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HAMOC
A COMPUTER PROGRAM
FOR FLUID HAMMER
ANALYSIS

MASTER

HANFORD ENGINEERING DEVELOPMENT LABORATORY
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H. G. Johnson

December, 1975

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H. G. Johnson

ABSTRACT

A computer program has been developed for fluid hammer analysis of piping systems attached to a vessel which has undergone a known rapid pressure transient. The program is based on the characteristics method for solution of the partial differential equations of motion and continuity. Column separation logic is included for situations in which pressures fall to saturation values.

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HAMOC, A COMPUTER PROGRAM FOR FLUID HAMMER ANALYSIS

1.0 INTRODUCTION

In the design and safety analysis of nuclear reactor systems, one important required calculation is the prediction of fluid hammer pressures in piping systems connected to a reactor which has undergone a hypothetical core disruptive accident. The WHAM⁽¹⁾ Computer Program was preliminarily adapted to the solution of the Fast Flux Test Facility (FFTF) problems, but the WHAM code incorrectly computed pressures below saturation during the time of the hydraulic transients. The appearance of these below-saturation pressures severely limits the code's usefulness because the possibility of such pressures is not considered in the code's logic. Therefore, calculations made after the first appearance of these subsaturation pressures are probably grossly in error.

The HAMOC (Hammer Analysis by the Method Of Characteristics) computer program was therefore developed to replace the WHAM code for FFTF Safety Analysis work being done at the Hanford Engineering Development Laboratory. HAMOC includes simplified column separation logic as outlined by Streeter and Wylie.⁽²⁾ HAMOC has also been written specifically for problems in which forcing pressures are known as a function of time at certain end boundary conditions, rather than as a general purpose code for the solution of pump coastdown or valve closing type problems. HAMOC could, however, be extended to solve these problems.

2.0 SUMMARY

A computer program, HAMOC, has been written for the solution of fluid hammer analysis problems for piping systems in which transient forcing pressures at one or two end boundary conditions are known. The program is based on the characteristics method, which converts the two partial differential equations of continuity and motion into four total differential equations which can be programmed for a first order finite difference computer solution. Frictional losses and changes in elevations are allowed for in piping runs and connecting pipe fittings. The common fittings--elbows, tees or Ys, expansions, contractions, orifices or orifice-type restrictions (i.e., valves)--are included in the logic. Dead ends and pressurizers may be included in system models at the ends of pipe runs; and one or more centrifugal pumps may be specified, with the limitation that the pumps have the same characteristics and speed.

Simplified column separation logic is included to approximate the conditions when pressures fall to saturation. Temporary internal boundary conditions are imposed until the vapor cavity vanishes. The special boundary conditions can be established as often as needed.

A greatly simplified plastic deformation model is available in the program. Plastic yielding is simulated by the use of appropriately placed fictitious tee junctions which absorb pressures greater than yield by means of branch connections to special pressurizer-type junctions held at the yield pressure of the pipe leg. Each of these tee junctions behaves as an ordinary continuing pipe junction whenever the junction pressure is equal to or less than the yield pressure. Energy deposition is estimated by integrating the volume flow out of these tee junctions.

Simple or complex piping systems can be modeled, within the limits of computer storage capability. Piping crossties and bypasses are permitted. Initial pressure conditions are computed from known initial flow rates and system characteristics of pipe size, lengths, fluid temperatures, and specified pipe fittings and boundary conditions. The fluid temperature is assumed to remain constant during the transient, which is usually of a very short duration.

The code has been checked by comparison with the WHAM and the Westinghouse Electric Corporation proprietary BLOWN-2 fluid hammer codes and by comparison with experimental data. HAMOC results, including column separation calculations, appear to be satisfactory.

The use of the program is demonstrated by a sample problem.

3.0 PROGRAM DEVELOPMENT

3.1 Mathematical Model

The unsteady flow equations used in HAMOC are taken from Streeter and Wylie's book on hydraulic transients.⁽²⁾ The equations are summarized below. There is no intention to detail the derivations. The reader should refer to the referenced book for details.

The differential equations of continuity and motion, as derived in Reference (2), are given as follows for a single phase fluid in slightly deformable conduits:

$$\frac{\partial H}{\partial t} + \frac{a^2}{g} \frac{\partial V}{\partial x} + V \frac{\partial H}{\partial x} + V \sin \alpha = 0 \quad (1)$$

$$g \frac{\partial H}{\partial x} + V \frac{\partial V}{\partial x} + \frac{\partial V}{\partial t} + \frac{f V |V|}{2D} = 0 \quad (2)$$

$$H = Z + P/\rho \quad (3)$$

where

H = instantaneous piezometric head

a = speed of pressure pulse

g = gravitational acceleration

V = instantaneous fluid velocity

α = slope of pipe

f = Darcy-Weisbach friction factor

D = diameter of pipe

Z = elevation above datum

ρ = fluid density

P = pressure

t = time

x = distance along pipe

These equations assume that vapor pressures do not occur within the piping system and that no entrapped gases are present. The modifications used to account for column separation due to pressures indicated at or below vapor pressure are discussed subsequently.

The pair of partial differential equations in terms of the two dependent variables of velocity and head and two independent variables of time and distance are converted into four ordinary differential equations by the characteristics method. These four characteristics equations are:

$$\left. \begin{aligned} \frac{g}{a} \frac{dH}{dt} + \frac{dV}{dt} + \frac{g}{a} V \sin \alpha + \frac{f V |V|}{2D} &= 0 \\ \frac{dx}{dt} &= V + a \end{aligned} \right\} C^+ \quad (4)$$

$$\left. \begin{aligned} - \frac{g}{a} \frac{dH}{dt} + \frac{dV}{dt} - \frac{g}{a} V \sin \alpha + \frac{f V |V|}{2D} &= 0 \\ \frac{dx}{dt} &= V - a \end{aligned} \right\} C^- \quad (6)$$

$$(7)$$

The diagram below is helpful in understanding the subscripts introduced in the finite difference equations which approximate the above equations.

$$V_P - V_R + \frac{g}{a} (H_P - H_R) + \frac{g}{a} V_R \sin \alpha (t_P - t_R) + \quad (8)$$

$$\frac{f}{2D} V_R |V_R| (t_P - t_R) = 0$$

$$x_P - x_R = (V_R + a)(t_P - t_R) \quad (9)$$

$$V_P - V_S - \frac{g}{a} (H_P - H_S) - \frac{g}{a} V_S \sin \alpha (t_P - t_S) + \quad (10)$$

$$\frac{f}{2D} V_S |V_S| (t_P - t_S) = 0$$

$$x_P - x_S = (V_S - a)(t_P - t_S) . \quad (11)$$

The numerical solution for V_P and H_P at present time t and position x is obtained using the method of specified time interval. Conditions are known at points A, B, and C which permits conditions at R and S to be approximated by linear interpolation. The C^+ and C^- identified characteristic curves are curved lines because V is a function of t and x . The interpolated values are,

$$V_R = \frac{V_C - \theta a (V_C - V_A)}{1 + \theta (V_C - V_A)} \quad (12)$$

$$V_S = \frac{V_C - \theta a (V_C - V_B)}{1 - \theta (V_C - V_B)} \quad (13)$$

$$H_R = H_C - \theta (V_R + a)(H_C - H_A) \quad (14)$$

$$H_S = H_C + \theta (V_S - a)(H_C - H_B) \quad (15)$$

$$\theta = \Delta t / \Delta x . \quad (16)$$

To assure problem solution stability and/or convergence, it is necessary that $\Delta t (a+V) \leq \Delta x$ for all pipe legs in the model.

The general solution for velocity and head within a pipe of uniform diameter is obtained by combining Equations (8), (10), and (12)-(16):

$$V_p = .5 \left[V_R + V_S + \frac{g}{a} (H_R - H_S) - \frac{g}{a} \Delta t \sin \alpha (V_R - V_S) - \frac{f \Delta t}{2D} (V_R |V_R| + V_S |V_S|) \right] \quad (17)$$

$$H_p = .5 \left[H_R + H_S + \frac{a}{g} (V_R - V_S) - \Delta t \sin \alpha (V_R + V_S) - \frac{a}{g} \frac{f \Delta t}{2D} (V_R |V_R| - V_S |V_S|) \right] \quad (18)$$

Of more interest than the piezometric head is the fluid pressure, which is defined by Equation (3). The pressure at point P is then,

$$P_p = \rho_J (H_p - Z_p) \quad (19)$$

where ρ_J denotes the fluid density in leg J which contains nodal point P.

Equations (17), (18), and (19) are the ones written into the computer program for all interior nodal points within a given pipe leg between any two junctions or pipe fittings.

3.2 Internal Boundary Conditions

Special boundary condition equations, which are based on Equations (8) and (10), are written for the ends of pipe legs to account for junctions and pipe fittings. These boundary condition equations include frictional losses when applicable.

The types of junctions considered at the end of straight runs of pipes are listed in Table 1. The derivations of the equations used at junction

points are similar and are typically represented by the pump and orifice type junction examples given below. The pump head is considered as being added at the junction point and for other junction types, where the minor pressure losses are relevant, the minor losses are considered to occur at the junction point.

TABLE 1
JUNCTION TYPES INCLUDED IN HAMOC

<u>Identification Number</u>	<u>Junction Description</u>
1	Pump with quadratic equation to describe head, capacity, speed family of curves. Accounts for possible changes in flow areas and pressure pulse speed in the connecting pipe legs, but the fluid temperature must be the same for the connecting pipe legs.
2	Continuing pipe with no change in flow area but with possible changes in pressure pulse speed and/or fluid temperature for the connecting pipe legs.
3	Area change with possible changes in pressure pulse speed and/or fluid temperature in the connecting pipe legs.
4	Orifice type including valves and orifice restrictions with fixed hydraulic resistance, with no change in flow area for the connecting pipe legs, but with possible changes in pressure pulse speed and/or fluid temperature for the connecting pipe legs.
5	Elbow with no change in flow area for the connecting pipes but with possible changes in pressure pulse speed and/or fluid temperature for the connecting pipe legs.

TABLE 1 (contd)

<u>Identification Number</u>	<u>Junction Description</u>
6	Tee or Y with no change in fluid temperature for the connecting pipe legs but with possible changes in the flow area and/or pressure pulse speed for the connecting pipe legs.
7	Pressurizer.
8	Dead end.
9	Prescribed end boundary condition which identifies the pressure-time history at the boundary.
10	Orifice type restriction within a crosstie or bypass pipe line. Type 10 is the same as a type 4 orifice restriction except that the hydraulic resistance constant is computed within the program for the type 10 junction to balance the initial value system pressures in the crosstie or bypass to satisfy the known initial value flow rate conditions.
11	Special tee-type junction for simplified modeling of plastic yielding of a pipe leg.
12	Special pressurizer junction, which is always used in conjunction with a type 11 junction, for simplified modeling of plastic yielding of a pipe leg.

3.2.1 Pump Junction

There is no change in fluid density at this junction. Thus,

$$H_{J+1} + \frac{V_{J+1}^2}{2g_c} = H_J + \frac{V_J^2}{2g_c} + HD \quad (20)$$

where

H = head

V = fluid velocity

g_c = gravitational constant

HD = pump head

subscripts

J = pump inlet point

J+1 = pump outlet point

By continuity, for $\rho_J = \rho_{J+1}$,

$$V_{J+1} = \frac{A_J}{A_{J+1}} V_J \quad (21)$$

where

A = flow area.

The normalized pump head is characterized by a quadratic equation of the type,

$$\delta = \alpha^2 \left[PCA - PCB \left(\frac{v}{\alpha} - PCC \right) \left| \frac{v}{\alpha} - PCC \right| \right] \quad (22)$$

where

δ = normalized head

α = normalized pump speed

v = normalized flow rate

PCA, PCB, PCC = characterization constants.

$$HD = \delta (HDESIN) \quad (23)$$

$$v = \frac{(V_J)(A_J)}{QDESIN} \quad (24)$$

where

HDESIN = pump design head

QDESIN = pump design flow rate.

The normalized speed is inputted as a function of time by means of a program function named SPEED. Equation (8) is used to relate the fluid

velocity and head on the inlet side of the pump junction while Equation (10) is used for the outlet side:

$$V_J = C_3 - C_4 H_J \quad (25)$$

$$V_{J+1} = C_1 + C_2 H_{J+1} \quad (26)$$

where

$$C_3 = V_R + \frac{g}{a_J} H_R - \frac{g}{a_J} V_R \Delta t \sin \alpha_J - \frac{f_R \Delta t}{2D_J} V_R |V_R| \quad (27)$$

$$C_4 = \frac{g}{a_J} \quad (28)$$

$$C_1 = V_S - \frac{g}{a_{J+1}} H_S - \frac{g}{a_{J+1}} V_S \Delta t \sin \alpha_{J+1} - \frac{f_S \Delta t}{2D_{J+1}} V_S |V_S| \quad (29)$$

$$C_2 = \frac{g}{a_{J+1}} \quad (30)$$

C_1 , C_2 , C_3 , and C_4 are known quantities because they are based on geometric constants and preceding time information.

Combining Equations (20) through (30) results in Equation (31) which contains only the one unknown velocity V_J .

$$|V_J - (A_1)\alpha| (V_J - (A_1)\alpha) + \frac{A_2/C_2 + 1/C_4}{A_3} V_J - \quad (31)$$

$$\frac{C_1/C_2 + C_3/C_4 + \alpha^2(A_4)}{A_3} - (A_5) V_J^2 = 0$$

where A_1 , A_2 , A_3 , A_4 and A_5 are combinations of known quantities:

$$A_1 = (PCC)(QDESIN)/A_J$$

$$A_2 = A_J/A_{J+1}$$

$$A_3 = A_J^2(HDESIN)(PCB)/QDESIN^2$$

$$A_4 = (PCA)(HDESIN)$$

$$A_5 = (1 - A_2^2)/(A_3)/2g_c .$$

V_J is obtained by an iterative solution using the value at the preceding time as the first trial value. Values at the present time for the other unknowns V_{J+1} , H_J , and H_{J+1} are found by substitution back into Equations (21), (25), and (26). Pressures are obtained from the piezometric heads:

$$P_J = \rho_J (H_J - Z_J) \quad (32)$$

$$P_{J+1} = \rho_{J+1} (H_{J+1} - Z_{J+1}) . \quad (33)$$

3.2.2 Orifice-Type Junction

This junction is used to represent an orifice or valve with fixed hydraulic resistance. The diameters of the 2 pipe legs joined at the junction must be the same; however, the pressure pulse velocities and fluid temperatures of the legs may be different.

The simple orifice equation is used to relate pressure loss and flow rate:

$$V_o = C_o \sqrt{2g_c \Delta H} \quad (34)$$

where

C_o = orifice coefficient

V_o = fluid velocity in orifice opening.

For flow in the positive direction (from leg J to leg J+1),

$$V_o A_o \rho_J = V_J A_J \rho_J \quad (35)$$

As before, J denotes the leg on the upstream side of the junction (for + flow) and J+1 denotes the continuing leg on the downstream side.

Combining Equations (34) and (35) gives the junctions pressure loss as

$$\Delta P = (A_J/A_o/C_o)^2 \rho_J V_J^2 / 2g_c \quad (36)$$

$$= K \rho_J V_J^2 / 2g_c \quad (37)$$

$$\text{for } K = (A_J/A_o/C_o)^2 \quad (38)$$

Equation (38) is assumed to apply for flow in either direction.

A pressure balance for positive flow is given by Equation (39)

$$P_J + \rho_J \left(\frac{V_J^2}{2g_c} + Z_J \right) = P_{J+1} + \rho_{J+1} \left(\frac{V_{J+1}^2}{2g_c} + Z_{J+1} \right) + \frac{K \rho_J V_J^2}{2g_c} \quad (39)$$

By continuity,

$$V_{J+1} = V_J A_J \rho_J / A_{J+1} \rho_{J+1} \quad (40)$$

which simplifies to

$$V_{J+1} = V_J \rho_J / \rho_{J+1}$$

$$\text{for } A_J = A_{J+1} .$$

Relating piezometric head and pressure,

$$P_J = \rho_J (H_J - Z_J) \quad (41)$$

$$P_{J+1} = \rho_{J+1} (H_{J+1} - Z_{J+1}) \quad (42)$$

Velocities and heads at the boundaries are related by Equations (25) through (30) which are also used for the pump junction. Combining Equations (25) through (30) with Equations (37) through (42) gives an equation with V_J as the only unknown:

$$A V_J^2 + B V_J + C = 0 \quad (43)$$

where

$$A = \frac{1}{2g} \left[1 - K - \frac{\rho_J A_J^2}{\rho_{J+1} A_{J+1}^2} \right] \quad (44)$$

$$B = -\frac{1}{C_4} - \frac{1}{C_2} \frac{A_J}{A_{J+1}} \quad (45)$$

$$C = \frac{\rho_{J+1} C_1}{\rho_J C_2} + \frac{C_3}{C_4} \quad (46)$$

The program considers both roots as possible solutions. The correct root is determined if it exists consistent with the assumed positive flow. If the flow is shown not to be positive, then similar calculations are made for flow in the negative direction. For negative flow, the A coefficient of the quadratic equation is given by Equation (47) while the B and C coefficients continue to be defined by Equations (45) and (46):

$$A = \frac{1}{2g} \left[1 + (K - 1) \frac{\rho_J A_J^2}{\rho_{J+1} A_{J+1}^2} \right] \quad (47)$$

The two possible roots of the quadratic equation are considered; the one which is consistent with the assumed negative flow direction is accepted.

Once the velocity V_J is determined, the other unknowns of V_{J+1} , H_J , H_{J+1} , P_J , and P_{J+1} are determined by substitution into Equations (40), (25), (26), (41), and (42).

3.2.3 Continuing Pipe Junction

By definition $A_J = A_{J+1}$. However, the pressure pulse speeds and fluid temperatures in the two pipe legs may be different. The derivation of the velocity equation for leg J is the same as for the orifice type junction above except, of course, there is no pressure loss term. V_J is obtained as outlined for the orifice type junction considering the possibilities of positive and negative flow directions and considering both roots of the quadratic equations in V_J . The computations of the other unknowns follow by substitution back into the equations, just as in the case of the orifice type junction.

3.2.4 Area Change Junction

There are no restrictions on the area change junction. The pressure pulse speeds and fluid temperatures, as well as the pipe leg diameters, may be different for the 2 pipe legs joined at the junction.

The K factors for area change frictional losses are listed in Table 2.

TABLE 2
K FACTORS FOR AREA CHANGES

<u>Type of Area Change</u>	<u>Flow Direction</u>	<u>K Factor Definition</u>
expansion	positive	$(1 - A_J/A_{J+1})^2$
contraction	positive	$.5(1 - A_{J+1}/A_J)$
contraction	negative	$.5(1 - A_J/A_{J+1})$
expansion	negative	$(1 - A_{J+1}/A_J)^2$

The fluid velocity V_J and other unknowns are obtained as outlined for the orifice type junction in which the above K factors replace the K as defined for the orifice.

3.2.5 Elbow Junction

The diameters of the joining pipe legs are assumed to be equal, but the pressure pulse speeds and fluid temperatures may be different for the two legs.

The minor pressure losses are accounted for by specifying in input an L/D value for the elbow. The product of L/D and friction factor f gives a K factor which is equivalent to the orifice K as used in the orifice junction derivation above.

To prevent an iterative procedure in computing the K value for the elbow, the preceding time plane fluid velocity for leg J for positive flow or leg J+1 for negative flow is used in computing a Reynolds number which in turn gives the friction factor. The procedure should be acceptable considering the uncertainty in the L/D values.

The velocity V_j and other unknowns are then computed identically as outlined for the orifice type junction above.

3.2.6 Tee or Y Junction

In order to prevent extensive complications in the column separation logic at the tee type junctions, it is necessary to make the fluid temperatures the same for all 3 legs joining at the junction. However, the diameters and pressure pulse speeds of the legs may be different.

The minor pressure losses are allowed for at the junction by use of input specified L/D values for each leg connection (i.e., for a total of 3). As in the case of the elbow junction, the product of the L/D value and friction factor f gives a K value which is used to estimate the pressure losses in each of the connections at the tee. The tee losses, whether in through flow or branch flow, are considered to be made up of two losses in series in which the L/D values represent the fixed hydraulic resistances. The characteristic values can be estimated by using typical L/D values assigned for through and branch flow. For example, if the L/D for a through flow tee is 20, each leg connection in the through flow pattern could be given a L/D of 10; likewise, if the branch flow L/D normally assigned to a tee is 60, then the branch connection would be assigned a L/D value of 50, with the associated through flow connection already having the balancing L/D of 10.

The friction factors, as in the case of the elbow junction, are based on the preceding time plane velocities. Individual factors are used for each of the 3 connections.

The derivation of the equations which results in a single equation with V_J as the only unknown proceeds in the same way as for the pump or elbow junctions except that more equations are involved because of the added junction connection. In this case, an iterative solution, making use of the preceding time plane velocity data as the first trial values, is used to find the proper V_J value considering all 6 possible combinations of flow directions shown in Figure 1. After the proper value of V_J is obtained, substitution back into the equations yields V_{J+1} , V_{J+i} , H_J , H_{J+1} , H_{J+i} , P_J , P_{J+1} , and P_{J+i} .

3.2.7 Pressurizer Junction

The pressurizer type junction is always located at the end of a pipe leg. Expanding flow into the pressurizer is then positive and contracting flow out is negative by definition. The pressurizer pressure at the junction point is held constant at the initial time value throughout the transient, but the boundary condition pressure at the last nodal point in the leg at the junction is computed recognizing the flow direction, and whether there is an expansion or contraction.

In the case of positive flow (i.e., expansion loss and velocity head recovery), the nodal point pressure and pressurizer pressure are the same because the expansion loss of one velocity head just balances the recovery of one velocity head. For negative flow, the total pressure difference allowed is 1.5 velocity heads, including 0.5 for the sudden contraction loss.

FIGURE 1. Tee of Y Junction Flow Direction Combinations.

For positive flow, V_J is given by a linear equation; for negative flow, V_J is obtained from a quadratic equation considering the two possible roots. The piezometric head and pressure at the junction are then obtained by substitution back into the appropriate equations.

3.2.8 Dead-End Junction

The dead-end junction is always placed at the end of a pipe leg. The fluid velocity at the junction point is zero throughout the transient. Hence, the solution of H_J is directly obtained from an equation typified by Equation (25). Pressure is then computed from the known piezometric head.

3.2.9 Special End Boundary Condition Junctions

The boundary condition junction equations at the upstream end of the first pipe leg and the special boundary condition junction equations at the end of a leg are derived considering flow direction and whether there is a sudden expansion or sudden contraction. The logic is the same as that given for the pressurizer junction, the only difference being that the pressures are not necessarily constant with time. The forcing pressure for the boundary condition at the start of leg number 1 is read into the computations using the program's PBACKR function, and the forcing pressure for the other special boundary conditions (only one permitted) is read from the PBACK function. These functions, of course, must be developed by the program user to describe the programs forcing conditions as functions of time.

3.2.10 Special Orifice-Type Junction

This special orifice-type junction is used whenever the system model includes bypasses or piping crossties. The logic is identical to the

ordinary orifice-type junction described before, except that the K value is computed within the program rather than being specified directly by an input K value. The K value is determined as a part of the initial value calculations such that the system pressures around the bypass or crosstie are entirely consistent with the other system pressures at the initial conditions. Once computed, the K value remains constant; hence, the transient calculations are identical to those described for the ordinary orifice-type junction.

3.2.11 Special Plastic Deformation Tee Junction

This junction represents a fictitious tee junction in a straight run of pipe. The branch leads directly to a special type 12 pressurizer junction (also imaginary) which is held at the yield pressure of the pipe run. These two junctions are closely coupled by a short pipe leg.

The junction behaves as a continuing pipe junction whenever the junction pressure is equal to or less than yield. When pressure exceeds yield, it allows coolant flow to the connected pressurizer. In this way, the pipe leg maximum pressure is more or less kept close to yield. The flow out of the tee branch is integrated to give an estimate of the energy deposition:

$$E = PA \int_0^t V dt \quad (48)$$

where

E = energy, lb-ft

P = constant pressurizer pressure (yield), psi

A = cross sectional area of tee branch pipe leg, sq ft

V = branch leg coolant velocity, ft/sec.

3.2.12 Special Plastic Deformation Pressurizer Junction

This junction is only used with the type 11 tee junction. It is the same as an ordinary type 7 pressurizer except that the pressure is constant at the yield pressure of the pipe run which includes the type 11 tee junction. The yield pressure is determined during initial value calculations from the inputted leg temperature and pipe size data.

3.3 Column Separation

The column separation model is based on the logic given in Chapter 12 of Reference 2. Admittedly, the procedure is a simplification of the actual process, but reasonable results can be expected especially since the cavity volumes are small relative to the pipe volumes.

Whenever the pressure at an interior nodal point I within a leg J is calculated to be less than the saturation pressure, temporary boundary conditions are imposed at that point and at the following point I+1 by setting these nodal point pressures to saturation. The boundary fluid velocities are recomputed at the saturation pressure by using Equations (8) and (10) for nodal points I and I+1, respectively. The cavity volume is then computed for nodal point I in leg J as,

$$CAVOL_J = \sum A_J \Delta t (\bar{V}_{I+1} - \bar{V}_I) \quad (49)$$

where

CAVOL = cavity volume

Δt = program specified time step

$\bar{V}$ = average velocities over the time step.

The temporary boundary conditions are retained until the cavity vanishes, as shown by a negative value for CAVOL.

When the cavity collapses, the two separate liquid columns may impact to produce a sudden pressure rise at I as given by Equation (50), but limited by (51):

$$P_I = PSAT_J + \frac{a_J}{2g} (V_I - V_{I+1}) \rho_J \quad (50)$$

$$P_I \geq PSAT_J \quad (51)$$

where

$PSAT_J$ = saturation pressure in leg J containing nodal point I.

There is uncertainty that the impact pressure calculated in this way is entirely realistic for the LMFBR loop-type piping systems. An alternative calculation is to hold the pressure at saturation when the cavity just vanishes and compute the subsequent pressure rise by the usual characteristics method solution using Equations (17), (18), and (19). The former scheme gives the most conservative results. The code is programmed to select one method or the other using an inputted control integer, KAVITY.

Calculations return to the normal solution by the characteristic method after the cavity collapses and the collapse pressure is computed.

Only one cavity is allowed to form in a leg at any one time. The formation of a subsequent cavity is further constrained by the time it takes the pressure wave from the first cavity to reach the end of that leg after the cavity collapses. In addition, a new cavity is not allowed to form until the fluid pressure at some point in a following leg is greater than saturation. The pressures are set to saturation for the nodal and junction points associated with the given cavity in leg J when pressures are calculated to be less than saturation by the usual characteristics method. The

usual characteristics method fluid velocities are used for such interior nodal points and junction points. These nodal points contribute to the leg J cavity volume by using Equation (49).

If the pressure at a junction point is the first pressure calculated to be less than saturation, it is simply set to saturation and calculations proceed in the usual way. An adjacent interior nodal point very quickly reaches saturation so the cavity is said to form there, rather than at the junction point. In this way, a cumbersome, simultaneous solution of a set of boundary condition equations is avoided at the junction, with little loss of accuracy.

There is one last adjustment which has to be made in case the pressure at the next-to-last nodal point in a leg is the first pressure to fall below saturation. There would be a problem in computing the velocity at the I+1 nodal point because of the need for I+2 data. Thus, an adjustment is made which shifts the cavity to the preceeding nodal point when the above occurs.

3.4 Initial Conditions

3.4.1 Pressure and Piezometric Head

Initial values for pressure are obtained from a mechanical energy balance in which the fluid density within a leg is constant. The calculations are based on input specified values of fluid flow rate and temperature and pipe data. The Darcy-Weisbach friction factor for frictional losses is computed as a function of Reynolds number, pipe diameter, and input given pipe wall surface roughness.

The pressure losses at junctions are computed using the same definitions for minor pressure losses previously given for the transient calculations.

Calculations proceed from leg to leg in sequence until a type 10 orifice junction is encountered in a bypass or crosstie line. This type junction denotes that a special calculation procedure is needed to balance the system pressures in accordance with the known flow rates. When the type 10 junction is encountered, calculations then jump to the end of the bypass or crosstie where the pressure has already been computed, and the steady state pressure calculations then proceed backward from this point to the downstream side of the type 10 junction. One or more legs may be included in this backward direction calculation procedure. In this way, the pressures on the two sides of this special orifice-type junction are identified, which allows the junction's K value to be determined to give the required pressure loss at the known flow rate. This K value is held constant for subsequent transient calculations.

The steady-state equations are listed below for nodal point I in leg J:

$$V_I = w_J / (\rho_J \pi D_J^2 / 4) \quad (52)$$

where

w_J = input specified mass flow rate for leg J.

$$P_I = P_{I-1} + \rho_J \left[\frac{g}{g_c} Z_{I-1} + \frac{V_{I-1}^2}{2g_c} - \frac{g}{g_c} Z_I - \frac{V_I^2}{2g_c} - F \right] \quad (53)$$

where

F = friction loss head.

For pipe runs in which $V_{I-1} = V_I$

$$F = \frac{f_J(\Delta x_J) V_I |V_I|}{2g_c D_J} \quad (54)$$

where

Δx_J = distance between nodal points.

$$f_J = \text{function } (Re_J, D_J, E) \quad (55)$$

where

f = Darcy-Weisbach friction factor

Re = Reynolds number

E = pipe wall surface roughness.

For junctions connecting legs J and $J+1$,

$$P_{J+1} = P_J + \rho_J \left[\frac{g}{g_c} Z_J + \frac{V_J^2}{2g_c} \right] - \rho_{J+1} \left[\frac{g}{g_c} Z_{J+1} + \frac{V_{J+1}^2}{2g_c} \right] \quad (56)$$

$$+ (\rho_J)(HD) - FL$$

where

HD = pump head, if any

ρ_J = fluid density

FL = friction pressure loss, if any

$$V_{J+1} = V_J A_J \rho_J / A_{J+1} \rho_{J+1} \quad (57)$$

The equations for HD and FL for junction types are listed in Table 3.

The piezometric heads are determined from the pressures and elevations using the definition provided by Equation (3). The reference elevation is the beginning of leg 1 which is taken as zero feet.

TABLE 3
FRICTION LOSS AND PUMP HEAD EQUATIONS FOR JUNCTIONS

Junction Type	Junction Name	Equation
1	Pump	see Equations (22) - (24) for HD
2	Continuing pipe	none
3	Area Change:	
	a. + Flow with contraction	$FL = \left[.5 (1 - A_{J+1}/A_J) V_{J+1}^2 / 2g_c \right] \rho_{J+1}$
	b. + Flow with expansion	$FL = \left[(1 - A_J/A_{J+1})^2 V_J^2 / 2g_c \right] \rho_J$
	c. - Flow with expansion	$FL = \left[(1 - A_{J+1}/A_J)^2 V_{J+1}^2 / 2g_c \right] \rho_{J+1}$
	d. - Flow with contraction	$FL = \left[.5 (1 - A_J/A_{J+1}) V_J^2 / 2g_c \right] \rho_J$
4	Orifice	
	a. + flow	$FL = \left[\left(\frac{A_J}{A_o C_o} \right)^2 V_J^2 / 2g_c \right] \rho_J$
	b. - flow	$FL = \left[\left(\frac{A_J}{A_o C_o} \right)^2 V_{J+1}^2 / 2g_c \right] \rho_{J+1}$
5	Elbow	
	a. + flow	$FL = \left[f (L/D) V_J^2 / 2g_c \right] \rho_J$ $f = \text{function } (Re_J, D_J, E)$
	b. - flow	$FL = \left[f (L/D) V_{J+1}^2 / 2g_c \right] \rho_{J+1}$ $f = \text{function } (Re_{J+1}, D_{J+1}, E)$

TABLE 3 (Cont'd)

Junction Type	Junction Name	Equation
6	Tee or Y For P_{J+1}	$FL = \left[f_J (L/D)_J V_J V_J / 2g_c \right. \\ \left. + f_{J+1} (L/D)_{J+1} V_{J+1} V_{J+1} / 2g_c \right] \rho_J$
	For P_{J+i}	$FL = \left[f_J (L/D)_J V_J V_J / 2g_c \right. \\ \left. + f_{J+i} (L/D)_{J+i} V_{J+i} V_{J+i} / 2g_c \right] \rho_J$
7	Pressurizer a. + flow	$FL = \left[V_J^2 / 2g_c \right] \rho_J$
	b. - flow	$FL = \left[.5 V_J^2 / 2g_c \right] \rho_J$
8	Dead End	$FL = 0$
9	Special Boundary Condition	
	a. Sudden contraction	$FL = \left[.5 V_J V_J / 2g_c \right] \rho_J$
	b. Sudden expansion	$FL = \left[V_J V_J / 2g_c \right] \rho_J$
10	Special Orifice	see type 4 orifice equations
11	Special Plastic Deformation Tee	None
12	Special Plastic Deformation Pressurizer	same as junction type 7 with + flow

The special plastic deformation type 11 junctions revert to ordinary continuing pipe junctions initially, while the special type 12 pressurizer junction's pressures are determined based on yield pressure for the inputted leg temperatures and pipe size data.

3.4.2 Pressure Pulse Speed

The pressure pulse speed is computed based on the input specified fluid temperature and pipe diameter and pipe wall thickness. For leg J,

$$a_J = \frac{\sqrt{g K_J / \rho_J}}{\sqrt{1 + \left(\frac{K D}{E e} \right)_J C}} \quad (58)$$

where

K = bulk modulus of elasticity of the fluid

E = Young's modulus of elasticity of the pipe material

e = pipe wall thickness

C = correction for Poisson ratio effects.

C = 1 used in HAMOC for a piping system in which the overall pipe length is maintained constant by anchors, with expansion joints throughout. Speeds for other types of construction would be only slightly greater because the values of C do not exceed 1, and range usually from .91 to 1.

3.4.3 Physical and Mechanical Properties

HAMOC includes properties of liquid sodium and 304 stainless steel as given below:

Sodium density is given as ⁽³⁾,

$$\rho = 59.566 - 7.9504 \times 10^{-3} T - .2872 \times 10^{-6} T^2 + .06035 \times 10^{-9} T^3, \text{ lb/ft}^3 \quad (59)$$

where

T = fluid temperature, °F.

Sodium viscosity is obtained from⁽³⁾,

$$\text{Log}_{10} \mu = 1.0203 + \frac{397.17}{T + 459.688} - .4925 \text{Log}_{10}(T + 459.688) \quad (60)$$

with μ units of lb/ft-hr

The bulk modulus of elasticity of liquid sodium is determined as

$$K = \rho C^2 / g \quad , \text{ psf} \quad (61)$$

where

C = sonic velocity in sodium .

Sonic velocity is given as⁽³⁾,

$$C = 8488. - .95T \quad , \text{ ft/sec} \quad (62)$$

The saturation pressure of sodium is obtained from⁽³⁾,

$$\text{Log}_{10} PA = 6.4818 - \frac{10020.6}{T + 460} - .5 \text{Log}_{10} (T + 460) \quad (63)$$

where

PA = vapor pressure, atm.

