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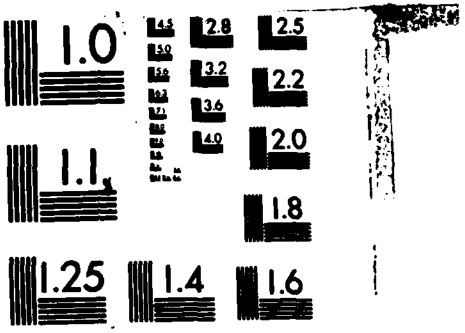

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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

MARINE STEAM CONDENSER DESIGN OPTIMIZATION

by

Thomas M. Buckingham

December 1983

Thesis Advisor: R. H. Nunn

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Marine Steam Condenser Design Optimization

by

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Lieutenant, United States Navy
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requirements for the degree of

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ABSTRACT

A surface-condenser analysis code was coupled with a constrained function minimization code to produce an automated marine condenser design and optimization package. The program, CONDIP, was based on the principles developed in ORCON1, a sophisticated computer code produced by the Oak Ridge National Laboratory. CONMIN, the optimization program, was developed at the Ames Research Center.

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I. INTRODUCTION

A. BACKROUND

For many years the steam plant was unchallenged in its role as the primary type of marine propulsion systems. But recently gas turbines have become a desirable alternative despite the fact that they are less efficient than comparable steam plants. The primary advantage of gas turbines is their light weight and compact size. Thus, in order for the marine steam plant to survive, it is imperative that lighter, more compact and efficient steam plants be developed.

While there are numerous advanced concepts in all areas of steam propulsion which can be explored, one simple way to streamline the steam plant is the elimination of overdesign. Most overdesign is due to unnecessary safety factors used to offset lack of detailed knowledge about the thermal processes in the plant. Identification of the minimum safe design could significantly reduce unnecessary overdesign and result in the development of a smaller, more compact power plant.

B. METHODOLOGY

In the United States the most prevalent criterion for the design and specification of surface condensers is based on the "square-root of V" relationship, as developed by the Heat Exhange Institute (HEI) [Ref. 1]. The HEI method was adopted by the Department of the Navy Bureau of Ships (now Naval Sea System Command) for specification of U.S. Naval condensers.

The HEI method is very simple in its approach, calculating the overall heat transfer coefficient as a function of cooling water velocity through the tubes, inlet coolant temprature, tube wall thickness and material, and fouling. The limitations of this method are apparent. Designs based on HEI are insensitive to shell-side conditions. Saturation steam pressure, temperature and enthalpy are assumed to be constant as steam passes through the bundle, whereas in reality there is a continual pressure drop as steam flow passes over the rows of tubes, with a corresponding decrease in saturation temperature. There is also no provision for any effects of condensate film, external tube enhancement, etc. on the shell-side of the bundle. In addition, the HEI method does not account for the presence and effect of non-condensible gases that inevitably contaminate a condenser.

With the capabilities of high speed computers now available, more comprehensive methods have been developed to account for the deficiencies of the HEI method. In particular, a radial flow computer code was developed to calculate the local heat transfer and thermodynamic properties on a row by row basis. Known as ORCON1, this code was developed by Oak Ridge National Laboratory (ORNL) under contract to the Office of Saline Water during the period from 1968-1970 [Ref. 2]. The program was based , in part, on the work performed by Eissenberg [Ref. 3]. Eissenberg's experimental results led to correction factors on the basic Nusselt equation to account for condensate inundation effects on tubes within a condenser bundle. Basically, ORCON1 divides the condenser into sectors and performs a row by row analysis within each sector, determing local heat transfer coefficients, heat flux, steam charactaristics, the affect of condensate inundation and numerous other parameters at each row. ORCON1 is also capable of incorporating the effects of both tube-side and steam-side enhancement factors. Since

ORCON1 represented a much more comprehensive and detailed analysis of the condenser then the less exact HEI method, its results could be expected to be more precise.

Some work has been done at the Naval Postgraduate School to improve the capabilities of ORCON1. In his developement of OPCODE2, Johnson [Ref. 5] added subroutines to ORCON1 which calculated tube-side pressure drops, corresponding pumping power and condenser volume. Nunn and Marto [Ref. 14] have incorporated the effects of vapor shear in an amended version of ORCON1 called MORCON. MORCON includes the correlations developed by Fujii [Ref. 4] to determine the effect of vapor velocity on the thermal resistance of the condensate film on the condenser tubes. In general, vapor shear effects tend to enhance the condenser heat transfer on the steam-side of the tube while condensate inundation tends to inhibit it.

The ability to represent numerically the actual thermodynamic processes occurring within the condenser has improved dramatically. However, the capability to couple these increasingly comprehensive and complex condenser design programs with an optimizing procedure has not made comparable progress. Optimization is a powerful tool which can help in reducing overdesign and achieving the goal of a safe compact condenser design.

There are currently numerous computer optimization programs available which can be coupled with general design programs of all types to numerically improve and ultimately determine the best design. The key is to properly write the design program so that it is compatible with the optimizer. Johnson [Ref. 5] developed a computer program called OPCODE1, based on the HEI method of condenser design, and was able to couple it with one such numerical optimizer. The results of OPCODE1 demonstrated how condenser designs can indeed be safely improved upon. It also revealed the versatility of condenser design optimization as a powerful design tool. However, Johnson was unsuccessful in coupling OPCODE2 (his derivative of ORCON1) with an optimizer. This failure does not alter the fact that that in order to fully appreciate more sophisticated condenser design analyses, such as that used in ORCON1, it is imperative that computer programs be developed which will be compatible with current numerical optimizers.

C. OBJECTIVE

There were two primary objectives of this thesis. The first objective was to develop a computer code which incorporates the basic condenser analysis of ORCON1 and the subsequent improvements made in MORCON and OPCODE2, but which will be capable of being coupled with a numerical optimizer to yield a complete, detailed design package. This design package can then be used as a tool in obtaining a much more reasonable conceptual design and for use in comparison studies. It would provide the naval architect the ability to optimize weight, volume, cost or any other potential design objective of the marine plant.

The second objective was to make this design package capable of determining the single best design rather than simply an improvement over the initial design. The key was to construct the program in such a way so the optimizer does not stop at some relative optimum, but continues the analysis until no further improvement can be realized. It is most desirable to be able to reach this single true optimium design regardless of initial design variable values.

II. NUMERICAL OPTIMIZATION

A. BACKGROUND

Nearly all design problems require either the minimization or maximization of a parameter. This parameter will be called the problem's objective function or design objective [Ref. 6]. For a given design to be feasible or acceptable, it must satisfy a set of design constraints which are either maximum or minimum limiting values for a pre-determined set of parameters or functions of parameters. For example, in any condenser design the outer diameter of a condenser tube can never be less than zero and there is normally some practical upper limit which also cannot be exceeded. These limits are design constraints on the tube outer diameter. In the design problem there is also a set of design variables which are parameters whose values can be changed within specified limits in order to minimize or maximize the design objective. For example, in minimizing the condenser volume an engineer may want to vary tube inner diameter, tube wall thickness and tube length. These three parameters would thus be examples of typical design variables.

For such complex design problems as the treatment of the condenser design in ORCON1, it is necessary to choose an optimization scheme which can handle the problem and provide a rational, rapid approach to design automation and optimization. An optimization program based on direct methods for solution of constrained problems [Ref. 11] was chosen for this research work.

B. CONSTRAINED FUNCTION MINIMIZATION (CONMIN)

Vanderplaats [Ref. 7] developed an optimization program, CONMIN, capable of optimizing a very wide class of engineering problems. CONMIN is a fortran program, in subprogram form, that optimizes a multi-variable function subject to a set of inequality constraints.

It is practical at this point to introduce three basic definitions and their respective conditions [Ref. 8].

DESIGN VARIABLES: Those parameters which the optimization program is permitted to change in order to improve the design. Design variables appear only on the right side of an equation, are continuous, and have continuous first derivatives.

DESIGN CONSTRAINTS: Any parameter which must not exceed specified bounds for the design to be acceptable. Design constraints may be linear or nonlinear, implicit or explicit, but they must be functions of the design variables. Design constraints appear only on the left side of equations.

OBJECTIVE FUNCTION: The parameter which is going to be minimized or maximized during the optimization process. The objective function may also be either linear or nonlinear, implicit or explicit, and must be a function of the design variables. The objective function usually appears on the left side of an equation. The only exception is if the objective function is also a design variable.

Assuming that the optimization process requires the minimization of a particular objective function the general optimzation problem can be stated as:

Find the vector of design variables, $\underline{X}$,
To minimize the objective function, $F(\underline{X})$,
Subject to the constraints:

$$G_j(\underline{X}) \le 0.0 \qquad j = 1,NCON \qquad \text{(eqn 2.1)}$$

$$VLB_i \le \underline{X} \le VUB_i \qquad i = 1,NDV \qquad \text{(eqn 2.2)}$$

In the general problem, $G_j(\underline{X})$ are the constraint functions; there are NCON constraints and NDV design variables; VLB_i and VUB_i are the lower bounds and upper bounds of the i-th design variable. If the equality condition is met, $(G_j(\underline{X})=0.)$, the constraint is active. If the inequality is met, $(G_j(\underline{X})<0.)$, the constraint is inactive. Finally, if the inequality of equation 2.1 is violated, $(G_j(\underline{X})>0.)$, that constraint is said to be violated. Because of numerical inaccuracies representing exact zero on the computer, the equality condition is represented by a band around the value $G_j(\underline{X})=(0.\pm CT)$ where CT is the constraint thickness.

Any design which satisfies the inequalities of equations 2.1 and 2.2, thus having no violated constraints, is said to be feasible. If the design violates any of these constraints it is said to be an infeasible design. The design which best minimizes the objective function while still remaining feasible is said to be optimal.

CONMIN requires an initial set of values for the design variables $\underline{X}$ to obtain an initial design which is either feasible or infeasible. If the initial design is feasible, CONMIN moves in a direction which will minimize the objective function. If the initial design is infeasible, CONMIN moves toward a feasible solution with minimal increase in the object function.

The optimization process proceeds in an iterative fashion. Johnson [Ref. 5] presents in greater detail the procedures utilized in CONMIN to search for the minimum objective value. In general, the methods used by CONMIN to determine search direction include the method of steepest descent, the method of conjugate direction, and the method of feasible directions. For further background concerning CONMIN and the numerical techniques utilized in optimization, consult Vanderplaats [Ref. 7], Fletcher and Reeves [Ref. 9], Zoutendijk [Ref. 10], and Vanderplaats and Moses [Ref. 12]. However, it is necessary to stress a few pertinent points which will aid in understanding how the program was developed in this thesis.

The optimization process begins by calculating the gradient of the objective function using a finite difference technique. A perturbation is applied to each of the design variables in a single forward step and the gradient vector is determined.

$$\Delta F(\underline{X}) = \begin{bmatrix} \frac{\partial F(\underline{X})}{\partial X} \\ \\ \frac{\partial F(\underline{X})}{\partial X} \end{bmatrix}$$

The search direction is then calculated and is a function of this gradient and any active or violated constraints resulting from the applied perturbation. Subsequent search directions are a function of previous search directions, as well as current gradient information and any appropriate constraint factors. Obviously, the size of the perturbation and the size of the bandwidth about an active constraint will have a great deal of effect on the search direction and ultimate optimization process. This detail will be recalled later-on during the code development.

There are some limitations to CONMIN. The number of design variables (NDV) directly affects the computational time required to reach an optimum. Since the calculation of the gradient information required for each design variable at the beginning of each design iteration is found by using a single forward finite difference step, requiring a complete pass through the analysis portion of the program, there is an increase in CPU time as NDV inceases. Also, as NDV increases, there is the corresponding rise in machine related numerical innacuracy. Vanderplaats [Ref. 6] recommends no more than twenty as a practical limit for the number of design variables.

It is quite possible that while design improvement may be obtained, the single best design optimum or true optimum may not be reached. This is not an uncommon occurrence and there are several possible explanations. For example, the design problem may not be formulated properly or the analysis may be extremely complex and non-linear. However, a more common reason is that there are "relative optimums" between the initial design and the single true optimum. This concept of relative vs true optimum design can be better explained through an analogy. The search for the best optimum design can be likened to a blind man climbing to the top of a mountain. The blind man knows he is proceeding up the mountain by sensing the direction of ascent. However, the paths he takes may be limited by barriers or fences which will restrict the directions he can go. These fences represent constraints in the optimization problem. During the journey he may also encounter small crests and valleys. If the available paths lead the blind man up to one of these crests prior to reaching the mountain top, he will be confronted with a situation where he will sense no further rate of ascent and he will stop his journey. So although he has made progress from his initial starting point, the man did not achieve his ultimate goal of climbing the mountain.

During optimization, the search for a true optimum may proceed along a path on which the objective function assumes such relative optimum values. If the optimizer can not be made to "look beyond" these relative peaks, then the optimization will cease - at a design which may be an improvement over the initial one but short of the true optimum. This problem may be overcome by starting the design with several different initial design vectors, $\underline{X}$, until the same optimal design is repeated. Another alternative may be to increase the size of the finite difference so that the optimizer uses larger perturbations of $\underline{X}$ thus looking beyond any small increases in the objective function which could stand in the way of further design progress. This second alternative will be specifically addressed during the discussion of the code development.

C. CONTROL PROGRAM FOR ENGINEERING SYNTHESIS (COPES)

The optimizer, CONMIN, was written in subroutine form. Vanderplaats [Ref. 13] has developed a main program to simplify the use of CONMIN and aid in the design optimization process.

The user must supply an analysis subroutine called ANALIZ, which consists of three segments: input, analysis and output. COPES acts as an interface between ANALIZ and the optimizer CONMIN. Based on a flag from COPES (ICALC=1,2,3) ANALIZ performs the proper function. Figure 2.1 offers a simplified illustration of the interrelationship between COPES, ANALIZ and CONMIN.

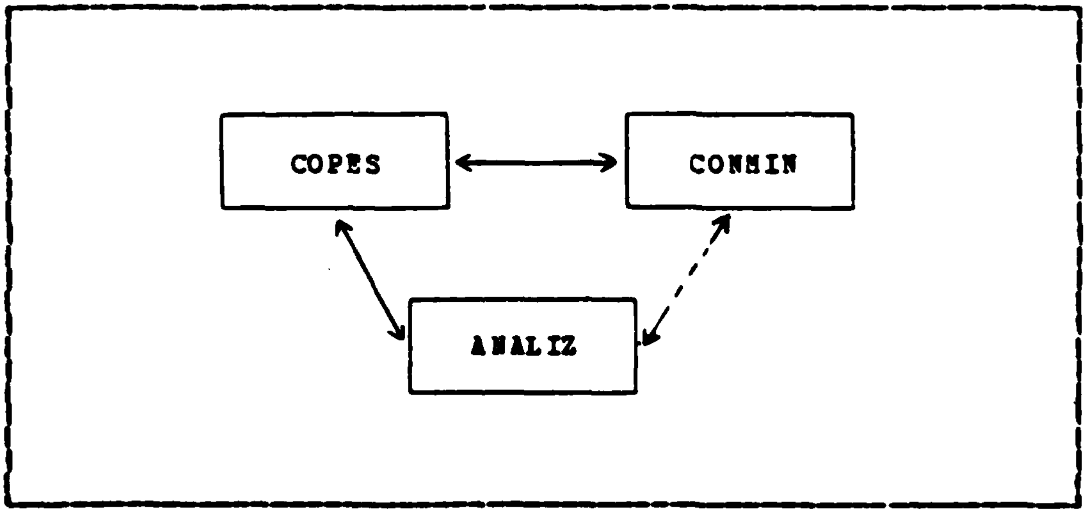


Figure 2.1 Flow Diagram For ANALIZ and COPES/CONMIN.

COPES currently provides four specific capabilities, two of which will be applied in this work:

1. Single analysis - just as if COPES/CONMIN were not used.

2. Optimization - minimization or maximization of a multivariable function with corresponding constraints.

COPES requires certain initial data from the user in order to coordinate the optimization process. Initial values for the design variables as well optimizer control parameters are utilized by CONMIN to conduct its numerical analysis. There are a few optimizer parameters which are particularly important to the treatment of condenser designs. One is the finite difference step used in gradient calculations. Another is the normalization factor used in COPES evaluation of a constraint function. COPES utilizes the following expressions in determining constraint function violations:

$$\frac{BU - CPV}{SCAL1} \leq 0.$$

$$\frac{CPV - BL}{SCAL2} \leq 0.$$

where SCAL1 and SCAL2 are the normalization factors, BU and BL are the upper and lower limits of the constraint, and CPV is the constraint function value. It is intuitive that the normalization factor can play an important role in determining the size of the active region about a given design constraint. Both finite difference and constraint normalization will be recalled later during the code development.

The power of COPES is that it has simplified the procedures involved in using a sophisticated program such as CONMIN. The user is therefore fread from the unwanted role of systems analyst and can concentrate on the design analysis.

III. CONDENSER DESIGN IMPROVEMENT PROGRAM (CONDIP)

A. BACKGROUND

In the late 1960's, engineers at the Oak Ridge National Laboratory developed a sophisticated computer code under contract to the Office of Saline Water. This code, called ORCON1, [Ref. 2] was generated to aid in the analysis and parametric study of large, generally circular condensers. Much of ORCON1 was dependent on Eissenberg's research work [Ref. 3] on the effects of condensate rain on the shell-side convective heat transfer coefficient. Johnson [Ref. 5] took ORCON1 and made a few minor modifications to determine tube side pressure losses and volumetric calculations. Nunn and Marto [Ref. 14] further incorporated the correlations proposed by Fujii [Ref. 4] to determine the effects of shearing forces exerted by high vapor velocities on the condensate film and resulting shell-side heat transfer coefficient.

It was at this point that the development of CONDIP was begun. CONDIP was dependent primarily on the principles detailed in ORCON1 but also incorporated subsequent developments to the basic program. CONDIP was written , however, in such a way as to be compatible with the optimizer, CONMIN.

CONDIP analyzes a single or double pass, circular or semicircular condenser, with steam flowing radially inward on the shell-side of the tubes and variable salinity water flowing on the tube-side. An optional, rectangular air cooler bundle is provided-for as well as shell-side baffles. The circular bundle is normally divided into 30-degree sectors with symmetry about the central axis to reduce computational effort. Unless otherwise specified, tubes are placed on a 60-degree equilateral, triangular pattern of concentric rows with the rows added from an inner void out to the outermost row. The void serves as a collection header for non-condensible gases prior to passage through an air cooler, if specified. As in ORCON1, CONDIP proceeds sector by sector, row by row through the condenser utilizing an average tube to represent the row segment, and calculates the following quantities in each sector:

a) Steam pressure losses at the entrance of a sector.

b) Total pressure of the steam/non-condensible gas mixture entering a row segment.

c) Saturation pressure of steam entering a row segment.

d) Saturation temperature of the steam entering a row segment.

e) Steam flow entering the row segment.

f) Velocity of the steam/non-condensible gas mixture at the minimum cross-section in the row segment.

g) The fraction of non-condensible gas in the mixture by weight.

h) The overall heat transfer coefficient for the average tube in the row segment.

i) The steam-side condensing coefficient.

j) The tube-side heat transfer coefficient.

k) The shell-side film heat transfer coefficiant composed of the non-condenible gas film and the condensate film.

l) The shell-side friction factor.

m) The shell-side pressure loss as steam passes over the row segment.

n) The shell-side Reynolds number based on the mass flow at the minimum cross-sectional area in the row segment.

o) The heat transfer rate per square foot of condenser tube.

p) The mass flow rate of steam/non-condensable gas mixture at the minmum cross-section in the row segment.

q) The mass flow of condensate produced as steam passes over the row segment.

r) The cooling water temperature at the outlet end of the condenser.

s) The coolant pressure loss on the tube-side.

t) The average Reynolds number of the coolant through the tube.

u) The heat transfer coefficient for the non-condensible gas film.

v) The internal heat film heat transfer coefficient.

w) The number of tubes per row segment.

x) The cross-section area available for steam flow per row segment.

y) The cumulative shell-side pressure drop.

z) The LMTD based on inlet and outlet coolant temperatures and saturation temperature at each row segment.

In addition to the above paramaters, the area-weighted overall heat transfer coefficients for the condenser, cooler and combined condenser are used to calculate the "back calculated" log mean temperature difference (LMTD). Steam exit-fraction, condenser volume, coolant pumping power and numerous other factors are calculated from the cumulative results of the row and sector analysis.

There are two significant contributions to the external film heat transfer coefficient which have a profound impact on the overall analysis. As mentioned earlier, Eissenberg [Ref. 3] corrected for condensate inundation effects on the external heat transfer coefficient with a series of emperical relations. He created a flooding factor F using the following relation:

$$F_n = .6F_d + (1 - .5647\ F_d)n^s \qquad \text{(eqn 3.1)}$$

where F_d is a constant indicating the effect of tube spacing and orientation on condensate side drainage. With closely packed tubes, significant side drainage can occur in low velocity steam flow. Condensate generated on tubes above may, due to surface tension effects, proceed laterally to adjacent tubes rather than down. Thus F_d tends to approach 1.0 for closely packed, staggered tube bundles and zerc for disperse bundle layouts. S is a constant ranging in value from:

$$(.07 < S < .25)$$

If the condensate rain is acting under the influence of gravity alone S approaches 0.25. But the influence of any steam velocity present begins to alter the rate and direction of condensate flow and correspondingly decrease S. Thus S is a function of vapor velocity and directon, as well as bundle geometry.

The condensate film coefficient for the average tube in the n-th vertical rcw is then calculated from the uncorrected heat transfer coefficient, h_o, as follows:

$$h_n = [nF_n - (n-1)F_{n-1}]\,h_o \qquad \text{(eqn 3.2)}$$

It is obvious that the determination of a corrected heat transfer coefficient is highly dependent on the choice of S an F_d in equation 3.1. S and F_d are extremely subjective constants and there does not exist a current analytical expression to determine them. Yet the choice of these constants can have profound impact on the condenser design. In CONDIP, as in ORCCN1 [Ref. 2], the following, relatively conservative values for S and F_d were used:

$$S = 0.2$$

$$F_d = 0.5$$

An additional important contribution to the external film coefficient is the effect of velocity shear forces on the condensate film. Fujii [Ref. 4] developed the following experimental correlations to correct the Nusselt number for the effect of velocity shear:

$$[Nu_m/Nu_o] = c_1 Nu_o^{(4a-1)} Re_L^{(.5-2a)} \qquad \text{(eqn 3.3)}$$

where Nu_m is the mean Nusselt number, Re_L is the two-phase Reynolds number (based on vapor velocity, tube outside diameter and kinematic viscosity of the condensate) and Nu_o is the standard Nusselt number for the zero shear case. The empirical constants c_1 and a lie within the following ranges:

$$1.13 < c_1 < 1.24$$
$$0.196 < a < 0.2$$

depending on how tube thermal conditions are described. In CONDIP the values for c_1 and a were:

$$c_1 = 1.24$$
$$a = 0.2$$

It should be noted that equation 3.3 is only valid in the range:

$$3.3 < (Re_L/Nu_o) < .28.$$

For smaller values of this parameter Fujii recommends the use of a slightly reduced value of the standard Nusselt number:

$$Nu_m = 0.96\ Nu_o \qquad \text{(eqn 3.4)}$$

It is apparent that the vapor velocities commonly encountered in naval condensers can have an impact on the heat transfer coeffcient.

B. CODE DEVELOPMENT

Johnson [Ref. 5] attempted to couple OPCODE2 (his version of ORCON1) with the optimizer CONMIN, but with little success. There were several reasons for this.

ORCON1 uses iterative techniques to solve for such quantities as condensate rate, steam mass flow rate and steam pressure through the sector. If unrealistic values are encountered, such as negative pressures or steam flow, or if the final steam exit-fraction exceeds a predetermined value, ORCON1 stops the analysis, returns to the beginning of the program and changes certain initial input parameters. The analysis begins again and the process is repeated until a satisfactory design is achieved. Thus ORCON1 has a limited capability to make design decisions to obtain a feasible design.

CONMIN, as do most optimizers, requires complete control in determining all iterative design variable values. As explained earlier, it uses perturbation techniques to calculate gradient information for each design variable and active design constraint, which it then uses to determine search directions. A perturbation of the design variable by CONMIN requires a complete, once-through analysis. If ORCON1 is coupled with CONMIN then any adjustment by ORCON1 will yield false gradient information to the optimizer and hinder, if not completely prevent, CONMIN from arriving at the optimum design. During program development it became apparent that the two programs were working independently against each other and that in its present state ORCON1 was incompatible with CONMIN.

In the formulation of CONDIP, it was necessary to locate and neutralize all the places where such design decisions are made. By removing the ability for CONDIP to make any design decisions it became totally passive and dependent on CONMIN for design variable changes.

However, once this was accomplished, another problem area was discovered. In the ORCON1 code and subsequently in CONDIP there are numerous thermal process and properties calculations that use logarithmic functions and other mathematical relationships which could produce singularities if the variables in the arguments approach zero or are negative. For example, saturation steam temperature is calculated from steam pressure using a logarithmic relationship. If, during a design analysis, saturation pressure approaches a negative value, this represents a clear violation of physical realities and of the limits of that property. Yet a computer cannot make that distinction so it tries to calculate the corresponding saturation temperature which, because of the logarithmic relationship, would be undefined. As just explained, ORCON1 with its built-in decision capability simply starts over when this situation is encountered. But CCNDIP, being completely dependent on CONMIN for design decisions, does not have that capability. Remembering that CONMIN requires a complete once-through analysis in order to collect enough information to make a design decision, it was necessary to somehow bypass such mathematical instabilities in order to keep the program operating. Yet the analysis still had to yield reasonable results from the given design in order to obtain meaningful gradients. This prompted the formulation of mathematical relationships to create "penalty" constraints which, if properly written, would indicate to the optimizer that a function or thermal property has violated its physical limits. However, not only would penalty constraints have to be defined, but a "fix up" or "correction" of the violated property or variable would be required in order to allow the analysis to continue. A good physical understanding of the inter-relationship between condenser parameters and the thermal processes resulting from the condenser design is necessary so that the "fix up" of the violated property would still yield fairly accurate condenser information on which CONMIN could base its search for the optimized design.

For example, a condenser is usually designed around a given steam load. If the condenser has too many tubes, is too long, or coolant flow is too great, then the condenser will be overdesigned. There will be dry tubes within the condenser as all the steam is condensed before steam flow reaches the inner void. In CONDIP this means that zero or negative steam flow will be encountered in the analysis.

If, on the other hand, tube surface area is too small, coolant flow is inadequate or the condenser tube spacing is too tight and is choking the steam flow, then one of two things will happen. Either a quantity of uncondensed steam will make it completely through the condenser, or steam pressure loss in the condenser will cause steam pressure to drop below zero. In addition, there are two reasons why all the steam might not condense. It could be simply due to insufficient heat transfer surface area or it could be because the saturation temperature of the steam has dropped below the coolant inlet temperature. If the latter situation occurs, then there is no driving force for heat to transfer from the steam to the coolant. There is only one way that this situation can occur: if steam saturation pressure drops below some value indirectly determined by the coolant inlet temperature. In any event this condenser is certainly underdesigned and not capable of supporting the required steam load.

As stated earlier, the purpose of optimization is to obtain the best, feasible design. Thus, an understanding of the relationship between the physical characteristics of a given design and the subsequent thermal performances will certainly help in defining the appropriate penalty constraints and their corresponding limits. It will also aid in the determination of appropriate "corrections" when those limits are violated. It is important to note that with the introduction of these penalty constraints, the definition of a feasible design is revised. A feasible design is now defined as one in which thermal properties and functions are not allowed to violate their physical limits, as well as other design constraints, anywhere in the condenser.

In CONDIP there are three basic thermal properties which could create the above mentioned problems if they fall below a certain value. They are steam saturation pressure, steam flow and steam temperature. Because of the direct relationship between steam saturation pressure and temperature, it was possible to deal with them simultaneously. The solutions that were developed to overcome the effects of these thermal violations determined the extent which CONDIP would optimize.

1. Steam Flow Effects

One source of mathematical instabilities within the program is if steam flow over the tubes falls to zero or below. It is intuitively obvious that steam flow can not physically fall below zero and that in order to keep the program running the steam flow rate must be kept greater than zero. However, correcting for this alone would certainly alter the results of that particular condenser design, perhaps even imply a feasible design.

To indicate to the optimizer an infeasible design was actually encountered - one in which steam flow had dropped below zero - the penalty function WTST was created. Since the condenser analysis is performed sector by sector and assuming there are J sectors in the condenser, then there had to be arrangements for J penalty constraints. This prompted the creation of the array, WTST(J), representing constraint penalty functions for each sector. The absolute magnitude of these functions were directly related to both the severity of the steam flow violation and the number of dry tubes remaining in the sector. WTST(J) ranged in value from negative infinity to zero, where a value of zero represented a condenser design in which no flow violations occurred. Thus, WTST(J) were constrained functions whose lower limit was zero. For example, during an analysis, if steam flow was determined to fall below zero, then WTST for that sector would be given some negative value. In subsequent designs, as the number of dry tubes approached zero and better designs were obtained, then the magnitude of the penalty function approached zero indicating no constraint violation.

Since penalty constraints are entirely contrived relationships with no real physical basis, it is desirable to minimize their number to avoid the possibility of sending innacurate signals to the optimizer.

To eliminate the need to use the WTST penalty functions as constraints, the values of WTST(J) were consolidated at the end of the sector analysis into the condenser steam exit-fraction constraint. Normally, steam exit-fraction ranges from zero to one and is simply equal to:

$$\frac{\text{steam leaving the condenser}}{\text{steam entering the condenser}}$$

By incorporating the WTST violations into steam exit-fraction, the exit-fraction was made a continuous function ranging in value from negative infinity to one. The negative steam exit-fraction represented a partially dry condenser and its magnitude was in direct proportion to the number of dry tubes. Thus instead of having to evaluate and calculate gradients for J number of WTST(J) contraints, the optimizer simply had to evaluate a previously defined and now expanded exit-fraction constraint.

It should be stressed that making steam exit-fraction continuous through zero was equally as important as eliminating the need for additional constraints. It can be reasonably assumed that for all practical condenser applications, exit steam fraction will always be limited to some positive number near zero. Here is where one applies the physical knowledge of the condenser and its relation to the thermal property of steam flow. As explained earlier, dry tubes represent an over-designed condenser. Thus the natural tendency is for the optimizer to alter those design variables so as to create a more compact condenser. As this occurs, steam exit-fraction will naturally increase. The upper active limit of that constraint will determine the optimum feasible design. While it is not necessary to have a lower limit for steam exit-fraction, it is very important for it to be a continuous smooth function especially in the region near the upper limit. It is therefore critical to properly define the penalty functions WTST(J) in a way so as to provide a smooth transition from the negative, artificial values of negative steam exit-fraction to the real, positive values.

Since the steam flow penalty functions will not be used as constraints, the analytical results will provide gradient information to the optimizer. However, once steam flow has been determined to fall below zero, steam flow for that first dry row of tubes and all subsequent rows must be fixed up with dummy values to allow the program analysis to continue. How that "fix-up" is accomplished will ultimately determine the search direction for the optimizer.

Physically, once steam flow has gone to zero, there should be no further latent heat transfer, no subsequent condensate production, and further pressure losses should be only due to the flow of non-condensible gases. It is necessary to make the computer generated analysis reflect as closely as possible these physical realities. Since the optimizer no longer has the penalty functions to use in calculating a search direction, other constraint values obtained from the analysis will dictate the next search direction. Gradients will also be calculated using these results and the determination of the next search direction will incorporate these gradients as well. In the case of negative steam flow, steam flow and condensate production over dry rows were given nominal values which were as small as the computer analysis would tolerate. These extremely small values closely approximate zero steam flow and generate results which resemble physical reality as closely as possible.

The following example is provided to better illustrate the logic used in CONDIP to handle negative steam flow. CONDIP determines flow rate through each row in each sector. During a sector analysis, CONDIP calculates the condensate generated at a given row and subtracts that value from the steam flow entering that row to calculate the steam leaving. The exiting steam flow rate is then checked to determine whether steam flow has gone to zero. If it has not, then the analysis continues. If it has, then the following two events occur.

The penalty function, WTST(J), is calculated for that sector and dummy values are inserted for steam flow and condensate rate at the row where the violation occurred. For the remainder of the analysis condensate generation and subsequent steam flow calculations are bypassed and the remaining rows in the sector are fixed up with dummy values for steam flow and condensate. The analysis continues utilizing these dummy values in all appropriate heat transfer and pressure calculations. At the conclusion of the sector analysis, the values of the penalty functions, WTST(J), of each sector are incorporated into the steam exit-fraction.

If the analysis revealed zero dry tubes then WTST(J) for all sectors would be zero and the steam exit-fraction would simply be calculated as:

$$\frac{\text{steam leaving the condenser}}{\text{steam entering the condenser}}$$

If, however, dry tubes were encountered in the condenser analysis then WTST(J) of some or all the sectors would be negative and dependent in magnitude on the number of dry tubes in each of the J sectors, as well as the severity of the steam flow violation. Steam flow leaving any sector which has gone dry would be zero and steam exit-fraction would be evaluated as:

$$\frac{\text{steam leaving any wet sectors}}{\text{steam entering the condenser}}$$

plus a weighted value of all the WTST(J) penalty function values. Using the relationships just described, it is apparent that steam exit-fraction: is negative if condenser tubes are dry; approaches zero as the design becomes feasible; and is greater than zero if there is steam leaving the condenser.

2. Steam Pressure and Temperature Effects

The other possible source of mathematical instability occurs when steam pressure falls below some preset limit. If pressure falls to zero, numerous mathematical singularities will be generated. Yet, before this situation can occur steam temperature will have already fallen below inlet coolant temperature causing singularities in the log mean temperature difference (LMTD) heat transfer calculation. Thus, the lower pressure limit which cannot be physically exceeded is not zero but the minimum saturation pressure established by the inlet coolant temperature. In CONDIP, this lower limit is given the variable name, PTLIM.

As steam flows through the condenser, pressure continually decreases due to friction losses and therefore, it is evaluated at each row in each sector. When the steam saturation pressure drops below PTLIM, indicating a physical violation of realistic limits, then the creation of a penalty function and a corresponding "fix up" of saturation pressure is required to allow the program to continue. The treatment of the problem was therefore analogous to the previous situation dealing with negative steam flow.

PTST(J) was the penalty function devised to indicate to the optimizer that the pressure limit, PTLIM, was violated in any of the J sectors. Values of these constraints ranged from negative infinity to zero, depending on the degree and location in the condenser of the violation. Since pressure is calculated on a row by row basis in each sector, the magnitudes of the pressure penalty functions were directly dependent not only on how much the calculated pressure dropped below PTLIM, but also on the number of rows remaining in the sector. Thus, as the condenser approached a feasible design the PTST(J) consraint values approached zero, indicating lessening violation of the minimum pressure.

As emphasized earlier, it is important to minimize the number of constraints, not only to avoid the possibility of sending confusing signals to the optimizer but also to reduce cost and improve program efficiency. This was accomplished here by inserting dummy values not only into the violated pressure variables but also associated thermal properties such as condensate generation, heat transfer coefficients and heat transfer rates for the row where the violation occurred and all subsequent rows in the sector. The dummy values were chosen such that realistic gradient information would be sent to the optimizer. The proper choice of "fix-up" values for these varaiables resulted in the elimination of penalty functions as design constraints, and provided sufficient information to determine subsequent search directions.

It is necessary to understand the influence that steam pressure and temperature exert on the overall condenser analysis. With this knowledge it will be easier to predict the physical designs which could cause violations of the pressure limit. PTLIM is violated due to excessive steam flow pressure losses. As explained earlier, these large pressure losses would result from large steam velocities that are found in condensers which are too tightly designed. Thus, the particular condenser design is incapable of handling the required steam load, implying an infeasible design. Understanding this relationship will aid in choosing the appropriate "fix-up" values which will indicate to the optimizer that when the pressure limit is violated an infeasible condenser has been designed.

Physically, When steam temperature falls below coolant inlet temperature (PTLIM is violated) there is no heat transfer from the steam to the coolant and no additional steam is condensed. These physical realities must be reflected in the condenser analysis. Therefore, in subsequent rows, condensation and heat transfer rates were set equal to zero. Since there is no further condensation, the steam exit-fraction is equal to the steam flow at the point of violation divided by the total flow into the condenser. Thus PTLIM indirectly determines the exit steam fraction of the infeasible design. This relationship between exit-fraction and the PTLIM violation is what makes the penalty constraints obsolete. If PTLIM is violated early in the steam's passage through the condenser, steam exit-fractions will be large, violating its upper constraint limit and thus reflecting an underdesigned condenser. As the condenser design improves, then exit-fractions will decrease.

Physically, this can only be accomplished if the condenser design "opens up", reducing pressure losses in the condenser. Consequently, as condenser designs become larger, steam exit-fractions decrease and the condenser is driven towards a feasible design.

The following example illustrates the logic employed by CONDIP to handle steam pressure and temperature violations within the analysis. Condenser inlet flow is divided by the number of sectors in the condenser. Condenser inlet saturation pressure is determined by the steam inlet temperature. Entrance pressure losses are calculated and subtracted from the inlet pressure. The resulting pressure is checked against PTLIM and a violation at this point indicates a totally infeasible condenser in which no steam is condensed. Steam exit-fraction will thus be equal to one. If the saturation pressure is greater than PTLIM the analysis continues row by row through the sector. Pressure losses over each row are calculated and subtracted from the row inlet pressure to determine pressure into the next row of tubes. If this next-row steam pressure is determined to fall below PTLIM, then a thermal violation has occurred requiring "fix up". Subsequent rows are made to indicate zero condensate generation and zero heat transfer. Steam flow over the remaining rows is maintained at a constant value, which will subsequently be used to determine steam exit-fraction. Pressure variables over the remaining rows are given small positive values just large enough to allow the analysis to continue. Although all heat transfer and condensate calculations will be bypassed, the analysis must be allowed to continue so that pressure losses will continue to be calculated based on the steam flow at the point of violation. This is important since steam flow adjustments to the sectors are based on certain pressure comparisons between the sectors. The cumulative sum of all row pressure losses in each of the sectors must be equal to within some tclerance. If they are not then steam flow into each of the sectors is altered so that the exit pressures from each sectcr converge to scme common value. Thus, an accurate reflection of true pressure losses is important to this calculation.

The value of the steam exit-fraction is again determined to be the single constraint necessary to drive subsequent condenser designs to a feasible optimum configuration. The pressure penalty constraints proved to be superflous information, but the corresponding variable "fix-up" was critical in the determination of search direction.

C. LIMITATIONS

During the develcpment of CONDIP, it became apparent that steam exit-fraction would become the key constraint during optimization of any objective function. A feasible design implies that steam exit-fraction is a small positive number perhaps somewhere between zero and 0.1 percent. As explained earlier, violaticns of either steam flow or pressure physical limits resulted in penalty functions and variable "fix-up" which were later directly or indirectly incorporated in the calculation of steam exit fraction. Thus any feasible design, let alone the optimum one, centers on the limits placed upon this design constraint. Any number of design variable combinations will yield a feasible design, and each design variable affects steam exit-fraction differently. The intertwined, complex calculations used to ultimately determining exit-fraction are done by sector and row with each design variable repeatedly playing a factor. For example, the profcund effect of both vapor shear and condensate inundation on the shell-side heat transfer coefficient and consequently steam exit-fraction, is indirectly determined by numerous design variables. However, their effects are impossible to predict. The cascading effect of the thousands of calculations performed during the course of a design analysis is to ultimately create a single, highly non-linear variable in the form of the steam exit-fraction, upon which design decisions will be made.

As more design variables were involved in the analysis, the optimizer had difficulty determining their often conflicting effects on both the objective function and the steam exit-fraction. A small perturbation of each of the design variables independently would yield gradients indicating design improvement. But when these gradients were evaluated simultaneously to actually determine the direction of the subsequent design, their combined effect would actually indicate either no improvement of the objective function or a violation of the steam exit fraction design constraint. The end result would be that the optimization process would stall as no feasible search direction could be obtained. Larger perturbations to the design variables were required to properly evaluate their relative effects on the objective function and any active or violated constraints. This would enable the optimizer to overcome either small inconsistencies or discontinuities in the objective function and the constraint functions which would otherwise prevent the optimizer from reaching the optimum design. This was accomplished during data input by changing the normalized finite difference step from 0.01 to about 0.1. Increasing the finite difference is not without its drawbacks. As the optimum objective value is approached, the optimizer overlooks the subtle effects of small changes in the design variables because of the relativaly large perturbations. Thus, depending on the initial design variables, the optimizer will improve the design to some point near, but necessarily at, the optimum.

When a design becomes feasible, steam exit-fraction will always become an active constraint. But the stated goal is not in achieving a feasible design but in driving the design to a feasible optimum. However, this iterative process can not be accomplished at the expense of violating a constraint and it was here that further complication was introduced. The initial impetus in any optimization process is to first obtain a feasible design. However, once the very small steam exit-fractions are obtained that are necessary for a feasible design, the exit-fraction becomes extremely sensitive to any further design variable changes. Thus any effort to further improve the current design could easily cause exit fraction to increase. Even slight increases would be perceived as violations of the constraint limit and thus prevent further optimization from the first feasible design. There are two possible solutions to this problem. Either increase the upper limit on the exit-fraction constraint or redefine the constraint. COPES formulates the general constraint function in such a way as to allow the user to increase the active region about the constraint limit. This is accomplished here by increasing the normalization factor in the following expression for the exit-fraction constraint function:

$$\frac{BU - EXITFR}{SCAL1} \leq 0.$$

where BU is the upper constraint bound, EXITFR is the exit-fraction constraint value and SCAL1 is the normalization factor for this constraint. Increasing the normalization factor reduces the optimizer's sensitivity to constraint violations by enlarging the range of constraint values in which the constraint is active. This enlarges the region of feasibility and allows the optimizer more flexibilty in altering design variables by reducing the risk of violating the constraint. The overall effect is that the design optimization can continue but at the expense of accurate constraint limits. The normalization factor used effectively for the exit-fraction in CONDIP analysis was approximately 0.1.

One of the stated objectives was to create a robust program which would consistently yield the single best optimum design independent of the initial design and not get hung up on a relative optimum. As it was explained earlier, although relative optimums represented design improvement, they also indicated the inability of the optimizer to locate the single best or true optimum design. However, the objective was achieved for only three design variables. When more than three design variables were used, the optimum designs became loosely dependent on the initial input, although not in any predictable way. This is not to say that the condenser design did not optimize. By incorporating the finite difference and scaling normalization on exit-fraction as described above, final designs did yield objective function values which were continually within about ten percent of the true optimum regardless of the initial design. However, there was just no guarantee that the single, best optimum design could be consistently obtained. In summary, the reasons why CONDIP did not consistently optimize to the single, true optimum were: the extreme non-linearity of the steam exit-fraction, the need for a large finite difference gradient, and the need for a normalization factor for the exit-fraction upper limit constraint.

While the optimum design solutions obtained from CONDIP may be sufficient, there are several ways to improve the results and increase the chances of obtaining the best possible design. The easiest way is to try several initial input values until the user is satisfied that the best solution has been obtained. The problem with this approach is that it is both costly and time consuming. A second recommendation is to couple an extremely simplified version of the condenser analysis with the optimizer to obtain a educated guess as to what the optimum design should be. The results of this analysis could then be used as input for CONDIP. OPCODE1, which utilizes the HEI methods in its analysis, is a likely candidate. The advantage of this approach is that a quicker, cheaper analysis can be used to obtain a rough idea of the anticipated optimum design. CONDIP can then use these design results to obtain even better and more accurate solutions, faster. There is still no guarantee, however, that the true optimum will be solved. Perhaps with the development of more robust and versatile optimizers, ones which uses numerical techniques and methods that are better suited to this type of problem than CONMIN, more precise solutions can be obtained. However, there is little more that can be done to simplify the analysis of the steam exit-fraction and subsequently linearize the problem.

IV. DESCRIPTION OF THE MAIN AND SUPPORTING SUBROUTINES

A. MAJOR SUBROUTINES

The following section contains a brief description of the major subroutines in CONDIP. The appropriate flow diagrams are also provided to better illustrate and complement the explanations. For further information concerning the various subroutines and functions see the CONDIP listing in Appendix C and ORCON1 [Ref. 2].

1. ANALIZ

This subroutine basically arranges CONDIP in a standardized form which is compatible with COPES/CONMIN. COPES uses a variable flag, ICALC, to coordinate the optimization process with ANALIZ. Utilizing this flag ANALIZ then calls the input, analysis and output portions of CONDIP as required. When COPES sets ICALC equal to one ANALIZ reads in all initial input. This is the only time any input can be entered. When ICALC equals two, COPES works with CONMIN to optimize the design. ANALIZ makes available the analysis portion of the program to be used repeatedly by CONMIN. When COPES sets ICALC equal to three, the optimization is complete and ANALIZ calls all applicable output subroutines. Figure 4.1 illustrates the flow process for ANALIZ.

2. INPUT

This subroutine enters all initial input of data by which the initial design is determined. The resultant design may be either feasible or infeasible, subject to the limitations previously discussed, so it is not critical what values are initially assigned to the design variables.

However, the initial input is screened to prevent the introduction of totally unrealistic values of variables into the program. For example, initial tube thickness, tube inner diameter, tube number and tube length are all checked to ensure that their values are greater than zero. If any of the screened initial inputs do not satisfy the minimum requirements, then the program exits prior to entry into the optimizer. The limits of the design variales and constraints will prevent similar situations from occurring during the analysis. Figure 4.2 presents the flow diagram for the INPUT subroutine.

3. OUT3

This subroutine simply prints all the initial values entered in the INPUT subroutine.

4. ORCON

This subroutine calculates the bundle geometry, flooding factors and such coolant flow parameters as pressure loss, flow rate, and pumping power. There are two options available to determine bundle geometry, each with certain advantages and disadvantages.

Option1: The number of rows is entered as a constant and the tube number is determined based on pitch, tube outer diameter, and row spacing. The advantage of this method to determine bundle geometry is that it allows the user to linearly vary pitch and/or tube inner diameter by row. The disadvantage is that tube number is a dependent variable. The optimzer is therefore limited in determining the optimum design by the specified number of rows.

Option2: The number of tubes can be used as a design variable while the number of rows is determined by tube number, row spacing, pitch and tube outer diameter. There is more flexibility in this method of condenser design but it is not possible to linearly vary tube pitch and inner diameter. The condenser bundle is generated from a specified inner void out, and all the appropriate condenser geometry is determined for one of the identical 30 degree sectors. Overall bundle volume is then calculated as is the ratio of tube hole area to tube sheet area.

Once the basic condenser geometry has been determined, the code then proceeds through an algorithm to calculate baffle location based on an input value specifying the number of baffles desired in the condenser bundle. After this has been completed, flooding factors are determined. That is, the number of tubes in a vertical row above the central tube in each row is calculated. This is done for each of the six sectors on one side of a circular bundle. Symmetry is assumed for the other side. These flooding factors are later used in calculations to determine the effect of condensate inundation on shell-side heat transfer coefficients.

Finally, ORCON calculates coolant mass flow, coolant velocity, header pressure difference and pumping power based on the type of coolant flow input received. The flow chart in Figure 4.3 is a simple illustration of the logic used in ORCON. From ORCON, the subroutine SECALC is called.

5. SECALC

This subroutine determines all the parameters of each of the sectors in the condenser by row. The first calculation made in SECALC is the determination of the cooler geometry, if there is one. Entrance pressure losses into the condenser bundle are calculated for each sector and saturation pressure is checked to ensure that it is greater that PTLIM. From this point, much of the remaining subroutine is comprised of two do-loops with one nested inside the other. The outer loop cycles through however many sectors are in the condenser model. The inner loop cycles through the rows in the sectors. Pressure, temperature, mixture velocity, steam flow and condensate flow are calculated at each sector row. The subroutine HETTRN is called repeatedly to provide the necessary heat transfer information. Pressure and steam flow is checked continually at each row to ensure that neither falls below its predetermined lower limits. In the event that either situation occurs, the appropriate penalty function and fix-up procedure is implemented to enable the analysis to continue. As previously discussed, these values are chosen to reflect as accurately as possible real conditions which would occur when steam flow or pressure violate their physical limits.

Once all the sectors have been analyzed the cumulative steam-side pressure losses from each sector are compared. Steam pressure at the inner void must be uniform, therefore the sector pressure losses are required to be equal within some allowable tolerance. If they are not, then the distribution of inlet steam flow into each sector is altered to force the pressure losses to converge to a single value. Once steam flow to the sectors has been adjusted, the sector and row analysis in SECALC is repeated until the pressure losses within each sector approach a common value. After the pressure comparison has been satisfied, certain overall condenser parameters are calculated such as steam exit-fraction, bundle heat load, and steam-side pressure drops.

Finally, if a cooler is required, the subroutine COOLEX is called. Otherwise the condenser analysis is complete. The flow diagram for SECALC is presented in Figure 4.4.

6. HETTRN

This subroutine is called repeatedly in SECALC to solve for all shell and tube-side heat transfer properties for each row in each sector of the condenser. In particular, values for the overall heat transfer coefficient and log mean temperature difference are utilized by SECALC in computing condensate production and heat transfer rate at each row of tubes.

On entering this subroutine, a series of estimates for certain row variables are calulated. Based on an assumed initial value for the overall heat transfer coefficient, the exit coolant temperature and corresponding film temperature are calculated. Utilizing these temperatures, the LMTD, thermal resistances, individual heat transfer coefficients and numerous other heat transfer parameters are then calculated. Finally, another value for the overall heat transfer coefficient is determined based on the above-mentioned analysis, and this final value is subsequently compared to the initial value. If they are not in agreement, within a specified degree of tolerance, then the initial value for the overall heat transfer coefficient is updated and the entire process is repeated until the initial and final values converge. This iterative process is necessary as temperature dependent heat transfer coefficients, film temperature drops, and exit coolant temperatures are all being calculated simultaneously.

Note that it is in HETTRN that the concepts of vapor shear and condensate inundation are incorporated. Heat transfer coefficients are corrected for both effects based on the calculations presented earlier. Also note that since steam temperature is never allowed to drop below inlet coolant temperature in the calling subroutine SECALC, resultant LMTD calculations in HETTRN will not yield singularities.

Once all the heat transfer variables have been determined, control is returned to SECALC where the appropriate results are utilized and stored. The appropriate flow diagram for HETTRN presented in Figure 4.5.

7. COOLEX

This subroutine solves for all the necessary parameters required in the cooler analysis. The cooler is assumed to be of rectangular cross-secton with the height of the cooler not to exceed the difference between the condenser inner and outer radii. The values used for tube pitch and tube diameters in the cooler are the same as the innermost row of the condenser bundle.

Steam exits the condenser bundle, collects in the inner void and enters the bottom row of the cooler. The steam then proceeds vertically up through the cooler. The physical location of the cooler is not a prerequisite to the subsequent design, although it is expected that the cooler will be placed within the condenser bundle, thus the limit on cooler height.

The first calculation in COOLEX determines the steam velocity at minimum cross-secton in the first row of tubes, VLCMAX. VLCMAX is directly proportional to the amount of steam and non-condensible gas entering the cooler as well as the cooler geometry. Therefore the constrained limits for VLCMAX will play a major factor in the overall condenser design.

Subsequent row analysis is treated identically as in SECALC. However, all pertinent heat transfer data are calculated directly within COOLEX, making it independent of HETTRN. Steam pressure and steam flow are checked at each row to ensure that the appropriate limits are not violated and all thermodynamic parameters are calculated. At the conclusion of COOLEX, cooler performance variables such as heat load, exit-fraction steam, steam pressure losses and overall heat transfer coefficients are calculated and control is returned to SECALC. The flow diagram for the COOLEX subroutine is illustrated in Figure 4.6.

8. OUT2

This subroutine prints the overall condenser bundle results including heat load, steam exit-fraction, overall heat transfer coefficient, overall condenser LMTD and bundle volume. Normally, OUT2 is called once after the initial design is analyzed and again after the optimum design has been determined. Final design variable values such as tube number, coolant flow, tube pitch, tube wall thickness and tube inner diameter are also printed.

9. OUT2C

This subroutine prints the cooler results as well as the combined cooler/condenser results. This subroutine is called from the subroutine OUT2 and is called only if a cooler is required and subsequently designed. Therefore, these results will always be printed in conjunction with OUT2 output.

10. OUT3

This subroutine prints a very detailed output of the condenser and cooler results by row and sector. Nearly all the thermodynamic and heat transfer properties are presented, thus providing a rather complete picture of conditions everywhere in the condenser. This is extremely helpful in determining, for example, where additional heat transfer enhancement would be most beneficial, or where baffles should be best located to reduce the effects of condensate inundation.

B. SUPPORTING SUBROUTINES

The following is a brief description of supporting functions and subroutines called frequently by the main subroutines.

1. DFSVTY: This subroutine returns the value of the mutual diffusivity of the steam and non-condensible gas present.

2. XTR: This funcion subroutine transforms the calculated data, received in the argument list, to the log values and performs a linear regression on two or more points using the model.

3. AMUFN: This function subroutine calculates the viscosity of the non-condensible gas in lbm/(ft-sec).

4. BMUFN: This function subroutine calculates the viscosity of a saline sclution in the range of 0-24 percent concentration and temperatures of 40-210 ^{o}F in lbm/(hr-ft).

5. CPAFN: This function subroutine returns a value for the heat capacity of the inert, non-condensible gas mixed in with the steam in units of Btu/(lbm-mol-^{o}F).

6. CPFN: This function subroutine calculates the specific heat of a saline sclution units of Btu/(lbm-^{o}F).

7. CPSFN: This function subroutine calculates the heat capacity of steam in Btu/(lbm-mol-^{o}F).

8. HFGFN: This function subroutine returns a value for the latent heat of vaporization of water in Btu/lbm.

9. PRSDRP: This subroutine returns the shell-side pressure drop across a row of tubes in psia.

10. PSATFN: This function subroutine calculates saturation

pressure of steam as functicn of temperature. Pressure is returned in units of psia.

11. ROEFN: This function subroutine calculates the density of a saline solution ofconcentration range 0-24 percent and temperature range of 40-300 °F. Density is returned in units of lbm/(cu.ft.).

12. SKBFN: This function subroutine calculates the thermal conductivity of a saline solution of concentration range 0-24 percent and a temperature range of 40-300 °F. Thermal conductivity is in (Btu)/(hr-f-°F).

13. TSATFN: This function suroutine returns the value for steam temperature in °R given a pressure in psia.

14. VGFN: This function subroutine calculates the specific volume of steam as a function of temperature and pressure. It has units of (cu.ft.)/lbm.

