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TECHNICAL MEMORANDUM

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TITLE: MUFAN, A Computer Program for the Analysis of Multi-Loop Fluid Flow Systems

ABSTRACT

MUFAN may be used to determine flow rates, pressures, and pressure drops in systems involving one-dimensional incompressible steady state fluid flow. The system may consist of one or more branches or loops. The program is coded in FORTRAN IV (G) for the IBM 360/65 computer.

Key Words: MUFAN, Fluid Flow, One-Dimensional, Incompressible, Steady-State, Multi-Loop, Piping System

APPROVED:

DEPARTMENT HEAD ____________________
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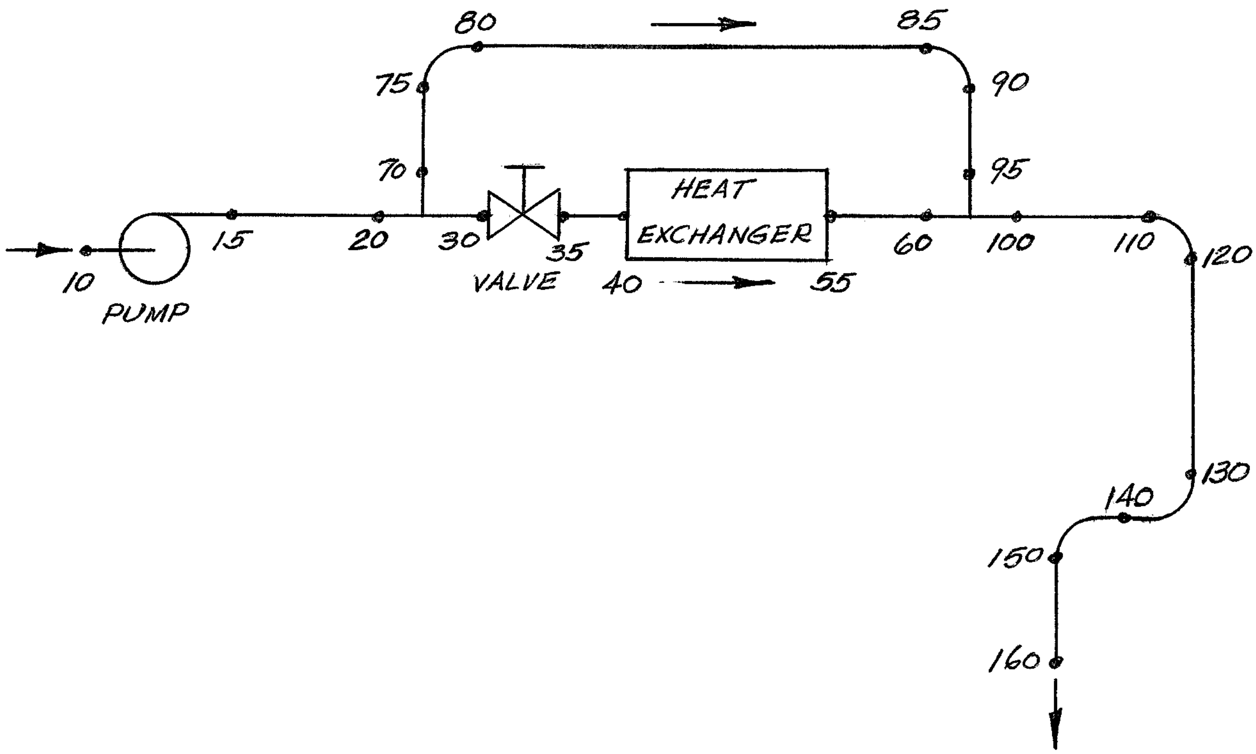
1.0 INTRODUCTION

MUFAN is a computer program (coded in FORTRAN IV (G) for the IBM 360/65) which solves fluid flow systems involving one or more branches or loops for flow rates, pressure drops and pressures. The program is primarily intended for the analysis of piping systems and the flow is assumed to be one-dimensional, incompressible and steady-state. Friction head loss data for several fittings commonly found in piping systems is built into the program as well as density and viscosity data for liquid water, liquid NaK, liquid mercury and 4P3E.

2.0 USER'S GUIDE

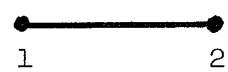
The first step in preparing data for MUFAN is to make a schematic of the system to be analyzed. The schematic should include only the details necessary for the fluid flow analysis. The next step is to indicate nodes (or stations) on the schematic. There must be a node at both ends of each fitting, pump, component, etc. Each node is then assigned a unique number from 1 to 500 (inclusive). The nodes may be numbered in any manner desired; however, it is suggested that, for the sake of readability, the nodes be numbered in increasing order in the direction of fluid flow and that numbers be left out so that, if necessary, additional nodes can be inserted at a later time without disturbing the numbering scheme. An example of a schematic with node numbers appears below.



The next step is to describe each of the members (straight pipes, fittings, pumps, components, etc.) that make up the system. The number of the node at which fluid enters the member and the number of the node at which fluid leaves the member (in that order) must be specified for each member. These pairs of node numbers determine how the members are connected to form the system and also determine the positive direction for fluid flow in each branch of the system. Member data is coded on MEMBER cards which are described in Section 2.1.6. If the member is a pump or component, flow rates are coded on CQ cards (Sec. 2.1.2) and the corresponding Δ P's are coded on CP cards (Sec. 2.1.2).

To complete the description of the system it is necessary to specify the fluid to be used, the fluid temperature at each node point, the elevation at each node point, and the appropriate pressure and fluid flow constraints. The type of fluid to be used is coded on the BEGIN card (Sec. 2.1.1), the temperatures at the nodes and the elevations at the nodes are specified on the NODE cards (Sec. 2.1.7), pressures which are to be fixed are coded on the PRESSURE cards (Sec. 2.1.8), and flow rates to be fixed are coded on the MEMBER card for the first member in the branch for which the flow rate is to be fixed.

The specification of proper fixed pressures and fixed flow rates is crucial to the analysis of the system. MUFAN will reject any system that is either underdetermined or overdetermined. As an example, consider a system which consists of a single straight pipe:



If the pressure is fixed at node 1 and node 2, the system can be solved. If, however, only the pressure at node 1 is fixed, the system is underdetermined and cannot be solved. If the pressure is fixed at node 1 only and the flow rate in the pipe is fixed, the system can be solved. If, however, the pressure at node 1, the pressure at node 2, and the flow rate are all fixed, the system is overdetermined and cannot be solved.

2.1 INPUT DATA DECK

The input data for MUFAN is contained on the following types of cards: BEGIN, CP, CQ, END, FD, FT, FV, LABEL, MEMBERS, NØDE, PRESSURE, AND TEMPERATURE. The BEGIN card must be the first card in the data deck and the END card must be the last card in the data deck; the remaining cards may appear in any order in the data deck. The data decks for several cases may be "stacked" so that they will be processed in a single computer run. A sample MUFAN deck set up appears below in Figure 1.

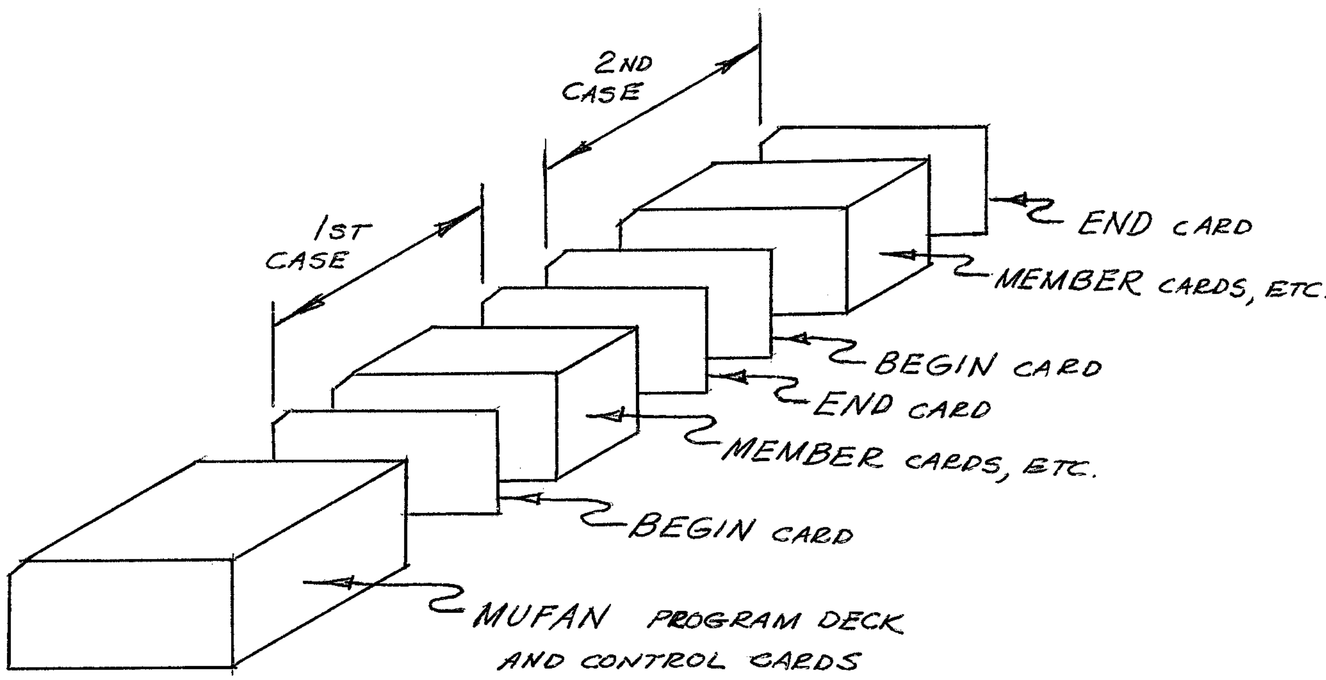


Figure 1 - MUFAN Deck Set-Up

Detailed descriptions of each type of card appear in the sections below. The entries under the heading "Field Type" have the following meanings:

A - alphanumeric data (any legal character). If a letter or group of letters appears in capitals under the "Data" heading for that field, the letter or letters must be coded exactly as shown.

F - floating point (real) data. Must have a decimal point. If the E notation is used (for example 2.0E-6 instead of .000002), the exponent must be coded in the right-most column(s) of the field.

I - Integer data. Must be coded in the right-most columns of the field and must not have a decimal point.

X - blank

2.1.1 BEGIN CARD

The BEGIN card must be the first card in the data deck for each case. The format of the card is described below.

CARD COLUMNS	FIELD TYPE	DATA
1	A	B or blank
2-3	X	blank
4	I	Fluid type 1 = NaK 2 = Mercury - liquid 3 = 4P3E 4 = Not used 5 = Water - liquid 6 = Fluid properties input by the user on FD, FT, and FV cards
5-14	F	X - acceleration, g's
15-24	F	Y - acceleration, g's
25-34	F	Z - acceleration, g's
35-44	F	Maximum allowable absolute error in flow rate (- 1.0 lb/hr if left blank)
45-54	F	Maximum allowable relative error in flow rate (=0.01 if left blank)
55-58	I	Maximum number of iterations to be performed (=50 if left blank)
59	X	blank
60	I	=0 or blank - lengths, bend radii and elevations are in feet =1 - lengths, bend radii and elevations are in inches
61-80	X	blank

2.1.2 CP and CQ CARDS

CP cards are used to specify pressure drop versus flow rate for components. The component pressure drop (in psi) for selected flow rates is coded on a CP card and the corresponding flow rates (lb/hr) are coded on a CQ card. For pumps, the head in feet of fluid for selected flow rates is coded on a CP card and the corresponding flow rates (in GPM) are coded on a CQ card. MUFAN uses linear interpolation to find values of pressure drop (or fluid head) that correspond to flow rates between the selected values on the CQ card. If a flow rate is less than the smallest flow rate on a CQ card, the pressure drop (fluid head) corresponding to the smallest flow rate on the card is used; if a flow rate is greater than the largest flow rate on a CQ card, the pressure drop (fluid head) corresponding to the largest flow rate is used. The flow rates must be coded in increasing order from left to right on each CQ card.

Component or pump data coded on CP and CQ cards is referenced by assigning a component or pump type number on the CP and CQ cards and also coding that type number on any MEMBER cards that represent a member which is that type of pump or component. For example, suppose that in the system to be analyzed we have several check valves that all have the same pressure drop versus flow rate characteristics. We could code the pressure drop versus flow rate data on a pair of CP and CQ cards, assign a component type, number, say 1, and then code that component type number on each MEMBER card that represents one of the check valves.

CARD COLUMNS	FIELD TYPE	DATA
1-2	A	CP or CQ
3	X	blank
4-7	A	COMP or PUMP
8-10	I	Component type, 1-41, or, pump type, 1-9
11-17	F	1st P, pump head, or flow rate
18-24	F	2nd P, pump head, or flow rate
25-31	F	3rd P, pump head, or flow rate

CARD COLUMNS	FIELD TYPE	DATA
32-38	F	4th P, pump head, or flow rate
39-45	F	5th P, pump head, or flow rate
46-52	F	6th P, pump head, or flow rate
53-59	F	7th P, pump head, or flow rate
60-66	F	8th P, pump head, or flow rate
67-73	F	9th P, pump head, or flow rate
74-80	F	10th P, pump head, or flow rate

2.1.3 END CARD

An END card indicates the end of the data cards for a case and must be the last card in the data deck for each case.

CARD COLUMNS	FIELD TYPE	DATA
1-3	A	END
4-80	X	blank

2.1.4 FD, FT, AND FV CARDS

If the user wishes to use a fluid other than those whose properties are built into the program (NaK, liquid mercury, 4P3E, liquid water), he must supply fluid density and viscosity versus temperature on FD, FV, and FT cards. Selected temperature values (degrees F.) are coded on the FT card, increasing from left to right. The fluid density values (pounds per cubic foot) corresponding to each temperature value are coded on the FD card and the fluid viscosity values (lb./hr.-ft.) corresponding to each temperature are coded on the FV card. Interpolation is performed by Subroutine INT4 (see Reference 10).

CARD COLUMNS	FIELD TYPE	DATA
1-2	A	FD or FT or FV
3-10	F	1st density, temperature or viscosity value
11-18	F	2nd density, temperature or viscosity value
19-26	F	3rd density, temperature or viscosity value

CARD COLUMNS	FIELD TYPE	DATA
27-34	F	4th density, temperature or viscosity value
35-42	F	5th density, temperature or viscosity value
43-50	F	6th density, temperature or viscosity value
51-58	F	7th density, temperature or viscosity value
59-66	F	8th density, temperature or viscosity value
67-74	F	9th density, temperature or viscosity value
75-80		blank

2.1.5 LABEL CARDS

LABEL cards are used to place title information at the top of each page of MUFAN printout. There may be up to 3 LABEL cards for each case.

CARD COLUMNS	FIELD TYPE	DATA
1	A	L
2-80	A	Any title information desired.

2.1.6 MEMBER CARDS

MEMBER cards are used to describe the members (straight pipe, fittings, components, pumps, etc.) that make up the system that is to be analyzed. Each MEMBER card describes one member.

CARD COLUMNS	FIELD TYPE		DATA
1	A		M
2	X		blank
3-5	I		Number of the node at which fluid enters the member.
6-7	X		blank
8-10	I		Number of the node at which fluid leaves the member.
11-17	X		blank
18-24	F		If member is
		...	Straight pipe, gradual expansion or contraction -- code the length in feet or inches
		...	A bend -- code the radius in feet or inches
		...	None of the above -- leave blank

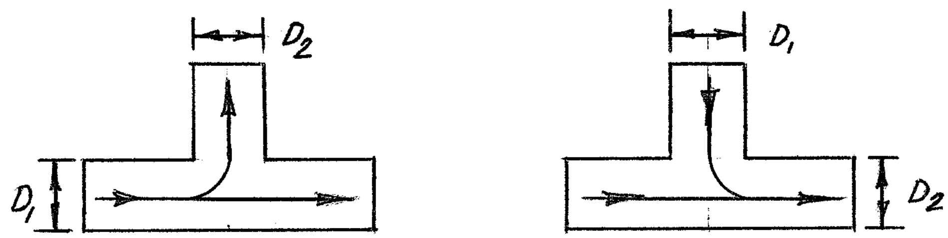
CARD COLUMNS	FIELD TYPE	DATA
25-30	F	Upstream outside diameter, D_1, inches. (See Sect. 2.1.6.1)
31-36	F	Upstream wall thickness, inches
37-41	F	If the member is a bend, code the angle of the bend in degrees (maximum bend angle allowed is 180^o). If the member requires a downstream outside diameter (D_2), code the downstream wall thickness. If neither of the above apply, leave blank.
42	X	blank
43	I	1 If fixed pressure drop (see Sect. 2.1.6.2) 2 If free pressure drop (see Sect. 2.1.6.2) 3 If fixed pressure rise (see Sect. 2.1.6.2) 0 or blank if none of the above
44	I	1 If fixed flow rate (see Sect. 2.1.6.3) 0 or blank if not
45	I	If the member is a pump, code the type number of the pump, otherwise 0 or blank.
46-47	I	If the member is a component, code the type number of the component, otherwise 0 or blank
48-49	I	If a K-factor is to be used for the member, enter the K-factor code (see Sect. 2.1.6.4), otherwise 0 or blank.
50-51	I	If an equivalent length (Le/D) is to be used for the member, enter the equivalent length code (see Sect. 2.1.6.5), otherwise 0 or blank.
52	X	blank
53-58	F	Depending on what is coded in columns 48-51, enter value of K-factor, value of Le/D, diameter of orifice (D_o), or blank.
59-65	F	Downstream outside diameter, D_2 (See Sect. 2.1.6.1)

CARD COLUMNS	FIELD TYPE	DATA
66-72	F	Depending on what is coded in columns 43-44, enter value of fixed flow rate, value of fixed pressure drop, value of fixed pressure rise, or blank.
73-79	F	If the member is a straight pipe or an equivalent length has been selected, enter the roughness in inches, otherwise leave blank
80	X	blank

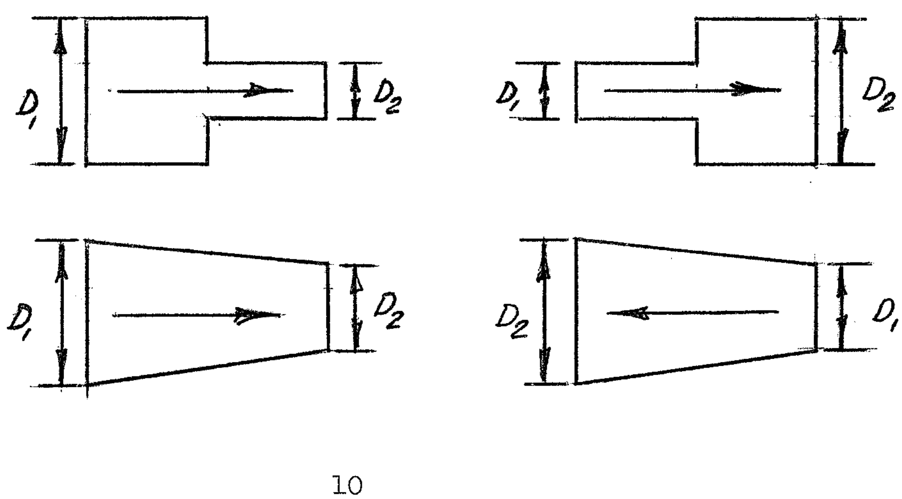
2.1.6.1 OUTSIDE DIAMETER

If a member has a constant diameter from inlet to outlet, the outside diameter, D., is coded in columns 25 thru 30 of the member card and the field for D_2 is left blank. If a member has an upstream outside diameter that differs from the downstream outside diameter, the upstream outside diameter (D_1) must be coded in columns 25 thru 30 and the downstream outside diameter (D_2) must be coded in columns 59-65. Pumps require both D_1 and D_2 whereas D_1 need be coded for components only if a printout of Reynolds number based on D_1 is desired. Examples showing D_1 and D_2 appear below.

TEE:

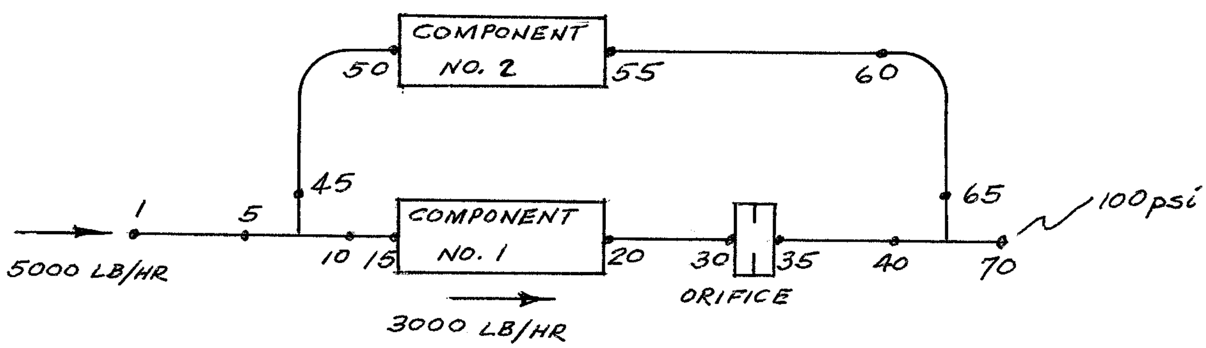


CHANGES OF SECTION:



2.1.6.2 <u>PRESSURE DROP CONSTRAINTS</u>

If a fixed pressure drop (or rise) is specified for a member, the pressure drop (or rise) provided by the user in columns 66 thru 72 of the MEMBER card is taken to be the pressure drop (or rise) across the member regardless of the flow rate. If a free pressure drop is specified for a member, MUFAN computes the pressure drop required to satisfy the conditions imposed on the system. As an example of the use of a free pressure drop, consider the system shown below:

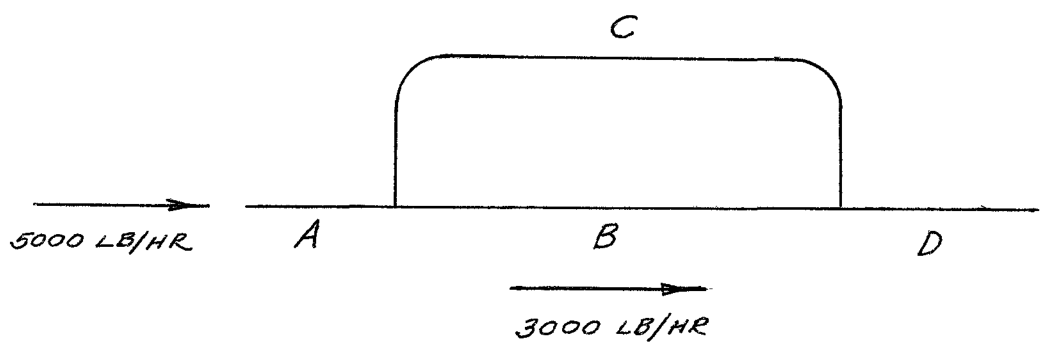


It is desired to size the orifice to obtain the flow distribution shown. To accomplish this, the flow rates shown are coded as fixed and the characteristics of the two components are coded on CP and CQ cards. Member 30-35 is coded as a free pressure drop and the outside diameter is coded in columns 25 thru 30 of the MEMBER card. The remaining members are coded on additional MEMBER cards and the pressure at node 70 is specified on a PRESSURE card. MUFAN will compute the pressure drop from node 30 to node 35 required to obtain that pressure drop. If the outside diameter is left blank on MEMBER card 30-35, the pressure drop will be computed but the orifice diameter will not.

It should be noted that if a fixed pressure drop (or rise) or a free pressure drop is called for, all but the following data items on the MEMBER card are ignored: the node numbers, the outside diameter (D_1), the wall thickness, the fixed flow rate flag, and the value of the fixed flow rate (if any).

2.1.6.3 FLOW RATE CONSTRAINTS

If the first member in a branch is coded as having a fixed flow rate, the entire branch is considered to have the same fixed flow rate (to satisfy continuity of mass flow). MUFAN checks to see if the flows fixed by the user imply fixed flows in other branches, and, if so, fixes the flows in these branches. As an example of implicitly fixed flow rates, consider the system shown below:



The flow rates in branches "A" and "B" are fixed at the values shown. To satisfy continuity the flow rate in branch "C" must be 2000 lb/hr. and the flow rate in branch "D" must be 5000 lb/hr., therefore MUFAN would automatically fix the flow rates in these two branches.

2.1.6.4 K-FACTORS

K-factors are used to compute the head loss through bends, fittings, components, etc. according to the relationship:

$$\Delta h = \frac{KV^2}{2g}$$

Where:

h = head loss, ft.

K = K-factor, dimensionless

V = fluid velocity, ft./sec.

g = acceleration of gravity, ft./sec./sec.

If the user chooses to have the program use a K-factor in the head loss computation for a member, he should code one of the numbers listed below, otherwise the field (cols. 48-49) should contain zero or blank. In the descriptions below, "tubing" refers to roughness on the order of smooth tubing while "piping" refers to roughness on the order of cast pipe. See Section 3.1.1 for the K-factor values which are built into the program.

CODE	DESCRIPTION
1	30° or 45° tubing branch-flow out through branch
2	60° tubing branch-flow out through branch
3	90° tubing branch-flow out through branch
4	45° branch on a 90° elbow-flow out through branch
5	7° branch on a 90° elbow-flow out through branch
6	15° branch on a 155° elbow-flow out through branch
7	135° tubing branch-flow out through branch
8	45° tubing branch-flow through main
9	90° tubing branch-flow through main
10	135° tubing branch-flow through main
11	45° tubing branch-flow in through branch
12	90° tubing branch-flow in through branch
13	135° tubing branch-flow in through branch
14	Tubing bend (code the angle of the bend in columns 37-41)
15	Standard 90° pipe elbow
16	Standard 45° pipe elbow
17	Long 90° pipe elbow
18	Standard pipe tee - flow through main
19	Standard pipe tee - flow through branch
20	Close return bend
21	Gradual contraction
22	Gradual expansion
23	Sudden contraction

CODE	DESCRIPTION
24	Sudden expansion
25	Orifice
99	K-factor provided by the user (K-factor value coded in columns 53-58)

2.1.6.5 EQUIVALENT LENGTHS

Equivalent lengths are used to compute the head loss through bends, fittings, components, etc. according to the relationship:

$$\Delta h = f\ (Le/D)\ \frac{V^2}{2g}$$

Where:

Δh = head loss, ft.

f = friction factor

Le/D = equivalent length, diameters

V = fluid velocity, ft./sec.

g = gravitational acceleration ft./sec./sec.

If the user chooses to have the program use an equivalent length in the head loss computation for a member, he should code one of the numbers listed below, otherwise the field (columns 50-51) should contain zero or blank. In the descriptions below "tubing" refers to roughness on the order of smooth tubing while "pipe" refers to roughness on the order of cast pipe. See Section 3.1.2 for the equivalent length values which are built into the program.

CODE	DESCRIPTION
1	Straight pipe, code the length (feet or inches) in columns 18-24 and code the roughness (inches) in columns 73-79
2	Tubing bend (code the angle of the bend in columns 37-41)
3	Standard 90° pipe elbow
4	Standard 45° pipe elbow
5	Long 90° pipe elbow
6	Close return bend
7	Gate Valve
8	Swing check
9	Angle Valve
10	Globe valve

CODE	DESCRIPTION
11	Standard pipe tee - flow thru main
12	Standard pipe tee - flow thru branch
99	Equivalent length (Le/D) provided by the user in columns 53-58.

2.1.7 NODE CARDS

NODE cards are used to input elevation and temperature data for the nodes in the system. Temperature data may be coded on TEMPERATURE cards instead of on the NODE cards if desired. If a node does not have elevation data coded for it on a NODE card, the elevation at that node is considered to be X = 0, I = 0, Z = 0. Thus for nodes that have elevation X = 0, Y = 0, Z = 0 the NODE card may be omitted provided that the fluid temperature for that node is coded on a TEMPERATURE card.

CARD COLUMNS	FIELD TYPE	DATA
1	A	N
2	X	blank
3-5	I	Node number
6	X	blank
7-9	I	If a node number is coded in this field, the elevation and temperature data coded on the remainder of the card will be assigned to all node numbers from the node number coded in columns 3-5 to and including the node number coded in this field. If, for example, 10 is coded in columns 4 and 5 and 130 is coded in columns 7-9, then nodes 10 thru 130 would all have the elevation and temperature coded on the remainder of the card. Any of the consecutive numbers between 10 and 130 that are not actual node numbers assigned by the user are ignored. If columns 7-9 are left blank, the temperature and elevation data re-assigned only to the node whose number appears in columns 3-5.

CARD COLUMNS	FIELD TYPE	DATA
10	X	blank
11-18	F	X-elevation
19-26	F	Y-elevation
27-34	F	Z-elevation
35-42	F	Temperature, deg. F.
43-80	X	blank

2.1.8 PRESSURE CARDS

PRESSURE cards are used to fix a pressure at a node.

CARD COLUMNS	FIELD TYPE	DATA
1	A	P
2	X	blank
3-5	I	Node number
6-8	X	blank
9-14	F	Pressure, psi (must be a positive number or zero)
15-80	X	blank

2.1.9 TEMPERATURE CARDS

If no elevation data is to be input (see Sect. 2.1.8), the TEMPERATURE cards are used to specify the fluid temperatures at the nodes. If each node has a different fluid temperature, there will be as many TEMPERATURE cards (with all but the first node number field left blank) as there are nodes -- one for each node. If, however, several nodes have the same fluid temperature, those node numbers may be listed on a single TEMPERATURE card. If a number is coded in the first node number field, the second node number field is left blank, and a number is coded in the third node number field, all nodes having consecutive node numbers starting with the number in the first field and up to (and including) the number in the third field will be assigned the temperature that appears in the fluid temperature field of the card. If some of the intermediate numbers are not actual nodes, they are merely ignored.

CARD COLUMNS	FIELD TYPE	DATA
1	A	T
2-3	X	blank
4-6	I	First node number
7-8	X	blank
9-11	I	Second node number
12-13	X	blank
14-16	I	Third node number
17-18	X	blank
19-21	I	Fourth node number
22-23	X	blank
24-26	I	Fifth node number
27-28	X	blank
29-31	I	Sixth node number
32-33	X	blank
34-36	I	Seventh node number
37-38	X	blank
39-41	I	Eighth node number
42-43	X	blank
44-46	I	Ninth node number
47-48	X	blank
49-51	I	Tenth node number
52-53	X	blank
54-56	I	Eleventh node number
57-58	X	blank
59-61	I	Twelfth node number
62-65	X	blank
66-72	F	Fluid temperature, $^{\circ}$F.
72-80	X	blank

Examples:

(a) If a TEMPERATURE card has 16 coded in columns 5 and 6 and 1201.0 coded in columns 66 thru 71, a fluid temperature of 1201.0°F. will be assigned to node 16.

(b) If a TEMPERATURE card has 10 coded in columns 5, and 6, a 55 coded in columns 10 and 11, a 105 coded in columms 14 thru 16, and 662.5 coded in columns 66 thru 70, then a fluid temperature of 662.5°F. will be assigned to nodes 10, 55, and 105.

(c) If a TEMPERATURE card has 5 coded in column 6, 200 coded in columns 14 thru 16, and 1152.0 coded in columns 66 thru 71, then all nodes having node numbers between and including 5 and 200 will be assigned a fluid temperature of 1152.0°F.

2.2 PRINTED OUTPUT

MUFAN produces four types of printed output for each case: Card Input Listing, Member Flow Characteristics, Flow and Pressure Drop, and Pressure. Each type of printout is discussed in detail below and the printed output for a sample problem appears in Appendix A. The date (month/day/year) and the time of day (0000-2400) that the problem was run are printed at the top of each page of MUFAN printed output.