The saturation pressure in psig units is then given as

$$PSAT = 14.7 (PA - 1) \quad . \quad (64)$$

Young's modulus of elasticity for 304 stainless steel is obtained by linearizing the data included in the LMFB Materials Handbook:⁽⁴⁾

For $T \leq 900^\circ\text{F}$,

$$E' = 29.2857 \times 10^6 - 6428.57 T \quad , \text{ psi} \quad (65)$$

and for $T > 900^\circ\text{F}$

$$E' = 31.2885 \times 10^6 - 8653.85 T \quad , \text{ psi} \quad (66)$$

The yield strength of Type 304 stainless steel is given as,

$$\sigma_Y = 1000 (11.29 - 1.23 \times 10^{-3} T) , \text{ psi} \quad (67)$$

The yield pressures of the pipes are estimated by,

$$P_Y = 0.1917 \sigma_Y e/D' \quad (68)$$

where

σ_Y = yield strength, psi

e = pipe wall thickness, in.

D' = pipe ID, ft.

The physical and mechanical properties are held constant throughout the transient.

3.5 Computer Program

3.5.1 Organization

The HAMOC Program's organization is illustrated in Figure 2. The main program, HAMOC, is used with the DATA, INIT, JNCTN REPT, BDUMP, PLTT, PPLT, SETPLT, and MOVEIT subroutines and PBACK, PBACKR, SPEED, FRICTF, and FLD functions. The common deck KOMMN is used with the main program and all subroutines and functions, except FRICTF, FLD, MOVEIT and possibly the user-developed PBACKR and PBACK functions.

Most calculations are done outside of the main program, but there are two exceptions. One is the transient calculations (for time >0) for the interior nodal points in all the pipe legs. The other is the transient calculation of the fluid velocity, pressure and piezometric head for the beginning junction for leg 1. Otherwise, HAMOC simply integrates the calling of subroutines, keeps track of the time, performs initialization requirements, and sets up plotting and writing requirements.

FIGURE 2. HAMOC Flow Chart.

The DATA subroutine reads into the program and writes out the input specified data, except for plotting information. The INIT subroutine is called from DATA.

The INIT subroutine performs the initial value calculations for all legs, all nodal points within the legs, and for all junction points. It also calculates the physical and mechanical properties for the fluid and pipe. INIT makes use of the SPEED, FRICTF, PBACKR, and PBACK functions.

The JNCTN subroutine calculates the fluid velocities, pressures and piezometric heads for all junctions at the end of pipe legs. It uses the FRICTF, SPEED, and PBACK functions.

The REPT subroutine writes out the calculated initial value and transient fluid velocities and pressures at the beginning and end of each leg as well as the adjacent interior points. Data are reported at each time plane as specified by the input variable NWRIT.

The SETPLT, BDUMP, PLTT, and PPLT subroutines plot the calculated pressure data versus time for locations as specified by input. Data are plotted at each time plane as specified by the input variable MPLOT. The SETPLT subroutine sets up disk files for storage, reads plot titles, plot scale data, and system model locations to be plotted. SETPLT also stores the plot titles for subsequent plotting.

BDUMP stores calculated data for subsequent plotting.

PLTT recalls data to be plotted and closes out the plotting routines when the plots are complete.

PPLT plots the data using a CALCOMP Plotter. Up to about 50 plots can be made per computer run, with only one line plotted per figure. A maximum number of 1000 points may be plotted per figure.

The SPEED function provides the normalized pump speed as a function of time. A special function must be written for each computer run.

The FRICTF function provides the Darcy-Weisbach friction factor as a function of fluid Reynolds number, pipe diameter in feet, and pipe wall surface roughness in feet. Comparative runs on typical piping systems have shown that output pressures and velocities are not changed significantly if a constant friction factor is used in place of the one which is a function of Reynolds number. Corresponding values differed by less than 1 percent, while the computer execution time was reduced by a factor of about 2.3 by use of the constant factor. The user must recompile the FRICTF function if he wishes to use a constant friction factor.

The PBACKR function provides the forcing pressure in units of psig at the inlet to the first pipe leg. This function must be written as a function of time for each computer run.

The PBACK function provides the forcing pressure in units of psig for a boundary condition junction at the end of one pipe leg. This function must be written as a function of time for each computer run.

FLD is an integer function which is used for bit string manipulation. There are three arguments:

- 1) ISTART is the starting bit position of argument WORD
- 2) MANY is the number of bits to be accessed in argument WORD
- 3) WORD is the bit string to be accessed.

FLD is used in the PPLT plotting subroutine and in the plotting portion of the main program for the exclusive purpose of manipulating plot information.

The MOVEIT subroutine transfers bits from one storage location to another. There are five arguments:

- 1) FROM is the word address of the source string to be moved
- 2) ISTRTF is the beginning bit position of the source string
- 3) TO is the word address of the destination string
- 4) ISTRTT is the beginning bit position of the destination string
- 5) Many is the number of bits to be moved.

MOVEIT is called from the SETPLT subroutine, and it is used only for manipulation of plot information.

The common deck, KOMMN, includes the necessary common and dimension statements for the program.

Copies of the Fortran listings of the program are included in Appendix B. The central processor's memory requirements are shown in the load map included in Appendix B.

3.5.2 Computer and Language and Program Size

The HAMOC Program is written in Fortran language for use with a CDC CYBER 74-18 computer, which has a central processing unit with 131072 60-bit word capacity. The computer storage capacity is nearly filled when the array variables dimensioned for NODAL and LEGS in the common deck KOMMN are such that about $60,300_{10}$ locations are used for these 33 variables:

$$60,300_{10} \approx (29 + 4 \times \text{NODAL}) \times \text{LEGS} .$$

Hence, the maximum value for the number of nodal points per leg would be about 43 for a specified dimension of 300 legs. These maximum dimensions may need to be changed (in either direction) depending on the storage needed for the user-specified PBACK, PBACKR and SPEED functions.

3.5.3 Program Restrictions and Limitations

There are a few program restrictions which the user must consider in setting up the model of the system to be analyzed. These rules are listed in Table 4.

Attention is called to paragraph 11 of Table 4. Although stability is assured by proper selection of the mesh ratio, the user should be aware of the accuracy dependence on the same mesh ratio. Improper mesh ratios can lead to numerical damping as discussed in Appendix A.

The plotting routines were originally developed for use in a UNIVAC 1108 version of HAMOC, but these routines have not been optimized for the CDC computer. These plotting routines require a large amount of computer capacity, which makes HAMOC a rather large program. Some of the problems with program size are alluded to in paragraph 13 of Table 4.

3.5.4 System Model Conventions

Program and program model conventions are listed in Table 5.

3.5.5 Organization of Input Data

A complete listing of input data definitions, organization and requirements is given in Table 6. The data on the 11 card types designated as A through K are self-explanatory except perhaps as follows:

- a. The pump constants PCA, PCB, and PCC are defined by Equation (22) in the text.
- b. The CV(J) values for the orifice and elbow junctions are defined as follows:

For an orifice,

$$CV(J) = K_J = \left(\frac{A_J}{A_O C_O} \right)^2$$

TABLE 4
HAMOC PROGRAM LIMITATIONS

1. Fluid temperatures are constant with time and they are also the same for all points within a leg.
2. Multiple pump junctions are permitted in the model, provided all pumps can be described by a single set of characteristics and speeds.
3. Fluid temperatures in all connecting legs around the pump and tee (or Y) junctions must be the same.
4. No more than 15 type 7 and/or type 12 pressurizer junctions and a maximum of 15 tee junctions are permitted.
5. Only one special boundary condition for the end of a pipe leg is permitted.
6. The flow areas of the legs connected by an orifice-type junction (type 4 or type 10 junctions) and by an elbow-type junction (type 5) must be the same.
7. There must be a pipe leg between any two junction points. Back-to-back junctions, such as two elbows to form a return bend, are not permitted. A fictitious short pipe leg can usually be used between adjacent fittings without losing significant problem solution accuracy.
8. Flow channels must be cylindrical or it must be acceptable to characterize them by cylindrical geometry.
9. All points within a given pipe leg must have the same slope.
10. The current version of HAMOC requires that the fluid be sodium and the pipe material to be a Type 304 stainless steel; but it would be a simple matter to expand the code to allow the use of other materials. The density, viscosity, saturation pressure, and the bulk modulus of elasticity for the fluid and Young's modulus, the yield strength and yield pressure of the pipe material would have to be provided as functions of temperature.

TABLE 4 (Cont'd)

11. The minimum leg length must be equal to or greater than the product of the inputted time step times the sum of the pressure pulse speed plus the fluid velocity,

$$\Delta x_{\text{MIN}} \geq \Delta t (a + V).$$

This limitation is needed to assure stability and/or convergence of the problem solution. The code provides output reports of legs with mesh ratios which may cause instability problems. Corrections can be made by changing the time step and/or by small changes of leg lengths.

12. No more than 50 plots are permitted per computer run, and a maximum of 1000 points can be plotted for each individual plot. Only plots of pressure in units of psig or pressure differences in units of psi between two locations versus time (in units of milliseconds) are programmed. Only one line can be drawn per plot.
13. The current dimensions of the number of legs (LEGS) and nodal points (NODAL) within a leg are 56 and 50, respectively. These values can be changed by recompiling the program using the common deck, KOMMN. The above values are consistent with the storage requirements for the plot routines which share memory with leg and nodal point dimensioned variables through the use of equivalence statements. A user would need to substantially revise the plotting routines if he wishes to reduce program size by using smaller dimensions for LEGS and/or NODAL. However, a user could use an equivalent combination such that,

$$12,824_{10} = (29 + 4 \times \text{NODAL}) \times \text{LEGS}.$$

TABLE 5
SYSTEM MODEL CONVENTIONS

1. Flow direction of fluid is taken as positive in the direction of increasing leg number and increasing nodal point number within a leg.
2. The beginning junction for the first leg (leg number 1) must be a boundary condition with the pressure/time history given by the function PBACKR.
3. Legs are numbered consecutively through all junctions until a prescribed boundary condition (type 9 junction), pressurizer (type 7 junction), or dead end (type 8 junction) is encountered. One of the two branches from a tee-type junction (type 6 or type 11) is numbered consecutively. The other branch of a tee-type junction is assigned a leg number following the last leg ending with a type 9 boundary condition, pressurizer, or dead end. Do not omit any numbers in the series of leg numbers. The input NOLEG must be equal to the highest leg number.
4. The prescribed boundary condition at the end of a leg is given by the function PBACK, which must be supplied in the program.
5. The elevation of the first nodal point of the first leg is taken to be zero feet as set internally in the subroutine INIT.
6. Nodal points within a given leg are numbered consecutively starting with 1 at the beginning of the leg:

7. The initial mass flow rates in units of lb/second must be specified for leg 1 and for each leg connected to a tee or Y junction in which the tee or Y is at the start of the leg. The initial fluid velocity for the leg ending with a dead end must be zero, of course.

TABLE 5 (Cont'd)

8. The pressurizer, dead end, and prescribed boundary condition junctions must be placed at the end of a leg (except for the forcing boundary condition at the start of leg 1).
9. The number of nodal points for each leg is computed within the program based in part on input specified leg lengths. An iteration on the system model will be needed if the number of nodal points in one or more legs exceeds NODAL. If this happens, make use of the continuing pipe junction type to increase the number of legs but to reduce the number of nodal points in the legs in question. Simple, preliminary hand calculations outside the program to determine the maximum allowable leg lengths will usually prevent the need for any model iterations.
10. The cavity collapse pressure is calculated from the impact equation (50) for KAVITY = 0. The impact equation is bypassed for KAVITY = 1. KAVITY is inputted on the second card of the data deck.
11. Computer memory can be used most efficiently with short leg lengths and extensive use of type 2 junctions.

TABLE 6

CARD ARRANGEMENT OF INPUT FOR HAMOC

Card Number	Card Type	Purpose (to provide)	Arrangement of Data on Standard 80 Column Computer Cards		
			Data	Column Locations	Type of Number and Format
1	A	Identification of run	Arbitrary run title (IDENA)	1-48	Alphanumeric. 4A10, A8
2	B	Miscellaneous data	Time step (DT), seconds	1-10	Real. F10.6
			Run stop time (TEND), seconds	11-20	Real. F10.6
			Absolute pipe wall roughness (E), ft	21-30	Real. F10.6
			Number of legs in system model (NOLEG)	31-35*	Integer. I5
			Frequency of writing output data (NWRIT)	36-40*	Integer. I5
			Frequency of plotting output data (MPLOT)	41-45*	Integer. I5
			Cavity collapse pressure equation integer control (KAVITY)	50	Integer. I1
3	C	Pump Curve Equations	Pump curve characterization constant PCA	1-10	Real. F10.6
			Pump curve characterization constant PCB	11-20	Real. F10.6
			Pump curve characterization constant PCC	21-30	Real. F10.6
			Pump design head (HDESIN), ft	31-40	Real. F10.4
			Pump design flow rate (QDESIN), cfs	41-50	Real. F10.4
4 thru (NOLEG+3)	D	Pipe leg data: Provide one card for each leg. Arrange consecutively.	Leg number (J)	1-5*	Integer. I5
			Pipe diameter [D(J)], ft	6-15	Real. F10.4
			Leg length [LNTH(J)], ft	16-25	Real. F10.4
			Pipe wall thickness [THK(J)], inches	26-35	Real. F10.4
			Fluid temperature [TEMP(J)], °F	36-45	Real. F10.4
			Hydraulic resistance constant for ordinary orifice and elbow-type junctions if at the end of the pipe leg; otherwise blank [CV(J)]	46-55	Real. F10.2
			Pipe leg slope [ANGLE(J)], degrees from hori- zontal. + for upward direction. - for down- ward direction.	56-60	Real. F5.1
			Junction type at start of leg [JTYPE1(J)]	61-65*	Integer. I5
			Junction type at end of leg [JTYPE2(J)]	66-70*	Integer. I5
			Junction number at start of leg [JN01(J)]	71-75*	Integer. I5
			Junction number at end of leg [JN02(J)]	76-80*	Integer. I5

*Integers right justified.

TABLE 6

CARD ARRANGEMENT OF INPUT FOR HAMOC (cont'd)

Arrangement of Data on Standard 80 Column Computer Cards					
Card Number	Card Type	Purpose (to provide)	Data	Column Locations	Type of Number and Format
(NOLEG+4) thru (NOLEG+4+X)	E	Flow Rate Data: Provide card for leg number 1, plus one card each for each leg connected to a tee or Y in which the tee or Y is at the start of the leg. Let X be the number of these legs leaving the tees or Ys.	Leg number (J) Flow rate [W(J)], lb/sec	1-5* 6-20	Integer. I5 Real. F15.6
(NOLEG+5+X)	F	Check for correctness of number of flow rate cards.	- 1	4-5	Integer. I2
(NOLEG+6+X) thru (NOLEG+5+X+Y)	G**	Tee junction hydraulic resistances: Provide one card for each tee-type junction. Let Y be the number of tees or Y.	Tee number (number consecutively starting with 1)(JN) Tee junction number (JNX) L/D value for first leg [CVTEE1(JN)] L/D value for next leg [CVTEE2(JN)] L/D value for other leg [CVTEE3(JN)]	1-5* 6-10* 11-20 21-30 31-40	Integer. I5 Integer. I5 Real. F10.4 Real. F10.4 Real. F10.4

NOLEG+6+X+Y	F**	Check for correctness of number of tee junction cards.	- 1	4-5	Integer. I2
NOLEG+7+X+Y	H	Plot Identification:	TITLE (TITLE denotes ID card) Second line on every plot.	1-5 21-80	Alphanumeric. A6 Alphanumeric. 6A10

*Integers right justified.

**Cards G and F are omitted if no tee or Y junctions are included in the model.

TABLE 6

CARD ARRANGEMENT OF INPUT FOR HAMOC (cont'd)

<u>Arrangement of Data on Standard 80 Column Computer Cards</u>					
<u>Card Number</u>	<u>Card Type</u>	<u>Purpose (to provide)</u>	<u>Data</u>	<u>Column Locations</u>	<u>Type of Number and Format</u>
NOLEG+8+X+Y	I	Plot Scale Data	SC (SC denotes scale card)	1-2	Alphanumeric. A6
			Initial time, milliseconds	21-30	Real. E10.0
			Time scale in milliseconds per inch on the X axis.	31-40	Real. E10.0
			Minimum pressure, psig for pressure plots or psi for ΔP plots.	41-50	Real. E10.0
			Pressure scale in psig (or psi) per inch on the y axis.	51-60	Real. E10.0
NOLEG+9+X+Y thru NOLEG+8+X+Y+Z	J	Model locations to be plotted and titles. Let Z be the number of plots.	P (P denotes plot card)	1	Alphanumeric. A1
			"L" denotes general location: Use S for start of leg Use E for end of leg Use I for interior point within a leg Use D for pressure difference between two points.	2	
			Leg number	3-5*	Integer. I3
			Nodal point number - only needed for L = I or D.	6-8*	Integer. I3
			Second leg number only needed for L = D.	9-11*	Integer. I3
			Second nodal point number - only needed for L = D.	12-14*	Integer. I3
			Additional plot identification as third line in plot title.	21-80	Alphanumeric. 6A10
			Additional plot identification as fourth, fifth -- lines in plot title.	21-80	Alphanumeric. 6A10
	K	Type J Continuation Card for additional plot identification. May have none or 1 or more type K cards for each plot, but not over 150 type Ks in the entire data deck.			

*Integers right justified.

and for an elbow,

$$CV(J) = (L/D)_J .$$

- c. None or one or more type K plot identification cards may be used as desired per each plot, consistent with a limit of 150 type K cards for the entire data deck. The type K identification cards supplement the ID-type cards A and H, which appear as the first two lines on each and every plot. The type K card information will appear as the fourth, fifth, . . . lines on each plot as specified for that particular plot.
- d. Junction-type identification numbers are given in Table 1.

3.6 Sample Problem

Use of the HAMOC program is illustrated by a typical problem. The primary sodium system to be analyzed for sodium hammer pressures following a hypothetical reactor core disruptive accident is shown in Figures 3 through 5. Figure 3 is a simple schematic of the system. Figure 4 provides elevation dimensions, and Figure 5 provides plan view data. These latter two figures provide the length data for pipe legs and identify the pipe fitting junctions which join straight runs of pipe.

The HAMOC program model of the system is shown in Figure 6. A model with 45 pipe legs and 45 junctions is selected as a satisfactory representation of the actual system. The model includes four tee junctions which require that seven flow rates be inputted in addition to the flow rate for leg 1. Note that three tee junctions require the inputting of two flow rates each while the fourth one (junction number 14) requires only one flow input because branch leg 43 is an incoming leg by definition.

FIGURE 3. Primary Loop Schematic.

FIGURE 4. Primary Loop Elevations.

FIGURE 5. Primary Loop Plan View.

FIGURE 6. HAMOC Model of Primary Loop.

Except for the plastic deformation types 11 and 12, at least one of every type junction is used in the model.

Valves are simply considered as cylinders of different diameters and wall thicknesses than the connecting pipes. The movement of the check valve disk is ignored during the short length of the transient. The IHX is considered as having a cylindrical geometry for the flow path and the pressure loss is represented by an orifice junction placed about at the midpoint of the IHX. Elbows which are used to change direction from horizontal to vertical or vice versa are shown as such; elbows in the horizontal plane only are represented by the following symbol:

The pump suction gap is represented as a tee junction as is the bearing coolant flow path leading from the discharge volute. The hydraulic resistance of the bearing is represented as an orifice. The hydraulic resistance of the suction gap and other restrictions in the flow path downstream of the bearing are represented as an orifice upstream of the suction gap tee.

The input data for the problem are listed in the computer report shown in Figure 7, and the arrangement of the input data on computer cards is illustrated in Figure 8. Seventy input cards which includes eight cards for six plots, are required for the problem. Included in the reports given in Figure 7 are the pressure pulse speeds, C , the number of nodal points, $N0$, for each leg, and mesh ratio information. These values are not inputted directly; they are computed in the program from the more basic inputs. Also,

CASE-- HAMOC SAMPLE PROBLEM WITH 45 LEG MODEL
BY HAMOC PROGRAM

FOR TIME STEP = .000195 SECONDS END TIME = .10 SECONDS PIPE ROUGHNESS = .000150 FEET
TOTAL LEGS IN MODEL = 45 RESULTS WRITTEN AFTER EVERY 5 TIME INTERVALS
MAXIMUM NODAL POINTS/LEG = 50 RESULTS PLOTTED AFTER EVERY 1 TIME INTERVALS
PUMP HEAD EQUATION CHARACTERIZATION CONSTANTS PCA,PCB,AND PCC = 1.19E673, .21400E, AND .056E750
PUMP DESIGN HEAD AND DESIGN FLOW RATE = 500.00 FEET AND 32.3100 CFS

THIS RUN MADE WITH CAVITY COLLAPSE PRESSURE CALCULATED USING $C/2G \cdot \Delta T(V)$.

LEG	W,LB/SEC	ID,FT	LENGTH,FT	THICKNESS,IN.	TEMP,F	C,FT/SEC	CV	SLOPE,DEG	JTYPE1	JTYPE2	JN01	JN02	NO	(C+100)OT/D
1	1600.0000	2.2710	.8700	.3750	1050.00	4309.95	20.00	0.00	9	5	1	2	2	.988438
2	1600.0000	2.2710	12.5000	.3750	1050.00	4309.95	20.00	90.00	5	5	2	3	15	.963134
3	1600.0000	2.2710	2.6000	.3750	1050.00	4309.95	20.00	0.00	5	5	3	4	4	.992239
4	1600.0000	2.2710	.8700	.3750	1050.00	4309.95	-0.00	-0.00	5	3	4	5	2	.988438
5	1600.0000	3.1920	5.9000	.5000	1050.00	4233.94	-0.00	-0.00	3	3	5	6	7	.859442
6	1600.0000	2.2710	.8700	.3750	1050.00	4309.95	20.00	-0.00	3	5	6	7	2	.988438
7	1600.0000	2.2710	27.1000	.3750	1050.00	4309.95	20.00	-0.00	5	5	7	8	32	.983696
8	1600.0000	2.2710	22.0000	.3750	1050.00	4309.95	25.00	-0.00	5	5	8	9	26	.977205
9	1600.0000	2.2710	.8700	.3750	1050.00	4309.95	25.00	-0.00	5	5	9	10	2	.988438
10	1600.0000	2.2710	14.3000	.3750	1050.00	4309.95	20.00	-0.00	5	5	10	11	17	.962171
11	1600.0000	2.2710	.8700	.3750	1050.00	4309.95	20.00	-0.00	5	5	11	12	2	.988438
12	1600.0000	2.2710	18.6000	.3750	1050.00	4309.95	20.00	-90.00	5	5	12	13	22	.971901
13	1600.0000	2.2710	.8700	.3750	1050.00	4309.95	-0.00	-0.00	5	6	13	14	2	.988438
14	1700.0000	2.2710	.8700	.3750	1050.00	4309.95	20.00	-0.00	6	5	14	15	2	.988438
35	1.100000	.933856											7	.985700
36	1.195000	.859617												
39	1.100000	.933856												
42	1.276667	.934022												
43	1.300000	.917257												
44	1.312500	.982419												
45	.900000	.866395												

PLOT REPORT HAMOC SAMPLE PROBLEM WITH 45 LEG MODEL
TITLE FORCING PERTURBATIONS AT REACTOR INLET AND OUTLET
SC TIME START = 0.00000 MILLISECONDS. INCREMENT = 20.00000 MILLISECONDS/INCH
PRESSURE START = -4.0000E+02 PSIG. INCREMENT = 2.0000E+02 PSIG/IN.

Report.

50-

CARD NO.	TYPE	DATA	CARD NO.	TYPE	DATA
1	A	HAMOC SAMPLE PROBLEM WITH 45 LEG MODEL	58	G	
2	B		61	G	
3	C		62	F	
4	D		63	H	
5	D		64	I	
48	D		65	J	
49	E		66	J	
56	E		67	J	
57	F		68	J	
			69	J	
			70	J	

FIGURE 8. Input Cards for Sample Problem.

1

2

3

TIME = 0.0000 SECONDS

LEG	PRESS. IN PSIG	PRESS. OUT PSIG	VEL. IN FT/SEC	VEL. OUT FT/SEC	P(2,J) PSIG	P(NO-1,J) PSIG	V(2,J) FT/SEC	V(NO-1,J) FT/SEC	ENERGY LB-FT
1	4.50448E+00	4.50303E+00	7.74944E+00	7.74944E+00	4.50303E+00	4.50448E+00	7.74944E+00	7.74944E+00	0.
2	4.42710E+00	1.83836E-02	7.74944E+00	7.74944E+00	4.1957E+00	2.99151E-01	7.74944E+00	7.74944E+00	0.
3	3.43168E-02	3.86529E-02	7.74944E+00	7.74944E+00	9.57555E-02	9.7242E-02	7.74944E+00	7.74944E+00	0.
4	1.74576E-01	1.75130E-01	7.74944E+00	7.74944E+00	1.7613E-01	1.74576E-01	7.74944E+00	7.74944E+00	0.
5	1.8825E-02	1.26224E-02	3.92264E+00	3.92264E+00	1.11725E-02	1.23324E-02	3.92264E+00	3.92264E+00	0.
6	3.39891E-01	3.41346E-01	7.74944E+00	7.74944E+00	3.41346E-01	3.39891E-01	7.74944E+00	7.74944E+00	0.
7	4.17269E-01	4.62569E-01	7.74944E+00	7.74944E+00	4.18730E-01	4.61107E-01	7.74944E+00	7.74944E+00	0.
8	5.38492E-01	5.75267E-01	7.74944E+00	7.74944E+00	5.39963E-01	5.73796E-01	7.74944E+00	7.74944E+00	0.
9	6.70170E-01	6.71625E-01	7.74944E+00	7.74944E+00	6.71625E-01	6.70170E-01	7.74944E+00	7.74944E+00	0.
10	7.66529E-01	7.90432E-01	7.74944E+00	7.74944E+00	7.68223E-01	7.88938E-01	7.74944E+00	7.74944E+00	0.
11	8.66355E-01	8.67810E-01	7.74944E+00	7.74944E+00	8.67810E-01	8.66355E-01	7.74944E+00	7.74944E+00	0.
12	9.43733E-01	5.63897E+00	7.74944E+00	7.74944E+00	6.31699E-01	5.29694E+00	7.74944E+00	7.74944E+00	0.
13	5.53305E+00	5.53159E+00	7.74944E+00	7.74944E+00	5.53159E+00	5.53305E+00	7.74944E+00	7.74944E+00	0.
14	5.40827E+00	5.40663E+00	8.23378E+00	8.23378E+00	5.40663E+00	5.40827E+00	8.23378E+00	8.23378E+00	0.
15	5.32109E+00	3.45287E+00	8.23378E+00	8.23378E+00	5.00972E+00	3.76424E+00	8.23378E+00	8.23378E+00	0.
16	1.74663E+02	1.74622E+02	2.62871E+01	2.62871E+01	1.74622E+02	1.74663E+02	2.62871E+01	2.62871E+01	0.
17	1.72257E+02	1.76108E+02	2.47408E+01	2.47408E+01	1.72611E+02	1.76154E+02	2.47408E+01	2.47408E+01	0.
18	1.75454E+02	1.75418E+02	2.47408E+01	2.47408E+01	1.75418E+02	1.75454E+02	2.47408E+01	2.47408E+01	0.
19	1.74364E+02	1.64338E+02	2.47408E+01	2.47408E+01	1.73963E+02	1.64739E+02	2.47408E+01	2.47408E+01	0.
20	1.63495E+02	1.63283E+02	2.47408E+01	2.47408E+01	1.63462E+02	1.63318E+02	2.47408E+01	2.47408E+01	0.
21	1.62440E+02	1.62370E+02	2.47408E+01	2.47408E+01	1.62405E+02	1.62405E+02	2.47408E+01	2.47408E+01	0.
22	1.63476E+02	1.67222E+02	5.02582E+00	5.02582E+00	1.63764E+02	1.66934E+02	5.02582E+00	5.02582E+00	0.
23	1.57002E+02	1.60938E+02	4.82863E+00	4.82863E+00	1.57304E+02	1.60635E+02	4.82863E+00	4.82863E+00	0.
24	1.56548E+02	1.57624E+02	2.37701E+01	2.37701E+01	1.56906E+02	1.57265E+02	2.37701E+01	2.37701E+01	0.
25	1.56609E+02	1.56774E+02	2.37701E+01	2.37701E+01	1.56574E+02	1.56609E+02	2.37701E+01	2.37701E+01	0.
26	1.55559E+02	1.45710E+02	2.37701E+01	2.37701E+01	1.55131E+02	1.46139E+02	2.37701E+01	2.37701E+01	0.
27	1.44898E+02	1.44675E+02	2.37701E+01	2.37701E+01	1.44861E+02	1.44712E+02	2.37701E+01	2.37701E+01	0.
28	1.43660E+02	1.43625E+02	2.37701E+01	2.37701E+01	1.43625E+02	1.43660E+02	2.37701E+01	2.37701E+01	0.
29	1.42610E+02	1.42210E+02	2.37701E+01	2.37701E+01	1.42573E+02	1.42247E+02	2.37701E+01	2.37701E+01	0.
30	1.41398E+02	1.41363E+02	2.37701E+01	2.37701E+01	1.41363E+02	1.41398E+02	2.37701E+01	2.37701E+01	0.
31	1.42942E+02	1.42932E+02	1.00571E+01	1.00571E+01	1.42939E+02	1.42935E+02	1.00571E+01	1.00571E+01	0.
32	1.39343E+02	1.38854E+02	2.37701E+01	2.37701E+01	1.39308E+02	1.38889E+02	2.37701E+01	2.37701E+01	0.
33	1.38042E+02	1.38007E+02	2.37701E+01	2.37701E+01	1.38007E+02	1.38042E+02	2.37701E+01	2.37701E+01	0.
34	1.39586E+02	1.39570E+02	1.00571E+01	1.00571E+01	1.39582E+02	1.39574E+02	1.00571E+01	1.00571E+01	0.
35	1.35981E+02	1.35946E+02	2.37701E+01	2.37701E+01	1.35946E+02	1.35981E+02	2.37701E+01	2.37701E+01	0.
36	1.35134E+02	1.34905E+02	2.37701E+01	2.37701E+01	1.35096E+02	1.34943E+02	2.37701E+01	2.37701E+01	0.
37	1.34093E+02	1.39729E+02	2.37701E+01	2.37701E+01	1.34445E+02	1.39377E+02	2.37701E+01	2.37701E+01	0.
38	1.39729E+02	1.44440E+02	2.37701E+01	2.37701E+01	1.40092E+02	1.44078E+02	2.37701E+01	2.37701E+01	0.
39	1.43628E+02	1.43593E+02	2.37701E+01	2.37701E+01	1.43593E+02	1.43628E+02	2.37701E+01	2.37701E+01	0.
40	1.76045E+02	1.76045E+02	2.77551E-01	2.77551E-01	1.76045E+02	1.76045E+02	2.77551E-01	2.77551E-01	0.
41	4.16944E+00	4.16944E+00	2.77551E-01	2.77551E-01	4.16944E+00	4.16944E+00	2.77551E-01	2.77551E-01	0.
42	4.16906E+00	5.52474E+00	2.77551E-01	2.77551E-01	4.62095E+00	5.07285E+00	2.77551E-01	2.77551E-01	0.
43	5.36372E+00	5.82387E+00	2.77551E-01	2.77551E-01	5.82387E+00	5.36372E+00	2.77551E-01	2.77551E-01	0.
44	4.16954E+00	4.52985E-01	0.	0.	3.70496E+00	9.17467E-01	0.	0.	0.
45	1.63630E+02	1.61400E+02	0.	0.	1.63312E+02	1.61719E+02	0.	0.	0.

FIGURE 9. Sample Problem Initial Values.