15. SWITCH: This function subroutine reverses the order of a stored array.

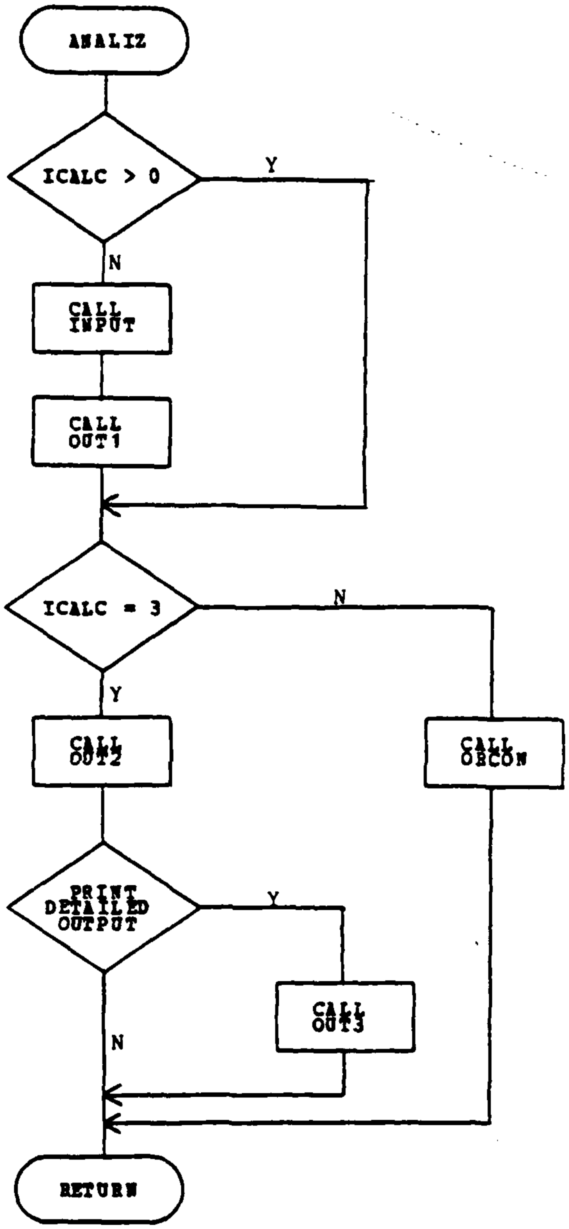


Figure 4.1 Flow Diagram for the ANALIZ Subroutine.

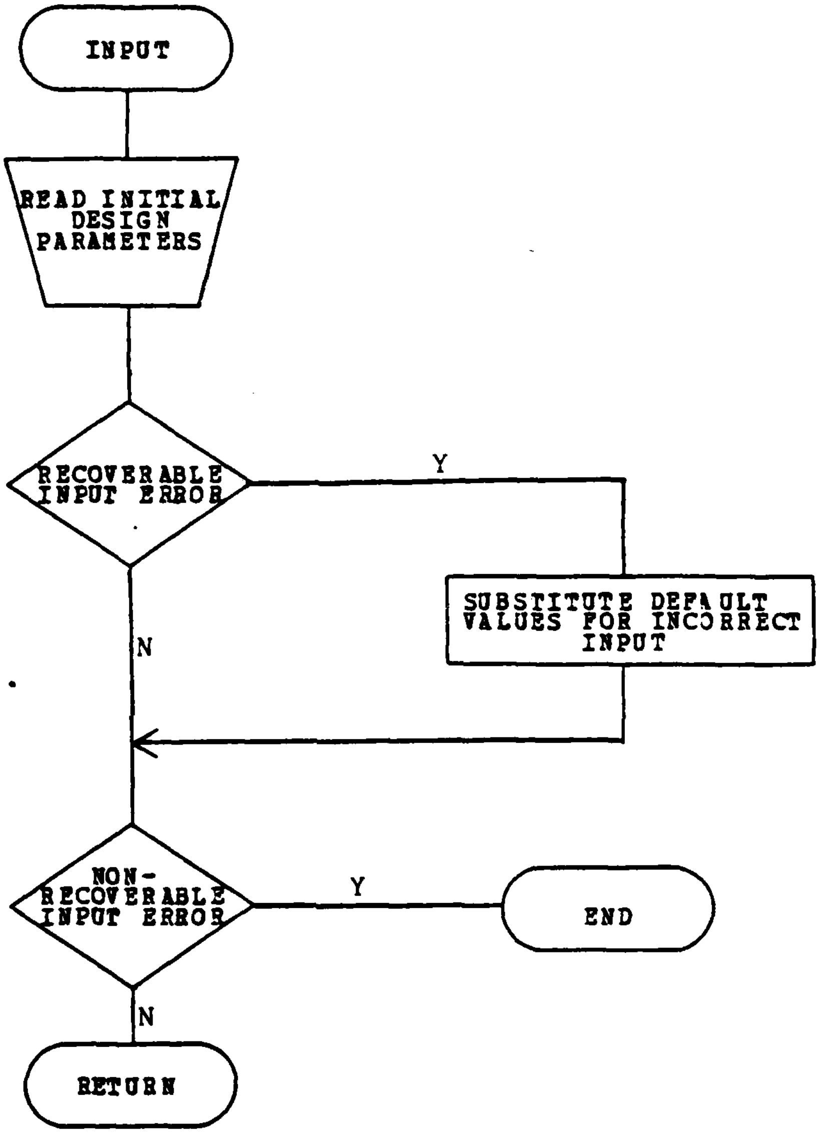

INPUT
READ INITIAL DESIGN PARAMETERS
RECOVERABLE INPUT ERROR
Y
SUBSTITUTE DEFAULT VALUES FOR INCORRECT INPUT
N
NON-RECOVERABLE INPUT ERROR
Y
END
N
RETURN

Figure 4.2 Flow Diagram for the INPUT Subroutine.

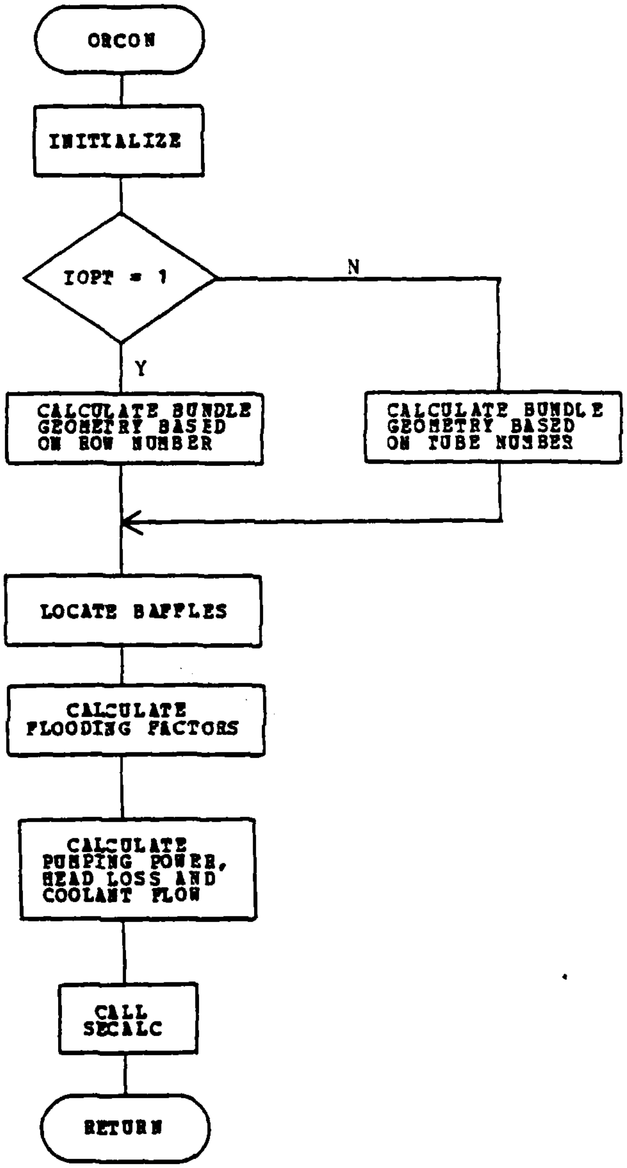

ORCON
INITIALIZE
IOPT = 1
N
Y
CALCULATE BUNDLE GEOMETRY BASED ON ROW NUMBER
CALCULATE BUNDLE GEOMETRY BASED ON TUBE NUMBER
LOCATE BAFFLES
CALCULATE FLOODING FACTORS
CALCULATE PUMPING POWER, HEAD LOSS AND COOLANT FLOW
CALL SECALC
RETURN

Figure 4.3 Flow Diagram for the ORCON Subroutine.

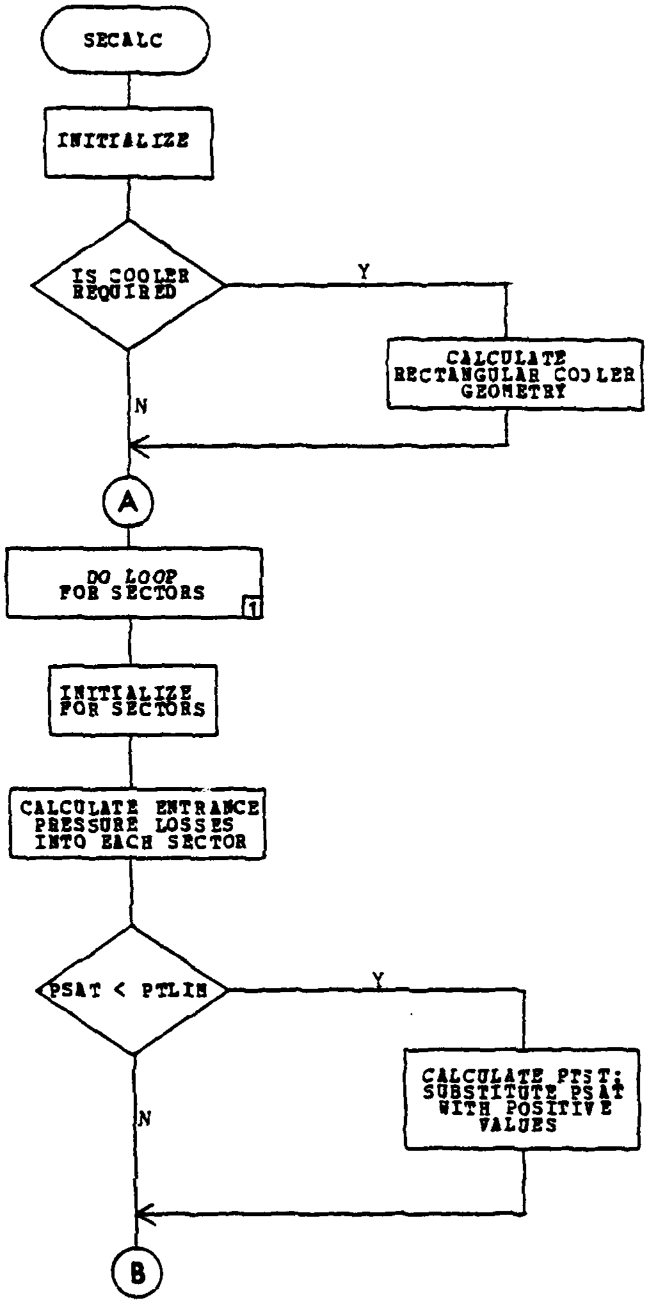
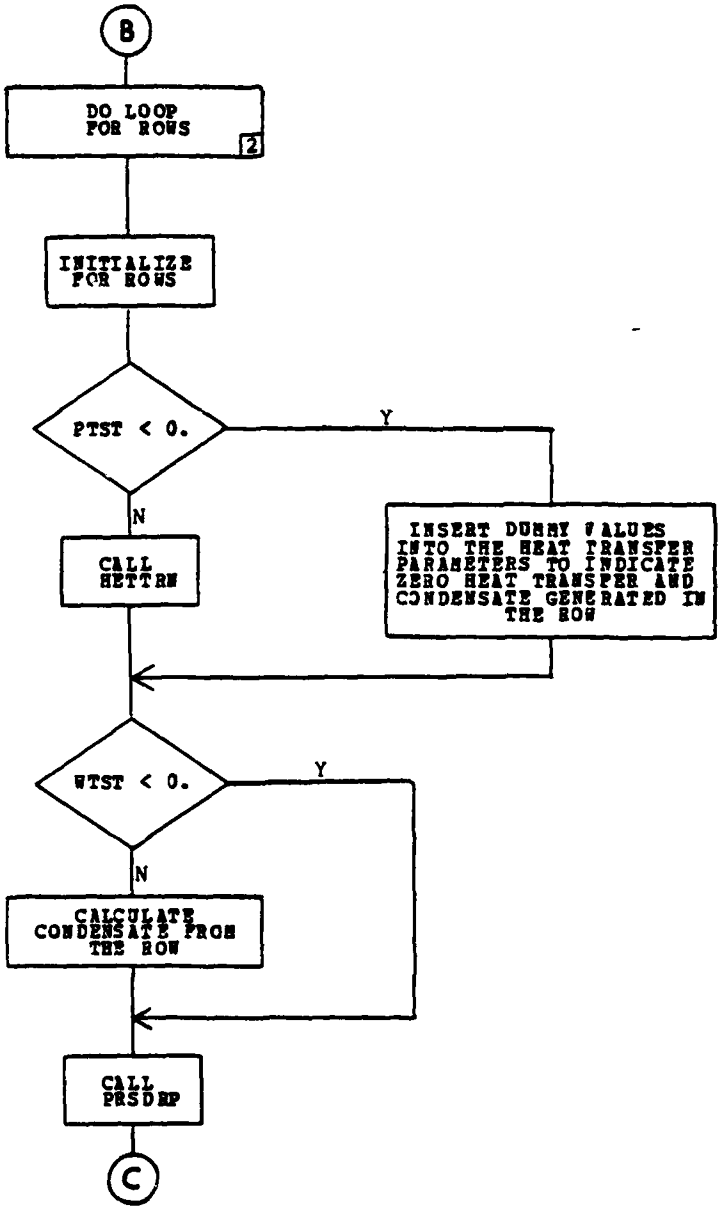
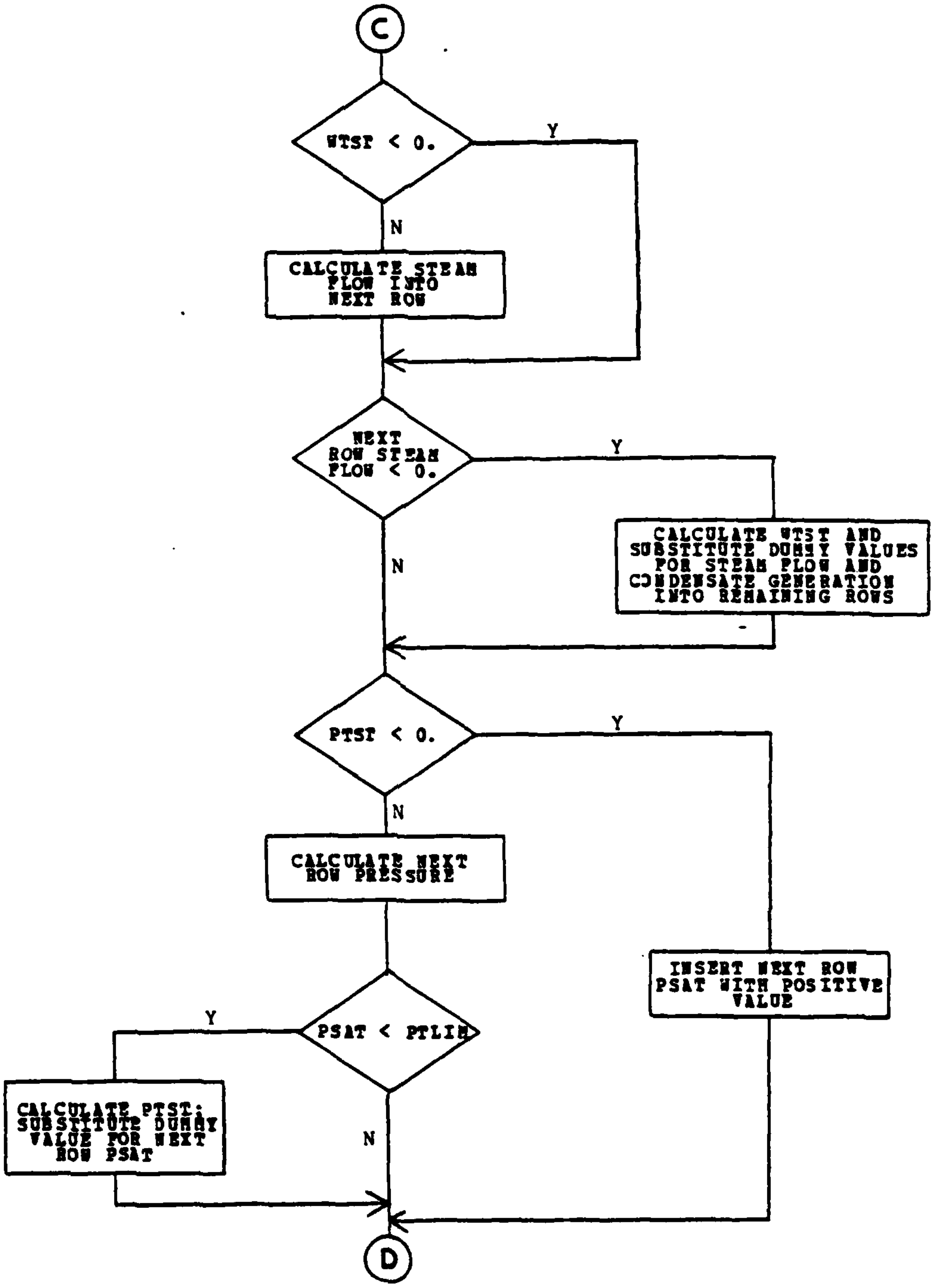

SECALC
INITIALIZE
IS COOLER REQUIRED
Y
CALCULATE RECTANGULAR COOLER GEOMETRY
N
A
DO LOOP FOR SECTORS
1
INITIALIZE FOR SECTORS
CALCULATE ENTRANCE PRESSURE LOSSES INTO EACH SECTOR
PSAT < PTLIM
Y
CALCULATE PTST; SUBSTITUTE PSAT WITH POSITIVE VALUES
N
B

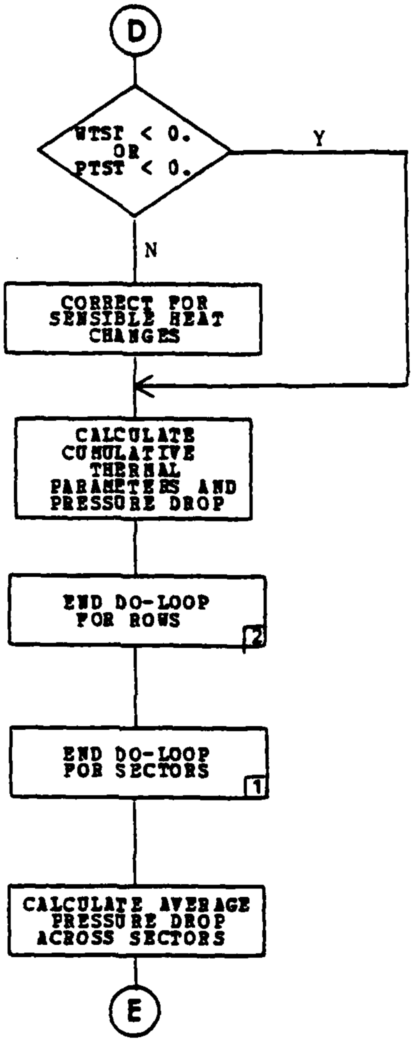
Figure 4.4 Flow Diagram for the SECALC Subroutine.


B
DO LOOP FOR ROWS
2
INITIALIZE FOR ROWS
PTST < 0.
Y
N
INSERT DUMMY VALUES INTO THE HEAT TRANSFER PARAMETERS TO INDICATE ZERO HEAT TRANSFER AND CONDENSATE GENERATED IN THE ROW
CALL HETTRN
WTST < 0.
Y
N
CALCULATE CONDENSATE FROM THE ROW
CALL PRSDRP
C

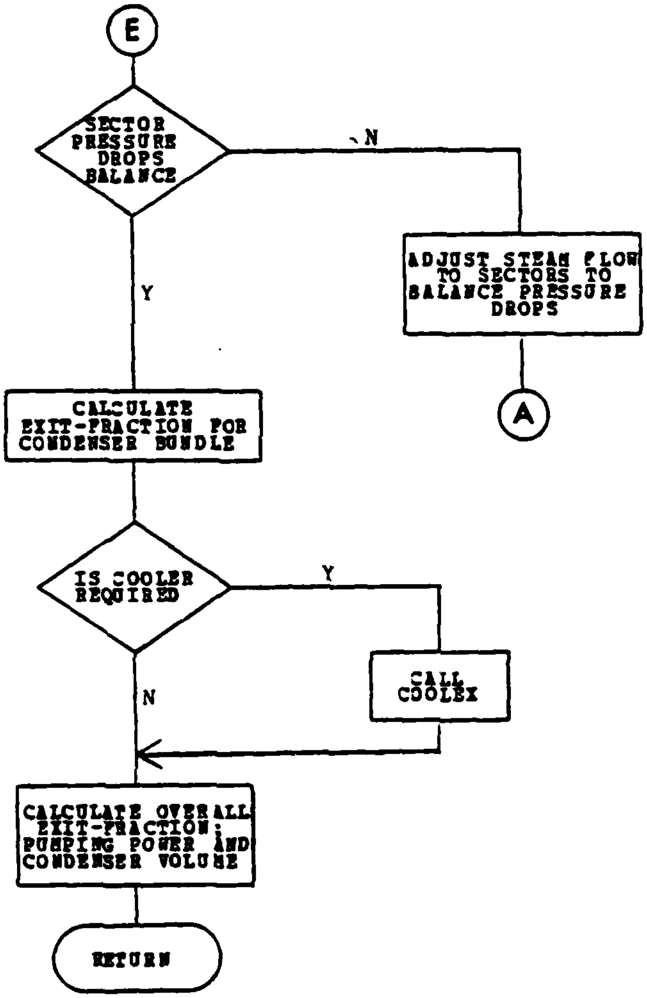
SECALC Flow Diagram (continued)


C
WTST < 0.
Y
N
CALCULATE STEAM FLOW INTO NEXT ROW
NEXT ROW STEAM FLOW < 0.
Y
CALCULATE WTST AND SUBSTITUTE DUMMY VALUES FOR STEAM FLOW AND CONDENSATE GENERATION INTO REMAINING ROWS
N
PTST < 0.
Y
N
CALCULATE NEXT ROW PRESSURE
INSERT NEXT ROW PSAT WITH POSITIVE VALUE
PSAT < PTLIM
Y
CALCULATE PTST; SUBSTITUTE DUMMY VALUE FOR NEXT ROW PSAT
N
D

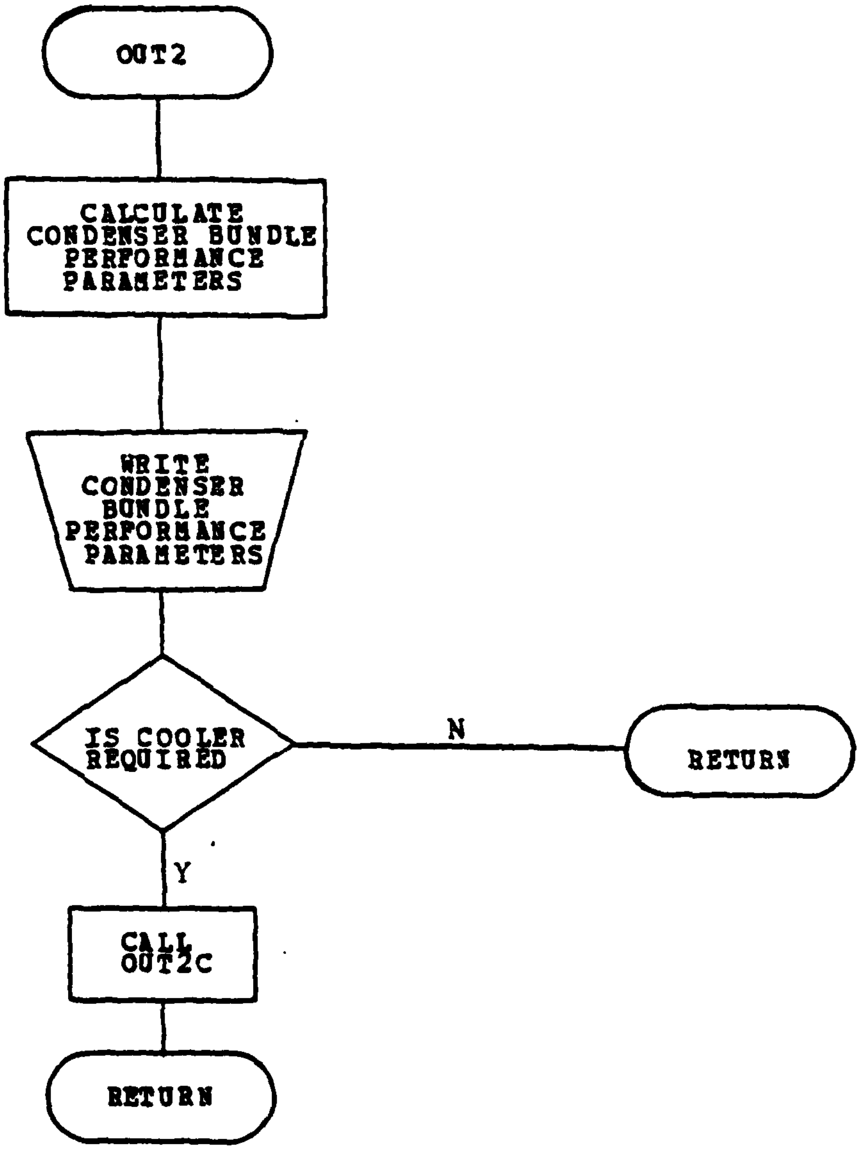
SECALC Flow Diagram (continued)


D
WTSI < 0.
OR
PTST < 0.
Y
N
CORRECT FOR SENSIBLE HEAT CHANGES
CALCULATE CUMULATIVE THERMAL PARAMETERS AND PRESSURE DROP
END DO-LOOP FOR ROWS
2
END DO-LOOP FOR SECTORS
1
CALCULATE AVERAGE PRESSURE DROP ACROSS SECTORS
E

SECALC Flow Diagram (continued)


E
SECTOR PRESSURE DROPS BALANCE
N
ADJUST STEAM FLOW TO SECTORS TO BALANCE PRESSURE DROPS
A
Y
CALCULATE EXIT-FRACTION FOR CONDENSER BUNDLE
IS COOLER REQUIRED
Y
CALL COOLEX
N
CALCULATE OVERALL EXIT-FRACTION; PUMPING POWER AND CONDENSER VOLUME
RETURN

SECALC Flow Diagram (continued)


OUT2
CALCULATE CONDENSER BUNDLE PERFORMANCE PARAMETERS
WRITE CONDENSER BUNDLE PERFORMANCE PARAMETERS
IS COOLER REQUIRED
N
RETURN
Y
CALL OUT2C
RETURN

Flow Diagram for the OUT2 Subroutine

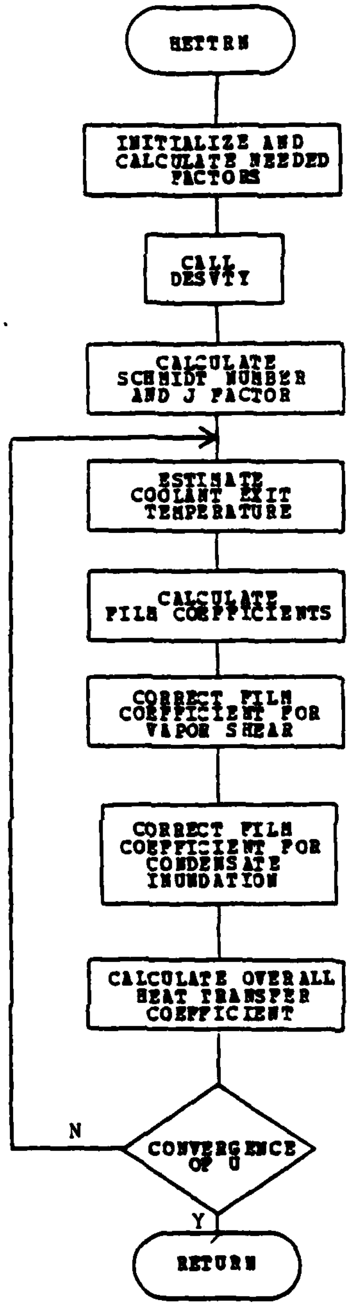

HETTRN
INITIALIZE AND CALCULATE NEEDED FACTORS
CALL DESVTY
CALCULATE SCHMIDT NUMBER AND J FACTOR
ESTIMATE COOLANT EXIT TEMPERATURE
CALCULATE FILM COEFFICIENTS
CORRECT FILM COEFFICIENT FOR VAPOR SHEAR
CORRECT FILM COEFFICIENT FOR CONDENSATE INUNDATION
CALCULATE OVERALL HEAT TRANSFER COEFFICIENT
N
CONVERGENCE OF U
Y
RETURN

Figure 4.5 Flow Diagram for the HETTRN Subroutine.

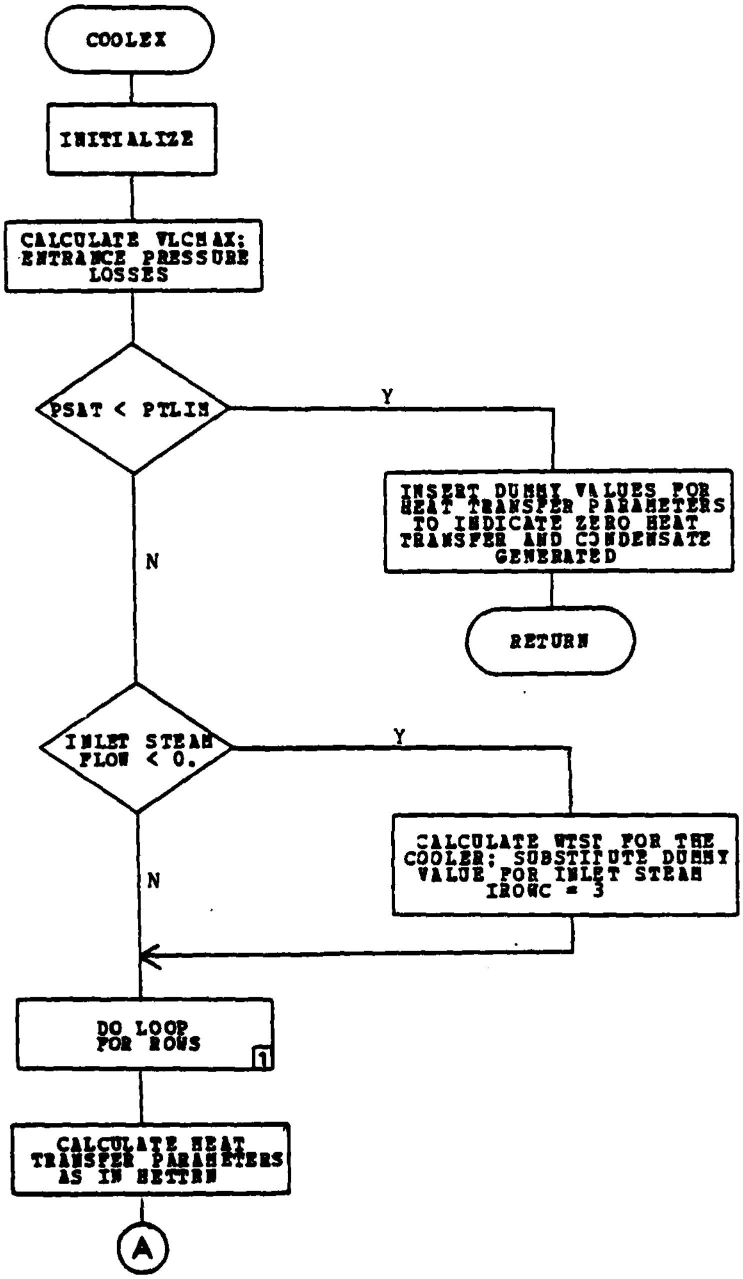
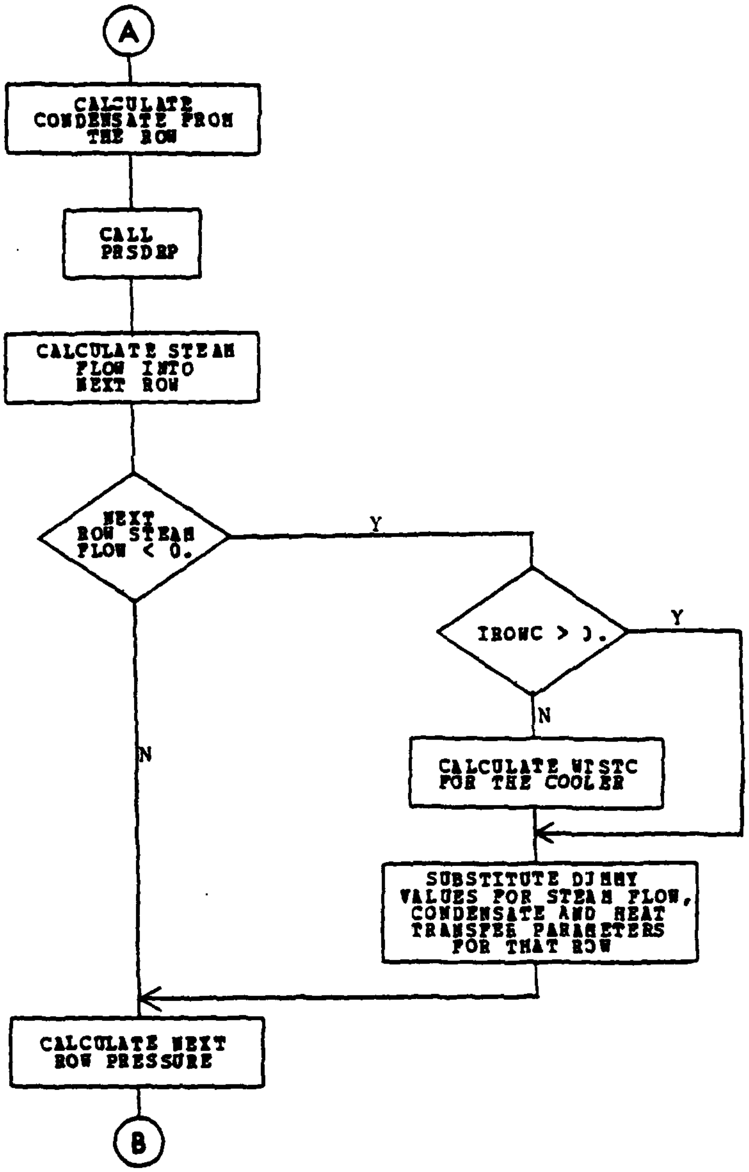
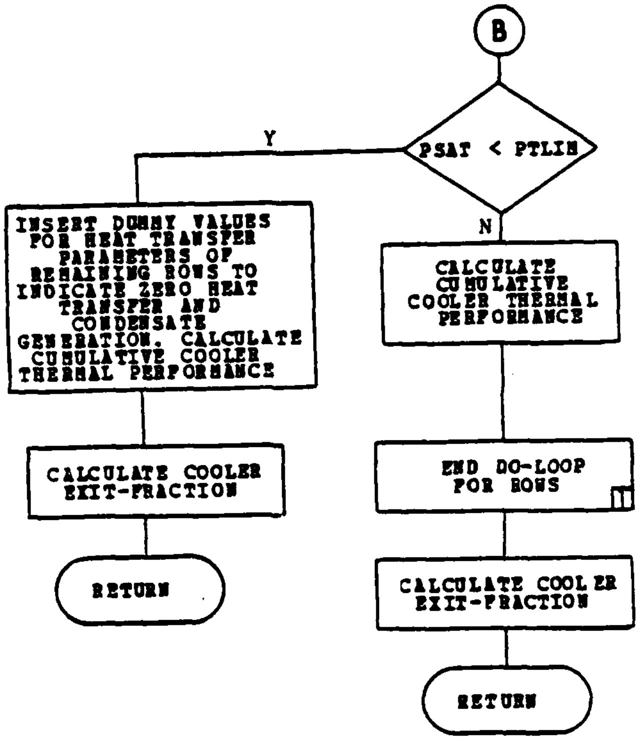

COOLEX
INITIALIZE
CALCULATE VLCMAX; ENTRANCE PRESSURE LOSSES
PSAT < PTLIM
Y
INSERT DUMMY VALUES FOR HEAT TRANSFER PARAMETERS TO INDICATE ZERO HEAT TRANSFER AND CONDENSATE GENERATED
RETURN
N
INLET STEAM FLOW < 0.
Y
CALCULATE WTST FOR THE COOLER; SUBSTITUTE DUMMY VALUE FOR INLET STEAM IROWC = 3
N
DO LOOP FOR ROWS
1
CALCULATE HEAT TRANSFER PARAMETERS AS IN HETTRN
A

Figure 4.6 Flow Diagram for the COOLEX Subroutine.


A
CALCULATE CONDENSATE FROM THE ROW
CALL PRSDRP
CALCULATE STEAM FLOW INTO NEXT ROW
NEXT ROW STEAM FLOW < 0.
Y
IROWC > 0.
Y
N
CALCULATE WTSTC FOR THE COOLER
SUBSTITUTE DUMMY VALUES FOR STEAM FLOW, CONDENSATE AND HEAT TRANSFER PARAMETERS FOR THAT ROW
N
CALCULATE NEXT ROW PRESSURE
B

COOLEX Flow Diagram (continued)


B
PSAT < PTLIM
Y
N
INSERT DUMMY VALUES FOR HEAT TRANSFER PARAMETERS OF REMAINING ROWS TO INDICATE ZERO HEAT TRANSFER AND CONDENSATE GENERATION. CALCULATE CUMULATIVE COOLER THERMAL PERFORMANCE
CALCULATE COOLER EXIT-FRACTION
RETURN
CALCULATE CUMULATIVE COOLER THERMAL PERFORMANCE
END DO-LOOP FOR ROWS
CALCULATE COOLER EXIT-FRACTION
RETURN

COOLEX Flow Diagram (continued)

V. RESULTS

A. CONDIP VERIFICATION

It was desirable to verify the single pass capability of CONDIP (i.e. without optimization) as a predictor of condenser performance by comparison with actual experimental data. However, complete and accurate data on condenser design and corresponding performance is not always readily available. Lynch [Ref. 18] encountered this same problem in attempting to verify ORCON1. However, he did manage to locate some actual experimental condenser data, obtained during a test conducted to determine the general performance of the DDG-37 class propulsion machinery [Ref. 16]. The test took place at the Naval Boiler and Turbine Laboratory and was conducted primarily to determine the performance of the turbine and reduction gears. Some limited condenser data was taken as a by-product. The various measurements were obtained as described below:

1. Steam flow measurements were made by weighing the condensate.

2. Cooling water inlet and outlet temperatures were measured by thermometers installed in the inlet and discharge lines.

3. The heat load is calculated based on total steam flow into the condenser multiplied by the difference between inlet steam and condensate enthalpies.

4. Circulating water flow was determined from a heat balance around the condenser. The total heat load was divided by the circulating water heat capacity and temperature rise to obtain flow rate.

5. Condenser inlet pressure was determined by pressure instruments located above the condenser inlet flanges.

6. Non-condensible gas flow was measured by a flowrator.

7. Pressure at the air ejector was measured directly. This pressure and the inlet pressure determined the pressure drop across the condenser.

It should be pointed out that this data were not recorded with the care that normally accompanies scientific data collection. Neither the instruments nor the techniques employed were particularly accurate. The possibility that this observed data are in error casts a cloud over the credibility of the corresponding condenser performance, which was calculated based on those values. However, for a lack of better alternatives, this data and the resulting condenser analysis will be used to determine the reliability of CONDIP.

The DDG-37 condenser geometric design variables obtained from the technical manual [Ref. 15] and input parameters corresponding to a full speed run are presented in Table I. An attempt was made to repeat the design using CONDIP. The results of CONDIP's proposed design as well as the experimental performance are presented for comparison in Table II. Percentages were calculated to quantify the differences between the actual and hypothetical performance.

Before elaborating on the results of this verification, some notable differences between the two designs must be clarified. First, a specific fouling factor was not determined at the time of the experiment and was therefore not provided. A somewhat realistic cleanliness factor of 87.5 percent (fouling factor of .0002) was utilized.

Second, in the DDG-37 condenser the rectangular cooler appears to be inserted directly into the condenser bundle.

However, in order to accomodate the cooler, the bundle must expand or distort. In addition, a void of some dimensions must be provided-for in the center of the bundle to collect any uncondensed steam and non-condensible gases. Diagrams in [Ref. 15] indicate that the DDG-37 condenser is indeed nearly elliptical in shape with bundle axes of 5.67 and 7.17 feet. Although it is apparent that a void does exist, exact dimensions can not be readily determined from the available information.

CONDIP approximates this design by creating separately a circular condenser bundle and a rectangular cooler, the height of which cannot exceed the difference between the outer and inner bundle radii. A circular void of pre-determined size is provided-for when determining the condenser bundle geometry. Subsequent volume calculations are performed on the condenser bundle and cooler separately and the overall condenser volume is computed as simply their sum.

Although CONDIP does not exactly duplicate the geometric configuration of the DDG-37 condenser, it was possible to manipulate certain initial design variables in order to cause CONDIP to develop an approximately equivalent configuration. These variables were chosen because, for small changes in their values, there is a rather significant change in the bundle geometry with relatively small effects on the overall condenser performance. Since there are no specific dimensions provided for the inner void in the DDG-37 technical manual, it was picked to be one of the design variables to be adjusted. Row spacing was also adjusted because it satisfied the conditions described above. Through trial and error a combination of row spacing and inner void radius were determined, from which CONDIP yielded a geometric design similar to the DDG-37 condenser and that satisfied condenser requirements specified in

[Ref. 17]. In this particular case, the void diameter and row spacing were determined to be 1.1 feet and 1.35 inches respectively. This arrangement enabled the condenser model to closely approximate the tube sheet area ratio of the actual DDG-37 condenser. This manipulation, however, must be interpreted as another source of error and innacuracy when comparing CONDIP's condenser performance with the experimental results.

Lastly, condenser designs in [Ref. 15] reveal that three different tube patterns were employed in the DDG-37 condenser. In addition, two different values for tube pitch were used - a pitch of 1.4 in the condenser bundle and a pitch of 1.3 in the cooler. This situation cannot be duplicated in CONDIP. Therefore a constant pitch of 1.40 and a uniform tube pattern were utilized throughout the condenser.

The design approximations utilized in CONDIP to try to geometrically simulate the actual DDG-37 condenser introduce significant uncertainty into subsequent design comparisons. This, coupled with the fact that the data collected is also suspect, would imply that it is rather difficult to verify CONDIP's analysis with the information available. It should also be noted that CONDIP is sensitive to even small variance in either the data collected (i.e. steam inlet temperature) or the approximated design variables. However, despite the above-mentioned problems associated with equating CONDIP's condenser to the DDG-37 condenser, the experimental data obtained from the DDG-37 condenser still provide the best available base upon which to make a reasonable determination of CONDIP's capabilities and limitations.

In comparing the results in Table II, it is immediately clear that there is significant difference between certain condenser performance parameters predicted by CONDIP and the corresponding experimentally derived condenser performance. Already, much has been said about the numerous geometric approximations used to model the DDG-37 condenser. But questionable data and geometric manipulations may not completely explain the 13 percent exit-fraction and general poor performance generated in CONDIP's analysis. Its values for the average overall heat transfer coefficient and heat rejected were significantly lower than the experimental results. One source of the problem lies in the actual heat transfer analysis performed in the code. Lynch [Ref. 18] graphically illustrated how sensitive this analysis is to the effects of condensate inundation. In particular, by making small changes - within the allowable ranges - in the constants used in Eissenberg's correlations for condensate rain, significant improvement could be realized in the overall heat transfer characteristics of the condenser. CONDIP's results, when compared to the experimental data support the argument that the values currently used in the inundation correlations are rather conservative in nature, and cause the overall analysis to yield a poor preformance for the given steam load and condenser design.

Therefore, in order to present CONDIP with a fair test to determine its credibility as a design predictor, some additional work must be first accomplished. A condenser geometrically identical to the general model created in CONDIP should be constructed with complete and accurate data acquisition systems to establish a thorough data base from which to compare. Also, more research should be performed on the effects of condensate inundation and velocity shear to obtain more precise correlations in determining their overall effects on the film heat transfer coefficients.

One last additional point should be mentioned. In comparing the steam-side pressure drops through the condenser, it was shown that CONDIP's pressure losses were nearly 72 percent larger the the actual physical measurements. However this radical difference is mainly due to the high pressure losses experienced at the entrance of the cooler as a large volume of steam tried to force its way through the small available area. Therefore, the significance of this large disagreement in results is relatively minor and can be treated simply as a consequence of the more important heat transfer limitations in the comparison run.

Although the goal of verifying CONDIP as a design predictor has proven elusive, it was still possible to demonstrate its capabilities through comparison studies. Therefore, the remaining emphasis in this thesis is to show the ability of CONDIP (in combination with the optimizer COPES/CONMIN) to take an initial design with a given framework of constraints and design variables, and obtain better designs based on a desired objective function.

B. EXPLANATION OF THE CASE STUDIES

The following case studies were devised to best exercise the capabilities of CONDIP. They were made as realistic as possible so as to simulate the problem of condenser design and specification confronting the engineer during the early stages of power plant design. The condenser performance returned by CONDIP during the verification run and contained in Table II will serve as a baseline for comparing the results of each case study. The baseline condenser performance is based on the design parameters from the DDG-37 condenser listed in Table I. It was stated earlier that CONDIP's optimization results are slightly sensitive to the initial design if more than three design variables are used. Since all the cases involve eight or more design variables it would be best, for the purposes of comparison, to start from the same initial design in all cases. Therefore, the initial design variables used for the verification run and contained in Table I will be utilized as the baseline design. Although many of these initial design variables will be allowed to change during optimization, certain basic condenser requirements will not. They include: steam flow into the condenser, inlet steam saturation pressure and temperature, cooling water injection temperature, the fraction of non-condensible gases in the steam, the tube fouling factor, and the tube material. It should be noted that although there was an initial value for row spacing given in Table I, row spacing was not used as a design variable during any of the optimizations. Instead, the program used the default method of row spacing calculation available in the code where the rows are spaced such that a 60-degree equilateral triangle pattern of concentric rows is obtained. Row spacing is therefore dependent on tube pitch and tube outer diameter by the following relation:

$$\text{RSPA} = (\text{SDDO} * \text{ODOI}) * .866 \qquad \text{(eqn 5.1)}$$

where RSPA is row spacing, SDDO is tube pitch, and ODOI is tube outer diameter in inches.

There are a few key points to be kept in mind when comparing the results of the case studies with the baseline. First, the baseline design is an infeasible and inadequate design. Its performance indicates that it is not capable of supporting the required steam load by returning a steam exit-fraction in excess of 13 percent. So any gains in the objective function that were realized in the case studies is even more remarkable since it is a necessary condition that the optimum design be a feasible design, defined as having an exit-fraction not greater than 1 percent. Second, the percent change referred to when analyzing the results is calculated based on the baseline design. Thus the baseline serves as a uniform frame of reference. Next, it should be noted that because of the large number of design variables and constraints, intuition on how an optimized result will turn out is not always applicable. Finally, it will be easier to understand the effects of the various design parameters by keeping in mind the following, very basic, heat transfer correlation:

$$Q = U * A * LMTD \qquad \text{(eqn 5.2)}$$

where Q is the rate of heat released as the steam condenses; U is the overall heat transfer coefficient; A is the heat transfer surface area; and LMTD can be interpreted as the thermal driving force between the steam and the coolant. Q is directly dependent on steam flow and pressure into the condenser, the percentage of that steam that is condensed, and any subcooling of the condensate. For a given steam load and a very small exit-fraction Q is nearly constant as the optimized results in all the case studies will indicate.

1. Constraint Framework for CONDIP

In order to simulate an actual trade-off study, the constraints and their respective limits were kept constant for all the case studies. The condenser was to be designed with a maximum bundle diameter of ten feet, a maximum and minimum tube outer diameter of 0.625 and 1.25 inches respectively, a steam exit-fraction of not more than 1 percent, a maximum cooler inlet velocity (VLCMAX) of 200 feet/second, and a ratio of tube sheet hole area to total tube sheet area of less than 0.30.

The constraint on bundle diameter was chosen somewhat arbitrarily. It seems unlikely that this limit would be realistically exceeded, although certainly space requirements would dictate the exact configuration. Tube outer diameter is dependent on the values for tube wall thickness and tube inner diameter. Thus the limits imposed on tube outer diameter represent realistic restrictions on the possible cobinations of inner diameter and wall thickness. These restrictions are based loosely on anticipated tube structural and strength requirements and correspond to values of normally available tubes [Ref. 19]. The maximum limit of 200 feet/second for VLCMAX was also a somewhat arbitrary but realistic limit. It is assumed that steam velocities often exceed that value in the condenser bundle.

It is recalled that steam exit-fraction will play a significant role in the determination of the final optimum design. The baseline exit-fraction of 13 percent predicted by CONDIP for the DDG-37 condenser is unsatisfactory. Therefore a more reasonable upper limit of 1 percent was placed on this constraint. Although CONDIP will return a much more conservative design if 1 percent vice 13 percent is used as the upper limit, the subsequent design will be much more credible.

Finally, the amount of tube sheet material that can be removed by drilling for the installation of condenser tubes is specified at 24 percent of the total tube sheet area in [Ref. 17]. This area ratio limit represents a structural limit imposed to ensure that the tube sheets do not fail due to heat and pressure stresses in the condenser. However, CONDIP does not take into account the space between the condenser and tube shell normally used in area ratio calculations as blank tube sheet area. For this reason and to allow more flexibility in the design analysis, the constraint limit was set at 30 percent.

In summary, the general design constraints and the associated upper and lower bounds were:

$$0.625 \leq \text{tube outer diameter (inch)} \leq 1.25$$

$$1.0 \leq \text{bundle diameter (feet)} \leq 10.0$$

$$\text{steam exit-fraction (\%)} \leq 1.0$$

$$\text{VLCMAX (ft/sec)} \leq 200.0$$

$$\text{area ratio} \leq .30$$

These design constraints and associated bounds were used in all the case studies except where specifically modified.

2. Design Variable Framework for CONDIP

At least eight design variables were used in all the case studies. They include tube inner diameter, tube wall thickness, tube pitch, the number of tubes in the condenser, tube length, the inner void radius, the percent of the tubes in the cooler, and cooling water velocity. Side constraints were placed on all of these variables to correspond to either realistic physical limits or available standardized materials.

Tube wall thickness was not allowed to fall below 0.022 inches (BWG 24) or exceed .109 inches (12 BWG), sizes normally available commercially. Tube inner diameter was restricted to values between .407 and 1.206 inches so as to yield tube outer diameters within the limits specified earlier.

Tube pitch is defined as the ratio of the center to center spacing between adjacent tubes in a row to the tube outer diameter. Tube pitch is an accurate measure of how closely packed the tube bundle is. Generally accepted values for pitch lie in the range of 1.3 to 1.7. However, to provide more latitude in the design process this design variable was allowed to vary in the range between 1.1 to 2.0.

There is no guidance available as to the allowable range for tube length in the condenser. Since the lower limit was not expected to be crucial, it was set randomly at 1.0 feet. The upper limit of 25.0 feet was a realistic limit considering the size of the tube diameter being worked with. Inner void radius and the percent of tubes in the cooler were chosen to be design variables simply to enhance the flexibility of the code in designing the condenser model. The bounds for both variables were entirely arbitrary with only common sense as the determining factor. The upper and lower limits on the percent of tubes in the cooler was established as 10.0 and 2.0 percent respectively. The upper and lower bounds on the inner void radius was set at 1.0 and 0.1 feet.

Cooling water velocity generally ranges from three to nine feet per second in value for all common tube materials, except titanium which has an upper limit of 15 feet per second. Exceeding these upper limits risks excessive tube erosion and material damage. Finally the number of tubes was permitted to vary between 1000 and 8000 tubes for the purpose of improving design flexibilty. It is extremely unlikely that, for most propulsion applications, tube number would fall below 1000. The upper limit was simply chosen as a realistic cutoff point in terms of complexity, cost and maintainability.

In summary, the general design variables and the associated side-constraints were:

$$0.407 \le \text{tube inner diameter (inches)} \le 1.206$$

$$0.022 \le \text{tube thickness (inches)} \le 0.109$$

$$2.0 \le \text{percent of tubes in cooler} \le 10.0$$

$$0.10 \le \text{inner void radius (feet)} \le 1.0$$

$$3.0 \le \text{coolant velocity (ft/sec)} \le 9.0$$

$$1.0 \le \text{tube length (feet)} \le 25.0$$

$$1000 \le \text{tube number} \le 8000$$

$$1.1 \le \text{tube pitch} \le 2.0$$

As in the case of design constraints, these design variables and their respective limits were used consistently in all the case studies unless otherwise specified.

C. CASE STUDIES USING CONDIP

1. Case One

The objective of this case was to minimize condenser volume. The final results of the optimization along with the initial parameters is listed in Table III.

These results show a 16 percent decrease in condenser volume with a corresponding 24 percent increase in pumping power. The source of the improvement can be understood by noting the following:

1) Tube wall thickness was reduced from 0.049 to 0.022, the minimum side-constraint, thus allowing tube inner diameter to increase while maintaining a minimum tube outer diameter.

2) The number of tubes shrank slightly as did tube length, resulting in a smaller heat transfer surface area.

3) Tube pitch increased markedly, causing a reduction in steam pressure losses which then ensured that high values for steam saturation pressure and temperature would be maintained throughout the condenser. The large pitch also reduced steam velocities, allowing the cooler inlet velocity limit to be satisfied. Row spacing decreased from the initial value of 1.35 inches, thus decreasing condenser volume.

4) Cooling water velocity increased to the maximum allowable value of 9 ft/sec which correspondingly resulted in larger head losses and coolant flow, causing overall pumping power to increase.

As cooling water velocity increased and tube wall thickness decreased, then their respective thermal resistances were diminished. The cumulative effect was to improve the overall heat transfer coefficient. LMTD rose primarily as a result of the higher steam temperatures throughout the condenser. It is apparent by looking at equation 5.2 that increasing the driving forces for heat transfer, such as the overall heat transfer coefficient and LMTD, allows the heat transfer surface area to decrease. This resulted in a similar reduction in condenser volume.

The constraint limits that prevented further design improvement were the upper bound on the cooling water velocity, the upper limit on the tube sheet area and the upper limit on VLCMAX.

2. Case Two

The objective of this case was to minimize the pumping power required to overcome the tube-side head losses and drive the cooling water through the condenser tubes. The final results of the optimization are presented along with the initial design in Table IV.

The results indicate a dramatic 90 percent reduction in required pumping power with an equally large 120 percent increase in condenser volume. The major factors involved in the design improvement along with their relative effects are briefly explained below:

1) Tube inner diameter increased 27 percent while tube thickness remained relatively unchanged. Thus tube outer diameter was caused to increase.

2) The number of tubes in the condenser rose significantly, along with tube length. This, coupled with the enlarged tube outer diameter resulted in nearly doubling the heat transfer area.

3) Tube pitch icreased 29 percent, which allowed steam saturation pressure and temperature to be maintained at consistently large values in the condenser. This had a benefiting effect on the associated LMTD calculation. The large pitch also helped satisfy the steam velocity limit into the cooler. The tube spacing decreased from the initial value of 1.35, but by a smaller amount than the previous case because of the large values for tube pitch and outer diameter.

4) Cooling water velocity dropped to the minimum allowable limit of 3 ft/sec. This had the effect of reducing tube-side head losses and coolant flow through the condenser. Consequently, pumping power was drastically reduced.