2.2.1 CARD INPUT LISTING

The cards in the deck for a case are listed exactly as they are punched. When errors in the data deck are detected by MUFAN, a descriptive error message is printed out and MUFAN skips to the next case (if any).

2.2.2 MEMBER FLOW CHARACTERISTICS

The following information is printed out for each member: member number (in ascending numerical order), type, length, outside diameter (D1), wall thickness, radius, angle, D2, roughness, Le/D, K-factor. Items in the preceding list that do not apply to a particular member are printed out as asterisks for that member. In the event that errors in the data are detected, MUFAN prints out a descriptive error message and skips to the next case (if any).

2.2.3 FLOW AND PRESSURE DROP

The flow rate (lb/hr) in each branch is printed out immediately followed by the pressure drop through each member on that branch. The pressure drop is also broken down into pressure drop due to changes in elevation and pressure drop due to friction losses. Cumulative pressure drop along the branch is also printed out. Fixed flow rates, pressure drops and pressure rises are followed by an X. Free pressure drops are enclosed in parentheses.

2.2.4 PRESSURE

The pressure at each node in the system is printed out. Fixed pressures are followed by an X.

2.3 SAMPLE PROBLEM

The schematic for the system to be solved is shown in Figure 2. Node numbers have already been assigned. Additional system data appears in Figure 3.

Figure 4 contains the coding sheets filled out for this problem. The first card coded is the BEGIN card. A 1 in column 4 indicates that the fluid to be used is NaK, 1.0 in columns 15-17 indicates that there is a 1.0 g acceleration in the Y-direction, and 1 in column 60 indicates that the lengths, bend radii, and elevations are to be coded in inches. The remaining fields are left blank, which means that the default values shown in section 2.1.1 for the absolute error, relative error, and maximum number of iterations will be used. If for a problem which must be solved iteratively (such as this sample problem) it may be necessary to specify different values in order to get a satisfactory solution (see Section 3.3.1).

The next two cards coded are LABEL cards which provide a title to be printed at the top of each page of the printout. Since the HRPMA (185 to 10) is a pump, a pump type number is coded in column 45 of the MEMBER card. The upstream and downstream diameters and wall thicknesses are also coded. A CQ card gives the flow rates (in GPM) and a CP card gives the corresponding heads (in feet) for a type 1 pump. (Note that if there were other identical pumps in the system, they could all have a 1 coded in column 45 of their MEMBER cards and only the single set of

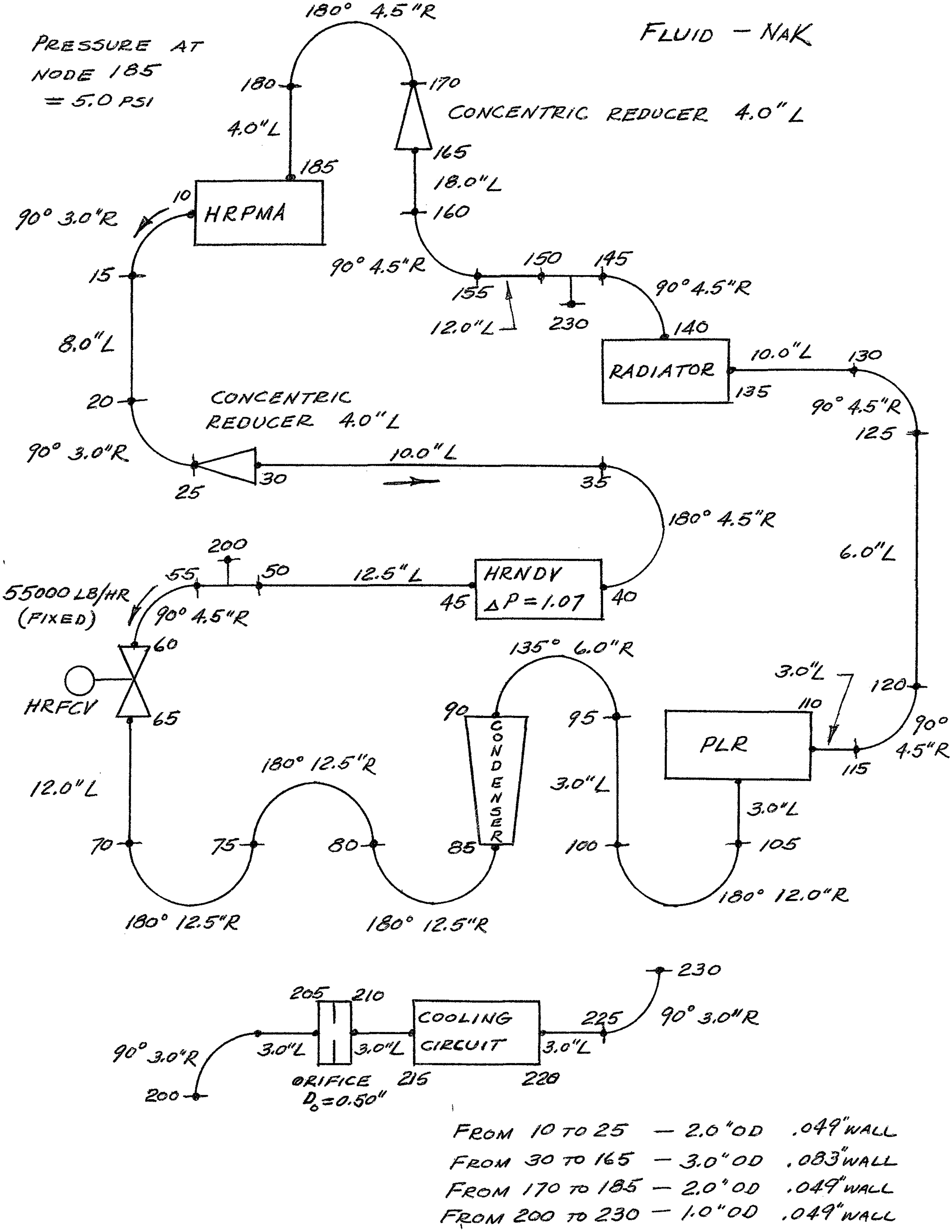


FIGURE 2 SYSTEM SCHEMATIC

FIGURE 3 - ADDITIONAL SYSTEM DATA

Condenser

Q, lb/hr	ΔP, psi
30,000	2.3
40,000	3.5
54,000	6.4
70,000	12.5

PLR

Q, lb/hr	ΔP, psi
32,000	0.33
40,000	0.48
48,000	0.70
56,000	1.00
65,000	1.35
70,000	1.56

Radiator

Q, lb/hr	ΔP,psi
30,000	3.0
50,000	5.0
70,000	7.0

Cooling Circuit

Q, lb/hr	ΔP, psi
0	0
4,000	16.0
8,000	64.0

HRPMA

Q, GPM	Head, ft.
0	143
30	142
60	135
90	118
120	93
150	64
180	30

Fluid Temperature

Nodes 10 thru 85	417°F
Nodes 90 thru 135	490°F
Nodes 140 thru 185	417°F

Y Elevation

Node(s)	Y, inches
10 thru 85	40.0
90 thru 95	85.0
100 thru 120	75.0
125 thru 135	120.0
140 thru 185	40.0

10-132-[illegible] (REV. 5/68)

L30016

COMPUTING SCIENCES
80 COLUMN INPUT

DATE 7/16/70 PROGRAM NO. ________ PROGRAMMED BY D. Michaels

Box 49

```
B  1          1.0                                          1
L                        MUFAN SAMPLE PRØBLEM
L                        BY DAN MICHAELS
M 185   10              2.0    .049  .049   1              2.0
CQ PUMP  1  0.0 30.0   60.0    90.0 120.0     150.0  180.0
CP PUMP  1 143.0  142.0  135.0  118.0  93.0    64.0   30.0
M  10   15       3.0    2.0    .049  90.0      14
M  15   20       8.0    2.0    .049               1                       .00004
M  20   25       3.0    2.0    .049  90.0      14
M  25   30       4.0    2.0    .049  .083      22    3.0
M  30   35      10.0    3.0    .083               1                       .00004
M  35   40       4.5    3.0    .083 180.0      14
M  40   45              3.0    .083            99   0.73
M  45   50      12.5    3.0    .083               1                       .00004
M  50   55              3.0    .083         1   9                55000.
M  55   60       4.5    3.0    .083  90.0      14
M  60   65                                2
M  65   70      12.0    3.0    .083               1                       .00004
M  70   75      12.5    3.0    .083 180.0      14
M  75   80      12.5    3.0    .083 180.0      14
M  80   85      12.5    3.0    .083 180.0      14
M  85   90                                    1
M  90   95       6.0    3.0    .083 135.0      14
M  95  100       3.0    3.0    .083               1                       .00004
M 100  105      12.0    3.0    .083 180.0      14
M 105  108       3.0    3.0    .083               1                       .00004
```

(V 34) (K 80)

STK. NO. D-1-083

FIGURE 4 (PAGE 1 OF 3)

Figure 4

10-132-138 (REV. 5/68)

COMPUTING SCIENCES
80 COLUMN INPUT

DATE 9/16/70 PROGRAM NO.______ PROGRAMMED BY D. Michaels

```
M 108  110                                                    2
CP CØMP  2 0.33   0.48   0.70   1.00   1.35   1.56
CQ CØMP  2 32000. 40000. 48000. 56000. 65000. 70000.
CQ CØMP  1 30000. 40000. 54000. 70000.
CP CØMP  1 2.3    3.5    6.4    12.5
M 110  115        3.0    3.0    .083                             1                      .00004
M 115  120        4.5    3.0    .083 90.0                  14
M 120  125        6.0    3.0    .083                             1                      .00004
M 125  130        4.5    3.0    .083 90.0                  14
M 130  135       10.0    3.0    .083                             1                      .00004
M 135  140                                                  3
M 140  145        4.5    3.0    .083 90.0                  14
M 145  150               3.0    .083                        9
M 150  155       12.0    3.0    .083                             1                      .00004
M 155  160        4.5    3.0    .083 90.0                  14
M 160  165       18.0    3.0    .083                             1                      .00004
M 165  170        4.0    3.0    .083 .049                  21              2.0
M 170  180        4.5    2.0    .049 180.0                 14
M 180  185        4.0    2.0    .049                             1                      .00004
M  50  200               3.0    .083 .049                   3              1.0
M 200  202        3.0    1.0    .049 90.0                  14
M 202  205        3.0    1.0    .049                             1                      .00004
M 205  210               1.0    .049                       25   0.50
M 210  215        3.0    1.0    .049                             1                      .00004
M 215  220                                                  4
M 220  225        3.0    1.0    .049                             1                      .00004
```

(V 34) (K 80)

STK. NO. D-1-083

FIGURE 4 (PAGE 2 OF 3)

Figure 4

10-132 (REV. 5/68)

COMPUTING SCIENCES
80 COLUMN INPUT

DATE 9/16/70 PROGRAM NO. PROGRAMMED BY D. Michaels

```
M 225  230           3.0      1.0    .049 90.0        14
M 230  150                    1.0    .049 .083        12         3.0
CQ CØMP  3 30000.  50000.  70000.
CP CØMP  3 3.0     5.0     7.0
CQ CØMP  4 0.0     4000.   8000.
CP CØMP  4 0.0     16.0    64.0
T   10         85                                                   417.0
T   90        135                                                   490.0
T  140        185                                                   417.0
T  200        230                                                   450.0
N  10  85          40.0
N  90  95          85.0
N 100 120          75.0
N 125 135          120.0
N 140 230          40.0
P 185   5.0
END
```

STK. NO. D-1-083

FIGURE 4 (PAGE 3 OF 3)

Figure 4

CQ and CP shown would be required.) The concentric reducers are coded as a Gradual Expansion (22 in columns 48-49) in the case of member 25-30, and as a Gradual Contraction (21 in columns 48-49) in the case of member 165-170. The HRNDV is coded as having its K-factor input by the user (99 in columns 48-49); the K-factor is coded in columns 53-58.

Suppose we wish to find the pressure drop needed across the valve HRFCV such that the flow rate in that branch is 55,000 lb/hr. We can fix the flow rate in the branch by indicating a fixed flow rate (a 1 in column 44) on the MEMBER card for the first member in the branch, 50-55. We can then make member 60-65 a free pressure drop by coding a 2 in column 43 of its MEMBER card, and the program will compute the required pressure drop.

The Condenser, PLR, Radiator, and Cooling Circuit are coded as component types 1, 2, 3 and 4, respectively; and their characteristica are coded on the corresponding CQ and CP cards. Member 205-210 is coded as an orifice by coding 25 in columns 48-49 of its MEMBER card. The orifice diameter (D_o) is coded in columns 53-58 and the outside diameter and wall thickness are coded in columns 25-30 and 31-36 respectively. Fluid temperature data is coded on TEMPERATURE cards and elevation data is coded on NODE cards. The pressure at node is 5.0 psi by a PRESSURE Card. A listing of the MUFAN computer program appears in Appendix A.

Suppose that the system to be analyzed contains liquid bismuth instead of liquid NaK. Liquid bismuth has the properties shown below (Ref. 9):

Temp., ^{o}F.	ρ, lb/ft^3	μ, lb/sec-ft
600	625	1.09×10^{-3}
800	616	0.90×10^{-3}
1000	608	0.74×10^{-3}
1200	600	0.62×10^{-3}
1400	591	0.53×10^{-3}

A 6 would be coded in column 4 of the BEGIN card and FT, FD, and FV cards would be coded as shown in figure 5. Note that the viscosity data must be converted to lb/hr-ft.

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COMPUTING SCIENCES
80 COLUMN INPUT

DATE ______ PROGRAM NO. ______ PROGRAMMED BY D. Michaels

```
FT 600.     800.      1000.     1200. 1400.
FD 625.     616.      608.      600.  591.
FV.392      .324      .266      .223  .191
```

FIGURE 5

STK. NO. D-1-083

Figure 5 Input Card for Temperature, Density and Viscosity of Liquid Bismuth

2.4 LIMITATIONS

The following limitations apply to the current version of MUFAN:

(a) Node numbers must be integers between (and including) 1 and 500.

(b) The maximum number of members allowed is 600.

(c) The maximum number of Branches allowed is 150.

(d) The maximum number of Branch Points allowed is 100.

(e) Pressure cannot be fixed at a Branch Point.

(f) An open Branch must have either a fixed flow rate and/or have the pressure at its End Point fixed.

3.0 ANALYSIS

The problems handled by MUFAN are limited to those involving one dimensional incompressible steady state fluid flow. The approach taken involves an application of the Bernoulli equation:

$$(3.1)\quad Z_1 + \frac{P_1}{144\rho_1} + \frac{V_1^2}{288g} = Z_2 + \frac{P_2}{144\rho_2} + \frac{V_2^2}{288g} + \Delta h_{12}$$

Where: Z = elevation, ft.

P = pressure, psi

ρ = weight density, lb/ft^3

V = bulk velocity, ft/sec

g = gravitational acceleration, ft/sec/sec.

Δh_{12} = friction head loss between 1 and 2, ft.

Subscript 1 denotes the upstream station and subscript 2 denotes the downstream station. Use is also made of the continuity equation:

$$(3.2)\quad \rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

Where: A = area, ft^2

If we assume that the density is the same at stations 1 and 2, that is:

$$\rho_1 = \rho_2 = \rho_{12}$$

we can rewrite equation 3.1 as:

$$(3.3)\quad 144\rho_{12} Z_1 + P_1 + \frac{\rho_{12} V^2}{2g} = 144\rho_{12} Z_2 + P_2 + \frac{\rho_{12} V^2}{2g} + \Delta P_{12}$$

Where: $\Delta P_{12} = 144\rho_{12} \Delta h_{12}$ = friction head loss, psi

The subscript 12 denotes properties of the member connecting stations 1 and 2. It is convenient to define a fluid resistance, r_{12}, as follows:

(3.4) $$P_1 + 144\rho_{12} Z_1 = P_2 + 144\rho_{12} Z_2 + r_{12} Q$$

Where: r_{12} = resistance, psi-hr/lb

Q = weight flow rate, lb/hr

$= 3600\rho_{12} A_1 V_1 = 3600\rho_{12} A_2 V_2$

Then, from 3.3 and 3.4:

(3.5) $$r_{12} = \frac{1}{Q}\left[\frac{\rho_{12}(V_2^2 - V_1^2)}{2g} + \Delta P_{12}\right]$$

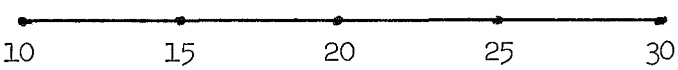
For members having the areas at stations 1 and 2 equal, 3.5 reduces to:

(3.6) $$r_{12} = \frac{\Delta P_{12}}{Q}$$

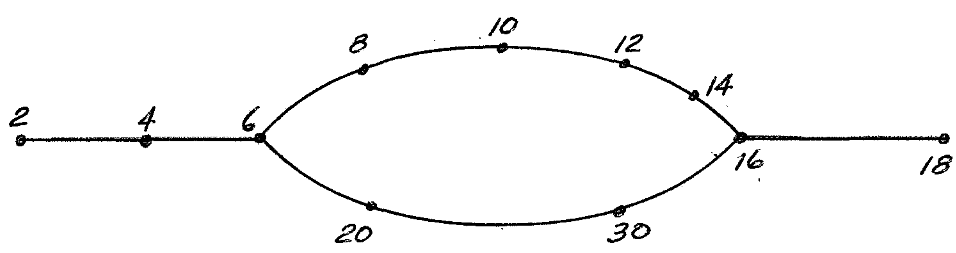
A Branch is a line consisting of one or more members connected end to end. The weight flow rate in each member of a Branch is the same (from continuity; equation 3.2). The system to be analyzed may consist either of a single branch, or, of three or more branches connected to form a network. The points at which three or more branches meet are called Branch points.

Examples:

Branch



System with 4 Branches and 2 Branch Points



If a node is connected to only one other node, then it is an End Point. Both examples above have 2 End Points each. The resistances of the members in a Branch may be summed along the Branch to give the total resistance of the Branch, R; and, the elevation head at each node in the branch (relative to the node preceding it in the branch) may be summed to give the elevation head of the end of the branch relative to the beginning of the branch, E:

$$R_{IJ} = \sum_{i=1}^{n-1} r_{i,\ i+1} \tag{3.7}$$

$$E_{IJ} = \sum_{i=1}^{n-1} \rho_{i,\ i+1} (Z_{i+1} - Z_i) \tag{3.8}$$

The subscripts on R and E indicate that the Branch connects Branch (or End) Point I to Branch (or End) Point J. The fluid conductance of a branch is:

$$G_{IJ} = \frac{1}{R_{IJ}} \tag{3.9}$$

The net flow out of each Branch Point must be zero. This requirement is satisfied for the I^{th} Branch Point if:

$$\sum_{\substack{J \\ J \neq K}} G_{IJ} \left[P_I - P_J \pm (E_{IJ} + \Delta P_{IJ}) \right] - \sum_K \pm Q_{IK} = 0 \tag{3.10}$$

Where: P_I = pressure at Branch Point I

P_J = pressure at Branch Point J

ΔP_{IJ} = pump pressure rise and/or fixed pressure rise on Branch IJ (if any)

Q_{IK} = fixed flow rate in Branch IK

The index J runs over all Branch Points (and End Points) connected to Branch Point I by a Branch not having a fixed flow rate; the index K runs over all Branch Points (and End Points) connected to Branch Point I by a Branch having a fixed flow rate. The signs in front of E_{IJ}, ΔP_{IJ} and Q_{IK} are positive if the positive direction of flow in a Branch is from J (or K) to I. The positive direction of flow in a branch depends on how the members are coded (see section 2.0).

The solution of the set of equations 3.10 proceeds as follows:

(a) An initial guess is made for the values of the flow rates in all the Branches with non-fixed flow rates.

(b) In each of the Branches with non-fixed flow rates the current estimate of the flow rate in that Branch is used to compute the conductance of the Branch.

(c) The set of equations (3.10) is set up and solved for the Branch Point pressures.

(d) The new values of the Branch Point pressures along with the current values of the Branch conductances are used to compute a new estimate for the flow rate in each Branch not having a fixed flow rate.

Steps b through d are repeated until successive estimates of each Branch flow rate agree sufficiently.

The sections which follow contain a more detailed discussion of the items discussed.

3.1 FRICTION HEAD LOSS COMPUTATIONS

The method by which the friction head loss through a member is computed depends on the type of member. Three distinct methods are used:

(3.11) $$\Delta P = K \frac{\rho V^2}{288g}$$

(3.12) $$\Delta P = f \frac{L}{D} \frac{\rho V^2}{288g}$$

(3.13) $$\Delta P = F(Q)$$

Where: ΔP = friction head loss, psi

K = K-factor, dimensionless

f = friction factor, dimensionless

L = length, ft.

D = diameter, ft.

ρ = weight density, lb/ft^3

V = bulk velocity, ft/sec

g = gravitational acceleration, ft/sec/sec

$F(Q)$ = a relationship between ΔP and Q which is specified by tabular data (see section 2.1.2)

Q = weight flow rate, lb/hr

3.1.1 K-FACTORS

The K-factors listed in Table 1 below are computed by the program from input supplied by the user. In the table below the velocity used to compute the friction head loss in equation 3.11 is identified as either 1 for inlet velocity or 2 for outlet velocity. K-factors which are not given by a constant, a simple table of values, or an algebraic expression are given in Appendix B. In the descriptions below "Tubing" refers to fittings having wall roughness on the order of smooth tubing, while "piping" refers to fittings having wall roughness on the order of cast pipe. Linear interpolation is used in the tables for pipe fittings to determine K-factors for intermediate values of inside diameter. Fittings with inside diameters less than 0.5 inches are assigned the K-factor for 0.5 inches; fittings with inside diameters greater than 4.0 inches are assigned the K-factor for 4.0 inches.

<u>TABLE 1 - K-FACTORS</u>

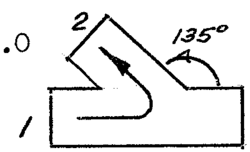
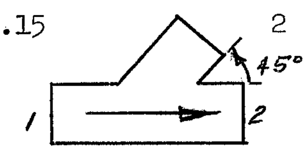
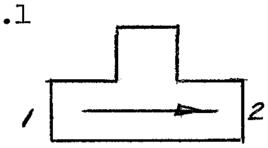
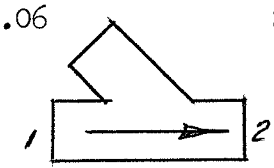
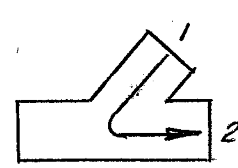
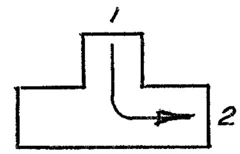
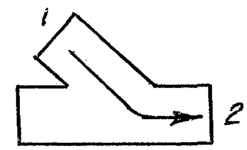
Description	Velocity	K-factor	Ref.
30° or 45° Tubing branch -flow out thru branch	1	(See Appendix B)	1
60° Tubing branch - flow out thru branch	1	(See Appendix B)	1
90° Tubing branch - flow out thru branch	1	(See Appendix B)	1
45° Tubing branch from 90° elbow - flow out thru branch	1	(See Appendix B)	1
7° Tubing branch from 90° elbow - flow out thru branch	1	(See Appendix B)	1
15° Tubing branch from 155° elbow- flow out thru branch	1	(See Appendix B)	1
135° Tubing branch - flow out thru branch	1	K=3.0 	2
45° Tubing branch - flow thru main	1	K=0.15 	2
90° Tubing branch - flow thru main	1	K=0.1 	2
135° Tubing branch - flow thru main	1	K=0.06 	2
45° Tubing branch - flow in thru branch	1	K=3.0 	2

TABLE 1 - K-FACTORS (continued)

Description	Velocity	K-factor	Ref.
90° Tubing branch - flow in thru branch	1	K=1.2 	2
135° Tubing branch - flow in thru branch	1	K=0.5 	2
Tubing bend, 0 deg.	1	(See Appendix B)	3
90° standard piping elbow	1	I.D. 0.5 1.0 2.0 4.0 K 0.82 0.68 0.58 0.50	2
45° standard piping elbow	1	I.D. 0.5 1.0 2.0 4.0 K 0.43 0.36 0.30 0.26	2
90° long piping elbow	1	I.D. 0.5 1.0 2.0 4.0 K 0.55 0.45 0.38 0.33	2
Standard piping tee - flow thru main	1	I.D. 0.5 1.0 2.0 4.0 K 0.55 0.45 0.38 0.33	2
Standard piping tee - flow thru branch	1	I.D. 0.5 1.0 2.0 4.0 K 1.7 1.4 1.2 1.0	2
Close return piping bend	1	I.D. 0.5 1.0 2.0 4.0 K 1.4 1.2 0.96 0.82	2
Gradual contraction	2	(See Appendix B)	2
Gradual expansion	1	(See Appendix B)	2
Sudden contraction	2	(See Appendix B)	2
Sudden expansion	1	$K = \left(1 - \frac{A_1}{A_2}\right)^2$	2
Orifice	1	(See Appendix B)	4, 7

3.1.2 EQUIVALENT LENGTHS

The equivalent lengths (Le/D) listed in table 2 below are computed by the program from input supplied by the user. The following relationships are used by the program to compute the friction factor: (Reference 6):

(3.14) $$R = \frac{48Q}{3600\ \pi\ D\ \mu}$$

(3.15) $$f = \frac{64}{R} \quad \text{for } R \leq 2100$$

(3.16) $$\frac{1}{\sqrt{f}} = 2 \log_{10} \left(\frac{D}{e}\right) + 1.14 - 2 \log_{10} \left[1 + \frac{9.28}{R \left(\frac{e}{D}\right) \sqrt{f}} \right]$$

for $R \geq 4000$

Where: R = Reynold's number

Q = Weight flow rate, lb/hr

D = Inside diameter, in.

μ = Viscosity, lb/ft-hr.

f = friction factor

e = Roughness, in.

In the transition region ($2100 < R < 4000$) interpolation is performed between the value of the friction factor a R=2100 and the friction factor at R=4000.

The equivalent length values in Table 2 are for fully turbulent flow. A correction is made for laminar flow as follows (Reference 4):

(3.17) $$(Le/D)_{LAMINAR} = \frac{R}{1000} (Le/D)_{TURBULENT}$$

for $R < 1000$

The equivalent length and friction factor values described above are used in equation 3.12 to compute the friction head loss.

TABLE 2 - EQUIVALENT LENGTHS

Description	Le/D	Ref.
Straight pipe	(Pipe Length)/(Inside diameter)	
Tubing bend, θ deg.	$(Le/D)=0.0202\ X\ \theta^{1.10} R^{0.032}$	5
	r/D: 1.0, 1.5, 2.0, 2.5, 3.0, 4.0 X: 3.0, 1.7, 1.3, 1.2, 1.3, 1.8 r/D: 5.0, 6.0, 7.5 X: 2.1, 2.7, 3.5 $X = 0.482\ r/D$ for $r/D > 7.5$ r = Bend radius D = inside diameter R = Reynold's number	
90° standard pipe elbow	(Le/D) = 30.0	2
45° standard pipe elbow	(Le/D) = 16.0	2
90° Long pipe elbow	(Le/D) = 20.0	2
Close return pipe bend	(Le/D) = 50.0	2
Gate Valve	(Le/D) = 13.0	2
Swing Check	(Le/D) = 135.0	2
Angle Valve	(Le/D) = 145.0	2
Globe Valve	(Le/D) = 340.0	2
Standard pipe tee - flow thru main	(Le/D) = 20.0	2
Standard pipe tee - flow thru branch	(Le/D) = 60.0	2

3.2 FLUID DENSITY AND VISCOSITY

The density and viscosity (as a function of temperature) of NaK, liquid mercury, and 4P3E used by MUFAN was obtained from reference (8); that of liquid water was obtained from reference (9). The data is coded in tabular form in the program and subroutine INT4 (see ref. 10) is used to perform interpolation in the tables.

3.3 SOLUTION PROCEDURE

The set of equations represented by (3.10) may be written in matrix form as follows:

$$\begin{bmatrix} b_{11} & b_{12} & \cdot & \cdot & \cdot & b_{IN} \\ b_{21} & b_{22} & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ b_{NI} & \cdot & \cdot & \cdot & \cdot & b_{NN} \end{bmatrix} \begin{Bmatrix} P_1 \\ P_2 \\ \cdot \\ \cdot \\ \cdot \\ P_N \end{Bmatrix} = \begin{Bmatrix} F_1 \\ F_2 \\ \cdot \\ \cdot \\ \cdot \\ F_N \end{Bmatrix} \tag{3.18}$$

Where: N = number of Branch Points

$$b_{II} = \sum_{J=1}^{N+M} G_{IJ}$$

$$b_{IJ} = -G_{IJ}$$

M = number of End Points

P_I = pressure at Branch Point I

$$F_I = -\sum_{\substack{J=1 \\ J \neq K}}^{N} \pm G_{IJ} (E_{IJ} + \Delta P_{IJ}) + \sum_{K} \pm Q_{IK}$$

$$+ \sum_{\substack{L=N+1 \\ L \neq K}}^{N+M} G_{IL} \left[P_L \pm (E_{IJ} + \Delta P_{IJ}) \right]$$

P_L = fixed pressure at an End Point

Gaussian elimination (with pivoting) is used to solve the system of equations (3.18) for $P_1, \ldots, P_N$. The new estimate for the flow rate in each Branch not having a fixed flow rate is computed as:

$$(3.19) \quad Q'_{IJ} = \frac{1}{2} \left\{ Q_{IJ} \pm G_{IJ} \left[P_I - P_J \pm (E_{IJ} + \Delta P_{IJ}) \right] \right\}$$

Where: Q'_{IJ} is the new flow rate estimate

Q_{IJ} is the old flow rate estimate

The Q'_{IJ} are used to compute a new set of G_{IJ} and pump Δ P's which are in turn substituted in the system of equations (3.18) which are solved for a new set of P_I's, . . . etc. This process continues until sufficient convergence of flow rates is obtained.

