOR TB2 IN HEAT TRANSFER ROUTINE - The iterative computation which computes the downstream (hot) coolant (brine) temperature did not converge to within the required one percent after 20 iterations. Execution concludes with a printout of the computations made up to this point. The message initiates near program statement number 305 if an error occurs during condenser section calculations or statement number 545 if an error occurs in the cooler computations.

5. (Case Identification) - ERROR IN INTPL2 WHICH IS CALLED BY PRSDRP - The occurrence of this message should be extremely rare and indicates a failure in communication between subroutines which compute pressure drop through tube banks. This message is initiated near statements numbers 310 or 555 for computations in the condenser or cooler sections, respectively.

6. NO CONVERGENCE FOR WCNDC (I) - Error occurred at I^{th} row in the cooler section (see 1, above) near statement number 610 in the main program.

7. (Case Identification)

I = NUMBER

NO CONVERGENCE FOR QGC (I) - Error occurred at I^{th} row in the cooler section (see 2, above) near statement number 630.

8. NO CONVERGENCE FOR EXITFR AFTER 5 TRIES - The iterative computation which adjusts the tube bundle length has failed to obtain an exit steam fraction which is less than 25 percent of the specified exit fraction (see Input Data, item EXITFR). Computations conclude with a printout of the computations made up to this point. This message is near statement number 655.

HETTRN (SUBROUTINE)

1. KSTFO = iii KK = kkk FILM TEMPS. NOT CONVERGING - This message is generated near subroutine statements numbers 380 and 435 and occurs occasionally when log mean temperature differences are very small. The condenser bundle under consideration is probably overdesigned and no EXITFR has been specified.

2. IDIV = iiii - An attempt was made to divide by zero at some point in the subroutine. See subroutine listing above the point where IDIV = iiii to locate the trouble spot.

PRSDRP (SUBROUTINE)

1. See INTPL2 error message in CNDNSR (MAIN ROUTINE), item 5.

NOTE: There is a combination of conditions which can seem to result in unrealistically high pressure and/or temperature losses through the system being considered. This combination is:

(1) EXITFR = 0.0. (i.e., the exit steam fraction option has not been exercised), and

(2) The computed exit steam is less than 0.5 percent of the input steam (i.e., the tube bundle is overdesigned).

The effect of these conditions is enhanced when the amount of non-condensables has been specified as zero (i.e., WNCI = 0.0).

Actually, the high pressure and/or temperature losses are realistic because the program assumes the exit pressure condition can be controlled (by throttle or vacuum system); and, as steam condensation approaches 100 percent, the vapor temperature approaches the condensing film temperature which, in turn, very rapidly approaches the coolant temperature. The saturation vapor pressure at, or near, the coolant temperature is, generally, quite low with respect to the entering steam vapor pressure. Thus, the pressure drop through the system is large and serves to indicate that a better design is possible. The optimum condenser should contain less condensing tube surface.

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