The combined effect of all these changes can again be put in perspective by looking at equation 5.2. For the given steam and corresponding heat load, the heat transfer area increased drastically, allowing both LMTD and the overall heat transfer coefficient to decrease. A smaller overall heat transfer implies a smaller convective tube-side contribution which in turn permits coolant velocity to reduce to its lowest allowable value. The LMTD decrease is explained by the fact that cooling water was spending more time in the tubes, thus causing the average cooling water temperature to rise. However, the subsequent reduction in LMTD was minimized by the fact that a high steam temperature was maintained in the condenser.

There were no active constraints in this design outside of cooling water velocity which prevented further design improvement. However, the penalty paid in terms of a huge condenser volume, appears prohibitive.

3. Case Three

The objective of this case was to minimize pumping power while holding condenser volume constant at the initial value of 432 cubic feet. This was a particularly interesting test case as the results in Table V bear out. The required pumping power was reduced by nearly 38 percent with no change in volume. The effects of the design changes which resulted in the design improvement are presented below:

1) Tube inner diameter increased noticeably. However, the effects of this increase on tube outer diameter was minimized by a large drop in tube wall thickness. Thus, tube outer diameter remained relatively unchanged.

2) The number of tubes experienced a minor reduction, while tube length increased. The overall affect was to increase heat transfer surface area.

3) Tube pitch again rose by nearly 25 percent, causing steam saturation temperature and pressure to maintain a nearly constant value throughout the condenser. This had a beneficial effect on the LMTD between the steam and the cooling water. The larger pitch also had the additional effect of reducing steam velocity thus allowing the subsequent design to satisfy the upper limit on steam velocity into the cooler (VLCMAX). The combination of tube pitch and tube outer diameter resulted in a reduction in row spacing from the initial value of 1.35

4) Cooling water velocity decreased by about 21 percent. This effect was manifested in subsequent pressure head, coolant flow and pumping power calculations.

Looking at equation 5.2 we see the same general pattern emerging as in Case 3, but with more subtlety in the changes. Heat transfer increased, but not at the expense of volume. Cooling water velocity was allowed to decrease while the overall heat transfer coefficient actually rose. One explanation is that as the tube wall got thinner its thermal resistance got smaller which more than offset the loss of convective heat transfer contribution from the coolant. The LMTD dropped slightly due to the higher average coolant temperature of the coolant in the tubes.

The constraints which became active and prevented further improvement in the design include tube sheet area ratio as well as tube wall thickness. However, tube wall thickness was particular crucial because of its related effect on heat transfer.

4. Case Four

The objective of this case was to minimize condenser volume while holding pumping power constant at the initial value of 55.7 horsepower. The results of this case can be found in Table VI. Chosen to contrast the results in Case 4, the relative improvement in this design objective was not nearly so impressive. Condenser volume shrank by only 12 percent. An explanation of the causes and effects is provided below:

1) Tube inner diameter increased, with a corresponding decrease in tube wall thickness to yield the minimum allowable tube outer diameter.

2) The number of tubes decreased noticeably, tending minimize bundle volume. Note, there was only slight increase in tube length. The overall effect was to similarly reduce heat transfer surface area as condenser volume decreased.

3) Tube pitch again increased significantly, having the same effects on steam pressure, temperature and steam velocity into the cooler as discussed earlier. A large tube pitch benefits the LMTD between the steam and the cooling water. Row spacing was again a factor in reducing condenser volume as before.

4) Cooling velocity decreased slightly as did head loss. But overall coolant flow increased due to an increase in tube inner diameter. The net effect was to maintain pumping power.

Again, referring to equation 5.2 , it is clear that the slight decrease in heat transfer area was offset by the slight rise in LMTD resulting from higher condenser steam temperatures. The significant improvement in overall heat transfer coefficient, therefore, is what makes the heat balance work. The large decrease in tube wall thickness and corresponding reduction in thermal resistance contributed heavily to this improvement.

There were several contraint limits which prevented any additional objective optimization. They include the minimum tube wall thickness, tube sheet area ratio and steam velocity entering the cooler.

5. Case Five

The objective of this case was to minimize condenser volume while exercising CONDIP's capabilities to linearly vary tube pitch and tube inner diameter by row. Thirty-five rows were used, which was the identical number as the initial design. Tube pitch and tube inner diameter of both the outermost and innermost rows served as design variables in this case. However - because tube number is now a dependent variable based on the number of rows, tube pitch, and tube diameter - it could not be used as a design variable. The optimized results of this analysis along with the initial design are presented in Table VII.

The results of this test case indicate a condenser volume which is 20 percent smaller than the initial design as compared to a 16 percent decrease in Case 1. The basic reasons and explanations as to why volume was able to be reduced remain fundamentally the same as in Case 1. Attention will therefore be focussed on the effects of linearly varying pitch and tube diameter. Final tube pitch ranged in value from 1.75 in the inner row to 1.44 in the outer row. Similarly, tube inner diameter ranged from .729 in the inner row to .583 in the outer row.

It is believed that smaller pitch and inner diameter were used in the outer row because of the higher available steam saturation pressure and temperature. The resulting higher steam velocities enhanced the beneficial effects of vapor shear on the external heat transfer coefficient thereby improving heat transfer on the outer rows. As steam pressure decreased, then tube pitch and tube inner diameter increased to compensate and extract all the available heat from the steam. Consequently, steam velocity decreased and was able to satisfy to the limit imposed on the cooler entrance velocity. The end result is a condenser geometry that makes complete use of the available resources and conforms to the geometry to take advantage of the thermal conditions in the condenser. The big limitation with this approach is that the number of rows is held constant. Thus the subsequent condenser is designed around that value and the subsequent optimum design is a function of the number of rows specified.

TABLE I

Input Design Data

PARAMETER	VALUE
Total number of tubes	5230
Tube length (feet)	10.3
Tube inner diameter (inches)	0.527
Tube wall thickness (inches)	0.049
Tube outer diameter (inches)	0.625
Tube mat'l thermal conductivity btu/(ft-hr-°F)	26.0
Tube pitch	1.38
Percent of tubes in the cooler	7.0
Steam inlet flow (lbm/hr)	161,961
Fraction of non-condensible gas (ppm)	37.1
Steam inlet pressure (psia)	1.294
Steam inlet temperature (°F)	110.52
Coolant inlet velocity (ft/sec)	8.473
Coolant inlet temperature (°F)	76.66
Fouling factor	.0002
Inner void diameter (feet)	1.1
Row spacing (inches)	1.35

TABLE II

CONDIP Verification Results

PARAMETER	EXPERIMENT RESULTS	CONDIP RESULTS	CHANGE (%)
Heat transfer area (sq.ft.)	8805	8814	+0.10
Overall heat transfer coefficient btu/(hr-sq.ft.-°F)	635.2	547.9	-9.5
Log mean temperature difference (°F)	28.24	28.62	+1.3
Coolant temperature rise (°F)	10.61	9.90	-6.7
Coolant mass flow rate (10^7 lbm/hr)	1.503	1.540	+2.5
Condenser volume (cu.ft.)	-----	432.3	-----
Bundle diameter (ft)	5.7 7.2	7.17	-----
Shell-side pressure drop (psia)	0.751	1.29	+71.8
Steam exit-fraction (% of input)	-----	13.3	-----
Heat rejected (10^8 btu/hr)	1.595	1.451	-9.03
Area ratio	0.291	0.266	-8.59

TABLE III
Volume Minimization

PARAMETER	BASELINE RESULTS	OPTIMIZED RESULTS	CHANGE (%)
Total number of tubes	5230	5117	-2.2
% of tubes in cooler	7.0	7.01	+0.1
Tube length (ft)	10.3	9.92	-3.7
Tube inner diam. (in)	.527	.582	+10.4
Tube wall thick. (in)	.049	.022	-55.1
Tube outer diam. (in)	.625	.626	+0.2
Tube pitch	1.4	1.73	+23.6
Void diameter (ft)	1.10	1.34	+21.8
Bundle diameter (ft)	7.17	6.59	-8.1
Condenser volume (cu.ft.)	432.3	362.2	-16.2
Area ratio	0.266	0.300	+12.7
Coolant inlet vel. (ft./sec)	8.473	9.00	+6.2
Coolant mass flow rate (10^7 lbm/hr)	1.540	1.955	+26.9
Head loss (ft H20)	7.35	7.18	-2.3
Pumping power (hp)	55.69	68.99	+23.9
Coolant temperature rise (°F)	9.90	9.00	-9.1
Log mean temperature difference (°F)	28.62	29.13	+1.8
Heat transfer area (sq.ft.)	8814.	8320.	-5.6
Average overall heat transfer coefficient btu/(hr-sq.ft.-°F)	574.9	689.9	+20.0
Steam exit-fraction (% of input)	13.3	0.0	-100.
Heat rejected (10^8 btu/hr)	1.451	1.672	+15.2

TABLE IV
Power Minimization

PARAMETER	BASELINE RESULTS	OPTIMIZED RESULTS	CHANGE (%)
Total number of tubes	5230	6393	+22.2
% of tubes in cooler	7.0	7.4	+5.7
Tube length (ft)	10.3	13.34	+29.5
Tube inner diam. (in)	.527	.667	+26.6
Tube wall thick. (in)	.049	.0455	-7.1
Tube outer diam. (in)	.625	.758	+21.3
Tube pitch	1.4	1.812	+29.4
Void diameter (ft)	1.10	1.13	+2.7
Bundle diameter (ft)	7.17	9.25	+29.0
Condenser volume (cu.ft.)	432.3	964.4	+123.1
Area ratio	0.266	0.277	+4.1
Coolant inlet vel. (ft./sec)	8.473	3.00	-64.6
Coolant mass flow rate (10^7 lbm/hr)	1.540	1.067	-30.7
Head loss (ft H20)	7.35	1.11	-84.9
Pumping power (hp)	55.69	5.84	-89.5
Coolant temperature rise (°F)	9.90	16.3	+64.6
Log mean temperature difference (°F)	28.62	24.82	-13.3
Heat transfer area (sq.ft.)	8814.	16,921	+92.0
Average overall heat transfer coefficient btu/(hr-sq.ft.-°F)	574.9	393.8	-31.5
Steam exit-fraction (% of input)	13.3	1.0	-92.5
Heat rejected (10^8 btu/hr)	1.451	1.654	+14.0

TABLE V

Power Minimization With Volume Constant

PARAMETER	BASELINE RESULTS	OPTIMIZED RESULTS	CHANGE (%)
Total number of tubes	5230	5062	+3.2
% of tubes in cocler	7.0	6.7	-4.3
Tube length (ft)	10.3	11.39	+10.6
Tube inner diam. (in)	.527	.594	+12.7
Tube wall thick. (in)	.049	.022	-55.1
Tube outer diam. (in)	.625	.638	+2.1
Tube pitch	1.4	1.753	+25.2
Void diameter (ft)	1.10	1.14	+3.6
Bundle diameter (ft)	7.17	6.73	-6.1
Condenser volume (cu.ft.)	432.3	431.6	-0.2
Area ratio	0.266	0.297	+11.7
Coolant inlet vel. (ft./sec)	8.473	6.74	-20.5
Coolant mass flow rate (10^7 lbm/hr)	1.540	1.508	-2.1
Head loss (ft H2O)	7.35	4.69	-36.2
Pumping power (hp)	55.69	34.77	-37.6
Coolant temperature rise (^oF)	9.90	11.6	+17.2
Log mean temperature difference (^oF)	28.62	27.63	-3.5
Heat transfer area (sq.ft.)	8814.	9631.4	+9.3
Average overall heat transfer coefficient btu/(hr-sq.ft.-^oF)	574.9	627.3	+9.1
Steam exit-fraction (% of input)	13.3	0.0	-100.
Heat rejected (10^8 btu/hr)	1.451	1.669	+15.0

TABLE VI

Volume Minimization With Power Constant

PARAMETER	BASELINE RESULTS	OPTIMIZED RESULTS	CHANGE (%)
Total number of tubes	5230	4867	-6.9
% of tubes in cocler	7.0	7.2	+2.9
Tube length (ft)	10.3	10.92	+6.0
Tube inner diam. (in)	.527	.581	+10.2
Tube wall thick. (in)	.049	.022	-55.1
Tube outer diam. (in)	.625	.625	0.0
Tube pitch	1.4	1.739	+24.2
Void diameter (ft)	1.10	1.20	+9.1
Bundle diameter (ft)	7.17	6.41	-10.6
Condenser volume (cu.ft.)	432.3	378.4	-12.4
Area ratio	0.266	0.299	+12.4
Coolant inlet vel. (ft./sec)	8.473	8.27	-2.4
Coolant mass flow rate (10^7 lbm/hr)	1.540	1.701	+10.5
Head loss (ft H2O)	7.35	6.67	-9.3
Pumping power (hp)	55.69	55.80	+0.2
Coolant temperature rise (°F)	9.90	10.34	+4.4
Log mean temperature difference (°F)	28.62	28.38	-0.8
Heat transfer area (sq.ft.)	8814.	8697.	-1.3
Average overall heat transfer coefficient btu/(hr-sq.ft.-°F)	574.9	677.4	+17.5
Steam exit-fraction (% of input)	13.3	0.0	-100.
Heat rejected (10^8 btu/hr)	1.451	1.672	+15.2

TABLE VII

Volume Minimization With Linear Variations

PARAMETER	BASELINE RESULTS	OPTIMIZED RESULTS	CHANGE (%)
Total number of tubes	5230	5348	+2.3
% of tubes in cocler	7.0	7.3	+4.3
Tube length (ft)	10.3	8.7	-15.5
Tube inner diam. (in)	.527	*.729 .583	----
Tube wall thick. (in)	.049	.022	-55.1
Tube outer diam. (in)	.625	*.773 .627	----
Tube pitch	1.4	*1.75 1.44	----
Void diameter (ft)	1.10	1.28	+16.4
Bundle diameter (ft)	7.17	6.8	-5.2
Condenser volume (cu.ft.)	432.3	345.8	-20.0
Area ratio	0.266	0.298	+12.0
Coolant inlet vel. (ft./sec)	8.473	9.0	+6.2
Coolant mass flow rate (10^7 lbm/hr)	1.540	2.48	+61.0
Head loss (ft H2O)	7.35	5.84	-20.5
Pumping power (hp)	55.69	71.1	+27.7
Coolant temperature rise (°F)	9.90	7.1	-28.8
Log mean temperature difference (°F)	28.62	30.14	+5.3
Heat transfer area (sq.ft.)	8814.	7746.	-12.1
Average overall heat transfer coefficient btu/(hr-sq.ft.-°F)	574.9	713.1	+24.0
Steam exit-fraction (% of input)	13.3	0.5	-96.2
Heat rejected (10^8 btu/hr)	1.451	1.665	+14.7

* Inner row values followed by outer row values.

VI. CONCLUSIONS

The intent of this research was to create a detailed condenser analysis ccde capable of being coupled with a numerical optimizer and to test the program to prove its versatility. An additional objective was to validate the analysis with existing data. The results of the test cases were presented in Chapter Five; the resulting conlusions are summarized here.

A. There were significant difficulties encountered in formulating the complex condenser design anaysis, CONDIP, in a way that was compatible with the optimizer COPES/CONMIN. However, the majority of those problems were overcome resulting in the creation of a program which, when combined with the optimizer, is capable of taking any initial design, no matter how impractical or infeasible, and solving for an optimum solution based on a set of pre-determined constraints and design variables. There are still some minor limitations as to the degree of optimization, but the final design is usually within 10 pecent of the single best optimum. In additicn, the test cases indicate that as many as ten design variables and six constraints can be used simultaneously in the design optimization with CONDIP.

B. The test cases demonstrated the effectiveness of CONDIP as a design tool for not only the conceptual design of a condenser, but also in evaluating comparison studies based on any number of design variable combinations. The number of possible combinations of design objectives, design variables and design constraints implies limitless possibilities to be explored and evaluated.

C. An attempt was made to verify CONDIP with existing data with inconclusive results. Part of the blame can be placed on the rather inadequate quality and quantity of the data, but the general performance of CONDIP's condenser indicates a weakness in the analysis. As stated earlier, the source of the this weakness may be found in the correlations used for condensate inundation. The constants used in the expression for correcting shell-side heat transfer coefficients are based somewhat on conjecture. Yet they play a significant role in the overall condenser performance. Despite this limitation, the ability to optimize CONDIP's detailed analysis is a significant step forward over using the traditional and limited HEI method.

D. CONDIP incorporates features that further increase its appeal as a design tool. By possessing the ability to linearly vary pitch and tube diameter, a better understanding of how to improve condenser performance based on its configuration is realized. The capability to incorporate shell-side tube enhancement is another added plus. The possibilities that can now be investigated are limitless.

VII. RECOMMENDATIONS

In addition to the insight that this investigation has given into the generation of automated condenser design programs, it has specifically addressed the shortcomings and pitfalls which may be encountered along the way and offered possible solutions to overcome them. Presented below are recommendations for furthering the developmentof CONDIP as a completely versatile and accepted design program.

A. Since the weak link and the most signifcant unknown in condenser analysis is the effect of condensate rain in typical condenser environments, subsequent research should be devoted to investigating this phenomenon and developing more precise analytic correlations. In particular, the effects of velocity and flow direction on the condensate film should be attended to.

B. Perhaps in conjunction with the above, a test condenser should be constructed which is geometrically similar to the model proposed in CONDIP in order to physically observe and record the condenser performance. This data could then be used to either verify CONDIP or strengthen some of its anaysis. In addition, this condenser should be built such that the tube bank can be arranged in any combination of pitch, tube diameter and row spacing to fully appreciate the effects of these variables.

C. A series of sensitivity studies should be conducted on CONDIP to fully exercise its capabilities and determine the relative effects of various designvariables on condenser performance. Tradeoff studies similar to those performed in this research would be most beneficial to fully understand condenser behavior.

D. Additicnal subroutines should be created which would allow tube enhancement to be a design variable. This involves developing correlations between heat transfer enhancement and associated frictional losses. This type of relationship can be developed for both tube-side and shell-side enhancement.

E. Finally, it is recommended that additional refinement be performed on the code to increase its capability and flexibility. One such way is to somehow allow pitch, tube diameter and tube wall thickness to vary linearly by row while still allcwing the number of tubes to be a design variable. The options available are limitless.

APPENDIX A
GLOSSARY

While it would most beneficial to present a complete glossary of all the variables used in CONDIP, the sheer number makes it difficult to present a comprehensive list. However, CONDIP makes liberal use of comment cards to define as many variables as possible to make the code easier to follow. Therefore, the computer listing in Appendix C is available for reference. A list of the possible design variables and constraints is provided here along with its corresponding position in the GLOBCM common block for easy reference in writing the appropriate COPES data cards. In addition, it will be specified whether these variables can be used as design constraints or design variables.

1. ALST: The length of the condenser and cooler tubes in feet. ALST is to be used only as a design variable.

2. DELWP: The pressure difference between the inlet and outlet coolant headers of the condenser bundle in psi. DELWP is to be used only as a design variable.

3. DELWPC: The pressure difference between the inlet and outlet coolant headers of the condenser bundle in psi. DELWPC is to be used only as a design constraint.

4. GFLOW: The mass flow rate of the coolant in lbm/hour. GFLOW cannot be used as a design variable simultanouesly with VELBI. Otherwise it can be used as a design variable or a design constraint.

5. SIDI: The tube inner diameter of the innermost row of

the condenser bundle in inches. SIDI is to be used only as a design variable.

7. SIDO: The tube inner diameter of the outermost row of the condenser bundle in inches. If there is to linear variation of tube inner diameter then this variable represents the tube inner diameter of the entire condenser bundle. SIDO is to be used only as a design variable.

8. PHP: The coolant pumping power in horsepower. PHP is to be used only as a design constraint.

9. RSPA: The spacing between concentric rows in the condenser bundle in inches. RSPA is to be used only as a design variable.

10. RADINS: The inner void radius of the condenser bundle in feet. RADINS is to be used only as a design variable.

11. REWI: The tube-side Reynolds number of the coolant in the innermost row of the condenser bundle. REWI is to be used only as a design constraint.

12. REWO: The tube-side Reynolds number of the coolant in the outermost row of the condenser bundle. If there is no linear variation of tube inner diameter then this variable represents the tube-side Reynolds number of the entire condenser bundle. REWO is to be used only as a constraint.

13. SDDI: Tube pitch (tube spacing/tube outer diameter) of the innermost row of the condenser bundle. SDDI is to be used only as a a design variable.

14. SDDO: The tube pitch of the outermost row of the condenser bundle. If there is no linear variation of tube pitch then this variable represents the tube pitch for the entire condenser bundle. SDDO is to be used only as a design variable.

15. SLDI: Ratio of tube length to tube outer diameter of the outermost row of the condenser bundle. SLDI is to be used only as a design constraint.

16. SLDO: Ratio of tube length to tube outer diameter of the outermost row of the condenser bundle. If there is no linear variation of tube pitch then this variable represents the tube pitch for the entire condenser bundle. SLDO is to be used only as a design constraint.

17. VELBI: The velocity of the coolant in feet/sec. VELBI cannot be used as a design variable simultaneously with GFLOW. Otherwise it can be used as either a design constraint or as a design variable.

18. XW1: The ratio of tube thickness to tube inner diameter. XW1 can be used only as a design variable.

19. XW2: Tube thickness in inches. XW2 is to be used only as a design variable. XW2 and XW1 cannot be used simultaneously.

20. VOL1: The overall condenser and cooler volume in cubic feet. VOL1 is to be used only as a design constraint.

21. VOL2: The volume occupied by the tube bank, excluding the volume of the inner void, in cubic feet. VOL2 is to be used only as a design constraint.

22. TNOTOT: The total number of tubes in the condenser and cooler combined. If Option 1 is being used then TNOTOT is to be used only as a design constraint. If Option 2 is being used then TNOTOT is to be used only as a design variable.

23. BNDRAD: The condenser bundle in feet. BNDRAD is to be used only as a design constraint.

24. ARATIO: The ratio of the total cross-sectional area of

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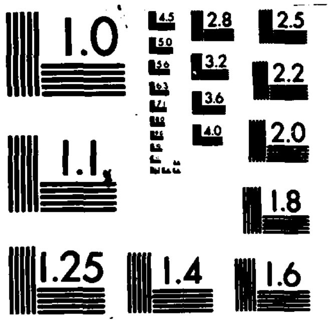

MICROCOPY RESOLUTION TEST CHART
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the tubes (based on the tube outer diameter) to the tube sheet area. ARATIO is to be used only as a design constraint.

25. ODII: The tube cuter diameter of the innermost row in inches. ODII is to be used only as a design constraint.

26. ODOI: The tube cuter diameter of the outermost row in inches. If there is no linear variation of tube inner diameter then this variable represants the tube outer diameter of the entire condenser bundle. ODOI is to be used only as a design constraint.

27. VLCMAX: The maximum allowable steam velocity into the cooler. VLCMAX can be used only as a design constraint and only when a cooler is being designed in the system.

28. PRCCLR: The percent of the total number of tubes in the cooler. PRCCLR can be used only as a design variable.

APPENDIX B

USERS MANUAL FOR CONDIP

This appendix describes the data cards that are necessary in order to couple any design program with COPES/CONMIN. Also described are cards illustrating data input required by CONDIP to initiate analysis. Thus, the data is divided into the COPES/CONMIN program section and the CONDIP-based condenser design program section.

The COPES data is segmented into "blocks" for convenience. All formats are alphanumeric for title, end and stop cards; F10 for real data; and I10 for integer data. The formatted input may be overridden by inserting commas between data entries. Comment cards may be inserted anywhere in the data stack prior to the end card and are identified by a dollar sign ($) in column 1. The COPES data stack must terminate with an end card containing the word "END" in column 1-3. It should be noted that information pertaining only to single analysis and optimization is presented here. Information concerning the other options available in COPES along with further explanation of COPES capabilities can be found in [Ref. 13].

The analysis data is also segmented into blocks for convenience and they begin immediately following the "END" card in the COPES data. No comment cards are permitted here, and the analysis data stack must terminate with the word "STOP" in columns 1-4. This is where the initial design values are placed for entry into CONDIP.

Default values are recommended for use in the following COPES data cards unless otherwise noted. It is recommended that these values in the COPES data blocks be used until the user becomes familiar with the program. In addition a saaple data input is illustrated in figure B.1 at the end of this appendix.

DATA BLOCK A

DESCRIPTION: COPES Title Card

FORMAT: 20A4

1	2	3	4	5	6	7	8
TITLE							

REMARKS:

1) This line is available for a brief description.

DATA BLOCK B

DESCRIPTION: COPES Program Control Parameters

FORMAT: 7I10

1	2	3	4	5	6	7	8
NCALC	NDV						

FIELD			**CONTENTS**
1	NCALC:		Calculation control
	0		Read input and stop. Data of blocks A-B is required. Remaining data is optional.
	1		One cycle through the program. Data of blocks A-B is required. Remaining data is optional.
	2		Optimization. Data of blocks A-I is required. Remaining data is optional.
2	NDV:		Number of independent design variables in optimization or optimum sensitivity study.

REMARKS:

1) Field 1 determines program execution

2) Fields 3-8 are to be left blank for the CONDIP application of COPES/CONMIN.

DATA BLOCK C

DESCRIPTION: COPES Integer Optimization Control Parameters

FORMAT: 8I10

1	2	3	4	5	6	7	8
IPRINT	ITMAX	ICNDIR	NSCAL	ITRM	LINOBJ	NACMX1	NFDG

FIELD **CONTENTS**

1 IPRINT: Print control used in optimization program, CONMIN.

0 No print during optimization.

1 Print initial and final optimization information.

2 Print above plus function value and design variable values at each iteration.

3 Print above plus constraint values, direction vector and move parameter at each iteration.

4 Print above plus gradient information.

5 Print above plus each proposed design vector, objective function and constraints during the one-dimensional search. required. Remaining data is optional.

2 ITMAX: Maximum number of optimization iterations allowed. DEFAULT = 20.

3 ICNDIR: Conjugate direction restart parameter. DEFAULT = NDV+1.

4 NSCAL: Scaling parameter. GT.0 - Scale design variables to order of magnitude one every NSCAL iterations. LT.0 - Scale design variables according to scaling values input. DEFAULT = No scaling.

5 ITRM: Number of subsequent iterations which must satisfy relative or absolute convergence criterion before optimization process is terminated. DEFAULT = 3.

6 LINOBJ: Linear objective function identifier. If the optimization objective is known to be a linear function of the design variables, set LINOBJ = 1. DEFAULT = Non-Linear.

7 NACMX1: one plus the maximum number of active constraints anticipated. DEFAULT = NDV+2.

DATA BLOCK C (Continued)

FIELD **CONTENTS**

8 NFDG: Finite difference gradient identifier.

0 All gradient information is computed by finite difference.

1 Gradient of objective is computed anaytically. Gradients of constraints are computed by finite difference.

2 All gradient information is computed analytically

REMARKS:

1) The value of NSCAL = 0 is suggested and ITRM = NACMX1 = 0 should be used.

2) The value of IPRINT may be reduced when the user becomes familiar with the optimization output.

3) The default values will be used if the card is either left blank or a value of zero is entered.

4) Because of the complexity of the problem it is necessary to have a large value for ITMAX so the problem will not be terminated prematurely. Recommended value is ITMAX = 40

5) The complexity of the condenser analysis ensure that no function can be considered linearly dependent on any combination of variables. This justifies using the DEFAULT value for LINOBJ.

DATA BLOCK D

DESCRIPTION: COPES Floating Point Optimization Program Parameters

FORMAT: 8F10

1	2	3	4	5	6	7	8
FDCH	FDCHM	CT	CTMIN	CTL	CTLMIN	THETA	PHI

FIELD CONTENTS

1 FDCH: Relative change in design variables in calculating finite difference gradients. DEFAULT = 0.01

2 FDCHM: Minimum absolute step in finite difference gradient calculations. DEFAULT = 0.001.

3 CT: Constraint thicknass parameter. DEFAULT = -0.1.

4 CTMI: Minimum absolute value of CT considered in the optimization process. DEFAULT = 0.004

5 CTL: Constraint thicknass parameter for linear and side constraints.

6 CTLMIN: Minimum absolute value of CTL considered in the optimization process. DEFAULT = 0.001

7 THETA: Mean value of push-off factor in the method of feasible directions. DEFAULT = 1.0

8 PHI: Participation coefficient, used if one or more constraints are violated. DEFAULT = 5.0.

DATA BLOCK D (continued)

FORMAT: 2F10

1	2	3	4	5	6	7	8
DELFUN	DABFUN						

FIELD **CONTENTS**

1 DELFUN: Minimum relative change in objective function to indicate convergence of optimization process. DEFAULT = 0.001.

2 DABFUN: Minimum absolute change in objective function to indicate convergence of the optimization process.
DEFAULT = 0.001 times the initial objective value.

REMARKS:

1) Note that data for Data Block D is entered on two separate cards. A blank card indicates the default value is to be used.

2) If the NDV is greater than 3, the recommended value for FDCH is between 0.05 and 0.10.

DATA BLOCK E

DESCRIPTION: Total Number of Design Variables, Design Objective Identification and Sign on Design Objective.

FORMAT: 2I10, F10

1	2	3	4	5	6	7	8
NDVTOT	IOBJ	SGNOPT					

FIELD **CONTENTS**

1 NDVTOT: Total number of variables linked to the design variables. NDVTOT must be greater or equal to NDV. This option allows two or more parameters to be assigned to a single design variable. The value of each parameter is the value of the design variable times a multiplier which may be different for each parameter.
DEFAULT = NDV.

2 IOBJ: Global variable number associated with objective function in optimization or optimum sensitivity analysis.

3 SGNOPT: Sign used on objective of optimization to identify whether function is to be maximized or minimized, +1.0 indicates maximization; -1.0 indicates minimization.
DEFAULT = -1.0

REMARKS:

1) Currently there are not any variables in CONDIP which are linked to any of the design variables. Therefore the DEFAULT value is used for NDVTOT.

DATA BLOCK F

DESCRIPTION: Design Variable Bounds, Initial Values, and Scaling Factors.

FORMAT: 4F10

1	2	3	4	5	6	7	8
VLB	VUB	X	SCAL				

FIELD		CONTENTS
1	VLB:	Lower bound on the design variable.
2	VUB:	Upper bound on the design variable.
3	X:	Initial value of the design variable. If X is non-zero, this will supercede the value initialized by subroutine ANALIZ.
4	SCAL:	Design variable scale factor. Not used if NSCAL ≥ 0 in Block C

REMARKS:

1) There must be one separate data card for each design variable. Therefore there will be NDV data cards.

2) For all applications with CONDIP, initial values for the design variables will be entered through the INPUT subroutine called in ANALIZ.

DATA BLOCK G

DESCRIPTION: Design Variable Identification

FORMAT: 2I10,F10

1	2	3	4	5	6	7	8
NDSGN	IDSGN	AMULT					

FIELD **CONTENTS**

1 NDSGN: Design variable number associated with the variable.

2 IDSGN: Global variable number associated with the variable.

3 AMULT: Constant multiplier on the variable. The value of the variable will be the value of the design variable, NDSGN, times AMULT. DEFAULT = 1.0.

REMARKS:

1) There must be one separate card for each of the NDVTOT design variables. These data cards must follow the same order as the corresponding design variable parameter cards in Block F.

DATA BLOCK H

DESCRIPTION: Number cf Constrained Parameters.

FORMAT: I10

1	2	3	4	5	6	7	8
NCONS							

FIELD CONTENTS

1 NCONS: Number of constraint SETS in the optimization problem.

REMARKS:

1) If two or more adjacent parameters in the Global common block have the same limits imposed, these are part of the same constraint set.

DATA BLOCK I

DESCRIPTION: Constraint Identification and Bounds.

FORMAT: 3I10

1	2	3	4	5	6	7	8
ICON	JCON	LCON					

FIELD **CONTENTS**

1 ICCN: First Global number corresponding to the constraint set.

2 JCON: Last Global number corresponding to the constraint set. DEFAULT = ICON.

3 LCON: Linear constraint identifier for this set of constrained variables. LCCN = 1 indicates linear constraints. DEFAULT = 0 = Nonlinear constraint.

REMARKS:

1) In CONDIP there is only Global number and thus one constraint that comprise a constraint set. Therefore the DEFAULT value is used for JCON.

2) All the constraints in this analysis are nonlinear. The DEFAULT value was therefore used for LCON as well.

3) This is the first card of a two card set which must be read together.

DATA BLOCK I (Continued)

FORMAT: 4F10

1	2	3	4	5	6	7	8
BL	SCAL1	BU	SCAL2				

FIELD **CONTENTS**

1 BL: Lower bound on the constrained variables. Value less than -2.0E+15 is assumed unbounded

2 SCAL1: Normalization factor on lower bound. DEFAULT = Max of ABS(BL) or 0.1.

3 BU: Upper bound on the constrained variables. Value greater than +2.0E+15 is assumed unbounded.

4 SCAL2 Normalization factor on upper bound. DEFAULT = Max of ABS(BU) or 0.1.

REMARKS:

1) The normalization factor can usually be defaulted, with the notable exception of exit-fraction. the normalization factor used for this constraint is usually ten times the upper bound.

DATA BLOCK P

DESCRIPTION: COPES Data 'END' Card.

FORMAT: 3A1

1	2	3	4	5	6	7	8
END							

FIELD	CONTENTS
1	The word 'END' in column 1-3.

REMARKS:

1) This card must appear at the end of the COPES data.

2) This ends the COPES input deck.

DATA BLOCK AA

DESCRIPTION: Geometry Option

FORMAT: I5

1	2	3	4	5	6	7	8
IOPT							

FIELD **CONTENTS**

1 IOPT Two condenser geometric options

1 IOPT = 1. Number of condenser rows is a input as a constant; the number of tubes is a dependent variable. Use data blocks EE,FF,and GG.

2 IOPT = 2. Number of tubes is allowed to be an independant variable and the number of rows is a dependent variable. Use data blocks HH and II. DEFAULT value is IOPT = 2.

REMARKS:

1) Data is right-justified and blanks will be interpreted as zeros.

2) If IOPT = 1, a smaller finite difference (FDCH) can be utilized in data Block D. This is because with this option the design analysis is less sensitive to the problems discussed earlier. Recommended using the DEFAULT value of 0.01 for FDCH.

DATA BLOCK BB

DESCRIPTION: Condenser Orientation

FORMAT: 1I5,3F10

1	2	3	4	5	6	7	8
ISEC	SECWID	PHI	PRCCLR				

FIELD		CONTENTS
1	ISEC	The number of sectors in the condenser.
2	SECWID	Sector width in degrees of arc.
3	PHI	Symmetry angle measure from the vertical.
4	PRCCLR	The percent of the tubes in the cooler.

REMARKS:

1) Data BB is required, no matter what geometry option is chosen.

2) The only limitation on ISEC and SECWID is that their product is less than 360 degrees. If the product is exactly 360 degrees, certain trigonometric functions will return a singularity.

3) PHI is that angle from the vertical that cuts the condenser in half.

4) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK CC

DESCRIPTION: Void Size, Tube Length, Row Spacing

FORMAT: 3F10

1	2	3	4	5	6	7	8
RADINS	ALST	RSPA					

FIELD		CONTENTS
1	RADINS	The inner void radius; feet.
2	ALST	The tube length; feet.
3	RSPA	Concentric row spacing about the void; inches.

REMARKS:

1) Data CC is required, no matter what geometry option is chosen.

DATA BLOCK DD

DESCRIPTION: Tube Material Parameters

FORMAT: I5,4F10

1	2	3	4	5	6	7	8
IWALL	XW	TUBESW	SKW	FOUL			

FIELD		CONTENTS
1	IWALL	A Flag indicating the tube thickness specification.
	1	IWALL = 1. Tube thickness is input as ratio of tube thickness to tube inner diameter.
	2	IWALL = 2. Tube thickness is input in inches.
2	XW	The input for wall thickness, dependent on the value for IWALL.
3	TUBESW	Specifc weight of the tube material; lbm/(cu.ft.)
4	SKW	Tube material thermal conductivity; (btu-ft)/(sq.ft.-hr-°F)
5	FOUL	Tube fouling factor.

REMARKS:

1) Data DD is required, no matter what geometry option is chosen.

2) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK EE

DESCRIPTION: Number of Rows

FORMAT: I5

1	2	3	4	5	6	7	8
NOROWS							

FIELD		CONTENTS
1	NOROWS	The number of concentric rows in the condenser bundle built around the center void

REMARKS:

1) Data EE is used only when IOPT = 1

2) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK FF

DESCRIPTION: Tube Inner Diameter

FORMAT: 1I5,2F10

1	2	3	4	5	6	7	8
MDIAM	SIDO	SIDI					

FIELD **CONTENTS**

1 MDIAM A flag to indicate whether tube inner diameter will linearly vary by row through the condenser bunile.

1 MDIAM = 1. Tube inner diameter is uniform through the condenser bundle.

2 MDIAM = 2. Tube inner diameter varies linearly through the bundle by row.

2 SIDO Tube inner diameter of the outer row; inches.

3 SIDI Tube inner diameter of the inner row; inches.

REMARKS:

1) Data FF is used only when IOPT = 1

2) Data is right-justified and blanks will be interpreted as zeros.

3) Ccoler tubes use the inner diameter of the innermost bundle row.

4) The DEFAULT value is MDIAM = 1

DATA BLOCK GG

DESCRIPTION: Tube Pitch

FORMAT: 1I5,2F10

1	2	3	4	5	6	7	8
MPITCH	SDDO	SDDI					

FIELD **CONTENTS**

1 MPITCH A flag to indicate whether tube pitch will linearly vary by row through the condenser bundle.

1 MPITCH = 1. Tube pitch is uniform through the condenser bundle.

2 MPITCH = 2. Tube pitch varies linearly through the bundle by row.

2 SDDO Tube pitch of the outer row;

3 SDDI Tube pitch of the inner row;

REMARKS:

1) Data GG is used only when IOPT = 1

2) Data is right-justified and blanks will be interpreted as zeros.

3) Cooler tubes use the pitch of the innermost bundle row.

4) The DEFAULT value is MPITCH = 1

DATA BLOCK HH

DESCRIPTION: Tube Inner Diameter and Tube Pitch

FORMAT: 2F10

1	2	3	4	5	6	7	8
SIDO	SDDO						

FIELD		CONTENTS
1	SIDO	Tube inner diameter for the entire condenser; inches
2	SDDO	Tube pitch for the entire condenser

REMARKS:

1) Data HH is used <u>only</u> when IOPT = 2.

2) Data is right-justified and blanks will be interpreted as zeros.

3) In the calculations, SIDI is set equal to SIDO and SDDI is set equal to SDDO. This avoids the need for two systems of nomenclature for each geometry option.

DATA BLOCK II

DESCRIPTION: Total Number of Tubes in the Condenser

FORMAT: F12

1	2	3	4	5	6	7	8
TNOTOT							

FIELD		CONTENTS
1	TNOTOT	The total number of tubes in the condenser (cooler and the bundle).

REMARKS:

1) Data II is used only when IOPT = 2.

2) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK JJ

DESCRIPTION: Inlet Steam Mixture.

FORMAT: 15,2F10

1	2	3	4	5	6	7	8
JGAS	WSI	WNCIR					

FIELD		CONTENTS
1	JGAS	A Flag indicating the type of non-condensable gas entering the system.
	1	JGAS = 1. This indicates that the gas is air.
	2	JGAS = 2. This indicates that the gas is carbon dioxide.
	3	JGAS = 3. This indicates that the gas is a mixture of the two.
2	WSI	Steam flow rate entering the condenser; lbm/hr.
3	WNCIR	Ratio of the non-condensable gas flow to inlet steam flow; lbm/hr.

REMARKS:

1) Data JJ is required, no matter what geometry option is chosen.

2) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK KK

DESCRIPTION: Inlet Temperatures.

FORMAT: 2F10

1	2	3	4	5	6	7	8
STBI	STSAT1						

FIELD		CONTENTS
1	STBI	Coclant inlet temperature; °F.
2	STSAT1	Inlet steam saturation temperature; °F.

REMARKS:

1) Data KK is required no matter, what geometry option is chosen.

2) Data is right-justified and blanks will be interpreted as zeros.

DATA BLOCK LL

DESCRIPTION: Cooling Water Parameters

FORMAT: 2F10

1	2	3	4	5	6	7	8
IFLOW	X5						

FIELD CONTENTS

1 IFLOW A control flag for cooling water specifications.

1 IFLOW = 1. Input pressure drop across cooling water headers in psia.

2 IFLOW = 2. Input cooling water velocity in ft/sec.

3 IFLOW = 3. Input coolant flow in lbm/hr.

2 X5 Actually input the value for flow into this variable. The specification for flow to be determined by IFLOW

REMARKS:

1) Data LL is required, no matter what geometry option is chosen.

2) Data is right-justified and blanks will be interpreted as zeros.

3) X5 acts as a temporary all-purpose storage variable for whatever expression for coolant flow is used.

DATA BLOCK MM

DESCRIPTION: Internal Enhancement Regions

FORMAT: I5

1	2	3	4	5	6	7	8
NEI							

FIELD		CONTENTS
1	NEI	Number of internal enhancement regions. A value between 1 and 6.

REMARKS:

1) Data MM is optional. There must be NEI subsequent data cards providing the necessary paramaters for each region.

2) enhancement can only be used if IOPT = 1.

3) Data is right-justified and blanks will be interpreted as zeros.

4) This value was zero for all runs.

DATA BLOCK NN

DESCRIPTION: Internal Enhancement Parameters

FORMAT: 2I5,3F10

1	2	3	4	5	6	7	8
NRNI	NETI	ENI	BC	BE			

FIELD		CONTENTS
1	NRNI	Row number of first row in internal enhancement region.
2	NETI	Number of tubes in each internal enhancement region.
3	ENI	Internal heat transfer enhancement factor.
4	BC	Coefficient in internallyenhanced tube coolant pressure drop calculation.
5	BE	Exponent in coolant pressure drop calculation.

REMARKS:

1) Data NN is optional. However, if NEI is greater than zero then there must NEI "NN" data cards to provide the necessary data for each enhancement region.

2) enhancement can only be used if IOPT = 1.

3) Data is right-justified and blanks will be interpreted as zeros.

4) These values are constant for entire run and cannot be changed by the optimizer.

5) This value was zero for all runs.

DATA BLOCK OO

DESCRIPTION: External Enhancement Regions

FORMAT: I5

1	2	3	4	5	6	7	8
NEE							

FIELD		CONTENTS
1	NEE	Number of external enhancement regions. A value between 1 and 6.

REMARKS:

1) Data OO is optional. There must be NEE subsequent data cards providing the necessary parameters for each region.

3) Data is right-justified and blanks will be interpreted as zeros.

4) This value was zero for all runs.

DATA BLOCK PP

DESCRIPTION: External Enhancement Parameters

FORMAT: 2I5,2F10

1	2	3	4	5	6	7	8
NRNE	NETE	ENO	ENH				

FIELD		CONTENTS
1	NRNE	Row number of first row in external enhancement region.
2	NETE	Number of tubes in each external enhancement region.
3	ENI	External heat transfer enhancement factor.
4	ENH	Steam-side pressure drop factors.

REMARKS:

1) Data PP is optional. However, if NEE is greater than zero then there must NEE "PP" data cards to provide the necessary data for each enhancement region.

2) Data is right-justified and blanks will be interpreted as zeros.

3) Enhancement can only be used if IOPT = 1.

4) These values are constant for an entire run and cannot be changed by the optimizer.

5) This value was zero for all runs.

DATA BLOCK QQ

DESCRIPTION: Baffle Options

FORMAT: I5

1	2	3	4	5	6	7	8
IBAF							

FIELD		CONTENTS
1	IBAF	A flag to be used to determine baffle number and location.

REMARKS:

1) Data QQ is optional.

2) Data is right-justified and blanks will be interpreted as zeros.

3) These values are constant for an entire run and cannot be changed by the optimizer.

4) Additional specified baffles were not used in any of the runs. This value was zero for all runs.

DATA BLOCK RR

DESCRIPTION: Baffle Location

FORMAT: I5

1	2	3	4	5	6	7	8
JBAF							

FIELD		CONTENTS
1	JBAF	An array containing baffle locations

REMARKS:

1) Data RR is optional.

2) Data is right-justified and blanks will be interpreted as zeros.

3) These valuas are constant for an entire run and cannot be changed by the optimizer.

4) Additional specified baffles were not used in any of the runs. This value was zero for all runs.

DATA BLOCK SS

DESCRIPTION: Detailed Printout

FORMAT: I5

1	2	3	4	5	6	7	8
IPRT							

FIELD		**CONTENTS**
1	IPRT	A flag to generate a detailed output of the condenser analysis (OUT3)

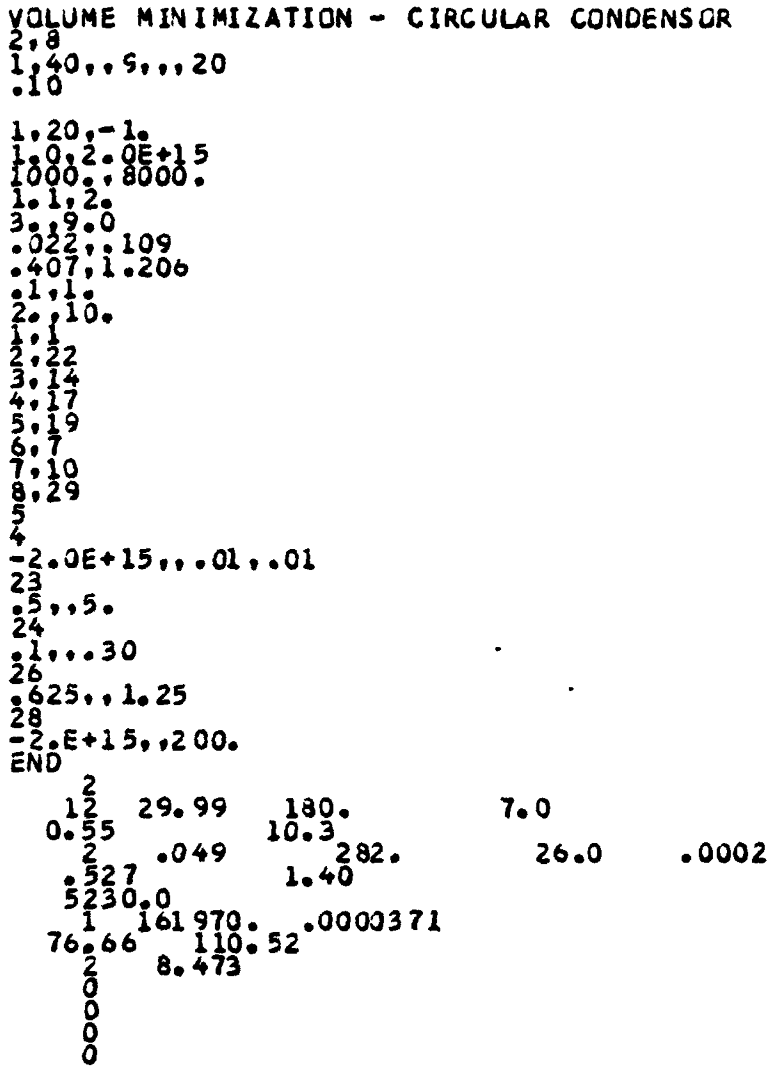
REMARKS:

1) Data SS is optional.

2) Data is right-justified and blanks will be interpreted as zeros.

3) These values are constant for an entire run and cannot be changed by the optimizer.

4) This value was zero for all runs.



```
VOLUME MINIMIZATION - CIRCULAR CONDENSOR
2,8
1,40,,9,,,20
.10

1,20,-1.
1.0,2.0E+15
1000.,8000.
1.1,2.
3.,9.0
.022,,109
.407,1.206
.1,1.
2.,10.
1,1
2,22
3,14
4,17
5,19
6,7
7,10
8,29
5
4
-2.0E+15,,.01,.01
23
.5,,5.
24
.1,,.30
26
.625,,1.25
28
-2.E+15,,200.
END
    2
   12  29.99   180.        7.0
  0.55        10.3
    2   .049      282.        26.0      .0002
   .527        1.40
   5230.0
    1   161 970.  .0000371
  76.66    110.52
    2   8.473
    0
    0
    0
    0
```

Figure B.1   Sample Data Input.