TIME = .507 SECONDS

LEG	PRESS. IN PSIG	PRESS. OUT PSIG	VEL. IN FT/SEC	VEL. OUT FT/SEC	P(2,J) PSIG	P(NO-1,J) PSIG	V(2,J) FT/SEC	V(NO-1,J) FT/SEC	ENERGY LB-FT
1	4.19395E+00	-1.14794E+00	9.88372E+00	9.87776E+00	-1.14794E+00	4.19395E+00	9.87776E+00	9.88372E+00	0.
2	-1.26346E+00	-1.44349E+01	9.87776E+00	6.72172E+00	-5.33932E+00	-1.44349E+01	9.86188E+00	6.24528E+00	0.
3	-1.44349E+01	-1.44349E+01	6.32172E+00	6.53132E+00	-1.44349E+01	-1.44349E+01	6.39770E+00	6.46755E+00	0.
4	-1.44349E+01	-1.44349E+01	6.53102E+00	6.58936E+00	-1.44349E+01	-1.44349E+01	6.58936E+00	6.53102E+00	0.
5	-1.43155E+01	-1.44349E+01	3.33543E+00	3.62795E+00	-1.44349E+01	-1.44349E+01	3.39539E+00	3.58803E+00	0.
6	-1.44349E+01	-1.44349E+01	7.16726E+00	7.20400E+00	-1.44349E+01	-1.44349E+01	7.20400E+00	7.16726E+00	0.
7	-1.44349E+01	-1.44349E+01	7.20400E+00	7.77204E+00	-1.44349E+01	-1.44349E+01	7.23797E+00	7.76080E+00	0.
8	-1.44349E+01	-1.44349E+01	7.77204E+00	1.12796E+01	-1.44349E+01	-1.44349E+01	7.78728E+00	1.10568E+01	0.
9	-1.44349E+01	-1.44349E+01	1.12796E+01	1.15167E+01	-1.44349E+01	-1.44349E+01	1.15167E+01	1.12796E+01	0.
10	-1.44349E+01	-1.44349E+01	1.15167E+01	1.64017E+01	-1.44349E+01	-1.44349E+01	1.17775E+01	1.61790E+01	0.
11	-1.44349E+01	-1.44349E+01	1.64017E+01	1.65251E+01	-1.44349E+01	-1.44349E+01	1.65251E+01	1.64017E+01	0.
12	-1.44349E+01	4.27634E+01	1.65251E+01	1.76033E+01	-1.20171E+01	4.38086E+01	1.65558E+01	1.75348E+01	0.
13	4.23790E+01	4.35015E+01	1.76033E+01	1.76937E+01	4.35015E+01	4.23790E+01	1.76937E+01	1.76033E+01	0.
14	4.46878E+01	3.75906E+01	7.45902E+00	7.52578E+00	3.75906E+01	4.46878E+01	7.52578E+00	7.45902E+00	0.
15	3.75188E+01	1.69665E+01	7.52578E+00	7.61153E+00	3.19200E+01	1.99776E+01	7.58451E+00	7.61153E+00	0.
16	1.94213E+02	1.82145E+02	2.43005E+01	2.43601E+01	1.82145E+02	1.94213E+02	2.43601E+01	2.43005E+01	0.
17	1.79800E+02	4.71439E+01	2.40038E+01	2.44475E+01	1.61404E+02	4.75181E+01	2.40856E+01	2.43853E+01	0.
18	3.91149E+01	3.22738E+01	2.44475E+01	2.45319E+01	3.22738E+01	3.91149E+01	2.45319E+01	2.44475E+01	0.
19	3.12378E+01	2.39627E+02	2.45319E+01	2.55977E+01	2.72695E+01	2.35577E+02	2.46491E+01	2.55610E+01	0.
20	2.38725E+02	2.78575E+02	2.55977E+01	2.55121E+01	2.43336E+02	2.69702E+02	2.56201E+01	2.55443E+01	0.
21	2.77679E+02	2.96870E+02	2.55121E+01	2.54633E+01	2.87104E+02	2.87104E+02	2.54836E+01	2.54836E+01	0.
22	2.97991E+02	3.61343E+02	5.91158E+00	4.59469E+00	2.99899E+02	3.61620E+02	5.88813E+00	4.58772E+00	0.
23	3.52798E+02	3.24589E+02	4.41441E+00	4.95863E+00	3.52561E+02	3.24499E+02	4.43024E+00	4.94623E+00	0.
24	3.19959E+02	2.16979E+02	2.44100E+01	2.62469E+01	3.78192E+02	2.68341E+02	2.46288E+01	2.53281E+01	0.
25	2.15742E+02	1.93810E+02	2.62469E+01	2.67187E+01	1.93810E+02	2.15742E+02	2.67187E+01	2.62469E+01	0.
26	1.92529E+02	4.07102E+02	2.67187E+01	2.70193E+01	2.18913E+02	4.21150E+02	2.64301E+01	2.69744E+01	0.
27	4.36155E+02	3.00808E+02	2.70193E+01	2.66561E+01	3.69381E+02	2.75809E+02	2.74409E+01	2.77012E+01	0.
28	2.99534E+02	2.99809E+02	2.66561E+01	2.59499E+01	2.99809E+02	2.99534E+02	2.59499E+01	2.66561E+01	0.
29	2.98600E+02	1.96364E+01	2.59499E+01	2.52851E+01	2.82518E+02	-1.15612E+00	2.54322E+01	2.60676E+01	0.
30	1.37187E+01	6.74116E+01	2.52851E+01	2.44902E+01	6.74116E+01	1.37187E+01	2.44902E+01	2.52851E+01	0.
31	6.90800E+01	1.19856E+02	1.43618E+01	9.75254E+00	6.09893E+01	7.38900E+01	1.01208E+01	9.54471E+00	0.
32	1.16431E+02	-1.46860E+01	2.30503E+01	2.06513E+01	5.77853E+01	-1.46860E+01	2.21200E+01	2.05969E+01	0.
33	-1.46860E+01	-1.46860E+01	2.06513E+01	2.07299E+01	-1.46860E+01	-1.46860E+01	2.07299E+01	2.06513E+01	0.
34	-1.34849E+01	-1.46860E+01	8.77799E+00	9.00224E+00	-1.46860E+01	-1.46860E+01	8.94508E+00	8.95349E+00	0.
35	-1.46860E+01	-1.46860E+01	2.12769E+01	2.13606E+01	-1.46860E+01	-1.46860E+01	2.13606E+01	2.12769E+01	0.
36	-1.46860E+01	-1.46860E+01	2.13606E+01	2.15788E+01	-1.46860E+01	-1.46860E+01	2.14444E+01	2.15711E+01	0.
37	-1.46860E+01	1.18264E+02	2.15788E+01	2.02634E+01	-1.46860E+01	1.18264E+02	2.15943E+01	2.03342E+01	0.
38	1.18264E+02	1.43186E+02	2.02634E+01	2.07366E+01	1.26288E+02	1.41797E+02	2.01948E+01	2.07359E+01	0.
39	1.42567E+02	1.43593E+02	2.07366E+01	2.07321E+01	1.43593E+02	1.42567E+02	2.07321E+01	2.07366E+01	0.
40	1.83366E+02	1.82154E+02	6.44829E+00	2.95992E+00	1.83300E+02	1.82347E+02	1.36225E+01	2.18988E+01	0.
41	-1.33262E+01	-1.21636E+01	2.95992E+00	3.56994E+00	-1.30283E+01	-1.25765E+01	3.21440E+01	3.43750E+01	0.
42	-1.23938E+01	-1.44349E+01	-6.85852E+00	-6.09294E+00	-1.44349E+01	-1.44349E+01	-6.85393E+00	-6.17011E+00	0.
43	6.32254E+01	4.47356E+01	-6.09294E+00	-6.86496E+00	4.47356E+01	6.32254E+01	-6.86496E+00	-6.09294E+00	0.
44	-1.23271E+01	4.52885E+01	5.18207E+00	5.18852E+00	-1.16622E+01	-1.63796E+00	5.17683E+00	5.19006E+00	0.
45	2.38202E+02	2.84714E+02	7.39765E+01	2.97522E+02	2.85183E+02	7.48771E+01	2.78444E+01	2.78444E+01	0.

FIGURE 10. Sample Problem Values at 0.0507 Seconds.

TIME = .09945 SECONDS

LEG	PRESS. IN PSIG	PRESS. OUT PSIG	VEL. IN FT/SEC	VEL. OUT FT/SEC	P(2,J) PSIG	P(NO-1,J) PSIG	V(2,J) FT/SEC	V(NO-1,J) FT/SEC	ENERGY LB-FT
1	4.37180E+00	3.96436E+00	8.72551E+00	8.72551E+00	3.96436E+00	4.37180E+00	8.72551E+00	8.72551E+00	0.
2	3.86845E+00	1.44349E+01	8.72551E+00	8.52953E+00	3.03882E+00	1.44349E+01	8.72392E+00	8.52343E+00	0.
3	-1.44349E+01	-1.44349E+01	8.52953E+00	7.64403E+00	-1.44349E+01	-1.44349E+01	8.53709E+00	7.64761E+00	0.
4	-1.44349E+01	-1.44349E+01	7.64403E+00	7.65600E+00	-1.44349E+01	-1.44349E+01	7.65600E+00	7.64403E+00	0.
5	-1.42737E+01	-1.44349E+01	3.87535E+00	4.00569E+00	-1.44349E+01	-1.44349E+01	3.89181E+00	3.97749E+00	0.
6	-1.44349E+01	-1.44349E+01	7.91351E+00	7.94778E+00	-1.44349E+01	-1.44349E+01	7.94778E+00	7.91351E+00	0.
7	-1.44349E+01	-1.44349E+01	7.94778E+00	1.01579E+01	-1.44349E+01	-1.44349E+01	7.98736E+00	1.01563E+01	0.
8	-1.44349E+01	-1.44349E+01	1.01579E+01	1.10170E+01	-1.44349E+01	-1.44349E+01	1.01652E+01	1.10008E+01	0.
9	-1.44349E+01	-1.44349E+01	1.10170E+01	1.10346E+01	-1.44349E+01	-1.44349E+01	1.10346E+01	1.10170E+01	0.
10	-1.44349E+01	-1.44349E+01	1.10346E+01	1.14507E+01	-1.44349E+01	-1.44349E+01	1.10543E+01	1.14139E+01	0.
11	-1.44349E+01	-1.44349E+01	1.14507E+01	1.14978E+01	-1.44349E+01	-1.44349E+01	1.14978E+01	1.14507E+01	0.
12	-1.44349E+01	7.37370E-01	1.14978E+01	1.14619E+01	-1.44349E+01	-2.31583E+00	1.15501E+01	1.15214E+01	0.
13	5.73078E-01	1.90182E+00	1.14619E+01	1.14324E+01	1.90182E+00	5.73078E-01	1.14324E+01	1.14619E+01	0.
14	2.18250E+00	4.98701E+00	7.61218E+00	7.54294E+00	4.98701E+00	2.18250E+00	7.54294E+00	7.61218E+00	0.
15	4.91504E+00	4.24272E+00	7.54294E+00	7.45116E+00	8.93525E+00	5.73408E+00	7.48876E+00	7.48658E+00	0.
16	1.82973E+02	1.77826E+02	2.37853E+01	2.37526E+01	1.77820E+02	1.82973E+02	2.37526E+01	2.37853E+01	0.
17	1.76024E+02	1.09514E+02	2.18528E+01	2.26854E+01	1.67602E+02	1.75062E+02	2.18323E+01	2.26823E+01	0.
18	1.08627E+02	1.14420E+02	2.26854E+01	2.26285E+01	1.14420E+02	1.08627E+02	2.26285E+01	2.26854E+01	0.
19	1.13538E+02	1.33757E+02	2.26285E+01	2.09711E+01	1.18768E+02	1.33282E+02	2.25335E+01	2.17486E+01	0.
20	1.33150E+02	1.43908E+02	2.09711E+01	2.06975E+01	1.35010E+02	1.43791E+02	2.09079E+01	2.07237E+01	0.
21	1.43316E+02	1.39943E+02	2.06975E+01	2.06891E+01	1.42111E+02	1.42111E+02	2.06859E+01	2.06859E+01	0.
22	1.40718E+02	1.56615E+02	4.10565E+00	4.80574E+00	1.44162E+02	1.57407E+02	4.12717E+00	4.78444E+00	0.
23	1.47269E+02	1.04317E+02	4.61720E+00	6.03074E+00	1.45491E+02	1.53871E+02	4.65383E+00	5.94451E+00	0.
24	9.74680E+01	9.79321E+01	2.96878E+01	2.97769E+01	9.90851E+01	9.96763E+01	2.97497E+01	2.97863E+01	0.
25	9.63439E+01	9.11016E+01	2.97769E+01	2.97326E+01	9.11016E+01	9.63439E+01	2.97326E+01	2.97769E+01	0.
26	8.95181E+01	1.59370E+02	2.97326E+01	2.65157E+01	8.24479E+01	1.64836E+02	2.96511E+01	2.66021E+01	0.
27	1.58361E+02	1.31947E+02	2.65157E+01	2.60839E+01	1.52861E+02	1.51547E+02	2.64214E+01	2.55768E+01	0.
28	1.30726E+02	1.33671E+02	2.60839E+01	2.61407E+01	1.33671E+02	1.30726E+02	2.61407E+01	2.60839E+01	0.
29	1.32446E+02	1.46860E+01	2.61407E+01	2.49092E+01	1.41121E+02	1.46860E+01	2.62846E+01	2.48686E+01	0.
30	-1.46860E+01	-1.46860E+01	2.49092E+01	2.49681E+01	-1.46860E+01	-1.46860E+01	2.49681E+01	2.49092E+01	0.
31	-1.29436E+01	-1.46242E+01	1.05640E+01	1.05962E+01	-1.46860E+01	-1.46860E+01	1.05955E+01	1.05963E+01	0.
32	-1.46860E+01	-1.46860E+01	2.50442E+01	2.63065E+01	-1.46860E+01	-1.46860E+01	2.51108E+01	2.62824E+01	0.
33	-1.46860E+01	-6.69908E+00	2.63065E+01	2.61728E+01	-6.69908E+00	-1.46860E+01	2.61728E+01	2.63065E+01	0.
34	-4.78445E+00	-1.46015E+01	1.10737E+01	1.05622E+01	3.27609E+00	-7.79492E-01	1.09112E+01	1.08011E+01	0.
35	-1.46860E+01	-1.46860E+01	2.49639E+01	2.50312E+01	-1.46860E+01	-1.46860E+01	2.50312E+01	2.49639E+01	0.
36	-1.46860E+01	-1.46860E+01	2.50312E+01	2.54667E+01	-1.46860E+01	-1.46860E+01	2.51177E+01	2.54110E+01	0.
37	-1.46860E+01	7.19721E+01	2.54667E+01	2.40055E+01	-1.46860E+01	6.18317E+01	2.55170E+01	2.39124E+01	0.
38	7.19721E+01	1.34155E+02	2.40055E+01	2.39394E+01	8.16951E+01	1.25579E+02	2.40944E+01	2.39515E+01	0.
39	1.33332E+02	1.43593E+02	2.39394E+01	2.39377E+01	1.43593E+02	1.33332E+02	2.39377E+01	2.39394E+01	0.
40	1.78979E+02	1.81574E+02	3.40999E-01	2.92213E-01	1.80207E+02	1.81467E+02	3.03480E-01	2.94783E-01	0.
41	-8.94227E+00	-7.28809E+00	2.92213E-01	2.37287E-01	-8.66591E+00	-8.13666E+00	2.62047E-01	2.44798E-01	0.
42	-7.30991E+00	-8.50905E+00	-2.12014E+00	-2.14564E+00	-8.43357E+00	-8.81712E+00	-2.11671E+00	-2.12459E+00	0.
43	-1.11432E+00	-2.49612E+00	-2.14564E+00	-2.18916E+00	-2.49612E+00	-1.11432E+00	-2.18916E+00	-2.14564E+00	0.
44	-7.30567E+00	4.52885E-01	1.69306E+00	1.70355E+00	-6.42877E+00	8.23325E-01	1.67828E+00	1.70074E+00	0.
45	1.40821E+02	1.21420E+02	9.71188E+02	9.	1.38185E+02	1.22181E+02	1.47889E-01	4.14763E-02	0.
PLOT TYPE PS LEG 1 NODE 1 REACTOR OUTLET NOZZLE									
PLOT TYPE PE LEG 3 NODE 4 HOT LEG ISOLATION VALVE INLET									
PLOT TYPE PS LEG 13 NODE 1 PUMP INLET									
PLOT TYPE PI LEG 17 NODE 11 PUMP OUTLET									
PLOT TYPE PE LEG 35 NODE 2 COLD LEG ISOLATION VALVE OUTLET									
PLOT TYPE PE LEG 39 NODE 2 REACTOR INLET NOZZLE									

FIGURE 11. Sample Problem Values Near the End of the Run at 0.09945 Seconds.
Plot Reports Also Listed.

PS LEG/NODE 1/ 1

FIGURE 12. HAMOC Sample Problem with 45 Leg Model
Forcing Perturbations at Reactor Inlet and Outlet
Reactor Outlet Nozzle.

PE LEG/NODE 39/ 2

FIGURE 13. HAMOC Sample Problem with 45 Leg Model
Forcing Perturbations at Reactor Inlet and Outlet
Reactor Inlet Nozzle.

PE LEG/NODE 3/ 4

FIGURE 14. HAMOC Sample Problem with 45 Leg Model
Forcing Perturbations at Reactor Inlet and Outlet
Hot Leg Isolation Valve Inlet.

PS LEG/NODE 13/ 1

FIGURE 15. HAMOC Sample Problem with 45 Leg Model
Forcing Perturbations at Reactor Inlet and Outlet
Pump Inlet.

PI LEG/NODE 17/11

FIGURE 16. HAMOC Sample Problem with 45 Leg Model
Forcing Perturbations at Reactor Inlet and Outlet
Pump Outlet.

PE LEG/NODE 35/ 2

FIGURE 17. HAMOC Sample Problem with 45 Leg Model
Forcing Perturbations at Reactor Inlet and Outlet
Cold Leg Isolation Valve Outlet.

different because the plots are for the pressures in the nozzles and therefore differ from the forcing data by the amount of the entrance or exit pressure losses, which are rather small.

The plots show that saturation pressures were reached during the problem time. The saturation pressures are -14.4349 and -14.6860 psig for the hot and cold legs, respectively. The plot for the cold leg isolation valve, Figure 17, shows that column separation first occurred at about 0.044 seconds and that the cavity which was formed vanished at about 0.054 seconds. Column separation reoccurred at about 0.087 seconds.

3.7 Verification of Program

The finished code was checked out five ways:

- a. Run to 0.1 second with no system perturbations, using a 0.00195-second time step and the sample problem system model. Pressures and velocities at all points in the system model should remain steady at the initial values.
- b. Long run to two seconds using the sample problem's system model and forcing perturbations, which return to the initial steady-state values by 0.02 seconds. Pressures and velocities should eventually return to the initial values for all points within the model.
- c. Compare the sample problem results to WHAM code results for the same system model.
- d. Compare HAMOC results to output from the more detailed Westinghouse proprietary TRAPP version of the BLOWDN-2 computer code.
- e. Compare HAMOC results to experimental data for a rapidly closing 16-inch check valve included in a large piping system.⁽⁵⁾

Results for the no perturbation run are illustrated by Figures 18 and 19 of typical pressure plots for the hot and cold leg valves on the low and high pressure sides of the pump. As shown, the pressures are exactly steady which indicates that the required consistency is achieved between the initial value and transient calculations and that the necessary stability of the finite difference solution for the selected grid-mesh ratio is obtained. About five hundred time-plane calculations were made in this run.

The run to two seconds was not long enough to again reach steady conditions; however, the typical pressure plots shown in Figures 20 and 21 for a low and high pressure component indicate that steady conditions unquestionably would be reached following the return to initial values at the reactor vessel. The fact that the pressures are headed toward steady values after removal of the perturbations indicates that there are no programming errors.

The WHAM code results are shown in Figures 22 through 25 for the hot leg isolation valve, pump inlet, pump outlet and cold leg isolation valve. These curves may be compared directly with the HAMOC plots shown in Figures 14 through 17 for the same system locations. The version of the WHAM code used here did not include frictional losses in the pipe legs or the explicit modeling of the pump, and WHAM does not allow for elevation changes. These were the only significant differences in the execution of the comparative cases. The agreement between the pressure plots is excellent until the first appearance of saturation pressures at about 0.031 seconds at the hot leg valve, 0.043 seconds at the cold leg valve, 0.044 seconds for the pump inlet and 0.049 seconds for the pump outlet. Agreement after saturation pressures were reached is not expected, of course, because WHAM does not allow for that possibility.

PE LEG/NODE 3/ 4

FIGURE 18. Primary Loop System Pressures
System Unperturbed
Hot Leg Isolation Valve Inlet.

PE LEG/NODE 35/ 2

FIGURE 19. Primary Loop System Pressures
System Unperturbed
Cold Leg Isolation Valve Outlet.

FIGURE 20. Long Run for HAMOC Verification
Sample Problem 45 Leg Model
Hot Leg Isolation Valve Inlet.

FIGURE 21. Long Run for HAMOC Verification
 Sample Problem 45 Leg Model
 Cold Leg Isolation Valve Outlet.

FIGURE 22. Primary Loop System Pressures by WHAM Code
Forcing Perturbations at Reactor Inlet and Outlet
Hot Leg Isolation Valve Inlet.

FIGURE 23. Primary Loop System Pressures by WHAM Code
Forcing Perturbations at Reactor Inlet and Outlet
Pump Inlet.

FIGURE 24. Primary Loop System Pressures by WHAM Code
Forcing Perturbations at Reactor Inlet and Outlet
Pump Outlet.

FIGURE 25. Primary Loop System Pressures by WHAM Code
Forcing Perturbations at Reactor Inlet and Outlet
Cold Leg Isolation Valve Outlet.

The TRAPP code, which is briefly described in Appendix C, is a modification of the BLOWN-2 Westinghouse proprietary code. These codes program the continuity, momentum, energy and appropriate state equations, and as such are more detailed than the HAMOC code in their treatment of column separation when saturation pressures occur. TRAPP was used by Westinghouse Advanced Reactors Division in the early days of the FFTF Project to provide preliminary response data for the FFTF's primary loop system as it is subjected to a hypothetical core disruptive accident. The system analyzed is about the same as the one shown in Figures 3, 4 and 5, with the TRAPP system model containing a total of 80 legs. A comparative HAMOC computer run, with an identical 80-leg model and identical boundary conditions, was made to check against these TRAPP code results with the comparison shown in Figures 26 through 29. The agreement of code output is excellent out to about 40 milliseconds when saturation pressures first occur in the loop. Agreement is still quite acceptable after that with marginal differences in the pressure peaks and valleys and minor differences in the times when these peaks and valleys occur.

The comparison of HAMOC to the check valve experimental data was done primarily to provide verification of the simplified column separation model used in the code. It was felt that the code's acceptability for analyses of systems at pressures above saturation had been established by the preceding checks.

HAMOC was recompiled for this check to use water properties and to use a time-dependent head loss coefficient for the orifice-type junction which represented the check valve. Data for the head loss coefficient were taken from the reference (5) report. Shown in Figure 30 are the transient data

FIGURE 26. Run to Check Against Trapp Results
80 Leg Primary Loop HCDA Model
Hot Leg Pipe Between Pump and Valve.

FIGURE 27. Run to Check Against Trapp Results
80 Leg Primary Loop HCDA Model
IHX Interior.

FIGURE 28. Run to Check Against Trapp Results
 80 Leg Primary Loop HCDA Model
 Cold Leg Pipe Between IHX and Check Valve.

PS LEG/NODE 58/ 1

FIGURE 29. Run to Check Against Trapp Results
80 Leg Primary Loop HCDA Model
Check Valve Outlet.

Reference Colorado State U. Hydro Machinery Lab. Rpt #36, June 1974. ⁽⁵⁾

FIGURE 30. 16-Inch Check Valve SLAM Test Experimental Data.

for disk position versus time. The plots given in this figure are reproductions of the reported results for slam test runs at an initial water velocity of about 6.5 ft/second. Elsewhere in the report⁽⁵⁾ were data relating the steady-state head loss coefficient to disk position. The characterization of the valve's flow resistance by the variable loss coefficient was very satisfactory as code calculated system pressures, both before and after column separation, were in good agreement with the experimental data.

The HAMOC model of the experimental set up is shown in Figure 31. The boundary conditions were characterized by the PBACK and PBACKR functions shown there. The referenced report⁽⁵⁾ stated that saturation pressures were substantially greater than those for pure water at the measured fluid temperatures due to the presence of air in the water. The average saturation pressure for experiment number 506 appeared to be in the range of -5 to -6 psig. A value of -5.2 psig was used in the HAMOC run.

HAMOC and test results are compared in Figures 32 and 33. The experimental results shown here are course replots of the actual data shown in Figure 30. As shown, HAMOC satisfactorily predicts the experimental data. The column separation model correctly computes the time when the first vapor cavity is refilled and gives an accurate representation of the first pressure spike following the collapse of the cavity. HAMOC's predictions of subsequent pressures are also reasonable. The HAMOC run was made using KAVITY equals 0 for the pressure calculations as the cavities collapse.

The accuracy of HAMOC appears to be satisfactory for solving problems associated with slightly deformable pipes, based on the above five checks.

-6/-

FIGURE 31. HAMOC Model of Colorado State University Run #506.

PI LEG/NODE 4/27

FIGURE 32. Check Valve Closure Simulation
Colorado State Check Valve System
Pressure at Approximate Location of Downstream P Tap.

FIGURE 33. Check Valve Closure Simulation
 Colorado State Check Valve System
 Pressure at Approximate Location of Upstream P Tap.

3.8 Execution Time

The sample problem is a representative case. The actual computer execution time for the 0.1-second problem time case was about 110 seconds, for an average of about 0.21 seconds for each time plane; the average execution time for the 377 mesh points used in the problem is about 0.00057 seconds per mesh point at each time plane. As mentioned before, the use of a constant friction factor results in a very significant reduction in computer time with little loss of accuracy.

4.0 REFERENCES

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4. "Liquid Metal Fast Breeder Reactor Materials Handbook," HEDL-TME 71-32, Hanford Engineering Development Laboratory, Richland, Washington, June 1971.
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APPENDIX A

MESH RATIO FOR ACCURACY

Because of the linear interpolations used in the characteristics method of solution of the partial differential equations of continuity and momentum using a specified time interval, it is necessary for accuracy that interpolations are applied over minimum distances by use of minimum ΔX values for the specified integration time interval. The inaccuracy shows up as numerical damping.

For stability and/or convergence, it is only necessary that

$$\Delta t(a + V) \leq \Delta X.$$

where

Δt = time interval

ΔX = space interval

a = pressure wave velocity

V = fluid velocity,

but for maximum accuracy it is desirable that

$$\Delta t(a + V) = \Delta X.$$

To illustrate this point, computer runs were made for a simple system model using various ΔX values.

The system model consisted of two legs of uniform diameter, each of length 3.52 feet. The second leg was terminated with a dead end. The boundary condition at the start of the first leg was a step pressure change at about zero time from 400 to 500 psig. Hence, the model is represented as--

Leg ID 3.271 ft
 Leg Length 3.52 ft

Pressure wave velocity -- specified as 4400 ft/sec
 Initial flow rate -- 0 lb/sec.
 Initial pressure -- 400 psig, stepping to 500 psig
 immediately

Frictionless system.

Theoretical results for a frictionless system are given by WHAM code results with data as shown in Figures A-1 and A-2 at the end of leg 1 and at the dead end, respectively.

Comparative information for HAMOC code runs are shown in Figures A-3 through A-10 for these HAMOC cases:

<u>Figure No.</u>	<u>Δt, sec</u>	<u>ΔX</u>	<u>$\Delta t(a)/\Delta X$</u>
A-3 } A-4 }	0.0001117	0.502857	0.9774
A-5 } A-6 }	0.00010	0.502857	0.875
A-7 } A-8 }	0.00002	0.502857	0.175
A-9 } A-10 }	0.00002	0.0902564	0.975

It can be seen from Figures A-3, -4, -9, and -10 that the greatest accuracy is obtained with the $\Delta t(a)/\Delta X$ value close to unity. Of these two cases, the use of the 0.00002 time step gives the most accurate results, but this is at the expense of about a 30-fold increase in computer time. A balance must be made between accuracy and computer cost for the practical solution of problems.

It should be further noted, by inspection of Figures A-5 through A-8 as compared to the WHAM results, the grossness of the error in the solution as the $\Delta t(a)/\Delta X$ value decreases.

The HAMOC code's input data reports include tabulated $(a + V)\Delta t/\Delta X$ data. Legs which have an $a\Delta t/\Delta X$ value of less than 0.95, which was arbitrarily selected, are reported as having suspect mesh ratios to alert the user to a possible numerical damping problem. Adjustments can be made by reducing the time step and/or by otherwise unimportant small changes in leg lengths.

PE LEG/NODE 1/ 9

FIGURE A-1. Dead End at End St. Pipe. (by WHAM) 100 psi Step, Dead End at End Leg 1.

PE LEG/NODE 2/ 9

FIGURE A-2. Dead End at End St. Pipe. (by WHAM) 100 psi Step, Dead End at End Leg 2.

FIGURE A-3. Case 10. Pipe W/Deadend. DT = 0.0001117, DX = 0.502857.
 100 psi Step Up from 400 psig, Half Way Point at End Leg 1.

FIGURE A-4. Pipe W/Deadend. DT = 0.0001117, DX = 0.502857. 100 psi Step Up from 400 psig Dead End.

FIGURE A-5. Case 1B. Pipe Ending with Dead End. $DT = 0.0001$ Sec. 100 psi Step Up From 400 psig, Half Way Point at End Leg 1.

FIGURE A-6. Case 1B. Pipe Ending with Dead End. DT = 0.001 Sec. 100 psi Step Up from 400 psig, Dead End.

PE LEG/NOOE 1/ 8

FIGURE A-7. Case 1A. Pipe Ending with Dead End. DT = 0.00002 Sec.
100 psi Step Up from 400 psig, Half Way Point at End Leg 1.

FIGURE A-8. Case 1A. Pipe Ending with Dead End. DT = 0.00002 Sec. 100 psi Step Up from 400 psig, Dead End.

PE LEG/NODE 1/40

FIGURE A-9. Case 1C. Pipe W/Dead End. DT = 0.00002, DX = 0.09026.
100 psi Step Up from 400 psig, Half Way Point at End Leg 1.

FIGURE A-10. Case 1C. Pipe W/Dead End. DT = 0.00002, DX = 0.09026.
100 psi Step Up from 400 psig, Dead End.

APPENDIX B

PROGRAM LISTINGS AND MAP

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PROGRAM HAMOC

PROGRAM HAMOC 74/74 OPT=1 FTN 4.2+74351 03/24/76 08.25.00.

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PROGRAM HAMOC(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE19,TAPE20, HAMOC      2
,TAPE21,TAPE22,TAPE23,TAPE24) HAMOC      3
C HAMOC      4
C HAMOC      5
5 C HAMOC--HAMMER ANALYSIS BY METHOD OF CHARACTERISTICS--MAIN PROGRAM. HAMOC      6
C DEVELOPED MAY,1972 BY HG JOHNSON. HAMOC      7
C PROGRAM INCLUDES COLUMN SEPARATION COMPUTATIONS. HAMOC      8
C HAMOC      9
C HAMOC     10
C ON 5/2/73, THERE WAS A MAJOR MODIFICATION OF HAMOC TO ADD HAMOC     11
10 C SIMPLIFIED PLASTIC DEFORMATION LOGIC, SIMULATED BY A COMBINATION HAMOC     12
C OF NEW TYPE 11 AND 12 JUNCTIONS. HAMOC     13
C TYPE 11 JUNCTION IS A SPECIAL TEE LEADING TO THE TYPE 12 HAMOC     14
C JUNCTION WHICH IS A PRESSURIZER TYPE JUNCTION HELD AT THE HAMOC     15
15 C YIELD PRESSURE OF THE PIPE LEG J FROM WHICH THE TEE HAMOC     16
C BRANCHES TO THE PRESSURIZER JUNCTION. WHEN THE LOOP HAMOC     17
C LEG J PRESS. IS LESS THAN YIELD, THE TYPE 11 BEHAVES AS A HAMOC     18
C CONTINUING PIPE JUNCTION TYPE 2, AND WHEN GREATER, THE TYPE HAMOC     19
C 11 TEE BEHAVES AS A TYPE 6 TEE JUNCTION WITH FLOW INTO HAMOC     20
20 C THE PRESSURIZER. FLOW, WHICH IS ALWAYS EQUAL TO OR GREATER HAMOC     21
C THAN ZERO, IS INTEGRATED TO GIVE PLASTIC DEFORMATION ENERGY HAMOC     22
C AT THE SPECIAL JUNCTION BY THE INTEGRAL OF P*O(VOLUME). HAMOC     23
C ADDITIONS ARE MADE TO THESE SUBROUTINES AND ETC.- HAMOC     24
C COMMON INIT HAMOC     25
25 C HAMOC(MAIN PROG.) REPT HAMOC     26
C DATA HAMOC     27
C JUNCTN HAMOC     28
C THESE CHANGES ARE IDENTIFIED BY THE 5/2/73 DATE BEYOND HAMOC     29
C COLUMN 72 ON THE PUNCHED CARDS. HAMOC     30
30 C NOTE ...HAMOC RESULTS ARE UNCHANGED FROM FORMER VERSION IF HAMOC     31
C NO TYPE 11 JUNCTIONS ARE SPECIFIED. ALSO DO NOT USE TYPE 12 HAMOC     32
C JUNCTIONS UNLESS THEY ARE COUPLED WITH TYPE 11'S. ALSO YIELD HAMOC     33
C PRESSURE IS BASED ON TYPE 304 YIELD STRESS. HAMOC     34
C HAMOC     35
75 C ---- NOTATION ---- HAMOC     36
C A LEG FLOW AREA,SQ FT. HAMOC     37
C ANGLEF ANGLE A LEG MAKES WITH THE HORIZONTAL,DEG.. (+ IS UP) HAMOC     38
C BULKMD BULK MODULUS OF ELASTICITY OF THE FLUID,PSI. HAMOC     39
C C SPEED OF PRESSURE PULSE,FT/SEC. HAMOC     40
40 C CAVOL CAVITY VOLUME,CU FT. HAMOC     41
C CV COMPONENT PRESSURE LOSS CHARACTERISTIC. HAMOC     42
C CVTEE1 L/D FOR TEE FOR LEG J FOR TEE AT END OF LEG J. HAMOC     43
C CVTEE2 L/D FOR TEE FOR LEG J+1 FOR TEE AT END OF LEG J. HAMOC     44
45 C CVTEE3 L/D FOR TEE FOR LEG LEG3 FOR TEE AT END OF LEG J. HAMOC     45
C C1 GROUPING OF CONSTANTS. SEE INIT SUBROUTINE. HAMOC     46
C C2 GROUPING OF CONSTANTS. SEE INIT SUBROUTINE. HAMOC     47
C C3 GROUPING OF CONSTANTS. SEE INIT SUBROUTINE. HAMOC     48
C C4 GROUPING OF CONSTANTS. SEE INIT SUBROUTINE. HAMOC     49
50 C D PIPE LEG INSIDE DIAMETER,FT. HAMOC     50
C DT TIME STEP,SEC. HAMOC     51
C DTINIT INPUT SPECIFIED DT VALUE,SEC. HAMOC     52
C DX NODE LENGTH,FT. HAMOC     53
C E PIPE WALL ROUGHNESS,IN/FT. HAMOC     54
55 C ENERGY ENERGY DISSIPATED AT PLASTIC DEFORMATION TEE TYPE HAMOC     55
C JUNCTION,LB-FT. HAMOC     56
C FRICTF FRICTION FACTOR. HAMOC     57
C G GRAVITATIONAL ACCELERATION,FT/SEC**2. HAMOC     58

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PROGRAM HAMOC (cont'd)

PROGRAM HAMOC

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.25.75.