3.3.1 CONVERGENCE CRITERIA

In any iterative solution process it is necessary to have some method of deciding when a sufficiently accurate solution has been achieved or, failing this, a method of terminating the process after some reasonable number of steps. A good estimate of the accuracy of the solution at any point is the "closeness" of two successive estimates of flow rates. The iterative process is terminated if either of the following relationships hold for each Branch in the system:

$$\left| Q'_{IJ} - Q_{IJ} \right| \leq \epsilon_A ,$$

or,

$$\left| \frac{Q'_{IJ} - Q_{IJ}}{D} \right| \leq \epsilon_R$$

Where: Q'_{IJ} is the new estimate for the flow rate in Branch IJ

Q_{IJ} is the old estimate for the flow rate in Branch IJ

ϵ_A is the absolute error tolerance

D is the smaller of Q'_{IJ}

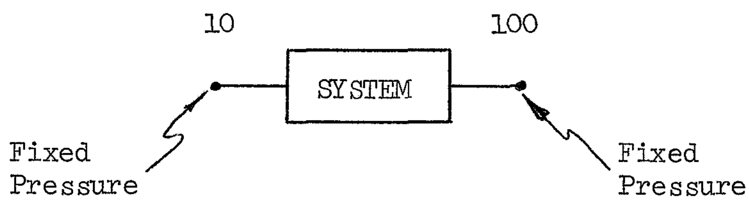
and Q_{IJ}

ϵ_R is the relative error tolerance

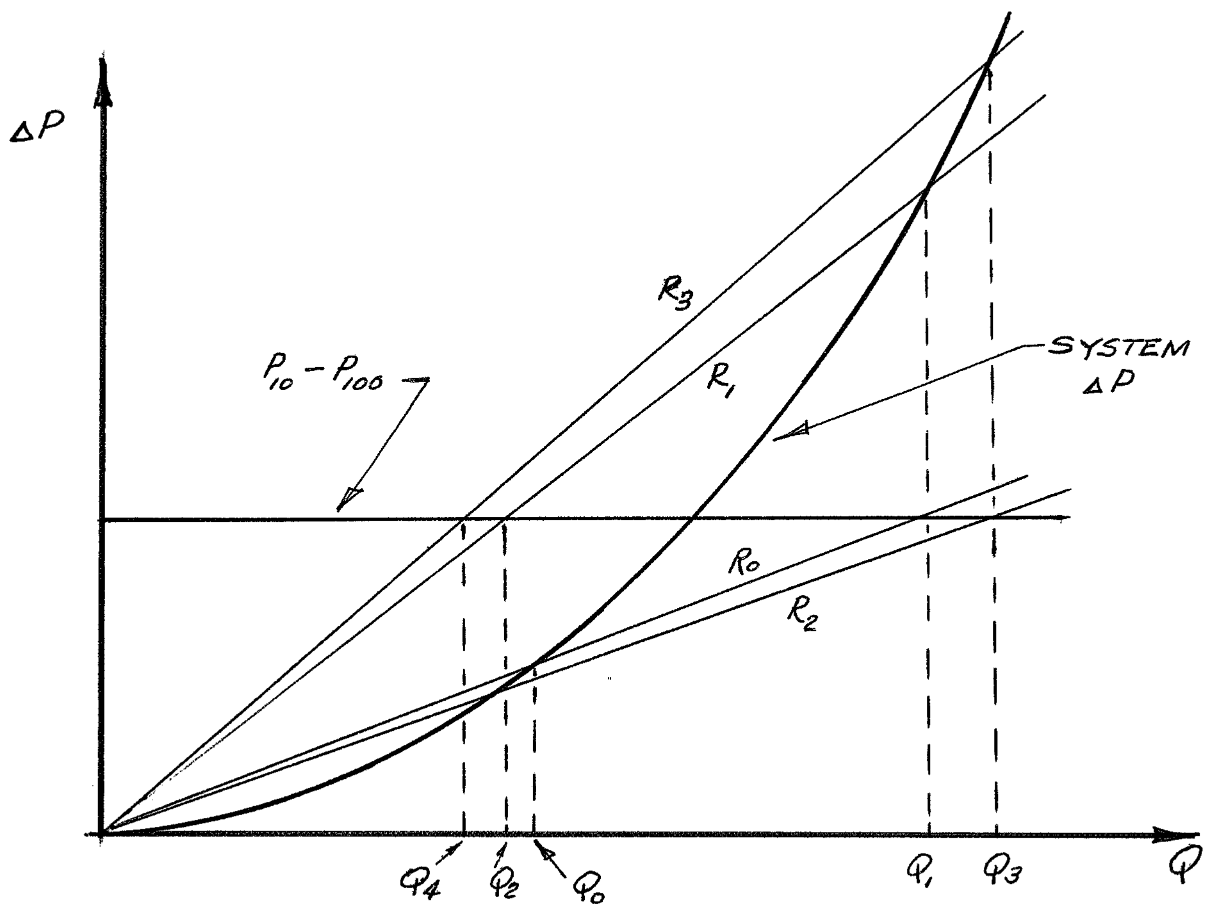
If the criteria given above are not met after the number of iterations specified by the user have been performed, the iteration process is halted and an error message is printed.

3.3.2 STABILITY AND RATE OF CONVERGENCE

As an illustration of the behavior of the iter ion procedure, consider a system with a fixed pressure drop across it.



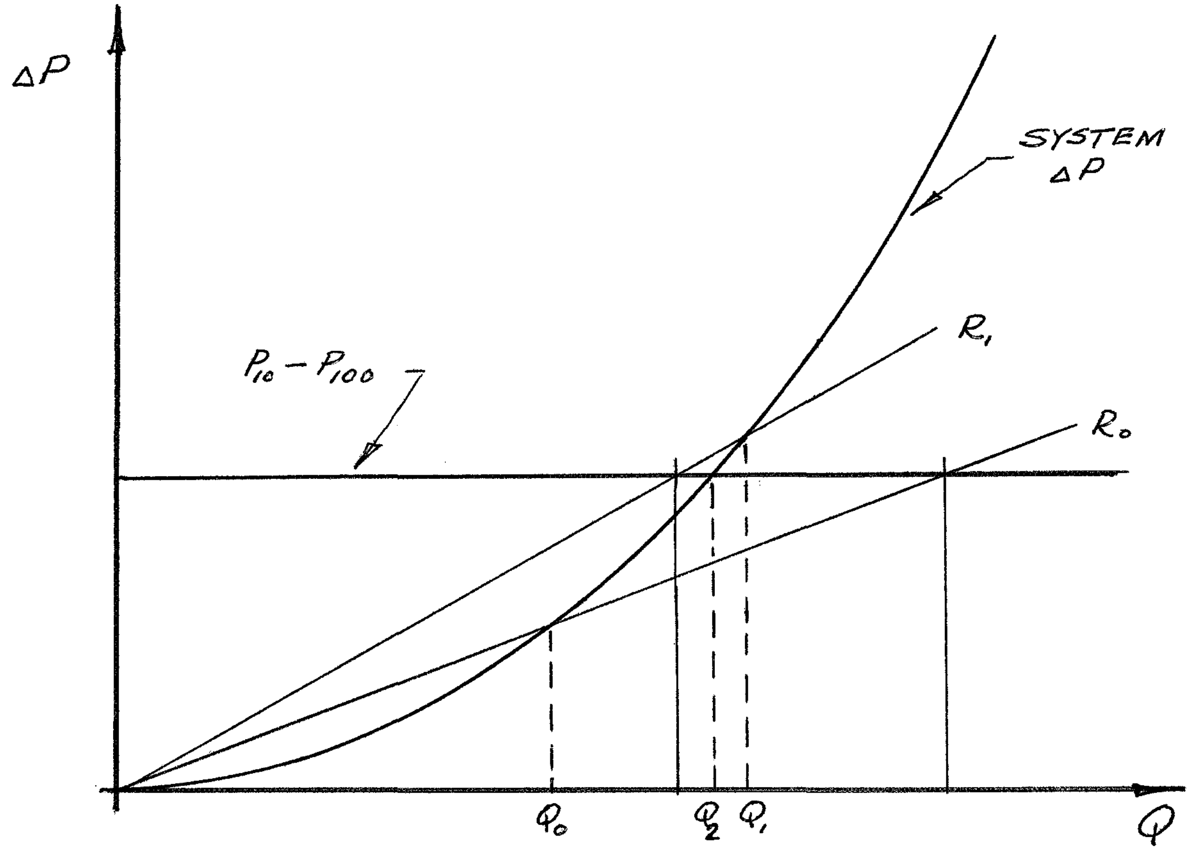
Starting with an initial estimate of the flow rate, Q_o, the resistance is determined. Using the resistance and the fixed pressure drop a new estimate of the flow rate, Q_1, is determined, . . . etc. A graphical example of this process follows.



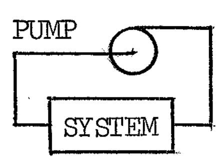
It is evident from the first four iterations that the process is diverging from the solution. In order to remedy this situation, let the new estimate for the flow rate be:

$$Q_{n+1} = \frac{1}{2} (Q_n + Q'_{n+1})$$

Where: Q'_{n+1} is the flow rate determined by the method used above. A graphical example with this new flow rate follows.



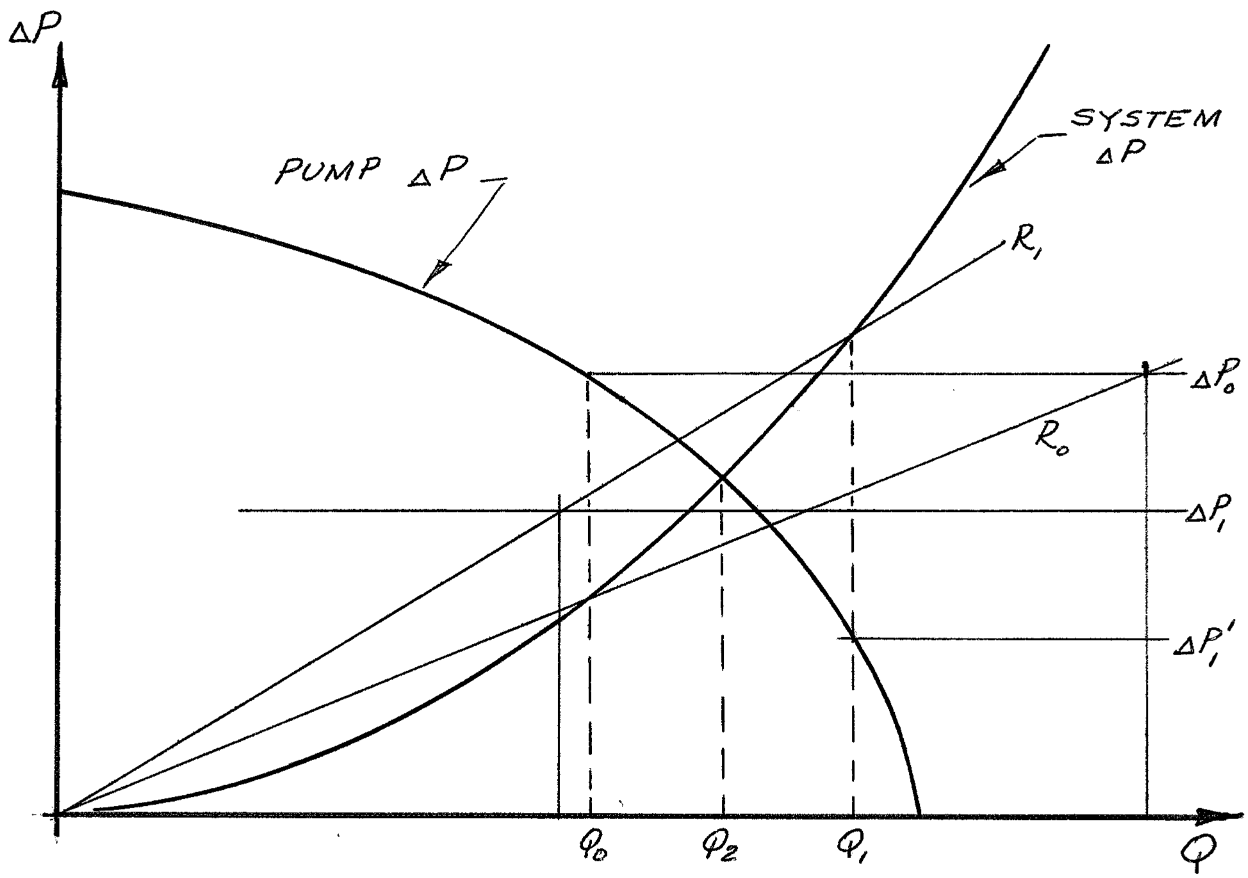
It is evident that this modified iteration procedure converges rapidly to the correct solution. As a further illustration of the behavior of the iteration procedure, consider a system with a pump.



Starting with an initial estimate of the flow rate, Q_o, the resistance and the pump Δ P are determined. Using the resistance and the pump Δ P a new estimate of the flow rate, Q_1, is determined, . . . etc. All pump Δ P's after the initial one are computed as:

$$\Delta P_{N+1} = \frac{1}{2} (\Delta P_N + \Delta P'_{N+1})$$

Where Δ P' is the value of pump Δ P which corresponds to Q_{N+1}. A graphical example of this process appears below.



The example indicates that the iteration process converges to the solution rapidly.

4.0 REFERENCES

(1) Daniels, C.M. and Pelton, H.A., "Pressure Losses in Hydraulic Branch-Off Fittings", Product Engineering, July 20 1959, pp. 61-62.

(2) Dodge, L., "Local Resistance + Fluid Flow", Product Engineering, March 2, 1964.

(3) North American Aviation Report 1808, 1951.

(4) Crane Technical Paper No. 410, "Flow of Fluids", Crane Industrial Products Group, 1957.

(5) Perry, J. H., Chemical Engineer's Handbook, McGraw Hill, 1950, p. 390.

(6) Streeter, V. L., Handbook of Fluid Dynamics, McGraw Hill, 1961, pp. 3-12, -14.

(7) Spink, L.K., Principles of Flowmeter Engineering, The Foxboro Co., 1958, p. 25.

(8) Aerojet-General Corp. Design Manual H-100B, "Properties of Fluids", section IV-2, 19 February 1968.

(9) Kreith F., Principals of Heat Transfer, International Textbook Co., 1964, p. 537.

(10) Programmer's Reference Manual, Computing Sciences Dept., Aerojet-General Corp., Azusa, 1970, pp. 25.13-1, -2.

APPENDIX A

MUFAN Program Listings

```
       OLD VOL=SER=004783                    DRC UPDATE                    NEW VOL=SER=007208

LD SEQ  MESSAGE       FILENAME=MUFAN                    DECKNAME=                                          YY.DDD

        CTRL CARD  ./ADD MUFAN,TYPE=SOURCE
        CTRL CARD  ./ADD MUFAN(MUFAN),FORT,RESEQ,LIST
        ADDED      C---------------------------------------------------------------------00000100  70.29
        ADDED      C                                                                     00000200  70.29
        ADDED      C     *       *  *     *  ********        *       **      *           00000300  70.29
        ADDED      C     **     **  *     *  *             * *       * *     *           00000400  70.29
        ADDED      C     * *   * *  *     *  *            *   *      *  *    *           00000500  70.29
        ADDED      C     *  *  *  * *     *  *****       *******     *   *   *           00000600  70.29
        ADDED      C     *   **   * *     *  *          *       *    *    *  *           00000700  70.29
        ADDED      C     *        * *     *  *         *         *   *     * *           00000800  70.29
        ADDED      C     *        *  ******  *        *           *  *      **           00000900  70.29
        ADDED      C                                                                     00001000  70.29
        ADDED      C                  MULTI-LOOP FLUID FLOW ANALYSIS PROGRAM             00001100  70.29
        ADDED      C                  FOR ANALYSIS OF ONE-DIMENSIONAL INCOMPRESSIBLE     00001200  70.29
        ADDED      C                  STEADY-STATE FLUID FLOW                            00001300  70.29
        ADDED      C                  VERSION 1  BY DAN MICHAELS  10/8/70                00001400  70.29
        ADDED      C                                                                     00001500  70.29
        ADDED      C---------------------------------------------------------------------00001600  70.29
        ADDED            REAL*8     DATE                                                 00001700  70.29
        ADDED            COMMON /MUFCOM/                                                 00001800  70.29
        ADDED           1    A(3),         TOLABS,       CONSTS(3,600), GC,              00001900  70.29
        ADDED           2    IBCON(600),   IBRAN(850),   IFLUID,       IOPT(10),         00002000  70.29
        ADDED           3    ITEMP,        ITYPE(600),   JBRPT(600),   LABEL(20,3),      00002100  70.29
        ADDED           4    LEVEL,        MBRAN(850),   NBCON(250),   NBRAN,            00002200  70.29
        ADDED           5    NBRPTS,       NNMAX,        NPTS(150),    PBRPT(250),       00002300  70.29
        ADDED           6    QBR(150),     QERR,         RHO(600),     TBULK(500),       00002400  70.29
        ADDED           7    TOLERR,       VISC(600),    XDOTA(500)                      00002500  70.29
        ADDED            COMMON  /MUFCOM/    INOUT(100),   NINOUT,   NDUMBP,     LOOP    00002600  70.29
        ADDED            COMMON  /PUNT/  MMEM,MNODES, DATE                               00002700  70.29
        ADDED            COMMON /PUNT/  TIME                                             00002800  70.29
        ADDED            EQUIVALENCE  (LIMIT,IOPT(1)), (INFT,IOPT(2))                    00002900  70.29
        ADDED            CALL READRE                                                     00003000  70.29
        ADDED         10 CONTINUE                                                        00003100  70.29
        ADDED            TOLABS=1.0                                                      00003200  70.29
        ADDED            TOLERR=0.01                                                     00003300  70.29
        ADDED            LIMIT=10                                                        00003400  70.29
        ADDED      C                  READ BEGIN CARD                                    00003500  70.29
        ADDED            READ(5,5000)  IFLUID, A, TOLABS, TOLERR, LIMIT, INFT            00003600  70.29
        ADDED       5000 FORMAT(A3,I1,5F10.0,I4,1X,I1)                                   00003700  70.29
        ADDED            CALL EDTDAT(DATE)                                               00003800  70.29
```

A-1

```
LD SEQ  MESSAGE        FILENAME=MUFAN                    DECKNAME=MUFAN                                 YY.DDD

        ADDED            CALL TIMDAY(TIME)                                                     00003900  70.29
        ADDED            DO 100 I=1,500                                                        00004000  70.29
        ADDED            XDOTA(I)=0.0                                                          00004100  70.29
        ADDED        100 CONTINUE                                                              00004200  70.29
        ADDED            CALL LNK1                                                             00004300  70.29
        ADDED            IF(LEVEL.GT.1)  GO TO 10                                              00004400  70.29
        ADDED            CALL LNK2                                                             00004500  70.29
        ADDED            CALL OUTPUT                                                           00004600  70.29
        ADDED            GO TO 10                                                              00004700  70.29
        ADDED            END                                                                   00004800  70.29
        ADDED            SUBROUTINE LINT(X,Y,XIN,YOUT)                                         00004900  70.29
        ADDED      C                                                                           00005000  70.29
        ADDED      C                    LINEAR INTERPOLATION ROUTINE                           00005100  70.29
        ADDED      C                      X=    ARRAY OF X VALUES                              00005200  70.29
        ADDED      C                      Y=    ARRAY OF Y VALUES                              00005300  70.29
        ADDED      C                      XIN= INPUT VALUE OF X                                00005400  70.29
        ADDED      C                      YOUT=INTERPOLATED Y VALUE CORRESPONDING TO XIN       00005500  70.29
        ADDED      C                                                                           00005600  70.29
        ADDED      C                    *** WARNING- CHECK THAT XIN DOES NOT FALL OUTSIDE      00005700  70.29
        ADDED      C                    THE RANGE OF VALUES IN X BEFORE ENTERING THIS          00005800  70.29
        ADDED      C                    ROUTINE ***                                            00005900  70.29
        ADDED      C                                                                           00006000  70.29
        ADDED            DIMENSION      X(1),          Y(1)                                    00006100  70.29
        ADDED            I=1                                                                   00006200  70.29
        ADDED        100 CONTINUE                                                              00006300  70.29
        ADDED            IF(XIN-X(I)) 130,120,110                                              00006400  70.29
        ADDED        110 CONTINUE                                                              00006500  70.29
        ADDED            I=I+1                                                                 00006600  70.29
        ADDED            GO TO 100                                                             00006700  70.29
        ADDED        120 CONTINUE                                                              00006800  70.29
        ADDED            YOUT=Y(I)                                                             00006900  70.29
        ADDED            GO TO 150                                                             00007000  70.29
        ADDED        130 CONTINUE                                                              00007100  70.29
        ADDED            YOUT=Y(I-1)+(XIN-X(I-1))*(Y(I)-Y(I-1))/(X(I)-X(I-1))                  00007200  70.29
        ADDED        150 CONTINUE                                                              00007300  70.29
        ADDED            RETURN                                                                00007400  70.29
        ADDED            END                                                                   00007500  70.29
        ADDED            SUBROUTINE LNK1                                                       00007600  70.29
        ADDED            EXTERNAL  RNAT, VNAT, RHGLT, VHGLT, R4P3ET, V4P3ET, RH2OT, VH2OT      00007700  70.29
        ADDED            EXTERNAL  RARBT, VARBT                                                00007800  70.29
```

```
       OLD VOL=SER=004783                    DRC UPDATE                    NEW VOL=SER=007208

LD SEQ  MESSAGE        FILENAME=MUFAN                         DECKNAME=MUFAN                                  YY.DDD

        ADDED             REAL*8     DATE                                                       00007900  70.29
        ADDED             COMMON /MUFCOM/                                                       00008000  70.29
        ADDED            1    A(3),            COERR,           CONSTS(3,600), GC,              00008100  70.29
        ADDED            2    IBCON(600),      IBRAN(850),      IFLUID,          IOPT(10),      00008200  70.29
        ADDED            3    ITEMP,           ITYPE(600),      JBRPT(600),      LABEL(20,3),   00008300  70.29
        ADDED            4    LEVEL,           MBRAN(850),      NBCON(250),      NBRAN,         00008400  70.29
        ADDED            5    NBRPTS,          NNMAX,           NPTS(150),       PBRPT(250),    00008500  70.29
        ADDED            6    QBR(150),        QERR,            RHO(600),        TBULK(500),    00008600  70.29
        ADDED            7    TOLERR,          VISC(600),       XDOTA(500)                      00008700  70.29
        ADDED             COMMON  /MUFCOM/       INOUT(100),   NINOUT,   NDUMBP,      LOOP      00008800  70.29
        ADDED             COMMON  /PUNT/  MMEM,MNODES, DATE                                     00008900  70.29
        ADDED             COMMON /PUNT/  TIME                                                   00009000  70.29
        ADDED             COMMON  /PQCHAR/                                                      00009100  70.29
        ADDED            1    PCHAR(11,50),        PCMAX(50),           QCHAR(11,50),           00009200  70.29
        ADDED            2    QCMAX(50)                                                         00009300  70.29
        ADDED             COMMON  /PQCHAR/                 PCMIN(50),     QCMIN(50)             00009400  70.29
        ADDED             COMMON  /LICOM/                                                       00009500  70.29
        ADDED            1    ALPHA(600),      INODE(1200),     JNODE(1200),     MEMNO(1200),   00009600  70.29
        ADDED            2    NMEM,            NPLANE(600),     P(500),          PHI(600),      00009700  70.29
        ADDED            3    Q(600),          RADLEN(600),     XYZ(500,3),      IEND(150,2),   00009800  70.29
        ADDED            4    NENDS(2)                                                          00009900  70.29
        ADDED             LEVEL=0                                                               00010000  70.29
        ADDED          C                 INITIALIZE NODE PRESSURE AND MEMBER FLOW RATE          00010100  70.29
        ADDED          C                 ARRAYS.  P(IZ).LT.0 INDICATES PRESSURE AT NODE         00010200  70.29
        ADDED          C                 IZ IS NOT FIXED.                                       00010300  70.29
        ADDED             DO 155 IZ=1,500                                                       00010400  70.29
        ADDED             P(IZ)=-1.0                                                            00010500  70.29
        ADDED             Q(IZ)=0.0                                                             00010600  70.29
        ADDED         155 CONTINUE                                                              00010700  70.29
        ADDED          C                 READ INPUT DATA                                        00010800  70.29
        ADDED             CALL  INPUT                                                           00010900  70.29
        ADDED          C                 SORT CONNECTIVITY DATA INTO ASCENDING ORDER            00011000  70.29
        ADDED             CALL  SORT(3,NMEM,JNODE,INODE,MEMNO)                                  00011100  70.29
        ADDED             CALL  SORT(3,NMEM,INODE,JNODE,MEMNO)                                  00011200  70.29
        ADDED          C                 COMPUTE K-FACTORS, EQUIVALENT LENGTHS,                 00011300  70.29
        ADDED          C                 FLUID DENSITY AND VISCOSITY,                           00011400  70.29
        ADDED          C                 AND PRINT OUT MEMBER CHARACTERISTICS.                  00011500  70.29
        ADDED                            GO TO(210,220,230,250,250,260), IFLUID                 00011600  70.29
        ADDED         210 CONTINUE                                                              00011700  70.29
        ADDED             CALL  FORK(RNAT,VNAT)                                                 00011800  70.29
```

```
LD SEQ  MESSAGE      FILENAME=MUFAN                    DECKNAME=MUFAN                                YY.DDD

        ADDED              GO TO 270                                                     00011900  70.29
        ADDED          220 CONTINUE                                                      00012000  70.29
        ADDED              CALL FORK(RHGLT,VHGLT)                                        00012100  70.29
        ADDED              GO TO 270                                                     00012200  70.29
        ADDED          230 CONTINUE                                                      00012300  70.29
        ADDED              CALL FORK(R4P3ET,V4P3ET)                                      00012400  70.29
        ADDED              GO TO 270                                                     00012500  70.29
        ADDED          250 CONTINUE                                                      00012600  70.29
        ADDED              CALL FORK(RH2OT,VH2OT)                                        00012700  70.29
        ADDED              GO TO 270                                                     00012800  70.29
        ADDED          260 CONTINUE                                                      00012900  70.29
        ADDED              CALL FORK(RARBT,VARBT)                                        00013000  70.29
        ADDED          270 CONTINUE                                                      00013100  70.29
        ADDED        C                      TRACE BRANCHES, SET UP BRANCH CONNECTIVITY   00013200  70.29
        ADDED        C                      AND CHECK CONSTRAINTS.                       00013300  70.29
        ADDED              CALL NETWRK                                                   00013400  70.29
        ADDED              RETURN                                                        00013500  70.29
        ADDED              END                                                           00013600  70.29
        ADDED              SUBROUTINE RESIST(MEM,Q ,INIT)                                00013700  70.29
        ADDED        C                      FLOW RESISTANCE SUBROUTINE                   00013800  70.29
        ADDED              COMMON  /MUFCOM/                                              00013900  70.29
        ADDED             1    A(3),          COERR,         CONSTS(3,600), GC,          00014000  70.29
        ADDED             2    IBCON(600),    IBRAN(850),    IFLUID,        IOPT(10),    00014100  70.29
        ADDED             3    ITEMP,         ITYPE(600),    JBRPT(600),    LABEL(20,3), 00014200  70.29
        ADDED             4    LEVEL,         MBRAN(850),    NBCON(250),    NBRAN,       00014300  70.29
        ADDED             5    NBRPTS,        NNMAX,          NPTS(150),     PBRPT(250), 00014400  70.29
        ADDED             6    QBR(150),      QERR,          RHO(600),      TBULK(500),  00014500  70.29
        ADDED             7    TOLERR,        VISC(600),     XDOTA(500)                  00014600  70.29
        ADDED              COMMON  /MUFCOM/  INOUT(100),  NINOUT,  NDUMBP,  LOOP         00014700  70.29
        ADDED              COMMON  /PQCHAR/                                              00014800  70.29
        ADDED             1    PCHAR(11,50),  PCMAX(50),     QCHAR(11,50),  QCMAX(50)    00014900  70.29
        ADDED              COMMON  /PQCHAR/            PCMIN(50),     QCMIN(50)          00015000  70.29
        ADDED              DIMENSION      ICONST(3,600)                                  00015100  70.29
        ADDED              EQUIVALENCE  (ICONST(1,1), CONSTS(1,1))                       00015200  70.29
        ADDED              IF(INIT.EQ.1)  QB=(QCMIN(IT)+QCMAX(IT))/2.0                   00015300  70.29
        ADDED              QB=ABS(Q)                                                     00015400  70.29
        ADDED              TOLABS=1.0                                                    00015500  70.29
        ADDED              IF(QB.LT.TOLABS)  QB=TOLABS                                   00015600  70.29
        ADDED              GC=32.17                                                      00015700  70.29
        ADDED              IT=ITYPE(MEM)                                                 00015800  70.29
```

```
LD SEQ  MESSAGE     FILENAME=MUFAN                    DECKNAME=MUFAN                                        YY.DDD

        ADDED             DIN=CONSTS(1,MEM)                                                    00015900  70.29
        ADDED             IF(IT.LT.100000000)   GO TO 100                                      00016000  70.29
        ADDED       C                    FIXED PRESSURE DROP                                   00016100  70.29
        ADDED             RESIST=CONSTS(2,MEM)/QB                                              00016200  70.29
        ADDED             GO TO 500                                                            00016300  70.29
        ADDED         100 CONTINUE                                                             00016400  70.29
        ADDED             IT=MOD(IT,10000000)                                                  00016500  70.29
        ADDED             IF(IT.LT.10000) GO TO 200                                            00016600  70.29
        ADDED         150 CONTINUE                                                             00016700  70.29
        ADDED       C                    COMPONENT                                             00016800  70.29
        ADDED             IT=IT/10000                                                          00016900  70.29
        ADDED             IF(INIT.EQ.1)   QB=(QCMIN(IT)+QCMAX(IT))/2.0                         00017000  70.29
        ADDED             RESIST=PTABLE(IT,QB)/QB                                              00017100  70.29
        ADDED             GO TO 500                                                            00017200  70.29
        ADDED         200 CONTINUE                                                             00017300  70.29
 A      ADDED             ELOVRD=CONSTS(2,MEM)                                                 00017400  70.29
 -      ADDED             RE=4.2441317E-3*QB/(VISC(MEM)*DIN)                                   00017500  70.29
 5      ADDED             IF(INIT.EQ.2)   GO TO 220                                            00017600  70.29
        ADDED             RE=4000.0                                                            00017700  70.29
        ADDED             QB=RE*VISC(MEM)*DIN/4.2441317E-3                                     00017800  70.29
        ADDED         220 CONTINUE                                                             00017900  70.29
        ADDED             IF(IT-99) 250,280,350                                                00018000  70.29
        ADDED         250 CONTINUE                                                             00018100  70.29
        ADDED             IF(IT-2) 280,260,270                                                 00018200  70.29
        ADDED         260 CONTINUE                                                             00018300  70.29
        ADDED       C                    BEND                                                  00018400  70.29
        ADDED             ELOVRD=ELOVRD*RE**0.032                                              00018500  70.29
        ADDED             GO TO 280                                                            00018600  70.29
        ADDED         270 CONTINUE                                                             00018700  70.29
        ADDED       C                    MODIFY EQUIVALENT LENGTH IF RE IS LESS THAN 1000      00018800  70.29
        ADDED             IF(RE.LT.1000.0) ELOVRD=ELOVRD/1000.0                                00018900  70.29
        ADDED         280 CONTINUE                                                             00019000  70.29
        ADDED             ITRANS=0                                                             00019100  70.29
        ADDED       C                    TEST FOR FLOW REGIME                                  00019200  70.29
        ADDED             IF(RE.GT.2100) GO TO 290                                             00019300  70.29
        ADDED       C                    LAMINAR FLOW                                          00019400  70.29
        ADDED             FRICT=64.0/RE                                                        00019500  70.29
        ADDED             GO TO 340                                                            00019600  70.29
        ADDED         290 CONTINUE                                                             00019700  70.29
        ADDED             IF(RE.GE.4000.0) GO TO 300                                           00019800  70.29
```

```
.D SEQ   MESSAGE       FILENAME=MUFAN                      DECKNAME=MUFAN                                    YY.DDD

         ADDED      C                TRANSITION REGION - SET FLAG                            00019900  70.29
         ADDED            ITRANS=1                                                           00020000  70.29
         ADDED            SAVRE=RE                                                           00020100  70.29
         ADDED            RE=4000.0                                                          00020200  70.29
         ADDED        300 CONTINUE                                                           00020300  70.29
         ADDED      C                TURBULENT FLOW - EVALUATE COLEBROOK EXPRESSION          00020400  70.29
         ADDED      C                FOR FRICTION FACTOR                                     00020500  70.29
         ADDED            FRICT=0.1                                                          00020600  70.29
         ADDED      C     RUFF=DIN/CONSTS(3,MEM)                                             00020700  70.29
         ADDED            RUFF=1.0E+6                                                        00020800  70.29
         ADDED            TERM=4.0*ALOG10(RUFF)+2.28                                         00020900  70.29
         ADDED            DO 310 I=1,10                                                      00021000  70.29
         ADDED            SFRICT=FRICT                                                       00021100  70.29
         ADDED            FRICT=4.0/(TERM-4.0*ALOG10(1.0+9.33*RUFF/(RE*SQRT(FRICT))))**2     00021200  70.29
         ADDED            IF(ABS(FRICT-SFRICT)/FRICT.LE.0.01)  GO TO 320                     00021300  70.29
         ADDED        310 CONTINUE                                                           00021400  70.29
         ADDED        320 CONTINUE                                                           00021500  70.29
         ADDED            IF(ITRANS.EQ.0) GO TO 340                                          00021600  70.29
         ADDED      C                INTERPOLATE FOR TRANSITION FRICTION FACTOR              00021700  70.29
         ADDED            FRICT=(ALOG10(SAVRE)-3.32222)*(FRICT-.03048)/0.27984 +  0.03048    00021800  70.29
         ADDED        340 CONTINUE                                                           00021900  70.29
         ADDED      C                CALCULATE RESISTANCE FOR EQUIVALENT LENGTH TYPE         00022000  70.29
         ADDED      C                MEMBERS                                                 00022100  70.29
         ADDED            RESIST=9.00637E-6*FRICT*ELOVRD*QB /(RHO(MEM)*GC*DIN**4)            00022200  70.29
         ADDED            GO TO 500                                                          00022300  70.29
         ADDED        350 CONTINUE                                                           00022400  70.29
         ADDED            AK=CONSTS(2,MEM)                                                   00022500  70.29
         ADDED      C                MEMBERS WITH 'K' FACTOR                                 00022600  70.29
         ADDED            IT=IT/100                                                          00022700  70.29
         ADDED            IF(IT.GT.13)  GO TO 400                                            00022800  70.29
         ADDED      C                BRANCH-OFF MEMBER                                       00022900  70.29
         ADDED            IF(IT.GT.6)  GO TO 360                                             00023000  70.29
         ADDED            RESIST=BRLOSS(MEM,QB,INIT,IT)                                      00023100  70.29
         ADDED            GO TO 500                                                          00023200  70.29
         ADDED        360 CONTINUE                                                           00023300  70.29
         ADDED            IB=ICONST(3,MEM)/1000000                                           00023400  70.29
         ADDED            IF(IB.LE.0)  GO TO 416                                             00023500  70.29
         ADDED            QBF=ABS(QBR(IB))                                                   00023600  70.29
         ADDED            IEXP=MOD(ICONST(3,MEM),1000000)/100000                             00023700  70.29
         ADDED            DIN=MOD(ICONST(3,MEM),100000)                                      00023800  70.29
```

```
LD SEQ   MESSAGE        FILENAME=MUFAN                      DECKNAME=MUFAN                        YY.DDD

         ADDED            DIN=DIN/10.0**IEXP                                            00023900  70.29
         ADDED            IF(INIT.EQ.1)  QBF=VISC(MEM)*DIN/1.06103E-6                   00024000  70.29
         ADDED            QB=QBF**2/QB                                                  00024100  70.29
         ADDED            GO TO 416                                                     00024200  70.29
         ADDED        400 CONTINUE                                                      00024300  70.29
         ADDED            IF(IT.NE.25)  GO TO 415                                       00024400  70.29
         ADDED            AK=1.0/SQRT(ORFICE(CONSTS(3,MEM),RE))                         00024500  70.29
         ADDED            DIN=CONSTS(2,MEM)                                             00024600  70.29
         ADDED            GO TO 420                                                     00024700  70.29
         ADDED        415 CONTINUE                                                      00024800  70.29
         ADDED            IF(IT.GE.99) GO TO 420                                        00024900  70.29
         ADDED        416 CONTINUE                                                      00025000  70.29
         ADDED        C                 CORRECT 'K' FOR REYNOLDS NO.                    00025100  70.29
         ADDED            IF(RE.GE.2000.0)  GO TO 420                                   00025200  70.29
         ADDED            IF(RE.GT.100.0)  GO TO 418                                    00025300  70.29
         ADDED            AK=1.5*AK                                                     00025400  70.29
         ADDED            GO TO 420                                                     00025500  70.29
         ADDED        418 CONTINUE                                                      00025600  70.29
         ADDED            AK=1.3*AK                                                     00025700  70.29
         ADDED        420 CONTINUE                                                      00025800  70.29
         ADDED        C                 CALCULATE RESISTANCE                            00025900  70.29
         ADDED            RESIST=9.006336E-6*AK*QB   /(GC*RHO(MEM)*DIN**4)              00026000  70.29
         ADDED        500 RETURN                                                        00026100  70.29
         ADDED            END                                                           00026200  70.29
         ADDED            FUNCTION PTABLE(INDEX,XQ)                                     00026300  70.29
         ADDED            COMMON  /PQCHAR/                                              00026400  70.29
         ADDED           1    PCHAR(11,50),       PCMAX(50),        QCHAR(11,50),       00026500  70.29
         ADDED           2    QCMAX(50)                                                 00026600  70.29
         ADDED            COMMON  /PQCHAR/             PCMIN(50),      QCMIN(50)        00026700  70.29
         ADDED            IF(XQ.LT.QCMAX(INDEX)) GO TO 20                               00026800  70.29
         ADDED            PTABLE=PCMAX(INDEX)                                           00026900  70.29
         ADDED            RETURN                                                        00027000  70.29
         ADDED         20 CONTINUE                                                      00027100  70.29
         ADDED            IF(XQ.GT.QCMIN(INDEX))  GO TO 50                              00027200  70.29
         ADDED            PTABLE=PCMIN(INDEX)                                           00027300  70.29
         ADDED            RETURN                                                        00027400  70.29
         ADDED         50 CONTINUE                                                      00027500  70.29
         ADDED            CALL LINT(QCHAR(1,INDEX),PCHAR(1,INDEX),XQ,PQTDUM)            00027600  70.29
         ADDED            PTABLE=PQTDUM                                                 00027700  70.29
         ADDED            RETURN                                                        00027800  70.29
```