APPENDIX C

CONDIP LISTING

The following Appendix contains a complete listing for CONDIP. An effort has been made to make the program as readable as possible through liberal use of comment cards.

```
      SUBROUTINE ANALIZ (ICALC)
C     IF (ICALC.GT.2) RETURN
      IF (ICALC.GT.1) GO TO 10
      ICOUNT=0
      CALL INPUT (IPRT)
      CALL OUT1
10    IF (ICALC.EQ.3) GO TO 20
      CALL ORCON (ICALC)
      GO TO 30
20    CALL OUT2
C     ICOUNT = 1
      IF (IPRT.NE.0.AND.ICOUNT.NE.0) CALL OUT3
      ICOUNT=ICOUNT+1
30    RETURN
      END
C
C*****************************************************************
C*****************************************************************
C
      SUBROUTINE INPUT (IPRT)
C--------------
C INP 1
C                    SUBROUTINE INPUT
C
C               INPUT CALLED BY ANALIZ WITH ICALC = 1
C
C ZZZ INP-1
C--------------
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNOTO
     2T,BNDRAD,ARATIO,ODII,ODDI,SDDC,VLCMAX,PRCCLR
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FJUL,PHI,SKW,STBI,S
     1TSAT1,TUBESW,NCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MD
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)
     3,WSI,PFILL
      COMMON /INPT1/ IFLOW,IWALL
C$--------------
C INP 2
C                    READ ENTERING DATA SET
C
C        ALST = TUBE LENGTH IN FEET
C        BC = COEFFICIENT IN INTERNALLY ENHANCED TUBE COOLANT PRESSURE
C                DROP CALCULATION.
C        BE = EXPONENT IN COOLANT PRESSURE DRCP CALCULATION.
C        DELWP = PRESSURE DROP ACROSS COOLANT WATER HEADERS,  PSI
C        ENI = INTERNAL HEAT TRANSFER ENHANCEMENT FACTORS.
C        ENH = STM SIDE PRESSURE DROP FACTORS.
C        ENO = EXTERNAL HEAT TRANSFER ENHANCEMENT FACTORS.
```

```
C        FOUL = TUBE FOULING FACTOR.                                     CON00490
C        GFLOW = COOLANT MASS FLOW RATE  LBM/HR                          CON00500
C        IBAF = CONTROL FLAG FOR BAFFLE OPTIONS                          CON00510
C        IFLOW = CONTROL FLAG FOR COOLING WATER SPECIFICATION.           CON00520
C        IPRT = CONTROL FLAG FOR OUTPUT.  (EXTENDED OUTPUT IF IPRT>0.)   CON00530
C        ISEC = NO. OF SECTORS IN CONDENSER                              CON00540
C        IWALL = CONTROL FLAG FOR TUBE THICKNESS SPECIFICATION.          CON00550
C        JBAF = ARRAY CONTAINING BAFFLE LOCCATIONS.                      CON00560
C        JGAS = N/C GAS IDENTIFIER 1,2, OR 3                             CON00570
C        MDIAM = CONTROL FLAG FOR LINEAR VARIATION IN TUBE DIAMETER.     CON00580
C        MPITCH = CONTROL FLAG FOR LINEAR VARIATION IN TUBE PITCH.       CON00590
C        NEE = NUMBER OF EXTERNAL ENHANCEMENT REGIONS.                   CON00600
C        NEI = NUMBER OF INTERNAL ENHANCEMENT REGIONS.                   CON00610
C        NETE = NUMBER OF TUBES IN EACH EXTERNAL ENHANCEMENT REGION.     CON00620
C        NETI = NUMBER OF TUBES IN EACH INTERNAL ENHANCEMENT REGION.     CON00630
C        NOROWS = NUMBER OF ROWS IN THE CONDENSER                        CON00640
C        NRNE = ROW NUMBER OF FIRST ROW IN EXTERNAL ENHANCEMENT REGION.  CON00650
C        NRNI = ROW NUMBER OF FIRST ROW IN INTERNAL ENHANCEMENT REGION.  CON00660
C        SIDI = TUBE ID AT INSIDE ROW - IN                               CON00670
C        SIDO = TUBE ID AT OUTSIDE ROW - IN                              CON00680
C        IOPT = FLAG TO INDICATE WHICH GEOMETRY MODULE IS BEING USED     CON00690
C              IF OPT=1 THEN NOROWS IS A CONSTANT IN THE MODEL AND       CON00700
C              VARIATION IN PITCH AND TUBE DIAMETER IS PERMITTED.        CON00710
C              IF OPT=2 THEN TNOTOT IS A DESIGN VARIABLE AND LINEAR      CON00720
C              VARIATIONS ARE NOT PERMITTED.                             CON00730
C        PHI    = SYMETRY ANGLE MEASURED FROM THE VERTICAL               CON00740
C        RADINS = BUNDLE INSIDE RADIUS - FT                              CON00750
C        RSPA = TUBE ROW RADIAL SEPARTATION - IN                         CON00760
C        SDDI = PITCH AT INSIDE ROW                                      CON00770
C        SDDO = PITCH AT OUTSIDE ROW                                     CON00780
C        SECWID = SECTOR WIDTH IN DEGREES OF ARC                         CON00790
C        SKW = TUBE MATERIAL THERMAL CONDUCTIVITY  BTU-FT/HR-FT**2-F     CON00800
C        STBI = COOLANT INLET TEMP    F                                  CON00810
C        STSAT1 = INLET STM SAT TEMP    F                                CON00820
C        TNOTOT = TOTAL NUMBER OF TUBES IN THE CONDENSOR/COOLER          CON00830
C        TUBESW = SPECIFIC WEIGHT OF THE TUBE MATERIAL  LBM/CU FT        CON00840
C        VELBI = COOLANT FLOW VELOCITY  FT/SEC                           CON00850
C        WNCIR = RATIO OF N/C MASS FLOW TO STEAM MASS FLOW               CON00860
C        WSI = STM FLOW RATE  LBM/HR                                     CON00870
C        XW  = TEMP INPUT VALUE OF XW1 AND XW2                           CON00880
C        XW1 = RATIO OF TUBE WALL THICKNESS TO TUBE ID                   CON00890
C        XW2 = TUBE WALL THICKNESS  INCHES                               CON00900
C                                                                        CON00910
C ZZZ INP-2                                                              CON00920
C--------------                                                          CON00930
      READ (5,330) IOPT                                                  CON00940
      READ (5,340) ISEC,SECWID,PHI,PRCCLR                                CON00950
      READ (5,360) RADINS,ALST,RSPA                                      CON00960
      READ (5,400) IWALL,XW,TUBESW,SKW,FOUL                            CON00970
C                                                                      CON00980
      IF ((IOPT.GE.2).OR.(IOPT.LT.1)) GO TO 10                         CON00990
C                                                                      CON01000
      READ (5,380) NOROWS                                              CON01010
      READ (5,370) MDIAM,SIDO,SIDI                                     CON01020
      READ (5,370) MPITCH,SDDO,SDDI                                    CON01030
      GO TO 20                                                         CON01040
10    READ (5,360) SIDO,SDDO                                           CON01050
      READ (5,390) TNOTOT                                              CON01060
      MPITCH=1                                                         CON01070
      MDIAM=1                                                          CON01080
C                                                                      CON01090
20    IF (MDIAM.EQ.1) SIDI=SIDO                                        CON01100
      IF (MPITCH.EQ.1) SDDI=SDDO                                       CON01110
      IW=IWALL                                                         CON01120
      IF (IWALL.NE.2) IW=1                                             CON01130
      XW1=0.                                                           CON01140
      XW2=0.                                                           CON01150
      IF (IW.EQ.1) XW1=XW                                              CON01160
      IF (IW.EQ.2) XW2=XW                                              CON01170
      READ (5,350) JGAS,WSI,WNCIR                                      CON01180
      READ (5,410) STBI,STSAT1                                         CON01190
      READ (5,420) IFLOW,X5                                            CON01200
      IFL=IFLOW                                                        CON01210
      GFLOW=0.                                                         CON01220
      VELBI=0.                                                         CON01230
      DELWP=0.                                                         CON01240
      IF (IFLOW.EQ.1) DELWP=X5                                         CON01250
      IF (IFLOW.EQ.2) VELBI=X5                                         CON01260
      IF (IFLOW.EQ.3) GFLOW=X5                                         CON01270
      READ (5,430) NEI                                                 CON01280
      IF (NEI.EQ.0) GO TO 40                                           CON01290
      IF ((NEI.LT.0).AND.(NEI.GT.6)) GO TO 120                         CON01300
      DO 30 I=1,NEI                                                    CON01310
30    READ (5,440) NRNI(I),NETI(I),ENI(I),BC(I),BE(I)                  CON01320
40    READ (5,430) NEE                                                 CON01330
      IF (NEE.EQ.0) GO TO 60                                           CON01340
      IF ((NEE.LE.0).OR.(NEE.GT.6)) GO TO 120                          CON01350
      DO 50 I=1,NEE                                                    CON01360
50    READ (5,450) NRNE(I),NETE(I),ENO(I),ENH(I)                       CON01370
60    READ (5,430) IBAF                                                CON01380
      IF ((IBAF.LE.-2).OR.(IBAF.GT.ISEC)) GO TO 120                    CON01390
      IF ((IBAF.EQ.0).OR.(IBAF.EQ.-1)) GO TO 80                        CON01400
      DO 70 I=1,IBAF                                                   CON01410
70    READ (5,430) JBAF(I)                                             CON01420
80    CONTINUE                                                         CON01430
      READ (5,430) IPRT                                                CON01440
```

```
C$--------------                                                        CONO1450
C INP 3                                                                 CONO1460
C                  TEST FOR RECOVERABLE INPUT ERRORS                    CONO1470
C                                                                       CONO1480
C ZZZ INP-3                                                             CONO1490
C---------------                                                        CONO1500
      IF ((IOPT.EQ.1).OR.(IOPT.EQ.2)) GO TO 90                          CONO1510
      WRITE (6,460)                                                     CONO1520
      WRITE (6,470) IOPT                                                CONO1530
      WRITE (6,510)                                                     CONO1540
      IOPT=2                                                            CONO1550
90    IF (IOPT.EQ.2) GO TO 110                                          CONO1560
      IF ((MDIAM.EQ.2).OR.(MDIAM.EQ.1)) GO TO 100                       CONO1570
      WRITE (6,460)                                                     CONO1580
      WRITE (6,480) MDIAM                                               CONO1590
      WRITE (6,510)                                                     CONO1600
      MDIAM=1                                                           CONO1610
100   IF ((MPITCH.EQ.1).OR.(MPITCH.EQ.2)) GO TO 110                     CONO1620
      WRITE (6,460)                                                     CONO1630
      WRITE (6,490) MPITCH                                              CONO1640
      WRITE (6,510)                                                     CONO1650
      MPITCH=1                                                          CONO1660
110   IF ((IWALL.EQ.1).OR.(IWALL.EQ.2)) GO TO 120                       CONO1670
      WRITE (6,460)                                                     CONO1680
      WRITE (6,500) IWALL                                               CONO1690
      WRITE (6,510)                                                     CONO1700
      IWALL=1                                                           CONO1710
C$--------------                                                        CONO1720
C INP 4                                                                 CONO1730
C                  LOCATE NON-RECOVERABLE INPUT ERRORS                  CONO1740
C                                                                       CONO1750
C ZZZ INP-4                                                             CONO1760
C---------------                                                        CONO1770
120   IERR=0                                                            CONO1780
      IF ((ISEC.GT.0).AND.(ISEC.LE.15)) GO TO 130                       CONO1790
      IERR=1                                                            CONO1800
      WRITE (6,520)                                                     CONO1810
      WRITE (6,530) ISEC                                                CONO1820
130   X2=SECWID*FLOAT(ISEC)                                             CONO1830
      IF ((X2.LE.360.).AND.(X2.GT.0.)) GO TO 140                        CONO1840
      WRITE (6,520)                                                     CONO1850
      WRITE (6,540) X2                                                  CONO1860
      WRITE (6,550) ISEC,SECWID                                         CONO1870
      IERR=1                                                            CONO1880
140   IF (IOPT.EQ.2) GO TO 150                                          CONO1890
      IF ((NOROWS.GT.0).AND.(NOROWS.LE.99)) GO TO 160                   CONO1900
      IERR=1                                                            CONO1910
      WRITE (6,520)                                                     CONO1920
      WRITE (6,560) NCROWS                                              CONO1930
      GO TO 160                                                         CONO1940
C                                                                       CONO1950
150   IF (TNOTOT.GT.0) GO TO 160                                        CONO1960
      IERR=1                                                            CONO1970
      WRITE (6,520)                                                     CONO1980
      WRITE (6,570) TNOTOT                                              CONO1990
C                                                                       CONO2000
160   IF (RADINS.GT.0.) GO TO 170                                       CONO2010
      IERR=1                                                            CONO2020
      WRITE (6,520)                                                     CONO2030
      WRITE (6,580) RADINS                                              CONO2040
170   IF (ALST.GT.0.) GO TO 180                                         CONO2050
      IERR=1                                                            CONO2060
      WRITE (6,520)                                                     CONO2070
      WRITE (6,590) ALST                                                CONO2080
180   IF (SIDO.GT.0.) GO TO 190                                         CONO2090
      IERR=1                                                            CONO2100
      WRITE (6,520)                                                     CONO2110
      WRITE (6,600) SIDO                                                CONO2120
190   IF ((MDIAM.EQ.1).OR.(SIDI.GT.0.)) GO TO 200                       CONO2130
      IERR=1                                                            CONO2140
      WRITE (6,520)                                                     CONO2150
      WRITE (6,610) SIDI                                                CONO2160
200   IF (SDDO.GT.1.) GO TO 210                                         CONO2170
      IERR=1                                                            CONO2180
      WRITE (6,520)                                                     CONO2190
      WRITE (6,620) SDDO                                                CONO2200
210   IF ((MPITCH.EQ.1).OR.(SDDI.GT.1.)) GO TO 220                      CONO2210
      IERR=1                                                            CONO2220
      WRITE (6,520)                                                     CONO2230
      WRITE (6,630) SDDI                                                CONO2240
220   IF (IW.EQ.2) GO TO 230                                            CONO2250
      IF (XW1.GT.0.) GO TO 240                                          CONO2260
      IERR=1                                                            CONO2270
      WRITE (6,520)                                                     CONO2280
      WRITE (6,640) XW1                                                 CONO2290
      GO TO 240                                                         CONO2300
230   X=XW2*2.                                                          CONO2310
      IF (X.GT.0.) GO TO 240                                            CONO2320
      IERR=1                                                            CONO2330
      WRITE (6,520)                                                     CONO2340
      WRITE (6,650) XW2                                                 CONO2350
240   IF ((WNCIR.GE.0.).AND.(WNCIR.LT.1.)) GO TO 250                    CONO2360
      IERR=1                                                            CONO2370
      WRITE (6,520)                                                     CONO2380
      WRITE (6,660) WNCIR                                               CONO2390
250   IF ((STBI.GT.-32.).AND.(STBI.LT.212)) GO TO 260                   CONO2400
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      IERR=1                                                            CONO2410
      WRITE (6,520)                                                     CONO2420
      WRITE (6,670) STBI                                                CONO2430
  260 IF (STBI.LT.STSAT1) GO TO 270                                     CONO2440
      IERR=1                                                            CONO2450
      WRITE (6,520)                                                     CONO2460
      WRITE (6,680) STBI,STSAT1                                         CONO2470
  270 IF ((IFLOW.GT.0).OR.(IFLOW.LE.3)) GO TO 280                       CONO2480
      IERR=1                                                            CONO2490
      WRITE (6,520)                                                     CONO2500
      WRITE (6,690) IFLOW                                               CONO2510
  280 IF ((NEI.GE.0).AND.(NEI.LE.6)) GO TO 290                          CONO2520
      IERR=1                                                            CONO2530
      WRITE (6,520)                                                     CONO2540
      WRITE (6,700) NEI                                                 CONO2550
  290 IF ((NEE.GE.0).AND.(NEE.LE.6)) GO TO 300                          CONO2560
      IERR=1                                                            CONO2570
      WRITE (6,520)                                                     CONO2580
      WRITE (6,710) NEE                                                 CONO2590
  300 IF ((IBAF.GE.-1).AND.(IBAF.LE.ISEC)) GO TO 310                    CONO2600
      IERR=1                                                            CONO2610
      WRITE (6,520)                                                     CONO2620
      WRITE (6,720) IBAF,ISEC                                           CONO2630
      WRITE (6,730)                                                     CONO2640
  310 IF (IERR.EQ.0) GO TO 320                                          CONO2650
      STOP                                                              CONO2660
  320 RETURN                                                            CONO2670
  330 FORMAT (I5)                                                       CONO2680
  340 FORMAT (I5,3F10.5)                                                CONO2690
  350 FORMAT (I5,F10.5,F10.7)                                           CONO2700
  360 FORMAT (4F10.5)                                                   CONO2710
  370 FORMAT (I5,F10.5,F10.5)                                           CONO2720
  380 FORMAT (I5)                                                       CONO2730
  390 FORMAT (F12.5)                                                    CONO2740
  400 FORMAT (I5,4F10.5)                                                CONO2750
  410 FORMAT (2F10.5)                                                   CONO2760
  420 FORMAT (I5,F10.5)                                                 CONO2770
  430 FORMAT (I5)                                                       CONO2780
  440 FORMAT (2I5,3F10.5)                                               CONO2790
  450 FORMAT (2I5,2F10.5)                                               CONO2800
  460 FORMAT (1H0,31H***  WARNING - INPUT ERROR  ***)                   CONO2810
  470 FORMAT (1H ,22H INPUT VALUE OF OPT = ,I5,27H OUT OF RANGE, OPT SETCONO2820
     1 TO 2)                                                            CONO2830
  480 FORMAT (1H ,21HINPUT VALUE OF MDIAM=,I5,29H OUT OF RANGE, MDIAM SECONO2840
     1T TO 1)                                                           CONO2850
  490 FORMAT (1H ,22HINPUT VALUE OF MPITCH=,I5,30H OUT OF RANGE, MPITCH CONO2860
     1SET TO 1)                                                         CONO2870
  500 FORMAT (1H ,21HINPUT VALUE OF IWALL=,I5,29H OUT OF RANGE, IWALL SECONO2880
      1T TO 1)                                                          CON02890
510   FORMAT (1H ,26H    EXECUTION CONTINUES ...)                       CON02900
520   FORMAT (1H0,38H****  RUN TERMINATED DURING INPUT ****)            CON02910
530   FORMAT (1H ,43HRANGE OF ALLOWABLE ISEC IS 1 THRU 15, ISEC=,I5)    CON02920
540   FORMAT (1H ,60HCONDENSER ANGULAR WIDTH IS OUT OF RANGE 0 TO 360 DECON02930
     1G, WIDTH=,E10.5,5H DEG.)                                          CON02940
550   FORMAT (1H ,5HISEC=,I5,10H    SECWID=,E10.3)                      CON02950
560   FORMAT (1H ,49HNUMBER OF ROWS MUST BE IN RANGE 0 TO 100, NOROWS=,ICON02960
     15)                                                                CON02970
570   FORMAT (1H ,51HTHE NUMBER OF TUBES MUST BE GREATER THAN 0, TNOTOT=CON02980
     1,F12.5)                                                           CON02990
580   FORMAT (1H ,48HBUNDLE RADIUS MUST BE GREATER THAN ZERO, RADINS=,E1CON03000
     10.3)                                                              CON03010
590   FORMAT (1H ,44HTUBE LENGTH MUST BE GREATER THAN ZERO, ALST=,E10.3)CON03020
600   FORMAT (1H ,53HTUBE INNER DIAMETER MUST BE GREATER THAN 0, SIDO =,CON03030
     1E10.3)                                                            CON03040
610   FORMAT (1H ,50HTUBE INNER DIAMETER MUST BE GREATER THAN 0, SIDO =,CON03050
     1E10.3)                                                            CON03060
620   FORMAT (1H ,40HTUBE PITCH MUST BE GREATER THAN 1, SDOO=,E10.3)    CON03070
630   FORMAT (1H ,40HTUBE PITCH MUST BE GREATER THAN 1, SDOI=,E10.3)    CON03080
640   FORMAT (1H ,75HRATIO OF TUBE THICKNESS TO TUBE INNER DIAMETER MUSTCON03090
     1 BE GREATER THAN 0, XW1=,E10.3)                                   CON03100
650   FORMAT (1H ,49HTUBE THICKNESS MUST BE GREATER THAN 0, XW2=,E10.3) CON03110
660   FORMAT (1H ,93HRATIO OF N/C GASSES TO STM FLOW MUST BE LESS THAN OCON03120
     1NE  AND GREATER THAN EQUAL TO ZERO, WNCIR=,E10.3)                 CON03130
670   FORMAT (1H ,63HINJECTION TEMP MUST BE GREATER THAN 32 AND LESS THACON03140
     1N 212, STBI=,E10.3)                                               CON03150
680   FORMAT (1H ,58HINJECTION TEMP MUST BE LESS THAN EXHAUST TRUNK TEMPCON03160
     1, STBI=,E10.3,8H  STSAT=,E10.3)                                   CON03170
690   FORMAT (1H ,31HIFLOW MUST BE 1,2 OR 3.  IFLOW=,I5)                CON03180
700   FORMAT (1H ,73HNUMBER OF INTERNAL ENHANCEMENT REGIONS MUST BE BETWCON03190
     1EEN ZERO AND SIX, NEI=,I5)                                        CON03200
710   FORMAT (1H ,73HNUMBER OF EXTERNAL ENHANCEMENT REGIONS MUST BE BETWCON03210
     1EEN ZERO AND SIX, NEE=,I5)                                        CON03220
720   FORMAT (1H ,50HIBAF MUST BE BETWEEN -1 AND ISEC INCLUSIVE.  IBAF=,CON03230
     1I5,7H  ISEC=,I5)                                                  CON03240
730   FORMAT (1H ,40H(IF USER WANTS IBAF=ISEC+1, SET IBAF=-1))          CON03250
      END                                                               CON03260
C                                                                       CON03270
C****************************************************************       CON03280
C****************************************************************       CON03290
C                                                                       CON03300
      SUBROUTINE OUT1                                                   CON03310
C--------------                                                         CON03320
C OUT1 1                                                                CON03330
C                     OUTPUT OF ENTERING DATA SET                       CON03340
C ZZZ OUT1-1                                                            CON03350
C                 SEE INP-2 FOR VARIABLE DEFINITIONS                    CON03360
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C--------------                                                         CON03370
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,CON03380
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNOTOCON03390
     2T,BNDRAD,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR                      CON03400
      COMMON /INPT/  BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON03410
     1TSAT1,TUBESW,NCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON03420
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON03430
     3,WSI,PFILL                                                        CON03440
      COMMON /INPT1/  IFLOW,IWALL                                       CON03450
      WRITE (6,60)                                                      CON03460
      WRITE (6,70)                                                      CON03470
      WRITE (6,80)                                                      CON03480
      WRITE (6,90)                                                      CON03490
      WRITE (6,100)                                                     CON03500
      WRITE (6,90)                                                      CON03510
      WRITE (6,80)                                                      CON03520
      WRITE (6,110)                                                     CON03530
      WRITE (6,120)  ISEC                                               CON03540
      WRITE (6,130)  SECWID                                             CON03550
      WRITE (6,140)  PHI                                                CON03560
      WRITE (6,150)  PRCCLR                                             CON03570
      IF (IOPT.EQ.2)  WRITE (6,170)  TNOTOT                             CON03580
      IF (IOPT.EQ.2)  GO TO 10                                          CON03590
      WRITE (6,160)  NOROWS                                             CON03600
10    WRITE (6,180)  RADINS                                             CON03610
      WRITE (6,190)  ALST                                               CON03620
      WRITE (6,200)  MDIAM                                              CON03630
      IF (MDIAM.EQ.0)  GO TO 20                                         CON03640
      WRITE (6,210)  SIDO                                               CON03650
      WRITE (6,240)                                                     CON03660
      GO TO 30                                                          CON03670
20    WRITE (6,220)  SIDO,SIDI                                          CON03680
30    WRITE (6,230)  MPITCH                                             CON03690
      IF (MPITCH.EQ.0)  GO TO 40                                        CON03700
      WRITE (6,260)  SDDO                                               CON03710
      WRITE (6,280)                                                     CON03720
      GO TO 50                                                          CON03730
40    WRITE (6,270)  SDDO,SDDI                                          CON03740
50    WRITE (6,250)  IWALL                                              CON03750
      IF (IWALL.EQ.1)  WRITE (6,300)  XW1                               CON03760
      IF (IWALL.EQ.2)  WRITE (6,290)  XW2                               CON03770
      WRITE (6,310)  TUBESW                                             CON03780
      WRITE (6,320)  SKW                                                CON03790
      WRITE (6,330)  FOUL                                               CON03800
      IF (JGAS.EQ.1)  WRITE (6,360)                                     CON03810
      IF (JGAS.EQ.2)  WRITE (6,370)                                     CON03820
      IF (JGAS.EQ.3)  WRITE (6,380)                                     CON03830
      WRITE (6,340)  WSI                                                CON03840
      WRITE (6,350) WNCIR
      WRITE (6,390) STBI
      WRITE (6,400) STSAT1
      WRITE (6,410) IFLOW
      IF (IFLOW.EQ.3) WRITE (6,420) GFLOW
      IF (IFLOW.EQ.2) WRITE (6,430) VELBI
      IF (IFLOW.EQ.1) WRITE (6,440) DELWP
      WRITE (6,450) NEI
      WRITE (6,460) NEE
      WRITE (6,470) IBAF
      RETURN
60    FORMAT (1H1)
70    FORMAT (1H ,51H                     GLOBAL COMMON BLOCK
     1/62H       1        2      3        4        5      6      7        8      9
     2/62H ALST    DELWP DELWPC EXITOA  GFLOW  SIDI   SIDO   PHP    RSPA
     3//62H      10      11     12       13       14      15      16      17     18
     4 /61H  RADINS   REWI  REWO    SDDI    SDDO    SLDI    SLDO   VELBI  XW1
     5//62H  19      20      21      22       23       24       25      26
     6 /56H XW2   VOL1  VOL2  TNOTOT  BNDRAD   ARATIO   ODII   ODOI//)
80    FORMAT (1H ,15X,16X,28H****************************)
90    FORMAT (1H ,15X,16X,1H*,26X,1H*)
100   FORMAT (1H ,15X,16X,28H* CONDIP ENTERING DATA SET *)
110   FORMAT (1H0///)
120   FORMAT (1H ,15X,17HNUMBER OF SECTORS,12X,I8)
130   FORMAT (1H ,15X,12HSECTOR WIDTH,18X,F9.1,10X,11HDEG. OF ARC)
140   FORMAT (1H ,15X,24HBUNDLE ORIENTATION ANGLE,6X,F9.1,7X,14HDEG. FRO
     1M VERT)
150   FORMAT (1H ,15X,53H% OF TOTAL TUBES ASSIGNED TO COOLER IS PRCCLR
     1   =  ,F5.2/)
160   FORMAT (1H ,15X,19HNUMBER OF TUBE ROWS,13X,I5)
170   FORMAT (1H ,15X,32HNUMBER OF TUBES IN THE CONDENSOR,8X,F12.5)
180   FORMAT (1H ,15X,20HBUNDLE INSIDE RADIUS,12X,F10.4,16X,4HFEET)
190   FORMAT (1H ,15X,11HTUBE LENGTH,19X,F10.2,5X,11X,4HFEET/)
200   FORMAT (1H ,15X,37HFLAG FOR TUBE OD VARIATION IS MDIAM =,I2)
210   FORMAT (1H ,15X,20HTUBE INSIDE DIAMETER,9X,F10.4,14X,6HINCHES)
220   FORMAT (1H ,15X,20HTUBE INSIDE DIAMETER/15X,13X,11HOUTSIDE ROW,7X,
     1F10.2,14X,6HINCHES/15X,14X,10HINSIDE ROW,7X,F10.2,14X,6HINCHES/)
230   FORMAT (1H ,15X,36HFLAG FOR PITCH VARIATION IS MPITCH =,I2)
240   FORMAT (1H ,15X,39HTUBE DIAMETER IS A CONSTANT THRU BUNDLE/)
250   FORMAT (1H ,15X,40HFLAG FOR TUBE WALL INPUT UNIT IS IWALL =,I2)
260   FORMAT (1H ,15X,26HTUBE CIRCUMFERENTIAL PITCH,4X,F10.2)
270   FORMAT (1H ,15X,26HTUBE CIRCUMFERENTIAL PITCH/15X,13X,11HOUTSIDE R
     1OW,7X,F11.3/15X,14X,10HINSIDE ROW,7X,F11.3/)
280   FORMAT (1H ,15X,29HPITCH IS CONSTANT THRU BUNDLE/)
290   FORMAT (1H ,15X,19HTUBE WALL THICKNESS,11X,F13.5,11X,6HINCHES)
300   FORMAT (1H ,15X,31HWALL THICKNESS TO TUBE ID RATIO,F10.3)
310   FORMAT (1H ,15X,25HTUBE WALL SPECIFIC WEIGHT,5X,F10.2,9X,6HLB/FT**
     13)
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320   FORMAT (1H ,15X,25HTUBE THERMAL CONDUCTIVITY,5X,F10.2,9X,11HBTU/FT
     1-HR-F)
330   FORMAT (1H ,15X,19HTUBE FOULING FACTOR,11X,F13.5/)
340   FORMAT (1H ,15X,20HSTEAM MASS FLOW RATE,9X,F9.0,16X,6HLBM/HR)
350   FORMAT (1H ,15X,27HWEIGHT FRACTION OF N/C FLOW,3X,1PE13.5/)
360   FORMAT (1H ,15X,14HN/C GAS IS AIR)
370   FORMAT (1H ,15X,25HN/C GAS IS CARBON DIOXIDE)
380   FORMAT (1H ,15X,46HN/C GAS IS A MISTURE OF AIR AND CARBON DIOXIDE)
390   FORMAT (1H ,15X,29HCOOLANT INJECTION TEMPERATURE,F10.1,16X,5HDEG F
     1)
400   FORMAT (1H ,15X,26HENTERING STEAM TEMPERATURE,4X,F9.2,16X,5HDEG F/
     1)
410   FORMAT (1H ,15X,28HCW FLOW SPECIFIER IS IFLOW =,I2)
420   FORMAT (1H ,22X,22HCOOLANT MASS FLOW RATE,15X,F9.1,15X,6HLBM/HR/)
430   FORMAT (1H ,15X,16HCOOLANT VELOCITY,14X,F9.1,15X,6HFT/SEC/)
440   FORMAT (1H ,15X,21HCOOLANT PRESSURE DROP,9X,F11.3,16X,3HPSI/)
450   FORMAT (1H ,15X,38HNO. OF INTERNAL ENHANCEMENT REGIONS IS,I2)
460   FORMAT (1H ,15X,38HNO. OF EXTERNAL ENHANCEMENT RETIONS IS,I2)
470   FORMAT (1H ,15X,26HFLAG FOR BAFFLE IS IBAF = ,I5)
      END
C
C**********************************************************************
C**********************************************************************
C
      SUBROUTINE ORCON (ICALC)
C--------------
C ORC 1
C                     SUBROUTINE ORCON
C
C              DIMENSION SIZE
C                     X = NO. OF ROWS + 1
C                     Y = NO. OF SECTORS
C                     Z = NO. OF ENHANCEMENT REGIONS
C
C         TPAR(X)   AOTFLW(X)   RADIUS(X)   TBNPR(X)   VW(X)   SID(X)
C         SECANG(Y)  WGAS(Y)   JBAF(Y+1)
C         ANT(X,Y)   WS(X,Y)    VEL(X,Y)    PMIX(X,Y)
C         BC(Z)   BE(Z)   ENI(Z)   ENO(Z)   NETI(Z)   NETE(Z)
C         NRNE(Z)   NRNI(Z)
C
C ZZZ ORC-1
C--------------
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNUTU
     2T,BNDRAD,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,S
     1TSAT1,TUBESW,WNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MD
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)
     3,WSI,PFILL
      COMMON /ORO1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMDUT(10
     10)
      COMMON /ORC2/ ANT(100,15),STB2ES,VW(100)
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNO,VEL2,FR
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST
      COMMON /SEC/ ALMTD(100,15),CUMDP(100,15),DELP(15),GFLW(100,15),HEF
     1F(100,15),PMIX(100,15),PSAT(100,15),QOA(100,15),RC(100,15),ROUT(10
     20,15),SHI(100,15),SHN(100,15),STSAT(100,15),UN(100,15),VEL(100,15)
     3,VNRE(1C0,15),VPSHH(100,15),WCND(100,15),WGAS(15),WP(15),WS(100,15
     4),WSP(15)
      COMMON /OUT2A/ RCORR,RSPF,PHPCON,VCL1C
C
      DIMENSICN TPAR(100),RADIUS(100),SECANG(15),BAFA(16)
C
C$-------------
C ORC 2
C                        DATA INITIALIZATION
C
C           AMWNC = MOLECULAR WEIGHT OF N/C GAS PRESENT
C           IFIRST IS A FLAG TO HETTRN TO INDICATE FIRST EXECUTION
C           CBI = SALT CONCENTRATION OF COOLANT  WT. PRCNT
C           CPB = COOLANT SPECIFIC HEAT (UNITS?)
C           PTST AND WTST ARE CONTRAINTS USED IN SEC-6
C
C           VW(1) = IS INITIALIZED AS A SEED FOR AN ITERATIVE
C              CALCULATICN IN ORC-9
C
C ZZZ ORC-2
C-------------
      IF (ICALC.EQ.2) GO TO 20
      SG=32.174
      PI=3.14159
      CBI=.035
      CPB=1.
      SECFLG=FLOAT(ISEC)
      WNCI=WSI*WNCIR
      A=1.
      DO 10 I=1,ISEC
      WS(1,I)=WSI/SECFLG*A
   10 WGAS(I)=WNCI/SECFLG*A
      IFIRST=1
      IF (JGAS.EQ.1) AMWNC=28.965
      IF (JGAS.EQ.2) AMWNC=44.
      IF (JGAS.EQ.3) AMWNC=36.5
      VW(1)=10.
      GO TO 20
C$-------------
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C ORC 3                                                                 CONO5290
C                   ENTERING POINT FOR ICALC = 2                        CONO5300
C                                                                       CONO5310
C ZZZ ORC-3                                                             CONO5320
C-------------                                                          CONO5330
20    CONTINUE                                                          CONO5340
      DO 30 I=1,ISEC                                                    CONO5350
      WTST(I)=0.                                                        CONO5360
30    PTST(I)=0.                                                        CONO5370
C$------------                                                          CONO5380
C ORC 4                                                                 CONO5390
C                          BUNDLE GEOMETRY                              CONO5400
C                                                                       CONO5410
C          TUBE PITCH IS DEFINED AS THE RATIO CF TUBE CENTER TO CENTECONO5420
C          SPACING TO TUBE OD, MEASURED ALONG A ROW OF CONSTANT BUNDLCONO5430
C          RADIUS.  ROW RADIAL SEPARATION IS NOT DIRECTLY RELATED TO CONO5440
C          PITCH.                                                       CONO5450
C                                                                       CONO5460
C       AOTFLW = AREA OPEN TO STEAM FLOW IN EACH ROW I OF               CONO5470
C                A SECTOR                                               CONO5480
C       AHOLES = AREA OF THE ENDS OF THE TUBES                          CONO5490
C       ARATIO = TOTAL AREA OF THE ENDS OF THE TUBES DIVIDED BY THE     CONO5500
C                THE TUBE SHEET AREA THRU WHICH THE TUBES PASS          CONO5510
C       ARCPR = CIRCUMFERENTIAL ARC LENGTH OF EACH SECTOR PER UNIT      CONO5520
C                RADIUS OF THE ROW BEING CONSIDERED                     CONO5530
C       ALST = TUBE LENGTH   FT                                         CONO5540
C       BNDRAD = TUBE BUNDLE RADIUS - FT                                CONO5550
C       CSP = TUBE CNTR - CNTR SPACING AT A GIVEN ROW                   CONO5560
C       CSPI = CSP FOR INNER ROW                                        CONO5570
C       CSPO = CSP FOR OUTER ROW                                        CONO5580
C       DELCSP = RADIAL CHANGE IN CSP PER ROW  FT                       CONO5590
C       DELODF = CHANGE IN TUBE OD / ROW  FT                            CONO5600
C       FCWID = ANGULAR WIDTH OF CONDENSER MINUS ONE SECTOR   DEG       CONO5610
C       ISEC = NUMBER OF SECTORS IN THE CONDENSER                       CONO5620
C       NOROWS = NO. OF ROWS IN EACH SECTOR                             CONO5630
C       OD = TUBE OD ON A GIVEN ROW  FT                                 CONO5640
C       ODOI = TUBE OD, OUTER ROW - IN                                  CONO5650
C       ODIF = TUBE OD, INNER ROW - FT                                  CONO5660
C       ODII = TUBE OD, INNER ROW - IN                                  CONO5670
C       ODOF = TUBE OD, OUTER ROW - FT                                  CONO5680
C       PRCCLR = PERCENT OF TOTAL TUBES ASSIGNED TO COOLER              CONO5690
C       RAD = RADIUS OF A GIVEN ROW  FT                                 CONO5700
C       RADINS = BUNDLE INSIDE RADIUS - FT                              CONO5710
C       RADIUS = RADIUS OF ROW I  FT                                    CONO5720
C       RCORR = A CORRECTION FACTOR INTRODUCED TC SMOOTH THE STEP DIFF  CONO5730
C               BETWEEN ROWS WHEN TUBES ARE ADDED OR DELETED            CONO5740
C       ROWS = NO OF ROWS IN CONDENSER                                  CONO5750
C       RSPA = TUBE ROW RADIAL SEPARATION, IN                           CONO5760
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C          RSPF = TUBE ROW RADIAL SEPARATION, FT                                  CON05770
C          SDDI = TUBE PITCH ON INSIDE ROW                                        CON05780
C          SDDO =  TUBE PITCH  ON  OUTSIDE ROW                                    CON05790
C          SECA = TEMP VALUE FOR SECANG   DEG                                     CON05800
C          SECANG = ANGLE FROM THE VERTICAL PASSING THROUGH EACH SECTOR           CON05810
C          SECFLG =  THE NUMBER OF SECTORS IN THE CONDENSER                       CON05820
C          SECWID = SECTOR WIDTH IN DEGREES OF ARC                                CON05830
C          SID = TUBE ID FOR EACH ROW    -  FT                                    CON05840
C          SIDIF = TUBE ID FOR INNER ROW IN FEET                                  CON05850
C          SIDI = TUBE  ID FOR INNER ROW IN INCHES                                CON05860
C          SIDOF = TUBE ID FOR OUTER ROW IN FEET                                  CON05870
C          SIDO = TUBE  ID FOR OUTER ROW IN INCHES                                CON05880
C          DELSDF = LINEAR VARIATION OF TUBE INNER DIAMETER                       CON05890
C          TBNPR = NO. OF TUBES IN ROW I OF EACH SECTOR                           CON05900
C          TNOTCT = TOTAL NO. OF TUBES IN CONDENSER + COOLER                      CON05910
C          TNO = NO. OF TUBES IN THE CONDENSER MODEL                              CON05920
C          TNOS = TOTAL NUMBER OF TUBES PER SECTOR                                CON05930
C          TNR = NUMBER OF TUBES IN A ROW OF A SECTCR                             CON05940
C          TPAR = TUBE DENSITY /UNIT AREA FOR EACH ROW  TUBES/FT**2               CON05950
C          TSAREA = TUBE SHEET AREA                                               CON05960
C          VOL1 = GONDENSOR VOLUME                                                CON05970
C          VOL1C = STORED CONDENSER VOLUME                                        CON05980
C          VOL2 = VOLJME ACTUALLY OCCJPIED BY THE CONDENSOR TUBE BUNDLE           CON05990
C          XW1 = RATIO OF TUBE WALL THICKNESS TO TUBE OD                          CON06000
C          XW2 = TUBE WALL THICKNESS  INCHES                                      CON06010
C                                                                                 CON06020
C                      NOTE:  ADD CALC FOR SID                                    CON06030
C                                                                                 CON06040
C                  NOTE: RADIAL ROW SEPARATION IS CALCULATED                      CON06050
C                        AS THE AVERAGE OF CSPI ANC CSPO UNLESS                   CON06060
C                        RSPA HAS A NON-ZERO VALUE FOR INPUT.                     CON06070
C                                                                                 CON06080
C                    VALUES CARRIED INTO THIS ROUTINE                             CON06090
C          COMMON/NEW/ - , SECWID , NOROWS , RADINS , SDDO , SDDI ,               CON06100
C          COMMCN/NEW/ - , ODII , ODOI , RSP , ISEC ,                             CON06110
C                                                                                 CON06120
C ZZZ ORC-4                                                                       CON06130
C--------------                                                                   CON06140
        IF (NDIAM.EQ.1) SIDI=SIDO                                                 CON06150
        IF (MPITCH.EQ.1) SDDI=SDDO                                                CON06160
        ARCPR=6.283/360.*SECWID                                                   CON06170
        TNOS=0.0                                                                  CON06180
        SECFLG=FLOAT(ISEC)                                                        CON06190
C                                                                                 CON06200
        IF (IOPT.EQ.2) GO TO 50                                                   CON06210
C                                                                                 CON06220
C       COMPUTATION OF GEOMETRY WHEN IOPT = 1                                     CON06230
C          NOROWS IS A CONSTANT                                                   CON06240
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C                                                                       CON06250
      AHOLES=0.                                                         CON06260
      ROWS=FLOAT(NOROWS)                                                CON06270
      SIDOF=SIDO/12.                                                    CON06280
      SIDIF=SIDI/12.                                                    CON06290
      DELSDF=(SIDOF-SIDIF)/(ROWS-1.)                                    CON06300
      IF (XW2.GT.0) ODOF=SIDOF+XW2/6.                                   CON06310
      IF (XW2.GT.0) ODIF=SIDIF+XW2/6.                                   CON06320
      IF (XW2.LE.0) ODOF=SIDOF+(2*SIDOF*XW1)                            CON06330
      IF (XW2.LE.0) ODIF=SIDIF+(2*SIDIF*XW1)                            CON06340
      ODOI=ODOF*12.                                                     CON06350
      ODII=ODIF*12.                                                     CON06360
      DELODF=(ODOF-ODIF)/(ROWS-1.)                                      CON06370
      DELOD=DELODF*12.                                                  CON06380
      CSPO=SDDO*ODOF                                                    CON06390
      CSPI=SDDI*ODIF                                                    CON06400
      DELCSP=(CSPO-CSPI)/(ROWS-1.)                                      CON06410
      RSPF=.866*(CSPO+CSPI)/2.                                          CON06420
      RSP=RSPF*12.                                                      CON06430
      IF (RSPA.NE.0.) RSP=RSPA                                          CON06440
      RSPF=RSP/12.                                                      CON06450
      BNDRAD=RADINS+RSPF*(ROWS-1.)                                      CON06460
      DO 40 I=1,NOROWS                                                  CON06470
      RAD=BNDRAD-RSPF*FLOAT(I-1)                                        CON06480
      CSP=CSPO-DELCSP*FLOAT(I-1)                                        CON06490
      TPAR(I)=1./(CSP*RSPF)                                             CON06500
      TNR=ARCPR*RAD/CSP                                                 CON06510
      OD=ODOF-DELODF*FLOAT(I-1)                                         CON06520
      SID(I)=SIDOF-DELSDF*FLOAT(I-1)                                    CON06530
      AOLFLW(I)=(CSP-OD)*TNR                                            CON06540
      AOTFLW(I)=AOLFLW(I)*ALST                                          CON06550
      TNOS=TNOS+TNR                                                     CON06560
      RADIUS(I)=RAD                                                     CON06570
      AHOLES=AHOLES+PI*(ODOF**2)*TNR/4.                                 CON06580
40    TBNPR(I)=TNR                                                      CON06590
      TNO=TNOS*SECFLG                                                   CON06600
      AHOLES=AHOLES*SECFLG                                              CON06610
      TNOTOT=TNO*100./(100.-PRCCLR)                                     CON06620
      GO TO 100                                                         CON06630
C                                                                       CON06640
C                                                                       CON06650
50    CONTINUE                                                          CON06660
C                                                                       CON06670
C     COMPUTATION OF BUNDLE GEOMETRY IF IOPT = 2                        CON06680
C        SIDI=SIDO                                                      CON06690
C        SDDI=SDDO                                                      CON06700
C                                                                       CON06710
      ERR1=0.                                                           CON06720
      TNOC=0.                                                           CON06730
      TNOS=0.                                                           CON06740
      TNR=0.                                                            CON06750
      TDIFF=0.                                                          CON06760
      SIDOF=SIDO/12.                                                    CON06770
      SIDIF=SIDI/12.                                                    CON06780
      IF (XW2.GT.0) ODOF=SIDOF+XW2/6.                                   CON06790
      IF (XW2.GT.0) ODIF=SIDIF+XW2/6.                                   CON06800
      IF (XW2.LE.0) ODOF=SIDOF+(2*SIDOF*XW1)                            CON06810
      IF (XW2.LE.0) ODIF=SIDIF+(2*SIDIF*XW1)                            CON06820
      ODOI=ODOF*12.                                                     CON06830
      ODII=ODIF*12.                                                     CON06840
      DELOOF=0.                                                         CON06850
      DELOD=DELOOF                                                      CON06860
      CSPO=SDDO*ODOF                                                    CON06870
      CSPI=SDDI*ODIF                                                    CON06880
      DELCSP=0.                                                         CON06890
      RSPF=.866*(CSPO+CSPI)/2.                                          CON06900
      RSP=RSPF*12.                                                      CON06910
      IF (RSPA.NE.0.) RSP=RSPA                                          CON06920
      RSPF=RSP/12.                                                      CON06930
C                                                                       CON06940
C        DETERMINE THE NUMBER OF TUBES IN THE CONDENSOR                 CON06950
C        ALL SECTORS ARE IDENTICAL IN GEOMETRY                          CON06960
C        BEGINNING WITH THE INNERMOST ROW, CALCULATE THE NUMBER         CON06970
C        OF ROWS IN THE CONDENSOR                                       CON06980
C                                                                       CON06990
      I=1                                                               CON07000
      NOROWS=1                                                          CON07010
      TNO=TNOTOT*(100.-PRCCLR)/100.                                     CON07020
      RADIUS(1)=RADINS                                                  CON07030
C                                                                       CON07040
60    SID(I)=SIDOF                                                      CON07050
      TNR=(ARCPR*RADIUS(I))/CSPO                                        CON07060
      TNOS=TNOS+TNR                                                     CON07070
C                                                                       CON07080
C        CHECK TO ENSURE THAT THE NUMBER OF TUBES IN THE SECTOR         CON07090
C        HAS NOT EXCEEDED THE NUMBER OF TUBES AVAILABLE                 CON07100
C                                                                       CON07110
      IF (TNOS.LT.(TNO/SECFLG)) GO TO 70                                CON07120
      TNOS=TNOS-TNR                                                     CON07130
      TNOC=TNOS*SECFLG                                                  CON07140
      TDIFF=TNO-TNOC                                                    CON07150
      TBNPR(I)=TDIFF/SECFLG                                             CON07160
      PFILL=TBNPR(I)/TNR                                                CON07170
      GO TO 80                                                          CON07180
C                                                                       CON07190
70    TPAR(I)=1./(CSPO*RSPF)                                            CON07200
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      AOLFLW(I)=(CSPO-ODOF)*TNR                                         CONO7210
      AOTFLW(I)=AOLFLW(I)*ALST                                          CONO7220
      TBNPR(I)=TNR                                                      CONO7230
      RADIUS(I+1)=RADIUS(I)+RSPF                                        CONO7240
      I=I+1                                                             CONO7250
      NOROWS=NOROWS+1                                                   CONO7260
C                                                                       CONO7270
C        CHECK TO SEE THAT THE NUMBER OF ROWS DOESNOT EXCEED 199         CONO7280
C        BECAUSE 200 IS THE LIMIT FOR THE DIMENSIONS OF NUMEROUS ARRAYS  CONO7290
C                                                                       CONO7300
      IF (NOROWS.LT.100) GO TO 60                                       CONO7310
      ERR1=TNO-(TNOS*SECFLG)                                            CONO7320
      TNO=TNOS*SECFLG                                                   CONO7330
      WRITE (6,640)                                                     CONO7340
      NOROWS=NOROWS-1                                                   CONO7350
      GO TO 90                                                          CONO7360
C                                                                       CONO7370
C        IF LAST ROW IS INCOMPLETE, FIND ITS PERTINENT GEOMETRY          CONO7380
C                                                                       CONO7390
80    SDOL=(RADIUS(I)*ARCPR)/(ODOF*TBNPR(I))                            CONO7400
      CSPL=SDCL*ODOF                                                    CONO7410
      TPAR(I)=1./(CSPL*RSPF)                                            CONO7420
      AOLFLW(I)=(CSPL-ODOF)*TBNPR(I)                                    CONO7430
      AOTFLW(I)=AOLFLW(I)*ALST                                          CONO7440
      TNOS=TNCS+TBNPR(I)                                                CONO7450
90    CONTINUE                                                          CONO7460
      AHOLES=PI*(ODOF**2)*TNO/4.                                        CONO7470
      ROWS=FLCAT(NOROWS)                                                CONO7480
      BNDRAD=RADINS+RSPF*(ROWS-1.)                                      CONO7490
C                                                                       CONO7500
C                                                                       CONO7510
C        THIS NEXT SUBROUTINE SWITCHES THE ARRAYS SO THE ARRAY VALUES    CONO7520
C        START WITH THE OUTSIDE ROW AND WORK TOWARDS THE CENTER.         CONO7530
C        THIS WILL MAKE THE GEOMETRY VALUES COMPATIBLE WITH THE REST     CONO7540
C        OF THE PROGRAM.                                                 CONO7550
C                                                                       CONO7560
      CALL SWITCH (RADIUS,NOROWS)                                       CONO7570
      CALL SWITCH (SID,NOROWS)                                          CONO7580
      CALL SWITCH (TBNPR,NOROWS)                                        CONO7590
      CALL SWITCH (TPAR,NOROWS)                                         CONO7600
      CALL SWITCH (AOLFLW,NOROWS)                                       CONO7610
      CALL SWITCH (AOTFLW,NOROWS)                                       CONO7620
C                                                                       CONO7630
100   CONTINUE                                                          CONO7640
C                                                                       CONO7650
      AOTFLW(NOROWS+1)=ALST*(RADINS-SDI*ODII/24.)*PI/6.                 CONO7660
C                                                                       CONO7670
      IF (ISEC.EQ.1) SECANG(1)=PHI                                      CONO7680
      IF (ISEC.EQ.1) GO TO 110                                          CONO7690
      FCWID=SECWID*(SECFLG-1.)                                          CONO7700
      DO 110 I=1,ISEC                                                   CONO7710
      SECA=(PHI-FCWID/2.)+SECWID*(I-1)                                  CONO7720
      IF (SECA.GT.360.) SECA=SECA-360.                                  CONO7730
110   SECANG(I)=SECA                                                    CONO7740
C                                                                       CONO7750
      DUMMY=ALST*PI*SECWID*SECFLG/360.                                  CONO7760
      BNDRA1=BNDRAD                                                     CONO7770
      VOL1=DUMMY*BNDRA1**2                                              CONO7780
      VOL1C=VCL1                                                        CONO7790
C                                                                       CONO7800
C     IF TNOTOT IS A DESIGN VARIABLE THEN THE INCREASE OF VOLUME  AND   CONO7810
C     OUTSIDE BUNDLE RADIUS MUST BE A GRADUAL PROCESS AND NOT A STEP    CONO7820
C     INCREASE OR DECREASE                                              CONO7830
C                                                                       CONO7840
      IF (IOPT.EQ.1) GO TO 120                                          CONO7850
      RCORR=RSPF                                                        CONO7860
      RCORR=RCORR*((1.-PFILL))                                          CONO7870
      BNDRAD=BNDRAD-RCORR                                               CONO7880
      VOL1=DUMMY*BNDRAD**2                                              CONO7890
      VOL1C=VCL1                                                        CONO7900
C                                                                       CONO7910
120   VOL2=DUMMY*(BNDRAD**2-RADINS**2)                                  CONO7920
C                                                                       CONO7930
C     COMPUTE THE AREA RATIO WHICH IS THE AREA OF TUBE HOLES DIVIDED    CONO7940
C     BY THE TUBE SHEET AREA                                            CONO7950
C                                                                       CONO7960
      TSAREA=PI*(BNDRAD**2)*SECFLG*SECWID/360.                          CONO7970
      ARATIO=AHOLES/TSAREA                                              CONO7980
C                                                                       CONO7990
C$-------------                                                         CONO8000
C ORC A4                                                                CONO8010
C                    TEMP OUTPUT SECTION                                CONO8020
C                                                                       CONO8030
C               THIS SECTION FOR DEBUGGING AID                          CONO8040
C                                                                       CONO8050
C ZZZ ORC-A4                                                            CONO8060
C-------------                                                          CONO8070
      ORCA4=0.                                                          CONO8080
      IF (ORCA4.NE.1.) GO TO 150                                        CONO8090
      WRITE (6,650)                                                     CONO8100
      WRITE (6,660)                                                     CONO8110
      WRITE (6,700) ODOF,ODIF,DELODF                                    CONO8120
      WRITE (6,670)                                                     CONO8130
      WRITE (6,700) CSPO,CSPI,DELCSP                                    CONO8140
      WRITE (6,680)                                                     CONO8150
      WRITE (6,700) RSPF,RSP,TNOS                                       CONO8160
      WRITE (6,690)                                                     CONO8170
      WRITE (6,700) AHOLES,TSAREA,ARATIO                                CONO8180
      WRITE (6,710)                                                     CONO8190
      DO 130 I=1,NOROWS                                                 CONO8200
130   WRITE (6,740) AOTFLW(I),RADIUS(I),TBNPR(I),TPAR(I)                CONO8210
      WRITE (6,720)                                                     CONO8220
      DO 140 I=1,ISEC                                                   CONO8230
140   WRITE (6,730) SECANG(I)                                           CONO8240
150   CONTINUE                                                          CONO8250
C$-------------                                                         CONO8260
C ORC 5                                                                 CONO8270
C                           LOCATE BAFFLES                              CONO8280
C                                                                       CONO8290
C                 THIS SECTION CALCULATES BAFFLE ANGULAR LOCATION       CONO8300
C                 BASED ON THE INPUT VALUES OF IBAF AND JBAF.           CONO8310
C                                                                       CONO8320
C         BAFA = BAFFLE LOCATIONS IN RADIANS MEASURED C-C WISE FROM VERT.CONO8330
C         FCWI = ONE-HALF OF THE BUNDLE ANGULAR WIDTH IN RADIANS        CONO8340
C         FCWID = FCWI EXPRESSED IN DEGREES OF ARC                      CONO8350
C         IBAF = BAFFLE CONTROL VARIABLE                                CONO8360
C                 IBAF = -1 IMPLIES BAFFLES BETWEEN EACH SECTOR         CONO8370
C                 IBAF =  0 IMPLIS NO BAFFLES (SEE NOTE)                CONO8380
C                 IBAF =  N IMPLIES N BAFFLES                           CONO8390
C         IBAFT = NUMBER OF BAFFLES IN CONDENSER                        CONO8400
C                 IBAFT = ISEC + 1 FOR IBAF = -1                        CONO8410
C                 IBAFT = 2 FOR IBAF = 0                                CONO8420
C                 IBAFT = N FOR IBAF = N                                CONO8430
C         ISEC = NUMBER OF SECTORS IN THE CONDENSER                     CONO8440
C         JBAF = SECTOR NUMBERS OF THOSE SECTORS WHOSE COUNTER-CLOCKWISE CONO8450
C                     SIDE HAS A BAFFLE ATTACHED.                       CONO8460
C         PHI  = BUNDLE ORIENTATION ANGLE IN DEGREES OF ARC CLOCK-WISE  CONO8470
C                 FROM VERTICLE.                                        CONO8480
C         PHII = PHI EXPRESSED IN RADIANS                               CONO8490
C         SECI = SECTOR ARC WIDTH IN RADIANS                            CONO8500
C         SECWID = SECTOR ARC WIDTH IN DEGREES OF ARC                   CONO8510
C                                                                       CONO8520
C ZZZ ORC-5                                                             CONO8530
C-------------                                                          CONO8540
      IBAFT=IBAF                                                        CONO8550
      SECI=SECWID*PI/180.                                               CONO8560
      FCWID=SECWID*SECFLG/2.                                            CONO8570
      FCWI=FCWID*PI/180.                                                CONO8580
      PHII=PHI*PI/180.                                                  CONO8590
      IF (IBAF) 160,200,180                                             CONO8600
160   IBAFT=ISEC+1                                                      CONO8610
      DO 170 I=1,IBAFT                                                  CONO8620
170   JBAF(I)=I                                                         CONO8630
180   DO 190 I=1,IBAFT                                                  CONO8640
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      IT=JBAF(I)                                                        CON08650
190   BAFA(I)=PHII-FCWI+SECI*FLOAT(IT-1)                                CON08660
      GO TO 210                                                         CON08670
200   BAFA(1)=PHII-FCWI                                                 CON08680
      BAFA(2)=PHII+FCWI                                                 CON08690
      IBAFT=2                                                           CON08700
      JBAF(1)=1                                                         CON08710
      JBAF(2)=ISEC+1                                                    CON08720
210   CONTINUE                                                          CON08730
C$--------------                                                        CON08740
C ORC A5                                                                CON08750
C                   TEMP OUTPUT SECTION                                 CON08760
C ZZZ ORC-A5                                                            CON08770
C--------------                                                         CON08780
      ORCA5=0.                                                          CON08790
      IF (ORCA5.NE.1) GO TO 240                                         CON08800
      WRITE (6,750)                                                     CON08810
      WRITE (6,760) IBAF,IBAFT                                          CON08820
      WRITE (6,770)                                                     CON08830
      DO 220 I=1,IBAFT                                                  CON08840
220   WRITE (6,780) I,JBAF(I)                                           CON08850
      WRITE (6,790)                                                     CON08860
      DO 230 I=1,IBAFT                                                  CON08870
      X=BAFA(I)*180./PI                                                 CON08880
230   WRITE (6,800) X,BAFA(I)                                           CON08890
240   CONTINUE                                                          CON08900
C$--------------                                                        CON08910
C ORC 6                                                                 CON08920
C                   LOCATE ACTIVE BAFFLE FOR EACH SECTOR                CON08930
C                                                                       CON08940
C ZZZ ORC-6                                                             CON08950
C----------                                                             CON08960
      DO 430 IS=1,ISEC                                                  CON08970
      SECA=SECANG(IS)*PI/180.                                           CON08980
      SEC=PI/2.-SECA                                                    CON08990
      IF ((SECA.GT.0.).AND.(SECA.LT.PI)) GO TC 270                      CON09000
      DO 250 I=1,IBAFT                                                  CON09010
      BAFAT=BAFA(I)                                                     CON09020
      IF (BAFAT.GT.SECA) GO TO 260                                      CON09030
250   CONTINUE                                                          CON09040
260   BAF=PI/2.-BAFAT                                                   CON09050
      IF ((BAFAT.GT.0.).AND.(SECA.LT.0.)) BAF=PI/2.                     CON09060
      GO TO 300                                                         CON09070
270   DO 280 I=1,IBAFT                                                  CON09080
      J=IBAFT+1-I                                                       CON09090
      BAFAT=BAFA(J)                                                     CON09100
      IF (BAFAT.LT.SECA) GO TO 290                                      CON09110
280   CONTINUE                                                          CON09120
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      BAF=PI/2.                                                         CONO9130
      GO TO 300                                                         CONO9140
290   BAF=PI/2.-BAFAT                                                   CONO9150
300   CONTINUE                                                          CONO9160
      IF (BAFAT.LT.0.) BAF=PI/2.                                        CONO9170
C$------------                                                          CONO9180
C ORC A6                                                                CONO9190
C                   TEMP OUTPUT SECTION                                 CONO9200
C                                                                       CONO9210
C ZZZ ORC-A6                                                            CONO9220
C-------------                                                          CONO9230
      ORCA6=C.                                                          CONO9240
      IF (ORCA6.NE.1.) GO TO 310                                        CONO9250
      WRITE (6,810)                                                     CONO9260
      WRITE (6,820)                                                     CONO9270
      X=SEC*180./PI                                                     CONO9280
      WRITE (6,830) IS,X,SEC                                            CONO9290
      X=BAF*180./PI                                                     CONO9300
      WRITE (6,840) X,BAF                                               CONO9310
310   CONTINUE                                                          CONO9320
C$------------                                                          CONO9330
C ORC 7                                                                 CONO9340
C                   CALCULATE FLOODING FACTORS                          CONO9350
C                                                                       CONO9360
C         AN = SUMMING RAGISTER FOR NO. OF TUBES                        CONO9370
C         ANT = NO. OF TUBES OVER THE TARGET TUBE                       CONO9380
C         BAF = ANGLE ABOUT HORIZONTAL OF 1ST BAFFLE ABOVE CURRENT SECTORCONO9390
C         DELODF = SEE ORC-4                                            CONO9400
C         D1 = FARTHEST DIST FROM HORIZONTAL TO CURRENT ROW INTERSECTION CONO9410
C         D2 = SHORTEST  "     "      "       "    "     "       "      CONO9420
C         IR = ROW NO. OF CURRENT TARGET TUB.                           CONO9430
C         IS = SECTOR NO. OF CURRENT TARGET TUBE                        CONO9440
C         ITR = ROW NO. FOR 1ST ROW TO BE SUMMED IN UPPER QUADRANT      CONO9450
C         I1 = ROW WHOSE CONTRIBUTION TO ANT IS BEING CALCULATED        CONO9460
C         I2 = LOOP COUNTER IN UPPER QUADRANT CALCULATION               CONO9470
C         NOROWS = NO. OF ROWS IN THE CONDENSER                         CONO9480
C         OD = TUBE OD IN ROW BEING CONSIDERED  - FT                    CONO9490
C         ODOF = TUBE DIAMETER IN OUTERMOST (IR = 1) ROW OF TUBES       CONO9500
C         RADIUS = RADIUS OF EACH TUBE ROW                              CONO9510
C         RSPF = ROW RADIAL SEPARATION  - FT                            CONO9520
C         R1 = RADIUS OF UPPER OR LOWER BOUNDARY OF ROW I1              CONO9530
C         SEC = ANGLE FROM HORIZONTAL OF CURRENT SECTOR MIDPOINT        CONO9540
C         SECA= ANGLE FROM VERTICAL OF CURRENT SECTOR MIDPOINT          CONO9550
C         TEST = TEST FOR VERTICAL BAFFLES                              CONO9560
C         TPAR = TUBE DENSITY PER UNIT AREA PFOR EACH ROW - TUBES/FT**2 CONO9570
C         XC = HORIZONTAL DIST OR CURRENT TUBE FROM COND CENTER         CONO9580
C         XCS = XC SQUARED                                              CONO9590
C         YC = VERTICAL (+/-) DIST OF CURRENT TUBE FROM COND CNTR - FT  CONO9600
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C        ZT = VERT DIST FROM TARGET TUBE TO BAFFLE INTERSECTION  -  FT  CON09610
C                                                                       CON09620
C ZZZ ORC-7                                                             CON09630
C---------------                                                        CON09640
      ORCA7=0.                                                          CON09650
      IF (ORCA7.EQ.1.) WRITE (6,860)                                    CON09660
      DO 420 IR=1,NOROWS                                                CON09670
C     IF(IS.EQ.ISEC.AND.IR.GE.20)ORCA7 = 1.                             CON09680
      ITR=IR                                                            CON09690
      AN=0.                                                             CON09700
      OD=ODOF-DELODF*FLOAT(IR-1)                                        CON09710
      R1=RADIUS(IR)                                                     CON09720
      YC=R1*SIN(SEC)                                                    CON09730
      XC=R1*CCS(SEC)                                                    CON09740
      XCS=XC*XC                                                         CON09750
      TEST=ABS(ABS(BAF)-PI/2.)                                          CON09760
      X=OD*12.                                                          CON09770
      IF (ORCA7.EQ.1.) WRITE (6,870) IR,IS                              CON09780
      IF (ORCA7.EQ.1.) WRITE (6,880) X,R1,YC,XC,TEST                    CON09790
      IF (TEST.GT.1E-2) GO TO 320                                       CON09800
      ZT=1E10                                                           CON09810
      GO TO 330                                                         CON09820
320   ZT=XC*TAN(BAF)                                                    CON09830
330   XC=ABS(XC)                                                        CON09840
      IF (YC.GT.0.) GC TO 370                                           CON09850
      IF (ORCA7.EQ.1.) WRITE (6,890) ZT                                 CON09860
      D1=YC                                                             CON09870
      DO 340 I1=IR,NOROWS                                               CON09880
      R1=RADIUS(I1)-RSPF/2.                                             CON09890
      IF (R1.LE.XC) GC TO 350                                           CON09900
      D2=-1.*SURT(R1*R1-XCS)                                            CON09910
      IF (ORCA7.EQ.1.) WRITE (6,900) I1,R1,D2                           CON09920
      IF (D2.GT.ZT) GO TO 360                                           CON09930
      IF (ORCA7.EQ.1.) WRITE (6,910)                                    CON09940
      AN=AN+(D2-D1)/(RSPF*2.)                                           CON09950
      IF (ORCA7.EQ.1.) WRITE (6,920) D1,D2,AN                           CON09960
      D1=D2                                                             CON09970
340   CONTINUE                                                          CON09980
      D2=-D2                                                            CON09990
      IF (ORCA7.EQ.1.) WRITE (6,940)                                    CON10000
      IF (D2.GT.ZT) GO TO 410                                           CON10010
      ITR=NORCWS                                                        CON10020
      D1=D2                                                             CON10030
      IF (ORCA7.EQ.1.) WRITE (6,950)                                    CON10040
      GO TO 380                                                         CON10050
350   AN=AN-C1/(RSPF*2.)                                                CON10060
      D1=0.                                                             CON10070
      ITR=I1                                                            CON10080
      IF (ORCA7.EQ.1.) WRITE (6,930) AN,ITR                             CON10090
      GO TO 380                                                         CON10100
360   AN=AN+(ZT-D1)/(RSPF*2.)                                           CON10110
      IF (ORCA7.EQ.1.) WRITE (6,960)                                    CON10120
      GO TO 410                                                         CON10130
370   D1=YC                                                             CON10140
      IF (ORCA7.EQ.1.) WRITE (6,970) D1                                 CON10150
380   DO 390 I2=1,ITR                                                   CON10160
      I1=ITR-I2+1                                                       CON10170
      R1=RADIUS(I1)+RSPF/2.                                             CON10180
      D2=SQRT(R1*R1-XCS)                                                CON10190
      IF (ORCA7.EQ.1.) WRITE (6,980) IR,I1,R1                           CON10200
      IF (ORCA7.EQ.1.) WRITE (6,990) D1,D2,ZT                           CON10210
      IF (D2.GT.ZT) GO TO 400                                           CON10220
      AN=AN+(D2-D1)/(RSPF*2.)                                           CON10230
      IF (ORCA7.EQ.1.) WRITE (6,1000) AN                                CON10240
390   D1=D2                                                             CON10250
      GO TO 410                                                         CON10260
400   AN=AN+(ZT-D1)/(RSPF*2.)                                           CON10270
      IF (ORCA7.EQ.1.) WRITE (6,1010)                                   CON10280
410   NF=AN+1.0                                                         CON10290
      RNF=NF                                                            CON10300
      ANT(IR,IS)=RNF                                                    CON10310
      IF (ORCA7.EQ.1.) WRITE (6,1020) IS,IR,AN                          CON10320
420   CONTINUE                                                          CON10330
430   CONTINUE                                                          CON10340
      ORCA7=0.                                                          CON10350
      IF (ORCA7.NE.1.) GO TO 450                                        CON10360
      DO 440 I=1,NOROWS                                                 CON10370
440   WRITE (6,850) I,(ANT(I,J),J=1,ISEC)                               CON10380
450   CONTINUE                                                          CON10390
C$-------------                                                         CON10400
C ORC 9                                                                 CON10410
C                     PUMPING POWER CALCULATION                         CON10420
C                                                                       CON10430
C          ALST = TUBE LENGTH   FT                                      CON10440
C          A1 = COEF IN FF CALCULATION                                  CON10450
C          B1 = EXP IN FF CALCULATION                                   CON10460
C          CBI = COOLANT SALT CONCENTRATION IN WT PRCNT                 CON10470
C          CMDOT = COOLANT MASS FLOW/TUBE IN EACH ROW  LBM/SEC          CON10480
C          CMTOT = TOTAL COOLANT MASS FLOW THROUGH CONDENSER LBM/SEC     CON10490
C          DELWP = HEADER PRESSURE DIFFERENCE  PSI                      CON10500
C          FF = TUBE FRICTION FACTORS                                   CON10510
C          HEAD = FT**2/SEC**                                           CON10520
C          SID = STORED INNER TUBE DIAMETER                             CON10530
C          TID = TEMPORARY VALUE FOR TUBE INNER DIAMETER                CON10540
C          SLD = STORED (LENGTH/TUBE INNER DIAMETER) RATIO              CON10550
C          SLDO = SLD RATIO OF TUBES IN OUTER ROW                       CON10560
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C         SLDI = SLD RATIO OF TUBES IN INNER ROW                         CON10570
C         SLD = THE AVERAGE OF SLDO AND SLDI                             CON10580
C         HLOSS = HEAD LOSS                                              CON10590
C         REW = REYNOLDS # OF COOLANT                                    CON10600