	C	H	PIEZOMETRIC HEAD,FT.	HAMOC	59
	C	HDESIN	PUMP DESIGN HEAD,FT.	HAMOC	60
60	C	HR	INTERPOLATED PIEZOMETRIC HEAD TOWARD NODAL POINT I-1 AT PRECEEDING TIME PLANE.	HAMOC	61
	C			HAMOC	62
	C	HS	INTERPOLATED PIEZOMETRIC HEAD TOWARD NODAL POINT I+1 AT PRECEEDING TIME PLANE.	HAMOC	63
	C			HAMOC	64
	C	IDENT	CASE IDENTIFICATION INFORMATION.	HAMOC	65
65	C	J	LEG NUMBER.	HAMOC	66
	C	JN	COUNTS NUMBER OF TEES IN THE MODEL.	HAMOC	67
	C	JN01	JUNCTION NUMBER AT START OF LEG.	HAMOC	68
	C	JN02	JUNCTION NUMBER AT END OF LEG.	HAMOC	69
	C	JNX	JUNCTION NUMBER OF THE JN(TH) TEE.	HAMOC	70
70	C	JTYP	TYPE OF JUNCTION AT END OF LEG.	HAMOC	71
	C	JTYPE1	TYPE OF JUNCTION AT START OF LEG.	HAMOC	72
	C	JTYPE2	TYPE OF JUNCTION AT END OF LEG.	HAMOC	73
	C	KAVITY	CONTROL INTEGER FOR CAVITY COLLAPSE PRESSURE CALCULATION- KAVITY=0 PRESSURE CALCULATED FROM C/2G*DELTA(V).	HAMOC	74
75	C		KAVITY=1 C/2G*DELTA(V) CALCULATION BYPASSED.	HAMOC	75
	C	LEG3	BRANCH LEG NUMBER FOR TEE JUNCTION.	HAMOC	76
	C	LNTH	PIPE LEG LENGTH,FT.	HAMOC	77
	C	MPL0T	FREQUENCY OF PLOTTING DATA.	HAMOC	78
	C	MU	FLUID VISCOSITY, LB/(HR-FT)	HAMOC	79
80	C	NN	NODAL POINT NUMBER.	HAMOC	80
	C	NO	NODAL POINT NUMBER AT END OF LEG.	HAMOC	81
	C	NOCE3	BRANCH LEG CONNECTING NODAL POINT NUMBER FOR TEE JUNCTION.	HAMOC	82
	C	NOLEG	TOTAL NUMBER OF LEGS IN THE SYSTEM MODELED.	HAMOC	83
	C	NPLOT	COUNTS DATA POINTS PLOTTED.	HAMOC	84
85	C	NT	COUNTS NUMBER OF TIME PLANES CALCULATED.	HAMOC	85
	C	NWRIT	FREQUENCY OF REPORTING DATA.	HAMOC	86
	C	P	PRESSURE,PSIG.	HAMOC	87
	C	PCA	PUMP CHARACTERISTIC FOR HEAD-CAPACITY CURVE.	HAMOC	88
	C	PC3	PUMP CHARACTERISTIC FOR HEAD-CAPACITY CURVE.	HAMOC	89
90	C	PCC	PUMP CHARACTERISTIC FOR HEAD-CAPACITY CURVE.	HAMOC	90
	C	PINIT	INITIAL PRESSURE FOR BOUNDARY CONDITION AT END OF A LEG, PSIG.	HAMOC	91
	C			HAMOC	92
	C	PRESF	PRESSURIZER JUNCTION FIXED PRESSURE,PSIG.	HAMOC	93
	C	PSAT	SATURATION PRESSURE OF FLUID,PSIG.	HAMOC	94
95	C	PY	YIELD PRESSURE OF PIPE WALL MATERIAL,PSIG.	HAMOC	95
	C	QDESIN	PUMP DESIGN FLOW RATE,CU FT/SEC.	HAMOC	96
	C	RE	REYNOLDS NUMBER.	HAMOC	97
	C	RHO	FLUID DENSITY, LB/CU FT.	HAMOC	98
	C	SIGMA	YIELD STRESS OF PIPE WALL MATERIAL,PSI.	HAMOC	99
100	C	SPEED	NORMALIZES PUMP SPEED AS FUNCTION OF TIME.	HAMOC	100
	C	STATIC	GROUPING OF CONSTANTS. SEE INIT SUBROUTINE.	HAMOC	101
	C	T	TIME,SEC.	HAMOC	102
	C	TEMP	FLUID TEMPERATURE,DEG. F.	HAMOC	103
	C	TEND	RUN STOP TIME,SEC.	HAMOC	104
105	C	THETA	MESH RATIO DT/DX.	HAMOC	105
	C	THK	PIPE WALL THICKNESS,IN.	HAMOC	106
	C	TWCG	2 TIMES GRAVITATIONAL ACCELERATION,FT/SEC**2.	HAMOC	107
	C	TWCG1	288 TIMES GRAVITATIONAL ACCELERATION,FT/SEC**2*IN**2/FT**2	HAMOC	108
	C	V	FLUID VELOCITY,FT/SEC.	HAMOC	109
110	C	W	INITIAL WEIGHT FLOW RATE OF FLUID, LB/SEC.	HAMOC	110
110	C	YOUNGS	YOUNGS MODULUS OF ELASTICITY FOR THE PIPE MATERIAL,PSI.	HAMOC	111
	C	Z	ELEVATION ABOVE DATUM,FT.	HAMOC	112
	C			HAMOC	113
	C			HAMOC	114
	C			HAMOC	115

PROGRAM HAMOC (cont'd)

PROGRAM HAMOC 74/74 OPT=1 FTM 4.2+74351 03/24/76 08.25.05.

115	COMMON/A1/	D (56),LNTH (56),C (56),CV (56),	KOMMN	2
	1	JTYPE2(56),JNO2 (56),NO (56),KK (56),	KOMMN	3
	2	LEG7 (56),NODE3 (56),RHO (56),C1 (56),	KOMMN	4
	3	C2 (56),C3 (56),C4 (56),STATIC(56),	KOMMN	5
	4	A (56),CPC3 (56),THETA (56),PSAT (56),	KOMMN	6
120	5	VSAV (56),HSAV (56),PY (56),ENERGY(56),	KOMMN	7
	6	LEGSAT(56),NNSAT (56),DX (56),EPASE (56),	KOMMN	8
	7	CAVOL (56),	KOMMN	9
	8	P(50, 56),H(5, 56),Z(50, 56),V(5, 56),	KOMMN	10
	9	CVTEE1(30),CVTEE2(30),CVTEE3(30),PRES(15),	KOMMN	11
125	X	E,CKJ,CKJ1,CKJ1,NOLEG,T,NT,J,JTYP,QDESIN,HDESIN,	KOMMN	12
	1	PCA,PCB,PCC,NX,DT,PEND,PSTART,GTHETA,NWRIT,MPLT,	KOMMN	13
	2	TEND,PINIT,J6,J7,JENDS6,VSARE,HSAVE,DTINIT,IMSAT,	KOMMN	14
	3	JC,NC,KAVITY	KOMMN	15
130	COMMON/PLT/NPCT,LF,LOC,KNT,ISW,NPLOT,NK(53),TIM(1003),BUF(1000)	KOMMN	16	
	COMMON NID,KPLT,TZ,TSCL,PZ,PSCL,IDENT(5),KID,L5,L8	KOMMN	17	
	COMMON LPLOT	KOMMN	18	
	INTEGER FLD	HAMOC	117	
	REAL LNTH	HAMOC	118	
	DOUBLE PRECISION DB,DCC,DBC	HAMOC	119	
135	DATA G/32.174/,THOG1/9266.112/,THOG/64.348/	HAMOC	120	
	C	HAMOC	121	
	T=0.	HAMOC	122	
	NT=0	HAMOC	123	
	NPCT=0	HAMOC	124	
140	NNJMP=0	HAMOC	125	
	CALL DATA	HAMOC	126	
	C	HAMOC	127	
	C	HAMOC	128	
	C	HAMOC	129	
145	DO 2 I=100,3100	HAMOC	130	
	2 BUF(I)=0.	HAMOC	131	
	CALL SETPLT	HAMOC	132	
	DO 3 J=1,NOLEG	HAMOC	133	
	NN=NO(J)	HAMOC	134	
150	ENERGY(J)=0.	HAMOC	135	
	LEGSAT(J)=0	HAMOC	136	
	NNSAT(J)=0	HAMOC	137	
	ERASE(J)=TEND	HAMOC	138	
	DO 3 I=1,NN	HAMOC	139	
155	CAVOL(J)=0.	HAMOC	140	
	3 CONTINUE	HAMOC	141	
	CALL REPT	HAMOC	142	
	GO TO 60	HAMOC	143	
	5 T=T+DT	HAMOC	144	
160	C	HAMOC	145	
	C	HAMOC	146	
	C	HAMOC	147	
	IF (T.GT.TEND) GO TO 90	HAMOC	148	
	J7=0	HAMOC	149	
165	J6=0	HAMOC	150	
	NT=NT+1	HAMOC	151	
	J=1	HAMOC	152	
	N=1	HAMOC	153	
	IMSAT=C	HAMOC	154	
170	C	HAMOC	155	
	C	HAMOC	156	
	COMPUTE DATA AT START OF LEG 1.			

PROGRAM HAMOC (cont'd)

PROGRAM HAMOC

74/74 OPT=1

FTN 4.2+74351

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	C	PSTART=PBACKR(T)	HAMOC	157
	C		HAMOC	158
175	C	FIRST ASSUME FLOW IS POSITIVE AT FIRST NODAL POINT IN PIPE LEG 1.	HAMOC	159
	C	CHECK ASSUMPTION LATER. IF INCORRECT, FLOW MUST BE NEGATIVE SO	HAMOC	160
	C	REPEAT CALCS. FOR NEG. FLOW.	HAMOC	161
	C		HAMOC	162
		VS=V(N,J)-V(N+1,J)	HAMOC	163
180		VS=(V(N,J)-THETA(J)*C(J)*VS)/(1.-THETA(J)*VS)	HAMOC	164
		HS=H(N,J)+THETA(J)*(VS-C(J))*(H(N,J)-H(N+1,J))	HAMOC	165
		VSAV(J) = V(N,J)	HAMOC	166
		MSAV(J) = H(N,J)	HAMOC	167
		RENO=C1(J)*VS	HAMOC	168
185		FF=FRICTF(RENO,D(J),E)	HAMOC	169
		CX1=VS-C4(J)*HS+G*THETA(J)*STATIC(J)/C(J)*VS-FF*VS*ABS(VS)*C3(J)	HAMOC	170
		F=C(J)/.75	HAMOC	171
		CC=F*(CX1+C4(J)*PSTART*144./RHO(J)+C4(J)*Z(N,J))	HAMOC	172
		DB=F	HAMOC	173
190		DCC=CC	HAMOC	174
		DBC=DB**2+4.00*DCC	HAMOC	175
		IF (DBC) 11,11,10	HAMOC	176
	10	V(N,J)=.5*(-DB+DSQRT(DBC))	HAMOC	177
		IF (V(N,J)) 11,11,12	HAMOC	178
195	C		HAMOC	179
	C	SINCE FLOW IS NOT POSITIVE, IT MUST BE NEGATIVE. PROCEED WITH THIS	HAMOC	180
	C	ASSUMPTION.	HAMOC	181
	C		HAMOC	182
		11 V(N,J)=CX1+C4(J)*(PSTART*144./RHO(J)+Z(N,J))	HAMOC	183
200		P(N,J)=PSTART	HAMOC	184
		H(N,J)=P(N,J)*144./RHO(J)+Z(N,J)	HAMOC	185
		GO TO 13	HAMOC	186
		12 H(N,J)=(V(N,J)-CX1)/C4(J)	HAMOC	187
		P(N,J)=(H(N,J)-Z(N,J))*RHO(J)/144.	HAMOC	188
205		13 CONTINUE	HAMOC	189
		DO 40 J=1,NOLEG	HAMOC	190
	C		HAMOC	191
	C	COMPUTE DATA FOR EACH LEG.	HAMOC	192
	C		HAMOC	193
210		NNN=NO(J)-1	HAMOC	194
		IF (NNN.EQ.1) GO TO 31	HAMOC	195
		DO 41 KN=2,NNN	HAMOC	196
		NN=KN	HAMOC	197
	C		HAMOC	198
215	C	COMPUTE NODAL POINT DATA.	HAMOC	199
	C		HAMOC	200
	C	IF (NNJMP.EQ.0) GO TO 17	HAMOC	201
		NNJMP=0	HAMOC	202
		GO TO 41	HAMOC	203
220		17 IF (JENDS6.EQ.1.AND.NN.EQ.NNN) GO TO 8	HAMOC	204
		VS=V(NN,J)-V(NN+1,J)	HAMOC	205
		VS=(V(NN,J)-C(J)*THETA(J)*VS)/(1.-THETA(J)*VS)	HAMOC	206
		HS=H(NN,J)+THETA(J)*(VS-C(J))*(H(NN,J)-H(NN+1,J))	HAMOC	207
		GO TO 9	HAMOC	208
225		8 VS=V(NN,J)-VSAVE	HAMOC	209
		VS=(V(NN,J)-C(J)*THETA(J)*VS)/(1.-THETA(J)*VS)	HAMOC	210
		HS=H(NN,J)+THETA(J)*(VS-C(J))*(H(NN,J)-HSAVE)	HAMOC	211
		9 VR=V(NN,J)-VSAV(J)	HAMOC	212
			HAMOC	213

PROGRAM HAMOC (cont'd)

PROGRAM HAMOC	74/74	OPT=1	FTN 4.2+74351	03/24/76	08.25.05.
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230	VR=(V(NN,J)-C(J)*THETA(J)*VR)/(1.+THETA(J)*VR)	HAMOC	214
	HR=H(NN,J)-THETA(J)*(VR+C(J))*H(NN,J)-HSAV(J)	HAMOC	215
	OLDV=VSAV(J)	HAMOC	216
	VSAV(J)=V(NN,J)	HAMOC	217
	HSAV(J)=H(NN,J)	HAMOC	218
	SAVV=V(NN,J)	HAMOC	219
235	SAVH=H(NN,J)	HAMOC	221
	RENOR=C1(J)*VP	HAMOC	221
	RENOS=C1(J)*VS	HAMOC	222
	FFR=FRICTF(RENOR,D(J),E)	HAMOC	223
	FFS=FRICTF(RENOS,D(J),E)	HAMOC	224
240	V(NN,J)=.5*(VR+VS+C4(J)*(HR-HS)-C4(J)*THETA(J)*STATIC(J)*(VR-VS	HAMOC	225
	1)-FFR*C3(J)*VR*ABS(VR)-FFS*C3(J)*VS*ABS(VS))	HAMOC	226
	H(NN,J)=.5*(HR+HS+(VR-VS)/C4(J)-THETA(J)*STATIC(J)*(VR+VS)	HAMOC	227
	1)-FFR/C4(J)*C3(J)*VR*ABS(VR)+FFS/C4(J)*C3(J)*VS*ABS(VS))	HAMOC	228
	P(NN,J)=(H(NN,J)-Z(NN,J))*RHO(J)/144.	HAMOC	229
245	C	HAMOC	231
	C ERASE(J) IS USED TO CONTROL THE TIME WHEN A NEW CAVITY CAN FORM.	HAMOC	231
	C A NEW ONE CAN FORM WHEN TIME T EXCEEDS ERASE(J) FOR THAT LEG.	HAMOC	232
	C THE INITIAL CAVITY IS AN EXCEPTION.	HAMOC	233
	C	HAMOC	234
250	IF(T.LE.ERASE(J)) GO TO 15	HAMOC	235
	LEGSAT(J)=C	HAMOC	236
	ERASE(J)=TEND	HAMOC	237
	15 IF(LEGSAT(J).EQ.1.AND.P(NN,J).LE.PSAT(J)) GO TO 16	HAMOC	238
	IF(NN.EQ.NNSAT(J)) GO TO 18	HAMOC	239
255	IF(P(NN,J).LE.PSAT(J)) GO TO 22	HAMOC	240
	IMSAT=1	HAMOC	241
	GO TO 30	HAMOC	242
	16 IF(LEGSAT(J+1).EQ.1.AND.P(2,J+1).LE.PSAT(J+1)) GO TO 23	HAMOC	243
	IF(NNN.NE.2) GO TO 19	HAMOC	244
260	GO TO 22	HAMOC	245
	19 IF(IMSAT.EQ.1) GO TO 22	HAMOC	246
	C	HAMOC	247
	C ALLOW NEW CAVITY TO FORM IN LEG J.	HAMOC	248
	C	HAMOC	249
265	LEGSAT(J)=1	HAMOC	250
	IF(NN.EQ.NNN) NN=NN-1	HAMOC	251
	NNSAT(J)=NN	HAMOC	252
	19 IF(KN.NE.NNN) NNJMP=1	HAMOC	253
	C	HAMOC	254
270	C SET NODAL POINT PRESSURE TO SATURATION AND CALCULATE BOUNDARY	HAMOC	255
	C CONDITION VELOCITIES AND CAVITY SIZE.	HAMOC	256
	C	HAMOC	257
	C	HAMOC	258
	IMSAT=1	HAMOC	259
	JC=J	HAMOC	259
275	NC=NN	HAMOC	260
	P(NN,J)=PSAT(J)	HAMOC	261
	H(NN,J)=Z(NN,J)+P(NN,J)*144./RHO(J)	HAMOC	262
	V(NN,J)=VR-C4(J)*(H(NN,J)-HR)-C4(J)*STATIC(J)*THETA(J)*VR-	HAMOC	263
	1) FFR*C3(J)*VR*ABS(VR)	HAMOC	264
280	VSAV(J)=V(NN+1,J)	HAMOC	265
	HSAV(J)=H(NN+1,J)	HAMOC	266
	P(NN+1,J)=PSAT(J)	HAMOC	267
	H(NN+1,J)=Z(NN+1,J)+P(NN+1,J)*144./RHO(J)	HAMOC	268
	VS=V(NN+1,J)-V(NN+2,J)	HAMOC	269
285	VS=(V(NN+1,J)-C(J)*THETA(J)*VS)/(1.-THETA(J)*VS)	HAMOC	270

PROGRAM HAMOC (cont'd)

PROGRAM HAMOC

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	HS=H(NN+1,J)+THETA(J)*(VS-C(J))*(H(NN+1,J)-H(NN+2,J))	HAMOC	271
	RENOS=C1(J)*VS	HAMOC	272
	FFS=FRICTF(RENOS,D(J),E)	HAMOC	273
290	V(NN+1,J)=VS+C4(J)*(H(NN+1,J)-HS)+C4(J)*STATIC(J)*THETA(J)*VS-	HAMOC	274
	1 FFS*C3(J)*VS*ABS(VS)	HAMOC	275
	CAVOL(J)=CAVOL(J)+A(J)*DT*(V(NN+1,J)+VSAV(J)-V(NN,J)-SAVV)/2.	HAMOC	276
	IF(CAVOL(J)) 20,20,30	HAMOC	277
	22 P(NN,J)=PSAT(J)	HAMOC	278
	H(NN,J)=Z(NN,J)+P(NN,J)*144./RHO(J)	HAMOC	279
295	IF(NNN.EQ.2) GO TO 30	HAMOC	280
	IF(IMSAT.EQ.1) GO TO 30	HAMOC	281
	VDIF=(V(NN,J)+VSAV(J)-V(NN-1,J)-OLDV)/2.	HAMOC	282
	CAVOL(JC)=CAVOL(JC)+A(J)*DT*VDIF	HAMOC	283
	GO TO 30	HAMOC	284
300	23 IMSAT=1	HAMOC	285
	JC=J+1	HAMOC	286
	NC=NNSAT(J+1)	HAMOC	287
	GO TO 22	HAMOC	288
	27 P(NN,J)=PSAT(J)+C(J)/THCG1*(V(NN,J)-V(NN+1,J))*RHO(J)	HAMOC	289
305	P(NN,J)=AMAX1(P(NN,J),PSAT(J))	HAMOC	290
	IF(KAVITY.EQ.1) P(NN,J)=PSAT(J)	HAMOC	291
	C	HAMOC	292
	C CALCULATE NODAL POINT PRESSURE AT TIME OF CAVITY COLLAPSE DEPENDING	HAMOC	293
	C ON THE INPUT SPECIFIED KAVITY.	HAMOC	294
310	C	HAMOC	295
	H(NN,J)=Z(NN,J)+P(NN,J)*144./RHO(J)	HAMOC	296
	C	HAMOC	297
	C RE-INITIALIZE CAVITY CONTROL INTEGERS, EXCEPT FOR LEGSAT(J) AND	HAMOC	298
	C ERASE(J).	HAMOC	299
315	C	HAMOC	300
	IMSAT=0	HAMOC	301
	NNSAT(J)=0	HAMOC	302
	LEND=(NO(J)-NN)	HAMOC	303
	ERASE(J)=T+DT*FLOAT(LEND)	HAMOC	304
320	CAVOL(J)=0.	HAMOC	305
	NNJMP=0	HAMOC	306
	VSAV(J)=SAVV	HAMOC	307
	HSAV(J)=SAVH	HAMOC	308
	37 IF(THETA(J)*(V(NN,J)+C(J)).LT.1.) GO TO 41	HAMOC	309
325	43 WRITE(6,44) J,NN,T	HAMOC	310
	44 FORMAT(1H "DT/DX MESH RATIO MAY BE TOO LARGE FOR STABILITY AT LEG"	HAMOC	311
	1,I3," AND NODAL POINT",I3," AT TIME",F8.5," SECONDS")	HAMOC	312
	41 CONTINUE	HAMOC	313
	31 JTYPE=JTYPE2(J)	HAMOC	314
330	JENOS6=0	HAMOC	315
	VSAV(J+1)=V(1,J+1)	HAMOC	316
	C	HAMOC	317
	C CALL JNCTN FOR JUNCTION DATA.	HAMOC	318
	C	HAMOC	319
335	C	HAMOC	320
	CALL JNCTN	HAMOC	321
	NN=NO(J)	HAMOC	322
	IF(THETA(J)*(V(NN,J)+C(J)).LT.1.) GO TO 40	HAMOC	323
	WRITE(6,44) J,NN,T	HAMOC	324
	40 CONTINUE	HAMOC	325
340	IF(MOD(NT,NWRIT).EQ.0) CALL REPT	HAMOC	326
	C	HAMOC	327
	C CALL REPT TO REPORT INFORMATION AT THIS TIME.	HAMOC	

PROGRAM HAMOC (cont'd)

PROGRAM HAMOC 74/74 OPT=1

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	C		HAMOC	328
		IF (MOD (NT,MPLT).EQ.0) GO TO 60	HAMOC	329
345	42	DT=DTINIT	HAMOC	330
		DO 50 J=1,NOLEG	HAMOC	331
		NNN=NO(J)	HAMOC	332
		DO 50 I=1,NNN	HAMOC	333
		OTS=.99*DX(J)/(C(J)+V(I,J))	HAMOC	334
358		DT=AMIN1(DT,OTS)	HAMOC	335
	C		HAMOC	336
	C	DETERMINE DT FOR NEXT TIME STEP.	HAMOC	337
	C		HAMOC	338
	50	CONTINUE	HAMOC	339
355		DO 48 J=1,NOLEG	HAMOC	340
		KK(J)=C	HAMOC	341
	C		HAMOC	342
	C	ADJUST THETA(J) AND C3(J) FOR THE CALCULATED DT.	HAMOC	343
	C		HAMOC	344
360		THETA(J)=DT/DX(J)	HAMOC	345
		C3(J)=DT/2./D(J)	HAMOC	346
	48	CONTINUE	HAMOC	347
		GO TO 5	HAMOC	348
	90	CONTINUE	HAMOC	349
365		IF (NPLT.EQ.0) GO TO 91	HAMOC	350
	C		HAMOC	351
	C	PLOT RESULTS.	HAMOC	352
	C		HAMOC	353
		CALL PLTT	HAMOC	354
370	91	STOP	HAMOC	355
	6	IF (NPLT.EQ.0) GO TO 42	HAMOC	356
	C		HAMOC	357
	C	SAVE DATA TO BE PLOTTED.	HAMOC	358
	C		HAMOC	359
375		NPCT=NPCT+1	HAMOC	360
	C	PLOT VS TIME IN MILLISECONDS	HAMOC	361
		TIM(NPCT)=10**0.*T	HAMOC	362
		IF (KNT.EQ.0) GO TO 61	HAMOC	363
		IF (UNIT(20)) 61,61,9999	HAMOC	364
380	61	CONTINUE	HAMOC	365
		DO 500 I=1,NPLT	HAMOC	366
		J1 = NK(I)	HAMOC	367
	C	FIRST LEG NO.	HAMOC	368
		J=FLO(10,9,J1)	HAMOC	369
385	C	FIRST NODE NO.	HAMOC	370
		NKN=FLO(20,8,J1)	HAMOC	371
	C	FIRST VALUE	HAMOC	372
		PV = P(NKN,J)	HAMOC	373
	C	CHECK FOR PD	HAMOC	374
390		IF (FLO(2,1,J1).NE.1) GO TO 400	HAMOC	375
	C****	DIFERENCES	HAMOC	376
	C		HAMOC	377
	C	SECOND LEG NO.	HAMOC	378
		J=FLO(30,9,J1)	HAMOC	379
395	C	SECOND NODE NO.	HAMOC	380
		NKN=FLO(40,8,J1)	HAMOC	381
		PV = PV-P(NKN,J)	HAMOC	382
	400	CONTINUE	HAMOC	383
		LOC = I + 1990*((I-1)/10) + MOD(KNT,200)*10	HAMOC	384

PROGRAM HAMOC (cont'd)

PROGRAM HAMOC 74/74 OPT=1

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03/24/76 08.25.05.

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400      B J F ( L O C ) = P V
          500 CONTINUE
          K N T = K N T + 1
C 100    I T E R A T I O N S   P E R   D U M P
          I F ( M O D ( K N T , 100 ) . E Q . 0 ) C A L L   B O U M P
405      G O   T O   42
          9999 STOP
          E N D

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HAMOC 385
HAMOC 386
HAMOC 387
HAMOC 388
HAMOC 389
HAMOC 390
HAMOC 391
HAMOC 392

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03/24/76 08.25.23.

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SUBROUTINE DATA

SUBROUTINE DATA

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.25.28.