OLD VOL=SER=004783 DRC UPDATE NEW VOL=SER=007208

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OLD SEQ  MESSAGE     FILENAME=MUFAN                     DECKNAME=MUFAN                              YY.DD

         ADDED             END                                                              00027900  70.29
         ADDED             FUNCTION QTABLE(IT,DP)                                           00028000  70.29
         ADDED             COMMON  /PQCHAR/                                                 00028100  70.29
         ADDED           1     PCHAR(11,50),  PCMAX(50),     QCHAR(11,50),  QCMAX(50)       00028200  70.29
         ADDED             COMMON  /PQCHAR/                 PCMIN(50),     QCMIN(50)        00028300  70.29
         ADDED             IF(DP.LT.PCMAX(IT))  GO TO 100                                   00028400  70.29
         ADDED             QTABLE=QCMAX(IT)                                                 00028500  70.29
         ADDED             RETURN                                                           00028600  70.29
         ADDED         100 CONTINUE                                                         00028700  70.29
         ADDED             IF(DP.GT.PCMIN(IT))  GO TO 200                                   00028800  70.29
         ADDED             QTABLE=QCMIN(IT)                                                 00028900  70.29
         ADDED             RETURN                                                           00029000  70.29
         ADDED         200 CONTINUE                                                         00029100  70.29
         ADDED             CALL INT4(PCHAR(1,IT),QCHAR(1,IT),DP,QDUM)                       00029200  70.29
         ADDED             QTABLE=QDUM                                                      00029300  70.29
         ADDED             RETURN                                                           00029400  70.29
         ADDED             END                                                              00029500  70.29
         ADDED             FUNCTION ORFICE(RATIN,REIN)                                      00029600  70.29
         ADDED             DIMENSION     COR20(28),     COR30(28),     COR40(28),           00029700  70.29
         ADDED           1               COR50(28),     COR60(28),     COR65(28),           00029800  70.29
         ADDED           2               COR70(28),     COR75(28),     COR80(28),           00029900  70.29
         ADDED           3               CORF(28,9),    C(5),          DRAT(9),             00030000  70.29
         ADDED           4               DR(5),         RORF(28)                            00030100  70.29
         ADDED             DATA  DRAT / 0.20, 0.30, 0.40, 0.50, 0.60, 0.65, 0.70, 0.75, 0.80/00030200  70.29
         ADDED             DATA  RORF / 0.60206, 0.77815, 0.90309, 1.00000, 1.30103,        00030300  70.29
         ADDED           1              1.60206, 1.77815, 1.90309, 2.00000, 2.30103,        00030400  70.29
         ADDED           2              2.60206, 2.77815, 2.90309, 3.00000, 3.30103,        00030500  70.29
         ADDED           3              3.47712, 3.50515, 3.60206, 3.77815, 3.90309,        00030600  70.29
         ADDED           4              4.00000, 4.30103, 4.60206, 4.77815, 4.90309,        00030700  70.29
         ADDED           5              5.00000, 5.30103, 0.00000 /                         00030800  70.29
  020    ADDED             DATA  COR20 / 0.328, 0.395, 0.441, 0.482, 0.580, 0.646, 0.677,   00030900  70.29
  030    ADDED           1               0.687, 0.698, 0.708, 0.703, 0.687, 0.677, 0.667,   00031000  70.29
  040    ADDED           2               0.636, 0.626, 0.624, 0.618, 0.616, 0.614, 0.613,   00031100  70.29
         ADDED           3               0.611, 0.611, 0.611, 0.611, 0.611, 0.611, 0.000 /  00031200  70.29
  070    ADDED             DATA  COR30 / 0.337, 0.406, 0.453, 0.495, 0.596, 0.664, 0.696,   00031300  70.29
  080    ADDED           1               0.706, 0.717, 0.733, 0.727, 0.717, 0.706, 0.696,   00031400  70.29
  090    ADDED           2               0.664, 0.651, 0.650, 0.642, 0.639, 0.637, 0.636,   00031500  70.29
         ADDED           3               0.632, 0.632, 0.632, 0.632, 0.632, 0.632, 0.000 /  00031600  70.29
  120    ADDED             DATA  COR40 / 0.351, 0.423, 0.472, 0.516, 0.626, 0.702, 0.735,   00031700  70.29
  130    ADDED           1               0.746, 0.757, 0.779, 0.774, 0.768, 0.752, 0.746,   00031800  70.29
```

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LD SEQ  MESSAGE   FILENAME=MUFAN                    DECKNAME=MUFAN                                  YY.DD

 140    ADDED     2            0.708, 0.692, 0.689, 0.681, 0.675, 0.673, 0.672,    00031900  70.29
        ADDED     3            0.666, 0.666, 0.666, 0.666, 0.666, 0.666, 0.000 /   00032000  70.29
 010    ADDED      DATA  COR50 / 0.370, 0.445, 0.497, 0.543, 0.664, 0.762, 0.808,  00032100  70.29
 020    ADDED     1            0.826, 0.837, 0.860, 0.860, 0.854, 0.843, 0.831,    00032200  70.29
 030    ADDED     2            0.797, 0.774, 0.771, 0.762, 0.745, 0.739, 0.734,    00032300  70.29
        ADDED     3            0.726, 0.722, 0.721, 0.721, 0.721, 0.721, 0.000 /   00032400  70.29
 C60    ADDED      DATA  COR60 / 0.398, 0.479, 0.535, 0.585, 0.735, 0.847, 0.909,  00032500  70.29
 070    ADDED     1            0.934, 0.959, 0.996, 1.009, 1.002, 0.996, 0.984,    00032600  70.29
 C80    ADDED     2            0.940, 0.909, 0.903, 0.884, 0.853, 0.845, 0.839,    00032700  70.29
        ADDED     3            0.826, 0.816, 0.812, 0.811, 0.811, 0.811, 0.000 /   00032800  70.29
 110    ADDED      DATA  COR65 / 0.417, 0.501, 0.560, 0.612, 0.768, 0.918, 0.989,  00032900  70.29
 120    ADDED     1            1.028, 1.061, 1.107, 1.126, 1.133, 1.126, 1.120,    00033000  70.29
 130    ADDED     2            1.081, 1.028, 1.015, 0.989, 0.931, 0.918, 0.911,    00033100  70.29
        ADDED     3            0.893, 0.880, 0.875, 0.874, 0.872, 0.872, 0.000 /   00033200  70.29
 010    ADDED      DATA  COR70 / 0.437, 0.526, 0.588, 0.649, 0.824, 0.991, 1.080,  00033300  70.29
 020    ADDED     1            1.135, 1.176, 1.251, 1.278, 1.285, 1.285, 1.278,    00033400  70.29
 030    ADDED     2            1.244, 1.183, 1.162, 1.107, 1.025, 0.999, 0.993,    00033500  70.29
        ADDED     3            0.969, 0.953, 0.949, 0.945, 0.945, 0.945, 0.000 /   00033600  70.29
 060    ADDED      DATA  COR75 / 0.469, 0.572, 0.645, 0.719, 0.917, 1.122, 1.232,  00033700  70.29
 070    ADDED     1            1.298, 1.349, 1.466, 1.525, 1.540, 1.543, 1.540,    00033800  70.29
 C80    ADDED     2            1.496, 1.422, 1.408, 1.342, 1.195, 1.131, 1.120,    00033900  70.29
        ADDED     3            1.097, 1.078, 1.071, 1.066, 1.063, 1.060, 0.000 /   00034000  70.29
 110    ADDED      DATA  COR80 / 0.474, 0.625, 0.719, 0.798, 1.044, 1.289, 1.431,  00034100  70.29
 120    ADDED     1            1.534, 1.613, 1.795, 1.897, 1.929, 1.945, 1.953,    00034200  70.29
 130    ADDED     2            1.945, 1.834, 1.739, 1.557, 1.399, 1.336, 1.289,    00034300  70.29
        ADDED     3            1.257, 1.235, 1.225, 1.221, 1.216, 1.208, 0.000 /   00034400  70.29
        ADDED      EQUIVALENCE (COR20(1),CORF(1,1)), (COR30(1),CORF(1,2)),         00034500  70.29
        ADDED     1            (COR40(1),CORF(1,3)), (COR50(1),CORF(1,4)),         00034600  70.29
        ADDED     2            (COR60(1),CORF(1,5)), (COR65(1),CORF(1,6)),         00034700  70.29
        ADDED     3            (COR70(1),CORF(1,7)), (COR75(1),CORF(1,8)),         00034800  70.29
        ADDED     4            (COR80(1),CORF(1,9))                                00034900  70.29
        ADDED      RE=ALOG10(ABS(REIN))                                            00035000  70.29
        ADDED      RE=AMIN1(AMAX1(RE,0.60206),5.30103)                             00035100  70.29
        ADDED      RATIO=AMIN1(AMAX1(RATIN,0.20),0.80)                             00035200  70.29
        ADDED      DO 100 I=1,9                                                    00035300  70.29
        ADDED      IF(RATIO-DRAT(I)) 120,110,100                                   00035400  70.29
        ADDED   100 CONTINUE                                                       00035500  70.29
        ADDED   110 CONTINUE                                                       00035600  70.29
        ADDED      I=I                                                             00035700  70.29
        ADDED      CALL INT4(RORF,CORF(1,I),RE,ANS)                                00035800  70.29
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.D SEQ  MESSAGE     FILENAME=MUFAN                    DECKNAME=MUFAN                                    YY.DD

        ADDED             ORFICE=ANS                                                          00035900  70.29
        ADDED             RETURN                                                              00036000  70.29
        ADDED         120 CONTINUE                                                            00036100  70.29
        ADDED             I1=MAX0(I-2,1)                                                      00036200  70.29
        ADDED             I2=MIN0(I+1,9)                                                      00036300  70.29
        ADDED             DO 200 I=I1,I2                                                      00036400  70.29
        ADDED             INDEX=I-I1+1                                                        00036500  70.29
        ADDED             DR(INDEX)=DRAT(I)                                                   00036600  70.29
        ADDED             CALL INT4(RORF,CORF(1,I),RE,C(INDEX))                               00036700  70.29
        ADDED         200 CONTINUE                                                            00036800  70.29
        ADDED             DR(INDEX+1)=0.0                                                     00036900  70.29
        ADDED             C(INDEX+1)=0.0                                                      00037000  70.29
        ADDED             CALL INT4(DR,C,RATIO,ANS)                                           00037100  70.29
        ADDED             ORFICE=ANS                                                          00037200  70.29
        ADDED             RETURN                                                              00037300  70.29
        ADDED             END                                                                 00037400  70.29
        ADDED             FUNCTION BRLOSS(MEM,QBRAN,INIT,IT)                                  00037500  70.29
        ADDED             COMMON  /MUFCOM/                                                    00037600  70.29
        ADDED            1    A(3),          COERR,        CONSTS(3,600), GC,                 00037700  70.29
        ADDED            2    IBCON(600),    IBRAN(850),   IFLUID,        IOPT(10),           00037800  70.29
        ADDED            3    ITEMP,         ITYPE(600),   JBRPT(600),    LABEL(20,3),        00037900  70.29
        ADDED            4    LEVEL,         MBRAN(850),   NBCON(250),    NBRAN,              00038000  70.29
        ADDED            5    NBRPTS,        NNMAX,        NPTS(150),     PBRPT(250),         00038100  70.29
        ADDED            6    QBR(150),      QERR,         RHO(600),      TBULK(500),         00038200  70.29
        ADDED            7    TOLERR,        VISC(600),    XDOTA(500)                         00038300  70.29
        ADDED             COMMON  /MUFCOM/    INOUT(100),   NINOUT,   NDUMBP,  LOOP           00038400  70.29
        ADDED             DIMENSION      BKELBO(7,3),  BKFHI(9,3),    BKFLO(9,3),             00038500  70.29
        ADDED            1               VRELBO(7),      VRF(9)                               00038600  70.29
        ADDED             DIMENSION      ICONST(3,600)                                        00038700  70.29
        ADDED             EQUIVALENCE   (ICONST(1,1), CONSTS(1,1))                            00038800  70.29
        ADDED             DATA  BKELBO/ 0.30, .303, 0.31, 0.33, 0.53, 1.00, 0.0,              00038900  70.29
        ADDED            1              0.21, 0.22, 0.23, 0.27, 0.41, 0.70, 0.0,              00039000  70.29
        ADDED            2              0.14, 0.15, 0.17, 0.21, 0.41, 0.53, 0.0 /,            00039100  70.29
        ADDED            3      VRELBO/ 0.10, 0.20, 0.30, 0.50, 1.00, 1.10, 0.0 /             00039200  70.29
        ADDED             DATA BKFHI/  1.00, 0.85, 0.73, 0.60, 0.50, 0.53, 1.05, 2.00, 0.0,   00039300  70.29
        ADDED            1             1.00, 0.85, 0.73, 0.70, 0.80, 0.90, 1.30, 2.20, 0.0,   00039400  70.29
        ADDED            2             1.00, 1.02, 1.10, 1.30, 2.00, 2.30, 4.00, 6.00, 0.0/   00039500  70.29
        ADDED             DATA BKFLO/  1.00, 0.80, 0.68, 0.50, 0.40, 0.43, 0.93, 1.40, 0.0,   00039600  70.29
        ADDED            1             1.00, 0.80, 0.68, 0.60, 0.65, 0.75, 1.05, 2.00, 0.0,   00039700  70.29
        ADDED            2            1.00, 1.01, 1.03, 1.20, 1.70, 2.05, 3.20, 4.80, 0.0/    00039800  70.29
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LD SEQ  MESSAGE      FILENAME=MUFAN                  DECKNAME=MUFAN                               YY.DDD

        ADDED              DATA  VRF  / 0.10, 0.20, 0.30, 0.50, 0.80, 1.00, 1.30, 2.00, 0.0/ 00039900  70.29
        ADDED              DATA  CONV/19.6349 /                                             00040000  70.29
        ADDED              DBRAN=CONSTS(1,MEM)                                              00040100  70.29
        ADDED              IB=ICONST(3,MEM)/1000000                                         00040200  70.29
        ADDED              IF(IB.GT.0)  GO TO 100                                           00040300  70.29
        ADDED              BRLOSS=1.08076E-6*QBRAN/(GC*RHO( MEM )*DBRAN**4)                 00040400  70.29
        ADDED              RETURN                                                           00040500  70.29
        ADDED          100 CONTINUE                                                         00040600  70.29
        ADDED              QMAIN=ABS(QBR(IB))                                               00040700  70.29
        ADDED              IEXP=MOD(ICONST(3,MEM),1000000)/100000                           00040800  70.29
        ADDED              DMAIN=MOD(ICONST(3,MEM),100000)                                  00040900  70.29
        ADDED              DMAIN=DMAIN/10.0**IEXP                                           00041000  70.29
        ADDED              IF(INIT.EQ.1)  QMAIN=VISC(MEM)*DMAIN/1.06103E-6                  00041100  70.29
        ADDED              VBRAN=QBRAN/(RHO( MEM )*CONV*DBRAN**2)                           00041200  70.29
        ADDED              VMAIN=QMAIN/(RHO( MEM )*CONV*DMAIN**2)                           00041300  70.29
        ADDED              VRATIO=VBRAN/VMAIN                                               00041400  70.29
        ADDED              IF(IT.GT.3)  GO TO 300                                           00041500  70.29
        ADDED              IF(VRATIO.GT.0.10)  GO TO 200                                    00041600  70.29
        ADDED              BK=1.0                                                           00041700  70.29
        ADDED              GO TO 400                                                        00041800  70.29
        ADDED          200 CONTINUE                                                         00041900  70.29
        ADDED              IF(VRATIO.GT.2.0)  VRATIO=2.0                                    00042000  70.29
        ADDED              DRATIO=DBRAN/DMAIN                                               00042100  70.29
        ADDED              IF(DRATIO.GT.0.333333)  GO TO 250                                00042200  70.29
        ADDED              CALL  INT4(VRF,BKFHI(1,IT),VRATIO,BK)                            00042300  70.29
        ADDED              GO TO 400                                                        00042400  70.29
        ADDED          250 CONTINUE                                                         00042500  70.29
        ADDED              IF(DRATIO.LT.1.0)  GO TO 260                                     00042600  70.29
        ADDED              CALL  INT4(VRF,BKFLO(1,IT),VRATIO,BK)                            00042700  70.29
        ADDED              GO TO 400                                                        00042800  70.29
        ADDED          260 CONTINUE                                                         00042900  70.29
        ADDED              CALL  INT4(VRF,BKFHI(1,IT),VRATIO,BKH)                           00043000  70.29
        ADDED              CALL  INT4(VRF,BKFLO(1,IT),VRATIO,BKL)                           00043100  70.29
        ADDED              BK=BKH -1.5*(DRATIO-0.333333)*(BKH -BKL )                        00043200  70.29
        ADDED              GO TO 400                                                        00043300  70.29
        ADDED          300 CONTINUE                                                         00043400  70.29
        ADDED              IF(VRATIO.LT.0.10)  VRATIO=0.10                                  00043500  70.29
        ADDED              IF(VRATIO.GT.1.10)  VRATIO=1.10                                  00043600  70.29
        ADDED              CALL  INT4(VRELBO,BKELBO(1,IT-3),VRATIO,BK)                      00043700  70.29
        ADDED          400 CONTINUE                                                         00043800  70.29
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OLD VOL=SER=004783                    DRC UPDATE                  NEW VOL=SER=007208

LD SEQ   MESSAGE       FILENAME=MUFAN                DECKNAME=MUFAN                          YY.DDD

         ADDED             BRLOSS=RHO(MEM)*((BK-1.0)*VMAIN**2+VBRAN**2)/(9273.6*QBRAN)   00043900  70.29
         ADDED             IF(BRLOSS.LT.0.0)  BRLOSS=0.0                                 00044000  70.29
         ADDED             RETURN                                                        00044100  70.29
         ADDED             END                                                           00044200  70.29
         ADDED             SUBROUTINE SKIP                                               00044300  70.29
         ADDED             DATA  IEND/4HEND /                                            00044400  70.29
         ADDED         100 CONTINUE                                                      00044500  70.29
         ADDED             READ(5,1000)  ID                                              00044600  70.29
         ADDED        1000 FORMAT(A4)                                                    00044700  70.29
         ADDED             IF(ID.NE.IEND)  GO TO 100                                     00044800  70.29
         ADDED             RETURN                                                        00044900  70.29
         ADDED             END                                                           00045000  70.29
         ADDED             SUBROUTINE INPUT                                              00045100  70.29
         ADDED             REAL*8     DATE                                               00045200  70.29
         ADDED             COMMON  /MUFCOM/                                              00045300  70.29
         ADDED             1    A(3),          COERR,          CONSTS(3,600), GC,        00045400  70.29
         ADDED             2    IBCON(600),    IBRAN(850),     IFLUID,        IOPT(10),  00045500  70.29
         ADDED             3    ITEMP,         ITYPE(600),     JBRPT(600),    LABEL(20,3), 00045600  70.29
         ADDED             4    LEVEL,         MBRAN(850),     NBCON(250),    NBRAN,     00045700  70.29
         ADDED             5    NBRPTS,        NNMAX,          NPTS(150),     PBRPT(250), 00045800  70.29
         ADDED             6    QBR(150),      QERR,           RHO(600),      TBULK(500), 00045900  70.29
         ADDED             7    TOLERR,        VISC(600),      XDOTA(500)                00046000  70.29
         ADDED             COMMON  /MUFCOM/    INOUT(100),     NINOUT,   NDUMBP,   LOOP  00046100  70.29
         ADDED             COMMON  /L1COM/                                               00046200  70.29
         ADDED             1    ALPHA(600),    INODE(1200),    JNODE(1200),   MEMNO(1200), 00046300  70.29
         ADDED             2    NMEM,          NPLANE(600),    P(500),        PHI(600),  00046400  70.29
         ADDED             3    Q(600),        RADLEN(600),    XYZ(500,3),    IEND(150,2), 00046500  70.29
         ADDED             4    NENDS(2)                                                 00046600  70.29
         ADDED             COMMON  /INCOM/                                               00046700  70.29
         ADDED             1    DOUT(600),     DOKCVL(600),    D2(600),       EPSLON(600), 00046800  70.29
         ADDED             2    THICK(600)                                               00046900  70.29
         ADDED             COMMON  /PQCHAR/                                              00047000  70.29
         ADDED             1    PCHAR(11,50),      PCMAX(50),         QCHAR(11,50),      00047100  70.29
         ADDED             2    QCMAX(50)                                                00047200  70.29
         ADDED             COMMON  /PQCHAR/              PCMIN(50),   QCMIN(50)          00047300  70.29
         ADDED             COMMON  /FARB/  FRHO(10),     FVISC(10),   FTEMP(10)          00047400  70.29
         ADDED             COMMON  /PUNT/  MMEM,MNODES, DATE                             00047500  70.29
         ADDED             COMMON /PUNT/  TIME                                           00047600  70.29
         ADDED             DIMENSION    ICARD(15),       NT(12),      DATA(10)           00047700  70.29
         ADDED             DIMENSION    CARD(20)                                         00047800  70.29
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LD SEQ  MESSAGE        FILENAME=MUFAN                  DECKNAME=MUFAN                                YY.DDD

        ADDED             EQUIVALENCE  (LIMIT,IOPT(1)), (INFT,IOPT(2))                     00047900  70.29
        ADDED             DATA  ICARD/2HCP, 2HCQ, 2HEN, 2HFD, 2HFT, 2HFV, 2HI , 2HL , 2HM , 00048000  70.29
        ADDED            1              2HN , 2HP , 2HT  /                                 00048100  70.29
        ADDED             DATA IPUMP/4HPUMP/, ICOMP/4HCOMP/                                00048200  70.29
        ADDED             NENDS(1)=1                                                       00048300  70.29
        ADDED             IEND(1,1)=1                                                      00048400  70.29
        ADDED             NCARD=1                                                          00048500  70.29
        ADDED             NLABEL=0                                                         00048600  70.29
        ADDED             NMEM=0                                                           00048700  70.29
        ADDED           5 CONTINUE                                                         00048800  70.29
        ADDED             IF(MOD(NCARD,30).NE.1)  GO TO 6                                  00048900  70.29
        ADDED             WRITE(6,800)  DATE, TIME                                         00049000  70.29
        ADDED         800 FORMAT(1H1///1H0,39(1H*),28H  MUFAN CARD INPUT LISTING  ,19(1H*), 00049100  70.29
        ADDED            1        2X,A8,              6H TIME ,   A4////7X,4HCARD,44X,     00049200  70.29
        ADDED            2        13H CARD COLUMNS/7X,4HSEQ.,10X,9(1H0),10(1H1),10(1H2),   00049300  70.29
        ADDED            3        10(1H3),10(1H4),10(1H5),10(1H6),10(1H7),1H8/,7X,4H NO.,  00049400  70.29
        ADDED            4        10X,8(10H1234567890)//)                                  00049500  70.29
        ADDED           6 CONTINUE                                                         00049600  70.29
        ADDED             IF(NCARD.GE.2) WRITE(6,700) NCARD,ID,(CARD(I),I=1,20)            00049700  70.29
        ADDED         700 FORMAT(7X,I4,10X,A2,19A4,A2)                                     00049800  70.29
        ADDED             NCARD=NCARD+1                                                    00049900  70.29
        ADDED             READ(5,900) ID,(CARD(I),I=1,20)                                  00050000  70.29
        ADDED         900 FORMAT(A2,19A4,A2)                                               00050100  70.29
        ADDED             DO  8 I=1,12                                                     00050200  70.29
        ADDED             IF(ICARD(I).EQ.ID) GO TO(10,10,30,40,50,60,70,80,90,100,110,120),I00050300  70.29
        ADDED           8 CONTINUE                                                         00050400  70.29
        ADDED             WRITE(6,999)                                                     00050500  70.29
        ADDED         999 FORMAT(1H0/1H ,100(1H*)/1H0,33H**  THE ABOVE CARD HAS AN ILLEGAL, 00050600  70.29
        ADDED            1        54H CARD TYPE SYMBOL STARTING IN COLUMN 1 - CASE BYPASSED, 00050700  70.29
        ADDED            2        9X,4H  **/1H0,100(1H*))                                  00050800  70.29
        ADDED             CALL SKIP                                                        00050900  70.29
        ADDED             LEVEL=10                                                         00051000  70.29
        ADDED             RETURN                                                           00051100  70.29
        ADDED          10 CONTINUE                                                         00051200  70.29
        ADDED       C                ** COMPONENT PRESSURE DROP OR FLOW RATE CARD **       00051300  70.29
        ADDED             READ(99,1000) KIND,NO, (DATA(K),K=1,10)                          00051400  70.29
        ADDED        1000 FORMAT(3X,A4,I3,10F7.0)                                          00051500  70.29
        ADDED             DATA(11)=0.0                                                     00051600  70.29
        ADDED             IBASE=0                                                          00051700  70.29
        ADDED             SGN=1.0                                                          00051800  70.29
```

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.D SEQ  MESSAGE     FILENAME=MUFAN                    DECKNAME=MUFAN                          YY.DDD