C         REWO = REYNOLDS # OF TUBES IN THE OUTER ROW                    CON10610
C         REWI = REYNOLDS # OF TUBES IN INNER ROW                        CON10620
C         PHP = PUMPING POWER IN HP                                      CON10630
C         PHPCON = PUMPING POWER OF THE CONDENSER BUNDLE ONLY            CON10640
C         DELWPC = PRESSURE LOSS THRU TUBES IN PSI                       CON10650
C         GFLOW = OVERALL COOLANT FLOW IN LBM/HR                         CON10660
C         RHOW = DENSITY OF COOLANT                                      CON10670
C         XMUW = VISCOSITY OF COOLANT                                    CON10680
C         VELBI = COOLING WATER VELOCITY IN FT/SEC                       CON10690
C                                                                        CON10700
C ZZZ ORC-9                                                              CON10710
C--------------                                                          CON10720
      ORCA9=0.                                                           CON10730
      RHOW=ROEFN(CBI,STBI)                                               CON10740
      XMUW=BMUFN(CBI,STBI)/3600.                                         CON10750
      XNUW=XMUW/RHOW                                                     CON10760
      CMTOT=0.                                                           CON10770
      IF ((GFLOW.GT.0.).OR.(VELBI.GT.0.)) GO TO 530                      CON10780
      HEAD=2.*DELWP*144.*SG/RHOW                                         CON10790
      DO 520 IR=1,NDROWS                                                 CON10800
      IF (ORCA9.EQ.1.) WRITE (6,1030) IR                                 CON10810
      ITEM=IR-1                                                          CON10820
      IF (ITEM.EQ.0) ITEM=1                                              CON10830
      VG=VW(ITEM)                                                        CON10840
      IF (ORCA9.EQ.1.) WRITE (6,1040) IR,ITEM,VG                         CON10850
      IENHAN=0                                                           CON10860
      IF (NEI.EQ.0) GO TO 480                                            CON10870
      DO 460 IT=1,NEI                                                    CON10880
      NRNI1=NRNI(IT)                                                     CON10890
      NRNI2=NRNI1+NETI(IT)-1                                             CON10900
      IF (IR.GE.NRNI1.AND.IR.LE.NRNI2) GO TO 470                         CON10910
460   CONTINUE                                                           CON10920
      GO TO 480                                                          CON10930
470   IENHAN=1                                                           CON10940
      A1=BC(IT)                                                          CON10950
      B1=BE(IT)                                                          CON10960
480   TID=SID(IR)                                                        CON10970
      SLD=ALST/TID                                                       CON10980
      IF (IR.EQ.1) SLDO=SLD                                              CON10990
      IF (IR.EQ.NDROWS) SLDI=SLD                                         CON11000
      IF (ORCA9.EQ.1.) WRITE (6,1050) TID,SLD,IR                         CON11010
490   REW=VG*TID/XNUW                                                    CON11020
      IF (ORCA9.EQ.1.) WRITE (6,1060) REW,TID,XNUW                       CON11030
      IF (IENHAN.EQ.1) GO TO 510                                         CON11040
      IF (REW.GE.51904.4) GO TO 500
      A1=.3164
      B1=-.25
      GO TO 510
500   A1=.184
      B1=-.2
510   CONTINUE
      IF (ORCA9.EQ.1.) WRITE (6,1070) A1,B1,REW
      FF=A1*REW**(B1)
      HLOSS=(1.1+FF*SLD)
      IF (ORCA9.EQ.1.) WRITE (6,1080) FF,SLD,HLOSS,HEAD
      VG1=SQRT(HEAD/HLOSS)
      TEST=ABS(VG-VG1)/VG
      IF (ORCA9.EQ.1.) WRITE (6,1090) TEST,VG,VG1
      VG=VG1
      IF (TEST.GT.0.01) GO TO 490
      IF (IR.EQ.1) REWO=REW
      IF (IR.EQ.NORJWS) REWI=REW
      CMDOT(IR)=PI*TID**2*VG*RHOW/4.
      VW(IR)=VG
520   CMTOT=SECFLG*CMDOT(IR)*TBNPR(IR)+CMTOT
      PHP=CMTOT*DELWP*144./(RHOW*550.)
      PHPCON=PHP
      DELWPC=DELWP
      GO TO 600
530   A=0.
      DO 540 IR=1,NJROWS
      TID=SIC(IR)
      IF (IR.EQ.1) SLDO=ALST/TID
      IF (IR.EQ.NORDWS) SLDI=ALST/TID
540   A=A+TIC*TID*PI*TBNPR(IR)/4.
      SLD=(SLDO+SLDI)/2.
      TID=ALST/SLD
      IF (GFLCW.LE.0.) GO TO 550
      VX=GFLOW/((RHJW*A*SECFLG)*3600.)
      CMTOT=GFLOW/3600.
      GO TO 560
550   CMTOT=VELBI*RHOW*A*SECFLG
      VX=VELBI
560   REW=VX*TID/XNJW
      IF (REW.GT.51904.4) GO TO 570
      FF=.3164*REW**(-.25)
      GO TO 580
570   FF=.184*REW**(-.2)
580   DELWPC=(1.1+FF*SLD)*VX**2*RHOW/(2.*SG*144.)
      DO 590 IR=1,NOROWS
      CMDOT(IR)=PI*SID(IR)**2*VX*RHOW/4.
590   VW(IR)=VX
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      REWO=VX*SID(1)/XNUW
      REWI=VX*SID(NJROWS)/XNUW
      HEAD=2.*DELWPC*144.*SG/RHOW
      PHP=CMTCT*DELWPC*144./(RHOW*550.)
      PHPCON=PHP
      DELWP=DELWPC
600   CONTINUE
      HFG=HFGFN(STSAT1)
      STB2ES=(WSI*HFG)/(CPB*CMTOT*3600.)+STBI
C$------------
C ORC A9
C                  TEMP OUTPUT SECTION
C ZZZ ORC-A9
C-------------
      ORCA9=0.
      IF (ORCA9.NE.1.) GO TO 630
      WRITE (6,1100)
      WRITE (6,1110) RHOW
      WRITE (6,1120) XMUW
      WRITE (6,1130) XNUW
      WRITE (6,1140) HEAD
      WRITE (6,1150) REW,FF
      WRITE (6,1160) DELWP
      WRITE (6,1170) SLDI,SLDO
      WRITE (6,1180) REWI,REWO
      WRITE (6,1190) CMTOT
      WRITE (6,1200) PHP
      WRITE (6,1210)
      DO 610 I=1,NOROWS
610   WRITE (6,1220) I,VW(I)
      DO 620 I=1,NOROWS
620   WRITE (6,1220) I,CMDOT(I)
630   CONTINLE
C$------------
C ORC 10
C                  CALL TO SECALC
C ZZZ ORC-10
C-------------
      CALL SECALC (ARCPR,DELODF,ODIF,ODOF)
      RETURN
640   FORMAT (1H0,46HTHE NUMBER OF ROWS EXCEEDS THE MAXIMUM ALLOWED)
650   FORMAT (1H1,24HOUTPUT SECTION FOR ORC-4)
660   FORMAT (1H0,10HODOF      ,10HODIF      ,10HDELODF     )
670   FORMAT (1H0,10HCSPO      ,10HCSPI      ,10HDELCSP     )
680   FORMAT (1H0,10HRSPF      ,10HRSP       ,10HTNOS       )
690   FORMAT (1H0,10HAHOLES    ,10HTSAREA    ,10HARATIO     )
700   FORMAT (1H ,3F10.5)
710   FORMAT (1H0,10HAOTFLW    ,10HRADIUS    ,10HTBNPR      ,10HTPAR
     1 )
720   FORMAT (1H0,10HSECANG     )
730   FORMAT (1H ,F10.6)
740   FORMAT (1H ,4F10.5)
750   FORMAT (1H1,24HOUTPUT FOR SECTION ORC-5)
760   FORMAT (1H0,7HIBAF = ,I4,5X,8HIBAFT = ,I4)
770   FORMAT (1H0,22HFOR I =  ;  JBAF(I) = )
780   FORMAT (1H ,3X,I4,8X,I4)
790   FORMAT (1H0,36HBAFFLE ANGLES IN DEGREES AND RADIANS)
800   FORMAT (1H ,3X,F6.1,3X,F6.4)
810   FORMAT (1H1,24HOUTPUT FOR SECTION ORC-6)
820   FORMAT (1H0,50HANGLES ARE MEASURED CNTR-CLCK WISE FROM HORIZONTAL)
830   FORMAT (1H0,16HCURRENT SECTOR =,I3,16H  ANGLE IN DEG =,F6.1,21H  A
     1NGLE  IN RADIANS =,F6.4)
840   FORMAT (1H0,32HANGLE OF ACTIVE BAFFLE IN DEG. =,F6.1,14H  IN RADIA
     1NS =,F6.4)
850   FORMAT (1H ,I3,2X,6(F5.2,2X))
860   FORMAT (1H0,28H***    OUTPUT FOR ORC-7    ***)
870   FORMAT (1H0,5HROW =,I4,11H  SECTOR = ,I4)
880   FORMAT (1H ,4HOD =,F6.4,10H  RADIUS =,F6.2,6H  YC =,F6.2,6H  XC =,
     1F6.2,8H  TEST =,E10.3)
890   FORMAT (1H0,36HTARGET TUBE IN LOWER QUADRANT,  ZT =,F20.4)
900   FORMAT (1H ,15HLWR QUAD - ROW=,I3,5H  R1=,F7.3,5H  D2=,F7.3)
910   FORMAT (1H ,18HBAFFLE WAS NOT HIT)
920   FORMAT (1H ,15HSTILL LWR - D1=,F7.3,5H  D2=,F7.3,5H  AN=,F6.2)
930   FORMAT (1H ,34HPASSING INTO UPPER QUADRANT - AN =,F6.2,15H  CURREN
     1T ROW =,I4)
940   FORMAT (1H ,30HMOVING THRU VOID TO UPPER QUAD)
950   FORMAT (1H ,22HBAFFLE NOT HIT IN VOID)
960   FORMAT (1H ,28HBAFFLE HIT IN LOWER QUADRANT)
970   FORMAT (1H ,35HTARGET TUBE IS IN UPPER QUAD - D1 =,F8.4)
980   FORMAT (1H ,37HCALCULATING IN UPPER QUAD - TRGET RW=,I4,12H  CALC
     1ROW =,I4,11H  CORR RAD=,F8.4)
990   FORMAT (1H ,4HD1 =,F6.3,6H  D2 =,F6.3,6H  ZT =,E10.3)
1000  FORMAT (1H ,34HUPPER QUAD - BAFFLE NOT HIT - AN =,F6.2)
1010  FORMAT (1H ,23HUPPER QUAD - BAFFLE HIT)
1020  FORMAT (1H0,26H** FINAL FOR TARGET ** IS=,I4,4H IR=,I4,5H ANT=,F8.
     12)
1030  FORMAT (1H ,16HAT DO LOOP - IR=,I4)
1040  FORMAT (1H ,9HTEMP  IR=,I4,7H  ITEM=,I4,5H  VG=,E10.3)
1050  FORMAT (1H ,16HABOVE 380 - TID=,E10.3,6H  SLD=,E10.3,5H  IR=,I4)
1060  FORMAT (1H ,16HBELOW 380 - REW=,E10.3,6H  TID=,E10.3,7H  XNUW=,E10
     1.3)
1070  FORMAT (1H ,12HAT 400 - A1=,E10.3,5H  B1=,E10.3,6H  REW=,E10.3)
1080  FORMAT (1H ,3HFF=,E10.3,5H SLD=,E10.3,7H HLCSS=,E10.3,6H HEAD=,E10
     1.3)
1090  FORMAT (1H ,5HTEST=,E10.3,5H  VG=,E10.3,6H  VG1=,E10.3)
1100  FORMAT (1H1,16HOUTPUT FOR ORC-9)
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1110  FORMAT (1H0,8H   RHO =  ,E10.3,10H LBM/FT**3)
1120  FORMAT (1H ,8H   MU  =  ,E10.3,11H LBM/SEC-FT)
1130  FORMAT (1H ,8H   NU  =  ,E10.3,10H FT**2/SEC)
1140  FORMAT (1H ,8H   HEAD=  ,E10.3,13H FT**2/SEC**2)
1150  FORMAT (1H ,8H   REW =  ,E10.3,3X,6HFF   = ,E10.3)
1160  FORMAT (1H ,8HDELWP =  ,E10.3,4H PSI)
1170  FORMAT (1H ,39HLENGTH TO DIAMETER RATIO - INSIDE ROW =,F6.2,16H
     1OUTSIDE ROW =,F6.2)
1180  FORMAT (1H ,27HREYNOLDS NO. - INSIDE ROW =,E10.3,15H  OUTSIDE ROW
     1=,E10.3)
1190  FORMAT (1H ,24HCOOLANT MASS FLOW RATE =,F15.3,8H LBM/SEC)
1200  FORMAT (1H ,24HPUMPING POWER REQUIRED =,F10.2,3H HP)
1210  FORMAT (1H ,37HCOOLANT VELOCITY IN EACH ROW - FT/SEC)
1220  FORMAT (1H ,I4,3X,F10.3)
      END
C
C*****************************************************************
C*****************************************************************
C
      SUBROUTINE SECALC (ARCPR,DELODF,ODIF,ODCF)
C--------------
C SEC 1
C                   SUBROUTINE SECALC
C
C             SUBROUTINES CALLED BY SECALC
C         HETTRN
C
C             FUNCTION ROUTINES CALLED BY SECALC
C       , TSATFN , VGFN , HFGFN , CPAFN ,
C
C ZZZ SEC-1
C--------------
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,
     1RADINS,REWI,REWO,SDOI,SDOO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNOTO
     2T,BNDRAC,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,S
     1TSATI,TUBESW,NNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MO
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)
     3,WSI,PFILL
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMDOT(10
     10)
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNG,VEL2,FR
      COMMON /OUTC/ EXITFC,EXITFR,HTCLR,AGC,SUMQC,SDIC,SDOC,UBARW,SMWBC,
     1SMTBIC,SMTB2C,VWBAR,STSATX,PMIX1,AGT,BUNWT,AVTB1,AVTB2,WTSTC,VGLC
      COMMON /SEC/ ALMTD(100,15),CUMDP(100,15),DELP(15),GFLW(100,15),HEF
     1F(100,15),PMIX(100,15),PSAT(100,15),QOA(100,15),RC(100,15),ROUT(10
     20,15),SHI(100,15),SHN(100,15),STSAT(100,15),UN(100,15),VEL(100,15)
     3,VNRE(100,15),VPSHH(100,15),WCND(100,15),WGAS(15),WP(15),WS(100,15
     4), WSP(15)                                                        CON12970
      COMMON /CONST/  AMWNC,CBI,CPB,PI,SG,IFIRST                        CON12980
      COMMON /COOL1/  VELC(100),PMIXC(100),PSATC(100),STSATC(100),WSC(100CON12990
     1),ALMTDC(100),SHIC(100),SHNFC(100),RCC(100),ROUTC(100),VNREC(100),CON13000
     2VPSHHC(100),HEFFC(100),UNC(100),WCNDC(100),GFLOWC(100),QUAC(100),CCON13010
     3UMDPC(1C0)                                                        CON13020
      COMMON /COOL/  IVNOC,HNOC,TNOC,TSATEX,PMXEXT,AMLSEX,WSEXIT,VELEXT,TCON13030
     1B2C,ENHIC,ENHOC,ENHFC,SHWINC,WBC                                  CON13040
      DIMENSICN C(15)                                                   CON13050
C$--------------                                                        CON13060
C SEC 2                                                                 CON13070
C                    INITIALIZE :OLD ORC 8,9                            CON13080
C                              PART - 1                                 CON13090
C                                                                       CON13100
C        ALST = TUBE LENGTH   FT                                        CON13110
C        AMOLNC = TOTAL MOLES OF N/C GAS ENTERING CONDENSER             CON13120
C        AMOLSS =  MOLES OF  STM  ENTERING COND                         CON13130
C        AMOLST = SUM OF MOLES OF STM AND N/C  ENTERING COND            CON13140
C        AMWNC = MOLECULAR WEIGHT OF N/C                                CON13150
C        ANT = TOTAL NO OF TUBE IN 360 DEG COND                         CON13160
C        ARAT = RATIO OF OUTSIDE ROW MIN FLOW AREA TO SECTOR FACE AREA  CON13170
C        ARCPR = CIRCUMFERENTIAL ARC LENGTH PER UNIT RADIUS             CON13180
C        AOTFLW = AREA OPEN TO FLOW IN A ROW OF TUBES IN A SECTOR FT**2 CON13190
C        BNDRAD = TUBE BUNDLE OD   FT                                   CON13200
C        DELODF = CHANGE IN TUBE OD PER ROW   FT                        CON13210
C        DELP12 = ENTRANCE STM PRESS LOSS  PSI                          CON13220
C        DELP23 = STM PRESS LOSS AS STM IS ACCEL INTO FIRST ROW   PSI   CON13230
C        G2 =                                                           CON13240
C        HFG = STEAM LATENT HEAT  OF VAPORIZATION  BTU/LBM              CON13250
C        NOROWS = NO. OF ROWS IN THE CONDENSER                          CON13260
C        ODOF = TUBE OD, OUTSIDE ROW   FT                               CON13270
C        ODIF = TUBE OD, INSIDE ROW    FT                               CON13280
C        ODOI = TUBE OD, OUTSIDE ROW   IN                               CON13290
C        ODII = TUBE OD, INSIDE ROW    IN                               CON13300
C        PMIX1 = PRESS OF STM - N/C MIXTURE ENERING COND   PSIA         CON13310
C        PSAT1 = ENTERING STEAM SAT PRESS PSIA                          CON13320
C        PTLIM = LOWEST SATURATION PRESSURE THE STEAM CAN GO BEFORE THE CON13330
C          CORRESPONDING SATURATION TEMPERATURE FALLS BELOW INLET       CON13340
C          COOLANT TEMPERATURE. THE RESULT IS O HEAT TRANSFER           CON13350
C        RADINS = BUNDLE VOID RADIUS   FT                               CON13360
C        ROWS = NO OF ROWS IN THE CONDENSER                             CON13370
C        SECFAR = FACE AREA FOR ONE SECTOR                              CON13380
C        SECFLG = NO. OF SECTORS IN THE CONDENSER MODEL                 CON13390
C        SMTBI = ROW BY ROW SUM OF (COOLANT INLET TEMP * FLOW RATE)     CON13400
C        SMWB = ROW BY ROW SUM OF COOLANT FLOW                          CON13410
C        SMTB2 = ROW BY ROW SUM OF (COOLANT OUTLET TEMP * FLOW RATE)    CON13420
C        SUMQ = ROW BY ROW SUM OF HEAT DUTY ON TUBES                    CON13430
C        SG = GRAVITY FACTOR  32.2                                      CON13440
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C         STSAT1 = ENTERING STM SAT TEMP   F                                 CON13450
C         SVMIX1 = ENTERING MIXTURE SPECIFIC VOL  FT**3/LBM                  CON13460
C         SVNC1 = ENTERING N/C GAS SPECIFIC VOL  FT**3/LBM                   CON13470
C         TSAT1 = ENTERING STEAM SATURATION TEMP   R                         CON13480
C         WGAS = N/C FLOW TO EACH SECTOR   LBM/HR                            CON13490
C         WNCI = N/C GAS FLOW TO CONDENSER LBM/HR                            CON13500
C         WNCIR = RATIO OF MASS FLOW OF N/C TO MASS FLOW OF STEAM            CON13510
C         WS = STEAM FLOW TO EACH SECTOR   LBM/HR                            CON13520
C         WSI = TOTAL STM FLOW TO CONDENSER LBM/HR                           CON13530
C         VEL1 = MIXTURE VELOCITY PRIOR TO ENTERING FIRST ROW  FT/SEC        CON13540
C         VEL2 = MIXTURE VELOCITY IN FIRST ROW OF TUBES  FT/SEC              CON13550
C         IVNOC = THE NUMBER OF VERTICAL TUBES IN THE COOLER                 CON13560
C         IHNOC = THE NUMBER OF HORIZONTAL TUBES IN THE COOLER               CON13570
C         HTCLR = THE HEIGHT OF THE COOLER                                   CON13580
C         VG1 = ENTERING STM SPECIFIC VOL   FT**3/LBM                        CON13590
C                                                                            CON13600
C ZZZ SEC-2                                                                  CON13610
C--------------                                                              CON13620
      ROWS=FLOAT(NOROWS)                                                     CON13630
      TNOC=0.                                                                CON13640
      IVNOC=1                                                                CON13650
      IF (PRCCLR.EQ.0.0) GO TO 10                                            CON13660
C                                                                            CON13670
C    COMPUTE THE NUMBER OF VERTICAL AND HCRIZONTAL ROWS IN THE COOLER        CON13680
C    IF THERE IS ONE                                                         CON13690
C                                                                            CON13700
      SDDC=SDDI                                                              CON13710
      TNOC=(PRCCLR/(100.-PRCCLR))*TNO                                        CON13720
      HTCLR=BNDRAD-RADINS                                                    CON13730
      VNOC=(HTCLR/(SDDC*ODIF*0.886))+1.                                      CON13740
      IHNOC=TNOC/VNOC                                                        CON13750
      HNOC=FLOAT(IHNOC)                                                      CON13760
      VNOC=TNOC/HNOC                                                         CON13770
      IVNOC=VNOC+.5                                                          CON13780
      VNOC=FLOAT(IVNOC)                                                      CON13790
C                                                                            CON13800
10    KSTOP=NCROWS+1                                                         CON13810
      SECFLG=FLOAT(ISEC)                                                     CON13820
      WNCI=WSI*WNCIR                                                         CON13830
      IPLOOP=0                                                               CON13840
      WSAVE=(WSI+WNCI)/SECFLG                                                CON13850
C                                                                            CON13860
C                                                                            CON13870
C                INITIALIZE TEST VARIABLES TO 0                              CON13880
C                                                                            CON13890
20    CONTINUE                                                               CON13900
      STMSUM=0.                                                              CON13910
      WTSAV=0.                                                               CON13920
      STBIR=STBI+459.69
      PTLIM=PSATFN(STBIR)
      TSAT1=STSAT1+459.69
      PSAT1=PSATFN(TSAT1)
      AMOLNC=WNCI/AMWNC
      HFG=HFGFN(STSAT1)
      AMOLSS=WSI/18.015
      AMOLST=AMOLSS+AMOLNC
      PMIX1=PSAT1*(AMOLST/AMOLSS)
      VG1=VGFN(TSAT1,PMIX1)
      SVNC1=10.729*TSAT1/(AMWNC*PMIX1)
      SVMIX1=1.0/(AMOLSS/(AMOLST*VG1)+AMOLNC/(SVNC1*AMOLST))
      G2=288.0*SG*SVMIX1
      SMTBI=0.0
      SMWB=0.0
      WB=0.
      SMTB2=0.0
      SUMQ=0.0
      CUMDRY=0.
      SUBFLO=0.
      NBAD=0
      WCNDAV=0.
      SUBAVE=0.
C
C
C     COMPUTE THE PRESSURE LOSSES AT THE ENTRANCE OF THE SECTOR
C
      SECFAR=ARCPR*(BNDRAD+ODOF/2.)*ALST
      ARAT=AOTFLW(1)/SECFAR
      VEL1=(WSI+WNCI)*SVMIX1/(3600.0*SECFAR*SECFLG)
      VEL2=VEL1/ARAT
      IF (ARAT-0.715) 30,30,40
30    DELP12=0.4*(1.25-ARAT)*VEL2**2/G2
      GO TO 50
40    DELP12=0.75*(1.0-ARAT)*VEL2**2/G2
50    DELP23=(VEL2**2-VEL1**2)/G2
C$-------------
C SEC A2
C                   TEMP OUTPUT SECTION
C
C ZZZ SEC-A2
C--------------
      SECA2=0.
      IF (SECA2.EQ.0.) GO TO 70
      DO 60 I=1,ISEC
      WRITE (6,610)
      WRITE (6,620)
      WRITE (6,700) WSI,WNCI
      WRITE (6,630)
      WRITE (6,700) WS(1,I),WGAS(I)
      WRITE (6,640)
      WRITE (6,700) HFG,AOTFLW(I)
      WRITE (6,650)
      WRITE (6,700) TSAT1,STSAT1
      WRITE (6,660)
      WRITE (6,700) PSAT1,PMIX1
      WRITE (6,670)
      WRITE (6,710) AMOLNC,AMOLSS,AMOLST
      WRITE (6,680)
      WRITE (6,700) SVNC1,SVMIX1
      WRITE (6,690)
      WRITE (6,700) VG1,G2
      WRITE (6,720)
      WRITE (6,750) SECFAR,ARAT
      WRITE (6,730)
      WRITE (6,750) VEL1,VEL2
      WRITE (6,740)
60    WRITE (6,750) DELP12,DELP23
70    CONTINUE
C$------------
C SEC 3
C                   DO LOOP ON SECTORS - HEREAFTER REFERRED TO AS
C                                 MAIN SECTOR LOOP
C
C             PROGRAM ENTERS SEC-3 FROM SEC-2 AND ALWAYS EXITS
C             TO SEC-4.
C
C             THIS SECTION STARTS THE J LOOP AND ESTABLISHES
C             SOME OF THE INITIAL CONDITIONS FOR THE FIRST
C             ROW OF THE CURRENT SECTOR CALCULATION.
C
C             SUBSRIPTED QUANTITIES ARE SET UP AS
C                VARIABLE (SUB1,SUB2) WHERE SUB1 IS
C                THE ROW NUMBER, AND SUB2 IS THE SECTOR
C                NUMBER.
C
C       PMIX = PRESSURE OF STM-N/C MIXTURE
C       PMIX1 = PRESSURE OF STM-N/C MIXTURE ENTERING SECTOR
C       J=DUMMY VARIABLE REPRESENTING SECTOR NUMBER
C       SECFLG = NO OF SECTORS IN THE CONDENSER
C       DELP = PRESSURE DROP ACROSS A SECTOR
C       DELP12 = ENTRANCE PRESSURE LOSS IN THE CONDENSER
C       DELP23 = PRESSURE LOSS AT BUNDLE DUE TO VELOCITY CHANGE
C       AMOLSS = MOLES OF STEAM ENTERING THE CONCENSER
C       ANOLST = TOTAL MOLES OF STEAM AND N/C ENTERING CONDENSER
C       AMOLNC = MOLES OF N/C GASSES ENTERING THE CONDENSER
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C          PSAT = SATURATED STEAM PRESS                                 CON14890
C          PAL = SAME AS PSAT                                           CON14900
C          PTLIM = LOWEST SATURATION PRESSURE THE STEAM CAN GO BEFORE THE CON14910
C            CORRESPONDING SATURATION TEMPERATURE FALLS BELOW INLET     CON14920
C            COOLANT TEMPERATURE. THE RESULT IS 0 HEAT TRANSFER         CON14930
C          TAL = SAT STEAM TEMP IN RANKIN                               CON14940
C          STSAT = STAT STEAM TEMP F                                    CON14950
C          VG = SPECIFIC VOLUME OF STEAM FT**3/LB                       CON14960
C          AMWNC = MOLECULAR WEIGHT OF N/C GASSES                       CON14970
C          VNC = SPECIFIC VOLUME OF N/C GAS FT**3/LB                    CON14980
C          VMIX = SPECIFIC VOLUME OF STEAM AND N/C GASSES IN MIXTURE    CON14990
C          WS = STEAM FLOW TO A ROW OF TUBES IN A SECTOR LB/HR          CON15000
C          WGAS = FLOW OF N/C TO A SECTOR LB/HR                         CON15010
C          WNC = SAME AS WGAS                                           CON15020
C          AOTFLW = AREA OPEN TO FLOW IN A BANK OF TUBES                CON15030
C          VEL = STEAM-N/C MIXTURE VELOCITY IN A ROW OF TUBES           CON15040
C                                                                       CON15050
C ZZZ SEC-3                                                             CON15060
C-------------                                                          CON15070
      DO 390 J=1,ISEC                                                   CON15080
C     INITIALIZE SECTOR TEST VARIABLES                                  CON15090
C                                                                       CON15100
      WTST(J)=0.                                                        CON15110
      PTST(J)=0.                                                        CON15120
      CHECK1=0.                                                         CON15130
      CHECK2=0.                                                         CON15140
      SUBRAT=0.                                                         CON15150
      TUBORY=0.                                                         CON15160
      IIII=0                                                            CON15170
      DELP(J)=0.                                                        CON15180
      DELPP=0.                                                          CON15190
      DELPTP=0.                                                         CON15200
      PMIX(1,J)=PMIX1-DELP12-DELP23                                     CON15210
      PSAT(1,J)=PMIX(1,J)*(AMOLSS/AMOLST)                               CON15220
C                                                                       CON15230
C     CHECK TO SEE IF SATURATION PRESSURE INTC THE SECTUR IS BELOW THE  CON15240
C     SATURATION PRESSURE CORRESPONDING TO THE COOLANT INLET TEMPERATURECON15250
C     (PTLIM). STEAM SATURATION PRESSURE CAN ONLY FALL TOO LOW DUE TO   CON15260
C     EXCESSIVE ENTRANCE PRESSURE LOSSES (DELP12,DELP23)                CON15270
C                                                                       CON15280
      IF (PSAT(1,J).GT.PTLIM) GO TO 90                                  CON15290
C                                                                       CON15300
C     IF PSAT<PTLIM THEN DUMMY VALUES MUST BE INSERTED FOR PSAT,PMIX    CON15310
C     AND DELPP IN ORDER TO KEEP THE PROGRAM RUNNING. A VALUE FOR PTST  CON15320
C     IS ALSO DETERMINED.                                               CON15330
C                                                                       CON15340
      PTST(J)=PSAT(1,J)-PTLIM-NOROWS                                    CON15350
      RTG=FLOAT(NOROWS+1)                                               CON15360
      NRWSP3=NOROWS+1                                                   CON15370
      DELPP=PTLIM/(RTG+1.)                                              CON15380
      CHECK2=-2.                                                        CON15390
      DO 80 M=1,NRWSP3                                                  CON15400
      PSAT(M,J)=PTLIM-(M-1)*DELPP                                       CON15410
80    CONTINUE                                                          CON15420
      PMIX(1,J)=PSAT(1,J)/(AMOLSS/AMOLST)                               CON15430
C                                                                       CON15440
90    PAL=PSAT(1,J)                                                     CON15450
      TAL=TSATFN(PAL)                                                   CON15460
      STSAT(1,J)=TAL-459.69                                             CON15470
      VG=VGFN(TAL,PMIX(1,J))                                            CON15480
      VNC=(10.729*TAL)/(AMWNC*PMIX(1,J))                                CON15490
      VMIX=1.0/((AMOLSS/(VG*AMOLST))+(AMOLNC/(VNC*AMOLST)))             CON15500
      VEL(1,J)=(WS(1,J)+WGAS(J))*VMIX/(3600.0*AOTFLW(1))                CON15510
      WNC=WGAS(J)                                                       CON15520
      AMOLSC=WNC/AMWNC                                                  CON15530
C$--------------                                                        CON15540
C SEC A3                                                                CON15550
C                     TEMP OUTPUT SECTION                               CON15560
C                                                                       CON15570
C ZZZ SEC-A3                                                            CON15580
C--------------                                                         CON15590
      SECA3=0.                                                          CON15600
      IF (SECA3.NE.1.) GO TO 100                                        CON15610
      WRITE (6,760) J                                                   CON15620
      WRITE (6,770) PMIX(1,J),PSAT(1,J)                                 CON15630
      WRITE (6,780) STSAT(1,J),TAL                                      CON15640
      WRITE (6,790) VG,VNC,VMIX                                         CON15650
      WRITE (6,800) VEL(1,J)                                            CON15660
100   CONTINUE                                                          CON15670
C$--------------                                                        CON15680
C SEC 4                                                                 CON15690
C                     DO LOOP ON ROWS - HEREAFTER REFERRED TO AS        CON15700
C                                MAIN ROW LOOP                          CON15710
C                                                                       CON15720
C                 THIS SECTION IS INSIDE THE MAIN SECTOR LOOP.  IT      CON15730
C                 INITIALIZES SOME VARIABLES PRICR TO CALLING HETTRN    CON15740
C                 IN SEC-5.                                             CON15750
C                                                                       CON15760
C             I = ROW NUMBER                                            CON15770
C             IL = ROW NUMBER DUMMY VARIABLE                            CON15780
C             AXO = AREA OPEN TO FLOW IN A ROW OF TUBES  FT**2          CON15790
C             AOTFLW = AME AS AXO                                       CON15800
C             L = SECTCR NUMBER                                         CON15810
C             J = SECTOR NUMBER DUMMY VARIABLE                          CON15820
C             NOROWS = NUMBER OF ROWS OF TUBES IN A SECTOR              CON15830
C             DELODF = CHANGE IN TUBE OD / ROW  FT                      CON15840
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C        OD = TUBE OD    FT
C        ODOF = TUBE CD, OUTSIDE ROW   FT
C        XW  = TUBE WALL THICKNESS    FT
C        SDW = LOG MEAN TUBE THICKNESS   FT
C        AXI = TUBE INNER CROSS-SECTIONAL AREA   FT**2
C        AI  = TUBE INNER SURFACE AREA   FT**2
C        AO  = TUBE OUTER SURFACE AREA   FT**2
C        AW  = LOG MEAN TUBE SURFACE AREA   FT**2
C        SHWINV = INVERSE OF WALL HEAT X-FER COEF  HR-FT**2-F/BTU
C        PTLIM = LOWEST SATURATION PRESSURE THE STEAM CAN GO BEFORE THE
C          CORRESPONDING SATURATION TEMPERATURE FALLS BELOW INLET
C          COOLANT TEMPERATURE. THE RESULT IS 0 HEAT TRANSFER
C        SKW = TUBE THERMAL CONDUCTIVITY    BTU-FT/HR-FT**2-F
C        TID = TUBE INNER DIAMETER   FT
C        WST = STEAM FLOW TO A ROW IN A SECTOR  LBM/HR
C
C ZZZ SEC-4
C---------------
      DO 380 IL=1,NJROWS
      I=IL
      L=J
      IJX=0
      LQ=0
      WB=CMDOT(I)*3600.
      AXO=AOTFLW(I)
      OD=ODOF-DELODF*FLOAT(IL-1)
      TID=SID(IL)
      XW=(OD-TID)/2.
      AI=ALST*PI*TID
      AO=ALST*PI*OD
      AXI=PI*(TID/2.)**2
      SDW=(OD-TID)/ALOG(OD/TID)
      AW=ALST*PI*SDW
      SHWINV=(AO*XW)/(SKW*AW)
      WST=WS(IL,J)
C*****
      IF (WST.LE.0) WRITE (6,600) J,IL
C$-------------
C SEC A4
C                   TEMP OUTPUT SECTION
C
C ZZZ SEC-A4
C---------------
      SECA4=0.
      IF (SECA4.NE.1) GO TO 110
      WRITE (6,810) IL
      WRITE (6,820) AI,AO
      WRITE (6,830) TID,AXI
      WRITE (6,840) SDW,AW                                              CON16330
      WRITE (6,850) SHWINV                                              CON16340
110   CONTINUE                                                          CON16350
C$-------------                                                         CON16360
C SEC 5                                                                 CON16370
C                   CALL TO HETTRN AND PRSDRP                           CON16380
C                                                                       CON16390
C              THIS SECTION INSIDE BOTH MAIN ROW AND SECTOR LOOPS       CON16400
C                                                                       CON16410
C                                                                       CON16420
C          STSAT = STEAM SATURATION TEMP  F                             CON16430
C          ANT = TARGET TUBE LOCATION IN VERTICAL RCW                   CON16440
C          WS = STEAM FLOW TO A ROW OF A SECTOR   LBM/HR                CON16450
C          WNC = N/C FLOW TO A ROW OF A SECTOR   LBM/HR                 CON16460
C          UN = OVERALL HEAT TRANSFER COEF FOR CNE ROW OF TUBES IN A SECT.CON16470
C          ALMTD = LMTD FOR A ROW IN A SECTOR  F                        CON16480
C          HOMCI = STSAT - COOLANT INLET TEMP                           CON16490
C          HOMCO = STSAT - COOLANT OUTLET TEMP                          CON16500
C          STFO = AVE TEMP OF OUTER TUBE FILM                           CON16510
C          SHI = INTERNAL TUBE FILM HEAT TRANSFER CCEF.                 CON16520
C          SHN = EXTERNAL TUBE FILM HEAT TRANSFER COEF                  CON16530
C          RC = RATIO OF N/C GAS TO STM AT ONE ROW OF TUBES             CON16540
C          ROUT = EXTERNAL HEAT TRANSFER COEF                           CON16550
C          AXO = AREA OPEN TO FLOW IN A ROW OF TUBES  FT**2             CON16560
C          VNRE = REYNOLDS NUMBER ON VAPOR SIDE AT A ROW IN A SECTOR    CON16570
C          DUMMY = NUSSELT NUMBER                                       CON16580
C          VPSHH = OUTLET COOLANT TEMP  F                               CON16590
C          HEFF = N/C GAS FILM HEAT TRANSFER COEF                       CON16600
C          L = SECTOR NUMBER                                            CON16610
C          HFG = STEAM LATENT HEAT OF VAPORIZATION  BTU/LBM             CON16620
C          WCND = CONDENSATE FROM ONE ROW OF TUBES IN A SECTOR  LBM/HR  CON16630
C          AD = OUTER SURFACE AREA OF A TUBE  FT**2                     CON16640
C          PTLIM = LOWEST SATURATION PRESSURE THE STEAM CAN GO BEFORE THE CON16650
C            CORRESPONDING SATURATION TEMPERATURE FALLS BELOW INLET     CON16660
C            COOLANT TEMPERATURE. THE RESULT IS O HEAT TRANSFER         CON16670
C          TBNPR = NUMBER OF TUBES IN A GIVEN ROW OF ASECTOR            CON16680
C          TAL = SATURATED STEAM TEMP  R                                CON16690
C          VMIX = SPECIFIC VOLUME OF STM-N/C MIXTURE  FT**3/LBM         CON16700
C          SDO = TUBE OD  FT                                            CON16710
C          VPSH = FRICTION FACTOR USED IN PRESSURE DROP CALC            CON16720
C          DELPTP = PRESS DROP ACROSS A ROW OF TUBES  PSI               CON16730
C          ENHF = PRESSURE DROP FRICTION FACTOR ENHANCEMENT             CON16740
C          ENHF = PRESS DROP FRICTION FACTOR ENHANCEMENT FACTOR, STM SIDE.CON16750
C                                                                       CON16760
C ZZZ SEC-5                                                             CON16770
C-------------                                                          CON16780
C                                                                       CON16790
C     CHECK TO ENSURE THAT THE SATURATION PRESSURE IN AN EARLIER ROW    CON16800
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C       CALCULATION HAS NOT DROPPED BELOW THE SATURATION PRESSURE
C       CORRESPCNDING TO THAT OF THE INLET COOLANT TEMPERATURE (PTLIM) FOR
C       A GIVEN SECTOR. IF IT HAS, CHECK2<0 AND WE SKIP HETTRN CALCS SINCE
C       DUMMY VARIABLES HAVE BEEN INSERTED FOR PSAT
C
        IF (CHECK2.LT.0) GO TO 120
C
        CALL HETTRN (ALST,AXO,I,L,OD,WB,SHWINV,STSAT(I,L),TID,WNC,WST,ALMT
       1D(I,L),ENHF,HEFF(I,L),HOMCI,HOMCO,RC(I,L),RCUT(I,L),SHI(I,L),SHN(I
       2,L),STFO,VPSHH(I,L),UN(I,L),VNRE(I,L),ENHI,ENHO,SDDU)
C
C       CHECK TO SEE IF THE FIRST ROW IN THE SECTOR HAS STEAM SATURATION
C       HAS DROPPED BELOW PTLIM. IF IT HAS THEN CHECK2<0 AND I=1.
C       DUMMY VALUES MUST THEN BE PLACED IN THOSE VARIABLES NORMALLY
C       RETURNED BY HETTRN SINCE HETTRN HAS BEEN BYPASSED.
C
120     IF ((CHECK2.GE.0.).OR.(I.NE.1)) GO TO 130
C
C       SINCE THE SATURATION STEAM PRESSURE IS BELOW PTLIM THEN THE STEAM
C       TEMPERATURE IS BELOW COOLANT INLET TEMPERATURE. THIS MEANS NO
C       HEAT IS REMOVED FROM THE STEAM AND THE ALMTD IS 0. THE COOLANT
C       OUTLET TEMP IS THE SAME AS THE COOLANT INLET TEMP AND THE TUBE
C       FILM TEMP IS THE SAME AS COOLANT INLET TEMPS. THE REMAINING
C       VARIABLE VALUES ARE APPROXIMATED.
C
        ALMTD(1,J)=0.
        HOMCI=0.
        HOMCO=0.
        VPSHH(1,J)=STBI
        HEFF(1,J)=1.E+8
        RC(1,J)=.161E-3
        VNRE(1,J)=.9E+5
        SHI(1,J)=.136E+4
        SHN(1,J)=.136E+5
        UN(1,J)=655.
        ROUT(1,J)=.136E+5
        STFO=STBI
        GO TO 150
C
C       CHECK TC SEE IF A ROW OTHER THAN THE FIRST ONE IN THE SECTOR HAS
C       HAD STEAM SATJRATION DROP BELOW PTLIM. IF IT HAS THEN CHECK2<0.
C       DUMMY VALUES MUST THEN BE PLACED IN THOSE VARIABLES NORMALLY
C       RETURNED BY HETTRN SINCE HETTRN HAS BEEN BYPASSED.
C
130     IF (CHECK2.LT.0) GO TO 140
        ENHFSV=ENHF
        GO TO 150
C
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C       IF CHECK2 < 0, THAT INDICATES THAT THE SATURATION STEAM PRESSURE  CON17290
C       IS BELOW PTLIM AND THUS THE STEAM TEMPERATURE IS BELOW COOLANT    CON17300
C       INLET TEMPERATURE. THIS MEANS THAT NO HEAT IS REMOVED FROM THE    CON17310
C       STEAM AND THE ALMTD IS 0. THE COOLANT OUTLET TEMP EQUALS THE      CON17320
C       COOLANT INLET TEMP AND THE TUBE FILM TEMP IS THE SAME AS THE      CON17330
C       COOLANT INLET TEMP. THE REMAINING VARIABLES ARE GIVEN THE LAST    CON17340
C       GOOD VALUES RETURNED BY HETTRN.                                   CON17350
C                                                                         CON17360
140     ALMTD(I,J)=0.                                                     CON17370
        HOMCI=0.                                                          CON17380
        HOMCO=0.                                                          CON17390
        VPSHH(I,J)=STBI                                                   CON17400
        HEFF(I,J)=HEFF(I-1,J)                                             CON17410
        RC(I,J)=RC(I-1,J)                                                 CON17420
        VNRE(I,J)=VNRE(I-1,J)                                             CON17430
        SHI(I,J)=SHI(I-1,J)                                               CON17440
        SHN(I,J)=SHN(I-1,J)                                               CON17450
        UN(I,J)=UN(I-1,J)                                                 CON17460
        ROUT(I,J)=ROUT(I-1,J)                                             CON17470
        STFO=STBI                                                         CON17480
        ENHF=ENFFSV                                                       CON17490
C                                                                         CON17500
150     TB2=VPSHH(I,L)                                                    CON17510
        HFG=HFGFN(STSAT(I,J))                                             CON17520
C                                                                         CON17530
C       CHECK TO SEE IF STEAM FLOW IN A SECTOR HAS ALREADY GONE TO 0      CON17540
C       IF IT HAS CHECK1<0 AND DUMMY VALUES HAVE ALREADY BEEN ASSIGNED    CON17550
C       TO WCNC.                                                          CON17560
C                                                                         CON17570
        IF (CHECK1.LT.0.) GO TO 160                                       CON17580
C                                                                         CON17590
        WCND(I,J)=UN(I,J)*AO*ALMTD(I,J)/HFG*TBNPR(I)                      CON17600
C                                                                         CON17610
C       CHECK TC SEE IF SATURATION PRESSURE HAS ALREADY GONE BELOW PTLIM  CON17620
C       AND DUMMY VARIABLES HAVE BEEN ASSIGNED TO DELPTP                  CON17630
C                                                                         CON17640
C       IF (CHECK2.LT.0) GO TO 170                                        CON17650
C                                                                         CON17660
160     CALL PRSDRP (TAL,VMIX,WS(I,J),WNC,AXO,OD,VPSH,DELPTP,ENHF)        CON17670
C170    CONTINUE                                                          CON17680
        JX=0                                                              CON17690
C$--------------                                                          CON17700
C SEC A5                                                                  CON17710
C                     TEMP OUTPUT SECTION                                 CON17720
C                                                                         CON17730
C ZZZSEC-A5                                                               CON17740
C--------------                                                           CON17750
        SECA5=0.                                                          CON17760
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      IF (SECA5.NE.1.) GO TO 170                                        CON17770
      WRITE (6,860) I,J                                                 CON17780
      WRITE (6,910) TB2,UN(I,L),VNRE(I,L)                               CON17790
      WRITE (6,870) ALMTD(I,L),HEFF(I,L)                                CON17800
      WRITE (6,880) HOMCI,HOMCO                                         CON17810
      WRITE (6,890) RC(I,L),ROUT(I,L)                                   CON17820
      WRITE (6,900) SHI(I,L),SHN(I,L)                                   CON17830
      WRITE (6,920) WNC,WS(I,L)                                         CON17840
      WRITE (6,930) DELPTP,VPSH                                         CON17850
      WRITE (6,940) WCND(I,J),HFG                                       CON17860
      WRITE (6,950) AO,TBNPR(I)                                         CON17870
C$------------                                                          CON17880
C SEC 6                                                                 CON17890
C                   TEST FOR POSITIVE STM FLOW AND SAT PRESS            CON17900
C                                                                       CON17910
C       WS = STM FLOW TO ONE ROW IN A SECTOR  LB/HR                     CON17920
C       WNCD = CONDENSATE FROM ONE ROW OF TUBES IN A SECTOR  LB/HR      CON17930
C       WNC = N/C GAS FLOW TO ONE ROW OF TUBES IN ASECTOR  LB/HR        CON17940
C       AXO = AREA OPEN TO FLOW IN A ROW OF A SECTOR                    CON17950
C       GFLW = MASS FLW RATE OF MIXTURE IN A TUBE BUNDLE LB/(HR-FT**2)  CON17960
C       I = ROW NUMBER                                                  CON17970
C       AMOLS = MOLES OF STEAM IN A ROW OF A SECTOR                     CON17980
C       PMIX = PRESS OF STM - N/C MIXTURE                               CON17990
C       DELPTP = PRESS DROP ACROSS A ROW OF TUBES                       CON18000
C       AMWNC = MOLECULAR WEIGHT OF N/C                                 CON18010
C       PSAT = SATURATED STEAM PRESS                                    CON18020
C       J = SECTCR NUMBER                                               CON18030
C       STSAT = SATURATED STEAM TEMP - F                                CON18040
C       TSAT = SATURATED STEAM TEMP - R                                 CON18050
C       PAL = DUMMY FOR PSAT                                            CON18060
C       CHECK1 = INDICATOR THAT NEG. STEAM FLOW HAS BEEN ENCOUNTERED    CON18070
C                IN SECTOR ANALYSIS                                     CON18080
C       CHECK2 = INDICATOR THAT PRESS<PSATFN(STBI) HAS BEEN             CON18090
C                ENCOUNTERED IN SECTOR ANALYSIS                         CON18100
C       PTEST = NEXT ROW PRESSURE VALUE TO CHECK FOR A BAD VALUE        CON18110
C       WTEST = NEXT ROW STEAM FLOW TO CHECK FOR A NEGATIVE VALUE       CON18120
C       WTST = TEST VARIABLE WHICH IS NEGATIVE WHEN NEGATIVE STEAM FLOWCON18130
C              IS ENCOUNTERED IN A SECTOR                               CON18140
C       PTST = TEST VARIABLE WHICH IS A NEGATIVE WHEN PSAT DROPS BELOW  CON18150
C              PTLIM IN A SECTOR                                        CON18160
C                                                                       CON18170
C ZZZ SEC-6                                                             CON18180
C------------                                                           CON18190
C     CHECK TO SEE IF STEAM FLOW HAS ALREADY GONE TO 0 IN AN EARLIER    CON18200
C     ROW CALCULATIO AND FIXUP HAS BEEN MADE TO WS AND WCND             CON18210
C                                                                       CON18220
170   IF (CHECK1.LT.0) GO TO 180                                        CON18230
      WS(I+1,J)=WS(I,J)-WCND(I,J)                                       CON18240
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C                                                                       CON18250
C       CHECK TO SEE IF STEAM FLOW OF NEXT ROW IS 0 AND DUMMY VALUES    CON18260
C       MUST BE ASSIGNED TO WS AND WCND TO ALLOW THE PROGRAM TO CONTINUE  CON18270
C                                                                       CON18280
        IF (WS(I+1,J).LE.1.) IIII=1                                     CON18290
        IF (WS(I+1,J).LE.1.) GO TO 300                                  CON18300
C                                                                       CON18310
C       BEGIN COMPUTING NEXT ROW PRESSURES                              CON18320
C                                                                       CON18330
180     AMOLS=WS(I+1,J)/18.015                                          CON18340
        SECA6=0.                                                        CON18350
        IIII=0                                                          CON18360
C                                                                       CON18370
C       CHECK TC SEE IF SATURATION PRESSURES HAVE ALREADY GONE BELOW    CON18380
C       PTLIM AND STANDARD FIXUP TO PSAT HAS BEEN MADE. PRESSURE FALLING  CON18390
C       BELOW PTLIM IS CONSIDERED ONLY FOR THE CASE OF EXCESSIVE PRESSURE  CON18400
C       LOSSES CNLY AND NOT AS A CONSEQUENCE OF LOSS OF STEAM FLOW      CON18410
C                                                                       CON18420
        IF (CHECK2.GE.0) GC TO 190                                      CON18430
        PAL=PSAT(I+1,J)                                                 CON18440
        IF (I.EQ.1) DELPTP=DELPP/(AMOLS/(AMOLS+WNC/AMWNC))              CON18450
        PMIX(I+1,J)=PMIX(I,J)-DELPTP                                    CON18460
        IF (PMIX(I+1,J).LE..001) PMIX(I+1,J)=.001                       CON18470
        GO TO 230                                                       CON18480
C                                                                       CON18490
190     PMIX(I+1,J)=PMIX(I,J)-DELPTP                                    CON18500
        PSAT(I+1,J)=PMIX(I+1,J)*AMOLS/(AMOLS+WNC/AMWNC)                 CON18510
        PAL=PSAT(I+1,J)                                                 CON18520
        PTEST=PSAT(I+1,J)                                               CON18530
        IF (SECA6.NE.1) GO TO 200                                       CON18540
        IF (SECA6.EQ.1) WRITE (6,1020) I,J                              CON18550
        IF (SECA6.EQ.1) WRITE (6,970) WS(I,J),WS(I+1,J)                 CON18560
        IF (SECA6.EQ.1) WRITE (6,1000) PSAT(I,J),PSAT(I+1,J)            CON18570
C                                                                       CON18580
C       CHECK FCR NEXT ROW SATURATION PRESSURE TO SEE IF DROPS BELOW PTLIMCON18590
C                                                                       CON18600
200     IF (PTEST-PTLIM) 210,210,230                                    CON18610
C                                                                       CON18620
C        PSAT(I+1) < PTLIM AND SUBSEQUENT ROW PRESSURES MUST BE FIXED   CON18630
C        UP WITH DUMMY VALUES IN ORDER TO KEEP THE PROGRAM RUNNING.     CON18640
C        PSAT,AND DELPP ARE GIVEN DUMMY VALUES.                         CON18650
C                                                                       CON18660
210     IK2=I+1                                                         CON18670
        SECA6=0.                                                        CON18680
        NRWSP2=NOROWS+1                                                 CON18690
        ROTOG=FLCAT(NRWSP2-1)                                           CON18700
        DELPP=PTLIM/(ROTOG+1)                                           CON18710
C                                                                       CON18720
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C      DELPP IS AN ARBITRARY INCREMENTAL PRESS. DROP OVER REMAINING ROWS CON18730
C                                                                        CON18740
       DO 220 IK=IK2,NRWSP2                                              CON18750
       PSAT(IK,J)=PSAT(IK-1,J)-DELPP                                     CON18760
220    CONTINUE                                                          CON18770
       X1=PTEST-PTLIM                                                    CON18780
       X2=PSAT(I,J)                                                      CON18790
C                                                                        CON18800
C       CALCULATE PTST WHICH IS A TEST VALUE INDICATING THAT SATURATION  CON18810
C       PRESSURES WERE REACHED IN THE ANALYSIS FROM WHICH THE            CON18820
C       CORRESPONDING TSAT IS EXCEEDED BY THE INLET COOLANT TEMP(IE PTLIMCON18830
C       WAS VIOLATED) A LARGE NEGATIVE VALUE FOR PTST INDICATES A BAD    CON18840
C       CONDENSOR DESIGN IN WHICH PTLIM WAS VIOLATED EARLY IN THE SECTOR CON18850
C       ANALYSIS. AS THE CONDENSOR MODEL IMPROVES AND SATURATION PRESSURECON18860
C       STAYS ABOVE PTLIM THEN PTST CONVERGES TO 0.                      CON18870
C                                                                        CON18880
       PTST(J)=(X1/(X2-X1))-FLOAT(NOROWS-I)                              CON18890
       CHECK2=-2.                                                        CON18900
       PAL=PSAT(I+1,J)                                                   CON18910
       PMIX(I+1,J)=PMIX(I,J)-DELPTP                                      CON18920
       IF (PMIX(I+1,J).LE..001) PMIX(I+1,J)=.001                         CON18930
C                                                                        CON18940
       IF (SECA6.EQ.1) WRITE (6,990) I,J                                 CON18950
       IF (SECA6.EQ.1) WRITE (6,1000) PSAT(I,J),PSAT(I+1,J)              CON18960
       IF (SECA6.EQ.1) WRITE (6,1010) PTST(J)                            CON18970
C                                                                        CON18980
       GO TO 230                                                         CON18990
C$-------------                                                          CON19000
C SEC 7                                                                  CON19010
C                    CORRECTION TO CONDENSATE RATE FOR                   CON19020
C                         SENSIBLE HEAT                                  CON19030
C                                                                        CON19040
C         PAL = SAT STM PRESS                                            CON19050
C         STFO = AVE TEMP OF OUTER TUBE FILM                             CON19060
C         UN = OVERALL HEAT X-FER COEF FOR A ROW OF TUBES                CON19070
C         AO = TUBE OUTER SURFACE AREA                                   CON19080
C         ALMTD = LMTD                                                   CON19090
C         TBNPR = NUMBER OF TUBES IN A ROW OF A SECTOR                   CON19100
C         WS = STEAM FLOW TO A ROW OF A SECTOR                           CON19110
C         WNC = N/C FLOW TO A ROW OF A SECTOR                            CON19120
C         JGAS = FLAG FOR TYPE OF N/C                                    CON19130
C         AMWNC = MOLECULAR WEIGHT OF N/C                                CON19140
C         TAL = SAT STM TEMP ENTERING SECTOR  R                          CON19150
C         WCNDP = CONDENSATE FROM ONE ROW CORRECTED FOR SENSIBLE         CON19160
C                HEAT CHANGE  LB/HR                                      CON19170
C         WCND = CONDENSATE FROM ONE ROW                                 CON19180
C         JX =                                                           CON19190
C         IDENT = USER INPUT IDENTIFICALTION STRING FOR RUN              CON19200
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C          AMOLS = MOLES OF STEAM IN A ROW OF A SECTOR                      CON19210
C          PMIX = PRESSURE OF STEAM - N/C MIXTURE                           CON19220
C          PSAT = SATURATED STEAM PRESS                                     CON19230
C          TSAT = SATURATED STEAM TEMP  R                                   CON19240
C          STSAT = SATURATED STEAM TEMP  F                                  CON19250
C                                                                           CON19260
C                                                                           CON19270
C ZZZ SEC-7                                                                 CON19280
C--------------                                                             CON19290
230    TSAT=TSATFN(PAL)                                                     CON19300
       SECA7=0.                                                             CON19310
       STSAT(I+1,J)=TSAT-459.69                                             CON19320
       IF (STSAT(I+1,J)-STFO) 240,240,250                                   CON19330
240    STSAT(I+1,J)=STFO                                                    CON19340
       TSAT=STSAT(I+1,J)+459.69                                             CON19350
250    CONTINUE                                                             CON19360
       WCNDP=(UN(I,J)*AO*ALMTC(I,J)*TBNPR(I)-(WS(I,J)*CPSFN(TSAT)/18.015+CON19370
      1WNC*CPAFN(TSAT,JGAS)/AMWNC)*(TAL-TSAT))/HFG                          CON19380
       IF (SECA7.EC.1) WRITE (6,1070) WCND(I,J),WCNDP                       CON19390
       IF (SECA7.EQ.1) WRITE (6,1080) TAL,TSAT                              CON19400
C                                                                           CON19410
C                                                                           CON19420
C      CHECK TO SEE IF WCND IS 0 WHICH CAN OCCUR IF PSAT HAS DROPPED        CON19430
C      BELOW PTLIM (CHECK2<0). IF IT HAS THERE IS NO HEAT TRANSFER FROM     CON19440
C      THE STEAM AND NO NEED TO CORRECT FOR SENSIBLE HEAT                   CON19450
C                                                                           CON19460
       IF (CHECK2.LT.0) WCNDP=WCND(I,J)                                     CON19470
C                                                                           CON19480
C      CHECK TO SEE IF STEAM FLOW HAS ALREADY GONE TO 0 (CHECK<0)           CON19490
C      AND WCND HAS BEEN FIXED UP WITH DUMMY VALUES                         CON19500
C                                                                           CON19510
       IF (CHECK1.LT.0) WCNDP=WCND(I,J)                                     CON19520
C                                                                           CON19530
C      IF CONDENSATE FLOW HAS GONE TO 0 AVOID ITERATIONS                    CON19540
C                                                                           CON19550
       IF (WCND(I,J).EQ.0.) GO TO 290                                       CON19560
C                                                                           CON19570
C      IF EITHER CHECK IS TRUE THEN AVOID CORRECTIVE ITERATION TO WCND      CON19580
C                                                                           CON19590
       IF (ABS(WCNDP/WCND(I,J)-1.0)-.005) 290,260,260                       CON19600
260    JX=JX+1                                                              CON19610
       IF (JX-50) 280,280,270                                               CON19620
270    IF (SECA7.EQ.1) WRITE (6,1120) IDENT,I,J,I,J                         CON19630
       GO TO 250                                                            CON19640
280    WCND(I,J)=WCNDP                                                      CON19650
       GO TO 170                                                            CON19660
290    CONTINUE                                                             CON19670
       SECA6=0.                                                             CON19680
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C                                                                       CON19690
C     CHECK TO SEE IF STEAM FLOW HAS GONE TO 1 IN AN EARLIER ROW        CON19700
C     CALCULATION AND SUBSEQUENT ROWS HAVE BEEN FIXED UP WITH DUMMY     CON19710
C     VALUES. A NEGATIVE CHECK1 INDICATES FIXUP HAS BEEN MADE FOR       CON19720
C     THAT SECTOR                                                       CON19730
C                                                                       CON19740
      IF (CHECK1.GE.0) GO TO 300                                        CON19750
      GO TO 350                                                         CON19760
C                                                                       CON19770
300   WTEST=WS(I+1,J)                                                   CON19780
C                                                                       CON19790
C     CHECK THE NEXT ROW TO SEE IF STEAM FLOW < 1                       CON19800
C                                                                       CON19810
      IF (WTEST-1.) 310,310,340                                         CON19820
C                                                                       CON19830
C     IF STEAM FLOW HAS GONE TO 1 THEN A STANDARD FIXUP IS MADE TO      CON19840
C     ALLOW THE PROGRAM TO CONTINUE AND DUMMY VALUES FOR STEAM FLOW     CON19850
C     AND CONDENSATE ARE ENTERED INTO THE REMAINING ROWS. IF STEAM FLOW CON19860
C     HAS GONE TO 1 THAT INDICATES ZERO STEAM FLOW. A VERY SMALL NUMBER CON19870
C     WILL BE USED TO SIMULATE 0 STEAM FLOW IN THE REMAINING ROWS.      CON19880
C                                                                       CON19890
310   IK1=I+1                                                           CON19900
      ROTOGO=FLOAT(NOROWS-I)                                            CON19910
      WSEND=(WTEST-1.)/(WS(I,J)-WTEST+1.)                               CON19920
      WTST(J)=WSEND-ROTOGO                                              CON19930
C                                                                       CON19940
      IF (SECA6.EQ.1) WRITE (6,960) I,J                                 CON19950
      IF (SECA6.EQ.1) WRITE (6,970) WS(I,J),WTEST                       CON19960
      IF (SECA6.EQ.1) WRITE (6,980) WTST(J)                             CON19970
C                                                                       CON19980
C     CALCULATE NEGATIVE FLOW RATE FOR USE IN CALCULATING EXTITFR       CON19990
C                                                                       CON20000
      DO 320 KK=IK1,NCROWS                                              CON20010
      TUBDRY=TUBDRY+TBNPR(KK)                                           CON20020
320   CONTINUE                                                          CON20030
      TUBDRY=TUBDRY-WSEND*TBNPR(I)                                      CON20040
      CUMDRY=CUMDRY+TUBDRY                                              CON20050
      SUBRAT=WCND(I-1,J)/TBNPR(I)                                       CON20060
      SUBAVE=SUBAVE+SUBRAT                                              CON20070
      NBAD=NBAD+1                                                       CON20080
      SUBFLO=SUBFLO+SUBRAT*TUBDRY                                       CON20090
C                                                                       CON20100
      NRWSP1=NOROWS+1                                                   CON20110
      RSTOGO=FLOAT(NRWSP1-I)                                            CON20120
      WS(I,J)=(1.0)*(RSTOGO+1)                                          CON20130
      WCND(I,J)=WS(I,J)                                                 CON20140
      DELWS=WS(I,J)/(RSTOGO+1)                                          CON20150
      DELWC=WCND(I,J)/(RSTOGO+1)                                        CON20160
      DO 330 IK=IK1,NRWSP1                                                CON20170
      IF (SECA6.EQ.1) WRITE (6,970) WS(IK,J)                              CON20180
      WS(IK,J)=WS(IK-1,J)-DELWS                                           CON20190
330   WCND(IK,J)=WCND(IK-1,J)-DELWC                                       CON20200
C                                                                         CON20210
C     CALCULATE A VALUE FOR THE TEST VARIABLE (WTST) INDICATING 0 OR      CON20220
C     NEGATIVE STEAM FLOW. A LARGE NEGATIVE VALUE FOR WTST INDICATES      CON20230
C     A VERY BAD CONDENSOR MODEL WHERE NEGATIVE STEAM FLOW WAS            CON20240
C     ENCOUNTERED EARLY IN THE SECTORS. AS THE CONDENSOR MODEL IMPROVES   CON20250
C     STEAM FLOW STAYS POSITIVE THROUGHOUT THE CONDENSOR AND WTST         CON20260
C     CONVERGES TO 0.                                                     CON20270
C                                                                         CON20280
      CHECK1=-2.                                                          CON20290
      IF (IIII.EQ.1) GO TO 180                                            CON20300
      GO TO 350                                                           CON20310
340   WCND(I,J)=WCNDP                                                     CON20320
      WS(I+1,J)=WS(I,J)-WCND(I,J)                                         CON20330
350   GFLW(I,J)=(WS(I,J)+WNC)/AXO                                         CON20340
      AMOLS=WS(I+1,J)/18.015                                              CON20350
C                                                                         CON20360
C     CHECK TO SEE IF PRESURE HAS ALREDY GONE BELOW PTLIM                 CON20370
C     AND DUMMY VALUES ARE IN THE PRESSURE ARRAY (CHECK2<0)               CON20380
C                                                                         CON20390
      IF (CHECK2.LT.0.) GO TO 360                                         CON20400
C                                                                         CON20410
      PSAT(I+1,J)=PMIX(I+1,J)*AMOLS/(AMOLS+WNC/AMWNC)                     CON20420
360   TSAT=TSATFN(PSAT(I+1,J))                                            CON20430
      STSAT(I+1,J)=TSAT-459.69                                            CON20440
C$-------------                                                           CON20450
C SEC A7                                                                  CON20460
C                     TEMP OUTPUT SECTION                                 CON20470
C                                                                         CON20480
C ZZZ SEC-A7                                                              CON20490
C-------------                                                            CON20500
      IF (SECA7.NE.1.) GO TO 370                                          CON20510
      WRITE (6,1030) I,J                                                  CON20520
      WRITE (6,1040) WS(I,J),WCND(I,J)                                    CON20530
      WRITE (6,1050) TSAT,STSAT(I,J)                                      CON20540
      WRITE (6,1060) GFLW(I,J),PSAT(I,J)                                  CON20550
C$-------------                                                           CON20560
C SEC 8                                                                   CON20570
C                     COMPLETION OF MAIN ROW AND SECTOR LOOPS             CON20580
C                                                                         CON20590
C                 NOTE THAT THE MAIN ROW LOOP IS COMPLETED IN IN LINE 360, CON20600
C                 AND THE MAIN SECTOR LOOP IS COMPLETED IN LINE 390.      CON20610
C                                                                         CON20620
C        VG = SPECIFIC VOLUME OF STM                                      CON20630
C        VMIX = SPECIFIC VOLUME OF STM-N/C MIXTURE                        CON20640
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C          AMOLS = MOLES OF STM TO A ROW
C          TSAT = STM SATURATION TEMP  R
C          PMIX = ST -N/C MIXTURE PRESSURE
C          AMWNC = MOLECULAR WEIGHT OF N/C GASSES
C          VNC = SPECIFIC VOLUME OF N/C GASSES
C          WNC = N/C FLOW TO A ROW OF A SECTOR
C          AMOLSC = MOLES OF A N/C TO A SECTOR
C          VEL = STM-N/C MIXTURE VELOCITY IN A ROW OF TUBES
C          WS = STM FLOW TO A ROW IN A SECTOR  LB/HR
C          AOTFLW = AREA OPEN TO STM FLOW IN A ROW OF TUBES
C          SMTBI = SUM OF (COOLANT INLET TEMP*COOLANT FLOW RATE)
C          WB = COLLANT FLOW TO ONE TUBE IN THE CONDENSER
C          STBI = COOLANT INLET TEMP
C          TBNPR = NUMBER OF TUBES IN A ROW OF A SECTOR
C          SMWB = ROW BY ROW SUM OF COOLANT FLOW
C          SMTB2 = ROW BY ROW SUM OF (COOLANT OUTLET TEMP*FLOW RATE)
C          TB2 = COOLANT OUTLET TEMP FOR A TUBE
C          SUMQ = SUM OF HEAT DUTY ON ROWS OF TUBES
C          UN = OVERALL HEAT X-FER COEF FOR A ROW
C          AO = TUBE OUTER SURFACE AREA
C          ALMTC = LMTD
C          QOA = HEAT FLUX ACROSS TUBE WALL
C          CUMCP = ACCUMULATED PRESS DROP FROM INLET TO CURRENT ROW
C          PMIX = PRESS OF STM-N/C MIXTURE
C          PHP = OVERALL POWER TO DRIVE THE COOLANT THROUGH THE CONDENSER
C                AND THE COOLER TUBES IN HP.
C          DELP = PRESSURE DROP ACROSS A SECTOR
C          DELPTP = PRESSURE DROP ACROSS A ROW
C          TAL = SAT STEAM TEMP  R
C          I = ROW NUMBER
C          IT = DUMMY LOOP VARIABLE(IT = I)
C          SVMIX1 = SPECIFIC VOLUME OF STM-N/C MIXTURE ENTERING CONDENSER
C          WGAS = FLOW OF N/C GAS TO A SECTOR
C          AOTFLW = AREA OPEN TO STEAM FLOW IN A ROW OF TUBES
C          C = USED TO ADJUST STEAM FLOW TO MATCH PRESS DROPS IN SEC-10
C ZZZ SEC-8
C--------------
370   VG=VGFN(TSAT,PMIX(I+1,J))
      AMOLSC=WNC/AMWNC
      VNC=(10.729*TSAT)/(AMWNC*PMIX(I+1,J))
      VMIX=1.0/((AMOLS/(VG*(AMOLS+AMOLSC)))+(AMOLSC/(VNC*(AMOLS+AMOLSC))
     1))
C     IF (I.EQ.NOROWS) GOTO 190
      VEL(I+1,J)=(WS(I+1,J)+WNC)/(AOTFLW(I+1))*VMIX/3600.0
      SMTBI=SMTBI+WB*STBI*TBNPR(I)
      SMWB=SMWB+WB*TBNPR(I)
      SMTB2=SMTB2+WB*TBNPR(I)*TB2
      SUMQ=SUMQ+UN(I,J)*AO*ALMTD(I,J)*TBNPR(I)
      QOA(I,J)=UN(I,J)*ALMTD(I,J)
      CUMDP(I,J)=(PMIX1)-PMIX(I+1,J)
      DELP(J)=DELP(J)+DELPTP
      TAL=TSAT
380   CONTINUE
      C(J)=(WS(1,J)+WGAS(J))/SQRT(DELP(J))
C
C     INCLUDE ONLY THOSE SECTORS WHERE STEAM FLOW HAS NOT GONE TO 0
C     IN STMSUM SO AS NOT TO INCLUDE DUMMY VALUES IN THE CALCULATION
C     OF EXIT STEAM FRACTION
C
      IF (CHECK1.GE.0) STMSUM=STMSUM+WS(NOROWS+1,J)
390   CONTINUE
C$-------------
C SEC A8
C                    TEMP OUTPUT SECTION
C ZZZ SEC-A8
C-------------
      SECA8=0.
      IF (SECA8.NE.1.) GO TO 410
      WRITE (6,1090)
      DO 400 I=1,ISEC
400   WRITE (6,1100) WTST(I),PTST(I)
410   CONTINUE
C$-------------
C SEC 9
C                    EXIT FRACTION AND PRESS ADJUST
C ZZZ SEC-9
C-------------
      PMXEXT=0.
      DELPVE=0.
      PSUM=0.
      VELEXT=0.
      DO 420 I=1,ISEC
      PAL=PSAT(KSTOP,I)
      PSUM=PSUM+PAL/SECFLG
      VELEXT=VELEXT+VEL(NOROWS+1,I)
      DELPVE=DELPVE+DELP(I)
420   PMXEXT=PMXEXT+PMIX(NOROWS+1,I)
C
C      MAKE PTST AND EXIT STEAM FRACTION VARIABLES CONTINOUOUS
C      THIS IS DONE TO SATISFY AND ENHANCE OPTIMIZER CALCULATIONS.
C      THE VARIABLE PTST IS GIVEN THE LAST ROW +1 PRESSURE VALUES IF
C      IT IS NON-NEGATIVE. IN ORDER TO MAKE EXIT STEAM FRACTION
C      (EXITFR) CONTINOUS THE VARIABLE FR IS CREATED WHICH INCORPORATES
C      WTST OF ALL THE SECTORS. IF THE WTST VALUES ARE LARGE NEGATIVE
C      NUMBERS THEN FR-->-1. AS WTST VALUES APPROACH 0 INDICATING STEAM
C      THROUGHOUT THE CONDENSOR THEN FR-->0. FR IS THEN ADDED TO EXITFR
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C       TO MAKE IT CONTINOUS FROM 1-->-1 REFLECTING THE CONDENSOR IN
C       NO STEAM IS EXTRACTED AND THE CONDENSOR WHERE ALL THE TUBES ARE
C       DRY.
C
        DO 430 I=1,ISEC
        IF (PTST(I).GE.0.) PTST(I)=PSAT(NOROWS+1,I)-PTLIM
  430   WTSAV=WTSAV+WTST(I)
        FR=-(SUBFLO)/WSI
        DELPVE=DELPVE/SECFLG
        DO 450 J=1,ISEC
C
        IF (ABS(DELP(J)/DELPVE-1.0)-.01) 450,450,440
  440   IF (ABS(DELPVE).GT.0.001) GO TO 460
  450   CONTINUE
        GO TO 580
  460   CONTINUE
        DLPVES=DELPVE
        CONSM=0.0
        WNCFR=WNCI/(WNCI+WSI)
        DO 470 J=1,ISEC
        CONSM=CCNSM+C(J)
  470   CONTINUE
        DELPVE=(WSAVE*SECFLG)**2/CONSM**2
        DELPVE=(DELPVE+DLPVES)/2.0
        DMAX=ABS(DELPVE-DELP(1))
        JMAX=1
        DO 480 J=2,ISEC
        DHOLD=ABS(DELPVE-DELP(J))
        IF (DHOLD.LE.DMAX) GO TO 480
        DMAX=DHCLD
        JMAX=J
  480   CONTINUE
        WSPT=0.0
        WPT=0.0
        DO 500 J=1,ISEC
        WP(J)=C(J)*SQRT(DELPVE)
        WSP(J)=WP(J)*WSI/(WNCI+WSI)
        IF (J.EQ.JMAX) GO TO 500
        FAC=WSP(J)-WS(1,J)
        AFAC=ABS(FAC)
        IF (AFAC.LT.1.E-3) GO TO 490
        CHGSC=0.5*WS(1,J)**0.26
        IF (IPLCOP.GT.3) CHGSC=CHGSC/IPLOOP*2.0
        WSP(J)=WS(1,J)+FAC/AFAC*SQRT(AFAC)*CHGSC
  490   CONTINUE
        WSPT=WSPT+WSP(J)
        WGAS(J)=WSP(J)*WNCFR
        WP(J)=WSP(J)+WGAS(J)
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      WPT=WPT+WP(J)
500   CONTINUE
      WSP(JMAX)=WSI-WSPT
      WSPT=WSPT+WSP(JMAX)
      WGAS(JMAX)=WSP(JMAX)*WNCFR
      WP(JMAX)=WSP(JMAX)+WGAS(JMAX)
      WPT=WPT+WP(JMAX)
      IPLOOP=IPLOCP+1
C
C     CHECK FOR STEAMM ADJUSTMENTS WHICH TRY TO PUT TO LOW A STEAM
C     VALUE INTO A SECTOR
C
510   IFAIL=0
      DO 520 K=1,ISEC
      COMP=WSI/200.
      IF (WSP(K).LT.COMP) IFAIL=K
      IF (WSP(K).LT.COMP) WRITE (6,999)
999   FORMAT (1X,'STEAM FLOW ADJUSTMENT WAS REQUIRED')
      IF (WSP(K).LT.COMP) GO TO 530
520   CONTINUE
      GO TO 550
530   DIFF=2.*COMP-WSP(IFAIL)
      WSP(IFAIL)=2.*COMP
      ADJ=DIFF/FLOAT(ISEC-1)
      DO 540 J=1,ISEC
      IF (J.EQ.IFAIL) GO TO 540
      WSP(J)=WSP(J)-ADJ
540   CONTINUE
      GO TO 510
550   CONTINCE
C
      DO 560 J=1,ISEC
560   WS(1,J)=WSP(J)
      IF (IPLOOP-50) 20,20,570
570   WRITE (6,1110) IDENT
C
C     INCORPORATE FR INTO EXITFR TO MAKE IT CONTINUOUS FROM 1-->-1
C
580   EXITFR=STMSUM/WSI+FR
      WSEXIT=STMSUM
      VELEXT=VELEXT/SECFLG
C     DELPVE = DELPVE/SECFLG
      PMXEXT=PMXEXT/SECFLG
      TSATEX=TSATFN(PSUM)
      AMLSEX=STMSUM/18.015
      IF ((STMSUM.LE.0.).AND.(PRCCLR.GT.0.)) AMLSEX=1.0/18.015
      EXITFC=1.
      IF (PRCCLR.EQ.0.0) EXITOA=EXITFR
      IF (PRCCLR.EQ.0.0) GO TO 590                                      CON22570
C                                                                       CON22580
C    CALL TO COOLER, IF THERE IS ONE                                    CON22590
C                                                                       CON22600
      ENHIC=ENHI                                                        CON22610
      ENHOC=ENHO                                                        CON22620
      ENHFC=ENHF                                                        CON22630
      SHWINC=SHWINV                                                     CON22640
      TB2C=TB2                                                          CON22650
      WBC=WB                                                            CON22660
      IF (NBAD.GT.0) WCNDAV=SUBAVE/FLOAT(NBAD)                          CON22670
      CALL COCLEX (TBDRYC,WCNDAV,SBFLOC,WSOUT)                          CON22680
C                                                                       CON22690
C     CALCULATE OVERALL POWER REQUIRE TO DRIVE THE COOLANT              CON22700
C                                                                       CON22710
      PHP=PHP*(SMWBC/(SMWBC+SMWB)+1.)                                   CON22720
C                                                                       CON22730
C     CALCULATE THE OVERALL COOLER/CONDENSER VOLUME                     CON22740
      VOL1=(VOL1+VOLC)                                                  CON22750
C                                                                       CON22760
C     CALCULATE OVERALL EXIT FRACTION                                   CON22770
C                                                                       CON22780
      IF ((EXITFR.GT.0.).AND.(EXITFC.GT.0.)) EXITOA=EXITFR*EXITFC       CON22790
      IF ((EXITFR.GT.0.).AND.(EXITFC.GT.0.)) RETURN                     CON22800
C                                                                       CON22810
      EXITOA=WSOUT/WSI+(-(SUBFLO+SBFLOC)/WSI)                           CON22820
C                                                                       CON22830
590   RETURN                                                            CON22840
600   FORMAT (1X,7HSECTOR ,I3,2X,5HROW  ,I4)                            CON22850
610   FORMAT (1H1,37H      *****    OUTPUT FOR SEC-2    *****)          CON22860
620   FORMAT (1H0,10HWSI       ,10HWNCI      )                          CON22870
630   FORMAT (1H0,10HWS(1,I)   ,10HWGAS(I)   )                          CON22880
640   FORMAT (1H0,10HHFG       ,10HAOTFLW(I) )                          CON22890
650   FORMAT (1H0,10HTSAT1     ,10HSTSAT1    )                          CON22900
660   FORMAT (1H0,10HPSAT1     ,10HPMIX1     )                          CON22910
670   FORMAT (1H0,10HAMOLNC    ,10HAMOLSS    ,10HAMOLST    )            CON22920
680   FORMAT (1H0,10HSVNC1     ,10HSVMIX1    )                          CON22930
690   FORMAT (1H0,10HVG1       ,10HG2        )                          CON22940
700   FORMAT (1H ,2F10.3)                                               CON22950
710   FORMAT (1H ,3F10.3)                                               CON22960
720   FORMAT (1H0,10HSECFAR    ,10HARAT      )                          CON22970
730   FORMAT (1H0,10HVEL1      ,5HVEL2 )                                CON22980
740   FORMAT (1H0,10HDELP1     ,5HDELP2)                                CON22990
750   FORMAT (1H ,2F10.4)                                               CON23000
760   FORMAT (1H1,29HOUTPUT FOR SEC-3 -SECTOR NO. ,I2)                  CON23010
770   FORMAT (1H0,36HENTERING PRESSURES IN PSI - MIXTURE=,E10.3,13H SATUCON23020
     1RATION= ,E10.3)                                                   CON23030
780   FORMAT (1H ,21HENTERING STM TEMPS - ,F6.2,4H F  ,F6.2,2H R)       CON23040
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790   FORMAT (1H ,32HENT SP. VOL. IN FT**3/LBM - STM=,E10.3,9H N/C GAS=,CON23050
     1E10.3,9H MIXTURE=,E10.3)                                          CON23060
800   FORMAT (1H ,23HENTERING STM VELOCITY =,E10.3,8H  FT/SEC)          CON23070
810   FORMAT (1H0,33H** OUTPUT FOR SEC-4 - ROW NUMBER ,I4)              CON23080
820   FORMAT (1H0,33HTUBE WALL AREA - SQ.FT. - INSIDE=,E10.3,10H  OUTSIDCON23090
     1E=,E10.3)                                                         CON23100
830   FORMAT (1H ,9HTUBE ID= ,F6.3,30H' FT - TUBE X-SECTIONAL AREA =,E10CON23110
     1.3,6H FT**2)                                                      CON23120
840   FORMAT (1H ,24HLOG MEAN TUBE THICKNESS=,E10.3,25H FT - LOG MEAN TUCON23130
     1BE AREA=,E10.3,6H FT**2)                                          CON23140
850   FORMAT (1H ,30HINVERSE WALL HEAT X-FER COEF =,E10.3,17H HR-FT**2-FCON23150
     1/B  TU)                                                           CON23160
860   FORMAT (1H0,22HIN SECALC, SEC-5, ROW,,I4,9H, SECTOR,,I3)          CON23170
870   FORMAT (1H ,7HALMTD =,E10.3,8H HEFF  =,E10.3)                     CON23180
880   FORMAT (1H ,7HHOMCI =,E10.3,8H HOMCO =,E10.3)                     CON23190
890   FORMAT (1H ,7HRC    =,E10.3,8H ROUT  =,E10.3)                     CON23200
900   FORMAT (1H ,7HSHI   =,E10.3,8H SHN   =,E10.3)                     CON23210
910   FORMAT (1H ,7HTB2   =,E10.3,8H UN    =,E10.3,8H VNRE  =,E10.3)    CON23220
920   FORMAT (1H ,7HWNC   =,E10.3,8H WS    =,E10.3)                     CON23230
930   FORMAT (1H ,7HDELPTP=,E10.3,8H VPSH  =,E10.3)                     CON23240
940   FORMAT (1H ,7HWCND  =,E10.3,8H HFG   =,E10.3)                     CON23250
950   FORMAT (1H ,7HAO    =,E10.3,8H TBNPR =,E10.3)                     CON23260
960   FORMAT (1H0,32HNEG STEAM MASS FLOW IN SEC-6 ROW,I4,10H OF SECTOR,ICON23270
     14)                                                                CON23280
970   FORMAT (1H ,18HCURRENT FLOW RATE=,F12.6,17H  NEXT FLOW RATE=,F12.6CON23290
     1)                                                                 CON23300
980   FORMAT (1H ,8HWTST(I)=,F12.6)                                     CON23310
990   FORMAT (1H0,30HNEGATIVE SAT PRSS IN SEC-6 ROW,I4,9H  SECTOR ,I4)  CON23320
1000  FORMAT (1H ,18HCURRENT SAT PRESS=,E10.3,11H  NEXT ROW=,E10.3)     CON23330
1010  FORMAT (1H ,8HPTST(I)=,E10.3)                                     CON23340
1020  FORMAT (1H ,25HNO PROBLEMS IN SE-6, ROW=,I4,8H SECTOR=,I4)        CON23350
1030  FORMAT (1H0,23HOUTPUT FROM SEC-7, ROW ,I4,11H OF SECTOR ,I4)      CON23360
1040  FORMAT (1H ,9HWS(I,J) =,E10.3,13H  WCND(I,J) =,E10.3)             CON23370
1050  FORMAT (1H ,6HTSAT =,E10.3,14H  STSAT(I,J) =,E10.3)               CON23380
1060  FORMAT (1H ,11HGFLW(I,J) =,E10.3,13H  PSAT(I,J) =,E10.3)          CON23390
1070  FORMAT (1H ,28HSEC-7, BELOW 130, WCND(I,J)=,E10.3,8H  WCNDP=,E10.3CON23400
     1)                                                                 CON23410
1080  FORMAT (1H ,22HSEC-7, BELOW 130, TAL=,E10.3,6H TSAT=,E10.3)       CON23420
1090  FORMAT (1H1,3X,4HWTST,8X,4HPTST/)                                 CON23430
1100  FORMAT (1H ,E10.3,2X,E10.3,2X,E10.3)                              CON23440
1110  FORMAT (1H1,19A4,A3,40HNO CONVERGENCE IN COND. DELTA P (IPLOOP))  CON23450
1120  FORMAT (1H1,19A4,A3/1H0,5X,2HI=,I2,5X,2HJ=,I1/1H0,24HNO CONVERGENCCON23460
     1E FOR WCND(,I2,1H,,I1,1H))                                        CON23470
      END                                                               CON23480
C                                                                       CON23490
C*********************************************************************  CON23500
C*********************************************************************  CON23510
C                                                                       CON23520
```