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SUBROUTINE DATA
C
C DATA READS INPUT INFORMATION FOR EACH CASE AND THEN REPORTS
C THIS INFORMATION.
C
C SEE HAMOC MAIN PROGRAM FOR NOTATION.
C
C DIMENSION JTYPE1(500),JNO1(500),W(500),THK(500),TEMP(500),
C   1 ANGLE(500)
C EQUIVALENCE (BUF(100),JTYPE1),(BUF(600),JNO1),(BUF(1100),W),
C   X (BUF(1600),THK),(BUF(2100),TEMP),(BUF(2600),ANGLE)
C COMMON/A1/ C ( 56),LNTH ( 56),C ( 56),CV ( 56),
C   1 JTYPE2( 56),JNO2 ( 56),NO ( 56),KK ( 56),
C   2 LEG3 ( 56),NODE3 ( 56),RHO ( 56),C1 ( 56),
C   3 C2 ( 56),C3 ( 56),C4 ( 56),STATIC( 56),
C   4 A ( 56),CPC3 ( 56),THETA ( 56),PSAT ( 56),
C   5 VSAV ( 56),HSAV ( 56),PY ( 56),ENERGY( 56),
C   6 LEGSAT( 56),NNSAT ( 56),DX ( 56),EPASE ( 56),
C   7 CAVOL ( 56),
C   8 P( 50, 56),H( 50, 56),Z( 50, 56),V( 50, 56),
C   9 CVTEE1(3),CVTEE2(3),CVTEE3(3),FRESP(15),
C   X E,CKJ,CKJ1,CKJ2,NOLEG,T,NT,J,JTYP,QDESIN,HDESIN,
C   1 PCA,PCB,PCC,NX,DT,PEND,PSTART,GTHETA,NWRIT,MPLLOT,
C   2 TEND,PINIT,J6,J7,JENDS6,VSAVE,HSAVE,DTINIT,IMSAT,
C   3 JC,NC,KAVITY
C COMMON/PLT/NPCT,LF,LOC,KNT,ISW,NPLOT,NK(53),TIM(1003),BUF(10000)
C COMMON NID,KPLT,TZ,TSC, PZ,PSCL,IDENT(5),KID,L5,L8
C COMMON LPLLOT
C REAL LNTH
C CALL DATE(ETAD)
C NX IS SET TO FIRST DIMENSION OF P
C NX=50
C READ(5,10) IDENT
C   10 FORMAT(4A10,A8)
C READ(5,11) DT,TEND,E,NOLEG,NWRIT,MPLLOT,KAVITY
C   11 FORMAT(3F10.6,4I5)
C JEND=NOLEG+1
C DO 100 J=1,JEND
C   LEG3(J)=0
C   NODE3(J)=0
C   KK(J)=0
C   DO 100 NN=1,NX
C     V(NN,J)=0.
C     P(NN,J)=0.
C   100 CONTINUE
C READ(5,12) PCA,PCB,PCC,HDESIN,QDESIN
C   12 FORMAT(3F10.6,2F10.4)
C WRITE(6,15) IDENT,ETAD
C   15 FORMAT(1H1//1X6HCASE--4A10,A8,50XA10/10X"BY HAMOC PROGRAM"/)
C WRITE(6,16) DT,TEND,E,NOLEG,NWRIT,NX,MPLLOT,PCA,PCB,PCC,HDESIN,
C   1 QDESIN
C   16 FORMAT(1X,"FOR TIME STEP =",F10.6," SECONDS",5X,
C     1 "END TIME =",F6.3," SECONDS",6X,"PIPE ROUGHNESS ="
C     2,F8.6," FEET",/6X,"TOTAL LEGS IN MODEL =",I4,9X,"RESULTS WRITTEN A
C     3FTER EVERY",I3," TIME INTERVALS",/6X,"MAXIMUM NODAL POINTS/LEG =",
C     4I4,4X,"RESULTS PLOTTED AFTER EVERY",I3," TIME INTERVALS",/

```

DATA	2
DATA	3
DATA	4
DATA	5
DATA	6
DATA	7
DATA	8
DATA	9
DATA	10
DATA	11
DATA	12
DATA	13
KOMM	2
KOMM	3
KOMM	4
KOMM	5
KOMM	6
KOMM	7
KOMM	8
KOMM	9
KOMM	10
KOMM	11
KOMM	12
KOMM	13
KOMM	14
KOMM	15
KOMM	16
KOMM	17
KOMM	18
DATA	19
DATA	20
DATA	21
DATA	22
DATA	23
DATA	24
DATA	25
DATA	26
DATA	27
DATA	28
DATA	29
DATA	30
DATA	31
DATA	32
DATA	33
DATA	34
DATA	35
DATA	36
DATA	37
DATA	38
DATA	39
DATA	40
DATA	41
DATA	42

SUBROUTINE DATA (cont'd)

SUBROUTINE DATA

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.25.28.

	56X,"PUMP HEAD EQUATION CHARACTERIZATION CONSTANTS PCA,PCB,AND PCC	DATA	43
	6=",F9.6,"",F8.6,"", AND",F10.7,/6X,	DATA	44
60	7"PUMP DESIGN HEAD AND DESIGN FLOW RATE =",F8.2," FEET AND",F8.4,	DATA	45
	8" CFS",/)	DATA	46
	M=CAVITY+1	DATA	47
	GO TO (4,5),M	DATA	48
	4 WRITE(6,6)	DATA	49
65	6 FORMAT(6X,"THIS RUN MADE WITH CAVITY COLLAPSE PRESSURE CALCULATED	DATA	50
	1USING C/2G*DELTA(V)."/)	DATA	51
	GO TO 9	DATA	52
	5 WRITE(6,7)	DATA	53
	7 FORMAT(6X,"THIS RUN MADE WITH THE C/2G*DELTA(V) CAVITY COLLAPSE PR	DATA	54
70	1ESSURE BY-PASSED."/6X,"THE NODAL POINT PRESSURE IS SET TO SATURATI	DATA	55
	2ON INSTEAD."/)	DATA	56
	9 CONTINUE	DATA	57
	NTEE=C	DATA	58
	NTEEP="	DATA	59
75	DO 20 J=1,NOLEG	DATA	60
	READ (5,21) K,D(J),LNTH(J),THK(J),TEMP(J),CV(J),ANGLE(J),	DATA	61
	1 JTYPE1(J),JTYPE2(J),JNO1(J),JNO2(J)	DATA	62
	IF(J.NE.K) GO TO 19	DATA	63
	21 FORMAT(I5,4F10.4,F10.2,F5.1,4I5)	DATA	64
80	IF(JTYPE2(J).NE.6.AND.JTYPE2(J).NE.11) GO TO 20	DATA	65
	M6=JNO2(J)	DATA	66
	IF(KK(M6).EQ.1) GO TO 8	DATA	67
	C	DATA	68
	C COUNT NUMBER OF TEES IN THE SYSTEM MODEL AS NTEE.	DATA	69
85	C	DATA	70
	NTEE=NTEE+1	DATA	71
	IF(NTEE.GT.30) GO TO 54	DATA	72
	KK(M6)=1	DATA	73
	GO TO 20	DATA	74
90	8 NTEEP=NTEEP+1	DATA	75
	20 CONTINUE	DATA	76
	C	DATA	77
	C DETERMINE NUMBER OF FLOW RATE CARDS REQUIRED IN THE DATA DECK AS	DATA	78
	C NTEE1.	DATA	79
95	C	DATA	80
	NTEE1=(NTEE-NTEEP)*2+NTEEP+1	DATA	81
	DO 25 M=1,NTEE1	DATA	82
	C	DATA	83
	C READ NTEE1 FLOW RATE DATA CARDS.	DATA	84
100	C	DATA	85
	READ (5,26) J,W(J)	DATA	86
	26 FORMAT (I5,F15.6)	DATA	87
	IF(J.LE.0) GO TO 41	DATA	88
	25 CONTINUE	DATA	89
105	READ(5,27) IMOK	DATA	90
	27 FORMAT(I5)	DATA	91
	IF(IMOK.NE.-1) GO TO 41	DATA	92
	IF(NTEE.EQ.3) GO TO 31	DATA	93
	DO 22 M=1,NTEE	DATA	94
110	C	DATA	95
	C READ NTEE TEE JUNCTION CARDS FOR L/D VALUES.	DATA	96
	C	DATA	97
	READ(5,23) JN,JNX,CVTEE1(JN),CVTEE2(JN),CVTEE3(JN)	DATA	98
	23 FOPMAT(2I5,3F10.4)	DATA	99

SUBROUTINE DATA (cont'd)

SUBROUTINE DATA

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.25.28.

115	IF(JN.LE.0) GO TO 43	DATA	100
	22 CONTINUE	DATA	101
	READ(5,24) IMOK	DATA	102
	24 FORMAT(I5)	DATA	103
	IF(IMOK.NE.-1) GO TO 43	DATA	104
120	31 WRITE(6,30)	DATA	105
	30 FORMAT(132H LEG W,LR/SEC ID,FT LENGTH,FT THICKNESS,IN. T	DATA	106
	TEMP,F C,FT/SEC CV SLOPE,DEG JTYPE1 JTYPE2 JNO1 JNO2 NO (	DATA	107
	20+100)DT/DX)	DATA	108
	CALL INIT	DATA	109
125	DO 40 J=1,NOLEG	DATA	110
	IF(J.EQ. 1) GO TO 35	DATA	111
	IF(JTYPE1(J).EQ.6.OR.JTYPE1(J).EQ.11) GO TO 35	DATA	112
	W(J)=W(J-1)	DATA	113
	35 RATIO=(C(J)+100.)*DT/DX(J)	DATA	114
130	WRITE(6,36) J,W(J),D(J),LNTH(J),THK(J),TEMP(J),C(J),CV(J),ANGLE(J)	DATA	115
	1 ,JTYPE1(J),JTYPE2(J),JNO1(J),JNO2(J),NO(J),RATIO	DATA	116
	36 FORMAT(I5,F12.4,F10.4,F10.4,F10.4,F14.2,3F10.2,I5,I6,I7,2I5,F11.6)	DATA	117
	40 CONTINUE	DATA	118
	IF(NT.EE.EQ.0) GO TO 53	DATA	119
135	DO 49 J=1,NOLEG	DATA	120
	49 KK(J)=0	DATA	121
	WRITE(6,50)	DATA	122
	50 FORMAT(1H0,24X,"TEE JUNCTION L/D VALUES---"/10X,"TEE NUMBER JUNCT	DATA	123
	1ION NO. LEG-1 L/D LEG-2 L/D LEG-3 L/D "/)	DATA	124
140	JN=0	DATA	125
	DO 52 J=1,NOLEG	DATA	126
	IF(JTYPE2(J).NE.6.AND.JTYPE2(J).NE.11) GO TO 52	DATA	127
	JNX=JNO2(J)	DATA	128
	IF(KK(JNX).EQ.1) GO TO 52	DATA	129
145	JN=JN+1	DATA	130
	WRITE(6,51) JN,JNX,J,CVTEE1(JN),J+1,CVTEE2(JN),LEG3(JNX),	DATA	131
	1 CVTEE3(JN)	DATA	132
	51 FORMAT(15X,I3,10X,I3,6X,I3,F9.2,I6,F9.2,I6,F9.2)	DATA	133
	KK(JNX)=1	DATA	134
150	52 CONTINUE	DATA	135
	53 K=0	DATA	136
	WRITE(6,60)	DATA	137
	60 FORMAT(1H0,10X,"THE FOLLOWING LEGS HAVE A HIGH MESH RATIO WHICH MA	DATA	138
155	1Y CAUSE NUMERICAL INSTABILITY."/5X,"LEG DX (C+100)DT/DX"/	DATA	139
	2/)	DATA	140
	DO 65 J=1,NOLEG	DATA	141
	RATIO=(C(J)+100.)*DT/DX(J)	DATA	142
	C	DATA	143
	C CHECK MESH RATIO FOR POSSIBLE NUMERICAL INSTABILITY.	DATA	144
160	C	DATA	145
	IF(RATIO.LE.1.) GO TO 65	DATA	146
	K=1	DATA	147
	WRITE(6,62) J,DX(J),RATIO	DATA	148
	62 FORMAT(I8,F12.6,F10.6)	DATA	149
165	65 CONTINUE	DATA	150
	IF(K.EQ.1) GO TO 66	DATA	151
	WRITE(6,64)	DATA	152
	64 FORMAT(5X,"NONE"/)	DATA	153
	66 K=0	DATA	154
170	WRITE(6,67)	DATA	155
	67 FORMAT(1H0,10X,"THE FOLLOWING LEGS HAVE A LOW MESH RATIO WHICH MAY	DATA	156

SUBROUTINE DATA (cont'd)

SUBROUTINE DATA 74/74 OPT=1 FTM 4.2+74351 03/24/76 08.25.28.

	1 CAUSE UNACCEPTABLE NUMERICAL DAMPING."/5X,"LEG DX	C* DATA	157
	2DT/DX"//)	DATA	158
	DO 69 J=1,NOLFG	DATA	159
175	RATIO=C(J)*DT/DX(J)	DATA	160
	C	DATA	161
	C CHECK MESH RATIO FOR POSSIBLE EXCESSIVE NUMERICAL DAMPING.	DATA	162
	C	DATA	163
	IF(RATIO.GT..95) GO TO 69	DATA	164
180	K=1	DATA	165
	WRITE(6,62) J,DX(J),RATIO	DATA	166
	69 CONTINUE	DATA	167
	IF(K.EQ.0) WRITE(6,64)	DATA	168
	RETURN	DATA	169
185	19 WRITE(6,18) J	DATA	170
	18 FORMAT(1H0,"ERROR IN INPUT ORDERING OF LEGS AT J= ",I4)	DATA	171
	STOP	DATA	172
	41 WRITE(6,42)	DATA	173
	42 FORMAT(1H0,"INCORRECT INPUTTING OF FLOW RATE DATA CARDS.")	DATA	174
190	STOP	DATA	175
	43 WRITE(6,44)	DATA	176
	44 FORMAT(1H0,"INCORRECT INPUTTING OF TEE JUNCTION FLOW RESISTANCE DATA	DATA	177
	1TA CARDS.")	DATA	178
	STOP	DATA	179
195	54 WRITE(6,55)	DATA	180
	55 FORMAT(1H0,"NUMBER OF TEE JUNCTIONS EXCEEDS 30 ALLOWABLE BY DIMENS	DATA	181
	XION STATEMENT. STOP PROGRAM.",)	DATA	182
	STOP	DATA	183
	END	DATA	184

FUNCTION (FLD)

FUNCTION FLD

74/74 OPT=1

FTN 4.2+74351

C 3/24/76 08.25.34.

INTEGER FUNCTION FLD(ISTART,MANY,WORD)	FLD	2
FLD=SHIFT(WORD.AND.SHIFT(MASK(MANY),60-ISTART),MOD(ISTART+MANY,50)	FLD	3
.)	FLD	4
RETURN	FLD	5
END	FLD	6

5

FUNCTION FRICTF

FUNCTION FRICTF 74/74 GPT=1

FTN 4.2+74351

3/24/76 08.25.36.

	FUNCTION FRICTF(RE,D,E)	FRICTF	2
	C	FRICTF	3
	C FUNCTION FRICTF(RE,D,E) CALCULATES THE MOODY FRICTION	FRICTF	4
	C FACTOR FOR PIPE OF DIAMETER D FT., ROUGHNESS E FT.,	FRICTF	5
5	C FOR COOLANT REYNOLDS NUMBER RE.	FRICTF	6
	C	FRICTF	7
	C	FRICTF	8
	C SEE HAMOC MAIN PROGRAM FOR NOTATION.	FRICTF	9
	C	FRICTF	10
10	DATA KUTOFF,FIRST,F2ND,TEST/25,0.1,0.12,.001/	FRICTF	11
	100 FORMAT(1HC/3QH NO SOLUTION FOR FRICTF AFTER 15,12H ITERATIONS./	FRICTF	12
	17H RE IS E15.7,7H D IS E15.7,7H E IS E15.7)	FRICTF	13
	RE=ABS(RE)	FRICTF	14
	IF (RE.LT.2000.) GO TO 10	FRICTF	15
15	KOUNT=-1	FRICTF	16
	DO 6 J=1,KUTOFF	FRICTF	17
	IF (KOUNT) 1,2,3	FRICTF	18
	1 KOUNT=0	FRICTF	19
	F=FIRST	FRICTF	20
20	GO TO 4	FRICTF	21
	2 KOUNT=1	FRICTF	22
	F=F2ND	FRICTF	23
	GO TO 4	FRICTF	24
	3 F=F1-(F2-F1)*D1/(D2-D1)	FRICTF	25
25	4 X=E/D/3.7+2.51/RE/F	FRICTF	26
	X=ABS(X)	FRICTF	27
	X=-.5/ALOG10(X)	FRICTF	28
	B=F-X	FRICTF	29
	IF (ABS(B/F)-TEST) 7,7,5	FRICTF	30
30	5 D2=D1	FRICTF	31
	F2=F1	FRICTF	32
	D1=8	FRICTF	33
	F1=F	FRICTF	34
	6 CONTINUE	FRICTF	35
35	WRITE (6,100) KUTOFF,RE,D,E	FRICTF	36
	GO TO 8	FRICTF	37
	7 FRICTF=F*F	FRICTF	38
	9 RETURN	FRICTF	39
	10 IF (RE.LT.1.5) RE=1.5	FRICTF	40
40	FRICTF=64./RE	FRICTF	41
	RETURN	FRICTF	42
	END	FRICTF	43

SUBROUTINE INIT

SUBROUTINE INIT

74/74 OPT=1

FTN 4.2+743F1

03/24/76 08.25.38.

		SUBROUTINE INIT	INIT	2
	C		INIT	3
	C	INIT PROVIDES INITIAL CONDITIONS AND CONSTANTS.	INIT	4
5	C		INIT	5
	C		INIT	6
	C	SEE HAMOC MAIN PROGRAM FOR NOTATION.	INIT	7
	C		INIT	8
		DIMENSION JTYPE1(500),JNO1(500),W(500),THK(500),TEMP(500),	INIT	9
10	1	ANGLE(500)	INIT	10
		EQUIVALENCE (BUF(100),JTYPE1),(BUF(600),JNO1),(BUF(1100),W),	INIT	11
		X(BUF(1600),THK),(BUF(2100),TEMP),(BUF(2600),ANGLE)	INIT	12
		COMMON/A1/ D (56),LNTH (56),C (56),CV (56),	KOMMN	2
	1	JTYPE2(56),JNO2 (56),NO (56),KK (56),	KOMMN	3
	2	LEG3 (56),NODE3 (56),RHO (56),C1 (56),	KOMMN	4
15	3	C2 (56),C3 (56),C4 (56),STATIC(56),	KOMMN	5
	4	A (56),CPC3 (56),THETA (56),PSAT (56),	KOMMN	6
	5	VSAT (56),HSAV (56),PY (56),ENERGY(56),	KOMMN	7
	6	LEGSAT(56),NNSAT (56),CX (56),ERASE (56),	KOMMN	8
	7	CAVOL (56),	KOMMN	9
20	8	P(50, 56),H(50, 56),Z(50, 56),V(50, 56),	KOMMN	10
	9	CVTEE1(30),CVTEE2(30),CVTEE3(30),FRESP(15),	KOMMN	11
	X	E,CKJ,CKJ1,CKJ1,NOLEG,T,NT,J,JTYP,QOESIN,HDESIN,	KOMMN	12
	1	PCA,PCB,PCC,NX,DT,PEND,PSTART,GTHETA,NWPIT,MPLDT,	KOMMN	13
	2	TEND,PINIT,J6,J7,JENDS6,VSATV,HSAV,DTINIT,IMSAT,	KOMMN	14
25	3	JC,NC,KAVITY	KOMMN	15
		COMMON/PLT/NPCT,LF,LOC,KNT,ISW,NPLOT,NK(53),TIM(1003),BUF(10000)	KOMMN	16
		COMMON NID,KPLT,TZ,TSCL,PZ,PSCL,IDENT(5),KID,LF,LB	KOMMN	17
		COMMON LPLDT	KOMMN	18
		REAL LNTH,MU	INIT	14
30		DATA PI/3.14159/,TWOG/64.348/,TWOG1/9266.112/,G/32.174/	INIT	15
		KA=0	INIT	16
		KB=0	INIT	17
		KC=0	INIT	18
		KD=0	INIT	19
35		KTEE=0	INIT	20
		J7=0	INIT	21
		KT=0	INIT	22
		J6=0	INIT	23
		DTINIT=DT	INIT	24
40		DO 10 J=1,NOLEG	INIT	25
	C		INIT	26
	C	PHYSICAL PROPERTIES AND CONSTANTS CALCULATED.	INIT	27
	C		INIT	28
		A(J)=PI*D(J)**2/4.	INIT	29
45		RHO(J)=59.566-7.9504E-3*TEMP(J)-.2872E-6*(TEMP(J))**2+	INIT	30
		1.06035E-9*(TEMP(J))**3	INIT	31
		MU =10.**((1.0273+397.17/(TEMP(J)+459.688)-.4925*ALOG10(TEMP(J)	INIT	32
		1+459.688))	INIT	33
		IF(TEMP(J)-900.) 120,120,121	INIT	34
50	120	YOUNGS=29.2857E06-6428.57*TEMP(J)	INIT	35
		GO TO 122	INIT	36
	121	YOUNGS=31.2885E06-8653.85*TEMP(J)	INIT	37
	122	BULKMD=RHO(J)*(8488.-.95*TEMP(J))**2/G	INIT	38
		C(J)=SQRT(G*BULKMD/RHO(J)/(1.+BULKMD*D(J)/YOUNGS/THK(J)/12.))	INIT	39
55		PSAT(J)=6.4818- 10**2*.6/(460.+TEMP(J))-5*ALOG10(TEMP(J)+460.)	INIT	40
	C	UNITS OF PSIG	INIT	41
		PSAT(J)=14.7*(EXP(2.30259*PSAT(J))-1.)	INIT	42

SUBROUTINE INIT (cont'd)

SUBROUTINE INIT

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	IF (J.GT. 1) GO TO 11	INIT	43
	Z(1,1)=0.	INIT	44
60	V(1,1)=W(1)/RHO(1)/A(1)	INIT	45
	PSTART=PBACKR(T)	INIT	46
	P(1,1)=PSTART-1.5/TWOG1*RHO(1)*V(1,1)**2	INIT	47
	IF (V(1,1).LT.0.) P(1,1)=PSTART	INIT	48
65	H(1,1)=P(1,1)*144./RHO(1)+Z(1,1)	INIT	49
	GO TO 15	INIT	50
	11 JTYPE=JTYPE1(J)	INIT	51
	GO TO (13,13,13,13,13,12,12,12,12,13,12,13),JTYPE	INIT	52
	13 V(1,J)=V(1,J-1)*A(J-1)/A(J)*RHO(J-1)/RHO(J)	INIT	53
	GO TO 15	INIT	54
70	12 V(1,J)=W(J)/RHO(J)/A(J)	INIT	55
	15 XD=DT*(C(J)+100.)	INIT	56
	XD=AIN(TLNTH(J)/XD+1.)	INIT	57
	NO(J)=IFIX(XD)	INIT	58
	IF (NO(J).LT.2) NO(J)=2	INIT	59
75	IF (NO(J).GT.NX) GO TO 90	INIT	60
	DX(J)=LNTH(J)/FLCAT(NO(J)-1)	INIT	61
	THETA(J)=DT/DX(J)	INIT	62
	C1(J)=C(J)*RHO(J)/MU*3600.	INIT	63
	C2(J)=DX(J)/TWOG1/D(J)	INIT	64
80	C3(J)=DT/2./D(J)	INIT	65
	C4(J)=G/C(J)	INIT	66
	STATIC(J)=DX(J)*SIN(ABS(ANGLE(J)*PI/180.))	INIT	67
	IF (ANGLE(J).LT.0.) STATIC(J)=-STATIC(J)	INIT	68
	13 CONTINUE	INIT	69
85	DO 1 J=1,NOLEG	INIT	70
	1 KK(J)=0	INIT	71
	DO 6 J=1,NOLEG	INIT	72
	C	INIT	73
90	C DETERMINE TEE BRANCH LEG AND CONNECTING NODAL POINT NUMBERS.	INIT	74
	C	INIT	75
	IF (JTYPE2(J).NE.6.AND.JTYPE2(J).NE.11) GO TO 6	INIT	76
	K=JNO2(J)	INIT	77
	IF (KK(K).EQ.1) GO TO 6	INIT	78
	KK(K)=1	INIT	79
95	JSTRT=J+2	INIT	80
	DO 5 I=JSTRT,NOLEG	INIT	81
	IF (JNO1(I).EQ.K) GO TO 2	INIT	82
	IF (JNO2(I).EQ.K) GO TO 4	INIT	83
	GO TO 5	INIT	84
100	2 LEG3(K)=I	INIT	85
	NODE3(K)=1	INIT	86
	GO TO 6	INIT	87
	4 LEG3(K)=I	INIT	88
	NODE3(K)=NO(I)	INIT	89
105	GO TO 6	INIT	90
	5 CONTINUE	INIT	91
	6 CONTINUE	INIT	92
	DO 7 J=1,NOLEG	INIT	93
	7 KK(J)=0	INIT	94
110	DO 26 J=1,NOLEG	INIT	95
	C	INIT	96
	C CALCULATE INITIAL CONDITIONS FOR ALL NODAL AND JUNCTION POINTS.	INIT	97
	C	INIT	98
	IF (J.LE.KD) GO TO 26	INIT	99

SUBROUTINE INIT (cont'd)

SUBROUTINE INIT	74/74	OPT=1	FTN 4.2+74351	03/24/76	08.25.38.
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115	RENO=C1(J)*V(1,J)	INIT	100
	FF=FRICTF(RENO,D(J),E)	INIT	101
	XX1=FF*V(1,J)*ABS(V(1,J))*RHO(J)	INIT	102
	NN=NO(J)	INIT	103
	DO 25 JJ=2,NN	INIT	104
120	P(JJ,J)=P(JJ-1,J)-STATIC(J)*RHO(J)/144.-C2(J)*XX1	INIT	105
	V(JJ,J)=V(1,J)	INIT	106
	Z(JJ,J)=Z(JJ-1,J)+STATIC(J)	INIT	107
	H(JJ,J)=P(JJ,J)*144./RHO(J)+Z(JJ,J)	INIT	108
	25 CONTINUE	INIT	109
125	JTYP=JTYPE2(J)	INIT	110
	GO TO (31,32,33,34,35,36,37,26,39,40,36,37),JTYP	INIT	111
	C	INIT	112
	C THIS IS FOR A PUMP JUNCTION.	INIT	113
	C	INIT	114
130	31 ALPHA=SPEED(T)	INIT	115
	NN=NO(J)	INIT	116
	Z(1,J+1)=Z(NN,J)	INIT	117
	XX2=V(NN,J)*A(J)/ALPHA/QDESIN-PCG	INIT	118
	P(1,J+1)=P(NN,J)+RHO(J)/144.*ALPHA**2*(PCA-PCB*	INIT	119
135	1 (XX2)*ABS(XX2))*HDESIN-RHO(J+1)*V(1,J+1)**2/TWOG1+	INIT	120
	2 RHO(J)*V(NN,J)**2/TWOG1+Z(NN,J)*RHO(J)/144.-RHO(J+1)/144.	INIT	121
	3 *Z(1,J+1)	INIT	122
	H(1,J+1)=P(1,J+1)*144./RHO(J+1)+Z(1,J+1)	INIT	123
	GO TO 26	INIT	124
140	32 NN=NO(J)	INIT	125
	Z(1,J+1)=Z(NN,J)	INIT	126
	C	INIT	127
	C THIS IS FOR A CONTINUING PIPE JUNCTION	INIT	128
	C	INIT	129
145	P(1,J+1)=P(NN,J)+RHO(J)*V(NN,J)**2/TWOG1-RHO(J+1)*V(1,J+1)	INIT	130
	1 **2/TWOG1+Z(NN,J)*RHO(J)/144.-Z(1,J+1)*RHO(J+1)/144.	INIT	131
	H(1,J+1)=P(1,J+1)*144./RHO(J+1)+Z(1,J+1)	INIT	132
	GO TO 26	INIT	133
	33 NN=NO(J)	INIT	134
150	C	INIT	135
	C THIS IS FOR AN AREA CHANGE JUNCTION	INIT	136
	C	INIT	137
	Z(1,J+1)=Z(NN,J)	INIT	138
	ARATIO=A(J+1)/A(J)	INIT	139
155	IF(V(NN,J).GT.0..AND.ARATIO.GT.1.) GO TO 101	INIT	140
	IF(V(NN,J).GT.0..AND.ARATIO.LE.1.) GO TO 102	INIT	141
	IF(V(NN,J).LE.0..AND.ARATIO.GT.1.) GO TO 103	INIT	142
	IF(V(NN,J).LE.0..AND.ARATIO.LE.1.) GO TO 104	INIT	143
	C K FACTOR FOR + FLOW AND EXPANSION	INIT	144
160	101 DELPI=(1.-1./ARATIO)**2	INIT	145
	DELPI=-DELPI*V(NN,J)**2/TWOG1*RHO(J)	INIT	146
	GO TO 105	INIT	147
	C K FACTOR FOR + FLOW AND CONTRACTION	INIT	148
	102 DELPI=.5*(1.-ARATIO)	INIT	149
165	DELPI=-DELPI*V(1,J+1)**2/TWOG1*RHO(J+1)	INIT	150
	GO TO 105	INIT	151
	C K FACTOR FOR - FLOW AND CONTRACTION	INIT	152
	103 DELPI=.5*(1.-1./ARATIO)	INIT	153
	DELPI=DELPI*V(NN,J)**2/TWOG1*RHO(J)	INIT	154
170	GO TO 105	INIT	155
	C K FACTOR FOR - FLOW AND EXPANSION	INIT	156

SUBROUTINE INIT (cont'd)

SUBROUTINE INIT

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104	DELPI=(1.-ARATIO)**2	INIT	157
	DELPI=DELPI*V(1,J+1)**2/TWOG1*RHO(J+1)	INIT	158
105	P(1,J+1)=P(NN,J)+(V(NN,J)**2/TWOG+Z(NN,J))*RHO(J)/144.	INIT	159
175	1 -(V(1,J+1)**2/TWOG+Z(1,J+1))*RHO(J+1)/144. +DELPI	INIT	160
	H(1,J+1)=P(1,J+1)*144./RHO(J+1)+Z(1,J+1)	INIT	161
	GO TO 26	INIT	162
34	NN=NO(J)	INIT	163
	Z(1,J+1)=Z(NN,J)	INIT	164
180	C	INIT	165
	C THIS IS FOR AN ORIFICE TYPE JUNCTION.	INIT	166
	C	INIT	167
	DELPI=-CV(J)*V(NN,J)**2/TWOG1*RHO(J)	INIT	168
	IF(V(NN,J).LE.0.) DELPI=CV(J)*V(1,J+1)**2/TWOG1*RHO(J+1)	INIT	169
185	109 P(1,J+1)=P(NN,J)+(V(NN,J)**2/TWOG+Z(NN,J))*RHO(J)/144.	INIT	170
	1 -(V(1,J+1)**2/TWOG+Z(1,J+1))*RHO(J+1)/144. +DELPI	INIT	171
	H(1,J+1)=P(1,J+1)*144./RHO(J+1)+Z(1,J+1)	INIT	172
	GO TO 26	INIT	173
190	35 NN=NO(J)	INIT	174
	Z(1,J+1)=Z(NN,J)	INIT	175
	C	INIT	176
	C THIS IS AN ELBOW JUNCTION.	INIT	177
	C	INIT	178
195	IF(V(NN,J))110,110,111	INIT	179
	111 RENOS=C1(J)*V(NN,J)	INIT	180
	FF5=FRICTF(RENOS,D(J),E)	INIT	181
	DELPI=-CV(J)*FF5*V(NN,J)**2/TWOG1*RHO(J)	INIT	182
	GO TO 109	INIT	183
200	110 RENOS=C1(J+1)*ABS(V(1,J+1))	INIT	184
	FF5=FRICTF(RENOS,D(J+1),E)	INIT	185
	DELPI=CV(J)*FF5*V(1,J+1)**2/TWOG1*RHO(J+1)	INIT	186
	GO TO 109	INIT	187
	36 NN=NO(J)	INIT	188
205	C	INIT	189
	C THIS IS FOR A TEE OR Y JUNCTION.	INIT	190
	C	INIT	191
	M6=JNO2(J)	INIT	192
	IF(KK(M6).EQ.1) GO TO 26	INIT	193
210	J5=J6+1	INIT	194
	L2=J+1	INIT	195
	L3=LEG3(M6)	INIT	196
	N2=1	INIT	197
	N3=NODE3(M6)	INIT	198
215	Z(N2,L2)=Z(NN,J)	INIT	199
	Z(N3,L3)=Z(NN,J)	INIT	200
	V(N2,L2)=V(1,L2)	INIT	201
	V(N3,L3)=V(1,L3)	INIT	202
	RENOJ=C1(J)*V(NN,J)	INIT	203
	RENOJ1=C1(L2)*V(N2,L2)	INIT	204
220	RENOJ1=C1(L3)*V(N3,L3)	INIT	205
	FFJ=FRICTF(RENOJ,D(J),E)	INIT	206
	FFJ1=FRICTF(RENOJ1,D(L2),E)	INIT	207
	FFJ1=FRICTF(RENOJ1,D(L3),E)	INIT	208
	CKJ=CVTEE1(J6)*FFJ	INIT	209
225	CKJ1=CVTEE2(J6)*FFJ1	INIT	210
	CKJ1=CVTEE2(J6)*FFJ1	INIT	211
	CKJ1=CVTEE3(J6)*FFJ1	INIT	212
	IF(N3.GT.1) CKJ1=-CKJ1	INIT	213

SUBROUTINE INIT (cont'd)

SUBROUTINE INIT

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		P(N2,L2)=P(NN,J)+RHO(J)/TWOG1*(V(NN,J)**2-V(N2,L2)**2	INIT	214
230	1	-CKJ*V(NN,J)*ABS(V(NN,J))-CKJ1*V(N2,L2)*ABS(V(N2,L2)))	INIT	215
		IF(JTYP.NE.11) GO TO 125	INIT	216
		SIGMA=1000.*(11.29-.00123*TEMP(J))	INIT	217
		PY(J)=.1917*SIGMA*THK(J)/D(J)	INIT	218
		PY(L3)=PY(J)	INIT	219
235	C	THIS IS YIELD PRESSURE TO USE FOR PSEUDO SIMULATION OF PLASTIC	INIT	220
	C	DEFORMATION AT LEG J BY TYPE 11 AND 12 JUNCTIONS.	INIT	221
		P(N3,L3)=PY(L3)	INIT	222
		GO TO 126	INIT	223
	125	P(N3,L3)=P(NN,J)+RHO(J)/TWOG1*(V(NN,J)**2-V(N3,L3)**2	INIT	224
240	1	-CKJ*V(NN,J)*ABS(V(NN,J))-CKJ1*V(N3,L3)*ABS(V(N3,L3)))	INIT	225
	126	H(N2,L2)=P(N2,L2)*144./RHO(L2)+Z(N2,L2)	INIT	226
		H(N3,L3)=P(N3,L3)*144./RHO(L3)+Z(N3,L3)	INIT	227
		KK(M6)=1	INIT	228
		GO TO 26	INIT	229
245	37	J7=J7+1	INIT	230
	C		INIT	231
	C	THIS IS FOR A PRESSURIZER JUNCTION.	INIT	232
	C		INIT	233
		NN=NO(J)	INIT	234
250		PRESP(J7)=P(NN,J)	INIT	235
		IF(V(NN,J).LT.C.) PRESP(J7)=P(NN,J)+1.5*V(NN,J)**2/TWOG1*	INIT	236
	1	RHO(J)	INIT	237
		GO TO 26	INIT	238
	38	CONTINUE	INIT	239
255	C		INIT	240
	C	NO SPECIAL INITIAL CALCULATIONS NEEDED FOR A DEAD END JUNCTION	INIT	241
	C	AS VELOCITY IN PIPE LEGS LEADING TO THE DEAD END HAVE ALREADY	INIT	242
	C	BEEN SET TO 0 BY INPUT. PRESSURE CALCULATED FOR THE LAST	INIT	243
	C	NODAL POINT BEFORE THE DEAD END IS THEREFORE VALID.	INIT	244
260	C		INIT	245
	39	NN=NO(J)	INIT	246
	C		INIT	247
	C	THIS IS FOR AN END BOUNDARY CONDITION	INIT	248
	C	ALSO ASSUMES POSITIVE FLOW FROM PIPE LEG INTO BOUNDARY.	INIT	249
265	C		INIT	250
		PINIT=P(NN,J)	INIT	251
		IF(V(NN,J).LT.C.) PINIT=P(NN,J)+1.5*V(NN,J)**2*RHO(J)/TWOG1	INIT	252
		GO TO 26	INIT	253
	C	KA IS THE TYPE 10 JUNCTION NO.	INIT	254
270	40	KA=JNO2(J)	INIT	255
	C	THIS IS FOR AN ADJUSTABLE ORIFICE OR VALVE, WHICH HAS ITS CV	INIT	256
	C	CALCULATED IN THE PROGRAM TO SATISFY INITIAL PRESSURE AND FLOW	INIT	257
	C	CONDITIONS RATHER THAN HAVING AN INPUT SPECIFIED CV. THERE	INIT	258
	C	IS NO DIFFERENCE BETWEEN THE TYPE 10 AND 4 JUNCTIONS AFTER	INIT	259
275	C	ZERO TIME.	INIT	260
	C		INIT	261
	C	KB IS THE LEG NO. ENDING WITH TYPE 10 JUNCTION	INIT	262
		KB=J	INIT	263
		JSTRT=J+1	INIT	264
280		DO 410 J10=JSTRT,NOLEG	INIT	265
		IF(JTYPE2(J10).NE.6) GO TO 410	INIT	266
		KC=JNO2(J10)	INIT	267
		IF(KK(KC).EQ.0) GO TO 409	INIT	268
	C	KD IS THE LEG NO. ENDING WITH A PREVIOUSLY CALCULATED TEE OR Y	INIT	269
285	C	AND KC IS ITS JUNCTION NO. AT THE END OF THE LEG.	INIT	270

SUBROUTINE INIT (cont'd)

SUBROUTINE INIT	74/74	CPT=1	FTN 4.2+74351	03/24/76	08.25.38.
	KD=J10			INIT	271
	GO TO 411			INIT	272
	409 KT=KT+1			INIT	273
	410 CONTINUE			INIT	274
290	411 K10=KB+1			INIT	275
	NN=NO(KD)			INIT	276
	J6=J6+KT			INIT	277
	V(NN,KD)=V(1,KD)			INIT	278
295	DO 430 I921X=K10,KD			INIT	279
	J10=KD+K10-I921X			INIT	280
	RENO=C1(J10)*V(1,J10)			INIT	281
	FF=FRICTF(RENO,D(J10),E)			INIT	282
	XX1=FF*V(1,J10)*ABS(V(1,J10))*RHO(J10)			INIT	283
	NN=NO(J10)-1			INIT	284
300	DO 425 J921X=1,NN			INIT	285
	JJ=NN+1-J921X			INIT	286
	P(JJ,J10)=P(JJ+1,J10)+STATIC(J10)*RHO(J10)/144.+C2(J10)*XX1			INIT	287
	V(JJ,J10)=V(1,J10)			INIT	288
305	Z(JJ,J10)=Z(JJ+1,J10)-STATIC(J10)			INIT	289
	H(JJ,J10)=P(JJ,J10)*144./RHO(J10)+Z(JJ,J10)			INIT	290
	425 CONTINUE			INIT	291
	JTYP=JTYPE1(J10)			INIT	292
	GO TO (440,450,460,470,480,490,500,510,520,530,540,550,560,570,580,590,600,610,620,630,640,650,660,670,680,690,700,710,720,730,740,750,760,770,780,790,800,810,820,830,840,850,860,870,880,890,900,910,920,930,940,950,960,970,980,990),JTYP			INIT	293
310	C PUMP JUNCTION			INIT	294
	440 JNX=J10-1			INIT	295
	NXN=NO(JNX)			INIT	296
	Z(NXN,JNX)=Z(1,J10)			INIT	297
	V(NXN,JNX)=V(1,JNX)			INIT	298
315	XX2=V(NXN,JNX)*A(JNX)/ALPHA/QDESIN-PCG			INIT	299
	P(NXN,JNX)=P(1,J10)-RHO(JNX)/144.*ALPHA**2*(PCA-PCB*			INIT	300
	1 (XX2)*ABS(XX2))*HDESIN+RHO(J10)*V(1,J10)**2/TWOG1-			INIT	301
	2 RHO(JNX)*V(NXN,JNX)**2/TWOG1-Z(NXN,JNX)*RHO(JNX)/144.+			INIT	302
	3 Z(1,J10)*RHO(J10)/144.			INIT	303
320	H(NXN,JNX)=P(NXN,JNX)*144./RHO(NXN)+Z(NXN,JNX)			INIT	304
	GO TO 430			INIT	305
	C CONTINUING PIPE JUNCTION			INIT	306
	450 JNX=J10-1			INIT	307
	NXN=NO(JNX)			INIT	308
325	V(NXN,JNX)=V(1,JNX)			INIT	309
	Z(NXN,JNX)=Z(1,J10)			INIT	310
	P(NXN,JNX)=P(1,J10)-RHO(JNX)*V(NXN,JNX)**2/TWOG1+RHO			INIT	311
	1(J10)*V(1,J10)**2/TWOG1-Z(NXN,JNX)*RHO(JNX)/144.+Z(1,J10)*			INIT	312
	2RHO(J10)/144.			INIT	313
330	H(NXN,JNX)=P(NXN,JNX)*144./RHO(JNX)+Z(NXN,JNX)			INIT	314
	GO TO 430			INIT	315
	C AREA CHANGE JUNCTION			INIT	316
	460 JNX=J10-1			INIT	317
	NXN=NO(JNX)			INIT	318
335	V(NXN,JNX)=V(1,JNX)			INIT	319
	Z(NXN,JNX)=Z(1,J10)			INIT	320
	ARATIO=A(J10)/A(JNX)			INIT	321
	IF(V(1,J10).GT.0..AND.ARATIO.GT.1.) GO TO 461			INIT	322
	IF(V(1,J10).GT.0..AND.ARATIO.LE.1.) GO TO 462			INIT	323
	IF(V(1,J10).LE.0..AND.ARATIO.GT.1.) GO TO 463			INIT	324
340	IF(V(1,J10).LE.0..AND.ARATIO.LE.1.) GO TO 464			INIT	325
	C K FACTOR FOR FLOW AND EXPANSION			INIT	326
	461 DELPI=(1.-1./ARATIO)**2			INIT	327

SUBROUTINE INIT (cont'd)

SUBROUTINE INIT

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	DELPI=-DELPI*(V(NXN,JNX))**2/TWOG1*RHO(JNX)	INIT	328
	GO TO 471	INIT	329
345	C K FACTOR FOR + FLOW AND CONTRACTION	INIT	330
	462 DELPI=.5*(1.-ARATIO)	INIT	331
	DELPI=-DELPI*V(1,J1C)**2/TWOG1*RHO(J1C)	INIT	332
	GO TO 471	INIT	333
	C K FACTOR FOR - FLOW AND CONTRACTION	INIT	334
350	463 DELPI=.5*(1.-1./ARATIO)	INIT	335
	DELPI=DELPI*V(NXN,JNX)**2/TWOG1*RHO(JNX)	INIT	336
	GO TO 471	INIT	337
	C K FACTOR FOR - FLOW AND EXPANSION	INIT	338
	464 DELPI=(1.-ARATIO)**2	INIT	339
355	DELPI=DELPI*V(1,J1C)**2/TWOG1*RHO(J1C)	INIT	340
	GO TO 471	INIT	341
	C ORIFICE OR VALVE JUNCTION	INIT	342
	471 JNX=J1C-1	INIT	343
	NXN=NO(JNX)	INIT	344
360	V(NXN,JNX)=V(1,JNX)	INIT	345
	Z(NXN,JNX)=Z(1,J1C)	INIT	346
	DELPI=-CV(JNX)*V(NXN,JNX)**2/TWOG1*RHO(JNX)	INIT	347
	IF (V(NXN,JNX).LE.C.) DELPI=CV(JNX)*V(1,J1C)**2/TWOG1*RHO(J1C)	INIT	348
	471 P(NXN,JNX)=P(1,J1C)-(V(NXN,JNX)**2/TWOG +Z(NXN,JNX))*RHO	INIT	349
365	1(JNX)/144.+(V(1,J1C)**2/TWOG +Z(1,J1C))*RHO(J1C)/144.-DELPI	INIT	350
	H(NXN,JNX)=P(NXN,JNX)*144./RHO(JNX)+Z(NXN,JNX)	INIT	351
	GO TO 43C	INIT	352
	C ELBOW JUNCTION	INIT	353
	480 JNX=J1C-1	INIT	354
370	NXN=NO(JNX)	INIT	355
	V(NXN,JNX)=V(1,JNX)	INIT	356
	Z(NXN,JNX)=Z(1,J1C)	INIT	357
	IF (V(1,J1C)) 481,481,482	INIT	358
	481 RENOS=C1(J1C)*ABS(V(1,J1C))	INIT	359
375	FF5=FRICTF(RENOS,D(J1C),E)	INIT	360
	DELPI=CV(JNX)*FF5*V(1,J1C)**2/TWOG1*RHO(J1C)	INIT	361
	GO TO 471	INIT	362
	482 RENOS=C1(JNX)*V(NXN,JNX)	INIT	363
	FF5=FRICTF(RENOS,D(JNX),E)	INIT	364
380	DELPI=-CV(JNX)*V(NXN,JNX)**2/TWOG1*RHO(JNX)*FF5	INIT	365
	GO TO 471	INIT	366
	C TEE OR Y JUNCTION	INIT	367
	490 JNX=J1C-1	INIT	368
	NXN=NO(JNX)	INIT	369
385	V(NXN,JNX)=V(1,JNX)	INIT	370
	M6=JNO2(JNX)	INIT	371
	IF (KK(M6).EQ.1) GO TO 43C	INIT	372
	L2=J1C	INIT	373
	L3=LEG3(M6)	INIT	374
390	N2=1	INIT	375
	N3=NODE3(M6)	INIT	376
	V(N2,L2)=V(1,L2)	INIT	377
	V(N3,L3)=V(1,L3)	INIT	378
	RENOJ=C1(JNX)*V(NXN,JNX)	INIT	379
395	RENOJ1=C1(L2)*V(N2,L2)	INIT	380
	RENOJ1=C1(L3)*V(N3,L3)	INIT	381
	FFJ=FRICTF(RENOJ,D(JNX),E)	INIT	382
	FFJ1=FRICTF(RENOJ1,D(L2),E)	INIT	383
	FFJ1=FRICTF(RENOJ1,D(L3),E)	INIT	384

SUBROUTINE INIT (cont'd)

	SUBROUTINE INIT	74/74	OPT=1	FTN 4.2+74351	03/24/76	08.25.38.
400	CKJ =CVTEE1(J6)*FFJ				INIT	385
	CKJ1=CVTEE2(J6)*FFJ1				INIT	386
	CKJI=CVTEE3(J6)*FFJI				INIT	387
	J6=J6-1				INIT	388
	IF (N3.GT.1) CKJI=-CKJI				INIT	389
405	Z(NXN,JNX)=Z(1,J10)				INIT	390
	Z(N3,L3)=Z(1,J10)				INIT	391
	P(NXN,JNX)=P(1,J10)+RHO(J10)/TWOG1*(V(1,J10)**2-V(NXN,JNX)				INIT	392
	1 **2+CKJ1*V(1,J10)*ABS(V(1,J10))+CKJ*V(NXN,JNX)*ABS(V(NXN,J				INIT	393
	2 NX))				INIT	394
410	P(N3,L3)=P(NXN,JNX)+RHO(J10)/TWOG1*(V(NXN,JNX)**2-V(N3,L3)				INIT	395
	1 **2-CKJ*V(NXN,JNX)*ABS(V(NXN,JNX))-CKJI*V(N3,L3)*ABS(V(N3,				INIT	396
	2 L3))				INIT	397
	H(NXN,JNX)=F(NXN,JNX)*144./RHO(JNX)+Z(NXN,JNX)				INIT	398
	H(N3,L3)=P(N3,L3)*144./RHO(L3)+Z(N3,L3)				INIT	399
415	KK(M6)=1				INIT	400
	GO TO 430				INIT	401
	500 WRITE(6,501)				INIT	402
	501 FORMAT(1H,"INCORRECT ARRANGEMENT OF JUNCTIONS IN A CROSS TIE LINE				INIT	403
	1")				INIT	404
420	GO TO 520				INIT	405
	510 JNX=J10-1				INIT	406
	NXN=NO(JNX)				INIT	407
	V(NXN,JNX)=V(1,JNX)				INIT	408
	DELPI=F(NXN,JNX)-P(1,J10)+(V(NXN,JNX)**2/TWOG+Z(NXN,				INIT	409
425	1JNX))*RHO(JNX)/144.-(V(1,J10)**2/TWOG+Z(1,J10))*RHO(J10)/144.				INIT	410
	IF (V(NXN,JNX).EQ.0.) GO TO 511				INIT	411
	CV(JNX)=DELPI/V(NXN,JNX)**2*TWOG1/RHO(JNX)				INIT	412
	IF (V(NXN,JNX).LT.0.) CV(JNX)=-DELPI/V(1,J10)**2*TWOG1/				INIT	413
	1RHO(J10)				INIT	414
430	J6=J6+KT				INIT	415
	KT=0				INIT	416
	GO TO 26				INIT	417
	511 CV(JNX)=10.				INIT	418
	C CV(JNX)=10. IS A DEFAULT VALUE FOR VELOCITY =0.			8-15-73	INIT	419
435	GO TO 26				INIT	420
	430 CONTINUE				INIT	421
	26 CONTINUE				INIT	422
	RETURN				INIT	423
	900 WRITE(6,901) J,LNTH(J),V(1,J),C(J),DX(J),NO(J)				INIT	424
440	901 FORMAT(1H,"INPUT LENGTH IS TOO GREAT FOR LEG",I5/1X," LNTH(J),				INIT	425
	1V(1,J),C(J),DX(J),AND NO(J) ARE",4E15.6,I5)				INIT	426
	STOP				INIT	427
	8 WRITE(6,9) K				INIT	428
	9 FORMAT(1H,"SYSTEM MODEL SET UP WRONG IN THAT BOTH BRANCHES OFF T				INIT	429
445	1YPE 6 JUNCTION NO.",I4," CONNECT TO THE LAST NODAL POINTS",/10X,"				INIT	430
	2OF THE CONNECTING LEGS OR NEITHER BRANCH IS NUMBERED CONSECUTIVELY				INIT	431
	3 WITH THE INCOMING LEG.")				INIT	432
	520 STOP				INIT	433
	END				INIT	434

SUBROUTINE JNCTN

SUBROUTINE JNCTN

74/74 OPT=1

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		SUBROUTINE JNCTN	JNCTN	2
	C		JNCTN	3
	C	JNCTN SUBROUTINE PROVIDES VELOCITIES AND PRESSURES AT JUNCTION	JNCTN	4
	C	POINTS.	JNCTN	5
5	C		JNCTN	6
	C		JNCTN	7
	C	SEE HAMOC MAIN PROGRAM FOR NOTATION.	JNCTN	8
	C		JNCTN	9
		COMMON/A1/ D (56),LNTH (56),C (56),CV (56),	KOMMN	2
10	1	JTYPE2(56),JNO2 (56),NO (56),KK (56),	KOMMN	3
	2	LEG3 (56),NODE3 (56),RHO (56),C1 (56),	KOMMN	4
	3	C2 (56),C3 (56),C4 (56),STATIC(56),	KOMMN	5
	4	A (56),CPC3 (56),THETA (56),PSAT (56),	KOMMN	6
	5	VSAV (56),HSAV (56),PY (56),ENERGY(56),	KOMMN	7
15	6	LEGSAT(56),NNSAT (56),DX (56),ERASE (56),	KOMMN	8
	7	CAVOL (56),	KOMMN	9
	8	P(50, 56),H(50, 56),Z(50, 56),V(50, 56),	KOMMN	10
	9	CVTEE1(30),CVTEE2(30),CVTEE3(30),PRES(15),	KOMMN	11
	X	E,CKJ,CKJ1,CKJ1,NOLEG,T,NT,J,JTYP,QDESIN,HDESIN,	KOMMN	12
20	1	PCA,PCB,PCC,NX,DT,PEND,PSTART,GTHETA,NWRIT,MPLT,	KOMMN	13
	2	TENC,PINIT,J6,J7,JENDS6,VSAVE,HSAVE,DTINIT,IMSAT,	KOMMN	14
	3	JC,NC,KAVITY	KOMMN	15
		COMMON/PLT/NPCT,LF,LOC,KNT,ISW,NPLOT,NK(53),TIM(1003),BUF(10000)	KOMMN	16
		COMMON NID,KPLT,TZ,TSCL,PZ,PSCL,IDENT(5),KID,L5,LB	KOMMN	17
25		COMMON LPLT	KOMMN	18
		REAL KFCTR,LNTH	JNCTN	11
		DOUBLE PRECISION OBBCP,DSR,DCCCP,DAACP	JNCTN	12
		DATA TWOG1/9266.112/,TWOG/64.348/	JNCTN	13
		IF(J.EQ.NOLEG) GO TO 90	JNCTN	14
30		IF(JTYPE2(J+1).EQ.6.AND.KK(JNO2(J+1)).EQ.1) GO TO 80	JNCTN	15
		GO TO 90	JNCTN	16
	80	IF(NC(J+1).EQ.2) GO TO 81	JNCTN	17
		VSAVE=VSAV(J+1)	JNCTN	18
		HSAVE=HSAV(J+1)	JNCTN	19
35		JENDS6=1	JNCTN	20
		GO TO 90	JNCTN	21
	81	VSAVE=V(2,J+1)	JNCTN	22
		HSAVE=H(2,J+1)	JNCTN	23
		V(2,J+1)=VSAV(J+1)	JNCTN	24
40		H(2,J+1)=HSAV(J+1)	JNCTN	25
		JENDS6=1	JNCTN	26
	90	GO TO (100,200,200,200,200,600,900,200,900,200,600,900),JTYP	JNCTN	27
	C		JNCTN	28
	C	TYPE 1 JUNCTION IS A CENTRIFUGAL PUMP.	JNCTN	29
45	C		JNCTN	30
	100	IF (INT .GT. 1) GO TO 110	JNCTN	31
		PC1 = FCC*QDESIN/A(J)	JNCTN	32
		PC2=A(J)/A(J+1)*(RHO(J)/RHO(J+1))	JNCTN	33
50		PC3 = A(J)**2*HDESIN*PCB/QDESIN**2	JNCTN	34
		PC4 = PCA*HDESIN	JNCTN	35
		PC5=C4(J+1)*THETA(J+1)*STATIC(J+1)	JNCTN	36
		PC6=C4(J)*THETA(J)*STATIC(J)	JNCTN	37
		PC9=(1.-PC2**2)/TWOG	JNCTN	38
55	110	ALPHA = SPEED(T)	JNCTN	39
		NPMP=NC(J)	JNCTN	40
		NPMP1=NPMP-1	JNCTN	41
		VR = V(NPMP,J) -VSAV(J)	JNCTN	42

SUBROUTINE JNCTN (cont'd)

SUBROUTINE JNCTN	74/74	OPT=1	FTN 4.2+74351	03/24/76	08.25.04.
	VS = V(1,J+1)-V(2,J+1)		JNCTN	43	
	VR= (V(NPMP,J)-THETA(J)*C(J)*VR)/(1.+THETA(J)*VR)		JNCTN	44	
60	VS= (V(1,J+1)-THETA(J+1)*C(J+1)*VS)/(1.-THETA(J+1)*VS)		JNCTN	45	
	HR= H(NPMP,J)-THETA(J)*(VR+C(J))*(H(NPMP,J)-HSAV(J))		JNCTN	46	
	HS= H(1,J+1)+THETA(J+1)*(VS-C(J+1))*(H(1,J+1)-H(2,J+1))		JNCTN	47	
	OLDV=VSAV(J)		JNCTN	48	
	PREV=V(NPMP,J)		JNCTN	49	
65	VSAV(J+1)=V(1,J+1)		JNCTN	50	
	HSAV(J+1)=H(1,J+1)		JNCTN	51	
	RENOR = VR*C1(J)		JNCTN	52	
	FFR = FRICTF(RENOR,D(J),E)		JNCTN	53	
	RENOS = VS*C1(J+1)		JNCTN	54	
70	FFS = FRICTF(RENOS,D(J+1),E)		JNCTN	55	
	PC7 = VR+C4(J)*HR-PC6*VR-FFR*VR*ABS(VR)*C3(J)		JNCTN	56	
	PC8 = VS-C4(J+1)*HS+PC5*VS-FFS*VS*ABS(VS)*C3(J+1)		JNCTN	57	