        ADDED             IF(KIND.EQ.IPUMP) GO TO 11                                  00051900  70.29
        ADDED             IF(KIND.EQ.ICOMP) GO TO 12                                  00052000  70.29
        ADDED             WRITE(6,1999) NCARD,KIND                                    00052100  70.29
        ADDED        1999 FORMAT(1H1//////////1X,7H** THE ,I4,21HTH DATA CARD FOR THIS,  00052200  70.29
        ADDED           1         36H CASE HAS AN ILLEGAL COMPONENT TYPE,,A4, 6H -CASE,  00052300  70.29
        ADDED           2         12H BYPASSED **)                                    00052400  70.29
        ADDED             IERROR=1002                                                 00052500  70.29
        ADDED             RETURN                                                      00052600  70.29
        ADDED          11 CONTINUE                                                    00052700  70.29
        ADDED             SGN=-1.0                                                    00052800  70.29
        ADDED             IBASE=41                                                    00052900  70.29
        ADDED          12 CONTINUE                                                    00053000  70.29
        ADDED             INDEX=IBASE+NO                                              00053100  70.29
        ADDED             IF(INDEX.LE.50.AND.INDEX.GT.0) GO TO 14                     00053200  70.29
        ADDED             WRITE(6,2999) NCARD,NO                                      00053300  70.29
        ADDED        2999 FORMAT(1H1//////////1X,7H** THE ,I4, 26HTH DATA CARD FOR THIS CASE,00053400  70.29
        ADDED           1         32H HAS AN ILLEGAL PUMP OR COMP NO.,I4,15H -CASE BYPASSED, 00053500  70.29
        ADDED           2          3H ** )                                            00053600  70.29
        ADDED             IERROR=1002                                                 00053700  70.29
        ADDED             RETURN                                                      00053800  70.29
        ADDED          14 CONTINUE                                                    00053900  70.29
        ADDED             CMAX=DATA(1)                                                00054000  70.29
        ADDED             IF(I.EQ.1)  CMAX=SGN*CMAX                                   00054100  70.29
        ADDED             DO 20 J=1,10                                                00054200  70.29
        ADDED             GO TO (16,18),I                                             00054300  70.29
        ADDED          16 CONTINUE                                                    00054400  70.29
        ADDED             IF(DATA(J).EQ.0.0.AND.J.GT.1)  GO TO 17                     00054500  70.29
        ADDED             CMAX=AMAX1(SGN*DATA(J),CMAX)                                00054600  70.29
        ADDED          17 CONTINUE                                                    00054700  70.29
        ADDED             PCHAR(J,INDEX)=DATA(J)                                      00054800  70.29
        ADDED             GO TO 20                                                    00054900  70.29
        ADDED          18 CONTINUE                                                    00055000  70.29
        ADDED             QCHAR(J,INDEX)=DATA(J)                                      00055100  70.29
        ADDED             QCMAX(INDEX)=AMAX1(DATA(J),CMAX)                            00055200  70.29
        ADDED             CMAX=QCMAX(INDEX)                                           00055300  70.29
        ADDED          20 CONTINUE                                                    00055400  70.29
        ADDED             GO TO(24,26), I                                             00055500  70.29
        ADDED          24 CONTINUE                                                    00055600  70.29
        ADDED             PCMIN(INDEX)=DATA(1)                                        00055700  70.29
        ADDED             PCMAX(INDEX)=SGN*CMAX                                       00055800  70.29
```

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_D SEQ   MESSAGE        FILENAME=MUFAN                 DECKNAME=MUFAN                            YY.DDD

         ADDED               GO TO 5                                                 00055900  70.29
         ADDED            26 CONTINUE                                                00056000  70.29
         ADDED               QCMIN(INDEX)=DATA(1)                                    00056100  70.29
         ADDED               GO TO 5                                                 00056200  70.29
         ADDED            30 CONTINUE                                                00056300  70.29
         ADDED         C                  **  END OF CASE CARD  **                   00056400  70.29
         ADDED               RETURN                                                  00056500  70.29
         ADDED            40 CONTINUE                                                00056600  70.29
         ADDED         C                  ** FLUID DENSITY CARD **                   00056700  70.29
         ADDED               READ(99,3000) (FRHO(K),K=1,9)                           00056800  70.29
         ADDED          3000 FORMAT(2X,9F8.0)                                        00056900  70.29
         ADDED               IRFARB=1                                                00057000  70.29
         ADDED               GO TO 5                                                 00057100  70.29
         ADDED            50 CONTINUE                                                00057200  70.29
         ADDED         C                 ** FLUID TEMPERATURE CARD **                00057300  70.29
         ADDED               READ(99,3000)  (FTEMP(K),K=1,9)                         00057400  70.29
         ADDED               FTEMP(10)=0.0                                           00057500  70.29
         ADDED               ITFARB=1                                                00057600  70.29
         ADDED               GO TO 5                                                 00057700  70.29
         ADDED            60 CONTINUE                                                00057800  70.29
         ADDED         C                  ** FLUID VISCOSITY CARD **                 00057900  70.29
         ADDED               READ(99,3000) (FVISC(K),K=1,9)                          00058000  70.29
         ADDED               FVISC(10)=0.0                                           00058100  70.29
         ADDED               IVFARB=1                                                00058200  70.29
         ADDED               GO TO 5                                                 00058300  70.29
         ADDED            70 CONTINUE                                                00058400  70.29
         ADDED         C                  ** INPUT NODE NUMBERS CARD **              00058500  70.29
         ADDED               READ(99,7000) (IEND(K,1),K=2,16)                        00058600  70.29
         ADDED          7000 FORMAT(5X,15I5)                                         00058700  70.29
         ADDED               GO TO 5                                                 00058800  70.29
         ADDED            80 CONTINUE                                                00058900  70.29
         ADDED         C                  ** LABEL CARD **                           00059000  70.29
         ADDED               NLABEL=NLABEL+1                                         00059100  70.29
         ADDED               IF(NLABEL.GT.3) GO TO 5                                 00059200  70.29
         ADDED               READ(99,8000) (LABEL(K,NLABEL),K=1,19)                  00059300  70.29
         ADDED          8000 FORMAT(1X,A3,19A4)                                      00059400  70.29
         ADDED               GO TO 5                                                 00059500  70.29
         ADDED            90 CONTINUE                                                00059600  70.29
         ADDED         C                  ** MEMBER  CARD  **                        00059700  70.29
         ADDED               NMEM=NMEM+2                                             00059800  70.29
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OLD SEQ  MESSAGE      FILENAME=MUFAN                        DECKNAME=MUFAN                                YY.DD

         ADDED            NM=NMEM/2                                                             00059900  70.29
         ADDED            IF(NMEM.LE.1200) GO TO 95                                             00060000  70.29
         ADDED            WRITE(6,9999) NCARD                                                   00060100  70.29
         ADDED       9999 FORMAT(1H1//////////1X, 7H** THE ,I4,21HTH DATA CARD FOR THIS,        00060200  70.29
         ADDED          1        33H CASE DEFINES  THE 1201ST MEMBER. /1X,9HONLY 1200,          00060300  70.29
         ADDED          2        39H MEMBERS ARE ALLOWED - CASE BYPASSED ** )                   00060400  70.29
         ADDED            RETURN                                                                00060500  70.29
         ADDED         95 CONTINUE                                                              00060600  70.29
         ADDED            READ(99,9000) INODE(NMEM-1),   JNODE(NMEM-1),   NPLANE(NM),           00060700  70.29
         ADDED          1               ALPHA(NM),  RADLEN(NM),  DOUT(NM),  THICK(NM),          00060800  70.29
         ADDED          2               PHI(NM),  ITYPE(NM),  DOKCVL(NM),  D2(NM),  Q(NM),      00060900  70.29
         ADDED          3               EPSLON(NM)                                              00061000  70.29
         ADDED       9000 FORMAT(2X,I3,2X,I3,1X,I1,1X,F3.0,1X,F7.0,1X,F5.0,1X,F5.0,1X,F4.0,     00061100  70.29
         ADDED          1              I10,1X,F6.0,1X,F6.0,1X,F6.0,1X,F6.0)                     00061200  70.29
         ADDED            IF(INFT.GT.0)  RADLEN(NM)=RADLEN(NM)/12.0                             00061300  70.29
A        ADDED            MEMNO(NMEM-1)=NM                                                      00061400  70.29
-        ADDED            MEMNO(NMEM)= -NM                                                      00061500  70.29
1        ADDED            INODE(NMEM)=JNODE(NMEM-1)                                             00061600  70.29
6        ADDED            JNODE(NMEM)=INODE(NMEM-1)                                             00061700  70.29
         ADDED            GO TO 5                                                               00061800  70.29
         ADDED        100 CONTINUE                                                              00061900  70.29
         ADDED       C                  ** NODE CARD **                                         00062000  70.29
         ADDED            READ(99,10000)  NODE,NODE2                                            00062100  70.29
         ADDED      10000 FORMAT(2X,I3,1X,I3)                                                   00062200  70.29
         ADDED            IF(NODE.GT.0.AND.NODE.LE.500) GO TO 105                               00062300  70.29
         ADDED        102 CONTINUE                                                              00062400  70.29
         ADDED            WRITE(6,10999) NCARD,NODE                                             00062500  70.29
         ADDED      10999 FORMAT(1H1//////////1X,7H** THE ,I4,25HTHDATA CARD FOR THIS CASE,     00062600  70.29
         ADDED          1        25H HAS AN ILLEGAL NODE NO.,,I4,15H -CASE BYPASSED )           00062700  70.29
         ADDED            IERROR=1010                                                           00062800  70.29
         ADDED            RETURN                                                                00062900  70.29
         ADDED        105 CONTINUE                                                              00063000  70.29
         ADDED            READ(99,10001) XYZ(NODE,1), XYZ(NODE,2), XYZ(NODE,3), TBULK(NODE)     00063100  70.29
         ADDED      10001 FORMAT(2X,I3,1X,I3,1X,4F8.0)                                          00063200  70.29
         ADDED            XDOTA(NODE)=XYZ(NODE,1)*A(1)+XYZ(NODE,2)*A(2)+XYZ(NODE,3)*A(3)        00063300  70.29
         ADDED            IF(NODE2) 102,108,106                                                 00063400  70.29
         ADDED        106 CONTINUE                                                              00063500  70.29
         ADDED            DO 107 I=NODE,NODE2                                                   00063600  70.29
         ADDED            XDOTA(I)=XDOTA(NODE)                                                  00063700  70.29
         ADDED        107 CONTINUE                                                              00063800  70.29
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LD SEQ   MESSAGE          FILENAME=MUFAN                         DECKNAME=MUFAN                    YY.DDD

         ADDED        108 CONTINUE                                                        00063900  70.29
         ADDED            GO TO 5                                                         00064000  70.29
         ADDED        110 CONTINUE                                                        00064100  70.29
         ADDED      C                 ** PRESSURE CONSTRAINT CARD **                      00064200  70.29
         ADDED            READ(99,11000) NODE, PRESS                                      00064300  70.29
         ADDED      11000 FORMAT(2X,I3,3X,F6.0)                                           00064400  70.29
         ADDED            IF(NODE.GT.0.AND.NODE.LE.500) GO TO 115                         00064500  70.29
         ADDED            WRITE(6,10999) NCARD,NODE                                       00064600  70.29
         ADDED            IERROR=1011                                                     00064700  70.29
         ADDED            RETURN                                                          00064800  70.29
         ADDED        115 CONTINUE                                                        00064900  70.29
         ADDED            P(NODE)=PRESS                                                   00065000  70.29
         ADDED            GO TO 5                                                         00065100  70.29
         ADDED        120 CONTINUE                                                        00065200  70.29
         ADDED      C                 ** TEMPERATURE CARD **                              00065300  70.29
         ADDED            IFLAG=1                                                         00065400  70.29
         ADDED            READ(99,12000) (NT(K),K=1,12), TEMP                             00065500  70.29
         ADDED      12000 FORMAT(1X,12(1X,I4),4X,F8.0)                                    00065600  70.29
         ADDED            DO 190 J=1,12                                                   00065700  70.29
         ADDED            IF(NT(J).GT.500) GO TO 200                                      00065800  70.29
         ADDED            IF(NT(J)) 200,130,140                                           00065900  70.29
         ADDED        130 CONTINUE                                                        00066000  70.29
         ADDED            IF(J.EQ.1) GO TO 200                                            00066100  70.29
         ADDED            IFLAG=0                                                         00066200  70.29
         ADDED            GO TO 190                                                       00066300  70.29
         ADDED        140 CONTINUE                                                        00066400  70.29
         ADDED            IF(IFLAG.EQ.0) GO TO 150                                        00066500  70.29
         ADDED            LNZ=NT(J)                                                       00066600  70.29
         ADDED            TBULK(LNZ)=TEMP                                                 00066700  70.29
         ADDED            GO TO 190                                                       00066800  70.29
         ADDED        150 CONTINUE                                                        00066900  70.29
         ADDED            IF(LNZ.LE.NT(J)) GO TO 160                                      00067000  70.29
         ADDED            NNZ=LNZ                                                         00067100  70.29
         ADDED            LNZ=NT(J)                                                       00067200  70.29
         ADDED            GO TO 170                                                       00067300  70.29
         ADDED        160 CONTINUE                                                        00067400  70.29
         ADDED            NNZ=NT(J)                                                       00067500  70.29
         ADDED        170 CONTINUE                                                        00067600  70.29
         ADDED            DO 180 K=LNZ,NNZ                                                00067700  70.29
         ADDED            TBULK(K)=TEMP                                                   00067800  70.29
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LD SEQ   MESSAGE        FILENAME=MUFAN                    DECKNAME=MUFAN                                      YY.DDI

         ADDED      180 CONTINUE                                                                    00067900  70.29
         ADDED          IFLAG=1                                                                     00068000  70.29
         ADDED          LNZ=NT(J)                                                                   00068100  70.29
         ADDED      190 CONTINUE                                                                    00068200  70.29
         ADDED          GO TO 5                                                                     00068300  70.29
         ADDED      200 CONTINUE                                                                    00068400  70.29
         ADDED          K=J                                                                         00068500  70.29
         ADDED          WRITE(6,10999) NCARD,NT(K)                                                  00068600  70.29
         ADDED          IERROR=1012                                                                 00068700  70.29
         ADDED          RETURN                                                                      00068800  70.29
         ADDED          END                                                                         00068900  70.29
         ADDED          SUBROUTINE FORK(/RXXXT/,/VXXXT/)                                            00069000  70.29
         ADDED          REAL*8     TYPES,      TYPES1,     TYPES2                                   00069100  70.29
         ADDED          REAL*8     TYPOUT                                                           00069200  70.29
         ADDED          REAL*8     DATE                                                             00069300  70.29
         ADDED          COMMON /MUFCOM/                                                             00069400  70.29
         ADDED         U     A(3),          CUERR,         CONSTS(3,600), GC,                       00069500  70.29
         ADDED         2     IBCON(600),    IBRAN(850),    IFLUID,        IOPT(10),                 00069600  70.29
         ADDED         3     ITEMP,         ITYPE(600),    JBRPT(600),    TITLE(20,3),              00069700  70.29
         ADDED         4     LEVEL,         MBRAN(850),    NBCON(250),    NBRAN,                    00069800  70.29
         ADDED         5     NBRPTS,        NNMAX,         NPTS(150),     PBRPT(250),               00069900  70.29
         ADDED         6     QBR(150),      QERR,          RHO(600),      TBULK(500),               00070000  70.29
         ADDED         7     TOLERR,        VISC(600),     XDOTA(500)                               00070100  70.29
         ADDED          COMMON  /MUFCOM/    INOUT(100),    NINOUT,    NDUMBP,      LOOP             00070200  70.29
         ADDED          COMMON  /LICOM/                                                             00070300  70.29
         ADDED         1     ALPHA(600),    INODE(1200),   JNODE(1200),   MEMNO(1200),              00070400  70.29
         ADDED         2     NMEM,          NPLANE(600),   P(500),        PHI(600),                 00070500  70.29
         ADDED         3     Q(600),        RADLEN(600),   XYZ(500,3),    IEND(150,2),              00070600  70.29
         ADDED         4     NENDS(2)                                                               00070700  70.29
         ADDED          COMMON  /INCOM/                                                             00070800  70.29
         ADDED         1     DOUT(600),     DOKCVL(600),   D2(600),       EPSLON(600),              00070900  70.29
         ADDED         2     THICK(600)                                                             00071000  70.29
         ADDED          COMMON  /PUNT/  MMEM,MNODES, DATE                                           00071100  70.29
         ADDED          COMMON /PUNT/  TIME                                                         00071200  70.29
         ADDED          COMMON /INCOM/  LABEL(8,600)                                                00071300  70.29
         ADDED          COMMON /FORKLD/                                                             00071400  70.29
         ADDED         1     ALOUT(4),      ODOUT(4),      THKOUT(4),     ROUT(4),                  00071500  70.29
         ADDED         2     ANGOUT(4),     D2OUT(4),      RUFOUT(4),     ELOUT(4),                 00071600  70.29
         ADDED         3     AKOUT(4)                                                               00071700  70.29
         ADDED          DIMENSION     OUT(4,9)                                                      00071800  70.29
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LD SEQ  MESSAGE   FILENAME=MUFAN                   DECKNAME=MUFAN                                          YY.DD

        ADDED      DIMENSION     IFORM(12,11)                                                    00071900  70.29
        ADDED      DIMENSION     TYPES(4,45),     TYPES1(4,13),  TYPES2(4,27),                   00072000  70.29
        ADDED     1              TYPES3(8,5),     MOUT(2,4),     ITENS(10),                      00072100  70.29
        ADDED     2              TYPOUT(4,4)                                                     00072200  70.29
        ADDED      DIMENSION     RTABLE(11),        XTABLE(11)                                   00072300  70.29
        ADDED      DIMENSION     BENDC(21),       ROVRD(21),     ANGLC(14),                      00072400  70.29
        ADDED     1              THETA(14),       AKFACT(10)                                     00072500  70.29
        ADDED      DIMENSION     ICONST(3,600)                                                   00072600  70.29
        ADDED      DIMENSION     LOUT(8,4)                                                       00072700  70.29
        ADDED      EQUIVALENCE  (ICONST(1,1), CONSTS(1,1))                                       00072800  70.29
        ADDED      EQUIVALENCE  (OUT(1,1), ALOUT(1))                                             00072900  70.29
        ADDED      EQUIVALENCE  (TYPES1(1,1),TYPES(1,1)), (TYPES2(1,1),TYPES(1,14)),            00073000  70.29
        ADDED     1             (TYPES3(1,1),TYPES(1,41)),  (ANUM, NUM)                          00073100  70.29
        ADDED      DATA RTABLE/ 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.5, 10.0,              00073200  70.29
        ADDED     1             0.0/                                                             00073300  70.29
        ADDED      DATA XTABLE/ 3.0, 1.8, 1.25, 1.20, 1.25, 1.70, 2.13, 2.70, 3.50,             00073400  70.29
        ADDED     1             4.82, 0.0 /                                                      00073500  70.29
        ADDED      DATA  ROVRD/ 0.00, 0.20, 0.60, 0.80, 1.00, 1.60, 2.00, 3.00,                 00073600  70.29
        ADDED     1             3.50, 4.00, 4.60, 5.00, 6.00, 7.00, 8.00, 10.0,                  00073700  70.29
        ADDED     2            12.0, 14.0, 16.0, 18.0, 0.00 /                                    00073800  70.29
        ADDED      DATA  BENDC/ 0.86, 0.85, 0.70, 0.45, 0.34, 0.26, .195, 0.16,                 00073900  70.29
        ADDED     1             0.15, .153, 0.16, .175, 0.21, 0.24, .165, .313,                  00074000  70.29
        ADDED     2             0.35, .378, .396, 0.41, 0.00 /                                   00074100  70.29
        ADDED      DATA  THETA/  0.0, 15.0, 30.0, 45.0, 60.0, 75.0, 90.0, 105.,                 00074200  70.29
        ADDED     1             120., 135., 150., 165., 180., 0.00 /                             00074300  70.29
        ADDED      DATA  ANGLC/ 0.00, 0.22, 0.43, 0.61, 0.76, 0.90, 1.00, 1.08,                 00074400  70.29
        ADDED     1            1.15, 1.22, 1.28, 1.33, 1.38, 0.00 /                              00074500  70.29
        ADDED      DATA  AKFACT / 3.00, 0.15, 0.10, 0.06, 0.50, 1.50, 3.00 /                    00074600  70.29
        ADDED      DATA  STARS/-1.0E+20/                                                         00074700  70.29
        ADDED      DATA  TYPES1/                                                                 00074800  70.29
        ADDED     1   ' STRAIGHT PIPE  ', '                ', ' TUBING BEND    ',               00074900  70.29
        ADDED     2   '                ', 'STANDARD 90 DEG.', '    ELBOW       ',               00075000  70.29
        ADDED     3   'STANDARD 45 DEG.', '     ELBOW      ', ' LONG 90 DEG.   ',               00075100  70.29
        ADDED     4   '     ELBOW      ', '  CLOSE RETURN  ', '     BEND       ',               00075200  70.29
        ADDED     5   '   GATE VALVE   ', '                ', ' SWING CHECK    ',               00075300  70.29
        ADDED     6   '                ', '  ANGLE VALVE   ', '                ',               00075400  70.29
        ADDED     7   '  GLOBE VALVE   ', '                ', ' STANDARD TEE   ',               00075500  70.29
        ADDED     8   '  STRAIGHT THRU ', '  STANDARD TEE  ', ' THRU BRANCH    ',               00075600  70.29
        ADDED     9   ' EQUIVALENT L/D ', ' INPUT BY USER  '/                                    00075700  70.29
        ADDED      DATA  TYPES2/                                                                 00075800  70.29
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        OLD VOL=SER=004783                DRC UPDATE                NEW VOL=SER=007208

OLD SEQ   MESSAGE     FILENAME=MUFAN                 DECKNAME=MUFAN                                      YY.DD

          ADDED       1  ' 45 DEG BRANCH  ', ' MAIN TO BRANCH ', ' 60 DEG BRANCH   ',      00075900  70.29
          ADDED       2  ' MAIN TO BRANCH ', ' 90 DEG BRANCH  ', ' MAIN TO BRANCH  ',      00076000  70.29
          ADDED       3  ' 45 DEG BRANCH  ', 'FROM 90 DEG BEND', '  7 DEG BRANCH   ',      00076100  70.29
          ADDED       4  'FROM 90 DEG BEND', ' 15 DEG BRANCH  ', 'FROM 25 DEG BEND',       00076200  70.29
          ADDED       5  ' 135 DEG BRANCH ', ' MAIN TO BRANCH ', ' 45 DEG BRANCH   ',      00076300  70.29
          ADDED       6  '   THRU MAIN    ', ' 90 DEG BRANCH  ', '   THRU MAIN     ',      00076400  70.29
          ADDED       7  ' 135 DEG BRANCH ', '   THRU MAIN    ', ' 45 DEG BRANCH   ',      00076500  70.29
          ADDED       8  ' BRANCH TO MAIN ', ' 90 DEG BRANCH  ', ' BRANCH TO MAIN  ',      00076600  70.29
          ADDED       9  ' 135 DEG BRANCH ', ' BRANCH TO MAIN ', '  TUBING BEND    ',      00076700  70.29
          ADDED       A  '                ',                                               00076800  70.29
          ADDED       B  'STANDARD 90 DEG ', '     ELBOW      ', 'STANDARD 45 DEG ',       00076900  70.29
          ADDED       C  '     ELBOW      ', ' LONG 90 DEG    ', '     ELBOW       ',      00077000  70.29
          ADDED       D  '  STANDARD TEE  ', ' THRU BRANCH    ', '  STANDARD TEE   ',      00077100  70.29
          ADDED       E  '  STRAIGHT THRU ', ' CLOSE RETURN   ', '      BEND       ',      00077200  70.29
          ADDED       F  '     GRADUAL    ', '  CONTRACTION   ', '     GRADUAL     ',      00077300  70.29
          ADDED       G  '    EXPANSION   ', '     SUDDEN     ', '   CONTRACTION   ',      00077400  70.29
          ADDED       H  '     SUDDEN     ', '    EXPANSION   ', '     ORFICE      ',      00077500  70.29
          ADDED       I  '                ', '     NOZZLE     ', '                 ',      00077600  70.29
          ADDED       J  '    K-FACTOR    ', ' INPUT BY USER  '/                           00077700  70.29
          ADDED        DATA TYPES3/                                                        00077800  70.29
          ADDED       1  '  COMPONENT  XX ', '                ', '     PUMP XX     ',      00077900  70.29
          ADDED       2  '                ', ' FIXED PRESSURE ', '      DROP       ',      00078000  70.29
          ADDED       3  '  FREE PRESSURE ', '      DROP      ', ' FIXED PRESSURE ',       00078100  70.29
          ADDED       4  '      RISE      ' /                                              00078200  70.29
          ADDED        DATA ITENS/ Z4040F040, Z40F1F040, Z40F2F040, Z40F3F040, Z40F4F040,00078300  70.29
          ADDED       1            Z40F5F040, Z40F6F040, Z40F7F040, Z40F8F040, Z40F9F040/00078400  70.29
          ADDED        DATA IFORM/ 48H(3X,'LENGTH, FT.',8X,1H*,  0(6X,F8.3,6X,1H*)/3X, , 00078500  70.29
          ADDED       1            48H'O.D., IN. (D1)',5X,1H*,   0(7X,F7.3,6X,1H*)/3X, , 00078600  70.29
          ADDED       2            48H'WALL THICKNESS, IN *',    0(7X,F7.4,6X,1H*)/3X, , 00078700  70.29
          ADDED       3            48H'RADIUS, FT.',8X,1H*,      0(6X,F8.3,6X,1H*)/3X, , 00078800  70.29
          ADDED       4            48H'ANGLE, DEG.',8X,1H*,      0(8X,F5.1,7X,1H*)/3X, , 00078900  70.29
          ADDED       5            48H'D2, IN.',12X,1H*,         0(7X,F7.3,6X,1H*)/3X, , 00079000  70.29
          ADDED       6            48H'ROUGHNESS, IN.',5X,1H*,   0(7X,E7.2,6X,1H*)/3X, , 00079100  70.29
          ADDED       7            48H'EQUIV. L/D',9X,1H*,       0(7X,F7.3,6X,1H*)/3X, , 00079200  70.29
          ADDED       8            48H'K-FACTOR',11X,1H*,        0(7X,F7.3,6X,1H*)/3X, , 00079300  70.29
          ADDED       9            48H'LABEL',14X,1H*,           0(2X,4A4,2X,1H*)/       , 00079400  70.29
          ADDED       A            48H22X,1H*,                   0(2X,4A4,2X,1H*))       / 00079500  70.29
          ADDED        NEQMAX=12                                                           00079600  70.29
          ADDED        NM=NMEM/2                                                           00079700  70.29
          ADDED        NPAGES=(NM-1)/8+1                                                   00079800  70.29
```

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LD SEQ   MESSAGE         FILENAME=MUFAN                      DECKNAME=MUFAN                       YY.DD
         ADDED                 IPAGE=0                                                  00079900  70.29
         ADDED                 IO=0                                                     00080000  70.29
         ADDED                 ISET=3                                                   00080100  70.29
         ADDED                 DO 1500 N=1,NMEM                                         00080200  70.29
         ADDED                 IF(MEMNO(N).LE.0)  GO TO 1500                            00080300  70.29
         ADDED                 MEM=MEMNO(N)                                             00080400  70.29
         ADDED         C              COMPUTE AVERAGE BULK TEMP, DENSITY AND VISCOSITY  00080500  70.29
         ADDED                 L=INODE(N)                                               00080600  70.29
         ADDED                 J=JNODE(N)                                               00080700  70.29
         ADDED                 TBAVG=0.5*(TBULK(L)+TBULK(J))                            00080800  70.29
         ADDED                 RHO(MEM)=RXXXT(TBAVG,ISTEP,IERR)                         00080900  70.29
         ADDED                 VISC(MEM)=VXXXT(TBAVG,ISTEP,IERR)                        00081000  70.29
         ADDED                 IO=IO+1                                                  00081100  70.29
         ADDED                 DO 20 L=1,8                                              00081200  70.29
         ADDED                 LOUT(L,IO)=LABEL(L,MEM)                                  00081300  70.29
         ADDED              20 CONTINUE                                                 00081400  70.29
         ADDED                 MOUT(1,IO)=INODE(N)                                      00081500  70.29
         ADDED                 MOUT(2,IO)=JNODE(N)                                      00081600  70.29
         ADDED                 DIN=DOUT(MEM)-2.0*THICK(MEM)                             00081700  70.29
         ADDED                 DO 30 J=1,9                                              00081800  70.29
         ADDED                 OUT(IO,J)=STARS                                          00081900  70.29
         ADDED              30 CONTINUE                                                 00082000  70.29
         ADDED                 IF(ITYPE(MEM)-100000000) 40,32,34                        00082100  70.29
         ADDED              32 CONTINUE                                                 00082200  70.29
         ADDED                 CALL LDTYPE(TYPES(1,43),TYPOUT,IO)                       00082300  70.29
         ADDED                 CONSTS(2,MEM)=Q(MEM)                                     00082400  70.29
         ADDED                 GO TO 1000                                               00082500  70.29
         ADDED              34 CONTINUE                                                 00082600  70.29
         ADDED                 IF(ITYPE(MEM).EQ.300000000) GO TO 36                     00082700  70.29
         ADDED                 CONSTS(1,MEM)=DIN                                        00082800  70.29
         ADDED                 ODOUT(IO)=DOUT(MEM)                                      00082900  70.29
         ADDED                 THKOUT(IO)=THICK(MEM)                                    00083000  70.29
         ADDED                 CALL LDTYPE(TYPES(1,44),TYPOUT,IO)                       00083100  70.29
         ADDED                 GO TO 1000                                               00083200  70.29
         ADDED              36 CONTINUE                                                 00083300  70.29
         ADDED                 CALL LDTYPE(TYPES(1,45),TYPOUT,IO)                       00083400  70.29
         ADDED                 CONSTS(2,MEM)=Q(MEM)                                     00083500  70.29
         ADDED                 GO TO 1000                                               00083600  70.29
         ADDED              40 CONTINUE                                                 00083700  70.29
         ADDED                 IF(EPSLON(MEM).LE.0.0)  EPSLON(MEM)=1.0E-7               00083800  70.29
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LD SEQ   MESSAGE      FILENAME=MUFAN                         DECKNAME=MUFAN                                  YY.DD

         ADDED              IT=MOD(ITYPE(MEM),10000000)                                           00083900  70.29
         ADDED              CONSTS(1,MEM)=DIN                                                     00084000  70.29
         ADDED              CONSTS(2,MEM)=RADLEN(MEM)                                             00084100  70.29
         ADDED              CONSTS(3,MEM)=EPSLON(MEM)                                             00084200  70.29
         ADDED              IF(IT-1) 100,50,110                                                   00084300  70.29
         ADDED           50 CONTINUE                                                              00084400  70.29
         ADDED        C                     STRAIGHT PIPE                                         00084500  70.29
         ADDED              ALOUT(IO)=RADLEN(MEM)                                                 00084600  70.29
         ADDED              ODOUT(IO)=DOUT(MEM)                                                   00084700  70.29
         ADDED              THKOUT(IO)=THICK(MEM)                                                 00084800  70.29
         ADDED              RUFOUT(IO)=EPSLCN(MEM)                                                00084900  70.29
         ADDED              CONSTS(2,MEM)=RADLEN(MEM)*12.0/DIN                                    00085000  70.29
         ADDED              CALL LDTYPE(TYPES(1,1),TYPOUT,IO)                                     00085100  70.29
         ADDED              GO TO 1000                                                            00085200  70.29
         ADDED          100 CONTINUE                                                              00085300  70.29
         ADDED              WRITE(6,9001) INODE(N), JNODE(N)                                      00085400  70.29
         ADDED         9001 FORMAT(1H1///////////////////1X,107(1H*)/1H0,21X,'MEMBER ',I3,        00085500  70.29
         ADDED            1 ' -',I3,' HAS AN ILLEGAL TYPE SPECIFIED IN CARD COLUMNS 42-51 ',      00085600  70.29
         ADDED            2     21(1H*)/1H0,107(1H*))                                             00085700  70.29
         ADDED              RETURN                                                                00085800  70.29
         ADDED          110 CONTINUE                                                              00085900  70.29
         ADDED              IF(IT-99) 120, 115,500                                                00086000  70.29
         ADDED          115 CONTINUE                                                              00086100  70.29
         ADDED              ELOUT(IO)=DOKCVL(MEM)                                                 00086200  70.29
         ADDED              ODOUT(IO)=DOUT(MEM)                                                   00086300  70.29
         ADDED              THKOUT(IO)=THICK(MEM)                                                 00086400  70.29
         ADDED              CONSTS(2,MEM)=DOKCVL(MEM)                                             00086500  70.29
         ADDED              CALL LDTYPE(TYPES(1,13),TYPOUT,IO)                                    00086600  70.29
         ADDED              GO TO 1000                                                            00086700  70.29
         ADDED          120 CONTINUE                                                              00086800  70.29
         ADDED              RUFOUT(IO)=EPSLCN(MEM)                                                00086900  70.29
         ADDED              ODOUT(IO)=DOUT(MEM)                                                   00087000  70.29
         ADDED              THKOUT(IO)=THICK(MEM)                                                 00087100  70.29
         ADDED              IT=IT-1                                                               00087200  70.29
         ADDED              CALL LDTYPE(TYPES(1,IT+1),TYPOUT,IO)                                  00087300  70.29
         ADDED              DIN=DIN/12.0                                                          00087400  70.29
         ADDED        C                CALCULATE EQUIVALENT LENGTH OF STRAIGHT PIPE               00087500  70.29
         ADDED        C               FOR THE STANDARD COMPONENTS AND FITTINGS                    00087600  70.29
         ADDED              IF(IT.LE.NEQMAX-1)  GO TO 130                                         00087700  70.29
         ADDED              WRITE(6,9001) INODE(N), JNODE(N)                                      00087800  70.29
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LD SEQ  MESSAGE       FILENAME=MUFAN                    DECKNAME=MUFAN                                  YY.DD