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      SUBROUTINE HETTRN (ALST,AXO,IR,LJ,CD,WB,SHWINV,STSAT,TID,WNC,WST,A
     1LMTD,ENHF,HEFF,HOMCI,HOMCO,RC,ROUT,SHI,SHNF,STFO,TB2,VNF,XNRE,ENHI
     2,ENHO,SDD)
C--------------
C HET 1
C                      SUBROUTINE HETTRN
C
C          HETTRN CALLED BY: SECALC
C          SUBROUTINES CALLED BY HETTRN:
C                , DSFVTY ,
C          FUNCTION ROUTINES CALLED BY HETTRN:
C                , PSATFN , SMUFN , AMUFN , HFCFN , SKBFN ,
C                , BMUFN , CPFN , ROEFN ,
C
C--------------
C**   DEC 69 REV.    COLBJ,FDAVE
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),END(6),FOUL,PHI,SKW,STBI,S
     1TSAT1,TUBESW,NCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MD
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)
     3,WSI,PFILL
      COMMON /ORC2/ ANT(100,15),STB2ES,VW(100)
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST
      DIMENSION R2(3),E2OK(3)
      HETON=0.
      IF (HETON.NE.1.) GO TO 10
      M5=1
      WRITE (6,310) M5
      WRITE (6,320) IR,LJ
      WRITE (6,330) OD,TID
      WRITE (6,340) SHWINV,STSAT
      WRITE (6,350) WST,WNC
C$------------
C HET 2
C                      DATA INITIALIZATION:
C
C         BB = COOLANT FLOW IN TUBE  LBM/HR-FT**2
C     DGFLM =CALCULATED TEMP DROP ACROSS FILM???
C     DLFLM = CALCULATED TEMP DROP ACROSS LIQUID FILM???
C     HEFF = NONCONDENSIBLE FILM HEAT TRANSFER COEF, BTU/HR-FT**2-F
C     UEST = ESTIMATED OVERALL HEAT TRANSFER COEF
C
C          VALUES FOR USE IN SUBROUTINE DFSVTY
C     E2OK = FORCE CONSTANT FOR NONCOND GAS
C     R2 = GAS COLLISION DIAMETER IN ANGSTROMS
C ZZZ HET-2
C--------------
10    IF (WNC.EQ.0.) DGFLM=0.
      IF ((LJ.EQ.1).AND.(IR.EQ.1)) GO TO 20
      IF (IR.EQ.1) GO TO 30                                             CON24010
      UEST=UESTSV                                                       CON24020
      HEFF=HEFFSV                                                       CON24030
      DGFLM=DGFLMS                                                      CON24040
      DLFLM=DLFLMS                                                      CON24050
      TB2=TB2SV                                                         CON24060
      XNRET=XNRES                                                       CON24070
      GO TO 40                                                          CON24080
   20 IF (IFIRST.EQ.0) GO TO 30                                         CON24090
      HEFF=2100.                                                        CON24100
      DATA UEST,DGFLM,DLFLM,XNRET/700.,0.05,2.0,100000./                CON24110
      DATA R2,E2OK/3.617,3.996,3.838,97.0,190.0,140.75/                 CON24120
      TB2=STB2ES                                                        CON24130
      IFIRST=0                                                          CON24140
      GO TO 40                                                          CON24150
   30 UEST=UEST1                                                        CON24160
      HEFF=HEFF1                                                        CON24170
      DGFLM=DGFLM1                                                      CON24180
      DLFLM=DLFLM1                                                      CON24190
      TB2=TB21                                                          CON24200
      XNRET=XNRE1                                                       CON24210
   40 CONTINUE                                                          CON24220
C                                                                       CON24230
C                                                                       CON24240
C    FDAVE IS AN INPUT ITEM WITH A VALUE BETWEEN 0 AND 1 RELATED TO TUBE CON24250
C    SPACING AND ORIENTATION.                                           CON24260
      FDAVE=C.5                                                         CON24270
C                                                                       CON24280
C                                                                       CON24290
      BNF=ANT(IR,LJ)                                                    CON24300
      IF (BNF.LT.1.) BNF=1.                                             CON24310
      BB=WB/(PI*TID*TID/4.)                                             CON24320
      AI=PI*TID*ALST                                                    CON24330
      AO=PI*CC*ALST                                                     CON24340
      ENHI=1.                                                           CON24350
      ENHF=1.                                                           CON24360
      ENHO=1.                                                           CON24370
      IF (NEI.EQ.0) GO TO 60                                            CON24380
      DO 50 I=1,NEI                                                     CON24390
      ITEM1=NRNI(I)                                                     CON24400
      ITEM2=ITEM1+NETI(I)-1                                             CON24410
   50 IF ((I.GE.ITEM1).AND.(I.LE.ITEM2)) ENHI=ENI(I)                    CON24420
   60 IF (NEE.EQ.0) GO TO 80                                            CON24430
      DO 70 I=1,NEE                                                     CON24440
      ITEM1=NRNE(I)                                                     CON24450
      ITEM2=ITEM1+NETE(I)-1                                             CON24460
      IF (I.LT.ITEM.OR.I.GT.ITEM2) GO TO 70                             CON24470
      EHNO=ENO(I)                                                       CON24480
      ENHF=ENH(I)                                                       CON24490
70    CONTINUE                                                          CON24500
80    CONTINUE                                                          CON24510
      IF (HETCN.NE.1.) GO TO 90                                         CON24520
      M5=2                                                              CON24530
      WRITE (6,310) M5                                                  CON24540
      WRITE (6,360) UEST,HEFF                                           CON24550
      WRITE (6,370) DGFLM,DLFLM                                         CON24560
      WRITE (6,380) TB2,XNRET                                           CON24570
      WRITE (6,390) BNF,AO,AI                                           CON24580
      WRITE (6,400) ENHI,ENHO                                           CON24590
C$-------------                                                         CON24600
C HET 3                                                                 CON24610
C                  CALCULATE SUBPROGRAM INITIAL VALUES                  CON24620
C                                                                       CON24630
C        AMOLSS & AMOLSC ARE MOLECULAR WEIGHTS USED TO CALCULAT         CON24640
C           AMWAV, THE MIXTURE MOLECULAR WEIGHT.                        CON24650
C        AXO = AREA OF TUBE BANK OPEN TO FLOW/TUBE                      CON24660
C        BB = COOLENT FLOW IN TUBE   LB/HR-FT**2                        CON24670
C        GMAX = STEAM-NC FLOW  LB/FT**2-HR                              CON24680
C        HSTO = LATENT HEAT OF VAPORIZATICN OF THE STEAM                CON24690
C        JGAS = INDICATOR FOR TYPE OF N/C GAS PRESENT                   CON24700
C        K = COUNTER FOR NUMBER OF ITERATIONS                           CON24710
C        PSAT = STEAM SATURATION PRESS IN PSI                           CON24720
C        RC = RATIO OF NON-CONDENSIBLES TO TOTAL FLOW                   CON24730
C        RMWNC & RMWSC ARE WEIGHTING FACTORS USED IN DETERMINATION      CON24740
C           OF THE MIXTURE VISCOSITY.                                   CON24750
C        OD = TUBE OUTER DIAMETER                                       CON24760
C        STBAVE = AVERAGE COOLANT TEMP                                  CON24770
C        STBI = INLET COOLANT TEMP                                      CON24780
C        STSAT = LOCAL STEAM SAT TEMP  F                                CON24790
C        STWG = TUBE OUTER WALL TEMP                                    CON24800
C        TB2 = OUTLET COOLANT TEMP                                      CON24810
C        WBOTH = SUM OF WS AND WNC                                      CON24820
C        WNC = NON-CONDENSIBLE FLOW LB(MASS)/HR                         CON24830
C        WST = STM FLCW TO ROW BEING CONSIDERED LB(M)/HR                CON24840
C        XNRE = MIXTURE REYNOLDS NUMBER                                 CON24850
C                                                                       CON24860
C             VALUES CARRIED INTO THIS ROUTINE                          CON24870
C        COMMCN - , AMWNC ,                                             CON24880
C             ORC2 - , AMWNC ,                                          CON24890
C        COMMCN/NEW/ - , STBI , JGAS ,                                  CON24900
C        PASS LIST - , STSAT ,                                          CON24910
C             SEC3 - , STSAT ,                                          CON24920
C        HET2 - , DLFLM , DGFLM , OD , AXO , WST , WNC ,                CON24930
C                                                                       CON24940
C             FUNCTION ROUTINES CALLED IN HET-3                         CON24950
C        , PSATFN , SMUFN , AMUFN , HFGFN ,                             CON24960
```