	C		JNCTN	58	
	C	ITERATIVE SOLUTION FOR V(NPMP,J).	JNCTN	59	
75	C	USE V(NPMP,J) AS FIRST TRIAL VALUE.	JNCTN	60	
	KNTE=0		JNCTN	61	
	VONE=V(NPMP,J)		JNCTN	62	
	BPMP=PC2/C4(J+1)+1./C4(J)		JNCTN	63	
	PC13=PC8/C4(J+1)+PC7/C4(J)+ALPHA**2*PC4		JNCTN	64	
80	115	PC12=VONE-PC1*ALPHA	JNCTN	65	
	CPMP=PC13+PC9*VONE**2-PC12*ABS(PC12)*PC3		JNCTN	66	
	V(NPMP,J)=CPMP/BPMP		JNCTN	67	
	118	IF (ABS((V(NPMP,J)-VONE)/V(NPMP,J))).LT..0001) GO TO 120	JNCTN	68	
		IF (KNTE.GE.1) GO TO 111	JNCTN	69	
85		V1=VONE	JNCTN	70	
		DEL1=V(NPMP,J)-VONE	JNCTN	71	
		KNTE=KNTE+1	JNCTN	72	
		VONE=V(NPMP,J)	JNCTN	73	
		GO TO 115	JNCTN	74	
90	111	DEL2=V(NPMP,J)-VONE	JNCTN	75	
		VGS=VONE-DEL2*(VONE-V1)/(DEL2-DEL1)	JNCTN	76	
		V1=VONE	JNCTN	77	
		VONE=VGS	JNCTN	78	
		DEL1=DEL2	JNCTN	79	
95		KNTE=KNTE+1	JNCTN	80	
		IF (KNTE.GE.25) GO TO 121	JNCTN	81	
		GO TO 115	JNCTN	82	
	121	WRITE(6,122) J,T	JNCTN	83	
	122	FORMAT(1H ,"TROUBLE WITH ITERATIVE SOLUTION AT PUMP JUNCTION AT TH	JNCTN	84	
100		1E END OF LEG",I4," AT TIME",F8.5," SECONDS")	JNCTN	85	
		STOP	JNCTN	86	
	120	V(1,J+1)=V(NPMP,J)*PC2	JNCTN	87	
		H(1,J+1)= (V(1,J+1)-PC8)/C4(J+1)	JNCTN	88	
		H(NPMP,J)=(PC7-V(NPMP,J))/C4(J)	JNCTN	89	
105		P(NPMP,J)=(H(NPMP,J)-Z(NPMP,J))*RHO(J)/144.	JNCTN	90	
		IF (P(NPMP,J).LT.PSAT(J)) GO TO 130	JNCTN	91	
		IMSAT=C	JNCTN	92	
		P(1,J+1)=(H(1,J+1)-Z(1,J+1))*RHO(J+1)/144.	JNCTN	93	
		IF (P(1,J+1).LT.PSAT(J+1)) GO TO 136	JNCTN	94	
110		GO TO 150	JNCTN	95	
	130	P(NPMP,J)=PSAT(J)	JNCTN	96	
		H(NPMP,J)=P(NPMP,J)*144./RHO(J)+Z(NPMP,J)	JNCTN	97	
		IF (IMSAT.EQ.0) GO TO 131	JNCTN	98	
		VDIF=(V(NPMP,J)+PREV-V(NPMP1,J)-OLDV)/2.	JNCTN	99	

SUBROUTINE JNCTN (cont'd)

	SUBROUTINE JNCTN	74/74	OPT=1	FTN 4.2+74351	03/24/76	08.26.04.
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115	CAVOL(JC)=CAVOL(JC)+A(J)*DT*VDIF	JNCTN	100
131	H(1,J+1)=H(NPMP,J)+V(NPMP,J)**2/TWOG-V(1,J+1)**2/TWOG+	JNCTN	101
	1 PC4*ALPHA**2-PC3*(V(NPMP,J)-PC1*ALPHA)*ABS(V(NPMP,J)-PC1*	JNCTN	102
	2 ALPHA)	JNCTN	103
	P(1,J+1)=(H(1,J+1)+Z(1,J+1))*RHO(J+1)/144.	JNCTN	104
120	IF(P(1,J+1).GT.PSAT(J+1)) GO TO 150	JNCTN	105
136	P(1,J+1)=PSAT(J+1)	JNCTN	106
	H(1,J+1)=P(1,J+1)*144./RHO(J+1)+Z(1,J+1)	JNCTN	107
150	IF(JENDS6.EQ.0) RETURN	JNCTN	108
	IF(NO(J+1).NE.2) RETURN	JNCTN	109
125	V(2,J+1)=VSAVE	JNCTN	110
	H(2,J+1)=HSAVE	JNCTN	111
	RETURN	JNCTN	112
	C	JNCTN	113
	C TYPE 2 JUNCTION IS A CONTINUING PIPE WITH NO AREA CHANGE. BUT	JNCTN	114
130	C WITH POSSIBLE CHANGES IN SONIC VELOCITY AND/OR TEMPERATURE.	JNCTN	115
	201 NCP=NO(J)	JNCTN	116
	NCP1=NCP-1	JNCTN	117
	VR=V(NCP,J)-VSAV(J)	JNCTN	118
	VS=V(1,J+1)-V(2,J+1)	JNCTN	119
135	VR=(V(NCP,J)-THETA(J)*C(J)*VR)/(1.+THETA(J)*VR)	JNCTN	120
	VS=(V(1,J+1)-THETA(J+1)*C(J+1)*VS)/(1.-THETA(J+1)*VS)	JNCTN	121
	HR=H(NCP,J)-THETA(J)*(VR+C(J))*(H(NCP,J)-HSAV(J))	JNCTN	122
	HS=H(1,J+1)+THETA(J+1)*(VS-C(J+1))*(H(1,J+1)-H(2,J+1))	JNCTN	123
	OLDV=VSAV(J)	JNCTN	124
140	PREV=V(NCP,J)	JNCTN	125
	VSAV(J+1)=V(1,J+1)	JNCTN	126
	HSAV(J+1)=H(1,J+1)	JNCTN	127
	VSAV2=V(NCP,J)	JNCTN	128
	RENOR=C1(J)*VR	JNCTN	129
145	RENOS=C1(J+1)*VS	JNCTN	130
	FFR=FRICTF(RENOR,D(J),E)	JNCTN	131
	FFS=FRICTF(RENOS,D(J+1),E)	JNCTN	132
	CPC1=VF+C4(J)*HR-C4(J)*THETA(J)*STATIC(J)*VR-FFR*VR*ABS(VR)*C3(J)	JNCTN	133
	CPC2=VS-C4(J+1)*HS+C4(J+1)*THETA(J+1)*STATIC(J+1)*VS-FFS*VS*ABS(VS	JNCTN	134
150	1)*C3(J+1)	JNCTN	135
	GO TO (100,201,300,400,500,600,1000,800,1000,400),JTY	JNCTN	136
	201 IF (INT.LT.2) CPC3(J)=C4(J+1)/TWOG*(RHO(J)/RHO(J+1)-RHO(J)**2/	JNCTN	137
	1 RHO(J+1)**2)	JNCTN	138
	BBCP=RHO(J)/RHO(J+1)*(1.+C4(J+1)/C4(J))	JNCTN	139
155	CCCP=CPC2+C4(J+1)/C4(J)*CPC1*RHO(J)/RHO(J+1)	JNCTN	140
	V(NCP,J)=CCCP/BBCP	JNCTN	141
	IF(ABS(1.-RHO(J)/RHO(J+1)).LT..001) GO TO 202	JNCTN	142
	DBBCF=BBCP	JNCTN	143
	DCCCP=CCCP	JNCTN	144
160	DAACP=CPC3(J)	JNCTN	145
	DSR=DBBCP**2-4.00*DAACP*DCCCP	JNCTN	146
	IF(DSR.LT..0) GO TO 210	JNCTN	147
	V(NCP,J)=(DBBCP-DSQRT(DSR))/2./DAACP	JNCTN	148
	GO TO 212	JNCTN	149
165	210 WRITE(6,211) J	JNCTN	150
	211 FORMAT (1H,"HAVE NEGATIVE SQUARE ROOT FOR A CONTINUING PIPE JUNCT	JNCTN	151
	1ION AT THE END OF LEG",I5,". IGNORE QUADRATIC"/1X,"BY NEGLECTING V	JNCTN	152
	2**2 TERM AND CONTINUE AS IF THERE IS NO CHANGE IN KINETIC ENERGY A	JNCTN	153
	3T THE JUNCTION.")	JNCTN	154
170	202 V(1,J+1)=V(NCP,J)*RHO(J)/RHO(J+1)*A(J)/A(J+1)	JNCTN	155
	H(NCP,J)=(-V(NCP,J)+CPC1)/C4(J)	JNCTN	156

SUBROUTINE JNCTN (cont'd)

SUBROUTINE JNCTN

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	H(1,J+1)=(V(1,J+1)-CPC2)/C4(J+1)	JNCTN	157
	P(NCP,J)=(H(NCP,J)-Z(NCP,J))*RHO(J)/144.	JNCTN	158
	IF(P(NCP,J).LT.PSAT(J)) GO TO 215	JNCTN	159
175	IMSAT=C	JNCTN	160
	P(1,J+1)=(H(1,J+1)-Z(1,J+1))*RHO(J+1)/144.	JNCTN	161
	IF(P(1,J+1).LT.PSAT(J+1)) GO TO 226	JNCTN	162
	GO TO 230	JNCTN	163
	215 P(NCP,J)=PSAT(J)	JNCTN	164
180	H(NCP,J)=P(NCP,J)*144./RHO(J)+Z(NCP,J)	JNCTN	165
	IF(IMSAT.EQ.0) GO TO 216	JNCTN	166
	VDIF=(V(NCP,J)+PREV-V(NCP1,J)-OLDV)/2.	JNCTN	167
	CAVOL(JC)=CAVOL(JC)+A(J)*DT*VDIF	JNCTN	168
	216 GO TO (1000,214,314,314,314,1000,1000,1000,1000,314),JTY	JNCTN	169
185	214 P(1,J+1)=P(NCP,J)+V(NCP,J)**2/TWOG1*RHO(J)-V(1,J+1)**2	JNCTN	170
	1/TWOG1*RHO(J+1)+Z(NCP,J)*RHO(J)/144.-Z(1,J+1)*RHO(J+1)/144.	JNCTN	171
	213 IF(P(1,J+1).LT.PSAT(J+1), P(1,J+1)=PSAT(J+1)	JNCTN	172
	H(1,J+1)=P(1,J+1)*144./RHO(J+1)+Z(1,J+1)	JNCTN	173
	GO TO 230	JNCTN	174
190	226 P(1,J+1)=PSAT(J+1)	JNCTN	175
	H(1,J+1)=P(1,J+1)*144./RHO(J+1)+Z(1,J+1)	JNCTN	176
	230 IF(JTYE2(J).EQ.11.AND.P(NCP,J).GT.PY(L3)) JTY=11	JNCTN	177
	IF(JTY.EQ.11) GO TO 660	JNCTN	178
	GO TO 150	JNCTN	179
195	C	JNCTN	180
	C TYPE 3 JUNCTION IS AN AREA CHANGE WITH POSSIBLE CHANGES IN SONIC	JNCTN	181
	C VELOCITY AND COOLANT TEMPERATURE.	JNCTN	182
	C	JNCTN	183
200	300 XAC=(A(J)/A(J+1))**2*RHO(J)/RHO(J+1)	JNCTN	184
	C	JNCTN	185
	C FIRST ASSUME POSITIVE FLOW. CHECK LATER.	JNCTN	186
	C	JNCTN	187
	BAC=-1./C4(J)-A(J)/A(J+1)/C4(J+1)	JNCTN	188
205	IF(A(J+1)/A(J).GT.1.) GO TO 301	JNCTN	189
	KFCTR=.5*(1.-A(J+1)/A(J))	JNCTN	190
	C CONTRACTION DENOTED BY KAC=1 FOR + FLOW	JNCTN	191
	KAC=1	JNCTN	192
	AAC=(1.-XAC-KFCTR*XAC)/TWOG	JNCTN	193
	GO TO 310	JNCTN	194
210	301 KFCTR=(1.-A(J)/A(J+1))**2	JNCTN	195
	C EXPANSION DENOTED BY KAC=2 FOR + FLOW	JNCTN	196
	KAC=2	JNCTN	197
	AAC=(1.-XAC-KFCTR)/TWOG	JNCTN	198
215	310 CAC=CPC2/C4(J+1)*RHO(J+1)/RHO(J)+CPC1/C4(J)	JNCTN	199
	IF(CAC.EQ.0.) GO TO 390	JNCTN	200
	C	JNCTN	201
	C CHECK AGAINST C ONLY DONE TO PREVENT SUBSEQUENT DIVISION BY C.	JNCTN	202
	C	JNCTN	203
	IF(ABS(BAC**2/(4.*AAC*CAC)).GT.10000.) GO TO 390	JNCTN	204
220	DAACP=AAC	JNCTN	205
	DBBCP=BAC	JNCTN	206
	DCCCP=CAC	JNCTN	207
	DSR=DBBCP**2-4.D1*DAACP*DCCCP	JNCTN	208
	IF(DSR.LT.0.) GO TO 322	JNCTN	209
225	V(NCP,J)=(-DBBCP-DSQRT(DSR))/2./DAACP	JNCTN	210
	IF(V(NCP,J).GE.0.) GO TO 212	JNCTN	211
	V(NCP,J)=(-DBBCP+DSQRT(DSR))/2./DAACP	JNCTN	212
	IF(V(NCP,J).LT.0.) GO TO 322	JNCTN	213

SUBROUTINE JNCTN (cont'd)

	SUBROUTINE JNCTN	74/74	OPT=1	FTN 4.2+74351	3/24/76	08.26.04.
230		IF (V(NCP,J) .GT. 1. ⁰ *ABS(VSAV2)) GO TO 322		JNCTN	214	
		GO TO 202		JNCTN	215	
232		IF (JTYP.EQ. 3) GO TO 320		JNCTN	216	
		IF (JTYP.EQ.4.OR.JTYP.EQ.10) GO TO 420		JNCTN	217	
		IF (JTYP.EQ.5) GO TO 520		JNCTN	218	
235		320 IF (A(J)/A(J+1).GT.1.) GO TO 321		JNCTN	219	
	C			JNCTN	220	
	C	FLOW MUST BE NEGATIVE SINCE IT WAS SHOWN NOT TO HAVE A REASONABLE		JNCTN	221	
	C	POSITIVE VALUE.		JNCTN	222	
	C			JNCTN	223	
240		KFCTR=.5*(1.-A(J)/A(J+1))		JNCTN	224	
	C	CONTRACTION DENOTED BY KAC=4 FOR - FLOW		JNCTN	225	
		KAC=4		JNCTN	226	
		AAC=(1.-XAC+KFCTR)/TWOG		JNCTN	227	
		GO TO 330		JNCTN	228	
245		321 KFCTR=(1.-A(J+1)/A(J))**2		JNCTN	229	
	C	EXPANSION DENOTED BY KAC=3 FOR - FLOW		JNCTN	230	
		KAC=3		JNCTN	231	
		AAC=(1.-XAC+KFCTR*XAC)/TWOG		JNCTN	232	
	330	DAACP=AAC		JNCTN	233	
250		DSR=DBBCP**2-4.D1*DAACP*OCCCP		JNCTN	234	
		IF (DSR.LT.0.) GO TO 394		JNCTN	235	
		V(NCP,J) = (-DBBCP-DSQRT(DSR))/2./DAACP		JNCTN	236	
		IF (V(NCP,J) .GT. 1.) GO TO 335		JNCTN	237	
		GO TO 202		JNCTN	238	
255		335 V(NCP,J) = (-DBBCP+DSQRT(DSR))/2./DAACP		JNCTN	239	
		IF (ABS(V(NCP,J)) .GT. ABS(VSAV2) *10.) GO TO 392		JNCTN	240	
		GO TO 202		JNCTN	241	
		314 GO TO (315,316,317,318),KAC		JNCTN	242	
		315 DELPAC=-KFCTR*V(1,J+1)**2/TWOG1*RHO(J+1)		JNCTN	243	
		GO TO 319		JNCTN	244	
260		316 DELPAC=-KFCTR*V(NCP,J)**2/TWOG1*RHO(J)		JNCTN	245	
		GO TO 319		JNCTN	246	
		317 DELPAC=KFCTR*V(1,J+1)**2/TWOG1*RHO(J+1)		JNCTN	247	
		GO TO 319		JNCTN	248	
		318 DELPAC=KFCTR*V(NCP,J)**2/TWOG1*RHO(J)		JNCTN	249	
265		319 P(1,J+1)=P(NCP,J)+(V(NCP,J)**2/TWOG+Z(NCP,J))*RHO(J)/144.		JNCTN	250	
		1 -(V(1,J+1)**2/TWOG+Z(1,J+1))*RHO(J+1)/144.+DELPAC		JNCTN	251	
		GO TO 213		JNCTN	252	
		394 WRITE(6,391) J,T		JNCTN	253	
270		391 FORMAT(1H0,"PROBLEM WITH NEGATIVE SQUARE ROOT FOR JUNCTION AT THE		JNCTN	254	
		END OF LEG",I5," AT",F10.5," SECONDS."/1X,"NEGLECT VELOCITY SQUARE		JNCTN	255	
		2D TERMS, SOLVE REMAINING LINEAR EQUATIONS FOR VELOCITY, AND CONTIN		JNCTN	256	
		3E."/)		JNCTN	257	
		392 V(NCP,J) =-CAC/BAC		JNCTN	258	
		GO TO 202		JNCTN	259	
275		393 WRITE(6,393) J		JNCTN	260	
		393 FORMAT(1H0," NO SOLUTION FOR VELOCITY FOR JUNCTION AT THE END OF L		JNCTN	261	
		EG",I5," EVEN THOUGH THE SQUARE ROOTS ARE OK.")		JNCTN	262	
		STOP		JNCTN	263	
280		400 BAC=-1./C4(J)-1./C4(J+1)		JNCTN	264	
	C			JNCTN	265	
	C	TYPE 4 JUNCTION IS AN ORIFICE TYPE WITH A(J)=A(J+1) BUT WITH		JNCTN	266	
	C	POSSIBLE CHANGES IN SONIC VELOCITY AND DENSITY AT THE JUNCTION.		JNCTN	267	
	C			JNCTN	268	
285	C	FIRST ASSUME POSITIVE FLOW. CHECK LATER.		JNCTN	269	
	C			JNCTN	270	

SUBROUTINE JNCTN (cont'd)

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	KAC=2	JNCTN	271
	KFCTR=CV(J)	JNCTN	272
	AAC=(1.-CV(J)-RHO(J)/RHO(J+1))/TWOG	JNCTN	273
	GO TO 310	JNCTN	274
291	42 KAC=3	JNCTN	275
	C	JNCTN	276
	C TRY NEGATIVE FLOW SINCE FLOW WAS NOT POSITIVE.	JNCTN	277
	C	JNCTN	278
	KFCTR=CV(J)	JNCTN	279
295	AAC=(1.+(CV(J)-1.)*RHO(J)/RHO(J+1))/TWOG	JNCTN	280
	GO TO 330	JNCTN	281
	50 BAC=-1./C4(J)-1./C4(J+1)	JNCTN	282
	C	JNCTN	283
	C TYPE 5 JUNCTION IS AN ELBOW WITH A(J)=A(J+1) BUT WITH POSSIBLE	JNCTN	284
300	C CHANGES IN SONIC VELOCITY AND DENSITY AT THE JUNCTION.	JNCTN	285
	C ONLY CONSIDERS WAVE ACTION DUE TO FRICTIONAL LOSSES.	JNCTN	286
	C	JNCTN	287
	C FIRST ASSUME POSITIVE FLOW. CHECK LATER.	JNCTN	288
	C	JNCTN	289
305	KAC=2	JNCTN	290
	RENOS=C1(J)*ABS(V(NCP,J))	JNCTN	291
	FF5=FRICTF(RENOS,0(J),E)	JNCTN	292
	KFCTR=CV(J)*FF5	JNCTN	293
	AAC=(1.-KFCTR-RHO(J)/RHO(J+1))/TWOG	JNCTN	294
310	GO TO 310	JNCTN	295
	52 KAC=3	JNCTN	296
	C	JNCTN	297
	C USE NEGATIVE FLOW SINCE IT IS NOT POSITIVE.	JNCTN	298
	AAC=(1.+(KFCTR-1.)*RHO(J)/RHO(J+1))/TWOG	JNCTN	299
315	GO TO 330	JNCTN	300
	60 JN=JN02(J)	JNCTN	301
	C	JNCTN	302
	C TYPE 6 JUNCTION IS A TEE OR Y WITH IDENTICAL COOLANT TEMPERATURE	JNCTN	303
	C IN ALL 3 CONNECTING LEGS BUT WITH POSSIBLE CHANGES IN DIAMETER	JNCTN	304
320	C AND SONIC VELOCITIES.	JNCTN	305
	C	JNCTN	306
	IF(KK(JN).EQ.1) GO TO 602	JNCTN	307
	NCP=NO(J)	JNCTN	308
	NCP1=NO(J)-1	JNCTN	309
325	J6=J6+1	JNCTN	310
	C NOTE THAT L2 IS LEG J+1	JNCTN	311
	L2=J+1	JNCTN	312
	L3=LEG3(JN)	JNCTN	313
	C NOTE THAT N2 IS ALWAYS 1	JNCTN	314
330	N2=1	JNCTN	315
	N3=NODE3(JN)	JNCTN	316
	IF(JTYP.EQ.6) GO TO 660	JNCTN	317
	IF(P(NCP,J).GT.PY(L3)) GO TO 660	JNCTN	318
	IF(P(NCP,J).GT.PY(L3)) GO TO 660	JNCTN	319
335	V(N3,L3)=C.	JNCTN	320
	P(N3,L3)=PY(L3)	JNCTN	321
	H(N3,L3)=PY(L3)*144./RHO(L3)+Z(N3,L3)	JNCTN	322
	JTYP=2	JNCTN	323
	GO TO 230	JNCTN	324
340	602 IF(IMSAT.EQ.0) GO TO 150	JNCTN	325
	NCP=NO(J)	JNCTN	326
	NCP1=NO(J)-1	JNCTN	327

SUBROUTINE JNCTN (cont'd)

SUBROUTINE JNCTN

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	IF (P(NCP,J).LE.PSAT(J)) GO TO 603	JNCTN	328
	IMSAT=0	JNCTN	329
345	GO TO 150	JNCTN	330
	603 VOIF=V(NCP,J)-V(NCP1,J)	JNCTN	331
	CAVOL(JC)=CAVOL(JC)+A(J)*DT*VOIF	JNCTN	332
	GO TO 150	JNCTN	333
	660 KK(JN)=1	JNCTN	334
350	VR=V(NCP,J)-VSAV(J)	JNCTN	335
	VS=V(1,J+1)-V(2,J+1)	JNCTN	336
	VR=(V(NCP,J)-THETA(J)*C(J)*VR)/(1.+THETA(J)*VR)	JNCTN	337
	VS=(V(1,J+1)-THETA(J+1)*C(J+1)*VS)/(1.-THETA(J+1)*VS)	JNCTN	338
	HR=H(NCP,J)-THETA(J)*(VR+C(J))*(H(NCP,J)-HSAV(J))	JNCTN	339
355	HS=H(1,J+1)+THETA(J+1)*(VS-C(J+1))*(H(1,J+1)-H(2,J+1))	JNCTN	340
	OLDV=VSAV(J)	JNCTN	341
	PREV=V(NCP,J)	JNCTN	342
	VSAV(J+1)=V(1,J+1)	JNCTN	343
	HSAV(J+1)=H(1,J+1)	JNCTN	344
360	RENOR=C1(J)*VR	JNCTN	345
	RENOS=C1(J+1)*VS	JNCTN	346
	FFR=FRICTF(RENOR,D(J),E)	JNCTN	347
	FFS=FRICTF(RENOS,D(J+1),E)	JNCTN	348
	CPC1=VR+C4(J)*HR-C4(J)*THETA(J)*STATIC(J)*VR-FFR*VF*ABS(VR)*C3(J)	JNCTN	349
365	CPC2=VS-C4(J+1)*HS-C4(J+1)*THETA(J+1)*STATIC(J+1)*VS-FFS*VS*ABS(VS)	JNCTN	350
	1 C3(J+1)	JNCTN	351
	CKJ=CVTEE1(J6)*FFR	JNCTN	352
	CKJ1=CVTEE2(J6)*FFS	JNCTN	353
	IF(N3.EQ.1) GO TO 605	JNCTN	354
370	V3=V(N3,L3)-V(N3-1,L3)	JNCTN	355
	V3=(V(N3,L3)-THETA(L3)*C(L3)*V3)/(1.+THETA(L3)*V3)	JNCTN	356
	H3=H(N3,L3)-THETA(L3)*(V3+C(L3))*(H(N3,L3)-H(N3-1,L3))	JNCTN	357
	REN03=C1(L3)*V3	JNCTN	358
	FF3=FRICTF(REN03,D(L3),E)	JNCTN	359
375	CPC4=V3+C4(L3)*H3-C4(L3)*THETA(L3)*STATIC(L3)*V3-FF3*V3*ABS(V3)*	JNCTN	360
	1 C3(L3)	JNCTN	361
	CPC4=-CPC4	JNCTN	362
	CKJ1=-CVTEE3(J6)*FF3	JNCTN	363
	GO TO 606	JNCTN	364
380	605 V3=V(N3,L3)-V(N3+1,L3)	JNCTN	365
	V3=(V(N3,L3)-THETA(L3)*C(L3)*V3)/(1.-THETA(L3)*V3)	JNCTN	366
	H3=H(N3,L3)+THETA(L3)*(V3-C(L3))*(H(N3,L3)-H(N3+1,L3))	JNCTN	367
	REN03=C1(L3)*V3	JNCTN	368
	FF3=FRICTF(REN03,D(L3),E)	JNCTN	369
385	CPC4=V3-C4(L3)*H3-C4(L3)*THETA(L3)*STATIC(L3)*V3-FF3*V3*ABS(V3)*	JNCTN	370
	1 C3(L3)	JNCTN	371
	CKJ1=CVTEE3(J6)*FF3	JNCTN	372
	606 CONTINUE	JNCTN	373
	VSAV(L3)=V(N3,L3)	JNCTN	374
390	HSAV(L3)=H(N3,L3)	JNCTN	375
	KNTE=0	JNCTN	376
	V1=V(NCP,J)	JNCTN	377
	V2=V(N2,L2)	JNCTN	378
	V3=V(N3,L3)	JNCTN	379
395	C	JNCTN	380
	C	JNCTN	381
	C	JNCTN	382
	THESE 3 VELOCITIES ARE FIRST TRIAL VALUES.	JNCTN	383
	X1=A(J)+A(L2)*C4(L2)/C4(J)+A(L3)*C4(L3)/C4(J)	JNCTN	384
	X2=A(L2)*C4(L2)/X1*(CPC1/C4(J)+CPC2/C4(L2))+A(L3)*C4(L3)/X1*	JNCTN	384

SUBROUTINE JNCTN (cont'd)

SUBROUTINE JNCTN	74/74	OPT=1	FTN 4.2+74351	C 3/24/76	08.26.04.
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400	1	(CPC1/C4(J)+CPC4/C4(L3))	JNCTN	385
	607	X3=A(L2)*C4(L2)/TWOG*(V1**2-CKJ*V1*ABS(V1)	JNCTN	386
	1	-V2**2-CKJ1*V2*ABS(V2))/X1	JNCTN	387
		X4=A(L3)*C4(L3)/TWOG*(V1**2-CKJ*V1*ABS(V1)	JNCTN	388
	1	-V3**2-CKJ1*V3*ABS(V3))/X1	JNCTN	389
405		V(NCP,J)=X2+X3+X4	JNCTN	390
		X5=V1**2/TWOG-CKJ*V1*ABS(V1)/TWOG	JNCTN	391
	1	-V1/C4(J)+CPC1/C4(J)	JNCTN	392
		V(N2,L2)=C4(L2)*(X5-V2**2/TWOG-CKJ1*V2*ABS(V2)/TWOG	JNCTN	393
	1	+CPC2/C4(L2))	JNCTN	394
410		V(N3,L3)=C4(L3)*(X5-V3**2/TWOG-CKJ1*V3*ABS(V3)/TWOG	JNCTN	395
	1	+CPC4/C4(L3))	JNCTN	396
		IF(N3.GT.1) V(N3,L3)=-V(N3,L3)	JNCTN	397
		ERER1=ABS((V(NCP,J)-V1)/(V(NCP,J)+1.E-09))	JNCTN	398
		ERER2=ABS((V(N2,L2)-V2)/(V(N2,L2)+1.E-09))	JNCTN	399
415		ERER3=ABS((V(N3,L3)-V3)/(V(N3,L3)+1.E-09))	JNCTN	400
		1.E-09 ADDED IN ABOVE EQUATIONS IN CASE VEL IS 0.	8-15-73 JNCTN	401
		IF(ERER1.LT..0001.AND.ERER2.LT..0001) GO TO 611	JNCTN	402
		GO TO 612	JNCTN	403
	611	IF(ERER3.LT..0001) GO TO 608	JNCTN	404
420	612	KNTE=KNTE+1	JNCTN	405
		IF(KNTE.GT.10) GO TO 613	JNCTN	406
		V1=V(NCP,J)	JNCTN	407
		V2=V(N2,L2)	JNCTN	408
		V3=V(N3,L3)	JNCTN	409
425		GO TO 607	JNCTN	410
	613	WRITE(6,690) JN2(J),J,T,ERER1,ERER2,ERER3,V(NCP,J),V(N2,L2),	JNCTN	411
		V(N3,L3)	JNCTN	412
	690	FORMAT(1H,"TROUBLE WITH ITERATIVE SOLUTION FOR TEE JUNCTION",I4,"	JNCTN	413
		1 AT END OF LEG",I4," AT TIME",F8.5," SECONDS. HOWEVER,"/5X,"CONTI	JNCTN	414
430		2NUE CASE USING LAST CALCULATED VALUES WITH THESE ERRORS---"/15X,"	JNCTN	415
		3ERER1,ERER2,ERER3 ="",3E15.6," DESIRED MAX ERROR IS .10E-4"/15X,"	JNCTN	416
		4V(NCP,J),V(N2,L2),V(N3,L3) VELOCITIES ARE",3E15.6)	JNCTN	417
	608	CONTINUE	JNCTN	418
		H(NCP,J)=(CPC1-V(NCP,J))/C4(J)	JNCTN	419
435		H(N2,L2)=(V(N2,L2)-CPC2)/C4(L2)	JNCTN	420
		IF(N3.GT.1) GO TO 609	JNCTN	421
		H(N3,L3)=(V(N3,L3)-CPC4)/C4(L3)	JNCTN	422
		GO TO 610	JNCTN	423
	609	H(N3,L3)=(-CPC4-V(N3,L3))/C4(L3)	JNCTN	424
440	610	P(NCP,J)=(H(NCP,J)-Z(NCP,J))*RHO(J)/144.	JNCTN	425
		P(N2,L2)=(H(N2,L2)-Z(N2,L2))*RHO(L2)/144.	JNCTN	426
		P(N3,L3)=(H(N3,L3)-Z(N3,L3))*RHO(L3)/144.	JNCTN	427
		IF(P(NCP,J).LT.PSAT(J)) GO TO 615	JNCTN	428
		IMSAT=0	JNCTN	429
445		IF(P(N2,L2).LT.PSAT(J)) GO TO 630	JNCTN	430
		IF(P(N3,L3).LT.PSAT(J)) GO TO 640	JNCTN	431
		GO TO 650	JNCTN	432
	615	P(NCP,J)=PSAT(J)	JNCTN	433
		H(NCP,J)=P(NCP,J)*144./RHO(J)+Z(NCP,J)	JNCTN	434
450		IF(IMSAT.EQ.0) GO TO 616	JNCTN	435
		VOIF=(V(NCP,J)+PREV-V(NCP1,J)-OLCV)/2.	JNCTN	436
		CAVOL(JC)=CAVOL(JC)+A(J)*DT*VOIF	JNCTN	437
	616	IF(P(N2,L2).LT.PSAT(J)) GO TO 630	JNCTN	438
		IF(P(N3,L3).LT.PSAT(J)) GO TO 640	JNCTN	439
455		GO TO 150	JNCTN	440
	630	P(N2,L2)=PSAT(J)	JNCTN	441

SUBROUTINE JNCTN (cont'd)

SUBROUTINE JNCTN		74/74	OPT=1	FTN 4.2+74351	03/24/76	08.26.44.
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	H(N2,L2)=P(N2,L2)*144./RHO(L2)+Z(N2,L2)	JNCTN	442
	IF(P(N3,L3).LT.PSAT(J)) GO TO 640	JNCTN	443
	GO TO 650	JNCTN	444
460	640 P(N3,L3)=PSAT(J)	JNCTN	445
	H(N3,L3)=P(N3,L3)*144./RHO(L3)+Z(N3,L3)	JNCTN	446
	650 GO TO 150	JNCTN	447
	800 NN=NO(J)	JNCTN	448
	C	JNCTN	449
465	C TYPE 8 IS A DEAD END JUNCTION.	JNCTN	450
	C	JNCTN	451
	V(NN,J)=0.	JNCTN	452
	NN1=NN-1	JNCTN	453
	VR=V(NN,J)-VSAV(J)	JNCTN	454
470	VR=(V(NN,J)-THETA(J)*C(J)*VR)/(1.+THETA(J)*VR)	JNCTN	455
	HR=H(NN,J)-THETA(J)*(VR+C(J))*(H(NN,J)-HSAV(J))	JNCTN	456
	RENO=C1(J)*VR	JNCTN	457
	FF=FRICTF(PENO,D(J),E)	JNCTN	458
	CCP3=VR+C4(J)*HR-C4(J)*THETA(J)*STATIC(J)*VR	JNCTN	459
475	1 -FF*VR*ABS(VR)*C3(J)	JNCTN	460
	H(NN,J)=CCP3/C4(J)	JNCTN	461
	P(NN,J)=(H(NN,J)-Z(NN,J))*RHO(J)/144.	JNCTN	462
	IF(P(NN,J).LT.PSAT(J)) GO TO 815	JNCTN	463
	IMSAT=	JNCTN	464
480	GO TO 830	JNCTN	465
	815 P(NN,J)=PSAT(J)	JNCTN	466
	H(NN,J)=P(NN,J)*144./RHO(J)+Z(NN,J)	JNCTN	467
	IF(IMSAT.EQ.0) GO TO 830	JNCTN	468
	VDIF=(-V(NN1,J)-VSAV(J))/2.	JNCTN	469
485	CAVOL(JC)=CAVOL(JC)+A(J)*DT*VDIF	JNCTN	470
	830 RETURN	JNCTN	471
	C	JNCTN	472
	C TYPE 9 IS A PRESCRIBED BOUNDARY CONDITION TYPE JUNCTION	JNCTN	473
	C TYPE 7 IS A PRESSURIZER JUNCTION. TYPE 7 AND TYPE 9 USE THE SAME	JNCTN	474
490	C BASIC LOGIC. EXCEPTIONS NOTED BY SWITCHES.	JNCTN	475
	C	JNCTN	476
	900 NN=NO(J)	JNCTN	477
	NN1=NN-1	JNCTN	478
	VR=V(NN,J)-VSAV(J)	JNCTN	479
495	VR=(V(NN,J)-THETA(J)*C(J)*VR)/(1.+THETA(J)*VR)	JNCTN	480
	HR=H(NN,J)-THETA(J)*(VR+C(J))*(H(NN,J)-HSAV(J))	JNCTN	481
	IF(JTYP.EQ.7.OR.JTYP.EQ.12) GO TO 901	JNCTN	482
	PENO=PBACK(T)	JNCTN	483
	GO TO 907	JNCTN	484
500	901 J7=J7+1	JNCTN	485
	VSAV2=V(NN,J)	JNCTN	486
	GO TO(902,903,904,905,906,907,908,909,910,911,912,913,914,915,916,917,918,919)	JNCTN	487
	1 ,J7	JNCTN	488
	902 PENO=PRESP(1)	JNCTN	489
505	GO TO 907	JNCTN	490
	903 PENO=PRESP(2)	JNCTN	491
	GO TO 907	JNCTN	492
	904 PENO=PRESP(3)	JNCTN	493
	GO TO 907	JNCTN	494
510	905 PENO=PRESP(4)	JNCTN	495
	GO TO 907	JNCTN	496
	906 PENO=PRESP(5)	JNCTN	497
	GO TO 907	JNCTN	498

SUBROUTINE JNCTN (cont'd)

SUBROUTINE JNCTN		74/74	OPT=1	FTN 4.2+74351	03/24/76	08.26.04.
	940 PEND=PRESP(6)				JNCTN	499
515	GO TO 907				JNCTN	500
	941 PEND=PFESP(7)				JNCTN	501
	GO TO 907				JNCTN	502
	942 PEND=PRESP(8)				JNCTN	503
	GO TO 907				JNCTN	504
520	943 PEND=PRESP(9)				JNCTN	505
	GO TO 907				JNCTN	506
	944 PEND=PRESP(10)				JNCTN	507
	GO TO 907				JNCTN	508
525	945 PEND=PRESP(11)				JNCTN	509
	GO TO 907				JNCTN	510
	946 PEND=PFESP(12)				JNCTN	511
	GO TO 907				JNCTN	512
	947 PEND=PRESP(13)				JNCTN	513
	GO TO 907				JNCTN	514
530	948 PEND=PFESP(14)				JNCTN	515
	GO TO 907				JNCTN	516
	949 PEND=PFESP(15)				JNCTN	517
	907 RENO=C1(J)*VR				JNCTN	518
	FF=FRICTF(RENO,D(J),E)				JNCTN	519
535	C				JNCTN	520
	C				JNCTN	521
	C				JNCTN	522
	FIRST ASSUME NEGATIVE FLOW DIRECTION,CHECK LATER.				JNCTN	523
	BCP=THOG/C4(J)/1.5				JNCTN	524
	CCP3= VR+C4(J)*HR-C4(J)*THETA(J)*STATIC(J)*VR				JNCTN	525
540	1 -FF*VR*ABS(VR)*C3(J)				JNCTN	526
	CCP=BCP*(CCP3-C4(J)*PEND*144./RHO(J)-C4(J)*Z(NN,J))				JNCTN	527
	IF(CCP.EQ.C.) GO TO 908				JNCTN	528
	IF(ABS(BCP**2/(4.*CCP)).GT.10000.) GO TO 908				JNCTN	529
545	DBBCP=BCP				JNCTN	530
	DCCCP=CCP				JNCTN	531
	DSF=DBBCP**2-4.00*DCCCP				JNCTN	532
	IF(DSR.LT.C.) GO TO 910				JNCTN	533
	V(NN,J)=-.5*(DBBCP-DSQRT(DSR))				JNCTN	534
550	909 IF(V(NN,J).LT.C.) GO TO 915				JNCTN	535
	910 IF(JTYP.EQ.9) GO TO 920				JNCTN	536
	GO TO(922,923,924,925,926,927,928,929,930,931,932,933,934,935,936)				JNCTN	537
	1 ,J7				JNCTN	538
	922 P(NN,J)=PRESP(1)				JNCTN	539
	GO TO 921				JNCTN	540
555	923 P(NN,J)=PRESP(2)				JNCTN	541
	GO TO 921				JNCTN	542
	924 P(NN,J)=PRESP(3)				JNCTN	543
	GO TO 921				JNCTN	544
560	925 P(NN,J)=PRESP(4)				JNCTN	545
	GO TO 921				JNCTN	546
	926 P(NN,J)=PRESP(5)				JNCTN	547
	GO TO 921				JNCTN	548
	927 P(NN,J)=PRESP(6)				JNCTN	549
	GO TO 921				JNCTN	550
565	928 P(NN,J)=PRESP(7)				JNCTN	551
	GO TO 921				JNCTN	552
	929 P(NN,J)=PRESP(8)				JNCTN	553
	GO TO 921				JNCTN	554
570	930 P(NN,J)=PRESP(9)				JNCTN	555
	GO TO 921				JNCTN	555

SUBROUTINE JNCTN (cont'd)

SUBROUTINE JNCTN

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.25.04.

	931 P(NN,J)=PRES(1)	JNCTN	556
	GO TO 921	JNCTN	557
	932 P(NN,J)=PRES(11)	JNCTN	558
	GO TO 921	JNCTN	559
575	933 P(NN,J)=PRES(12)	JNCTN	560
	GO TO 921	JNCTN	561
	934 P(NN,J)=PRES(13)	JNCTN	562
	GO TO 921	JNCTN	563
	935 P(NN,J)=PRES(14)	JNCTN	564
580	GO TO 921	JNCTN	565
	936 P(NN,J)=PRES(15)	JNCTN	566
	GO TO 921	JNCTN	567
	908 V(NN,J)=CCP/BCP	JNCTN	568
	GO TO 909	JNCTN	569
585	920 P(NN,J)=PFEND	JNCTN	570
C		JNCTN	571
C	FLOW MUST BE POSITIVE SINCE IT WAS SHOWN NOT TO HAVE A REASONBLE	JNCTN	572
C	NEGATIVE VALUE.	JNCTN	573
C		JNCTN	574
590	921 H(NN,J)=F(NN,J)*144./RHO(J)+Z(NN,J)	JNCTN	575
	V(NN,J)=VR-C4(J)*(H(NN,J)-HR)-C4(J)*THETA(J)*STATIC(J)*VR	JNCTN	576
	1 -FF*VR*ABS(VR)*C3(J)	JNCTN	577
	GO TO 916	JNCTN	578
	915 H(NN,J)=(CCP3-V(NN,J))/C4(J)	JNCTN	579
595	P(NN,J)=(H(NN,J)-Z(NN,J))*RHO(J)/144.	JNCTN	580
	916 IF(JTYP.NE.12) GO TO 1000	JNCTN	581
	IF(V(1,J).GT..0001) GO TO 911	JNCTN	582
	V(NN,J)=0.	JNCTN	583
	911 VAVG=.5*((VSAV2)+V(NN,J))	JNCTN	584
600	ENERGY(J)=ENERGY(J)+PY(J)*144.*A(J)*DT*VAVG	JNCTN	585
	1000 RETURN	JNCTN	586
	END	JNCTN	587

SUBROUTINE MOVEIT

SUBROUTINE MOVEIT 74/74 CPT=1 FTN 4.2+74351 03/24/76 08.26.32.

SUBROUTINE MOVEIT(FROM,ISTFTF,TO,ISTRIT,MANY)	MOVEIT	2
TO=(TO.AND..NOT.SHIFT(MASK(MANY),60-ISTRIT))	MOVEIT	3
..OR.	MOVEIT	4
.(SHIFT((FROM.AND.SHIFT(MASK(MANY),60-ISTRITF)),MOD(60-ISTRIT+ISTRITF	MOVEIT	5
..,60)))	MOVEIT	6
RETURN	MOVEIT	7
END	MOVEIT	8

5

FUNCTION PBACK

FUNCTION PBACK 74/76 OPT=1

FTN 4.2+74351

73/24/76 08.26.35.

	FUNCTION PBACK(TI)	PBACK	2
	C FUNCTION PBACK PROVIDES PRESSURES FOR THE BOUNDARY CONDITION AT THE	PBACK	3
	C END OF A LEG.	PBACK	4
5	C --- NOTATION ---	PBACK	5
	C	PBACK	6
	C	PBACK	7
	C	PBACK	8
	C TI TIME,SEC.	PBACK	9
	C PBACK BOUNDARY CONDITION PRESSURE AT END OF A LEG,PSIG.	PBACK	10
10	C PINIT INITIAL PRESSURE AT THE BOUNDARY CONDITION,PSIG.	PBACK	11
	C	PBACK	12
	COMMON/A1/ D (56),LNTH (56),C (56),CV (56),	KOMMN	2
	1 JTYPE2(56),JNO2 (56),NO (56),KK (56),	KOMMN	3
	2 LEG3 (56),NODE3 (56),RHO (56),C1 (56),	KOMMN	4
15	3 C2 (56),C3 (56),C4 (56),STATIC(56),	KOMMN	5
	4 A (56),CPC3 (56),THETA (56),PSAT (56),	KOMMN	6
	5 VSAV (56),HSAV (56),PY (56),ENERGY(56),	KOMMN	7
	6 LEGSAT(56),NNSAT (56),DX (56),ERASE (56),	KOMMN	8
	7 CAVOL (56),	KOMMN	9
20	8 P(56, 56),H(56, 56),Z(56, 56),V(56, 56),	KOMMN	10
	9 CVTEE1(30),CVTEE2(30),CVTEE3(30),PRES(15),	KOMMN	11
	X E,CKJ,CKJ1,CKJ2,NOLEG,T,NT,J,JTYP,QDESIN,HOESIN,	KOMMN	12
	1 PCA,PCB,PCX,NX,DT,PEND,PSTART,GTHETA,NWRIT,MPLT,	KOMMN	13
	2 TEND,PINIT,J6,J7,JENDS6,VSARE,HSAVE,DTINIT,IMSAT,	KOMMN	14
25	3 JC,NC,KAVITY	KOMMN	15
	COMMON/PLT/NPCT,LF,LOC,KNT,ISH,NPLOT,NK(53),TIM(1003),BUF(10000)	KOMMN	16
	COMMON NID,KPLT,TZ,TSCL,FZ,PSCL,IDENT(F),KID,LE,LB	KOMMN	17
	COMMON LPLOT	KOMMN	18
	C	PBACK	14
30	C ***FOR 151 MW-SEC HODA REXCO RESULTS 3/25/71***	PBACK	15
	C ***INLET NOZZLE***	PBACK	16
	C	PBACK	17
	C ERPL(S,TR,PH,HW)=PH/EXP(AMIN1(86.,((S-TR)/(1.2011*HW))**2))	PBACK	18
	C IF(TI.GT.0.006) GO TO 1	PBACK	19
35	C PBACK = 25000.*TI + ERPL(TI,.0015,90.,.0004)	PBACK	20
	1 + ERPL(TI,.0040,135.,.0002)	PBACK	21
	2 + ERPL(TI,.0052,180.,.0002)	PBACK	22
	3 + ERPL(TI,.0057,210.,.00025)	PBACK	23
	C IF(PBACK .GT. 460.)PBACK = 460.	PBACK	24
40	C PBACK =PBACK +PINIT	PBACK	25
	C RETURN	PBACK	26
	1 IF(TI.GT.0.010) GO TO 2	PBACK	27
	C PBACK = 25000.*TI + ERPL(TI,.0067,150.,.0004)	PBACK	28
	1 + ERPL(TI,.0076,240.,.00025)	PBACK	29
45	2 + ERPL(TI,.0083,290.,.0004)	PBACK	30
	3 + ERPL(TI,.0094,270.,.0004)	PBACK	31
	C IF(PBACK .GT. 460.)PBACK = 460.	PBACK	32
	C PBACK =PBACK +PINIT	PBACK	33
	C RETURN	PBACK	34
50	2 IF(TI.GT.0.014) GO TO 3	PBACK	35
	C PBACK = 25000.*TI + ERPL(TI,.0105,250.,.0003)	PBACK	36
	1 + ERPL(TI,.0113,250.,.0003)	PBACK	37
	2 + ERPL(TI,.0118,250.,.0003)	PBACK	38
	3 + ERPL(TI,.0134,250.,.0003)	PBACK	39
55	C IF(PBACK .GT. 460.)PBACK = 460.	PBACK	40
	C PBACK =PBACK +PINIT	PBACK	41
	C RETURN	PBACK	42

FUNCTION PBACK (cont'd)

FUNCTION PBACK 74/74 OPT=1

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03/24/76 09.26.35.

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3 PBACK=r.  
  PBACK =PBACK +PINIT  
  RETURN  
  END
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PBACK 43  
PBACK 44  
PBACK 45  
PBACK 46
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FUNCTION PBACKR

FUNCTION PBACKR 74/74 OPT=1

FTN 4.2+74351

03/24/76 08.25.39.

	FUNCTION PBACKR(TI)	PBACKR	2
	C	PBACKR	3
	C FUNCTION PBACKR PROVIDES PRESSURES FOR BOUNDARY CONDITION AT THE	PBACKR	4
	C START OF LEG 1.	PBACKR	5
5	C	PBACKR	6
	C --- NOTATION ---	PBACKR	7
	C	PBACKR	8
	C TI TIME,SEC.	PBACKR	9
10	C PBACKR BOUNDARY CONDITION PRESSURE AT START OF LEG 1,PSIG.	PBACKR	10
	C	PBACKR	11
	C	PBACKR	12
	C ***FOR 150 MW-SEC MCDA REXCO RESULTS 3/25/71***	PBACKR	13
	C ***OUTLET NOZZLE***	PBACKR	14
	C	PBACKR	15
15	C IF(TI.GT..0079) GO TO 2	PBACKR	16
	C PBACKR=50000.*TI+5.	PBACKR	17
	C RETURN	PBACKR	18
	C 2 IF(TI.GT. 0.12) GO TO 3	PBACKR	19
	C PBACKR=400.	PBACKR	20
20	C RETURN	PBACKR	21
	C 3 PBACKR=5.	PBACKR	22
	C RETURN	PBACKR	23
	C END	PBACKR	24

SUBROUTINE PLTT

SUBROUTINE PLTT

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.26.42.

		SUBROUTINE PLTT	PLTT	2
			PLTT	3
		PLTT SUBROUTINE RECALLS DATA TO BE PLOTTED AND CLOSES OUT PLOTTING	PLTT	4
		ROUTINES.	PLTT	5
5			PLTT	6
		COMMON/A1/ D (56),LNTH (56),C (56),CV (56),	KOMMN	2
	1	JTYPE2(56),JNO2 (56),NO (56),KK (56),	KOMMN	3
	2	LEG3 (56),NODE3 (56),RHO (56),C1 (56),	KOMMN	4
	3	C2 (56),C3 (56),C4 (56),STATIC(56),	KOMMN	5
10	4	A (56),CPC3 (56),THETA (56),PSAT (56),	KOMMN	6
	5	VSAV (56),HSAV (56),FY (56),ENERGY(56),	KOMMN	7
	6	LEGSAT(56),NNSAT (56),DX (56),ERASE (56),	KOMMN	8
	7	CAVOL (56),	KOMMN	9
	8	P(56, 56),H(56, 56),Z(56, 56),V(56, 56),	KOMMN	10
15	9	CVTEE1(30),CVTEE2(30),CVTEE3(30),PRES(15),	KOMMN	11
	X	E,CKJ,CKJ1,CKJ1,NOLEG,T,NT,J,JTYP,QDESIN,HDESIN,	KOMMN	12
	1	PCA,PCB,PCC,NX,DT,PEND,PSTART,GTHETA,NWRIT,MPLT,	KOMMN	13
	2	TEND,FINIT,J6,J7,JENDS6,VSAVE,HSAVE,DTINIT,IMSAT,	KOMMN	14
	3	JC,NC,KAVITY	KOMMN	15
20		COMMON/PLT/NPCT,LF,LOC,KNT,ISH,NPLOT,NK(53),TIM(1003),BUF(1000)	KOMMN	16
		COMMON NID,KPLT,TZ,TSCL,PZ,PSCL,IDENT(5),KID,L5,LB	KOMMN	17
		COMMON LPLT	KOMMN	18
		EQUIVALENCE (B1,D),(B1(11825),B),(B1(10001),ID)	PLTT	8
		DIMENSION B1(12825),B(1003),ID(12,150)	PLTT	9
25		LPLT = (NPCT+99)/100	PLTT	10
		LPLT=MIN(10000,1000*LPLT)	PLTT	11
		IF (NPCT.LT.1001) GO TO 2	PLTT	12
		NPCT=1000	PLTT	13
		GO TO 1	PLTT	14
30	2	CALL BDUMP	PLTT	15
		IF (UNIT(2)) 1,1,9999	PLTT	16
	1	CONTINUE	PLTT	17
		REWIND ALL DATA FILES	PLTT	18
35		REWIND 19	PLTT	19
		REWIND 20	PLTT	20
		REWIND 21	PLTT	21
		REWIND 22	PLTT	22
		REWIND 23	PLTT	23
		REWIND 24	PLTT	24
40		OPEN PLOT ROUTINES	PLTT	25
		CALL PLOTS(BUF,124,8)	PLTT	26
		CLEAN OUT ARRAYS FOR CLEAN DUMPS	PLTT	27
		DO 5 I=1,12825	PLTT	28
		B1(I) = 0.	PLTT	29
45	5	CONTINUE	PLTT	30
		TIM(NPCT+1) = TZ	PLTT	31
		TIM(NPCT+2) = TSCL	PLTT	32
		B(NPCT+1) = PZ	PLTT	33
		B(NPCT+2) = PSCL	PLTT	34
50			PLTT	35
		BUFFER IN (19,0) (ID,ID(NID))	PLTT	36
		IF (UNIT(19)) 3,9999,9999	PLTT	37
	3	CONTINUE	PLTT	38
55		MOVE PLOT UP 1.0 INCHES ON PAPER	PLTT	39
		CALL PLOT(0,1.0,-3)	PLTT	40
		KPLOT = (NPLOT-1)/10 + 1	PLTT	41
			PLTT	42

SUBROUTINE PLTT (cont'd)

SUBROUTINE PLTT

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.26.42.

	N22=20	PLTT	43
	DO 100 K1=1,KPLOT	PLTT	44
60	NPLT=MIN0(NPLOT-(K1-1)*10,10)	PLTT	45
	DO 20 I=1,10	PLTT	46
	3UFFER IN(N22,0) (B1(1+1000*(I-1)),B1(1000+1000*(I-1)))	PLTT	47
	IF(UNIT(N22)) 19,21,9999	PLTT	48
	19 CONTINUE	PLTT	49
65	20 CONTINUE	PLTT	50
	21 N22=N22+1	PLTT	51
	30 CALL PPLT(NPLT,B1)	PLTT	52
	100 CONTINUE	PLTT	53
	9999 CONTINUE	PLTT	54
70	C CLOSE OUT PLOT TAPE	PLTT	55
	CALL PLOT(1,0,999)	PLTT	56
	RETURN	PLTT	57
	END	PLTT	58

SUBROUTINE PPLT

SUBROUTINE PPLT

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.26.48

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SUBROUTINE PPLT(NPLT,BF)
C
C PPLT SUBROUTINE PLOTS DATA.
C
5 COMMON/A1/ D ( 56),LNTH ( 56),C ( 56),CV ( 56),
1 JTYPE2( 56),JNO2 ( 56),NO ( 56),KK ( 56),
2 LEG3 ( 56),NODE3 ( 56),RHO ( 56),C1 ( 56),
3 C2 ( 56),C3 ( 56),C4 ( 56),STATIC( 56),
4 A ( 56),CPC3 ( 56),THETA ( 56),PSAT ( 56),
10 VSAV ( 56),HSAV ( 56),PY ( 56),ENERGY( 56),
6 LEGSAT( 56),NNSAT ( 56),DX ( 56),ERASE ( 56),
7 CAVOL ( 56),
8 P( 50, 56),H( 50, 56),Z( 50, 56),V( 50, 56),
9 CVTEE1(30),CVTEE2(30),CVTEE3(30),PRESF(15),
15 X E,CKJ,CKJ1,CKJ1,NOLEG,T,NT,J,JTYP,QDESIN,HDESIN,
1 PCA,PCB,PCG,NX,OT,PEND,PSTART,GTHETA,NWRIT,MPLT,
2 TEND,PINIT,J6,J7,JENDS6,VSAVE,HSAVE,OTINIT,IMSAT,
3 JC,NC,KAVITY
COMMON/PLT/NPCT,LF,LCC,KNT,ISW,NPLOT,NK(53),TIM(1003),BUF(10000)
20 COMMON NID,KPLT,TZ,TSCL,PZ,PSCL,IDENT(5),KID,LE,LB
COMMON LPLT
EQUIVALENCE (B1,D),(B1(11801),8),(B1(10001),ID)
DIMENSION B1(12825),B(1003),ID(12,150)
25 DIMENSION BF(10,1000)
INTEGER FLD
EQUIVALENCE (B1(12804),Q)
TL=AINT((TIM(NPCT)-TZ)/TSCL+.99)
DO 500 K=1,NPLT
CALL AXIS(' ',0.,"TIME,M-SEC",-10,TL,' ',TZ,TSCL)
30 CALL SYMBOL(.5,9,...14,IDENT,1,48)
CALL SYMBOL(.5,8.5,...14,ID(3,1),0.,60)
C
C*** INTERPRET PLOT INFORMATION
35 JD=ID(1,KPLT)
KD = ID(2,KPLT)
I1=FLD(10,9,KD)
I2=FLD(20,8,KD)
LN=21
IF (FLD(2,2,KD).EQ.0) GO TO 21
40 I3=FLD(30,9,KD)
I4=FLD(40,8,KD)
LN=30
WRITE(6,13) JD,I1,I2,I3,I4,(ID(J,KPLT),J=3,8)
13 FORMAT("CPLT TYPE ",A2," LEG",I5," NODE",I5," LEG",I5,
. " NODE",I5,T70,6A10)
45 GO TO 30
C PS AND PE PLOTS
20 WRITE(6,21) JD,I1,I2,(ID(J,KPLT),J=3,8)
21 FORMAT("CPLT TYPE ",A2," LEG",I5," NODE",I5,T70,6A10)
50 31 CONTINUE
ENCODE(31,33,Q) JD,I1,I2,I3,I4
33 FORMAT(A2,3X,"LEG/NODE",I5,"/",I2," -",I4,"/",I2)
CALL SYMBOL(0.,-.7,...1,0,0.,LN)
CALL SYMBOL(.5,8.1,...14,ID(3,KPLT),1.,61)
55 KPLT = KPLT + 1
SYM = 8.0
IF (KPLT.GT.KID) GO TO 61