        ADDED            RETURN                                                            00087900  70.29
        ADDED        130 CONTINUE                                                          00088000  70.29
        ADDED            GO TO (140,180,190,200,210,220,230,240,250,260,270) ,IT           00088100  70.29
        ADDED        140 CONTINUE                                                          00088200  70.29
        ADDED       C                  TUBING    BEND                                      00088300  70.29
        ADDED            RATIO=ABS(RADLEN(MEM))/DIN                                        00088400  70.29
        ADDED            IF(RATIO.GE.1.0)  GO TO 150                                       00088500  70.29
        ADDED            WRITE(6,9002) INODE(N),  JNODE(N)                                 00088600  70.29
        ADDED            IF(IT.EQ.98) GO TO 900                                            00088700  70.29
        ADDED       9002 FORMAT(1H1//////////1X,9H** MEMBER,2I4,21H HAS R/D LESS THAN 1,,  00088800  70.29
        ADDED          1        47H CANNOT COMPUTE EQUIV LENGTH - CASE BYPASSED ** )      00088900  70.29
        ADDED            RETURN                                                            00089000  70.29
        ADDED        150 CONTINUE                                                          00089100  70.29
        ADDED            IF(RATIO.GT.7.5) GO TO 160                                        00089200  70.29
        ADDED            CALL INT4(RTABLE,XTABLE,RATIO,X)                                  00089300  70.29
        ADDED            GO TO 170                                                         00089400  70.29
        ADDED        160 CONTINUE                                                          00089500  70.29
        ADDED            X=0.482*RATIO                                                     00089600  70.29
        ADDED        170 CONTINUE                                                          00089700  70.29
        ADDED            ELOVD=0.0202*X*PHI(MEM)**1.1                                      00089800  70.29
        ADDED            CONSTS(2,MEM)=ELOVD                                               00089900  70.29
        ADDED            ROUT(IO)=RADLEN(MEM)                                              00090000  70.29
        ADDED            ANGOUT(IO)=PHI(MEM)                                               00090100  70.29
        ADDED            ELOUT(IO)=ELOVD                                                   00090200  70.29
        ADDED            GO TO 1000                                                        00090300  70.29
        ADDED        180 CONTINUE                                                          00090400  70.29
        ADDED       C                  STANDARD 90 DEG ELBOW                               00090500  70.29
        ADDED            ANGOUT(IO)=PHI(MEM)                                               00090600  70.29
        ADDED            ELOUT(IO)=30.0                                                    00090700  70.29
        ADDED            CONSTS(2,MEM)=30.0                                                00090800  70.29
        ADDED            GO TO 1000                                                        00090900  70.29
        ADDED        190 CONTINUE                                                          00091000  70.29
        ADDED       C                  STANDARD 45 DEG ELBOW                               00091100  70.29
        ADDED            ANGOUT(IO)=PHI(MEM)                                               00091200  70.29
        ADDED            ELOUT(IO)=16.0                                                    00091300  70.29
        ADDED            CONSTS(2,MEM)=16.0                                                00091400  70.29
        ADDED            GO TO 1000                                                        00091500  70.29
        ADDED        200 CONTINUE                                                          00091600  70.29
        ADDED       C                  LONG 90 DEG ELBOW                                   00091700  70.29
        ADDED            ANGOUT(IO)=PHI(MEM)                                               00091800  70.29
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LD SEQ  MESSAGE        FILENAME=MUFAN                      DECKNAME=MUFAN                          YY.DDD

        ADDED                ELOUT(IO)=20.0                                                00091900  70.29
        ADDED                CONSTS(2,MEM)=20.0                                            00092000  70.29
        ADDED                GO TO 1000                                                    00092100  70.29
        ADDED            210 CONTINUE                                                      00092200  70.29
        ADDED          C                   CLOSE RETURN BEND                               00092300  70.29
        ADDED                ANGOUT(IO)=PHI(MEM)                                           00092400  70.29
        ADDED                ELOUT(IO)=50.0                                                00092500  70.29
        ADDED                CONSTS(2,MEM)=50.0                                            00092600  70.29
        ADDED                GO TO 1000                                                    00092700  70.29
        ADDED            220 CONTINUE                                                      00092800  70.29
        ADDED          C                   GATE VALVE                                      00092900  70.29
        ADDED                ELOUT(IO)=13.0                                                00093000  70.29
        ADDED                CONSTS(2,MEM)=13.0                                            00093100  70.29
        ADDED                GO TO 1000                                                    00093200  70.29
        ADDED            230 CONTINUE                                                      00093300  70.29
        ADDED          C                   SWING CHECK                                     00093400  70.29
        ADDED                ELOUT(IO)=135.0                                               00093500  70.29
        ADDED                CONSTS(2,MEM)=135.0                                           00093600  70.29
        ADDED                GO TO 1000                                                    00093700  70.29
        ADDED            240 CONTINUE                                                      00093800  70.29
        ADDED          C                   ANGLE VALVE                                     00093900  70.29
        ADDED                ELOUT(IO)=145.0                                               00094000  70.29
        ADDED                CONSTS(2,MEM)= 145.0                                          00094100  70.29
        ADDED                GO TO 1000                                                    00094200  70.29
        ADDED            250 CONTINUE                                                      00094300  70.29
        ADDED          C                   GLOBE VALVE                                     00094400  70.29
        ADDED                ELOUT(IO)=340.0                                               00094500  70.29
        ADDED                CONSTS(2,MEM)=340.0                                           00094600  70.29
        ADDED                GO TO 1000                                                    00094700  70.29
        ADDED            260 CONTINUE                                                      00094800  70.29
        ADDED          C                   STANDARD TEE - STRAIGHT THRU                    00094900  70.29
        ADDED                ELOUT(IO)=10.0                                                00095000  70.29
        ADDED                CONSTS(2,MEM)= 10.0                                           00095100  70.29
        ADDED                GO TO 1000                                                    00095200  70.29
        ADDED            270 CONTINUE                                                      00095300  70.29
        ADDED          C                   STANDARD TEE - THRU BRANCH                      00095400  70.29
        ADDED                ELOUT(IO)=60.0                                                00095500  70.29
        ADDED                CONSTS(2,MEM)= 60.0                                           00095600  70.29
        ADDED            500 CONTINUE                                                      00095700  70.29
        ADDED          C                                                                   00095800  70.29
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LD SEQ  MESSAGE       FILENAME=MUFAN                     DECKNAME=MUFAN                          YY.DD

        ADDED     C                K-FACTORS                                            00095900  70.29
        ADDED     C                                                                     00096000  70.29
        ADDED           IT=IT/100                                                       00096100  70.29
        ADDED           IF(IT-99) 510,505,900                                           00096200  70.29
        ADDED       505 CONTINUE                                                        00096300  70.29
        ADDED           AKOUT(IO)=DOKCVL(MEM)                                           00096400  70.29
        ADDED           CONSTS(2,MEM)=DOKCVL(MEM)                                       00096500  70.29
        ADDED           ODOUT(IO)=DOUT(MEM)                                             00096600  70.29
        ADDED           THKOUT(IO)=THICK(MEM)                                           00096700  70.29
        ADDED           CALL LDTYPE(TYPES2(1,27),TYPOUT,IO)                             00096800  70.29
        ADDED           GO TO 1000                                                      00096900  70.29
        ADDED       510 CONTINUE                                                        00097000  70.29
        ADDED           CALL LDTYPE(TYPES2(1,IT),TYPOUT,IO)                             00097100  70.29
        ADDED           ODOUT(IO)=DOUT(MEM)                                             00097200  70.29
        ADDED           THKOUT(IO)=THICK(MEM)                                           00097300  70.29
        ADDED           IF(IT.GT.13)  GO TO 515                                         00097400  70.29
        ADDED           D2OUT(IO)=D2(MEM)                                               00097500  70.29
        ADDED           D2IN=D2(MEM)-2.0*THICK(MEM)                                     00097600  70.29
        ADDED           IEXP=ALOG10(D2IN)                                               00097700  70.29
        ADDED           IEXP=4-IEXP                                                     00097800  70.29
        ADDED           IND2=D2IN*10.0**IEXP                                            00097900  70.29
        ADDED           ICONST(3,MEM)=IEXP*100000+IND2                                  00098000  70.29
        ADDED           IF(IT.LE.6)  GO TO 1000                                         00098100  70.29
        ADDED       515 CONTINUE                                                        00098200  70.29
        ADDED           NKMAX=26                                                        00098300  70.29
        ADDED           IF(IT.LE.NKMAX) GO TO 520                                       00098400  70.29
        ADDED           WRITE(6,9001) INODE(N), JNODE(N)                                00098500  70.29
        ADDED           STOP                                                            00098600  70.29
        ADDED       520 CONTINUE                                                        00098700  70.29
        ADDED           IT=IT-6                                                         00098800  70.29
        ADDED           IF(IT-8) 530,540,560                                            00098900  70.29
        ADDED       530 CONTINUE                                                        00099000  70.29
        ADDED           AKOUT(IO)=AKFACT(IT)                                            00099100  70.29
        ADDED           CONSTS(2,MEM)=AKFACT(IT)                                        00099200  70.29
        ADDED           GO TO 1000                                                      00099300  70.29
        ADDED       540 CONTINUE                                                        00099400  70.29
        ADDED     C                TUBING BEND                                          00099500  70.29
        ADDED           ROUT(IO)=RADLEN(MEM)                                            00099600  70.29
        ADDED           ANGOUT(IO)=PHI(MEM)                                             00099700  70.29
        ADDED           IF(PHI(MEM).GT.0.0.AND.PHI(MEM).LE.180.0)   GO TO 550           00099800  70.29
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LD SEQ  MESSAGE       FILENAME=MUFAN                    DECKNAME=MUFAN                          YY.DD

        ADDED            WRITE(6,9004)  INODE(N), JNODE(N), PHI(MEM)                   00099900  70.29
        ADDED       9004 FORMAT(1H1//////////1X,107(1H*)//1H0,'ANGLE FOR TUBING BEND',I4,  00100000  70.29
        ADDED          1     2H -,I3,' =',G12.5,'-OUT OF LIMITS'//1H0,107(1H*))         00100100  70.29
        ADDED            STOP                                                          00100200  70.29
        ADDED        550 CONTINUE                                                      00100300  70.29
        ADDED            RD=ABS(RADLEN(MEM)*12.0/DIN)                                  00100400  70.29
        ADDED            IF(RD.GT.18.0)  RD=18.0                                       00100500  70.29
        ADDED            CALL INT4(ROVRD,BENDC,RD,BC)                                  00100600  70.29
        ADDED            AC=1.0                                                        00100700  70.29
        ADDED            IF(PHI(MEM).NE.90.0)  CALL INT4(THETA,ANGLC,PHI(MEM),AC)      00100800  70.29
        ADDED            CONSTS(2,MEM)=AC*BC                                           00100900  70.29
        ADDED            AKOUT(IO)=CONSTS(2,MEM)                                       00101000  70.29
        ADDED            GO TO 1000                                                    00101100  70.29
        ADDED        560 CONTINUE                                                      00101200  70.29
        ADDED            IT=IT-8                                                       00101300  70.29
        ADDED            GO TO(565,570,580,590,600,610,620,630,640,650,660,670), IT    00101400  70.29
        ADDED        565 CONTINUE                                                      00101500  70.29
        ADDED       C                  STANDARD 90 DEG ELBOW                           00101600  70.29
        ADDED            CONSTS(2,MEM)=PICK(1,DIN)                                     00101700  70.29
        ADDED            AKOUT(IO)=CONSTS(2,MEM)                                       00101800  70.29
        ADDED            GO TO 1000                                                    00101900  70.29
        ADDED        570 CONTINUE                                                      00102000  70.29
        ADDED       C                  STANDARD 45 DEGREE ELBOW                        00102100  70.29
        ADDED            CONSTS(2,MEM)=PICK(2,DIN)                                     00102200  70.29
        ADDED            AKOUT(IO)=CONSTS(2,MEM)                                       00102300  70.29
        ADDED            GO TO 1000                                                    00102400  70.29
        ADDED        580 CONTINUE                                                      00102500  70.29
        ADDED       C                  LONG 90 DEGREE ELBOW                            00102600  70.29
        ADDED            CONSTS(2,MEM)=PICK(3,DIN)                                     00102700  70.29
        ADDED            AKOUT(IO)=CONSTS(2,MEM)                                       00102800  70.29
        ADDED            GO TO 1000                                                    00102900  70.29
        ADDED        590 CONTINUE                                                      00103000  70.29
        ADDED       C                  STANDARD TEE - THRU BRANCH                      00103100  70.29
        ADDED            CONSTS(2,MEM)=PICK(4,DIN)                                     00103200  70.29
        ADDED            AKOUT(IO)=CONSTS(2,MEM)                                       00103300  70.29
        ADDED            GO TO 1000                                                    00103400  70.29
        ADDED        600 CONTINUE                                                      00103500  70.29
        ADDED       C                  STANDARD TEE - THRU MAIN                        00103600  70.29
        ADDED            CONSTS(2,MEM)=PICK(5,DIN)                                     00103700  70.29
        ADDED            AKOUT(IO)=CONSTS(2,MEM)                                       00103800  70.29
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LD SEQ   MESSAGE        FILENAME=MUFAN                    DECKNAME=MUFAN                          YY.DDD

         ADDED               GO TO 1000                                                 00103900  70.29
         ADDED           610 CONTINUE                                                   00104000  70.29
         ADDED         C                    CLOSE RETURN BEND                           00104100  70.29
         ADDED               CONSTS(2,MEM)=PICK(6,DIN)                                  00104200  70.29
         ADDED               AKOUT(IO)=CONSTS(2,MEM)                                    00104300  70.29
         ADDED               GO TO 1000                                                 00104400  70.29
         ADDED           620 CONTINUE                                                   00104500  70.29
         ADDED         C                    GRADUAL CONTRACTION                         00104600  70.29
         ADDED               D1=D2(MEM)                                                 00104700  70.29
         ADDED               CONSTS(2,MEM)=GRCOK(D1,DIN,RADLEN(MEM),ISTEP,IERR)         00104800  70.29
         ADDED               D2OUT(IO)=D2(MEM)                                          00104900  70.29
         ADDED               ALOUT(IO)=RADLEN(MEM)                                      00105000  70.29
         ADDED               CONSTS(1,MEM)=D2(MEM)                                      00105100  70.29
         ADDED               AKOUT(IO)=CONSTS(2,MEM)                                    00105200  70.29
         ADDED               IF(CONSTS(2,MEM).GT.0.0) GO TO 1000                        00105300  70.29
         ADDED               IERR=1                                                     00105400  70.29
         ADDED               RETURN                                                     00105500  70.29
         ADDED           630 CONTINUE                                                   00105600  70.29
         ADDED         C                    GRADUAL EXPANSION                           00105700  70.29
         ADDED               DB=D2(MEM)                                                 00105800  70.29
         ADDED               CONSTS(2,MEM)=GREXK(DIN,DB,RADLEN(MEM),ISTEP,IERR)         00105900  70.29
         ADDED               D2OUT(IO)=D2(MEM)                                          00106000  70.29
         ADDED               ALOUT(IO)=RADLEN(MEM)                                      00106100  70.29
         ADDED               AKOUT(IO)=CONSTS(2,MEM)                                    00106200  70.29
         ADDED               IF(CONSTS(2,MEM).GT.0.0)  GO TO 1000                       00106300  70.29
         ADDED               IERR=2                                                     00106400  70.29
         ADDED               RETURN                                                     00106500  70.29
         ADDED           640 CONTINUE                                                   00106600  70.29
         ADDED         C                    SUDDEN CONTRACTION                          00106700  70.29
         ADDED               DB=D2(MEM)                                                 00106800  70.29
         ADDED               CONSTS(2,MEM)=SUSC(DB,DIN,ISTEP,IERR)                      00106900  70.29
         ADDED               AKOUT(IO)=CONSTS(2,MEM)                                    00107000  70.29
         ADDED               D2OUT(IO)=D2(MEM)                                          00107100  70.29
         ADDED               CONSTS(1,MEM)=D2(MEM)                                      00107200  70.29
         ADDED               IF(CONSTS(2,MEM).GE.0.0) GO TO 1000                        00107300  70.29
         ADDED               IERR=3                                                     00107400  70.29
         ADDED               RETURN                                                     00107500  70.29
         ADDED           650 CONTINUE                                                   00107600  70.29
         ADDED         C                    SUDDEN EXPANSION                            00107700  70.29
         ADDED               DB=D2(MEM)                                                 00107800  70.29
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LD SEQ   MESSAGE       FILENAME=MUFAN                   DECKNAME=MUFAN                                   YY.DDI

         ADDED              CONSTS(2,MEM)=SUSX(DIN,DB,ISTEP,IERR)                            00107900  70.29
         ADDED              D2OUT(IO)=D2(MEM)                                                00108000  70.29
         ADDED              AKOUT(IO)=CONSTS(2,MEM)                                          00108100  70.29
         ADDED              IF(CONSTS(2,MEM).GE.0.0)  GO TO 1000                             00108200  70.29
         ADDED              IERR=4                                                           00108300  70.29
         ADDED              RETURN                                                           00108400  70.29
         ADDED          660 CONTINUE                                                         00108500  70.29
         ADDED        C                 ORFICE                                               00108600  70.29
         ADDED              CONSTS(3,MEM)=D2(MEM)/DIN                                        00108700  70.29
         ADDED              CONSTS(2,MEM)=D2(MEM)                                            00108800  70.29
         ADDED              D2OUT(IO)=D2(MEM)                                                00108900  70.29
         ADDED              GO TO 680                                                        00109000  70.29
         ADDED          670 CONTINUE                                                         00109100  70.29
         ADDED        C                 NOZZLE                                               00109200  70.29
         ADDED              CONSTS(3,MEM)=D2(MEM)/DIN                                        00109300  70.29
         ADDED              CONSTS(2,MEM)=D2(MEM)                                            00109400  70.29
         ADDED              D2OUT(IO)=D2(MEM)                                                00109500  70.29
         ADDED          680 CONTINUE                                                         00109600  70.29
         ADDED              IF(CONSTS(3,MEM).GT.0.0.AND.CONSTS(3,MEM).LE.0.80)  GO TO 1000   00109700  70.29
         ADDED              WRITE(6,9003) INODE(N), JNODE(N)                                 00109800  70.29
         ADDED         9003 FORMAT(1H1//////////1X,107(1H*)/1H0,16X,'MEMBER ',I3,' -',I3,    00109900  70.29
         ADDED            1      ' IS A NOZZLE OR ORFICE WITH D2/D1=',G10.3,' (OUT OF RANGE)'/00110000  70.29
         ADDED            2    1H0,107(1H*))                                                 00110100  70.29
         ADDED              STOP                                                             00110200  70.29
         ADDED          900 CONTINUE                                                         00110300  70.29
         ADDED              IT=IT/100                                                        00110400  70.29
         ADDED              IF(IT.GT.41)  GO TO 920                                          00110500  70.29
         ADDED              JT=IT/10                                                         00110600  70.29
         ADDED              KT=(IT-10*JT)*256                                                00110700  70.29
         ADDED              NUM=ITENS(JT+1)+KT                                               00110800  70.29
         ADDED              TYPES(4,1)=ANUM                                                  00110900  70.29
         ADDED              CALL LDTYPE(TYPES3(1,1),TYPOUT,IO)                               00111000  70.29
         ADDED              GO TO 1000                                                       00111100  70.29
         ADDED          920 CONTINUE                                                         00111200  70.29
         ADDED              IT=IT/100                                                        00111300  70.29
         ADDED              NUM=ITENS(1)+IT*256                                              00111400  70.29
         ADDED              TYPES3(3,2)=ANUM                                                 00111500  70.29
         ADDED              CALL LDTYPE(TYPES3(1,2),TYPOUT,IO)                               00111600  70.29
         ADDED         1000 CONTINUE                                                         00111700  70.29
         ADDED              GO TO(1120,1120,1100),ISET                                       00111800  70.29
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LD SEQ  MESSAGE        FILENAME=MUFAN                    DECKNAME=MUFAN                             YY.DDD

        ADDED     1100 CONTINUE                                                          00111900  70.29
        ADDED          IPAGE=IPAGE+1                                                     00112000  70.29
        ADDED          WRITE(6,6000) DATE,  TIME, IPAGE,NPAGES,TITLE                     00112100  70.29
        ADDED     6000 FORMAT(1H1//1H0,36(1H*),' MUFAN MEMBER FLOW CHARACTERISTICS ** ',00112200  70.29
        ADDED        1     A8,2X,A4,' ** PAGE',I3,' OF',I3,' *'//(17X,19A4))          00112300  70.29
        ADDED          ISET=1                                                            00112400  70.29
        ADDED     1120 CONTINUE                                                          00112500  70.29
        ADDED          IF(N.GE.NMEM-1)  GO TO 1150                                       00112600  70.29
        ADDED          IF(IO.LT.4)  GO TO 1500                                           00112700  70.29
        ADDED     1150 CONTINUE                                                          00112800  70.29
        ADDED          DO 1200 J=1,11                                                    00112900  70.29
        ADDED          IFORM(7,J)=IFORM(7,J)+IO                                          00113000  70.29
        ADDED     1200 CONTINUE                                                          00113100  70.29
        ADDED          WRITE(6,6001)  ((MOUT(I,J),I=1,2),J=1,IO)                         00113200  70.29
        ADDED     6001 FORMAT(1H0//3X,'MEMBER',13X,1H*,4(6X,I3,' -',I3,6X,1H*))          00113300  70.29
        ADDED          WRITE(6,6002)  ((TYPOUT(I,J),I=1,2),J=1,IO)                       00113400  70.29
        ADDED     6002 FORMAT(3X,19(1H-),1H*,4('-------------------*')/3X,'TYPE',15X,   00113500  70.29
        ADDED        1     1H*,4(2X,2A8,2X,1H*))                                         00113600  70.29
        ADDED          WRITE(6,6003)  ((TYPOUT(I,J),I=3,4),J=1,IO)                       00113700  70.29
        ADDED     6003 FORMAT(22X,1H*,4(2X,2A8,2X,1H*))                                  00113800  70.29
        ADDED          WRITE(6,IFORM)    ((OUT(I,J),I=1,IO),J=1,9),                      00113900  70.29
        ADDED        1  ((LOUT(K,L),K=1,4),L=1,IO),  ((LOUT(K1,L1),K1=5,8),L1=1,IO)      00114000  70.29
        ADDED          DO 1250 J=1,11                                                    00114100  70.29
        ADDED          IFORM(7,J)=IFORM(7,J)-IO                                          00114200  70.29
        ADDED     1250 CONTINUE                                                          00114300  70.29
        ADDED          IO=0                                                              00114400  70.29
        ADDED          ISET=ISET+1                                                       00114500  70.29
        ADDED     1500 CONTINUE                                                          00114600  70.29
        ADDED          RETURN                                                            00114700  70.29
        ADDED          END                                                               00114800  70.29
        ADDED          SUBROUTINE LDTYPE(TYPIN,TYPOUT,IO)                                00114900  70.29
        ADDED          REAL*8        TYPIN,     TYPOUT                                   00115000  70.29
        ADDED          DIMENSION     TYPIN(1),        TYPOUT(4,4)                        00115100  70.29
        ADDED          DO 100 I=1,4                                                      00115200  70.29
        ADDED          TYPOUT(I,IO)=TYPIN(I)                                             00115300  70.29
        ADDED      100 CONTINUE                                                          00115400  70.29
        ADDED          RETURN                                                            00115500  70.29
        ADDED          END                                                               00115600  70.29
        ADDED          FUNCTION SUDD(X)                                                  00115700  70.29
        ADDED          DIMENSION  RATABL(12), KEXP(12), KCONT(12)                        00115800  70.29
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        OLD VOL=SER=004783                 DRC UPDATE                  NEW VOL=SER=007208

LD SEQ  MESSAGE        FILENAME=MUFAN                  DECKNAME=MUFAN                                    YY.DD

        ADDED              REAL KEXP, KCONT                                                     00115900  70.29
        ADDED              DATA RATABL / 0., 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, .7, .8, .9, 1.,0./00116000  70.29
        ADDED              DATA KEXP   / 1., .82, .64, .5, .385, .27, .19, .12, .05, .02,       00116100  70.29
        ADDED             1 .005, 0.0/                                                          00116200  70.29
        ADDED              DATA KCONT / .44, .42, .39, .35, .31, .26, .19,.12, .05, .02,        00116300  70.29
        ADDED             1 .005, 0.0/                                                          00116400  70.29
        ADDED              ENTRY SUSX (D1, D2, ISTEP, IERR)                                     00116500  70.29
        ADDED              IERR = 1                                                             00116600  70.29
        ADDED              RATIO = D1/D2                                                        00116700  70.29
        ADDED              IF( RATIO .LT. 0.0 .OR. RATIO .GT. 1.0) GO TO 10                     00116800  70.29
        ADDED              CALL INT4 ( RATABL, KEXP, RATIO, ANS)                                00116900  70.29
        ADDED              SUSX = ANS                                                           00117000  70.29
        ADDED              RETURN                                                               00117100  70.29
        ADDED              ENTRY SUSC (D1, D2, ISTEP, IERR)                                     00117200  70.29
        ADDED              IERR = 1                                                             00117300  70.29
        ADDED              RATIO = D1/D2                                                        00117400  70.29
        ADDED              IF( RATIO .LT. 0.0 .OR. RATIO .GT. 1.0) GO TO 10                     00117500  70.29
        ADDED              CALL INT4 ( RATABL, KCONT, RATIO, ANS)                               00117600  70.29
        ADDED              SUSC = ANS                                                           00117700  70.29
        ADDED              RETURN                                                               00117800  70.29
        ADDED           10 CONTINUE                                                             00117900  70.29
        ADDED         C ERROR MESSAGE                                                           00118000  70.29
        ADDED              SUDD = -1.0                                                          00118100  70.29
        ADDED              RETURN                                                               00118200  70.29
        ADDED              END                                                                  00118300  70.29
        ADDED              FUNCTION GREXK (D1, D2, ALONG, ISTEP, IERR)                          00118400  70.29
        ADDED              DIMENSION ZETAD(6), TABLK(15, 6), TABLRT(15), V(6)                   00118500  70.29
        ADDED              DATA ZETAD/ 15., 20., 30., 40., 60., 0.0 /                           00118600  70.29
        ADDED              DATA  TABLRT            / 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8,         00118700  70.29
        ADDED             1 1.9, 2.0, 2.25, 2.5, 3.0, 3.5, 4.0, 0.0/                            00118800  70.29
        ADDED              DATA  TABLK             / .06,.067,.077,.087, .10, .11, .12,         00118900  70.29
        ADDED             1 .133, .147, .173, .193, .220, .233, .240, 0.0,                      00119000  70.29
        ADDED             2                        .080, .107, .133, .160, .180, .210,          00119100  70.29
        ADDED             3 .230, .253, .267, .295, .320, .350, .367, .370, 0.0,                00119200  70.29
        ADDED             4                        .087, .113, .176, .233, .300, .347,          00119300  70.29
        ADDED             5 .383, .420, .447, .486, .509, .533, .543, .547, 0.0,                00119400  70.29
        ADDED             6                        .100, .147, .207, .280, .367, .440,          00119500  70.29
        ADDED             7 .487, .527, .560, .601, .640, .667, .676, .680, 0.0,                00119600  70.29
        ADDED             8                        .133, .200, .267, .367, .467, .533,          00119700  70.29
        ADDED             9 .600, .643, .683, .747, .783, .840, .867, .880, 0.0,                00119800  70.29
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OLD SEG   MESSAGE   FILENAME=MUFAN                    DECKNAME=MUFAN                              YY.DD

          ADDED          A                            0., 0., 0., 0., 0., 0., 0., 0., 0.,   00119900  70.29
          ADDED          B 0., 0., 0., 0., 0., 0.0/                                         00120000  70.29
          ADDED           IERR = 0                                                          00120100  70.29
          ADDED           DIFF = D2 - D1                                                    00120200  70.29
          ADDED           RATIO = D2 / D1                                                   00120300  70.29
          ADDED           X = DIFF / 2.0                                                    00120400  70.29
          ADDED           ZETA =   ATAN (X/ALONG) * (360.0/(2.0 * 3.141592))* 2.0           00120500  70.29
          ADDED           IF (RATIO .GT. 4.0 .OR. RATIO .LT. 1.2) GO TO 500                 00120600  70.29
          ADDED           IF (ZETA .GT. 60.0 .OR. ZETA .LT. 15.0) GO TO 700                 00120700  70.29
          ADDED           DO 10 J = 1,6                                                     00120800  70.29
          ADDED           CALL INT4 ( TABLRT, TABLK(1,J), RATIO, V(J))                      00120900  70.29
          ADDED        10 CONTINUE                                                          00121000  70.29
          ADDED           CALL INT4 ( ZETAD, V, ZETA, ANS)                                  00121100  70.29
          ADDED           GREXK = ANS                                                       00121200  70.29
          ADDED        20 RETURN                                                            00121300  70.29
A         ADDED     C                                                                       00121400  70.29
-         ADDED     C  ERROR MESSAGES                                                       00121500  70.29
3         ADDED       500 CONTINUE                                                          00121600  70.29
1         ADDED           IERR=-1                                                           00121700  70.29
          ADDED           GREXK = -1.0                                                      00121800  70.29
          ADDED           GO TO 20                                                          00121900  70.29
          ADDED       700 CONTINUE                                                          00122000  70.29
          ADDED           IERR = 1                                                          00122100  70.29
          ADDED           GREXK = -1.0                                                      00122200  70.29
          ADDED           RETURN                                                            00122300  70.29
          ADDED           END                                                               00122400  70.29
          ADDED           FUNCTION GRCOK (D1, D2, ALONG, ISTEP, IERR)                       00122500  70.29
          ADDED           DIMENSION PHITAB(16), TABLD1(7), TABLK(16,7), V(7), Z(16)         00122600  70.29
          ADDED           EQUIVALENCE (TABLD1, Z), (V, Z(8)), (RATIO, Z(15)), (ANS, Z(16))  00122700  70.29
          ADDED           NAMELIST /DEBUG/ V,Z                                              00122800  70.29
          ADDED           DATA PHITAB / 2., 6., 10., 15., 20., 30., 40., 50., 60., 80.,     00122900  70.29
          ADDED          1 100., 120., 140., 160., 180., 0.0/                               00123000  70.29
          ADDED           DATA TABLD1/ 1.0, .25, .1, .07, .05, .02, 0.0/                    00123100  70.29
          ADDED           DATA TABLK           / .8, .55, .4, .25, .19, .125, .10,          00123200  70.29
          ADDED          1 .097, .10,       .12, .17, .23, .31, .40, .50, 0.0,              00123300  70.29
          ADDED          2                      .93, .80, .69, .56, .47, .34, .26,          00123400  70.29
          ADDED          3 .21, .19, .20, .24, .30, .36, .44, .50, 0.0,                     00123500  70.29
          ADDED          4                      .94, .875, .81, .73, .67, .56, .48,         00123600  70.29
          ADDED          5 .43, .40,       .40, .42, .44, .465, .48, .50, 0.0,              00123700  70.29
          ADDED          6                      .96, .925, .89, .84, .80, .725, .655,       00123800  70.29
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OLD VOL=SER=004783 DRC UPDATE NEW VOL=SER=007208