```
C                                                                       
C ZZZ HET-3
C-------------
90      K=0
        WBOTH=WST+WNC
        RC=WNC/(WBOTH)
        TSAT=STSAT+459.69
        GMAX=(WBOTH)/AXO
        PSAT=PSATFN(TSAT)
        AMOLSS=WST/18.015
        AMOLSC=WNC/AMWNC
        AMOLT=AMOLSS+AMOLSC
        AMWAV=(WBOTH)/AMOLT
        RMWNC=SQRT(AMWNC)*AMOLSC/AMOLT
        RMWSC=4.24444*AMOLSS/AMOLT
        AVIS=(SMUFN(TSAT)*RMWSC+AMUFN(TSAT,JGAS)*RMWNC)/(RMWSC+RMWNC)
        HSTO=HFGFN(STSAT)
        STBAVE=(STBI+TB2)/2.0
        DELFLM=DLFLM
        DLGFLM=DGFLM
        STWO=STSAT-DELFLM-DLGFLM
        STFO=(STSAT+STWO)/2.0
        XNRE=OD*(WBOTH)/(AXO*3600.*AVIS)
        IF (HETCN.NE.1.) GO TO 100
        M5=3
        WRITE (6,310) M5
        WRITE (6,410) GMAX,PSAT
        WRITE (6,420) AMOLSS,AMOLSC,AMOLT
        WRITE (6,430) RMWNC,RMWSC
        WRITE (6,440) AVIS,HSTO,XNRE
        WRITE (6,450) STBAVE,STFO,STWO
        WRITE (6,460) DELFLM,DLGFLM
C$-------------
C HET 5
C                     COLBY J FACTOR CALCULATION AND BRANCH
C
C          WNCI = TOTAL WEIGHT OF NONCOND ENTERING CONDENSER
C                IF NO NONCOND, THEN SKIP DIFUSIVITY CALCULATION.
C
C ZZZ HET-5
C-------------
100     CONTINUE
        COLBJ=EXP(0.53883-0.544*ALOG(XNRE))
        IF (HETCN.NE.1.) GO TO 110
        M5=5
        WRITE (6,310) M5
        WRITE (6,470) COLBJ,WNC
110     IF (WNC.EQ.0.) GO TO 120
```

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C$--------------
C HET 6
C                   PREPARATION FOR CALL TO SUBROUTINE DFSVTY;
C                   CALCULATE SCHMIDT NUMBER AND PARAMETER CJ.
C
C               THIS SECTICN IS BRANCHED ARCUND IF NO NONCOND GASSES ARE
C                   PRESENT.
C
C           AMWAV = STEAM-N/C GAS MIXTURE MOLECULAR WEIGHT
C           AVIS = AVG VISCOSITY OF STEAM-N/C GAS MIXTURE
C           CJ = PARAMETER USED IN CALCULATION OF THE HEAT TRANSFER COEF.
C              SEE EQUATION 11 IN APP B
C           DD = DIFFUSIVITY (SEE NOTE)
C           DDG = DUMMY PASSING PARAMETER FOR SUB DSFVTY
C           E20K = N/C GAS FORCE CONSTANT (SEE SUB DSFVTY)
C           PATM = SAT PRESS IN ATM
C           PGB = NONCOND PARTIAL PRESSURE
C           PSAT = STEAM SATURATION PRESS PSI
C           R = N/C GAS COLLISION DIAMETER (SEE SUB CSFVTY)
C           TSAT = STEAM SATURATION TEMP
C           TSATK = SATURATION TEMP IN DEGREES KELVIN
C           XNSCH = SCHMIDT NUMBER
C
C               NOTE:   PATM, PGB, AND TSATK ARE USED FOR CALL TO DFSVTY
C                       SEE NOTE IN HET-3, BUT REM PGB IS USED AGAIN
C                       IN HET-12.
C
C               NOTE:   18.015 IS THE MOLECULAR WEIGHT OF WATER
C                       2.655 IS THE STEAM COLLISION DIAMETER IN ANGSTROMS
C                       363. IS THE STEAM FORCE CONSTANT USED IN DFSVTY
C
C               NOTE:   ONLY DG (DIFFUSIVITY IN CM**2/SEC) IS MODIFIED IN
C                       SUBROUTINE DFSVTY.
C
C               NOTE:   0.258 CONVERTS UNITS OF DIFUSIVITY FROM
C                       CM**2/SEC TO FT**2/HR, AND 3600 CONVERTS
C                       VISCOSITY  FROM LB(F)-HR TO LB(F)-SEC.
C                       IN XNSCH CALC, .258*3600 = 928.8
C
C ZZZ HET-6
C--------------
      PATM=PSAT/14.7
      PGB=PSAT*(AMOLSC/AMOLSS)
      TSATK=TSAT/1.8
      CALL DFSVTY (TSATK,PATM,18.015,AMWNC,2.655,R2(JGAS),363.,E20K(JGAS
     1),0.,0.,DG,DGG)
      XNSCH=(AVIS*TSAT*10.73/((PSAT+PGB)*AMWAV*DG))*928.8
      CJ=COLBJ*GMAX/(XNSCH**0.066667)                                   CON25930
      IF (HETCN.NE.1.) GO TO 120                                        CON25940
      M5=6                                                              CON25950
      WRITE (6,310) M5                                                  CON25960
C$-------------                                                         CON25970
C HET 7                                                                 CON25980
C                  BEGIN ITERATIVE CALCULATIONS FOR:                    CON25990
C                             HEAT TRANSFER COEF                        CON26000
C                     TEMP DROP ACROSS LIQUID FILM                      CON26010
C                  TEMP DROP ACROSS N/C FILM (IF ANY)                   CON26020
C                                                                       CON26030
C              THE PROGRAM CONTINUES TO RETURN HERE UNTIL ONE           CON26040
C              OR MORE OF THE FOLLOWING CONDITIONS ARE MET:             CON26050
C                  1)  CHANGE IN THE CALCULATED HEAT TRANSFER COEF IS   CON26060
C                     LESS THAN  OF THE PREVICUS VALUE AND AT LEAST     CON26070
C                     FOUR ITERATIONS HAVE BEEN MADE.                   CON26080
C                  2)  CHANGE IN THE CALCULATED TEMP ACROSS THE LIQUID  CON26090
C                     FILM IS LESS THAN .01 DEGREES AND THE CHANGE      CON26100
C                     IN CALCULATED TEMP DIFF ACROSS THE GAS FILM       CON26110
C                     IS LESS THEN .001 DEGREES.                        CON26120
C                  3)  TEN ITERATIONS HAVE BEEN CCMPLETED.              CON26130
C                                                                       CON26140
C       AI = INTERNAL SURFACE AREA OF ONE TUBE  FT**2                   CON26150
C       AO = EXTERNAL SURFACE AREA OF ONE TUBE  FT**2                   CON26160
C       BB = COOLANT FLOW IN TUBE  LBM/HR-FT**2                         CON26170
C       BMU = COOLANT VISCOSITY  LBM/HR-FT                              CON26180
C       BNF = TUBE FLOODING FACTOR                                      CON26190
C       CBI = COOLANT CONCENTRATION                                     CON26200
C       ENHI = INTERNAL FILM COEF ENHANCEMENT FACTOR                    CON26210
C       ENHO = EXTERNAL FILM COEF ENHANCEMENT FACTOR                    CON26220
C       RIN = RESISTANCE TO HEAT TRANSFER DUE INNER FILM                CON26230
C       TID = TUBE ID  FT                                               CON26240
C       OD = TUBE OD  FT                                                CON26250
C       SHBI = SPECIFIC HEAT OF COOLANTBTU/LBM-F                        CON26260
C       SHI = INTERNAL FILM HEAT TRANSFER COEF  BTU/HR-FT**2-F          CON26270
C       SHMK = EXTERNAL FILM HEAT TRANSFER COEF  BTU/HR-FT**2-F         CON26280
C       SKB = THERMAL CONDUCTIVITY OF THE CCOLANT  BTU-FT/HR-FT**2-F    CON26290
C       SKBO = THERMAL CONDUCTIVITY OF OUTER LIQUID FILM                CON26300
C       STBAVE = AVE COOLANT TEMP.                                      CON26310
C       STFO = AVE TEMP OF OUTER LIQUID FILM (SEE NOTE)                 CON26320
C       STSAT = LOCAL SAT STM TEMP                                      CON26330
C       TB2 = OUTLET COOLANT TEMP.  (SEE NOTE ON TB2 IN HET-3)          CON26340
C       WB = COOLANT FLOW RATE PER TUBE  LBM/HR                         CON26350
C       XNREB = REYNOLDS NUMBER OF COOLANT                              CON26360
C       XNPRB = PRANDTL NUMBER OF COOLANT                               CON26370
C                                                                       CON26380
C                  VOTE:SHMK IS CALCULATED FIRST WHTHOUT TAKING FLOODINGCON26390
C                       INTO ACCOUNT.  SEE NUSSELT EQN PG. 16.          CON26400
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C                                                                         CON26410
C                      NOTE: STFO  IS INITIALLY GUESSED BASED ON STWO WHICH  CON26420
C                            IS IN TURN BASED ON DLFLM AND DGFLM.  DGFLM AND  CON26430
C                            DLFLM ARE INITIALIZED BY CATA STATEMENT UPON     CON26440
C                            ENTERING THIS SUBROUTINE.  ALL FOUR OF           CON26450
C                            THESE VARIABLES ARE UPDATED BELOW.               CON26460
C                                                                         CON26470
C                                                                         CON26480
C ZZZ HET-7                                                               CON26490
C--------------                                                           CON26500
120   TB2=STSAT-(STSAT-STBI)/EXP(UEST*AO/(WB*CPFN(CBI,STBAVE)))           CON26510
      STBAVE=(STBI+TB2)/2.                                                CON26520
      SKBO=SKBFN(0.,STFO)                                                 CON26530
      SKB=SKBFN(CBI,STBAVE)                                               CON26540
      BMU=BMUFN(CBI,STBAVE)                                               CON26550
      SHBI=CPFN(CBI,STBAVE)                                               CON26560
      XNREB=TID*BB/BMU                                                    CON26570
      XNPRB=SHBI*BMU/SKB                                                  CON26580
      SHI=0.023*(XNREB)**0.8*XNPRB**0.33333*(SKB/TID)*ENHI                CON26590
      RIN=AO/(SHI*AI)                                                     CON26600
      SHMK=0.725*(SKBO**3*ROEFN(0.0,STFO)**2*HFGFN(STFO)*416975040.0/(BMCON26610
     1UFN(0,STFO)*OD*DELFLM))**.25*ENHO                                   CON26620
C                                                                         CON26630
C  THIS IS THE PLACE TO ENTER CORRECTIONS TO THE EXTERNAL FILM COEFF.THECON26640
C  FOLLOWING IS A CORRECTION ACCORDING TO FUJII, ET. AL, TO ACCOUNT FOR  CON26650
C  THE EFFECTS OF VAPOR SHEAR AT HIGH VAPOR REYNOLDS NUMBERS.             CON26660
C                                                                         CON26670
      SHMK1=SHMK                                                          CON26680
      ANUS=SHMK*OD/SKBO                                                   CON26690
      EMUL=BMUFN(0.,STSAT)                                                CON26700
      EMUS=SMUFN(TSAT)*3600.                                              CON26710
      RHOL=ROEFN(0.,STSAT)                                                CON26720
      RHOS=1./VGFN(TSAT,PSAT)                                             CON26730
      VISRAT=(EMUS/RHOS)/(EMUL/RHOL)                                      CON26740
      RETP=XNRE*VISRAT                                                    CON26750
      TERM=SCRT(RETP)/ANUS                                                CON26760
      IF (TERM.LT..278) GO TO 130                                         CON26770
      ANUSP=1.24*(ANUS**0.8)*(RETP**0.1)                                  CON26780
      GO TO 140                                                           CON26790
130   ANUSP=ANUS*0.70/0.725                                               CON26800
140   SHMKP=ANUSP*SKBO/OD                                                 CON26810
      SHMK=SHMKP                                                          CON26820
C                                                                         CON26830
C                                                                         CON26840
      IF (HETCN.NE.1.) GO TO 150                                          CON26850
      M5=7                                                                CON26860
      WRITE (6,310) M5                                                    CON26870
      WRITE (6,480) TB2,STBAVE                                            CON26880
      WRITE (6,490) SKBO,SKB
      WRITE (6,500) BMU,SHBI
      WRITE (6,510) XNREB,XNPRB
      WRITE (6,520) SHI,RIN,SHMK
C$-------------
C HET 9
C                     TEST FOR TUBE FLOODING, MODIFY
C                          SHMK AS NEEDED
C
C                 THIS SECTION MODIFIES THE EXTERNAL HEAT TRANSFER
C                   COEF GIVEN BY NUSSELT EQN. FOR TUBE FLOODING.
C
C            BNF = CALCULATED TUBE FLOODING FACTOR (SEE NOTE BELOW)
C            FDAVE = INPUT VALUE OF TUBE FLOODING FACTOR (SEE NOTE BELOW)
C            FDAVN & FDAVM ARE INTERMEDIATE VALUES USED LATER.
C            FOUL = TUBE FOULING FACTOR INPUT BY USER
C            RFACT = SUM OF THERMAL RESISTANCES NEGLECTING GAS FILM
C            RIN = RESESTANCE TO HEAT X-FER DUE TO INTERNAL FILM
C            SHNF = EXTERIOR HEAT X-FER COEF, SHMK MODIFIED FOR RAIN
C            SHWINV = INVERSE OF WALL HEAT TRANSFER COEF
C
C                     NOTE:ADD CALC FOR FDAVE     CURRENTLY UNDEF
C
C                     NOTE:CALC FOR FDAVM AND FDAVN SHOULD BE MOVED
C                          ABOVE LINE 40.
C
C
C ZZZ HET-9
C-------------
150   CONTINUE
C
C      INUNDATION EFFECT MAY BE BYPASSED BY SETTING BNF = 1.
C
C     BNF = 1.
      IF (FDAVE.LT.0..OR.BNF.LT.2.) GO TO 160
      FDAVN=0.6*FDAVE+(1.-0.5647*FDAVE)/BNF**.20
      FDAVM=0.6*FDAVE+(1.-0.5647*FDAVE)/(BNF-1.)**.20
      SHNF=SHMK*(BNF*FDAVN-(BNF-1.)*FDAVM)
      GO TO 170
160   SHNF=0.95*(BNF**0.9-(BNF-1.)**0.9)*SHMK
170   RFACT=RIN+SHWINV+FOUL+1./SHNF
      IF (HETCN.NE.1.) GO TO 180
      M5=9
      WRITE (6,310) M5
      WRITE (6,530) FDAVN,FDAVM
      WRITE (6,540) SHNF,RFACT
C$-------------
C HET 10
```

```
C           CONTROL PASSES FROM THIS ROUTINE TO ONE OF TWO PLACES,      CON27850
C           LINE 40 (HET-7) TO START A NEW ITERATION, OR TO             CON27860
C           LINE 170 (HET-13) TO TERMINATE THIS HETTRN CALL             CON27870
C           WHEN ONE OF THE FOLLOWING CRITERIA ARE MET:                 CON27880
C               1) 10 ITERATIONS COMPLETED WITHOUT CONDITION 2 BEING    CON27890
C                  MET.                                                 CON27900
C               2) CHANGE IN HEAT TRANSFER COEF .LT. 1 PERCENT          CON27910
C                  BETWEEN SUCCESSIVE ITERATIONS.                       CON27920
C                                                                       CON27930
C       DELFLM = SAVED VALUE OF DLFLM,USED ONLY FOR PRINT               CON27940
C       DGFLM = TEMP DROP ACROSS GAS FILM, SET TO 0 HERE                CON27950
C       DLFLM = TEMP DROP ACROSS LIQUID CONDENSATE FILM                 CON27960
C       K = COUNTER FOR NUMBER OF ITERATIONS                            CON27970
C       RFACT = SUM OF THERMAL RESISTANCES                              CON27980
C       ROUT = EXTERNAL FILM RESISTANCE. (SEE NOTE)                     CON27990
C       OD = TUBE OD                                                    CON28000
C       SHNF = EXTERNAL FILM HEAT X-FER COEF                            CON28010
C       SKBO = THERMAL CONDUCTIVITY OF EXTERNAL LIQUID FILM             CON28020
C       STCO = TEMP AT SURFACE OF OUTER LIQUID FILM                     CON28030
C       STFO = AVE TEMP OF OUTER LIQUID FILM                            CON28040
C       STBAVE = AVE COOLANT TEMP                                       CON28050
C       STSAT = STEAM SATURATION TEMP                                   CON28060
C       STWO = TUBE OUTER WALL TEMP                                     CON28070
C       UEST = VALUE OF UEST FROM LAST ITERATION                        CON28080
C       UESTS = SAVED VALUE OF UEST, USED ONLY FOR PRINT                CON28090
C       UTEST = TUBE HEAT X-FER COEF.                                   CON28100
C       XNU = NUSSELT NUMBER                                            CON28110
C                                                                       CON28120
C               NOTE:CONSIDER REQUIREMENT FOR MINIMUM OF                CON28130
C                    FOUR ITERATIONS PRIOR TO UPDATING UEST.  COULD     CON28140
C                    BE AN ALLOWANCE FOR DELFLM TO CATCH UP IN          CON28150
C                    CONVERGENCE.  IF SO, TEST DELFLM FOR ITS           CON28160
C                    OWN CONVERGENCE, ELIMINATE MIN OF 4 ITERATIONS.    CON28170
C                                                                       CON28180
C               NOTE:ROUT WILL BE REDEFINED AS 1/ROUT                   CON28190
C                    IN HET-13 PRIOR TO EXIT FROM HETTRN                CON28200
C                                                                       CON28210
C                                                                       CON28220
C ZZZ HET-11                                                            CON28230
C--------------                                                         CON28240
      ROUT=1./SHNF                                                      CON28250
      UTEST=1./RFACT                                                    CON28260
      XNU=SHNF*OD/SKBO                                                  CON28270
      IF (ABS(UEST-UTEST)/UTEST.LT..01) GO TO 290                       CON28280
      UESTSV=UEST                                                       CON28290
      UEST=UTEST                                                        CON28300
      IF (K.GT.4) UEST=0.5*(UTEST+UESTSV)                               CON28310
      STWO=STSAT-(STSAT-STBAVE)*UTEST/SHNF                              CON28320
```

```
C                     CALCULATE LOG-MEAN TEMP-DIFFERENCE
C
C                THIS CALCULATION IS COMPLETED ONCE DURING EACH
C                ITERATION.  UPON COMPLETION, A TEST IS MADE
C                FOR THE PRESENCE OF N/C GASSES.  IF ANY
C                GAS IS PRESENT, PROGRAM BRANCES TO LINE 110 (HET-12).
C                IF NOT, THEN PROGRAM FLOWS TO HET-11, BELOW.
C
C           ALMCT = LMTD
C           HOMCO = TEMP DIFF BETWEEN STEAM AND COOLANT OUTLET
C           HOMCI = TEMP DIFF BETWEEN STEAM AND COOLANT AT INLET
C           JRC = PRINT CONTROL FLAG
C           RODT = RATIO OF HOMCI TO HOMCO
C           STBI = COOLANT INLET TEMP
C           STSAT = STEAM SATURATION TEMP
C           TB2 = COOLANT OUTLET TEMP
C           WNCI = TOTAL N/C GAS FLOW TO CONDENSER
C
C
C ZZZ HET-10
C--------------
180     HOMCI=STSAT-STBI
        HOMCO=STSAT-TB2
C
C       IF (HOMCO.LT.1.E-15) WRITE(6,20600) HOMCI,HCMCO
C       IF (HOMCI.LT.1.E-15) WRITE(6,20600) HOMCI,HOMCO
        IF (HOMCO.LT.1.E-15) HOMCO=1.E-15
C
        RODT=HCMCI/HOMCO
C
C       IF INLET/OUTLET DELTA T RATIO IS NEAR 1.0, ALMTD = ARITH. AVG.
        IF (RODT.GT.1.1) GO TO 190
        ALMTD=0.5*(HOMCI+HOMCO)
        IF (HETCN.EQ.1.) WRITE (6,670) STSAT,STBI,TB2,LJ,IR,II
        GO TO 200
190     ALMTD=(HOMCI-HOMCO)/ALOG(RODT)
200     CONTINUE
        IF (HETCN.NE.1.) GO TO 210
        M5=10
        WRITE (6,310) M5
        WRITE (6,550) HOMCI,HOMCO
        WRITE (6,560) RCDT,ALMTD
210     IF (WNC.NE.0.) GO TO 230
C--------------
C HET 11
C                     CALCULATE FINAL HEAT TRANSFER PARAMETERS
C                     FOR NO N/C GASSES ENTERING THE CONDENSER.
C
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AD-A138 568 MARINE STEAM CONDENSER DESIGN OPTIMIZATION(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA T M BUCKINGHAM DEC 83 3/3

UNCLASSIFIED F/G 13/1 NL

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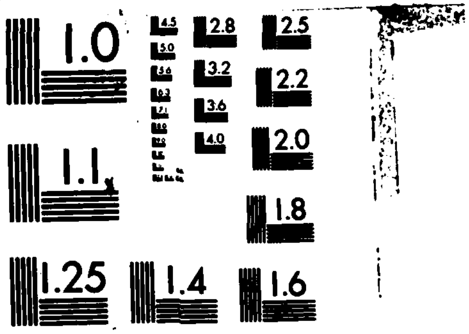
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1.25
1.4
1.6

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      STCO=STSAT                                                        CON28330
      STFO=(STCO+STWO)/2.                                               CON28340
      DGFLM=0.                                                          CON28350
      DLFLM=STCO-STWO                                                   CON28360
      DELFLM=DLFLM                                                      CON28370
      K=K+1                                                             CON28380
      IF (HETCN.NE.1.) GO TO 220                                        CON28390
      M5=11                                                             CON28400
      WRITE (6,310) M5                                                  CON28410
      WRITE (6,570) UTEST,UESTSV                                        CON28420
      WRITE (6,580) XNU,ROUT                                            CON28430
      WRITE (6,590) STWO,STCO,STFO                                      CON28440
      WRITE (6,600) DGFLM,DLFLM                                         CON28450
  220 IF (K.LT.20) GO TO 120                                            CON28460
      WRITE (6,640) UESTSV,UTEST                                        CON28470
      GO TO 290                                                         CON28480
C$-------------                                                         CON28490
C HET 12                                                                CON28500
C                   CALCULATE FINAL HEAT TRANSFER PARAMETERS            CON28510
C                   FOR N/C GASSES ENTERING CONDENSER                   CON28520
C                                                                       CON28530
C              PROGRAM CONTROL COMES HERE FROM HET-10. CONTROL PASSES   CON28540
C              FROM HERE TO ONE OF TWO PLACES, EITHER LINE 40 (HET-7) TO CON28550
C              BEGIN THE NEXT ITERATION, OR TO LINE 170 (HET-13) WHEN   CON28560
C              ONE OF THE FOLLOWING CONDITIONS ARE MET:                 CON28570
C                   1) 10 ITERATIONS HAVE BEEN COMPLETED PRIOR TO MEETINGCON28580
C                      CONDITION 2.                                     CON28590
C                   2) CHANGES IN UEST .LT. .001, IN DLFLM .LT.         CON28600
C                      .01 AND IN DGFLM .LT. .001                       CON28610
C                                                                       CON28620
C         ALMTD = LMTD                                                  CON28630
C         BONE = CONSTANT IN SOLUTION OF EQN 11A, APP A.                CON28640
C         CJ - SEE BONE                                                 CON28650
C         CONE - SEE BONE                                               CON28660
C         DELFLM = DLFLM FROM PREVIOS ITERATION                         CON28670
C         DELTAU = HEAT DUTY ON HEAT X-FER SURFACE                      CON28680
C         DENOM =                                                       CON28690
C         DGFLM = TEMP DIFF ACROSS N/C GAS FILM                         CON28700
C         DLFLM = TEMP DIFF ACROSS CONDENSATE FILM                      CON28710
C         DLGFLM = DGFLM FROM PREVIOS ITERATION                         CON28720
C         DTDP = INVERSE OF DPDT (SEE NOTE)                             CON28730
C         HEFF = N/C GAS HEAT X-FER COEF                                CON28740
C         HSTO = STEAM LATENT HEAT OF VAPORIZATION                      CON28750
C         IBT = PRINT CONTROL                                           CON28760
C         IR = CURRENT ROW NUMBER                                       CON28770
C         K = ITERATION COUNTER                                         CON28780
C         LJ = CURRENT SECTOR NUMBER                                    CON28790
C         PGB = PARTIAL PRESSURE OF N/C GASSES                          CON28800
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C        RFACT = SUM CF THERMAL RESISTANCES NEGLECTING N/C GASSES       CON28810
C        ROUT = EXTERNAL HEAT X-FER COEF                                CON28820
C        OD = TUBE OD                                                   CON28830
C        SHNF = EXTERNAL LIQUID FILM HEAT X-FER COEF                    CON28840
C        SKBO = THERMAL CONDUCTIVITY OF OUTER LIQUID                    CON28850
C        STBAVE = AVG COOLANT TEMP                                      CON28860
C        STCO = TEMP AT SURFACE OF OUTER LIQUID FILM                    CON28870
C        STFC = OUTER LIQUID FILM AVG TEMP                              CON28880
C        STSAT = STM SATURATION TEMP                                    CON28890
C        STWO = TUBE OUTER WALL TEMP                                    CON28900
C        T = AVG LIQUID FILM TEMP IN RANKIN                             CON28910
C        TDIF = TEMP DIFF BETWEEN SAT STM AND AVE COOLANT TEMP          CON28920
C        TSAT = STM SAT TEMP IN RANKIN                                  CON28930
C        UEST & UESTSV - VALUE OF UTEST AND UEST FROM PREVIOS ITERATION CON28940
C        UTEST = OVERALL HEAT X-FER COEF.                               CON28950
C        XNU = NUSSELT NUMBER                                           CON28960
C                                                                       CON28970
C                                                                       CON28980
C ZZZ HET-12                                                            CON28990
C-------------                                                          CON29000
230   CONTINUE                                                          CON29010
      M5=12                                                             CON29020
      IF (HETCN.EQ.1.) WRITE (6,310) M5                                 CON29030
      STCO=STSAT-DLGFLM                                                 CON29040
      T=(TSAT+STCO+459.69)/2.0                                          CON29050
      DTDP=1./(((6452.562+2.*837533.2/T)/T**2)*EXP(14.15012-(6452.562+83CON29060
     17533.2/T)/T))                                                     CON29070
      BONE=-1.*(CJ*HSTO/ALMTD+(PGB*DTDP/ALMTD+1.)/RFACT)                CON29080
      CONE=CJ*HSTO/(ALMTD*RFACT)                                        CON29090
      UTEST=(-SQRT(BONE**2-4.*CONE)-BONE)/2.                            CON29100
      DENOM=1.-UTEST*RFACT                                              CON29110
      IF (DENOM.GT.1.E-7) GO TO 240                                     CON29120
      HEFF=1.0E8                                                        CON29130
      GO TO 250                                                         CON29140
240   HEFF=UTEST/DENOM                                                  CON29150
250   CONTINUE                                                          CON29160
      ROUT=(HEFF+SHNF)/(HEFF*SHNF)                                      CON29170
      TDIF=STSAT-STBAVE                                                 CON29180
      IF (TDIF.GT.0) GO TO 260                                          CON29190
      IF (IBT.EQ.0) WRITE (6,660) STSAT,STBAVE,LJ,IR                    CON29200
      IBT=1                                                             CON29210
      TDIF=.1                                                           CON29220
260   CONTINUE                                                          CON29230
      DELTAU=TDIF*UTEST                                                 CON29240
      DGFLM=DELTAU/HEFF                                                 CON29250
      DLFLM=DELTAU/SHNF                                                 CON29260
      STCO=STSAT-DGFLM                                                  CON29270
      STWO=STCO-DLFLM                                                   CON29280
      STFO=(STCO+STWO)/2.
      XNU=OD/(SKBO*ROUT)
      IF (ABS(UTEST-UEST)/UTEST.LT..001) GO TC 270
      IF (HETCN.EQ.1.) WRITE (6,610) K
      DELFLM=DLFLM
      DLGFLM=DGFLM
      UESTSV=UEST
      UEST=UTEST
      K=K+1
      IF (K.GT.4) UEST=0.5*(UTEST+UESTSV)
      IF (K.LT.10) GO TO 120
      IF (HETCN.EQ.1.) WRITE (6,640) UESTSV,UTEST
      GO TO 290
270   IF (ABS(DELFLM-DLFLM).LT..01) GO TO 280
      IF (HETCN.EQ.1.) WRITE (6,620) K
      DELFLM=DLFLM
      DLGFLM=DGFLM
      K=K+1
      IF (K.LT.10) GO TO 120
      WRITE (6,650) DELFLM,LJ,IR
280   IF (ABS(DLGFLM-DGFLM).LT..001) GO TO 290
      DLGFLM=DGFLM
      K=K+1
      IF (K.LT.20) GO TO 120
      WRITE (6,630) DLGFLM,UEST,UTEST,LJ,IR
C$-------------
C HET 13
C                   FINAL CALCULATIONS; EXIT HETTRN
C
C        HEFF = SEE XHEFF
C        TB2 = TUBE OUTLET TEMP
C        VNF = OVERAL HEAT X-FER COEF
C        VPSHH = OUTLET COOLANT TEMP
C        XHEFF = N/C GAS FILM HEAT X-FER COEF
C
C                   NOTE:HERE VALUES OF HEFF, UEST, AND TB2 ARE PASSED
C                        OUT OF HETTRN AND SAVED, BUT NOT RE-USED
C                        TO START NEXT ITERATICN.  SEE NOTES IN
C                        HET-2 AND HET-3.
C
C ZZZ HET-13
C-------------
      M5=13
      WRITE (6,310) M5
290   VNF=UTEST
      ROUT=1./ROUT
      IF (IR.GT.1) GO TO 300
      UEST1=UEST
      HEFF1=HEFF
      DLFLM1=CLFLM
      DGFLM1=DGFLM
      TB21=TB2
      XNRE1=XNRE
300   CONTINUE
      UESTSV=UEST
      HEFSV=HEFF
      DGFLMS=DGFLM
      DLFLMS=CLFLM
      TB2SV=TB2
      XNRESV=XNRE
      RETURN
C$     TOP OF PAGE CHARACTOR FOR USE WITH $PRT
310   FORMAT (1H0,17HIN HETTERN   -HET,I2)
320   FORMAT (1H ,4HRGW=,I4,10H  SECTOR =,I4)
330   FORMAT (1H ,3HOD=,F6.4,6H  TID=,F6.4)
340   FORMAT (1H ,7HSHWINV=,E10.3,8H  STSAT=,E10.3)
350   FORMAT (1H ,4HWST=,F8.2,6H  WNC=,F8.2)
360   FORMAT (1H ,5HUEST=,E10.3,7H  HEFF=,E10.3)
370   FORMAT (1H ,6HDGFLM=,E10.3,8H  DLFLM=,E10.3)
380   FORMAT (1H ,4HTB2=,E10.3,8H  XNRET=,E10.3)
390   FORMAT (1H ,4HBNF=,E10.3,5H  AO=,E10.3,5H  AI=,E10.3)
400   FORMAT (1H ,5HEHNI=,E10.3,7H  EHNO=,E10.3)
410   FORMAT (1H ,5HGMAX=,E10.3,7H  PSAT=,E10.3)
420   FORMAT (1H ,7HAMOLSS=,E10.3,9H  AMOLSC=,E10.3,8H  AMOLT=,E10.3)
430   FORMAT (1H ,6HRMWNC=,E10.3,8H  RMWSC=,E10.3)
440   FORMAT (1H ,5HAVIS=,E10.3,7H  HSTO=,E10.3,7H  XNRE=,E10.3)
450   FORMAT (1H ,7HSTBAVE=,E10.3,7H  STFC=,E10.3,7H  STWC=,E10.3)
460   FORMAT (1H ,7HDELFLM=,E10.3,9H  DLGFLM=,E10.3)
470   FORMAT (1H ,6HCOLBJ=,E10.3,6H  WNC=,E10.3)
480   FORMAT (1H ,4HTB2=,E10.3,9H  STBAVE=,E10.3)
490   FORMAT (1h ,5HSKBO=,E10.3,6H  SKB=,E10.3)
500   FORMAT (1H ,4HBMU=,E10.3,7H  SHBI=,E10.3)
510   FORMAT (1H ,6HXNREB=,E10.3,8H  XNPRB=,E10.3)
520   FORMAT (1H ,4HSHI=,E10.3,6H  RIN=,E10.3,5HSHMK=,E10.3)
530   FORMAT (1H ,6HFDAVN=,E10.3,8H  FDAVM=,E10.3)
540   FORMAT (1H ,5HSHNF=,E10.3,8H  RFACT=,E10.3)
550   FORMAT (1H ,6HHOMCI=,E10.3,8H  HOMCO=,E10.3)
560   FORMAT (1H ,5HRODT=,E10.3,8H  ALMTD=,E10.3)
570   FORMAT (1H ,6HUTEST=,E10.3,8H  ESTSV=,E10.3)
580   FORMAT (1H ,4HXNU=,E10.3,7H  ROUT=,E10.3)
590   FORMAT (1H ,5HSTWO=,E10.3,7H  STCO=,E10.3,7h  STFO=,E10.3)
600   FORMAT (1H ,6HDGFLM=,E10.3,8H  DLFLM=,E10.3)
610   FORMAT (1H ,50HCONVERGENCE NOT YET ACHIEVED ON UEST IN HET-12, K=,
     1I4)
620   FORMAT (1H ,52HCONVERGENCE NOT YET ACHIEVED ON DELFLM IN HET-12, K
     1=, I4)
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630   FORMAT (1H0,36H NO CONVERGENCE IN FILM TEMPERATURES,8H DLGFLM=,E12CON30250
     1.5,7H UEST =,E12.5,8H UTEST =,E12.5/10H SECTOR = ,I5,5H ROW=,I5)   CON30260
640   FORMAT (1H0,32H NO CONVERGENCE IN UESY, UEST = ,E12.5,9H UTEST = ,CON30270
     1E12.5)                                                             CON30280
650   FORMAT (1H0,34H NO CONVERGENCE IN DELFLM, DELFLM=,E12.5,8H SECTOR=CON30290
     1,I5,5H ROW=,I5)                                                    CON30300
660   FORMAT (1H0,53H  SAT STEAM TEMP LESS THAN AVG BRINE TEMP,    STSATCON30310
     1 =,E12.5,10H STBAVE = ,E12.5,9H    SECTOR,I3,6H   ROW,I4)         CON30320
670   FORMAT (1H0,47H INPET/OUTLET DELTA T RATIO IS NEAR 1.0, STSAT=,E13CON30330
     1.6,7H  STBI=,E13.6,6H  TB2=,E13.6,8H  SECTOR,I3,5H  ROW,2I5)       CON30340
      END                                                                CON30350
C                                                                        CON30360
C**************************************************************          CON30370
C**************************************************************          CON30380
C                                                                        CON30390
      SUBROUTINE COOLEX (TBDRYC,WCNDAV,SBFLOC,WSOUT)                     CON30400
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,CON30410
     1RADINS,REWI,REWO,SODI,SODO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNCTOCON30420
     2T,BNDRAC,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR                       CON30430
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON30440
     1TSAT1,TUBESW,WNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON30450
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON30460
     3,WSI,PFILL                                                         CON30470
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMDOT(10CON30480
     10)                                                                 CON30490
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNC,VEL2,FR               CON30500
      COMMON /OUTC/ EXITFC,EXITFR,HTCLR,AOC,SUMQC,SDIC,SDOC,UBARW,SMWBC,CON30510
     1SMTBIC,SMTB2C,VWBAR,STSATX,PMIX1,AOT,BUNWT,AVTBI,AVTB2,WTSTC,VOLC CON30520
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST                          CON30530
      COMMON /COOL1/ VELC(100),PMIXC(100),PSATC(100),STSATC(100),WSC(100CON30540
     1),ALMTDC(100),SHIC(100),SHNFC(100),RCC(100),ROUTC(100),VNREC(100),CON30550
     2VPSHHC(100),HEFFC(100),UNC(100),WCNDC(100),GFLOWC(100),QOAC(100),CCON30560
     3UMDPC(100)                                                         CON30570
      COMMON /COOL/ IVNOC,HNOC,TNOC,TSATEX,PMXEXT,AMLSEX,WSEXIT,VELEXT,TCON30580
     1B2C,ENHIC,ENHOC,ENHFC,SHWINC,WBC                                   CON30590
      DIMENSICN R2(3),E2OK(3),VPSHC(100)                                 CON30600
      DATA HEFF,UEST,DGFLM,DLFLM/2100.,700.,0.05,2.0/                    CON30610
      DATA R2,E2OK/3.617,3.996,3.838,97.0,109.0,140.75/                  CON30620
C                                                                        CON30630
C              ***VARIABLES USED IN COOLER***                            CON30640
C                                                                        CON30650
C                                                                        CON30660
C        ALMTCC = LMTD FOR A ROW IN COOLER                               CON30670
C        AOC = OUTER SURFACE AREA OF A TUBE  FT**2                       CON30680
C        AHOLES = THE X-SECTIONAL AREA OCCUPIED BY THE TUBES             CON30690
C        AXOC = AREA OPEN TO FLOW IN A ROW OF TUBES  FT**2               CON30700
C        AMWNC = MOLECULAR WEIGHT OF N/C GASSES                          CON30710
C        DELPC = PRESSURE DROP ACROSS COOLER                             CON30720
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C      DELPCT = PRESSURE LOSS AT COOLER DUE TO VELOCITY CHANGE        CON30730
C      DELTPC = PRESS DROP ACROSS A ROW OF TUBES  PSI                 CON30740
C      HEFFC = N/C GAS FILM HEAT TRANSFER COEF                        CON30750
C      HFG = STEAM LATENT HEAT OF VAPORIZATION  BTU/LBM               CON30760
C      HTCLR = THE HEIGHT OF THE COOLER                               CON30770
C      IHNOC = THE NUMBER OF HORIZONTAL TUBES IN THE COOLER           CON30780
C      IVNOC = THE NUMBER OF VERTICAL TUBES IN THE COOLER             CON30790
C      PAL = SAME AS PSAT                                             CON30800
C      PMIX1 = PRESS OF STM - N/C MIXTURE ENERING COND   PSIA         CON30810
C      PSATC = SATURATED STEAM PRESS                                  CON30820
C      PTLIM = LOWEST SATURATION PRESSURE THE STEAM CAN GO BEFORE THE CON30830
C         CORRESPONDING SATURATION TEMPERATURE FALLS BELOW INLET      CON30840
C         COOLANT TEMPERATURE. THE RESULT IS 0 HEAT TRANSFER          CON30850
C      RCC = RATIO OF N/C GAS TO STM AT ONE ROW OF TUBES              CON30860
C      ROUTC = EXTERNAL HEAT TRANSFER COEF                            CON30870
C      SDDC = COOLER TUBE PITCH                                       CON30880
C      SDO = TUBE OD  FT                                              CON30890
C      SHIC = INTERNAL TUBE FILM HEAT TRANSFER COEF.                  CON30900
C      SHNFC = EXTERNAL TUBE FILM HEAT TRANSFER COEF                  CON30910
C      SMTB1C = ROW BY ROW SUM OF (COOLANT INLET TEMP * FLOW RATE)    CON30920
C      SMWBC = ROW BY ROW SUM OF COOLANT FLOW                         CON30930
C      SMTB2C = ROW BY ROW SUM OF (COOLANT OUTLET TEMP * FLOW RATE)   CON30940
C      SUMQC = ROW BY ROW SUM OF HEAT DUTY ON TUBES                   CON30950
C      SVMXEX = ENTERING MIXTURE SPECIFIC VOL  FT**3/LBM              CON30960
C      SVNCEX = ENTERING N/C GAS SPECIFIC VOL  FT**3/LBM              CON30970
C      STSATC = STAT STEAM TEMP AT A GIVEN ROW F                      CON30980
C      STSATC = STEAM SATURATION TEMP  F                              CON30990
C      STFO = AVE TEMP OF OUTER TUBE FILM                             CON31000
C      TAL = SATURATED STEAM TEMP  R                                  CON31010
C      TNOC = THE NUMBER OF TUBES IN THE COOLER                       CON31020
C      TSAREA = TUBE SHEET AREA                                       CON31030
C      UNC = OVERALL HEAT TRANSFER COEF FOR ONE ROW OF TUBES IN COOLERCON31040
C      VG = SPECIFIC VOLUME OF STEAM FT**3/LB                         CON31050
C      VMIX = SPECIFIC VOLUME OF STEAM AND N/C GASSES IN MIXTURE      CON31060
C      VNREC = REYNOLDS NUMBER ON VAPOR SIDE AT A ROW IN COOLER       CON31070
C      VNC = SPECIFIC VOLUME OF N/C GAS FT**3/LB                      CON31080
C      VOLC = COOLER VOLUME                                           CON31090
C      VPSHHC = OUTLET COOLANT TEMP  F                                CON31100
C      WCNDC = CONDENSATE FROM ONE ROW OF TUBES IN COOLER  LBM/HR     CON31110
C      WS = STEAM FLOW TO A ROW OF TUBES IN A SECTOR LB/HR            CON31120
C      WSC = STEAM FLOW TO A ROW OF COOLER   LBM/HR                   CON31130
C      WNCC = N/C FLOW TO A ROW OF COOLER   LBM/HR                    CON31140
C      WSEXIT = TOTAL STM FLOW TO COOLER LBM/HR                       CON31150
C                                                                     CON31160
      WNCC=WNCIR                                                      CON31170
      SDOC=ODII/12.                                                   CON31180
      SDO=SDOC                                                        CON31190
      SDOMIN=SDOC                                                     CON31200
      TB2=TB2C                                                          CON31210
      AOC=PI*ALST*SDO                                                   CON31220
      AO=AOC                                                            CON31230
      WB=WBC                                                            CON31240
      FDAVE=0.5                                                         CON31250
      SDIC=SIC(NOROWS)                                                  CON31260
      SDI=SDIC                                                          CON31270
      AI=PI*ALST*SDI                                                    CON31280
      SHWINV=SHWINC                                                     CON31290
      ENHI=ENHIC                                                        CON31300
      ENHO=ENHOC                                                        CON31310
      ENHF=ENHFC                                                        CON31320
      STBIR=STBI+459.69                                                 CON31330
      PTLIM=PSATFN(STBIR)                                               CON31340
      SMTBIC=0.0                                                        CON31350
      SMWBC=0.0                                                         CON31360
      SMTB2C=0.0                                                        CON31370
      SUMQC=0.0                                                         CON31380
      WTSTC=0.                                                          CON31390
      IROWC=0                                                           CON31400
      WSOUT=0.                                                          CON31410
      SBFLOC=0.                                                         CON31420
      SBRATC=0.                                                         CON31430
      TBDRYC=0.                                                         CON31440
      AMLSCC=WNCC/AMWNC                                                 CON31450
      AXOC=SDC*HNOC*ALST*(SDDMIN-1.0)                                   CON31460
      SVGEXT=VGFN(TSATEX,PMXEXT)                                        CON31470
      SVNCEX=10.729*TSATEX/(AMWNC*(PMXEXT))                             CON31480
      AMLT=AMLSEX+AMLSCC                                                CON31490
      SVMXEX=1.0/(AMLSEX/(AMLT*SVGEXT)+AMLSCC/(AMLT*SVNCEX))            CON31500
      VELC(1)=(WSEXIT+WNCC)*SVMXEX/(AXOC*3600.0)                        CON31510
C                                                                       CON31520
      VLCMAX=VELC(1)                                                    CON31530
      G2=288.0*SG*SVMXEX                                                CON31540
      IF (VELC(1)-VELEXT) 10,10,20                                      CON31550
10    A2DAI=VELC(1)/VELEXT                                              CON31560
      DELPCT=((1.0-A2DAI)*VELEXT**2)/G2                                 CON31570
      GO TO 50                                                          CON31580
20    A2DAI=VELEXT/VELC(1)                                              CON31590
      IF (A2DAI-0.715) 40,40,30                                         CON31600
30    DELPCT=(0.75*(1.0-A2DAI)*VELC(1)**2)/G2                           CON31610
      GO TO 50                                                          CON31620
40    DELPCT=(0.4*(1.25-A2DAI)*VELC(1)**2)/G2                           CON31630
50    PMIXC(1)=PMXEXT-DELPCT-(VELC(1)**2-VELEXT**2)/G2                  CON31640
      PSATC(1)=PMIXC(1)*AMLSEX/(AMLSEX+AMLSCC)                          CON31650
C                                                                       CON31660
C     RECALCULATE THE AREA RATIO (THE RATIO OF TUBE X-SECTIONAL         CON31670
C     AREA TO TTUBE SHEET AREA) TO INCLUDE THE COCLER                   CON31680
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C
      SECFLG=FLOAT(ISEC)
      TSAREA=PI*(BNDRAD**2)*SECFLG*SECWID/360.
      AHOLES=ARATIO*TSAREA
      AHOLES=AHOLES+(PI*SDO**2)*TNOC/4.
      TSAREA=TSAREA+HTCLR*HNOC*SDDC*SDOC
      ARATIO=AHOLES/TSAREA
C
C     CALCULATE THE CCOLER VOLUME
C
      VOLC=HTCLR*SDDC*SDOC*HNOC*ALST
C
C    CHECK TO SEE IF INITIAL PRESSURE LOSSES DROP THE PRESSURE
C    BELOW PTLIM
C
      IF (PSATC(1).GT.PTLIM) GO TO 80
      SUMOC=0.
      NRWSP4=IVNOC+1
      CONS1A=PTLIM/FLOAT(NRWSP4)
      CONS1B=PMXEXT/FLOAT(NRWSP4)
      CUMDPC(1)=PMIX1-PMXEXT
      PSATC(1)=PTLIM
      PMIXC(1)=PMXEXT
      QOAC(1)=0.
      DELPC=PMXEXT
      UNC(1)=700.
      WSC(1)=WSEXIT
      WCNDC(1)=0.
C
      DO 60 M=2,NRWSP4
      WSC(M)=WSEXIT
      WCNDC(M)=0.
      PMIXC(M)=PMIXC(M-1)-CONS1B
      PSATC(M)=PSATC(M-1)-CONS1A
      CUMDPC(M)=PMIX1-PMIXC(M)
60    CONTINUE
C
      DO 70 M=2,IVNOC
      UNC(M)=700.
      QOAC(M)=0.
      ALMTDC(M)=0.
70    CONTINUE
      SMWBC=SMWBC+WB*TNOC
      SMTBIC=WB*TNOC*STBI
      SMTB2C=SMTBIC
      EXITFC=1.
      RETURN
C
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80    PAL=PSATC(1)                                                      CON32170
      TAL=TSATFN(PAL)                                                   CON32180
      STSATC(1)=TAL-459.69                                              CON32190
      WSC(1)=WSEXIT                                                     CON32200
C                                                                       CON32210
C    CHECK TO SEE IF INLET STEAM TO COOLER IS 0                         CON32220
C                                                                       CON32230
      IF (WSC(1).GT.1.) GO TO 90                                        CON32240
C                                                                       CON32250
C    ENTER DUMMY VALUES IN COOLER VARIABLES                             CON32260
C    CREATE NEGATIVE FLOW PARAMETER FOR USE IN COMPUTING EXITFRC        CON32270
C                                                                       CON32280
      TBDRYC=TNOC                                                       CON32290
      SBRATC=WCNDAV                                                     CON32300
      SBFLOC=SBRATC*TBDRYC                                              CON32310
C                                                                       CON32320
C                                                                       CON32330
      WSC(1)=1.                                                         CON32340
      IROWC=3                                                           CON32350
C                                                                       CON32360
90    VG=VGFN(TAL,PMIXC(1))                                             CON32370
      AMLSSC=WSC(1)/18.015                                              CON32380
      VNC=10.729*TAL/(AMWNC*PMIXC(1))                                   CON32390
      VMIX=1.0/((AMLSSC/(VG*(AMLSSC+AMLSCC)))+(AMLSCC/(VNC*(AMLSSC+AMLSCCON32400
     1C))))                                                             CON32410
      VELC(1)=(WSC(1)+WNCC)*VMIX/(AXOC*3600.0)                          CON32420
      NFC=(VNCC+1.)/2.0                                                 CON32430
      ANFC=NFC                                                          CON32440
      IDT=0                                                             CON32450
      JRC=0                                                             CON32460
      IBT=0                                                             CON32470
      DO 450 IK=1,IVNOC                                                 CON32480
      I=IK                                                              CON32490
      LJ=7                                                              CON32500
C                                                                       CON32510
C     ROW BY ROW CALCULATION A LA HETTRN                                CON32520
C                                                                       CON32530
      STSAT=STSATC(I)                                                   CON32540
      ANF=ANFC                                                          CON32550
      WS=WSC(I)                                                         CON32560
      WNC=WNCC                                                          CON32570
      AXO=AXOC                                                          CON32580
      IR=I                                                              CON32590
C     DATA HEFF,UEST,DGFLM,DLFLM/2100.,700.,0.05,2.0/                   CON32600
C     DATA R2,E20K / 3.617,3.996,3.838,97.0,109.0,140.75/               CON32610
      DATA R2/3.617,3.996,3.838/                                        CON32620
      K=0                                                               CON32630
      RC=WNC/(WS+WNC)                                                   CON32640
      TSAT=STSAT+459.69                                                 CON32650
      GMAX=(WS+WNC)/AXO                                                 CON32660
      PSAT=PSATFN(TSAT)                                                 CON32670
      AMOLSS=WS/18.015                                                  CON32680
      AMOLSC=WNC/AMWNC                                                  CON32690
      AMOLT=AMOLSS+AMOLSC                                               CON32700
      AMWAV=(WS+WNC)/AMOLT                                              CON32710
      RMWNC=SQRT(AMWNC)*AMOLSC/AMOLT                                    CON32720
      RMWSC=4.24444*AMOLSS/AMOLT                                        CON32730
      AVIS=(SMUFN(TSAT)*RMWSC+AMUFN(TSAT,JGAS)*RMWNC)/(RMWSC+RMWNC)     CON32740
      HSTO=HFGFN(STSAT)                                                 CON32750
      BB=WB/(PI*SDI*SDI/4.)                                             CON32760
      STBAVE=(STBI+TB2)/2.0                                             CON32770
      DELFLM=DLFLM                                                      CON32780
      DLGFLM=DGFLM                                                      CON32790
      STWO=STSAT-DELFLM-DLGFLM                                          CON32800
      STFO=(STSAT+STWO)/2.0                                             CON32810
      XNRE=SDO*(WS+WNC)/(AXO*3600.*AVIS)                                CON32820
      IF (XNRE.GE.100.) GO TO 100                                       CON32830
100   CONTINUE                                                          CON32840
      COLBJ=EXP(0.53883-0.544*ALOG(XNRE))                               CON32850
      IF (WNCIR.EQ.0.) GO TO 110                                        CON32860
      PATM=PSAT/14.7                                                    CON32870
      PGB=PSAT*(AMOLSC/AMOLSS)                                          CON32880
      TSATK=TSAT/1.8                                                    CON32890
      CALL DFSVTY (TSATK,PATM,18.015,AMWNC,2.655,R2(JGAS),363.,E2OK(JGASCON32900
     1),0.,0.,DG,DGG)                                                   CON32910
C*****                                                                  CON32920
C  0.256 CONVERTS CM2/S TO FT2/HR AND 3600. CONVERTS VISCOSITY TO       CON32930
C  LB/F-HR FRCM LB-F-S.          0.258 * 3600.  = 928.8                 CON32940
C*****                                                                  CON32950
      XNSCH=(AVIS*TSAT*10.73/((PSAT+PGB)*AMWAV*DG))*928.8               CON32960
      CJ=COLBJ*GMAX/(XNSCH**0.666667)                                   CON32970
110   TB2=STSAT-(STSAT-STBI)/EXP(UEST*AO/(WB*CPFN(CBI,STBAVE)))         CON32980
      STBAVE=(STBI+TB2)/2.                                              CON32990
      SKBO=SKBFN(0.,STFO)                                               CON33000
      SKB=SKBFN(CBI,STBAVE)                                             CON33010
      BMU=BMUFN(CBI,STBAVE)                                             CON33020
      SHBI=CPFN(CBI,STBAVE)                                             CON33030
      XNREB=SDI*BB/BMU                                                  CON33040
      XNPRB=SHBI*BMU/SKB                                                CON33050
      SHI=0.023*(XNREB)**0.8*XNPRB**0.33333*(SKB/SDI)*ENHI              CON33060
      RIN=AO/(SHI*AI)                                                   CON33070
      BNF=ANF                                                           CON33080
      IF (ANF.LE.1.0) BNF=1.0                                           CON33090
      SHMK=0.725*(SKBO**3*ROEFN(0.0,STFO)**2*HFGFN(STFO)*416975040.0/(BMCON33100
     1UFN(0,STFO)*SDO*DELFLM))**.25*ENHO                                CON33110
C                                                                       CON33120
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C THIS IS THE PLACE TO ENTER CORRECTIONS TO EXTERNAL FILM COEFFICIENT
C FOLLOWING IS A CORRECTION ACCORDING TO FUJII, ET. AL, TO ACCOUNT FOR
C EFFECTS OF VAPOR SHEAR AT HIGH VAPOR REYNOLDS NUMBERS
C
      SHMK1=SHMK
      ANUS=SHMK*SDO/SKBO
      EMUL=BMUFN(0.,STSAT)
      EMUS=SMUFN(TSAT)*3600.
      RHOL=RCEFN(0.,STSAT)
      RHOS=1./VGFN(TSAT,PSAT)
      VISRAT=(EMUS/RHOS)/(EMUL/RHOL)
      RETP=XNRE*VISRAT
C
      IF (RETP.LT.0.) RETP=0.
      IF (RETP.LT.0.) GO TO 120
C
120   TERM=SQRT(RETP)/ANUS
      IF (TERM.LT..278) GO TO 130
      ANUSP=1.24*(ANUS**0.8)*(RETP**0.1)
      GO TO 140
130   ANUSP=ANUS*0.70/0.725
140   SHMKP=ANUSP*SKBC/SDO
      SHMK=SHMKP
C
C
C#######################################################################
C#                                                                     #
C#         IF HO > 40,000                                              #
C#                                                                     #
C#######################################################################
C     IF (SHMK .GT. 40000.)   GO TO 49
C     IF (SHMK.LT.40000..AND.DELFLM.GT..0001) GO TO 49
C  49 CONTINUE
C
C       INUNDATION EFFECT MAY BE BYPASSED BY SETTING BNF = 1.
C
C     BNF = 1.
      IF (FDAVE.LT.0..OR.BNF.LT.2.) GO TO 150
      FDAVN=0.6*FDAVE+(1.-0.5647*FDAVE)/BNF**.20
      FDAVM=0.6*FDAVE+(1.-0.5647*FDAVE)/(BNF-1)**.20
      SHNF=SHMK*(BNF*FDAVN-(BNF-1.)*FDAVM)
      GO TO 160
150   SHNF=0.95*(BNF**0.9-(BNF-1.)**0.9)*SHMK
C
160   RFACT=RIN+SHWINV+FOUL+1./SHNF
C
C     COMPUTE LOG MEAN DELTA TEMP., ALMTD
C
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C*****                                                                  CON33610
      HOMCI=STSAT-STBI                                                  CON33620
      HIMCO=STSAT-TB2                                                   CON33630
C                                                                       CON33640
C     IF (HIMCO.LT.1.E-15) WRITE (6,530) HOMCI,HIMCU,LJ,IR              CON33650
      IF (HIMCO.LT.1.E-15) HIMCO=1.E-15                                 CON33660
C                                                                       CON33670
      RODT=HCMCI/HIMCO                                                  CON33680
C                                                                       CON33690
C     IF INLET/OUTLET DELTA T RATIO IS NEAR 1.0, ALMTD = ARITH AVE      CON33700
      IF (RODT.GT.1.1) GO TO 170                                        CON33710
      ALMTD=0.5*(HOMCI+HIMCO)                                           CON33720
C     IF (JRC.EQ.0) WRITE (6,540) STSAT,STBI,TB2,LJ,IR                  CON33730
      JRC=1                                                             CON33740
      GO TO 180                                                         CON33750
170   ALMTD=(HOMCI-HIMCO)/ALCG(RODT)                                    CON33760
180   CONTINUE                                                          CON33770
      IF (WNCIR.NE.0.) GO TO 190                                        CON33780
      ROUT=1./SHNF                                                      CON33790
      UTEST=1./RFACT                                                    CON33800
      XNU=SHNF*SDO/SKBO                                                 CON33810
      IF (ABS(UEST-UTEST)/UTEST.LT..001) GO TC 280                      CON33820
      UESTSV=UEST                                                       CON33830
      UEST=UTEST                                                        CON33840
      IF (K.GT.4) UEST=0.5*(UTEST+UESTSV)                               CON33850
      STWO=STSAT-(STSAT-STBAVE)*UTEST/SHNF                              CON33860
      STCO=STSAT                                                        CON33870
      STFO=(STCO+STWO)/2.                                               CON33880
      DGFLM=0.                                                          CON33890
      DLFLM=STCO-STWO                                                   CON33900
      DELFLM=DLFLM                                                      CON33910
      K=K+1                                                             CON33920
      IF (K.LT.20) GO TO 110                                            CON33930
      WRITE (6,510) UESTSV,UTEST                                        CON33940
      GO TO 280                                                         CON33950
190   CONTINUE                                                          CON33960
      STCO=STSAT-DLGFLM                                                 CON33970
      T=(TSAT+STCO+459.69)/2.0                                          CON33980
      DTDP=1./((((6452.562+2.*837533.2/T)/T**2)*EXP(14.15012-(6452.562+83CON33990
     17533.2/T)/T))                                                     CON34000
      BONE=-1.*(CJ*HSTO/ALMTD+(PGB*DTDP/ALMTD+1.)/RFACT)                CON34010
      CONE=CJ*HSTO/(ALMTD*RFACT)                                        CON34020
      TTERM1=BONE**2                                                    CON34030
      TTERM2=4.*CONE                                                    CON34040
      TTERM=TTERM2/TTERM1                                               CON34050
      IF (TTERM.LT.0.999999) GO TO 200                                  CON34060
      UTEST=-BONE/2.                                                    CON34070
      GO TO 220                                                         CON34080
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200   IF ((4.*CONE).GT.(BONE**2)) UTEST=0.                              CON34090
      IF ((4.*CONE).GT.(BONE**2)) GO TO 210                             CON34100
      UTEST=(-SQRT(BONE**2-4.*CONE)-BONE)/2.                            CON34110
210   DENOM=1.-UTEST*RFACT                                              CON34120
220   CONTINUE                                                          CON34130
      IF (DENOM.GT.1.E-7) GO TO 230                                     CON34140
      HEFF=1.0E8                                                        CON34150
      GO TO 240                                                         CON34160
230   HEFF=UTEST/DENOM                                                  CON34170
240   CONTINUE                                                          CON34180
      ROUT=(HEFF+SHNF)/(HEFF*SHNF)                                      CON34190
      TDIF=STSAT-STBAVE                                                 CON34200
      IF (TDIF.GT.0) GO TO 250                                          CON34210
      IF (IBT.EQ.0) WRITE (6,530) STSAT,STBAVE,LJ,IR                    CON34220
      IBT=1                                                             CON34230
      TDIF=.1                                                           CON34240
250   CONTINUE                                                          CON34250
      DELTAU=TDIF*UTEST                                                 CON34260
      DGFLM=DELTAU/HEFF                                                 CON34270
      DLFLM=DELTAU/SHNF                                                 CON34280
      STCO=STSAT-DGFLM                                                  CON34290
      STWO=STCO-DLFLM                                                   CON34300
      STFO=(STCO+STWO)/2.                                               CON34310
      XNU=SDO/(SKBO*ROUT)                                               CON34320
      IF (ABS(UTEST-UEST)/UTEST.LT..001) GO TO 260                      CON34330
      DELFLM=DLFLM                                                      CON34340
      DLGFLM=DGFLM                                                      CON34350
      UESTSV=UEST                                                       CON34360
      UEST=UTEST                                                        CON34370
      K=K+1                                                             CON34380
      IF (K.GT.4) UEST=0.5*(UTEST+UESTSV)                               CON34390
      IF (K.LT.20) GO TO 110                                            CON34400
      WRITE (6,510) UESTSV,UTEST                                        CON34410
      GO TO 280                                                         CON34420
260   IF (ABS(DELFLM-DLFLM).LT..01) GO TO 270                           CON34430
      DELFLM=DLFLM                                                      CON34440
      DLGFLM=DGFLM                                                      CON34450
      K=K+1                                                             CON34460
      IF (K.LT.20) GO TO 110                                            CON34470
      WRITE (6,520) DELFLM,LJ,IR                                        CON34480
270   IF (ABS(DLGFLM-DGFLM).LT..001) GO TO 280                          CON34490
      DLGFLM=DGFLM                                                      CON34500
      K=K+1                                                             CON34510
      IF (K.LT.20) GO TO 110                                            CON34520
      WRITE (6,500) DLGFLM,UEST,UTEST,LJ,IR                             CON34530
280   VNF=UTEST                                                         CON34540
      VPSHH=TB2                                                         CON34550
      XHEFF=HEFF                                                        CON34560
      ROUT=1./ROUT                                                      CON34570
      UNC(I)=VNF                                                        CON34580
      ALMTDC(I)=ALMTD                                                   CON34590
      SHIC(I)=SHI                                                       CON34600
      SHNFC(I)=SHNF                                                     CON34610
      RCC(I)=RC                                                         CON34620
      ROUTC(I)=ROUT                                                     CON34630
      VNREC(I)=XNRE                                                     CON34640
      VPSHHC(I)=VPSHH                                                   CON34650
      HEFFC(I)=SHEFF                                                    CON34660
C                                                                       CON34670
C    COMPLETICN OF TUBE H/T CALCULATION                                 CON34680
C                                                                       CON34690
      HFG=HFGFN(STSATC(I))                                              CON34700
      WCNDC(I)=UNC(I)*AO*HNOC*ALMTDC(I)/HSTO                            CON34710
      CALL PRSDRP (TAL,VMIX,WSC(I),WNCC,AXOC,SDO,VPSHC(I),DELTPC,ENHF)  CON34720
      JY=0                                                              CON34730
290   WSC(I+1)=WSC(I)-WCNDC(I)                                          CON34740
      GFLOWC(I)=(WSC(I)+WNCC)/AXOC                                      CON34750
C                                                                       CON34760
C     CHECK FOR NEGATIVE STEAM FLOW                                     CON34770
C                                                                       CON34780
      IF (WSC(I+1)-1) 300,300,360                                       CON34790
C                                                                       CON34800
C     IF PREVIOUS COND. RATE PREDICTS STEAM FLOW WILL GO NEG AFTER THE  CON34810
C     NEXT ROW, SET CONDENSATE EQUAL TO STEAM FLOW.                     CON34820
C                                                                       CON34830
300   WCNDC(I)=WSC(I)                                                   CON34840
C                                                                       CON34850
C     IF STEAM FLOW HAS ALREADY GONE NEGATIVE THEN AVOID CALCULATING    CON34860
C     TEST VARIABLE                                                     CON34870
C                                                                       CON34880
      IF (IROWC.GT.0) GO TO 310                                         CON34890
C                                                                       CON34900
C     CREATE A TEST VARIABLE INDICATING POINT IN COOLER WHERE STEAM     CON34910
C     BAD AND A NEGATIVE FLOW RATE FOR USE IN CALCULATING EXITFRC       CON34920
C                                                                       CON34930
      WTSTC=(WSC(I+1)-1.)/(WSC(I)-WSC(I+1)+1.)                          CON34940
      WTSTC=WTSTC-FLOAT(IVNOC-I)                                        CON34950
      IROWC=1                                                           CON34960
C                                                                       CON34970
      NRODRY=IVNOC-I                                                    CON34980
      TBDRYC=TNOC*(FLOAT(NRODRY)/FLOAT(IVNOC))                          CON34990
      TBDRYC=TBDRYC-WTSTC*HNOC                                          CON35000
      SBRATC=WCNDC(I)/HNOC                                              CON35010
      SBFLOC=SBRATC*TBDRYC                                              CON35020
C                                                                       CON35030
C                                                                       CON35040
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310   STSATC(I+1)=STFG
      TSATMN=STSATC(I+1)+459.69
      PMIN=PSATFN(TSATMN)
C
C     ENTER DUMMY VALUE FOR NEXT ROW WSC
C
      WSC(I+1)=1.
C
      QGC=(WSC(I)*CPSFN(TAL)/18.015+WNCC*CPAFN(TAL,JGAS)/AMWNC)*(TAL-TSA
     1TMN)
      QTC=QGC+WCNDC(I)*HFG
      IF (STSATC(I)-TB2) 320,320,330
320   TB2=STSATC(I)-0.1
330   CONTINUE
      IF (STSATC(I+1).GT.STBI) GO TO 340
      ALMTDC(I)=ALMTDC(I-1)
      GO TO 350
340   CONTINUE
      ALMTDC(I)=((STSATC(I+1)-STBI)-(STSATC(I)-TB2))/ALOG((STSATC(I+1)-S
     1TBI)/(STSATC(I)-TB2))
350   CONTINUE
      UNC(I)=QTC/(AO*HNOC*ALMTDC(I))
      AMLSSC=WSC(I+1)/18.015
      PMIXC(I+1)=PMIXC(I)-DELTPC
      PSATC(I+1)=(PMIXC(I+1)*AMLSSC)/(AMLSSC+AMLSCC)
      TSATC=TSATMN
      GO TO 440
C
C
360   AMLSSC=WSC(I+1)/18.015
      PMIXC(I+1)=PMIXC(I)-DELTPC
      PSATC(I+1)=(PMIXC(I+1)*AMLSSC)/(AMLSSC+AMLSCC)
C
C     CHECK TO SEE IF STEAM CORRECTIONS FOR DRY TUBES DROVE PSATC TOO LO
C
      IF ((IROWC.GT.0).AND.(PSATC(I+1).LE.PTLIM)) WRITE (6,560) I
      IF ((IROWC.GT.0).AND.(PSATC(I+1).LE.PTLIM)) PSATC(I+1)=PSATC(I)
C
C     CHECK FCR PRESSURE DROPPING BELOW PTLIM
C
      IF (PSATC(I+1).GT.PTLIM) GC TO 390
C
C     CALCULATE PARAMETERS FOR CURRENT ROW
C
      PSATC(I)=PTLIM
      CUMDPC(I)=PMIX1-PMIXC(I)
      SUMQC=SUMQC+UNC(I)*AO*ALMTDC(I)*HNOC
      QOAC(I)=UNC(I)*ALMTDC(I)
      SMWBC=SMWBC+WB*HNOC                                               CON35530
      SMTB1C=SMTB1C+WB*HNOC*STB1                                        CON35540
      SMTB2C=SMTB2C+WB*HNOC*TB2                                         CON35550
C                                                                       CON35560
      NRWSP4=IVNOC+1                                                    CON35570
      RTG=FLOAT(NRWSP4-I)                                               CON35580
      NRWSP5=I+1                                                        CON35590
      CONST=PMIXC(I)/RTG                                                CON35600
      CONST2=PTLIM/RTG                                                  CON35610
C                                                                       CON35620
C     CALCULATE PARAMETERS FOR THE REMAINING ROWS                       CON35630
C                                                                       CON35640
      DO 370 M=NRWSP5,NRWSP4                                            CON35650
      QOAC(M)=0.                                                        CON35660
      WSC(M)=WSC(M-1)                                                   CON35670
      WCNOC(M)=0.                                                       CON35680
      STSATC(M)=STSATC(M-1)                                             CON35690
      PSATC(M)=PSATC(M-1)-CONST2                                        CON35700
      PMIXC(M)=PMIXC(M-1)-CONST                                         CON35710
      VELC(M)=VELC(M-1)                                                 CON35720
370   CONTINUE                                                          CON35730
C                                                                       CON35740
      DO 380 IFX=NRWSP5,IVNOC                                           CON35750
      UNC(IFX)=UNC(IFX-1)                                               CON35760
      CUMDPC(IFX)=PMIX1-PMIXC(IFX-1)                                    CON35770
      SMTB1C=SMTB1C+WB*HNOC*STB1                                        CON35780
      SMTB2C=SMTB1C                                                     CON35790
      QOAC(IFX)=0.                                                      CON35800
      SMWBC=SMWBC+WB*HNOC                                               CON35810
380   ALMTDC(IFX)=0.                                                    CON35820
C                                                                       CON35830
      DELPC=PMIXC(1)-PMIXC(NRWSP4)                                      CON35840
C                                                                       CON35850
      GO TO 460                                                         CON35860
C                                                                       CON35870
390   PAL=PSATC(I+1)                                                    CON35680
      IF (PAL.GT.0.) GO TO 400                                          CON35890
      WRITE (6,550) PMIXC(I),I                                          CON35900
400   CONTINUE                                                          CON35910
      TSATC=TSATFN(PAL)                                                 CON35920
      STSATC(I+1)=TSATC-459.69                                          CON35930
      IF (ABS(TSATC-TAL).LT.0.001) TSATC=TAL-0.001                      CON35940
      WCNDP=(UNC(I)*AO*HNOC*ALMTDC(I)-(WSC(I)*CPSFN(TSATC)/18.015+WNCC*CCON35950
     1PAFN(TSATC,JGAS)/AMWNC)*(TAL-TSATC))/HFG                          CON35960
      IF (ABS(WCNDP/WCNOC(I)-1.0)-.005) 430,410,410                     CON35970
410   WCNOC(I)=WCNDP                                                    CON35980
      JY=JY+1                                                           CON35990
      IF (JY-50) 290,290,420                                            CON36000
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420   WRITE (6,540) I                                                   CON36010
430   CONTINUE                                                          CON36020
      WCNDC(I)=WCNDP                                                    CON36030
      WSC(I+1)=WSC(I)-WCNDC(I)                                          CON36040
      AMLSSC=WSC(I+1)/18.015                                            CON36050
      PSATC(I+1)=(PMIXC(I+1)*AMLSSC)/(AMLSSC+AMLSCC)                    CON36060
      PAL=PSATC(I+1)                                                    CON36070
      TSATC=TSATFN(PAL)                                                 CON36080
      STSATC(I+1)=TSATC-459.69                                          CON36090
440   VG=VGFN(TSATC,PMIXC(I+1))                                         CON36100
      VNC=10.729*TSATC/(AMWNC*PMIXC(I+1))                               CON36110
      VMIX=1.07((AMLSSC/(VG*(AMLSSC+AMLSCC)))+(AMLSCC/(VNC*(AMLSSC+AMLSCCON36120
     1C))))                                                             CON36130
      VELC(I+1)=(WSC(I+1)+WNCC)*VMIX/(AXOC*36C0.0)                      CON36140
      SMTBIC=SMTBIC+WB*HNOC*STBI                                        CON36150
      SMWBC=SMWBO+WB*HNOC                                               CON36160
      SMTB2C=SMTB2C+WB*HNOC*TB2                                         CON36170
      SUMQC=SUMQC+UNC(I)*AO*ALMTDC(I)*HNOC                              CON36180
      QOAC(I)=UNC(I)*ALMTDC(I)                                          CON36190
      CUMDPC(I)=PMIX1-PMIXC(I)                                          CON36200
      TAL=TSATC                                                         CON36210
      ANFC=ANFC-1.0                                                     CON36220
450   CONTINUE                                                          CON36230
      DELPC=PMIXC(1)-PMIXC(IVNOC+1)                                     CON36240
460   CONTINUE                                                          CON36250
C                                                                       CON36260
C     CHECK TO SEE IF INLET STEAM FLOW WAS 0                            CON36270
C                                                                       CON36280
      IF (IROWC.LT.2) GO TO 480                                         CON36290
      NRWSP4=IVNOC+1                                                    CON36300
      SUMQC=0.                                                          CON36310
      DO 470 M=1,NRWSP4                                                 CON36320
      QOAC(M)=0.                                                        CON36330
      ALMTDC(M)=0.                                                      CON36340
      WSC(M)=0.                                                         CON36350
470   WCNDC(M)=0.                                                       CON36360
      EXITFC=-999                                                       CON36370
      WTSTC=FLOAT(IVNOC)                                                CON36380
      RETURN                                                            CON36390
C                                                                       CON36400
C     IF COOLER TUBES WENT DRY CREATING A NEGATIVE EXITFC               CON36410
C                                                                       CON36420
480   IF (WTSTC.GE.0.) GO TO 490                                        CON36430
      EXITFC=-(SBFLOC)/WSC(1)                                           CON36440
      RETURN                                                            CON36450
C                                                                       CON36460
490   EXITFC=WSC(I+1)/WSC(1)                                            CON36470
      WSOUT=WSC(I+1)                                                    CON36480
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C                                                                       CON36490
      RETURN                                                            CON36500
C                                                                       CON36510
500   FORMAT (1H0,36H NO CONVERGENCE IN FILM TEMPERATURES,8H DLGFLM=,E12CON36520
     1.5,7H UEST =,E12.5,8H UTEST =,E12.5/10H SECTOR = ,I5,5H ROW=,I5)  CON36530
510   FORMAT (1H0,32H NO CONVERGENCE IN UESY, UEST = ,E12.5,9H UTEST = ,CON36540
     1E12.5)                                                            CON36550
520   FORMAT (1H0,34H NO CONVERGENCE IN DELFLM, DELFLM=,E12.5,8H SECTOR=CON36560
     1,I5,5H ROW=,I5)                                                   CON36570
530   FORMAT (1H0,53H  SAT STEAM TEMP LESS THAN AVG BRINE TEMP,    STSATCON36580
     1 =,E12.5,10H STBAVE = ,E12.5,9H   SECTOR,I3,6H   ROW,I4)          CON36590
540   FORMAT (1H0,25HNO CONVERGENCE FOR WCNDC(,I2,2H).)                 CON36600
550   FORMAT (1H0,68H**** SATURATED STEAM PRESSURE IN COOLER HAS GONE NECON36610
     1GATIVE,    PMIXC =,E15.5,6H   ROW,I5)                             CON36620
560   FORMAT (1X,52HERROR,COOLER PTLIM VIOLATED DUE TO STEAM CORRECTIONSCON36630
     1/1X,41HFOR NEGATIVE FLOW. PTLIM VIOLATED IN ROW ,I5/)             CON36640
      END                                                               CON36650
C                                                                       CON36660
C*************************************************************          CON36670
C*************************************************************          CON36680
C                                                                       CON36690
      SUBROUTINE OUT2                                                   CON36700
C--------------                                                         CON36710
C OUT2 1                                                                CON36720
C                           SUMMARY OUTPUT                              CON36730
C ZZZ OUT2                                                              CON36740
C--------------                                                         CON36750
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,CON36760
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNOTOCON36770
     2T,BNDRAD,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR                      CON36780
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON36790
     1TSATI,TUBESW,WNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON36800
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON36810
     3,WSI,PFILL                                                        CON36820
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMOUT(10CON36830
     10)                                                                CON36840
      COMMON /ORC2/ ANT(100,15),STB2ES,VW(100)                          CON36850
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNC,VEL2,FR              CON36860
      COMMON /OUTC/ EXITFC,EXITFR,HTCLR,ACC,SUMQC,SDIC,SDOC,UBARW,SMWBC,CON36870
     1SMTBIC,SMTB2C,VWBAR,STSATX,PMIX1,AOT,BUNWT,AVTBI,AVTB2,WTSTC,VOLC CON36880
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST                         CON36890
      COMMON /SEC/ ALMTD(100,15),CUMDP(100,15),DELP(15),GFLW(100,15),HEFCON36900
     1F(100,15),PMIX(100,15),PSAT(100,15),QOA(100,15),RC(100,15),ROUT(10CON36910
     20,15),SHI(100,15),SHN(100,15),STSAT(100,15),UN(100,15),VEL(100,15)CON36920
     3,VNRE(100,15),VPSHH(100,15),WCND(100,15),WGAS(15),WP(15),WS(100,15CON36930
     4),WSP(15)                                                         CON36940
      COMMON /COOL1/ VELC(100),PMIXC(100),PSATC(100),STSATC(100),WSC(100CON36950
     1),ALMTDC(100),SHIC(100),SHNFC(100),RCC(100),ROUTC(100),VNREC(100),CON36960
     2VPSHHC(100),HEFFC(100),UNC(100),WCNDC(100),GFLOWC(100),QOAC(100),CCON36970
     3UMDPC(100)                                                       CON36980
      COMMON /COOL/ IVNOC,HNOC,TNOC,TSATEX,PMXEXT,AMLSEX,WSEXIT,VELEXT,TCON36990
     1B2C,ENHIC,ENHOC,ENHFC,SHWINC,WBC                                 CON37000
      COMMON /OUT2A/ RCORR,RSPF,PHPCON,VOL1C                           CON37010
      DIMENSICN AWTST(15)                                              CON37020
      DELPVE=0.                                                        CON37030
      AOT=0.                                                           CON37040
      VEL3=0.                                                          CON37050
      CAWT=0.                                                          CON37060
      UBARW=0.                                                         CON37070
      VWBAR=0.                                                         CON37080
      SECFLG=FLOAT(ISEC)                                               CON37090
      DO 10 I=1,NOROWS                                                 CON37100
      OD=ODOI-DELOD*FLOAT(I-1)                                         CON37110
      CAWT=CAWT+(OD*OD/144.-SID(I)*SID(I))*TBNPR(I)                    CON37120
      AO=3.14159*OD*ALST*TBNPR(I)/12.                                  CON37130
      VWBAR=VWBAR+VW(I)                                                CON37140
 10   AOT=AOT+AO                                                       CON37150
      BUNWT=PI*CAWT*ALST*TUBESW*SECFLG/4.                              CON37160
      AOT=AOT*SECFLG                                                   CON37170
      DO 30 J=1,ISEC                                                   CON37180
      DO 20 I=1,NOROWS                                                 CON37190
 20   UBARW=UBARW+UN(I,J)*TBNPR(I)                                     CON37200
      VEL3=VEL3+VEL(NOROWS,J)                                          CON37210
      DELPVE=DELPVE+DELP(J)                                            CON37220
 30   CONTINUE                                                         CON37230
      UBARW=UBARW/TNO                                                  CON37240
      VWBAR=VWBAR/FLOAT(NOROWS)                                        CON37250
      VEL3=VEL3/SECFLG                                                 CON37260
      DELPVE=DELPVE/SECFLG                                             CON37270
      ADTCND=SUMQ/(UBARW*AOT)                                          CON37280
      STSATX=TSATEX-459.69                                             CON37290
      TDROP1=STSAT(1,1)-STSATX                                         CON37300
C                                                                      CON37310
      RSPI=RSPF*12.                                                    CON37320
C                                                                      CON37330
      BNDIAM=BNDRAD*2.                                                 CON37340
      BL=ALST/2.                                                       CON37350
      VOIDID=RADINS*2.                                                 CON37360
      AVTBI=SMTBI/SMWB                                                 CON37370
      AVTB2=SMTB2/SMWB                                                 CON37380
      HDLOSS=DELWP*144./62.366                                         CON37390
C                                                                      CON37400
C     THERE IS THE POSSIBILITY THAT THE AVERAGE INLET COOLANT TEMP     CON37410
C     (AVTBI) EQUALS THE AVERAGE OUTLET COOLANT TEMP (AVTB2). WHEN     CON37420
C     THE CONDENSER IS COMNFIGURED SUCH THAT NO HEAT IS REMOVED FROM   CON37430
C     THE STEAM                                                        CON37440
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C                                                                       CON37450
      IF (AVTB1.EQ.AVTB2) DTCND2=0.                                     CON37460
      IF (AVTB1.EQ.AVTB2) UPCOND=UBARW                                  CON37470
      IF (AVTB1.EQ.AVTB2) GO TO 40                                      CON37480
C                                                                       CON37490
      DTCND2=(AVTB2-AVTB1)/ALOG((STSAT1-AVTB1)/(STSAT1-AVTB2))          CON37500
      UPCOND=SUMQ/(AOT*DTCND2)                                          CON37510
   40 WRITE (6,60)                                                      CON37520
      WRITE (6,80)                                                      CON37530
      WRITE (6,90)                                                      CON37540
      WRITE (6,100)                                                     CON37550
      WRITE (6,90)                                                      CON37560
      WRITE (6,80)                                                      CON37570
      WRITE (6,70)                                                      CON37580
      WRITE (6,110) UBARW,ADTCND,DELPVE,TDROP1,VEL2,VEL3                CON37590
      WRITE (6,120) SUMQ                                                CON37600
      WRITE (6,130) WSI                                                 CON37610
      WRITE (6,160) AOT                                                 CON37620
      WRITE (6,140) EXITFR                                              CON37630
C                                                                       CON37640
      DO 50 I=1,ISEC                                                    CON37650
      IF (WTST(I).LT.0.) AWTST(I)=-WTST(I)                              CON37660
      IF (WTST(I).LT.0.) WRITE (6,150) I,AWTST(I)                       CON37670
   50 CONTINUE                                                          CON37680
C                                                                       CON37690
      WRITE (6,170) TNO,NOROWS                                          CON37700
      WRITE (6,180) ALST                                                CON37710
      WRITE (6,190) VOIDID,BNDIAM,BL                                    CON37720
      IF (MDIAM.EQ.1) WRITE (6,200) SIDO,ODOI                           CON37730
      IF (MDIAM.EQ.2) WRITE (6,210) SIDI,ODII                           CON37740
      IF (MDIAM.EQ.2) WRITE (6,220) SIDO,ODOI                           CON37750
      IF (NPITCH.EQ.1) WRITE (6,230) SDDO                               CON37760
      IF (NPITCH.EQ.2) WRITE (6,240) SDDI,SDDO                          CON37770
      IF (XW2.GT.0.) WRITE (6,250) XW2                                  CON37780
      IF (XW2.LE.0.) WRITE (6,260) XW1                                  CON37790
      WRITE (6,270) RSPI                                                CON37800
      WRITE (6,280) VCL1C,VOL2,BUNWT                                    CON37810
      WRITE (6,290) AVTB1                                               CON37820
      WRITE (6,300) AVTB2                                               CON37830
      WRITE (6,320) SMWB                                                CON37840
      WRITE (6,330) VWBAR                                               CON37850
      WRITE (6,310) HDLOSS,PHPCON                                       CON37860
      WRITE (6,340) DTCND2                                              CON37870
      WRITE (6,350) UPCOND                                              CON37880
      WRITE (6,360) PFILL                                               CON37890
      IF (PRCCLR.LE.0) WRITE (6,370) ARATIO                             CON37900
      IF (PRCCLR.GT.0.) CALL OUT2C                                      CON37910
      RETURN                                                            CON37920
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60    FORMAT (1H1)
70    FORMAT (1H0,31X,29H********  CONDENSER  ********//)
80    FORMAT (1H ,15X,16X,29H*****************************)
90    FORMAT (1H ,15X,16X,1H*,27X,1H*)
100   FORMAT (1H ,15X,16X,29H* CONDIP SUMMARY OF RESULTS *)
110   FORMAT (1H ,10X,56HOVERALL U  LOG-MEAN  PRESSURE     TEMP.    STEAM
     1 VELOCITY/10X,54HB/HR-DEG.F  DELTA T     DROP       DROP           F
     2T/SEC/11X,57H-SQ.FT.     DEG.F        PSIA       DEG.F       INLET    OU
     3TLET//12X,F6.2,3X,F6.2,4X,1PE9.2,1P3E10.2/)
120   FORMAT (1H ,10X,12HHEAT DUTY    ,8X,1PE11.4,2X,6HBTU/HR)
130   FORMAT (1H ,10X,18HSTEAM TO BUNDLE    ,2X,1PE11.4,2X,5HLB/HR)
140   FORMAT (1H ,10X,13HEXIT FRAC.    ,7X,1PE11.4/)
150   FORMAT (1H ,10X,10HIN SECTOR ,I2,2X,29HTHE FRACTION OF DRY ROWS WA
     1S ,F10.6)
160   FORMAT (1H ,10X,19HHT. TRF. SURF. AREA,1X,1PE11.4,2X,6HSQ.FT.)
170   FORMAT (1H ,1X/10X,16HBUNDLE DIAMETER,,3X,2HFT,7X,F10.2,1X,6HTUBES
     1,,I5,1X,4HROWS)
180   FORMAT (1H ,12X,6HINSIDE,4X,7HOUTSIDE,13X,10HTUBES ARE ,F5.2,1X,7H
     1FT LONG)
190   FORMAT (1H ,12X,F5.2,5X,F5.2,14X,11HBUNDLE IS  ,F5.2,1X,7HFT LONG/
     1)
200   FORMAT (1H ,10X,20HTUBE INSIDE DIAMETER,15X,F7.4,2X,6HINCHES/1H ,1
     10X,21HTUBE OUTSIDE DIAMETER,14X,F7.4,2X,6HINCHES)
210   FORMAT (1H ,10X,30HTUBE INSIDE DIAMETER INNER ROW,6X,F7.4,2X,3HIN.
     1/11X,31HTUBE OUTSIDE DIAMETER INNER ROW,5X,F7.4,2X,3HIN./)
220   FORMAT (1H ,11X,30HTUBE INSIUE DIAMETER OUTER ROW,5X,F7.4,2X,3HIN.
     1/11X,31HTUBE OUTSIDE DIAMETER OUTER ROW,5X,F7.4,2X,3HIN.)
230   FORMAT (1H ,10X,26HTUBE CIRCUMFERENTIAL PITCH,9X,F7.4)
240   FORMAT (1H ,10X,36HTUBE CIRCUMFERENTIAL PITCH INNER ROW,5X,F7.4/1H
     1 ,10X,36HTUBE CIRCUMFERENTIAL PITCH OUTER ROW,5X,F7.4)
250   FORMAT (1H ,10X,14HTUBE THICKNESS,21X,F7.4,2X,6HINCHES)
260   FORMAT (1H ,10X,34HRATIO OF TUBE THICKNESS TO TUBE OD,5X,F7.4)
270   FORMAT (1H ,10X,28HSPACE BETWEEN COCENTRIC ROWS,7X,F7.4,2X,3HIN./)
280   FORMAT (1H ,10X,13HBUNDLE VOLUME,7X,1PE11.4,2X,6HCU.FT./11X,19HTUB
     1E SPACE VOLUME   ,1X,1PE11.4,2X,6HCU.FT./11X,19HTUBE METAL WEIGHT
     2,1X,1PE11.4,2X,2HLB/)
290   FORMAT (1H ,10X,19HINLET WATER TEMP    ,5X,F9.2,1X,5HDEG.F)
300   FORMAT (1H ,10X,20HOUTLET WATER TEMP    ,4X,F9.2,1X,5HDEG.F)
310   FORMAT (1H ,10X,9HHEAD LOSS,15X,F9.2,1X,6HFT H2O/11X,13HPUMPING PO
     1WER,11X,F9.2,1X,2HHP/)
320   FORMAT (1H ,10X,13HWATER FLOW    ,12X,1PE11.4,1X,5HLB/HR)
330   FORMAT (1H ,10X,17HWATER VELOCITY    ,8X,1PE11.4,1X,6HFT/SEC/)
340   FORMAT (1H ,10X,12HAVG. LMTD    ,14X,F7.2,1X,5HDEG.F)
350   FORMAT (1H ,10X,9HAVG. U    ,17X,F7.2,1X,18HBTU/HR-SQ.FT-DEG.F/)
360   FORMAT (1H ,10X,46HTHE PERCENTAGE OF THE OUTERMOST ROW FILLED IS ,
     1F7.4//)
370   FORMAT (1H ,10X,18HTHE AREA RATIO IS ,F7.4//)
      END
```

```
C                                                                       CON38410
C*****************************************************************      CON38420
C*****************************************************************      CON38430
C                                                                       CON38440
      SUBROUTINE OUT2C                                                  CON38450
C-------------------                                                    CON38460
C                                                                       CON38470
C                 SUMMARY OUTPUT FOR COOLER SECTION                     CON38480
C                                                                       CON38490
C-------------------                                                    CON38500
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,CON38510
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDC,VELBI,XW1,XW2,VOL1,VOL2,TNOTOCON38520
     2T,BNDRAC,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR                      CON38530
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,SCON38540
     1TSAT1,TUBESW,WNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MDCON38550
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)CON38560
     3,WSI,PFILL                                                        CON38570
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),ADLFLW(100),CMDOT(10CON38580
     10)                                                                CON38590
      COMMON /ORC2/ ANT(100,15),STB2ES,VW(100)                          CON38600
      COMMON /JUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNO,VEL2,FR              CON38610
      COMMON /OUTC/ EXITFC,EXITFR,HTCLR,ACC,SUMQC,SDIC,SDOC,UBARW,SMWBC,CON38620
     1SMTBIC,SMTB2C,VWBAR,STSATX,PMIX1,AOT,BUNWT,AVTBI,AVTB2,WTSTC,VOLC CON38630
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST                         CON38640
      COMMON /SEC/ ALMTD(100,15),CUMDP(100,15),DELP(15),GFLW(100,15),HEFCON38650
     1F(100,15),PMIX(100,15),PSAT(100,15),QOA(100,15),RC(100,15),ROUT(10CON38660
     20,15),SHI(100,15),SHN(100,15),STSAT(100,15),UN(100,15),VEL(100,15)CON38670
     3,VNRE(100,15),VPSHH(100,15),WCND(100,15),WGAS(15),WP(15),WS(100,15CON38680
     4),WSP(15)                                                         CON38690
      COMMON /COOL1/ VELC(100),PMIXC(100),PSATC(100),STSATC(100),WSC(100CON38700
     1),ALMTDC(100),SHIC(100),SHNFC(100),RCC(100),ROUTC(100),VNREC(100),CON38710
     2VPSHHC(100),HEFFC(100),UNC(100),WCNDC(100),GFLOWC(100),QOAC(100),CCON38720
     3UMDPC(100)                                                        CON38730
      COMMON /COOL/ IVNOC,HNOC,TNOC,TSATEX,PMXEXT,AMLSEX,WSEXIT,VELEXT,TCON38740
     1B2C,ENHIC,ENHDC,ENHFC,SHWINC,WBC                                  CON38750
      UBARWC=0.                                                         CON38760
      DO 10 J=1,IVNOC                                                   CON38770
      UBARWC=UBARWC+UNC(J)*HNOC                                         CON38780
10    CONTINUE                                                          CON38790
      DELPVC=PMIXC(1)-PMIXC(IVNOC+1)                                    CON38800
      UBARWC=UBARWC/TNOC                                                CON38810
      AOTC=AOC*TNOC                                                     CON38820
      ADTCLR=SUMQC/(UBARWC*AOTC)                                        CON38830
      TDROPC=STSATC(1)-STSATC(IVNOC+1)                                  CON38840
      AVTBIC=SMTBIC/SMWBC                                               CON38850
      AVTB2C=SMTB2C/SMWBC                                               CON38860
      WDCLR=SDOC*SDDC*HNOC                                              CON38870
      COOLWT=TUBESW*TNOC*ALST*PI*(SDOC*SDOC-SDIC*SDIC)/4.               CON38880
      VWBARC=VWBAR                                                      CON38890
C                                                                       CON38900
      IF (AVTBIC.EQ.AVTB2C) DTCOL2=0.                                   CON38910
      IF (AVTBIC.EQ.AVTB2C) UPCOOL=UBARWC                               CON38920
      IF (AVTBIC.EQ.AVTB2C) GO TO 20                                    CON38930
C                                                                       CON38940
      DTCOL2=(AVTB2C-AVTBIC)/ALOG((STSATX-AVTBIC)/(STSATX-AVTB2C))      CON38950
      UPCOOL=SUMQC/(AOTC*DTCOL2)                                        CON38960
C                                                                       CON38970
C     VALUES FOR OVERALL OUTPUT                                         CON38980
C                                                                       CON38990
20    AOTOT=AOTC+AOT                                                    CON39000
      TNOT=TNC+TNOC                                                     CON39010
      UBAROA=(UBARW*TNO+UBARWC*TNOC)/TNOT                               CON39020
      ADTOA=(SUMQC+SUMQ)/(UBAROA*AOTOT)                                 CON39030
      DELPOA=PMIX1-PMIXC(IVNOC+1)                                       CON39040
      TDRPOA=STSAT1-STSATC(IVNOC+1)                                     CON39050
      SUMQOA=SUMQC+SUMQ                                                 CON39060
      WTOA=BUNWT+COOLWT                                                 CON39070
      AVTBIA=(AVTBI*TNO+AVTBIC*TNOC)/TNOT                               CON39080
      AVTB2A=(AVTB2*TNO+AVTB2C*TNOC)/TNOT                               CON39090
      SMWBOA=SMWBC+SMWB                                                 CON39100
      HDLSOA=DELWP*144./62.366                                          CON39110
      DTOA=(AVTB2A-AVTBIA)/ALOG((STSAT1-AVTBIA)/(STSAT1-AVTB2A))        CON39120
      UPOA=SUMQOA/(AOTOT*DTOA)                                          CON39130
      WRITE (6,40)                                                      CON39140
      WRITE (6,50) JBARWC,ADTCLR,DELPVC,TDROPC,VELC(1),VELC(IVNOC)      CON39150
      WRITE (6,60) SUMQC                                                CON39160
      WRITE (6,70) WSC(1)                                               CON39170
      WRITE (6,110) AOTC                                                CON39180
C                                                                       CON39190
      IF (EXITFC.LT.-900.) WRITE (6,100)                                CON39200
      IF (EXITFC.LT.-900.) GO TO 30                                     CON39210
C                                                                       CON39220
      WRITE (6,80) EXITFC                                               CON39230
C                                                                       CON39240
30    IF (WTSTC.LT.0) WRITE (6,90) WTSTC                                CON39250
C                                                                       CON39260
      WRITE (6,120) TNOC,IVNOC                                          CON39270
      WRITE (6,130)                                                     CON39280
      WRITE (6,140) HTCLR,WDCLR                                         CON39290
      WRITE (6,150) VCLC,COOLWT                                         CON39300
      WRITE (6,160) AVTBIC                                              CON39310
      WRITE (6,170) AVTB2C                                              CON39320
      WRITE (6,180) SMWBC                                               CON39330
      WRITE (6,190) VWBARC                                              CON39340
      WRITE (6,210) DTCOL2                                              CON39350
      WRITE (6,220) UPCOOL                                              CON39360
      WRITE (6,230) SDDC                                                CON39370
      WRITE (6,250)                                                     CON39380
      WRITE (6,260) UBAROA,ADTOA,DELPOA,TORPOA                          CON39390
      WRITE (6,60) SUMQOA                                               CON39400
      WRITE (6,110) AOTOT                                               CON39410
      WRITE (6,80) EXITOA                                               CON39420
      WRITE (6,270) TNOT                                                CON39430
      WRITE (6,280) VOL1,WTOA                                           CON39440
      WRITE (6,160) AVTB1A                                              CON39450
      WRITE (6,170) AVTB2A                                              CON39460
      WRITE (6,180) SMWBOA                                              CON39470
      WRITE (6,200) HDLSOA,PHP                                          CON39480
      WRITE (6,210) DTOA                                                CON39490
      WRITE (6,220) UPOA                                                CON39500
      IF (PRCCLR.GT.0) WRITE (6,240) ARATIO                             CON39510
      RETURN                                                            CON39520
40    FORMAT (1H0,31X,29H********   COOLER    ********//)               CON39530
50    FORMAT (1H ,10X,56HOVERALL U  LOG-MEAN  PRESSURE    TEMP.    STEAMCON39540
     1 VELOCITY/10X,54HB/HR-DEG.F  DELTA T    DROP       DROP          FCON39550
     2T/SEC/11X,57H-SQ.FT.     DEG.F       PSIA       DEG.F      INLET    OUCON39560
     3TLET//12X,F6.2,3X,F6.2,4X,1PE9.2,1P3E10.2/)                       CON39570
60    FORMAT (1H ,10X,12HHEAT DUTY   ,8X,1PE11.4,2X,6HBTU/HR)           CON39580
70    FORMAT (1H ,10X,18HSTEAM TO COOLER   ,2X,1PE11.4,2X,5HLB/HR)      CON39590
80    FORMAT (1H ,10X,13HEXIT FRAC.    ,7X,1PE11.4/)                    CON39600
90    FORMAT (1H ,10X,39HIN COOLER, THE FRACTION CF DRY ROWS WAS,F10.6/)CON39610
100   FORMAT (1H ,10X,46HTHE COOLER IS ENTIRELY DRY AND THUS NO EXIT FR/CON39620
     1)                                                                 CON39630
110   FORMAT (1H ,10X,19HHT. TRF. SURF. AREA,1X,1PE11.4,2X,6HSQ.FT.)    CON39640
120   FORMAT (1H ,14X,11HDIMENSIONS,,7X,2HFT,7X,F10.2,1X,6HTUBES,,I5,1X,CON39650
     14HROWS)                                                           CON39660
130   FORMAT (1H ,12X,6HHEIGHT,5X,5HWIDTH)                              CON39670
140   FORMAT (1H ,12X,F5.2,5X,F5.2/)                                    CON39680
150   FORMAT (1H ,10X,19HTOTAL COOLER VOLUME,1X,1PE11.4,2X,6HCU.FT./11X,CON39690
     115HCOOLER WEIGHT  ,1X,1PE11.4,2X,2HLB/)                           CON39700
160   FORMAT (1H ,10X,19HINLET WATER TEMP   ,5X,F9.2,1X,5HDEG.F)        CON39710
170   FORMAT (1H ,10X,20HOUTLET WATER TEMP   ,4X,F9.2,1X,5HDEG.F)       CON39720
180   FORMAT (1H ,10X,13HWATER FLOW   ,9X,1PE11.4,1X,5HLB/HR/)          CON39730
190   FORMAT (1H ,10X,17HWATER VELOCITY   ,5X,1PE11.4,1X,6HFT/SEC/)     CON39740
200   FORMAT (1H ,10X,9HHEAD LOSS,15X,F9.2,1X,6HFT H2O/11X,13HPUMPING POCON39750
     1WER,11X,F9.2,1X,2HHP/)                                            CON39760
210   FORMAT (1H ,10X,12HAVG. LMTD   ,14X,F7.2,1X,5HDEG.F)              CON39770
220   FORMAT (1H ,10X,9HAVG. U   ,17X,F7.2,1X,18HBTU/HR-SQ.FT-DEG.F)    CON39780
230   FORMAT (1H ,10X,35HTHE COOLER CIRCUMFERENTIAL PITCH IS,2X,F6.2//) CON39790
240   FORMAT (1H ,10X,26HTHE OVERALL AREA RATIO IS ,F7.4//)             CON39800
250   FORMAT (1H0,31X,29H********   OVERALL    ********//)              CON39810
260   FORMAT (1H ,10X,38HOVERALL U  LOG-MEAN  PRESSURE    TEMP./10X,36HBCON39820
     1/HR-DEG.F  DELTA T     DROP       DROP/11X,37H-SQ.FT.    DEG.F    PCON39830
     2SIA      DEG.F//12X,F6.2,3X,F6.2,4X,1PE9.2,1PE10.2/)              CON39840
```

```
270   FORMAT (1H /12X,F10.2,2X,5HTUBES/)
280   FORMAT (1H ,10X,12HTOTAL VOLUME,7X,1PE11.4,2X,6HCU.FT./11X,14HTOTA
     1L WEIGHT  ,5X,1PE11.4,2X,2HLB/)
      END
C
C*********************************************************************
C*********************************************************************
C
      SUBROUTINE OUT3
C--------------
C OUT3 1
C                    DETAILED OUTPUT
C ZZZ OUT3-1
C--------------
      COMMON /GLOBCM/ ALST,DELWP,DELWPC,EXITOA,GFLOW,SIDI,SIDO,PHP,RSPA,
     1RADINS,REWI,REWO,SDDI,SDDO,SLDI,SLDO,VELBI,XW1,XW2,VOL1,VOL2,TNOTO
     2T,BNDRAC,ARATIO,ODII,ODOI,SDDC,VLCMAX,PRCCLR
      COMMON /INPT/ BC(6),BE(6),ENH(6),ENI(6),ENO(6),FOUL,PHI,SKW,STBI,S
     1TSAT1,TUBESW,WNCIR,IOPT,PTST(15),SECWID,IBAF,ISEC,JBAF(16),JGAS,MD
     2IAM,MPITCH,NEE,NEI,NETE(6),NETI(6),NRNE(6),NRNI(6),NOROWS,WTST(15)
     3,WSI,PFILL
      COMMON /ORC1/ AOTFLW(100),SID(100),TBNPR(100),AOLFLW(100),CMDOT(10
     10)
      COMMON /ORC2/ ANT(100,15),STB2ES,VW(100)
      COMMON /OUT/ DELOD,SMTBI,SMTB2,SMWB,SUMQ,TNO,VEL2,FR
      COMMON /OUTC/ EXITFC,EXITFR,HTCLR,ACC,SUMQC,SDIC,SDOC,UBARW,SMWBC,
     1SMTBIC,SMTB2C,VWBAR,STSATX,PMIX1,AOT,BUNWT,AVTBI,AVTB2,WTSTC,VOLC
      COMMON /CONST/ AMWNC,CBI,CPB,PI,SG,IFIRST
      COMMON /COOL1/ VELC(100),PMIXC(100),PSATC(100),STSATC(100),WSC(100
     1),ALMTDC(100),SHIC(100),SHNFC(100),RCC(100),ROUTC(100),VNREC(100),
     2VPSHHC(100),HEFFC(100),UNC(100),WCNDC(100),GFLOWC(100),QOAC(100),C
     3UMDPC(100)
      COMMON /COOL/ IVNOC,HNOC,TNOC,TSATEX,PMXEXT,AMLSEX,WSEXIT,VELEXT,T
     1B2C,ENHIC,ENHOC,ENHFC,SHWINC,WBC
      COMMON /SEC/ ALMTD(100,15),CUMDP(100,15),DELP(15),GFLW(100,15),HEF
     1F(100,15),PMIX(100,15),PSAT(100,15),QOA(100,15),RC(100,15),ROUT(10
     20,15),SHI(100,15),SHN(100,15),STSAT(100,15),UN(100,15),VEL(100,15)
     3,VNRE(100,15),VPSHH(100,15),WCND(100,15),WGAS(15),WP(15),WS(100,15
     4),WSP(15)
      ROWS=FLOAT(NOROWS)
      IF (MDIAM.EQ.1) ODII=ODOI
      IF (MPITCH.EQ.1) SDDI=SDDO
      DELSDD=(SDDO-SDDI)/(ROWS-1.)
      WRITE (6,140)
      DO 10 I=1,NOROWS
      A=CMDOT(I)*3600.
      OD=ODOI-DELOD*FLOAT(I-1)
      SDD=SDDO-DELSDD*FLOAT(I-1)
```

```
10    WRITE (6,160) I,VW(I),A,OD,SDD,TBNPR(I)
      DO 30 J=1,ISEC
      WRITE (6,120) J
      DO 20 I=1,NCROWS
      OD=ODOI-DELOD*FLOAT(I-1)
      AO=3.14159*OD*ALST
      Q=UN(I,J)*ALMTD(I,J)*AO
20    WRITE (6,160) I,Q,CUMDP(I,J),ALMTD(I,J),RC(I,J),VNRE(I,J)
30    CONTINUE
      DO 50 J=1,ISEC
      WRITE (6,130) J
      DO 40 I=1,NOROWS
40    WRITE (6,160) I,UN(I,J),ROUT(I,J),HEFF(I,J),SHN(I,J),SHI(I,J)
50    CONTINUE
      DO 70 J=1,ISEC
      WRITE (6,150) J
      DO 60 I=1,NOROWS
60    WRITE (6,160) I,WS(I,J),WCND(I,J),STSAT(I,J),PSAT(I,J),PMIX(I,J)
70    CONTINUE
      IF (PRCCLR.LE.0.) GO TO 110
      WRITE (6,170)
      DO 80 I=1,IVNOC
      QC=UNC(I)*ALMTDC(I)*AOC
      WRITE (6,200) I,QC,CUMDPC(I),ALMTDC(I),RCC(I),VNREC(I)
80    CONTINUE
      WRITE (6,180)
      DO 90 I=1,IVNOC
      WRITE (6,200) I,UNC(I),ROUTC(I),HEFFC(I),SHNFC(I),SHIC(I)
90    CONTINUE
      WRITE (6,190)
      DO 100 I=1,IVNOC
      WRITE (6,200) I,WSC(I),WCNDC(I),STSATC(I),PSATC(I),PMIXC(I)
100   CONTINUE
110   RETURN
120   FORMAT (1H1////15X,15X,28HROW BY ROW OUTPUT FOR SECTOR,I3//15X,3H
     1ROW,4X,4HHEAT,5X,8HPRESSURE,3X,8HLOG MEAN,3X,8HRATIO OF,2X,10HSTEA
     2M SIDE/15X,3HNO.,2X,8HTRANSFER,5X,4HDROP,5X,9HTEMP DIFF,2X,7HN/C G
     3AS,3X,12HREYNOLDS NO./15X,5X,8HPER TUBE,3X,7HPER ROW,14X,10HTO STM
     4 FLW/15X,6X,6HBTU/HR,6X,3HPSI,8X,5HDEG F/)
130   FORMAT (1H1////15X,5X,47HROW BY ROW HEAT TRANSFER COEFICIENTS FOR
     1 SECTOR,I3/15X,23X,14HBTU/HR-FT**2-F//15X,3HROW,2X,8HOVER-ALL,3X,8
     2HEXTERNAL,3X,8HEXTERNAL,3X,8HEXTERNAL,3X,8HINTERNAL/15X,3HNO.,4X,4
     3HTUBE,7X,4HTUBE,5X,8HGAS FILM,3X,8HLIQ FILM,3X,8HLIQ FILM/)
140   FORMAT (1H1////15X,9X,41HROW BY RCW VALUES OF CONDENSER PARAMETER
     1S//15X,3HROW,3X,7HCOOLANT,2X,12HCOOLANT MASS,3X,4HTUBE,7X,4HTUBE,4
     2X,9HNUMBER OF/15X,3HNO.,3X,21HVELOCITY  FLOW/TUBE  ,4X,2HOD,8X,5HP
     3ITCH,3X,9HTUBES PER/15X,17X,6HLBM/HR,6X,6HINCHES,14X,11HROW PER SE
     4C/)
```