```

PPLT	2
PPLT	3
PPLT	4
PPLT	5
KOMMN	2
KOMMN	3
KOMMN	4
KOMMN	5
KOMMN	6
KOMMN	7
KOMMN	8
KOMMN	9
KOMMN	10
KOMMN	11
KOMMN	12
KOMMN	13
KOMMN	14
KOMMN	15
KOMMN	16
KOMMN	17
KOMMN	18
PPLT	7
PPLT	8
PPLT	9
PPLT	10
PPLT	11
PPLT	12
PPLT	13
PPLT	14
PPLT	15
PPLT	16
PPLT	17
PPLT	18
PPLT	19
PPLT	20
PPLT	21
PPLT	22
PPLT	23
PPLT	24
PPLT	25
PPLT	26
PPLT	27
PPLT	28
PPLT	29
PPLT	30
PPLT	31
PPLT	32
PPLT	33
PPLT	34
PPLT	35
PPLT	36
PPLT	37
PPLT	38
PPLT	39
PPLT	40
PPLT	41
PPLT	42

SUBROUTINE PPLT (cont'd)

SUBROUTINE PPLT		74/74	OPT=1	FTN 4.2+74351	03/24/76	08.26.48.
	DO 50 I=KPLT,KID				PPLT	43
	IF (ID(1,I).GT.1) GO TO 60				PPLT	44
60	SYN = SYN -.5				PPLT	45
	CALL SYMBOL(.5,SYN,.14,ID(3,I),0.,60)				PPLT	46
	WRITE(6,31) (ID(J,I),J=3,8)				PPLT	47
	31 FORMAT(T7^,6A1:)				PPLT	48
	50 CONTINUE				PPLT	49
65	60 KPLT = I				PPLT	50
	61 CONTINUE				PPLT	51
	YMIN = 10000.				PPLT	52
	YMAX = -10000.				PPLT	53
	C				PPLT	54
70	DO 100 I=1,NPCT				PPLT	55
	Y=BF(K,I)				PPLT	56
	YMAX = AMAX1(Y,YMAX)				PPLT	57
	YMIN = AMIN1(Y,YMIN)				PPLT	58
	B(I) = Y				PPLT	59
75	100 CONTINUE				PPLT	60
	PMX=PSCL*8.+PZ				PPLT	61
	IF (PZ.GT.YMIN.OR.PMX.LT.YMAX) GO TO 210				PPLT	62
	C CHECK TO SEE IF PRESSURE DIFFERENCE IS TO BE PLOTTED				PPLT	63
	C JD=PDCC03 CHECK 2ND CHAR. FOR 0 BITS 6 THRU 11				PPLT	64
80	C 0=4 IN DISPLAY SET				PPLT	65
	IF (FLD(6,6,JD).EQ.4) GO TO 110				PPLT	66
	C				PPLT	67
	CALL AXIS(0.,0., "PRESSURE,PSIG",13,8.,90.,PZ,PSCL)				PPLT	68
	C				PPLT	69
85	GO TO 111				PPLT	70
	110 CALL AXIS(0.,0., "PRESSURE DIFFERENCE,PSI",23,8.,90.,PZ,PSCL)				PPLT	71
	111 CALL LINE(TIM,9,NPCT,1,0,1)				PPLT	72
	GO TO 490				PPLT	73
	C				PPLT	74
90	210 IF (FLD(6,6,JD).EQ.4) GO TO 230				PPLT	75
	C				PPLT	76
	C FOR PRESSURE PLOTS IF BEYOND SPECIFIED SCALE RANGE.				PPLT	77
	C				PPLT	78
	PNEED=YMAX/7.				PPLT	79
95	IF (PNEED.LE.PSCL) GO TO 211				PPLT	80
	IF (PNEED.LE.2.*PSCL) GO TO 213				PPLT	81
	IF (PNEED.LE.4.*PSCL) GO TO 215				PPLT	82
	IF (PNEED.LE.5.*PSCL) GO TO 217				PPLT	83
	IF (PNEED.LE.10.*PSCL) GO TO 219				PPLT	84
100	IF (PNEED.LE.20.*PSCL) GO TO 221				PPLT	85
	GO TO 230				PPLT	86
	211 YDEL= PSCL				PPLT	87
	GO TO 225				PPLT	88
105	213 YDEL= 2.*PSCL				PPLT	89
	GO TO 225				PPLT	90
	215 YDEL= 4.*PSCL				PPLT	91
	GO TO 225				PPLT	92
	217 YDEL= 5.*PSCL				PPLT	93
	GO TO 225				PPLT	94
110	219 YDEL=10.*PSCL				PPLT	95
	GO TO 225				PPLT	96
	221 YDEL=20.*PSCL				PPLT	97
	225 YMIN=-YDEL				PPLT	98
	B(NPCT+1)=YMIN				PPLT	99

SUBROUTINE PPLT (cont'd)

SUBROUTINE PPLT

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.26.48.