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OLD SEQ  MESSAGE  FILENAME=MUFAN                     DECKNAME=MUFAN                                YY.DD

         ADDED      7 .60, .56, .51, .50, .50, .50, .50, .50, .00,                         00123900  70.29
         ADDED      8                              .97, .94, .92, .88, .85, .795, .755,    00124000  70.29
         ADDED      9 .72, .68, .62, .585, .565, .54, .52, .50, 0.,                        00124100  70.29
         ADDED      A                              .99, .97, .954, .93, .915, .88, .85,    00124200  70.29
         ADDED      B .82, .795, .745, .695, .645, .60, .55, .50, 0.0,                     00124300  70.29
         ADDED      C                              0., 0., 0., 0., 0., 0., 0., 0., 0.,     00124400  70.29
         ADDED      D 0., 0., 0., 0., 0., 0., 0.0/                                         00124500  70.29
         ADDED        IERR = 1                                                             00124600  70.29
         ADDED        DIFF = D2 - D1                                                       00124700  70.29
         ADDED        RATIO = ALONG / D1                                                   00124800  70.29
         ADDED        X = DIFF / 2.0                                                       00124900  70.29
         ADDED        PHI =    ATAN(X/ALONG) * (360.0 / ( 2.0*3.141592)) * 2.0             00125000  70.29
         ADDED        IF (PHI .GT. 180.0 .OR. PHI .LT. 2.0) GO TO 700                      00125100  70.29
         ADDED        IF (RATIO .GT. 1.0 .OR. RATIO .LT. 0.02) GO TO 700                   00125200  70.29
         ADDED        DO 10 J = 1, 7                                                       00125300  70.29
         ADDED        CALL INT4 (PHITAB, TABLK(1,J), PHI, V(J))                            00125400  70.29
         ADDED     10 CONTINUE                                                             00125500  70.29
         ADDED        DO 15 I = 1,15                                                       00125600  70.29
         ADDED     15 Z(I) = -Z(I)                                                         00125700  70.29
         ADDED     19 CALL INT4 (TABLD1, V, RATIO, ANS)                                    00125800  70.29
         ADDED        DO 17 I = 1,16                                                       00125900  70.29
         ADDED     17 Z(I) = -Z(I)                                                         00126000  70.29
         ADDED        GRCOK = ANS                                                          00126100  70.29
         ADDED     20 RETURN                                                               00126200  70.29
         ADDED    700 CONTINUE                                                             00126300  70.29
         ADDED        GRCOK = -1.0                                                         00126400  70.29
         ADDED        RETURN                                                               00126500  70.29
         ADDED        END                                                                  00126600  70.29
         ADDED        FUNCTION PICK(I,D)                                                   00126700  70.29
         ADDED        DIMENSION     YK(5,10),      XD(5)                                   00126800  70.29
         ADDED        DATA YK     / 3.82, 0.68, 0.58, 0.50, 0.0,                           00126900  70.29
         ADDED      1               0.43, 0.36, 0.30, 0.26, 0.0 ,                          00127000  70.29
         ADDED      2               0.55, 0.45, 0.38, 0.33, 0.0 ,                          00127100  70.29
         ADDED      3               0.55, 0.45, 0.38, 0.33, 0.0 ,                          00127200  70.29
         ADDED      4               1.70, 1.40, 1.20, 1.00, 0.0 ,                          00127300  70.29
         ADDED      5               1.40, 1.20, 0.96, 0.80, 0.0/,                          00127400  70.29
         ADDED      6     XD      / 0.50, 1.00, 2.00, 4.00, 0.0/                           00127500  70.29
         ADDED        DI=D*12.0                                                            00127600  70.29
         ADDED        NPICK=6                                                              00127700  70.29
         ADDED        IF(I.LE.NPICK) GO TO 100                                             00127800  70.29
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LD SEQ  MESSAGE      FILENAME=MUFAN                    DECKNAME=MUFAN                                   YY.DD

        ADDED            WRITE(6,9000) MEM                                                  00127900  70.29
        ADDED       9000 FORMAT(1H1//////////1X,9H** MEMBER,I4,                             00128000  70.29
        ADDED          1          46H HAS AN ILLEGAL COMPONENT TYPE - CASE BYPASSED)       00128100  70.29
        ADDED            IERR=1                                                             00128200  70.29
        ADDED            RETURN                                                             00128300  70.29
        ADDED        100 CONTINUE                                                           00128400  70.29
        ADDED            IF(DI-XD(1)) 120,120,110                                           00128500  70.29
        ADDED        110 CONTINUE                                                           00128600  70.29
        ADDED            IF(DI-XD(6)) 130,140,140                                           00128700  70.29
        ADDED        120 CONTINUE                                                           00128800  70.29
        ADDED            PICK=YK(1,I)                                                       00128900  70.29
        ADDED            GO TO 150                                                          00129000  70.29
        ADDED        130 CONTINUE                                                           00129100  70.29
        ADDED            CALL LINT(XD,YK(1,I),DI,ANS)                                       00129200  70.29
        ADDED            PICK=ANS                                                           00129300  70.29
        ADDED            GO TO 150                                                          00129400  70.29
        ADDED        140 CONTINUE                                                           00129500  70.29
        ADDED            PICK=YK(6,I)                                                       00129600  70.29
        ADDED        150 CONTINUE                                                           00129700  70.29
        ADDED            RETURN                                                             00129800  70.29
        ADDED            END                                                                00129900  70.29
        ADDED            SUBROUTINE NETWRK                                                  00130000  70.29
        ADDED            COMMON  /MUFCOM/                                                   00130100  70.29
        ADDED          1     A(3),          COERR,          CONSTS(3,600), GC,              00130200  70.29
        ADDED          2     IBCON(600),    IBRAN(850),     IFLUID,        IOPT(10),        00130300  70.29
        ADDED          3     ITEMP,         ITYPE(600),     JBRPT(600),    LABEL(20,3),     00130400  70.29
        ADDED          4     LEVEL,         MBRAN(850),     NBCON(250),    NBRAN,           00130500  70.29
        ADDED          5     NBRPTS,        NNMAX,           NPTS(150),     PBRPT(250),     00130600  70.29
        ADDED          6     QBR(150),      QERR,           RHO(600),      TBULK(500),      00130700  70.29
        ADDED          7     TOLERR,        VISC(600),      XDOTA(500)                      00130800  70.29
        ADDED             COMMON  /MUFCOM/    INOUT(100),   NINOUT,   NDUMBP,      LOOP     00130900  70.29
        ADDED            COMMON  /L1COM/                                                    00131000  70.29
        ADDED          1     ALPHA(600),    INODE(1200),    JNODE(1200),   MEMNO(1200),     00131100  70.29
        ADDED          2     NMEM,          NPLANE(600),    P(500),        PHI(600),        00131200  70.29
        ADDED          3     Q(600),        RADLEN(600),    XYZ(500,3),    IEND(150,2),     00131300  70.29
        ADDED          4     NENDS(2)                                                       00131400  70.29
        ADDED            COMMON  /ARCOM/                                                    00131500  70.29
        ADDED          1                    IFIND(500),     IORDER(150),   NCON(500),       00131600  70.29
        ADDED          2                    NFIND(150)                                      00131700  70.29
        ADDED            COMMON  /ARCOM/     IORDBP(100)                                    00131800  70.29
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LD SEQ  MESSAGE        FILENAME=MUFAN                    DECKNAME=MUFAN                                YY.DDD

        ADDED                COMMON /PUNT/ MMEM, MNODES                                     00131900  70.29
        ADDED         C      WRITE(6,8001)  (INODE(I), MEMNO(I), JNODE(I), I=1,NMEM)        00132000  70.29
        ADDED         C8001 FORMAT(1H1,5HINODE,2X,5HMEMNO,2X,5HJNODE//(3X,I3,4X,I3,4X,I3))   00132100  70.29
        ADDED                DO 20 I=1,500                                                  00132200  70.29
        ADDED                NCON(I)=0                                                      00132300  70.29
        ADDED             20 CONTINUE                                                       00132400  70.29
        ADDED                INDEX=INODE(1)                                                 00132500  70.29
        ADDED                NCON(INDEX)=1                                                  00132600  70.29
        ADDED                NNODES=1                                                       00132700  70.29
        ADDED                DO 100 MEM=2,NMEM                                              00132800  70.29
        ADDED                IF(INODE(MEM).EQ.INODE(MEM-1)) GO TO 50                        00132900  70.29
        ADDED                INDEX=INODE(MEM)                                               00133000  70.29
        ADDED                NNODES=NNODES+1                                                00133100  70.29
        ADDED             50 CONTINUE                                                       00133200  70.29
        ADDED                NCON(INDEX)=NCON(INDEX)+1                                      00133300  70.29
        ADDED            100 CONTINUE                                                       00133400  70.29
        ADDED                NNMAX=INODE(NMEM)                                              00133500  70.29
        ADDED         C      WRITE(6,8001)  (INODE(I), MEMNO(I), JNODE(I), I=1,NMEM)        00133600  70.29
        ADDED         C      WRITE(6,7999) (I,NCON(I),P(I),I=1,NNMAX)                       00133700  70.29
        ADDED         C7999 FORMAT(1H1,3H I ,2X,4HNCON,2X,2H P/(1X,I3,3X,I3,2X,F4.1))       00133800  70.29
        ADDED                CALL BRANCH                                                    00133900  70.29
        ADDED         C      WRITE(6,8002) NINOUT,(INOUT(I),I=1,NINOUT)                     00134000  70.29
        ADDED         C8002 FORMAT(1H0,'NINOUT=',I4,' INOUT=',5I12)                         00134100  70.29
        ADDED                IF(LEVEL.GT.1) STOP                                            00134200  70.29
        ADDED                MMEM=NMEM                                                      00134300  70.29
        ADDED                MNODES=NNODES                                                  00134400  70.29
        ADDED                RETURN                                                         00134500  70.29
        ADDED                END                                                            00134600  70.29
        ADDED                SUBROUTINE BRANCH                                              00134700  70.29
        ADDED                COMMON  /MUFCOM/                                               00134800  70.29
        ADDED              1      A(3),         COERR,        CONSTS(3,600), GC,            00134900  70.29
        ADDED              2      IBCON(600),   IBRAN(850),   IFLUID,        IOPT(10),      00135000  70.29
        ADDED              3      ITEMP,        ITYPE(600),   JBRPT(600),    LABEL(20,3),   00135100  70.29
        ADDED              4      LEVEL,        MBRAN(850),   NBCON(250),    NBRAN,         00135200  70.29
        ADDED              5      NBRPTS,       NNMAX,        NPTS(150),     PBRPT(250),    00135300  70.29
        ADDED              6      QBR(150),     QERR,         RHO(600),      TBULK(500),    00135400  70.29
        ADDED              7      TOLERR,       VISC(600),    XDOTA(500)                    00135500  70.29
        ADDED                COMMON  /MUFCOM/  INOUT(100),  NINOUT,  NDUMBP,  LOOP          00135600  70.29
        ADDED                COMMON  /LICOM/                                                00135700  70.29
        ADDED              1      ALPHA(600),   INODE(1200),  JNODE(1200),   MEMNO(1200),   00135800  70.29
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OLD SEQ  MESSAGE        FILENAME=MUFAN               DECKNAME=MUFAN                                    YY.DD

         ADDED            2     NMEM,          NPLANE(600),   P(500),        PHI(600),       00135900  70.29
         ADDED            3     Q(600),        RADLEN(600),   XYZ(500,3),    IEND(150,2),    00136000  70.29
         ADDED            4     NENDS(2)                                                     00136100  70.29
         ADDED             COMMON  /ARCOM/                                                   00136200  70.29
         ADDED            1                    IFIND(500),    IORDER(150),   NCON(500),      00136300  70.29
         ADDED            2                    NFIND(150)                                    00136400  70.29
         ADDED             DIMENSION     IBRPT(600)                                          00136500  70.29
         ADDED             DIMENSION     ICONST(3,600)                                       00136600  70.29
         ADDED             EQUIVALENCE  (ICONST(1,1), CONSTS(1,1))                           00136700  70.29
         ADDED             NE=0                                                              00136800  70.29
         ADDED             NINOUT=0                                                          00136900  70.29
         ADDED             NSUM=0                                                            00137000  70.29
         ADDED             NBRPTS=0                                                          00137100  70.29
         ADDED        C                  CALCULATE NUMBER OF BRANCH POINTS, NBRPTS.          00137200  70.29
         ADDED             DO 180 I=1,NNMAX                                                  00137300  70.29
         ADDED             INODE(I)=0                                                        00137400  70.29
         ADDED             IFIND(I)=NSUM+1                                                   00137500  70.29
         ADDED             NSUM=NSUM+NCON(I)                                                 00137600  70.29
         ADDED             IF(NCON(I).LE.2)  GO TO 180                                       00137700  70.29
         ADDED             IF(P(I).LT.0.0)  GO TO 150                                        00137800  70.29
         ADDED             WRITE(6,9002)  I                                                  00137900  70.29
         ADDED        9002 FORMAT(1H0////1H0,107(1H*)/1H0,27X,'PRESSURE AT BRANCH NODE ',I3, 00138000  70.29
         ADDED           1 ' FIXED - ERROR SCAN CONTINUES'/1H0,107(1H*))                     00138100  70.29
         ADDED             P(I)=-1.0                                                         00138200  70.29
         ADDED             LEVEL=3                                                           00138300  70.29
         ADDED         150 CONTINUE                                                          00138400  70.29
         ADDED             NBRPTS=NBRPTS+1                                                   00138500  70.29
         ADDED             INODE(I)=NBRPTS                                                   00138600  70.29
         ADDED         180 CONTINUE                                                          00138700  70.29
         ADDED             IF(NBRPTS.LE.100)  GO TO 185                                      00138800  70.29
         ADDED             WRITE(6,9004)                                                     00138900  70.29
         ADDED        9004 FORMAT(1H0////1H0,107(1H*)/1H0,33X,'MORE THAN 100 BRANCH POINTS-',00139000  70.29
         ADDED           1  ' CASE SKIPPED'/1H0,107(1H*))                                    00139100  70.29
         ADDED             LEVEL=4                                                           00139200  70.29
         ADDED             RETURN                                                            00139300  70.29
         ADDED         185 CONTINUE                                                          00139400  70.29
         ADDED        C                  TRACE ALL BRANCHES IN THE NETWORK                   00139500  70.29
         ADDED             NRBP=0                                                            00139600  70.29
         ADDED             INDEX=0                                                           00139700  70.29
         ADDED             NUM=0                                                             00139800  70.29
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LD SEQ   MESSAGE      FILENAME=MUFAN              DECKNAME=MUFAN                                          YY.DDI

         ADDED              NFIN=0                                                                      00139900  70.29
         ADDED              NDUMBP=0                                                                    00140000  70.29
         ADDED              NBRAN=0                                                                     00140100  70.29
         ADDED              DO 600 I=1,NNMAX                                                            00140200  70.29
         ADDED        C                  SKIP NON - EXISTANT NODES                                      00140300  70.29
         ADDED              IF(NCON(I).LE.0)  GO TO 600                                                 00140400  70.29
         ADDED              NST=NFIN+1                                                                  00140500  70.29
         ADDED              NFIN=NFIN+NCON(I)                                                           00140600  70.29
         ADDED              WRITE(6,8001) I, NCON(I),NST,NFIN,INODE(I)                                  00140700  70.29
         ADDED         8001 FORMAT(1H0,'I=',I3,' NCON(I)=',I3,' NST=',I3,' NFIN=',I3,'INODE(I)00140800  70.29
         ADDED             1=',I3)                                                                      00140900  70.29
         ADDED              IF(INODE(I).LE.0)  GO TO 200                                                00141000  70.29
         ADDED        C                  NODE HAS ALREADY BEEN ASSIGNED A BRANCH PT. NO.                00141100  70.29
         ADDED              NBRPT=INODE(I)                                                              00141200  70.29
         ADDED              GO TO 250                                                                   00141300  70.29
         ADDED          200 CONTINUE                                                                    00141400  70.29
         ADDED              IF(P(I).GE.0.0)  GO TO 230                                                  00141500  70.29
         ADDED              IF(NCON(I)-2) 220,600,250                                                   00141600  70.29
         ADDED          220 CONTINUE                                                                    00141700  70.29
         ADDED              N=IFIND(I)                                                                  00141800  70.29
         ADDED              IF(MEMNO(N).LE.0)  GO TO 600                                                00141900  70.29
         ADDED              MEM=IABS(MEMNO(N))                                                          00142000  70.29
         ADDED              IF(MOD(ITYPE(MEM),100000000).GE.10000000)  GO TO 230                        00142100  70.29
         ADDED              WRITE(6,9010)  I                                                            00142200  70.29
         ADDED         9010 FORMAT(1H0///1H0,107(1H*)/1H0,15X,'NO FLOW OR PRESSURE CONSTRAI',00142300  70.29
         ADDED             1  'NT SPECIFIED FOR NODE',I4,' - ERROR SCAN CONTINUES'/1H0,                 00142400  70.29
         ADDED             2  107(1H*))                                                                 00142500  70.29
         ADDED              LEVEL=3                                                                     00142600  70.29
         ADDED              P(I)=0.0                                                                    00142700  70.29
         ADDED          230 CONTINUE                                                                    00142800  70.29
         ADDED        C                  ASSIGN A DUMMY BRANCH PT. NO. FOR FIXED PRESSURE               00142900  70.29
         ADDED        C                  NODES OR END PT. NODES                                         00143000  70.29
         ADDED              NDUMBP=NDUMBP+1                                                             00143100  70.29
         ADDED              NBRPT=NBRPTS+NDUMBP                                                         00143200  70.29
         ADDED              PBRPT(NBRPT)=P(I)                                                           00143300  70.29
         ADDED              IF(NCON(I).NE.1)  GO TO 240                                                 00143400  70.29
         ADDED              NINOUT =NINOUT+1                                                            00143500  70.29
         ADDED              INOUT(NINOUT)=NBRPT                                                         00143600  70.29
         ADDED          240 CONTINUE                                                                    00143700  70.29
         ADDED              INODE(I)=NBRPT                                                              00143800  70.29
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OLD SEQ   MESSAGE        FILENAME=MUFAN                  DECKNAME=MUFAN                          YY.DD

          ADDED         250 CONTINUE                                                  00143900  70.29
          ADDED             WRITE(6,8002) NRBP,NDUMBP,NBRPT                           00144000  70.29
          ADDED        8002 FORMAT(1H0,'NRBP=',I3,' NDUMBP=',I3,' NBRPT=',I3)         00144100  70.29
          ADDED       C               TRACE ALL BRANCHES ORIGINATING AT THIS NODE AND 00144200  70.29
          ADDED       C               STORE NETWORK DATA AS FOLLOWS...                00144300  70.29
          ADDED       C               BRANCH PT. NO. IBRAN(NUM) CONNECTED TO BRANCH PT. 00144400  70.29
          ADDED       C               NO. JBRAN(NUM) BY BRANCH NO. IBCON(NUM)         00144500  70.29
          ADDED             DO 500 N=NST,NFIN                                         00144600  70.29
          ADDED             IF(MEMNO(N).LE.0)  GO TO 500                              00144700  70.29
          ADDED       C               A BRANCH ORIGINATES AT THIS NODE - TRACE THE BRANCH 00144800  70.29
          ADDED             LAST=INDEX                                                00144900  70.29
          ADDED             NBRAN=NBRAN+1                                             00145000  70.29
          ADDED             IF(NBRAN.LE.150)  GO TO 260                               00145100  70.29
          ADDED             WRITE(6,9007)                                             00145200  70.29
          ADDED        9007 FORMAT(1H0///1H0,107(1H*)/1H0,25X,'MORE THAN 150 BRANCHES - CASE'00145300  70.29
A         ADDED          1   ,' SKIPPED'/1H0,107(1H*))                                00145400  70.29
-         ADDED             LEVEL=4                                                   00145500  70.29
3         ADDED             RETURN                                                    00145600  70.29
7         ADDED         260 CONTINUE                                                  00145700  70.29
          ADDED             JPOINT=N                                                  00145800  70.29
          ADDED       C               IF THE FIRST MEMBER IN THE BRANCH HAS A FIXED   00145900  70.29
          ADDED       C               FLOWRATE, STORE THE FLOWRATE AND SET THE FLAG=-1 00146000  70.29
          ADDED             MEM=MEMNO(N)                                              00146100  70.29
          ADDED             IF(MOD(ITYPE(MEM),100000000).LT.10000000) GO TO 270       00146200  70.29
          ADDED             QBR(NBRAN)=Q(MEM)                                         00146300  70.29
          ADDED             KFIX=-1                                                   00146400  70.29
          ADDED             GO TO 280                                                 00146500  70.29
          ADDED         270 CONTINUE                                                  00146600  70.29
          ADDED             KFIX=1                                                    00146700  70.29
          ADDED         280 CONTINUE                                                  00146800  70.29
          ADDED             IF(INDEX.GE.850)  GO TO 303                               00146900  70.29
          ADDED             IF(NCON(I).NE.1)  GO TO 290                               00147000  70.29
          ADDED             NE=NE+1                                                   00147100  70.29
          ADDED             IEND(NE,1)=I                                              00147200  70.29
          ADDED         290 CONTINUE                                                  00147300  70.29
          ADDED             INDEX=INDEX+1                                             00147400  70.29
          ADDED             IBRAN(INDEX)=I                                            00147500  70.29
          ADDED         300 CONTINUE                                                  00147600  70.29
          ADDED             MBRAN(INDEX)=MEMNO(JPOINT)                                00147700  70.29
          ADDED       C               IPOINT IS THE NEXT NODE IN THE BRANCH           00147800  70.29
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OLD SEQ  MESSAGE    FILENAME=MUFAN                 DECKNAME=MUFAN                                       YY.DD

         ADDED            IPOINT=JNODE(JPOINT)                                                00147900  70.29
         ADDED            INDEX=INDEX+1                                                       00148000  70.29
         ADDED            IF(INDEX.LE.850)  GO TO 304                                         00148100  70.29
         ADDED        303 CONTINUE                                                            00148200  70.29
         ADDED            WRITE(6,9005)                                                       00148300  70.29
         ADDED       9005 FORMAT(1H0///1H0,35X,'BRANCH STORAGE EXCEEDED - CASE SKIPPED'/      00148400  70.29
         ADDED          1 1H0,107(1H*))                                                       00148500  70.29
         ADDED            LEVEL=4                                                             00148600  70.29
         ADDED            RETURN                                                              00148700  70.29
         ADDED        304 CONTINUE                                                            00148800  70.29
         ADDED            IBRAN(INDEX)=IPOINT                                                 00148900  70.29
         ADDED            IF(NCON(IPOINT)-2) 320,310,400                                      00149000  70.29
         ADDED        310 CONTINUE                                                            00149100  70.29
         ADDED            JPOINT=IFIND(IPOINT)                                                00149200  70.29
         ADDED            IF(P(IPOINT).LT.0.0)  GO TO 315                                     00149300  70.29
         ADDED            IF(P(I).GE.0.0)  GO TO 344                                          00149400  70.29
         ADDED            IF(KFIX.GT.0)  GO TO 360                                            00149500  70.29
         ADDED            MEM=MEMNO(JPOINT)                                                   00149600  70.29
         ADDED            IF(MEM.GT.0)  GO TO 312                                             00149700  70.29
         ADDED            JPOINT=JPOINT+1                                                     00149800  70.29
         ADDED            MEM=MEMNO(JPOINT)                                                   00149900  70.29
         ADDED            IF(MEM.LE.0)  GO TO 318                                             00150000  70.29
         ADDED        312 CONTINUE                                                            00150100  70.29
         ADDED            ITYPE(MEM)=ITYPE(MEM)+10000000                                      00150200  70.29
         ADDED            Q(MEM)=Q(NBRAN)                                                     00150300  70.29
         ADDED            GO TO 360                                                           00150400  70.29
         ADDED      C                THE BRANCH DOES NOT TERMINATE AT IPOINT - STORE          00150500  70.29
         ADDED      C                MEMBER NO. AND SET POINTER TO NEXT POINT IN BRANCH       00150600  70.29
         ADDED        315 CONTINUE                                                            00150700  70.29
         ADDED            IF(MEMNO(JPOINT).GT.0)  GO TO 300                                   00150800  70.29
         ADDED            JPOINT=JPOINT+1                                                     00150900  70.29
         ADDED            IF(MEMNO(JPOINT).GT.0)  GO TO 300                                   00151000  70.29
         ADDED        318 CONTINUE                                                            00151100  70.29
         ADDED            WRITE(6,9008) IPOINT, JNODE(JPOINT-1), JNODE(JPOINT)                00151200  70.29
         ADDED       9008 FORMAT(1H0///1H0,107(1H*)/1H0,22X,'NODES',I4,', ',I4,' AND',        00151300  70.29
         ADDED          1  I4,' ARE CONNECTED ILLEGALLY - CASE SKIPPED'/1H0,107(1H*))         00151400  70.29
         ADDED            LEVEL=4                                                             00151500  70.29
         ADDED            RETURN                                                              00151600  70.29
         ADDED        320 CONTINUE                                                            00151700  70.29
         ADDED      C                THE BRANCH TERMINATES AT IPOINT, WHICH IS AN             00151800  70.29
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OLD SEQ  MESSAGE     FILENAME=MUFAN                 DECKNAME=MUFAN                          YY.DD

         ADDED     C                      END POINT NODE - CHECK FOR INCONSISTANT PRESSURE   00151900  70.29
         ADDED     C                      CCNSTRAINTS OR A SINGLE LOOP PROBLEM.             00152000  70.29
         ADDED             IF(NCON(I).EQ.1)  GO TO 330                                      00152100  70.29
         ADDED             IF(P(IPOINT).GE.0.0)  GO TO 360                                  00152200  70.29
         ADDED             IF(KFIX.EQ.-1)  GO TO 360                                        00152300  70.29
         ADDED             WRITE(6,9010)  IPOINT                                            00152400  70.29
         ADDED             LEVEL=3                                                          00152500  70.29
         ADDED             P(IPOINT)=0.0                                                    00152600  70.29
         ADDED             GO TO 360                                                        00152700  70.29
         ADDED         330 CONTINUE                                                         00152800  70.29
         ADDED             IF(NDUMBP.EQ.1.AND.NBRPTS.EQ.0)  GO TO 332                       00152900  70.29
         ADDED             LAST=LAST+1                                                      00153000  70.29
         ADDED             WRITE(6,9009)  (IBRAN(IB),IB=LAST,INDEX)                         00153100  70.29
         ADDED        9009 FORMAT(1H1///1H0,107(1H*)/1H0,20X,'THE FOLLOWING BRANCH IS NOT ',00153200  70.29
         ADDED           1  'CONNECTED TO THE NETWORK - CASE SKIPPED'//(4X,25I4))           00153300  70.29
         ADDED             LEVEL=4                                                          00153400  70.29
         ADDED             RETURN                                                           00153500  70.29
         ADDED         332 CONTINUE                                                         00153600  70.29
         ADDED     C                      THIS IS A SINGLE LOOP PROBLEM                     00153700  70.29
         ADDED             IF(P(IPOINT)) 334,336,336                                        00153800  70.29
         ADDED         334 CONTINUE                                                         00153900  70.29
         ADDED             IF(P(I)) 340,338,338                                             00154000  70.29
         ADDED         336 CONTINUE                                                         00154100  70.29
         ADDED             IF(P(I)) 338,342,342                                             00154200  70.29
         ADDED         338 CONTINUE                                                         00154300  70.29
         ADDED             IF(KFIX+1) 340,346,340                                           00154400  70.29
         ADDED         340 CONTINUE                                                         00154500  70.29
         ADDED             WRITE(6,9010)  IPOINT                                            00154600  70.29
         ADDED             LEVEL=4                                                          00154700  70.29
         ADDED             RETURN                                                           00154800  70.29
         ADDED         342 CONTINUE                                                         00154900  70.29
         ADDED             IF(KFIX+1) 346,344,346                                           00155000  70.29
         ADDED         344 CONTINUE                                                         00155100  70.29
         ADDED     C                      INCONSISTANT PRESSURE CONSTRAINTS                 00155200  70.29
         ADDED             WRITE(6,9003) I, IPOINT                                          00155300  70.29
         ADDED        9003 FORMAT(1H0///1H0,107(1H*)/1H0,23X,'2 NODES IN THE SAME BRANCH, ',00155400  70.29
         ADDED           1 I4,' AND',I4,' HAVE FIXED PRESSURES - ERROR SCAN CONTINUES'/1H0, 00155500  70.29
         ADDED           2 107(1H*))                                                        00155600  70.29
         ADDED             LEVEL=3                                                          00155700  70.29
         ADDED             IF(NCON(IPOINT).EQ.1)  GO TO 360                                 00155800  70.29
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OLD SEQ   MESSAGE          FILENAME=MUFAN                          DECKNAME=MUFAN                                      YY.DD

          ADDED                P(IPOINT)=-1.0                                                           00155900  70.29
          ADDED                GO TO 315                                                                00156000  70.29
          ADDED            346 CONTINUE                                                                 00156100  70.29
          ADDED                LEVEL=1                                                                  00156200  70.29
          ADDED                NBCON(1)=1                                                               00156300  70.29
          ADDED                NBCON(2)=1                                                               00156400  70.29
          ADDED            360 CONTINUE                                                                 00156500  70.29
          ADDED          C                        STORE NETWORK DATA FOR THIS BRANCH                    00156600  70.29
          ADDED                IF(INODE(IPOINT).GT.0)  GO TO 370                                        00156700  70.29
          ADDED          C                        ASSIGN DUMMY BRANCH PT. NO. TO IPOINT                 00156800  70.29
          ADDED                NDUMBP=NDUMBP+1                                                          00156900  70.29
          ADDED                JBP=NBRPTS+NDUMBP                                                        00157000  70.29
          ADDED                INODE(IPOINT)=JBP                                                        00157100  70.29
          ADDED                PBRPT(JBP)=P(IPOINT)                                                     00157200  70.29
          ADDED                IF(NCON(IPOINT).NE.1)  GO TO 410                                         00157300  70.29
          ADDED                NINOUT=NINOUT+1                                                          00157400  70.29
          ADDED                INOUT(NINOUT)=JBP                                                        00157500  70.29
          ADDED                GO TO 410                                                                00157600  70.29
          ADDED            370 CONTINUE                                                                 00157700  70.29
          ADDED          C                        USE PREVIOUSLY ASSIGNED BRANCH PT. NUMBER             00157800  70.29
          ADDED                JBP=INODE(IPOINT)                                                        00157900  70.29
          ADDED                GO TO 410                                                                00158000  70.29
          ADDED            400 CONTINUE                                                                 00158100  70.29
          ADDED          C                        THIS BRANCH TERMINATES AT IPOINT WHICH IS A BRANCH    00158200  70.29
          ADDED          C                        POINT - STORE NETWORK DATA FOR THIS BRANCH            00158300  70.29
          ADDED          C                        USE BRANCH PT. NO. PREVIOUSLY ASSIGNED                00158400  70.29
          ADDED                JBP=INODE(IPOINT)                                                        00158500  70.29
          ADDED          C                        STORE INFO FOR TEES                                   00158600  70.29
          ADDED                MNEG=0                                                                   00158700  70.29
          ADDED                JST=IFIND(IPOINT)                                                        00158800  70.29
          ADDED                JFIN=JST+NCON(IPOINT)-1                                                  00158900  70.29
          ADDED                DO 402 J=JST,JFIN                                                        00159000  70.29
          ADDED                IF(MEMNO(J).GT.0)  GO TO 402                                             00159100  70.29
          ADDED                IF(MNEG.NE.0)  GO TO 410                                                 00159200  70.29
          ADDED                MNEG=1                                                                   00159300  70.29
          ADDED            402 CONTINUE                                                                 00159400  70.29
          ADDED                DO 406 J=JST,JFIN                                                        00159500  70.29
          ADDED                MEM=MEMNO(J)                                                             00159600  70.29
          ADDED                IF(MEM.LE.0)  GO TO 406                                                  00159700  70.29
          ADDED                IT=MOD(ITYPE(MEM),10000)                                                 00159800  70.29
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OLD SEQ  MESSAGE         FILENAME=MUFAN                          DECKNAME=MUFAN                      YY.DD