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150     FORMAT (1H1/////15X,4X,49HROW BY ROW STEAM AND CONDENSATE VALUES FCON40810
       1OR SECTOR,I3//15X,3HROW,3X,8HSTM FLOW,2X,10HCONDENSATE,1X,10HSATURCON40820
       2ATION,1X,10HSATURATION,2X,7HMIXTURE/15X,3HNO.,3X,8HENTERING,2X,9HGCON40830
       3ENERATED,4X,4HTEMP,5X,8HPRESSURE,3X,8HPRESSURE/15X,7X,6HLBM/HR,5X,CON40840
       46HLBM/HR,6X,5HDEG F,7X,3HPSI,8X,3HPSI/)                           CON40850
160     FORMAT (1H ,14X,I3,5(2X,1PE9.3))                                   CON40860
170     FORMAT (1H1/////15X,15X,28HROW BY ROW OUTPUT FOR COOLER//15X,3HROWCON40870
       1,4X,4HHEAT,5X,8HPRESSURE,3X,8HLOG MEAN,3X,8HRATIO OF,2X,10HSTEAM SCON40880
       2IDE/15X,3HNO.,2X,8HTRANSFER,5X,4HDROP,5X,9HTEMP DIFF,2X,7HN/C GAS,CON40890
       33X,12HREYNOLDS NO./15X,5X,8HPER TUBE,3X,7HPER ROW,14X,10HTO STM FLCON40900
       4W/15X,6X,6HBTU/HR,6X,3HPSI,8X,5HDEG F/)                            CON40910
180     FORMAT (1H1/////15X,5X,47HROW BY ROW HEAT TRANSFER COEFICIENTS FORCON40920
       1 COOLER/15X,23X,14HBTU/HR-FT**2-F//15X,3HROW,2X,8HOVER-ALL,3X,8HEXCON40930
       2TERNAL,3X,8HEXTERNAL,3X,8HEXTERNAL,3X,8HINTERNAL/15X,3HNO.,4X,4HTU CON40940
       3BE,7X,4HTUBE,5X,8HGAS FILM,3X,8HLIQ FILM,3X,8HLIQ FILM/)           CON40950
190     FORMAT (1H1/////15X,4X,49HROW BY ROW STEAM AND CONDENSATE VALUES FCON40960
       1OR COOLER//15X,3HROW,3X,8HSTM FLOW,2X,10HCONDENSATE,1X,10HSATURATICON40970
       2ON,1X,10HSATURATION,2X,7HMIXTURE/15X,3HNO.,3X,8HENTERING,2X,9HGENECON40980
       3RATED,4X,4HTEMP,5X,8HPRESSURE,3X,8HPRESSURE/15X,7X,6HLBM/HR,5X,6HLCON40990
       4BM/HR,6X,5HDEG F,7X,3HPSI,8X,3HPSI/)                               CON41000
200     FORMAT (1H ,14X,I3,5(2X,1PE9.3))                                   CON41010
        END                                                                CON41020
C                                                                          CON41030
C*****************************************************************         CON41040
C                             SUPPORTING SUBROUTINES                       CON41050
C*****************************************************************         CON41060
C                                                                          CON41070
        SUBROUTINE DFSVTY (TK,PATM,AM1,AM2,R1,R2,E1OK,E2OK,V1,V2,DG,DGG)   CON41080
C   DG = GAS DIFFUSIVITY, SQ.CM./SEC - CHEM.ENGRS.HANDBOOK, 4TH ED.,       CON41090
C   R.H.PERRY, 14-20, 1963, MC GRAW-HILL  (WILKE-LEE MOD.)                 CON41100
C   CID = VALUES OF COLLISION INTEGRAL. FUNCTION FITTED BY R.W.BROWELL     CON41110
C         FROM TABLE 14-45 OF ABOVE REF. 4/11/68                           CON41120
C   TK  = ABS. TEMP., DEG. KELVIN                                          CON41130
C   PATM= ABS. PRESS., ATMOSPHERES                                         CON41140
C   R12 = COLLISION DIA., ANGSTROMS                                        CON41150
C   R1  = COMPCNENT 1 COLLISION DIA., ANGSTROMS                            CON41160
C   R2  = COMPCNENT 2 COLLISION DIA., ANGSTROMS                            CON41170
C  E12OK= COMBINED FORCE CONSTANT FOR COMPONENTS 1 & 2., DEG. KELVIN       CON41180
C   DGG = GAS DIFFUSIVITY - GILLILAND'S CRUDE APPROX. METHOD,PP.14-21 REFCON41190
        IF (E1OK.EQ.0.0.AND.V1.EQ.0.0) GO TO 30                            CON41200
        IF (E1OK.EQ.0.0) GO TO 20                                          CON41210
        IF (R1.GT.0.0) GO TO 10                                            CON41220
        R1=1.18*V1**.333                                                   CON41230
        R2=1.18*V2**.333                                                   CON41240
10      CONTINUE                                                           CON41250
        R12=(R1+R2)/2.0                                                    CON41260
        E12OK=(E1OK*E2OK)**0.5                                             CON41270
        TKOE=TK/E12OK                                                      CON41280
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```
      CID=0.1685/TKOE**1.2063+0.5328/TKOE**0.1579
      RTSM=(1./AM1+1./AM2)**0.5
      B=(10.7-2.46*RTSM)*1.E-4
      DG=B*TK**1.5*RTSM/PATM/R12**2/CID
      IF (V1.EQ.0.0) GO TO 40
   20 CONTINUE
      DGG=0.0043*TK**1.5*RTSM/PATM/(V1**.333+V2**.333)**2
      GO TO 40
   30 CONTINUE
      WRITE (6,50)
   40 CONTINUE
      RETURN
   50 FORMAT (103H0  ** NEITHER FORCE CONSTANTS NCR MULECULAR VOLUMES EX
     1IST AS ARGUMENTS. CALCULATIONS CANNOT PROCEED. **)
      END
C
C
      FUNCTICN XTR (X,Y,N,T,SW,X1N,YN,M)
C******
C         FUNCTION XTR ASSUMES A LOG-LOG MODEL, IE  LOG Y = A + B1 * LOG
C         AND PERFORMS A LINEAR LEAST SQUARE REGRESSION ON THE
C         TRANSFORMED POINTS, ALL POINTS ARE USED FOR EACH REGRESSION
C         EXCEPT FOR THE FIRST , WHICH IS NOT USED AT ALL
C********
      DIMENSICN X1N(11),YN(11)
      IF (Y.LE.0.) Y=.00001
      IF (N.EQ.0) GO TO 30
      X1N(N)=ALOG(X)
      YN(N)=ALOG(Y)
      IF (N.LT.2) GO TO 40
      SX1N=0.0
      SYN=0.0
      IF (M.LT.N-3) M=N-3
      DO 10 I=M,N
      SX1N=SX1N+X1N(I)
      SYN=SYN+YN(I)
   10 CONTINUE
      X1BAR=SX1NA(N-M+1)
      YBAR=SYN/(N-M+1)
      SX12=0.0
      SX1Y=0.0
      DO 20 I=M,N
      SX12=SX12+(X1N(I)-X1BAR)**2
      SX1Y=SX1Y+(X1N(I)-X1BAR)*(YN(I)-YBAR)
   20 CONTINUE
      B1=SX1Y/SX12
      A=YBAR-B1*X1BAR
      TN=ALOG(T)
      XTR=EXP((TN-A)/B1)
      GO TO 50
30    M=1
40    XTR=X*(1.+(Y-T)*5.*SW)
C******
C         CHANGE OF VARIABLE IS LIMITED TO 10 PERCENT
C******
50    IF (ABS(XTR-X)/X.LT.0.1) GO TO 60
      XTR=X*(1.+0.1*ABS(Y-T)/(Y-T)*SW)
60    RETURN
      END
C
C
      FUNCTICN AMUFN (T,JGAS)
      IMIX=0
      GO TO (30,20,10), JGAS
10    IMIX=1
20    CONTINUE
C  INERT GAS IS CO2
C**   VISCOSITY FOR CARBON DIOXIDE  LB/FT-SEC
      GAS2=1.0E-5*(-0.046+(2.282E-3+(-6.131E-7+9.699E-11*T)*T)*T)
      AMUFN=GAS2
      IF (IMIX.EQ.0) RETURN
30    CONTINUE
C  INERT GAS IS AIR
      GAS1=1.0E-5*(0.1490+(0.238E-2)*T-(.7209E-6)*T**2+(.1184E-9)*T**3)
      AMUFN=GAS1
      IF (IMIX.EQ.0) RETURN
C  INERT GAS IS MIXTURE OF AIR & CO2
      GAS3=(GAS1+GAS2)/2.0
      AMUFN=GAS3
      RETURN
      END
C
C
      FUNCTICN 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=DEXP(-0.11591155D+2*C+0.12602329D-1*C*R+0.38637378D+4*C/R+0.
     14606532D-2*R+0.47595941D+4/R-0.1059252566D+2)
      RETURN
      END
C
C
      FUNCTICN CPAFN (T,JGAS)
      IMIX=0
      GO TO (30,20,10), JGAS
```

```
10    IMIX=1                                                            CON42250
20    CONTINUE                                                          CON42260
C  INERT GAS IS CO2                                                     CON42270
C** HEAT CAPACITY FOR MW = 40.1   BTU/LB-MOL - DEG R                    CON42280
      GAS2=0.209*40.1                                                   CON42290
      CPAFN=GAS2                                                        CON42300
      IF (IMIX.EQ.0) RETURN                                             CON42310
30    CONTINUE                                                          CON42320
C  INERT GAS IS AIR                                                     CON42330
C AIR CP, BTU / LB MOLE-DEGREE RANKIN                                   CON42340
      GAS1=7.139-0.9884E-3*T+0.1393E-5*T**2-0.3367E-9*T**3              CON42350
      CPAFN=GAS1                                                        CON42360
      IF (IMIX.EQ.0) RETURN                                             CON42370
C  INERT GAS IS MIXTURE OF AIR & CO2                                    CON42380
      GAS3=(GAS1+GAS2)/2.0                                              CON42390
      CPAFN=GAS3                                                        CON42400
      RETURN                                                            CON42410
      END                                                               CON42420
C                                                                       CON42430
C                                                                       CON42440
      FUNCTION CPFN (C,T)                                               CON42450
10    IF (C-0.005) 20,20,30                                             CON42460
C*****EQUATION SPECIFIC HEAT FOR PURE WATER                              CON42470
20    CP=1.0121559+(-0.24618473E-3+0.10282155E-5*T)*T                   CON42480
      GO TO 40                                                          CON42490
C*****EQUATION SPECIFIC HEAT FOR BRINE                                   CON42500
30    CP=.96946859+(2.*(0.00010404965)*T)-(.91199294*C)+(2.*(-.000648296CON42510
     159)*C*T)+(-1.555779*(C**2))+(2.*(.0076721465)*(C**2)*T)+(6.7981008CON42520
     2*(C**3))+(2.*(-.012610354)*(C**3)*T)                              CON42530
40    CPFN=CP                                                           CON42540
      RETURN                                                            CON42550
      END                                                               CON42560
C                                                                       CON42570
C                                                                       CON42580
      FUNCTION CPSFN (T)                                                CON42590
C***                                                                    CON42600
C     CPSFN CALCULATES THE HEAT CAP OF STEAM IN BTU/LB-MOL-R GIVEN T IN CON42610
C    DEG R. EQUATIONS FROM H. NORITAKE, BASED ON TABULATED VALUES IN    CON42620
C    NASA TR-R-132                                                      CON42630
C***                                                                    CON42640
      CPSFN=(7.838-(.2531E-3-(.2892E-6-.7693E-10*T)*T)*T)               CON42650
      RETURN                                                            CON42660
      END                                                               CON42670
C                                                                       CON42680
C                                                                       CON42690
      FUNCTION HFGFN (T)                                                CON42700
      HFGFN=1093.88-0.5703*T+.00012819*T**2-.0000008824*T**3            CON42710
      RETURN                                                            CON42720
      END                                                               CON42730
C                                                                       CON42740
C                                                                       CON42750
      SUBROUTINE PRSDRP (TSAT,VMIX,WS,WNC,AXC,SDO,SF,DELPTP,ENHF)       CON42760
CCC                                                                     CON42770
C    PRSDRP  REBUILT ON 9-16-69 TO USE EQUATICN FCR SF                  CON42780
CCC                                                                     CON42790
      SG=32.174                                                         CON42800
      GSTAR=(WS+WNC)/(AXO*3600.)                                        CON42810
      ANRE=(SCO*GSTAR)/SMUFN(TSAT)                                      CON42820
      SF=(0.102+52.2/ANRE)*ENHF                                         CON42830
      DELPTP=SF*GSTAR**2*VMIX/(72.0*SG)                                 CON42840
      RETURN                                                            CON42850
      END                                                               CON42860
C                                                                       CON42870
C                                                                       CON42880
      FUNCTION PSATFN (T)                                               CON42890
      PSATFN=2.718**(14.150119-(6452.5621/T)-(837533.21/T**2))          CON42900
      RETURN                                                            CON42910
      END                                                               CON42920
C                                                                       CON42930
C                                                                       CON42940
      FUNCTICN ROEFN (C,T)                                              CON42950
C     DENSITY OF SALINE SOLUTION.  RANGE OF DATA WAS 0 - 26 PERCENT     CON42960
C     CONCENTRATION AND 40 - 300 DEGREES FARENHEIT.                     CON42970
      ROEFN=0.62707172E2+0.49364088E2*C-(0.43955304E-2+0.32554667E-1*C+(CON42980
     10.46076921E-4-0.63240299E-4*C)*T)*T                               CON42990
      RETURN                                                            CON43000
      END                                                               CON43010
C                                                                       CON43020
C                                                                       CON43030
      FUNCTICN SKBFN (C,T)                                              CON43040
C               THERMAL CONDUCTIVITY OF SALINE SCLUTION.  RANGE OF DATA CON43050
C               0 - 24 PERCENT CONCENTRATION AND 40 - 300 DEGREES FARENHEITCON43060
      SKBFN=(.30157913+.697989E-3*T-.12506E-5*T**2-.2072E-10*T**3)*(-.16CON43070
     187109*C+1.)                                                       CON43080
      RETURN                                                            CON43090
      END                                                               CON43100
C                                                                       CON43110
C                                                                       CON43120
      FUNCTICN SMUFN (T)                                                CON43130
      SMUFN=1.0E-5*(0.122+(1.001E-3)*T+(2.892E-7)*T**2-(7.693E-11)*T**3)CON43140
      RETURN                                                            CON43150
      END                                                               CON43160
C                                                                       CON43170
C                                                                       CON43180
      FUNCTION TSATFN (P)                                               CON43190
      AA=(ALOG(P)-14.150119)                                            CON43200
      DET=6452.5621**2-(4.0*AA*837533.21)                               CON43210
      IF (DET) 10,20,20                                                 CON43220
 10   WRITE (6,60)                                                      CON43230
      CALL EXIT                                                         CON43240
 20   X=(-6452.5621+SQRT(DET))/(2.0*AA)                                 CON43250
      Y=(-6452.5621-SQRT(DET))/(2.0*AA)                                 CON43260
      IF (X-Y) 30,40,40                                                 CON43270
 30   TSATFN=Y                                                          CON43280
      GO TO 50                                                          CON43290
 40   TSATFN=X                                                          CON43300
 50   CONTINUE                                                          CON43310
      RETURN                                                            CON43320
 60   FORMAT (1H1,37HSUBROUTINE TSATFN FINDS COMPLEX ROOTS)             CON43330
      END                                                               CON43340
C                                                                       CON43350
C                                                                       CON43360
      FUNCTION VGFN (T,P)                                               CON43370
      X=ALOG(T/P)                                                       CON43380
      VGFN=EXP(((.103758E-2*X-.0177861)*X+1.10267)*X-.72240)            CON43390
      RETURN                                                            CON43400
      END                                                               CON43410
C                                                                       CON43420
C                                                                       CON43430
      SUBROUTINE SWITCH (A,N)                                           CON43440
      DIMENSION A(N)                                                    CON43450
      NN=N/2                                                            CON43460
      K=N+1                                                             CON43470
      DO 10 I=1,NN                                                      CON43480
      T=A(I)                                                            CON43490
      A(I)=A(K-I)                                                       CON43500
      A(K-I)=T                                                          CON43510
 10   CONTINUE                                                          CON43520
      RETURN                                                            CON43530
      END                                                               CON43540
```

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