115	B(NPCT+2)=YDEL	PPLT	103
	GO TO 300	PPLT	101
	230 IF (YMIN.GE.0.) GO TO 231	PPLT	102
	C FOR DP PLOTS IF BEYOND SPECIFIED SCALE RANGE.	PPLT	103
	C	PFLT	104
120		PPLT	105
	IF (YMIN.GE.-100.) GO TO 233	PPLT	106
	IF (YMIN.GE.-200.) GO TO 235	PPLT	107
	IF (YMIN.GE.-500.) GO TO 237	PPLT	108
	IF (YMIN.GE.-1000.) GO TO 239	PPLT	109
125	GO TO 200	PPLT	110
	231 YMIN=0.	PPLT	111
	GO TO 240	PPLT	112
	233 YMIN=-100.	PPLT	113
	GO TO 240	PFLT	114
130	235 YMIN=-200.	PPLT	115
	GO TO 240	PPLT	116
	237 YMIN=-500.	PPLT	117
	GO TO 240	PPLT	118
	239 YMIN=-1000.	PPLT	119
135	240 PNEED=(YMAX-YMIN)/8.	PFLT	120
	IF (PNEED.LE. 50.) GO TO 241	PPLT	121
	IF (PNEED.LE. 100.) GO TO 243	PPLT	122
	IF (PNEED.LE. 200.) GO TO 245	PPLT	123
	IF (PNEED.LE. 500.) GO TO 247	PPLT	124
140	IF (PNEED.LE.1000.) GO TO 249	PPLT	125
	GO TO 200	PPLT	126
	241 YDEL=50.	PPLT	127
	GO TO 251	PPLT	128
	243 YDEL=100.	PPLT	129
145	GO TO 251	PPLT	130
	245 YDEL=200.	PPLT	131
	GO TO 251	PPLT	132
	247 YDEL=500.	PPLT	133
	GO TO 251	PPLT	134
150	249 YDEL=1000.	PPLT	135
	251 B(NPCT+1)=YMIN	PPLT	136
	B(NPCT+2)=YDEL	PPLT	137
	GO TO 300	PPLT	138
	200 PDEL = PSCL*8.	PPLT	139
155	YDEL = YMAX-YMIN	PPLT	140
	B(NPCT+1)=YMIN	PPLT	141
	IF (PDEL.LT.YDEL) GO TO 250	PPLT	142
	YDEL=PSCL	PPLT	143
	GO TO 300	PPLT	144
160	C	PPLT	145
	250 YDEL=YDEL/8.	PPLT	146
	B(NPCT+2)=YDEL	PPLT	147
	300 CONTINUE	PPLT	148
	C	PPLT	149
165	C CHECK TO SEE IF PRESSURE DIFFERENCE IS TO BE PLOTTED	PPLT	150
	C JD=PD0000 CHECK 2ND CHAR. FOR 0 BITS 6 THRU 11	PPLT	151
	C D=4 IN DISPLAY SET	PPLT	152
	IF (FLD(6,6,JD).EQ.4) GO TO 310	PPLT	153
	C	PPLT	154
170	CALL AXIS(0.,0., "PRESSURE,PSIG",13,8.,90.,YMIN,YDEL)	PPLT	155
	GO TO 311	PPLT	156

SUBROUTINE PPLT (cont'd)

SUBROUTINE PPLT

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.26.48.

	310 CALL AXIS(0.,0., "PRESSURE DIFFERENCE, PSI", 23, 8., 90., YMIN, YDEL)	PPLT	157
	311 CALL LINE(TIM, 8, NPCT, 1, 0, 1)	PPLT	158
175	C*** RESET ALL VALUE TO ORIGINAL	PPLT	159
	B(NPCT+1)=PZ	PPLT	160
	B(NPCT+2)=PSQL	PPLT	161
	C	PPLT	162
	C	PPLT	163
	C	PPLT	164
180	499 CALL PLOT(12., 0, -3)	PPLT	165
	500 CONTINUE	PPLT	166
	RETURN	PPLT	167
	END	PPLT	168

SUBROUTINE REPT

SUBROUTINE REPT

74/74 OPT=1

FTN 4.2+74351

03/24/76 08.26.57.

SUBROUTINE REPT

WRITES CALCULATED DATA FOR EACH PIPE LEG AT INLET AND OUTLET.

SEE HAMOC MAIN PROGRAM FOR NOTATION.

```

COMMON/A1/ D ( 56),LNTH ( 56),C ( 56),CV ( 56),
1 JTYPE2( 56),JNO2 ( 56),NO ( 56),KK ( 56),
2 LEG3 ( 56),NODE3 ( 56),RHO ( 56),C1 ( 56),
3 C2 ( 56),C3 ( 56),C4 ( 56),STATIC( 56),
4 A ( 56),CPC3 ( 56),THETA ( 56),PSAT ( 56),
5 VSAV ( 56),HSAV ( 56),PY ( 56),ENERGY( 56),
6 LEGSAT( 56),NNSAT ( 56),DX ( 56),ERASE ( 56),
7 CAVOL ( 56),
8 P( 50, 56),H( 50, 56),Z( 50, 56),V( 50, 56),
9 CVTEE1(30),CVTEE2(30),CVTEE3(30),PRES(15),
X E,CKJ,CKJ1,CKJ2,NOLEG,T,NT,J,JTYP,QDESIN,HDESIN,
1 PCA,PCB,PCC,NX,OT,PEND,PSTART,GTHETA,NWRIT,MPLT,
2 TEND,PINIT,J6,J7,JENDS6,VSAVE,HSAVE,OTINIT,IMSAT,
3 JC,NC,KAVITY
COMMON/PLT/NPCT,LF,LOC,KNT,ISW,NPLOT,NK(53),TIM(1003),BUF(10000)
COMMON NID,KPLT,TZ,TSC,L,PZ,PSCL,IDENT(5),KID,L5,LB
COMMON LPLT
25 WRITE(6,10) T
10 FORMAT(1H1, //7X, "TIME =", F8.5, " SECONDS", //8X, "LEG PRESS. IN PR
1 ESS. OUT VEL. IN VEL. OUT P(2,J) P(NO-1,J) V(2,J)
2 V(NO-1,J) ENERGY", /14X, "PSIG PSIG FT/SEC
3 FT/SEC PSIG PSIG FT/SEC FT/SEC LB-FT
30 4", //)
DO 20 J=1,NOLEG
NN=NO(J)
WRITE(6,12) J,P(1,J),P(NN,J),V(1,J),V(NN,J)
1 ,P(2,J),P(NN-1,J),V(2,J),V(NN-1,J),ENERGY(J)
35 12 FORMAT(1H ,I10,1P9E12.5)
20 CONTINUE
RETURN
END

```

REPT	2
REPT	3
REPT	4
REPT	5
REPT	6
REPT	7
REPT	8
KOMMN	2
KOMMN	3
KOMMN	4
KOMMN	5
KOMMN	6
KOMMN	7
KOMMN	8
KOMMN	9
KOMMN	10
KOMMN	11
KOMMN	12
KOMMN	13
KOMMN	14
KOMMN	15
KOMMN	16
KOMMN	17
KOMMN	18
REPT	10
REPT	11
REPT	12
REPT	13
REPT	14
REPT	15
REPT	16
REPT	17
REPT	18
REPT	19
REPT	20
REPT	21
REPT	22
REPT	23

SUBROUTINE SETPLT

SUBROUTINE SETPLT 74/74 CPT=1

FTN 4.2+74351

03/24/76 08.27.04.

		SUBROUTINE SETPLT	SETPLT	2
	C		SETPLT	3
	C	SETPLT SUBROUTINE READS PLOTTING INFORMATION AND SETS UP PLOT	SETPLT	4
	C	ROUTINES.	SETPLT	5
5	C		SETPLT	6
		COMMON/A1/ D (56),LNTH (56),C (56),CV (56),	KOMMN	2
	1	JTYPE2(56),JNO2 (56),NO (56),KK (56),	KOMMN	3
	2	LEG3 (56),NODE3 (56),PHO (56),C1 (56),	KOMMN	4
	3	C2 (56),C3 (56),C4 (56),STATIC(56),	KOMMN	5
10	4	A (56),CPC3 (56),THETA (56),PSAT (56),	KOMMN	6
	5	VSAV (56),HSAV (56),FY (56),ENERGY(56),	KOMMN	7
	6	LEGSAT(56),NNSAT (56),DX (56),ERASE (56),	KOMMN	8
	7	CAVOL (56),	KOMMN	9
	8	P(56, 56),H(56, 56),Z(56, 56),V(56, 56),	KOMMN	10
15	9	CVTEE1(3),CVTEE2(3),CVTEE3(30),FRESF(15),	KOMMN	11
	X	E,CKJ,CKJ1,CKJ1,NOLEG,T,NT,J,JTYP,QDESIN,HDESIN,	KOMMN	12
	1	PCA,PCB,PCG,NX,DT,PEND,PSTART,GTHETA,NWRIT,MPLT,	KOMMN	13
	2	TEND,FINIT,J6,J7,JENDS6,VSAVE,HSAVE,DTINIT,IMSAT,	KOMMN	14
	3	JC,NC,KAVITY	KOMMN	15
20		COMMON/PLT/NPCT,LF,LOC,KNT,ISW,NPLOT,NK(53),TIM(1003),BUF(1000)	KOMMN	16
		COMMON NID,KPLT,TZ,TSC,L,PZ,PSCL,IDENT(5),KID,L5,L8	KOMMN	17
		COMMON LPLT	KOMMN	18
		INTEGER PF,PE,PS,PD,PB,P1,P2	SETPLT	8
		DIMENSION ID(12,15)	SETPLT	9
25		EQUIVALENCE (ID,BUF)	SETPLT	10
		DATA PF,PE,PS,PD,PB/"P ","F ","S ","D ","I "/"	SETPLT	11
	C		SETPLT	12
	C		SETPLT	13
		NPLOT=0	SETPLT	14
30	C	READ TITLE CARD	SETPLT	15
		READ(5,3) (ID(J,1),J=2,8)	SETPLT	16
		7 FORMAT(A6,14X6A10)	SETPLT	17
		IF (EOF(5)) GO TO 2	SETPLT	18
		2 CONTINUE	SETPLT	19
75	C	SCALE FOR TIME AND PRESSURE	SETPLT	20
		READ(5,4) (ID(J,2),J=2,6)	SETPLT	21
		4 FORMAT(A6,14X,5E10.0)	SETPLT	22
	C	START TIME	SETPLT	23
		TZ=BUF(15)	SETPLT	24
40	C	TIME SCALE IN MILLISECONDS/INCH	SETPLT	25
		TSC=BUF(16)	SETPLT	26
	C	PRESSURE START (PSI)	SETPLT	27
		PZ=BUF(17)	SETPLT	28
	C	PRESSURE SCALE PSI/INCH	SETPLT	29
45		PSCL=BUF(18)	SETPLT	30
	C		SETPLT	31
		WRITE(6,6) IDENT,(ID(J,1),J=2,8),(ID(J,2),J=2,6)	SETPLT	32
	6	FORMAT("1PLOT REPORT "4A10,43/5XA6,6XE10.0//	SETPLT	33
		X5X,A6,6X,"TIME START ="',F11.5," MILLISECONDS. INCREMENT ="',F10.	SETPLT	34
50		15," MILLISECONDS/INCH"/	SETPLT	35
		217X,"PRESSURE START ="',F11.4," PSIG. INCREMENT ="',E11.4," PSIG/	SETPLT	36
		3IN."//)	SETPLT	37
	C		SETPLT	38
	C	PLOT CONTROL CARDS AND TITLES	SETPLT	39
55		DO 100 I=3,150	SETPLT	40
		K=0	SETPLT	41
		READ(5,11) P1,P2,I1,I2,I3,I4,(ID(J,I),J=3,8)	SETPLT	42

SUBROUTINE SETPLT (cont'd)

SUBROUTINE SETPLT		74/74	OPT=1	FTN 4.2+74351	03/24/76	08.27.04.
	11	FORMAT(2A1,4I3,6X6A10)			SETPLT	43
		IF (EOF(5)) 1000,7			SETPLT	44
60	7	CONTINUE			SETPLT	45
		IF (P1.NE.PF) GOTO 100			SETPLT	46
		IF (NPLCT.EQ.0) KPLT=I			SETPLT	47
		NPLCT = NPLCT + 1			SETPLT	48
		IF (P2.EQ.FS) I2 = 1			SETPLT	49
65		IF (P2.EQ.PE) I2 = NO(I1)			SETPLT	50
		IF (P2.NE.FD) GOTO 20			SETPLT	51
	C				SETPLT	52
		CALL MOVEIT(1,59,K,2,1)			SETPLT	53
		CALL MOVEIT(I3,51,K,30,9)			SETPLT	54
70		CALL MOVEIT(I4,52,K,40,8)			SETPLT	55
	C				SETPLT	56
	2	CALL MOVEIT(I1,51,K,10,9)			SETPLT	57
		CALL MOVEIT(I2,52,K,20,8)			SETPLT	58
	C				SETPLT	59
75		NK(NPLCT)=K			SETPLT	60
		ID(2,I) = K			SETPLT	61
		CALL MOVEIT(P2,0,P1,6,6)			SETPLT	62
		ID(1,I) = P1			SETPLT	63
	100	CONTINUE			SETPLT	64
80	C				SETPLT	65
	1000	KID=I-1			SETPLT	66
		NID=12*KID			SETPLT	67
		BUFFER OUT(19,0) (ID,ID(NID))			SETPLT	68
		IF (UNIT(19)) 77,9999,9999			SETPLT	69
85	77	CONTINUE			SETPLT	70
	C				SETPLT	71
		LF=0			SETPLT	72
		KNT=0			SETPLT	73
		LPLCT=(NPLCT+9)/10			SETPLT	74
90	2000	RETURN			SETPLT	75
	9999	STOP			SETPLT	76
		END			SETPLT	77

FUNCTION SPEED

FUNCTION SPEED 74/74 OPT=1

FTN 4.2+74351

03/24/76 08.27.10.

		FUNCTION SPEED(TI)	SPEED	2
	C		SPEED	3
	C	FUNCTION COMPUTES NORMALIZED PUMP SPEED AS A FUNCTION OF TIME.	SPEED	4
	C		SPEED	5
5	C		SPEED	6
	C	SEE HAMOC MAIN PROGRAM FOR NOTATION.	SPEED	7
	C		SPEED	8
		SPEED=1.	SPEED	9
	C		SPEED	10
10	C	SETS SPEED CONSTANT AT DESIGN VALUE.	SPEED	11
	C		SPEED	12
		RETURN	SPEED	13
		END	SPEED	14

LOAD MAP

SCOPE 3.4.2 - CONTROL-CARD-INITIATED LOAD

LOADER P3808

03/24/76 08.27.21.

FWA OF THE LOAD 101
LWA+1 OF THE LOAD 132212

TRANSFER ADDRESS -- HAMOC 77455

PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK	ADDRESS	LENGTH	FILE	PREFIX TABLE CONTENTS
/A1/	101	31242		
/PLT/	31343	25466		
HAMOC	57031	21612	LGO	03/24/76 08.25.05. SCOPE 3.4 FTN 4.274351666X I OPT=1
BDUMP	100643	207	LGO	03/24/76 08.25.23. SCOPE 3.4 FTN 4.274351666X I OPT=1
DATA	101052	1173	LGO	03/24/76 08.25.28. SCOPE 3.4 FTN 4.274351666X I OPT=1
FLD	102245	20	LGO	03/24/76 08.25.34. SCOPE 3.4 FTN 4.274351666X I OPT=1
FRICTF	102265	137	LGO	03/24/76 08.25.36. SCOPE 3.4 FTN 4.274351666X I OPT=1
INIT	102424	2111	LGO	03/24/76 08.25.38. SCOPE 3.4 FTN 4.274351666X I OPT=1
JNCTN	104535	3362	LGO	03/24/76 08.26.04. SCOPE 3.4 FTN 4.274351666X I OPT=1
MOVEIT	110117	35	LGO	03/24/76 08.26.32. SCOPE 3.4 FTN 4.274351666X I OPT=1
PBACK	110154	243	LGO	03/24/76 08.26.35. SCOPE 3.4 FTN 4.274351666X I OPT=1
PBACKR	110417	27	LGO	03/24/76 08.26.39. SCOPE 3.4 FTN 4.274351666X I OPT=1
PLTT	110446	200	LGO	03/24/76 08.26.42. SCOPE 3.4 FTN 4.274351666X I OPT=1
PPLT	110646	740	LGO	03/24/76 08.26.48. SCOPE 3.4 FTN 4.274351666X I OPT=1
REPT	111606	113	LGO	03/24/76 08.26.57. SCOPE 3.4 FTN 4.274351666X I OPT=1
SETPLT	111721	322	LGO	03/24/76 08.27.04. SCOPE 3.4 FTN 4.274351666X I OPT=1
SPEED	112243	12	LGO	03/24/76 08.27.10. SCOPE 3.4 FTN 4.274351666X I OPT=1
AXIS	112255	352	SL-FORTRAN	10/02/74 01.18.46. SCOPE 3.4 FTN 4.2P381 666X I OPT=1
EEADCP	112627	15	SL-FORTRAN	10/02/74 01.18.50. SCOPE 3.4 COMPASS 3.74261 2
NUMBER	112644	215	SL-FORTRAN	10/02/74 01.18.53. SCOPE 3.4 FTN 4.2P381 666X I OPT=1
BUFIN=	113061	123	SL-FORTRAN	12/17/74 15.13.26. SCOPE 3.4 COMPASS 3.74261 COMMON SETUP ROUTINE FOR BUFIN=BUFOUT=
/Q8.IO./	113204	134		
/IOCON./	113340	42		
FLTIN=	113402	153	SL-FORTRAN	12/17/74 15.42.02. SCOPE 3.4 COMPASS 3.74261 COMMON FLOATING INPUT CONVERTER.
FMTP=	113555	345	SL-FORTRAN	12/17/74 15.54.41. SCOPE 3.4 COMPASS 3.74261 CRACK APLIST AND FORMAT FOR KODER/KRAKER.

LOAD MAP (cont'd)

J	SCOPE 3.4.2	-	CONTROL-CAFD-INITIATED LOAD	LOADER	F380B	03/24/76	08.27.21.
BLOCK	ADDRESS	LENGTH	FILE	PREFIX TABLE CONTENTS			
INCOM=	114122	262	SL-FORTRAN	12/17/74	16.03.42.	SCOPE 3.4 COMPASS 3.74261	
INPC=	114474	164	SL-FORTRAN	12/17/74	16.06.14.	SCOPE 3.4 COMPASS 3.74261	
KODEP=	114570	461	SL-FORTRAN	12/17/74	16.08.26.	SCOPE 3.4 COMPASS 3.74261	
OUTCOM=	115251	141	SL-FORTRAN	12/17/74	16.15.48.	SCOPE 3.4 COMPASS 3.74261	
SGRT	115412	44	SL-FORTRAN	12/17/74	16.24.56.	SCOPE 3.4 COMPASS 3.74261	
SYS=AI0	115456	53	SL-FORTRAN	12/17/74	16.24.59.	SCOPE 3.4 COMPASS 3.74261	
XTDI=	115531	17	SL-FORTRAN	12/17/74	16.27.25.	SCOPE 3.4 COMPASS 3.74261	
XTDY=	115541	7	SL-FORTRAN	12/17/74	16.27.37.	SCOPE 3.4 COMPASS 3.74261	
CIDENT	115550	110	SL-FORTRAN	10/02/74	01.18.48.	SCOPE 3.4 FTN 4.2P380 566X I	
LINE	115660	210	SL-FORTRAN	10/02/74	01.19.51.	SCOPE 3.4 FTN 4.2P380 566X I	
PLOT	116070	704	SL-FORTRAN	10/02/74	01.19.55.	SCOPE 3.4 COMPASS 3.74261	2
SYMBOL	116774	433	SL-FORTRAN	10/02/74	01.19.59.	SCOPE 3.4 COMPASS 3.74261	2
BUFIN=	117427	46	SL-FORTRAN	12/17/74	15.13.23.	SCOPE 3.4 COMPASS 3.74261	
BUFOUT=	117475	35	SL-FORTRAN	12/17/74	15.24.13.	SCOPE 3.4 COMPASS 3.74261	
COMIO=	117532	62	SL-FORTRAN	12/17/74	15.25.19.	SCOPE 3.4 COMPASS 3.74261	
ENCODE=	117614	123	SL-FORTRAN	12/17/74	15.39.23.	SCOPE 3.4 COMPASS 3.74261	
EOF	117737	13	SL-FORTRAN	12/17/74	15.47.39.	SCOPE 3.4 COMPASS 3.74261	
FLTOUT=	117752	310	SL-FORTRAN	12/17/74	15.51.02.	SCOPE 3.4 COMPASS 3.74261	
FORSYS=	120262	1710	SL-FORTRAN	12/17/74	16.07.26.	SCOPE 3.4 COMPASS 3.74261	
GETFIT=	121272	34	SL-FORTRAN	12/17/74	16.03.40.	SCOPE 3.4 COMPASS 3.74261	
KRAKER=	121326	414	SL-FORTRAN	12/17/74	16.06.34.	SCOPE 3.4 COMPASS 3.74261	
LOADUT=	121742	254	SL-FORTRAN	12/17/74	16.09.05.	SCOPE 3.4 COMPASS 3.74261	
OUTC=	122216	165	SL-FORTRAN	12/17/74	16.17.07.	SCOPE 3.4 COMPASS 3.74261	
OUTF=	122403	162	SL-FORTRAN	12/17/74	16.15.55.	SCOPE 3.4 COMPASS 3.74261	
REWIND=	122565	37	SL-FORTRAN	12/17/74	16.16.22.	SCOPE 3.4 COMPASS 3.74261	
UNIT	122624	51	SL-FORTRAN	12/17/74	16.16.35.	SCOPE 3.4 COMPASS 3.74261	
CLOCK=	122675	31	SL-FORTRAN	12/17/74	16.16.41.	SCOPE 3.4 COMPASS 3.74261	
GOTOER=	122726	14	SL-FORTRAN	12/17/74	16.19.37.	SCOPE 3.4 COMPASS 3.74261	

LOAD MAP (cont'd)

SCOPE 3.4.2 - CONTROL-CAFD-INITIATED LOAD

LOADER P387B 03/24/76 08.27.21.

BLOCK	ADDRESS	LENGTH	FILE	PREFIX TABLE CONTENTS
				COMPUTED GC TO ERROR PROCESSOR.
ALOG	122742	73	SL-FORTRAN	12/17/74 16.20.17. SCOPE 3.4 COMPASS 3.74261
DSQRT=	123035	32	SL-FORTRAN	COMPUTE COMMON AND NATURAL LOGARITHMS. OPT=ALL.
				12/17/74 16.21.05. SCOPE 3.4 COMPASS 3.74261
STOI=	123067	21	SL-FORTRAN	DOUBLE PRECISION SQUARE ROOT.
				12/17/74 16.24.01. SCOPE 3.4 COMPASS 3.74261
EXP	123110	76	SL-FORTRAN	DOUBLE TO INTEGER EXPONENTIATION.
				12/17/74 16.24.14. SCOPE 3.4 COMPASS 3.74261
SINCOS=	123276	71	SL-FORTRAN	EXPONENTIAL FUNCTION E TO POWER X. OPT=ALL.
				12/17/74 16.24.53. SCOPE 3.4 COMPASS 3.74261
SYSID=	123277	1	SL-FORTRAN	COMPUTE THE TRIGONOMETRIC SINE AND COSINE. OPT=ALL.
				12/17/74 16.24.59. SCOPE 3.4 COMPASS 3.74261
				LINK BETWEEN SYS=AID AND INITIALIZATION CODE.
/JMP.SRM/	123377	11		
LSUF.SQ	123311	133	SL-SYSIO	12/19/74 15.28.19. SCOPE 3.4 COMPASS 3.74261
SBF.SQ	123444	2	SL-SYSIO	12/19/74 15.28.20. SCOPE 3.4 COMPASS 3.74261
/CON.RM/	123446	6		
CIO.RM	123454	25	SL-SYSIO	12/19/74 15.30.38. SCOPE 3.4 COMPASS 3.74261
/A3.RM/	123571	10		
MOVE.RM	123511	64	SL-SYSIO	12/19/74 15.30.50. SCOPE 3.4 COMPASS 3.74261
MCT.RM	123575	233	SL-SYSIO	12/19/74 15.31.28. SCOPE 3.4 COMPASS 3.74261
CHEK.RM	124730	172	SL-SYSIO	12/19/74 15.32.14. SCOPE 3.4 COMPASS 3.74261
OSUB.RM	124132	67	SL-SYSIO	12/19/74 15.32.12. SCOPE 3.4 COMPASS 3.74261
/OPEN.FO/	124221	7		
OPEN.SQ	124230	254	SL-SYSIO	12/19/74 15.32.15. SCOPE 3.4 COMPASS 3.74261
OPEX.SQ	124574	15	SL-SYSIO	12/19/74 15.32.29. SCOPE 3.4 COMPASS 3.74261
/PUT.RT/	124521	11		
RLEQ.RM	124532	42	SL-SYSIO	12/19/74 15.33.19. SCOPE 3.4 COMPASS 3.74261
/PUT.FO/	124574	7		
PTWR.SQ	124673	44	SL-SYSIO	12/19/74 15.33.51. SCOPE 3.4 COMPASS 3.74261
/CLSF.FO/	124647	7		
CLSF.SQ	124656	131	SL-SYSIO	12/19/74 15.35.22. SCOPE 3.4 COMPASS 3.74261
/CLSV.FO/	125077	7		
CLSV.SQ	125016	131	SL-SYSIO	12/19/74 15.35.35. SCOPE 3.4 COMPASS 3.74261
/REW.FO/	125147	7		
REW.SQ	125156	31	SL-SYSIO	12/19/74 15.36.05. SCOPE 3.4 COMPASS 3.74261
/GET.FO/	125277	7		
/GET.BT/	125216	5		
/GET.RT/	125223	11		
GET.SQ	125234	1010	SL-SYSIO	12/19/74 15.36.19. SCOPE 3.4 COMPASS 3.74261
Z.SQ	126244	101	SL-SYSIO	12/19/74 15.38.21. SCOPE 3.4 COMPASS 3.74261
FSU.SQ	126345	117	SL-SYSIO	12/19/74 15.38.32. SCOPE 3.4 COMPASS 3.74261
WEOX.SQ	126455	142	SL-SYSIO	12/19/74 15.39.10. SCOPE 3.4 COMPASS 3.74261
/SKFL.FO/	126617	7		
SKFL.SQ	126626	47	SL-SYSIO	12/19/74 15.39.17. SCOPE 3.4 COMPASS 3.74261
ERR.RM	126675	470	SL-SYSIO	12/19/74 15.30.38. SCOPE 3.4 COMPASS 3.74261
CHMR.SQ	127275	7	SL-SYSIO	12/19/74 15.30.51. SCOPE 3.4 COMPASS 3.74261
/MEMC.RM/	127374	3		
/OPES.FO/	127377	1		
OPEN.RM	127310	235	SL-SYSIO	12/19/74 15.32.77. SCOPE 3.4 COMPASS 3.74261
OPES.SQ	127545	72	SL-SYSIO	12/19/74 15.32.26. SCOPE 3.4 COMPASS 3.74261
PUT.SQ	127637	1242	SL-SYSIO	12/19/74 15.33.21. SCOPE 3.4 COMPASS 3.74261
MAP.SQ	131171	262	SL-SYSIO	12/19/74 15.33.53. SCOPE 3.4 COMPASS 3.74261
CLSF.RM	131363	23	SL-SYSIO	12/19/74 15.35.21. SCOPE 3.4 COMPASS 3.74261
GTWR.SQ	131406	35	SL-SYSIO	12/19/74 15.38.19. SCOPE 3.4 COMPASS 3.74261

LOAD MAP (cont'd)

SCOPE 3.4.2 - CONTROL-CARD-INITIATED LOAD LOADER P3808 03/24/76 08.27.21.

BLOCK	ADDRESS	LENGTH	FILE	PREFIX TABLE CONTENTS
BTRT.SQ	131443	117	SL-SYSIO	12/19/74 15.38.35. SCOPE 3.4 COMPASS 3.74261
LXER.SQ	131562	210	SL-SYSIO	12/19/74 15.39.05. SCOPE 3.4 COMPASS 3.74261
/SKSF.FO/	131772	1		
SKSF.SQ	131773	46	SL-SYSIO	12/19/74 15.39.19. SCOPE 3.4 COMPASS 3.74261
/SKBL.FO/	132041	7		
/SKSB.FO/	132050	1		
SKSB.SQ	132051	63	SL-SYSIO	12/19/74 15.39.57. SCOPE 3.4 COMPASS 3.74261
SYS.RM	132134	37	SL-NUCLEUS	05/12/75 20.46.08. SCOPE 3.4 COMPASS 3.74261
				PROCESS SYSTEM REQUEST.
//	132173	17		

1.480 CP SECONDS

1467518 CM STORAGE USED

15 TABLE MOVES

APPENDIX C

DESCRIPTION OF TRAPP CODE

1. Name of Code: BLOWDOWN-2 (TRAPP) Originator: Westinghouse
Advanced Reactor Division (WARD)
2. Computer for which Program is being Designed: CDC 7600
Program Language: FORTRAN IV
3. Nature of Physical Problem Solved: BLOWDOWN-2 (TRAPP) performs an analysis of the transient pressure field in the HTS primary loops when HCDA pressure pulses are simultaneously imposed at the inlet and outlet nozzles of the reactor vessel.
4. Method of Analysis: BLOWDOWN-2 (TRAPP) uses the method of characteristics to solve for the transient flow of compressible fluid in a one-dimensional network of flow channels. The partial differential equations of continuity, momentum, and energy and the equation of state are transformed into a set of ordinary differential equations which describe the fluid motion and properties along three characteristic paths: one representing a wave travelling in the positive direction with speed equal to the local speed of sound plus the local flow speed, the second representing a wave travelling in the negative direction with speed equal to the speed of sound minus the flow speed, and the third representing the path of the fluid particle with the local flow speed. The equations of characteristics are solved for a fixed spatial grid and a variable time step determined by the minimum time required for the fastest moving wave to traverse the smallest mesh spacing. The local values of flow rate, pressure, enthalpy, temperature, density, quality and speed of sound are determined for the fixed spatial grid as a function of time, accounting for the effects of compressibility in two-phase flow such as flow choking. The code may be used with either one or two input pulses.

The TRAPP code is a modified version of the two-phase water BLOWDOWN-2 code to allow sodium data input.

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