         ADDED           IF(IT.LT.100)  GO TO 406                                          00159900  70.29
         ADDED           IF(IT.GT.1300)  GO TO 406                                         00160000  70.29
         ADDED           ICONST(3,MEM)=ICONST(3,MEM)+NBRAN*1000000                         00160100  70.29
         ADDED       406 CONTINUE                                                          00160200  70.29
         ADDED       410 CONTINUE                                                          00160300  70.29
         ADDED           IF(NUM+2.LE.300)  GO TO 420                                       00160400  70.29
         ADDED           WRITE(6,9006)                                                     00160500  70.29
         ADDED      9006 FORMAT(1H0////1H0,107(1H*)/1H0,30X,'MORE THAN 150 BRANCHES IN',   00160600  70.29
         ADDED         1  ' NETWORK - CASE SKIPPED'/1H0,107(1H*))                          00160700  70.29
         ADDED           LEVEL=4                                                           00160800  70.29
         ADDED           RETURN                                                            00160900  70.29
         ADDED       420 CONTINUE                                                          00161000  70.29
         ADDED     C                STORE THE FORWARD CONNECTION, NBRPT-TO-JBP BY NBRAN    00161100  70.29
         ADDED           NUM=NUM+1                                                         00161200  70.29
         ADDED           IBRPT(NUM)=NBRPT                                                  00161300  70.29
         ADDED           IBCON(NUM)=NBRAN                                                  00161400  70.29
         ADDED           JBRPT(NUM)=JBP                                                    00161500  70.29
         ADDED           WRITE(6,8004) NUM, IBRPT(NUM), IBCON(NUM), JBRPT(NUM)             00161600  70.29
         ADDED      8004 FORMAT(1H0,'NUM, IBRPT, IBCON, JBRPT',4I12)                       00161700  70.29
         ADDED       430 CONTINUE                                                          00161800  70.29
         ADDED     C               STORE THE REVERSE CONNECTION, JBP-TO-NBRPT BY -NBRAN    00161900  70.29
         ADDED           NUM=NUM+1                                                         00162000  70.29
         ADDED           IBRPT(NUM)=JBP                                                    00162100  70.29
         ADDED           IBCON(NUM)=-NBRAN                                                 00162200  70.29
         ADDED           JBRPT(NUM)=NBRPT                                                  00162300  70.29
         ADDED           WRITE(6,8004) NUM, IBRPT(NUM), IBCON(NUM), JBRPT(NUM)             00162400  70.29
         ADDED       450 CONTINUE                                                          00162500  70.29
         ADDED     C                CALCULATE NO. OF NODES INT THIS BRANCH                 00162600  70.29
         ADDED           NPTS(NBRAN)=KFIX*(INDEX-LAST)                                     00162700  70.29
         ADDED           IF(LEVEL.EQ.1)  RETURN                                            00162800  70.29
         ADDED       500 CONTINUE                                                          00162900  70.29
         ADDED       600 CONTINUE                                                          00163000  70.29
         ADDED     C                SORT ARRAYS TO MAKE ALL BRANCH PT. NOS. CONTIGUOUS     00163100  70.29
         ADDED           CALL SORT(3,NUM,IBRPT,IBCON,JBRPT)                                00163200  70.29
         ADDED     C                COUNT THE NO. OF BRANCHES CONNECTED TO EACH BRANCH     00163300  70.29
         ADDED     C                POINT AND STORE IN NBCON                               00163400  70.29
         ADDED           IB=1                                                              00163500  70.29
         ADDED           NBCON(1)=1                                                        00163600  70.29
         ADDED           DO 700 I=2,NUM                                                    00163700  70.29
         ADDED           IF(IBRPT(I).EQ.IBRPT(I-1))  GO TO 650                             00163800  70.29
```

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OLD SEQ   MESSAGE   FILENAME=MUFAN                DECKNAME=MUFAN                                    YY.DD

          ADDED           IB=IBRPT(I)                                                     00163900  70.29
          ADDED           NBCON(IB)=1                                                     00164000  70.29
          ADDED           GO TO 700                                                       00164100  70.29
          ADDED       650 CONTINUE                                                        00164200  70.29
          ADDED           NBCON(IB)=NBCON(IB)+1                                           00164300  70.29
          ADDED       700 CONTINUE                                                        00164400  70.29
          ADDED     C                   CHECK BRANCH FLOW CONSTRAINTS (IF ANY)            00164500  70.29
          ADDED           NENDS(1)=NE                                                     00164600  70.29
          ADDED           RETURN                                                          00164700  70.29
          ADDED           END                                                             00164800  70.29
          ADDED           SUBROUTINE LNK2                                                 00164900  70.29
          ADDED           COMMON  /MUFCOM/                                                00165000  70.29
          ADDED          1    A(3),          COERR,          CONSTS(3,600), GC,           00165100  70.29
          ADDED          2    IBCON(600),    IBRAN(850),     IFLUID,        IOPT(10),     00165200  70.29
          ADDED          3    ITEMP,         ITYPE(600),     JBRPT(600),    LABEL(20,3),  00165300  70.29
          ADDED          4    LEVEL,         MBRAN(850),     NBCON(250),    NBRAN,        00165400  70.29
          ADDED          5    NBRPTS,        NNMAX,          NPTS(150),     PBRPT(250),   00165500  70.29
          ADDED          6    QBR(150),      QERR,           RHO(600),      TBULK(500),   00165600  70.29
          ADDED          7    TOLERR,        VISC(600),      XDOTA(500)                   00165700  70.29
          ADDED           COMMON  /MUFCOM/    INOUT(100),     NINOUT,   NDUMBP,      LOOP 00165800  70.29
          ADDED           COMMON  /L2COM/    BRDP(150),      POTHED(150),      IFIND(250) 00165900  70.29
          ADDED           QERR=1.0                                                        00166000  70.29
          ADDED           NFIN=0                                                          00166100  70.29
          ADDED           DO 100 IB=1,NBRAN                                               00166200  70.29
          ADDED           NST=NFIN+1                                                      00166300  70.29
          ADDED           NFIN=NFIN+IABS(NPTS(IB))                                        00166400  70.29
          ADDED           NSTOP=NFIN-1                                                    00166500  70.29
          ADDED           POTHED(IB)=0.0                                                  00166600  70.29
          ADDED           BRDP(IB)=0.0                                                    00166700  70.29
          ADDED           DO 50 N=NST,NSTOP                                               00166800  70.29
          ADDED           M=MBRAN(N)                                                      00166900  70.29
          ADDED           I1=IBRAN(N)                                                     00167000  70.29
          ADDED           I2=IBRAN(N+1)                                                   00167100  70.29
          ADDED           POTHED(IB)=POTHED(IB)+RHO(M)*(XDOTA(I2)-XDOTA(I1))              00167200  70.29
          ADDED        50 CONTINUE                                                        00167300  70.29
          ADDED           M=MBRAN(NST)                                                    00167400  70.29
          ADDED           IF(MOD(ITYPE(M),100000000).GE.10000000) GO TO 100               00167500  70.29
          ADDED           QBR(IB)=1000.0                                                  00167600  70.29
          ADDED       100 CONTINUE                                                        00167700  70.29
          ADDED           IFIND(1)=1                                                      00167800  70.29
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LD SEQ  MESSAGE       FILENAME=MUFAN               DECKNAME=MUFAN                                        YY.DD

        ADDED            IF(LEVEL.EQ.1.AND.NPTS(1).LT.0)  RETURN                                00167900  70.29
        ADDED            DO 200 I=2,NBRAN                                                       00168000  70.29
        ADDED            IFIND(I)=IFIND(I-1)+IABS(NPTS(I-1))                                    00168100  70.29
        ADDED        200 CONTINUE                                                               00168200  70.29
        ADDED            CALL SPSOLV                                                            00168300  70.29
        ADDED            RETURN                                                                 00168400  70.29
        ADDED            END                                                                    00168500  70.29
        ADDED            FUNCTION  RNAT1(X)                                                     00168600  70.29
        ADDED            DIMENSION TEMPA(8), RNAKT(8), VNAKT(8)                                 00168700  70.29
        ADDED            DATA TEMPA/      200., 400., 600., 800., 1000., 1200., 1400., 0.0/00168800  70.29
        ADDED            DATA RNAKT/       53., 51.82, 49.64, 48., 46.31, 44.64, 42.96, 0./00168900  70.29
        ADDED            DATA VNAKT/      1.17, .78, .58, .48, .418, .364, .31, 0.0/            00169000  70.29
        ADDED            ENTRY RNAT (TEMP, ISTEP, IERR)                                         00169100  70.29
        ADDED            IERR = 1                                                               00169200  70.29
        ADDED            RNAT1 = 53.0                                                           00169300  70.29
        ADDED            RNAT=RNAT1                                                             00169400  70.29
        ADDED            IF (TEMP .LT. 200.0) GO TO 10                                          00169500  70.29
        ADDED            RNAT1 = 42.96                                                          00169600  70.29
        ADDED            RNAT=RNAT1                                                             00169700  70.29
        ADDED            IF (TEMP .GT. 1400.0) GO TO 10                                         00169800  70.29
        ADDED            CALL INT4 (TEMPA,RNAKT, TEMP, ANS)                                     00169900  70.29
        ADDED            RNAT = ANS                                                             00170000  70.29
        ADDED            RETURN                                                                 00170100  70.29
        ADDED            ENTRY VNAT (TEMP, ISTEP, IERR)                                         00170200  70.29
        ADDED            IERR =1                                                                00170300  70.29
        ADDED            RNAT1 = 1.17 / 3600.0                                                  00170400  70.29
        ADDED            VNAT=RNAT1                                                             00170500  70.29
        ADDED            IF (TEMP .LT. 200.0) GO TO 10                                          00170600  70.29
        ADDED            RNAT1 = 0.31 / 3600.0                                                  00170700  70.29
        ADDED            VNAT=RNAT1                                                             00170800  70.29
        ADDED            IF (TEMP .GT. 1400.0) GO TO 10                                         00170900  70.29
        ADDED            CALL INT4 (TEMPA, VNAKT, TEMP, ANS)                                    00171000  70.29
        ADDED            VNAT = ANS  / 3600.0                                                   00171100  70.29
        ADDED            RETURN                                                                 00171200  70.29
        ADDED      C                                                                            00171300  70.29
        ADDED      C ERROR MESSAGE                                                              00171400  70.29
        ADDED         10 WRITE (6,1000) TEMP, ISTEP, RNAT1                                      00171500  70.29
        ADDED       1000 FORMAT (100(1H*)/ 1H0,103HTHE RANGE OF TEMPERATURE VALUES FOR LIQU00171600  70.29
        ADDED           1ID SODIUM HAVE BEEN EXCEEDED AND INTERPOLATION IS NOT POSSIBLE /  00171700  70.29
        ADDED           2 1H0, 7HTEMP = , F10.2, 10X, 8HISTEP = , I5, 10X, 11HFUNCTION = , 00171800  70.29
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LD SEQ  MESSAGE     FILENAME=MUFAN                 DECKNAME=MUFAN                                  YY.DDD

        ADDED        3 F10.5/)                                                             00171900  70.29
        ADDED         IERR = 2                                                             00172000  70.29
        ADDED         RETURN                                                               00172100  70.29
        ADDED         END                                                                  00172200  70.29
        ADDED         FUNCTION RHGLT1(X)                                                   00172300  70.29
        ADDED         DIMENSION TEMPA (10), RHOGLT(10), VISGLT(10)                         00172400  70.29
        ADDED         DATA TEMPA/ 50., 100., 200., 400., 600., 800., 1000., 1200.,         00172500  70.29
        ADDED        1 1250., 0.0/                                                         00172600  70.29
        ADDED         DATA RHOGLT/ 848., 843., 835., 817.5, 801., 784., 768., 753.,        00172700  70.29
        ADDED        1 749.5, 0.0/                                                         00172800  70.29
        ADDED         DATA VISGLT/ 3.87, 3.5, 3.03, 2.48, 2.26, 1.96, 1.82, 1.725, 1.7,    00172900  70.29
        ADDED        1 0.0/                                                                00173000  70.29
        ADDED         ENTRY RHGLT (TEMP, ISTEP, IERR)                                      00173100  70.29
        ADDED         IERR = 1                                                             00173200  70.29
        ADDED         RHGLT1 = 848.0                                                       00173300  70.29
        ADDED         RHGLT=RHGLT1                                                         00173400  70.29
        ADDED         IF(TEMP .LT. 50.0) GO TO 10                                          00173500  70.29
        ADDED         RHGLT1 = 749.5                                                       00173600  70.29
        ADDED         RHGLT=RHGLT1                                                         00173700  70.29
        ADDED         IF (TEMP . GT . 1250.0) GO TO 10                                     00173800  70.29
        ADDED         CALL INT4 (TEMPA, RHOGLT, TEMP, ANS)                                 00173900  70.29
        ADDED         RHGLT = ANS                                                          00174000  70.29
        ADDED         RETURN                                                               00174100  70.29
        ADDED         ENTRY VHGLT (TEMP, ISTEP, IERR)                                      00174200  70.29
        ADDED         IERR = 1                                                             00174300  70.29
        ADDED         RHGLT1 = 3.87 / 3600.0                                               00174400  70.29
        ADDED         VHGLT=RHGLT1                                                         00174500  70.29
        ADDED         IF(TEMP .LT. 50.0) GO TO 10                                          00174600  70.29
        ADDED         RHGLT1 = 1.7 / 3600.0                                                00174700  70.29
        ADDED         VHGLT=RHGLT1                                                         00174800  70.29
        ADDED         IF (TEMP . GT . 1250.0) GO TO 10                                     00174900  70.29
        ADDED         CALL INT4 (TEMPA, VISGLT, TEMP, ANS)                                 00175000  70.29
        ADDED         VHGLT = ANS  / 3600.0                                                00175100  70.29
        ADDED         RETURN                                                               00175200  70.29
        ADDED   C                                                                          00175300  70.29
        ADDED   C ERROR MESSAGE                                                            00175400  70.29
        ADDED      10 WRITE (6,1000) TEMP, ISTEP, RHGLT1                                   00175500  70.29
        ADDED    1000 FORMAT(1X,100(1H*)/1X,104HTHE RANGE OF TEMPERATURE VALUES FOR LIQU00175600  70.29
        ADDED        1ID MERCURY HAVE BEEN EXCEEDED AND INTERPOLATION IS NOT POSSIBLE / 00175700  70.29
        ADDED        2 1H0,  7HTEMP = , F10.2, 10X,  8HISTEP = , I5, 10X, 11HFUNCTION = 00175800  70.29
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LD SEQ  MESSAGE    FILENAME=MUFAN                    DECKNAME=MUFAN                              YY.DD

        ADDED        1   , F10.5/)                                                     00175900  70.29
        ADDED         IERR = 2                                                         00176000  70.29
        ADDED         RETURN                                                           00176100  70.29
        ADDED         END                                                              00176200  70.29
        ADDED         FUNCTION R4P3E (X)                                               00176300  70.29
        ADDED         DIMENSION  TEMPA( 9),  RHOP3E( 9), VISP3E( 9)                    00176400  70.29
        ADDED         DATA TEMPA / 100., 150., 200., 300., 400., 500., 600., 700., 0.0/ 00176500  70.29
        ADDED         DATA RHOP3E/ 72.8, 71.7, 70.3, 66.45, 64.6, 61.6, 58.8, 55.9, 0.0/00176600  70.29
        ADDED         DATA VISP3E/ 175., 43., 17.2, 6.45, 3.4, 2.04, 1.35, 1.04, 0.0/  00176700  70.29
        ADDED         ENTRY R4P3ET (TEMP, ISTEP, IERR)                                 00176800  70.29
        ADDED         IERR = 1                                                         00176900  70.29
        ADDED         R4P3E = 72.8                                                     00177000  70.29
        ADDED         R4P3ET=R4P3E                                                     00177100  70.29
        ADDED         IF (TEMP .LT. 100.0) GO TO 10                                    00177200  70.29
        ADDED         R4P3E = 55.9                                                     00177300  70.29
        ADDED         R4P3ET=R4P3E                                                     00177400  70.29
        ADDED         IF (TEMP .GT. 700.0) GO TO 10                                    00177500  70.29
        ADDED         CALL INT4 ( TEMPA, RHOP3E, TEMP, ANS)                            00177600  70.29
        ADDED         R4P3ET= ANS                                                      00177700  70.29
        ADDED         RETURN                                                           00177800  70.29
        ADDED         ENTRY V4P3ET (TEMP, ISTEP, IERR)                                 00177900  70.29
        ADDED         IERR = 1                                                         00178000  70.29
        ADDED         R4P3E = 175.0 / 3600.0                                           00178100  70.29
        ADDED         V4P3ET=R4P3E                                                     00178200  70.29
        ADDED         IF (TEMP .LT. 100.0) GO TO 10                                    00178300  70.29
        ADDED         R4P3E = 1.04 / 3600.0                                            00178400  70.29
        ADDED         V4P3ET=R4P3E                                                     00178500  70.29
        ADDED         IF (TEMP .GT. 700.0) GO TO 10                                    00178600  70.29
        ADDED         CALL INT4 (TEMPA, VISP3E, TEMP, ANS)                             00178700  70.29
        ADDED         V4P3ET= ANS / 3600.0                                             00178800  70.29
        ADDED         RETURN                                                           00178900  70.29
        ADDED   C                                                                      00179000  70.29
        ADDED   C ERROR MESSAGE                                                        00179100  70.29
        ADDED      10 WRITE (6, 1000) TEMP, ISTEP, R4P3E                               00179200  70.29
        ADDED    1000 FORMAT(1X,100(1H*)/1X,100HTHE RANGE OF TEMPERATURE VALUES FOR MIX 00179300  70.29
        ADDED        1- 4P3E HAVE BEEN EXCEEDED AND INTERPOLATION IS NOT POSSIBLE / 1H0,00179400  70.29
        ADDED        2 7HTEMP = , F10.2, 10X, 8HISTEP = , I5, 10X, 11HFUNCTION = , F10.500179500  70.29
        ADDED        3 /)                                                              00179600  70.29
        ADDED         IERR = 2                                                         00179700  70.29
        ADDED         RETURN                                                           00179800  70.29
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      OLD VOL=SER=004783              DRC UPDATE                  NEW VOL=SER=007208

LD SEQ   MESSAGE          FILENAME=MUFAN               DECKNAME=MUFAN                              YY.DDD

         ADDED                  END                                                      00179900  70.29
         ADDED                  FUNCTION H2OT(X)                                         00180000  70.29
         ADDED                  DIMENSION TEMPA (16), RHOH2O (16), VISH2O (16)           00180100  70.29
         ADDED                  DATA TEMPA/ 32., 40., 60., 80., 100., 150., 200., 250., 300.,  00180200  70.29
         ADDED                 1 350., 400., 450., 500., 550., 600., 0.0/                00180300  70.29
         ADDED                  DATA RHOH2O/ 62.4, 62.4, 62.3, 62.2, 62.0, 61.2, 60.1, 58.8, 57.3,00180400  70.29
         ADDED                 1 55.6, 53.6, 51.6, 49.0, 45.9, 42.4, 0.0/                00180500  70.29
         ADDED                  DATA VISH2O/ .0012, .00104, .00076, .000578, 0.000458, .000292,  00180600  70.29
         ADDED                 1 .000205, .000158, .000126, .000105, .000091, .000080, .000071,  00180700  70.29
         ADDED                 2 .000064, .000058, 0.0/                                  00180800  70.29
         ADDED                  ENTRY RH2OT (TEMP, ISTEP, IERR)                          00180900  70.29
         ADDED                  IERR = 1                                                 00181000  70.29
         ADDED                  H2OT = 62.4                                              00181100  70.29
         ADDED                  RH2OT=H2OT                                               00181200  70.29
         ADDED                  IF (TEMP .LT. 32.0) GO TO 10                             00181300  70.29
         ADDED                  H2OT = 42.4                                              00181400  70.29
         ADDED                  RH2OT=H2OT                                               00181500  70.29
         ADDED                  IF (TEMP .GT. 600.0) GO TO 10                            00181600  70.29
         ADDED                  CALL INT4 (TEMPA, RHOH2O, TEMP, ANS)                     00181700  70.29
         ADDED                  RH2OT= ANS                                               00181800  70.29
         ADDED                  RETURN                                                   00181900  70.29
         ADDED                  ENTRY VH2OT (TEMP, ISTEP, IERR)                          00182000  70.29
         ADDED                  IERR = 1                                                 00182100  70.29
         ADDED                  H2OT = .0012                                             00182200  70.29
         ADDED                  VH2OT=H2OT                                               00182300  70.29
         ADDED                  IF (TEMP .LT. 32.0) GO TO 10                             00182400  70.29
         ADDED                  H2OT = .000058                                           00182500  70.29
         ADDED                  VH2OT=H2OT                                               00182600  70.29
         ADDED                  IF (TEMP .GT. 600.0) GO TO 10                            00182700  70.29
         ADDED                  CALL INT4 (TEMPA, VISH2O, TEMP, ANS)                     00182800  70.29
         ADDED                  VH2OT= ANS                                               00182900  70.29
         ADDED                  RETURN                                                   00183000  70.29
         ADDED            C                                                              00183100  70.29
         ADDED            C ERROR MESSAGE                                                00183200  70.29
         ADDED            C                                                              00183300  70.29
         ADDED               10 WRITE (6,1000) TEMP, ISTEP, H2OT                         00183400  70.29
         ADDED             1000 FORMAT (1X, 100(1H*)/ 1X,  93HTHE RANGE OF TEMPERATURE VALUES FOR 00183500  70.29
         ADDED                 1H2O HAVE BEEN EXCEEDED AND INTERPOLATION IS NOT POSSIBLE / 1H0,   00183600  70.29
         ADDED                 2 7HTEMP = , F10.2, 10X, 8HISTEP = , I5, 10X, 11HFUNCTION = ,F10.5)00183700  70.29
         ADDED                  IERR = 2                                                 00183800  70.29
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LD SEQ   MESSAGE      FILENAME=MUFAN                    DECKNAME=MUFAN                          YY.DDD

         ADDED            RETURN                                                     00183900  70.29
         ADDED            END                                                        00184000  70.29
         ADDED            FUNCTION FLARB (X)                                         00184100  70.29
         ADDED            COMMON /FARB/ FRHO(10), FVISC(10), FTEMP(10)               00184200  70.29
         ADDED            ENTRY RARBT (TEMP, ISTEP, IERR)                            00184300  70.29
         ADDED            IERR = 1                                                   00184400  70.29
         ADDED            FLARB = FRHO(1)                                            00184500  70.29
         ADDED            RARBT=FLARB                                                00184600  70.29
         ADDED            IF ( TEMP .LT. FTEMP(1)) GO TO 10                          00184700  70.29
         ADDED            FLARB = FRHO(9)                                            00184800  70.29
         ADDED            RARBT=FLARB                                                00184900  70.29
         ADDED            IF (TEMP .GT. FTEMP(9)) GO TO 10                           00185000  70.29
         ADDED            CALL INT4 (FTEMP, FRHO, TEMP, ANS)                         00185100  70.29
         ADDED            RARBT = ANS                                                00185200  70.29
         ADDED            RETURN                                                     00185300  70.29
         ADDED            ENTRY VARBT (TEMP, ISTEP, IERR)                            00185400  70.29
         ADDED            IERR = 1                                                   00185500  70.29
         ADDED            FLARB = FVISC(1)                                           00185600  70.29
         ADDED            VARBT=FLARB                                                00185700  70.29
         ADDED            IF (TEMP . LT . FTEMP(1)) GO TO 10                         00185800  70.29
         ADDED            FLARB = FVISC(9)                                           00185900  70.29
         ADDED            VARBT=FLARB                                                00186000  70.29
         ADDED            IF (TEMP .GT. FTEMP(9)) GO TO 10                           00186100  70.29
         ADDED            CALL INT4 (FTEMP, FVISC, TEMP, ANS)                        00186200  70.29
         ADDED            VARBT = ANS                                                00186300  70.29
         ADDED            RETURN                                                     00186400  70.29
         ADDED      C                                                                00186500  70.29
         ADDED      C ERROR MESSAGE                                                  00186600  70.29
         ADDED      C                                                                00186700  70.29
         ADDED         10 WRITE (6,1000) TEMP, ISTEP, FLARB                          00186800  70.29
         ADDED       1000 FORMAT (1X, 100(1H*)/ 1X, 46HTHIS TEMPERATURE EXCEEDS ITS ESTABLIS00186900  70.29
         ADDED           1HED RANGE, 10X, 7HTEMP = , F10.3/ 1HO, 33HPROGRAM IS IN EXECUTION 00187000  70.29
         ADDED           2STEP NO. , I6, 4X, 33HTHE DESIRED VALUE HAS BEEN SET TO, F10.5/1X,00187100  70.29
         ADDED           3 100(1H*))                                                 00187200  70.29
         ADDED            IERR = 2                                                   00187300  70.29
         ADDED            RETURN                                                     00187400  70.29
         ADDED            END                                                        00187500  70.29
         ADDED            SUBROUTINE SPSOLV                                          00187600  70.29
         ADDED            REAL*8        BMATRX,        FLINBP,        PDUBL          00187700  70.29
         ADDED            COMMON   /MUFCOM/                                          00187800  70.29
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LD SEQ  MESSAGE   FILENAME=MUFAN                        DECKNAME=MUFAN                                YY.DDD

        ADDED         1     A(3),          TOLABS,        CONSTS(3,600),  GC,                00187900  70.29
        ADDED         2     IBCON(600),    IBRAN(850),    IFLUID,         IOPT(10),          00188000  70.29
        ADDED         3     ITEMP,         ITYPE(600),    JBRPT(600),     LABEL(20,3),       00188100  70.29
        ADDED         4     LEVEL,         MBRAN(850),    NBCON(250),     NBRAN,             00188200  70.29
        ADDED         5     NBRPTS,        NNMAX,          NPTS(150),      PBRPT(250),       00188300  70.29
        ADDED         6     QBR(150),      QERR,          RHO(600),       TBULK(500),        00188400  70.29
        ADDED         7     TOLERR,        VISC(600),     XDOTA(500)                         00188500  70.29
        ADDED          COMMON  /MUFCOM/  INOUT(100),  NINOUT,  NDUMBP,  LOOP                 00188600  70.29
        ADDED          COMMON  /L2COM/   BRDP(150),     POTHED(150),     IFIND(250)          00188700  70.29
        ADDED          COMMON  /PQCHAR/                                                      00188800  70.29
        ADDED         1     PCHAR(11,50),  PCMAX(50),     QCHAR(11,50),   QCMAX(50)          00188900  70.29
        ADDED          COMMON  /PQCHAR/  PCMIN(50),     QCMIN(50)                            00189000  70.29
        ADDED          DIMENSION     BMATRX( 70, 70),  BRCON(150),  FLINBP(100)              00189100  70.29
        ADDED          DIMENSION     DPUMP(150),     PDUBL(70)                               00189200  70.29
        ADDED          DIMENSION     ICONST(3,600)                                           00189300  70.29
        ADDED          EQUIVALENCE  (ICONST(1,1), CONSTS(1,1))                               00189400  70.29
        ADDED          EQUIVALENCE  (LIMIT,IOPT(1)), (INFT,IOPT(2))                          00189500  70.29
        ADDED          ITER8=0                                                               00189600  70.29
        ADDED          INIT=1                                                                00189700  70.29
        ADDED          NDO=NBRPTS+NDUMBP                                                     00189800  70.29
        ADDED          DO 40 I=NBRPTS,NDO                                                    00189900  70.29
        ADDED          PDUBL(I)=DBLE(PBRPT(I))                                               00190000  70.29
        ADDED       40 CONTINUE                                                              00190100  70.29
        ADDED     C                   ZERO OUT PUMP PRESSURE RISE ARRAY                      00190200  70.29
        ADDED          DO 50 I=1,NBRAN                                                       00190300  70.29
        ADDED          DPUMP(I)=0.0                                                          00190400  70.29
        ADDED       50 CONTINUE                                                              00190500  70.29
        ADDED      100 CONTINUE                                                              00190600  70.29
        ADDED          RELMAX=0.0                                                            00190700  70.29
        ADDED          MAXERR=1                                                              00190800  70.29
        ADDED     C                   ZERO OUT CONDUCTANCE MATRIX                            00190900  70.29
        ADDED          DO 150 I=1,NBRPTS                                                     00191000  70.29
        ADDED          DO 150 J=1,NBRPTS                                                     00191100  70.29
        ADDED          BMATRX(I,J)=0.0D0                                                     00191200  70.29
        ADDED      150 CONTINUE                                                              00191300  70.29
EBUG00  ADDED     C    WRITE(6,8000) ITER8                                                   00191400  70.29
        ADDED     C8000 FORMAT(1H1,45(1H*),I4,'TH ITERATION',45(1H*))                        00191500  70.29
        ADDED          NFIN=0                                                                00191600  70.29
        ADDED     C                   COMPUTE CONDUCTANCES OF ALL BRANCHES                   00191700  70.29
        ADDED     C                   WITH UNCONSTRAINED FLOW RATES.                         00191800  70.29
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OLD SEQ   MESSAGE      FILENAME=MUFAN                  DECKNAME=MUFAN                   YY.DD

          ADDED              NBP2=0                                           00191900  70.29
          ADDED              DO 250 IBP=1,NDO                                 00192000  70.29
          ADDED              NBP1=NBP2+1                                      00192100  70.29
          ADDED              NBP2=NBP2+IABS(NBCON(IBP))                       00192200  70.29
          ADDED              DO 250 NBP=NBP1,NBP2                             00192300  70.29
          ADDED              IF(IBCON(NBP).LE.0)  GO TO 250                   00192400  70.29
          ADDED              IB=IBCON(NBP)                                    00192500  70.29
          ADDED              IF(NPTS(IB).LE.0)  GO TO 250                     00192600  70.29
          ADDED              NST=IFIND(IB)                                    00192700  70.29
          ADDED              NFIN=NST+IABS(NPTS(IB))-1                        00192800  70.29
          ADDED              QB=ABS(QBR(IB))                                  00192900  70.29
          ADDED              BRRES=0.0                                        00193000  70.29
          ADDED              LASTM=NFIN-1                                     00193100  70.29
          ADDED              DO 200 N=NST,LASTM                               00193200  70.29
          ADDED              MEM=MBRAN(N)                                     00193300  70.29
          ADDED              IT=MOD(ITYPE(MEM),100000000)                     00193400  70.29
          ADDED              IF(ITYPE(MEM).NE.300000000)  GO TO 158           00193500  70.29
          ADDED              DPUMP(IB)=CONSTS(2,MEM)                          00193600  70.29
          ADDED              GO TO 200                                        00193700  70.29
          ADDED          158 CONTINUE                                         00193800  70.29
          ADDED              IF(IT.LT.1000000)  GO TO 180                     00193900  70.29
          ADDED              IT=IT/1000000 +41                                00194000  70.29
          ADDED          160 CONTINUE                                         00194100  70.29
          ADDED              IF(ITER8.GT.0)  GO TO 162                        00194200  70.29
          ADDED              DPUMP(IB)=(PCMIN(IT)+PCMAX(IT))/2.0              00194300  70.29
          ADDED              GO TO 164                                        00194400  70.29
          ADDED          162 CONTINUE                                         00194500  70.29
          ADDED              DPUMP(IB)=0.5*(PTABLE(IT,QB)+DPUMP(IB))          00194600  70.29
          ADDED          164 CONTINUE                                         00194700  70.29
          ADDED              GO TO 200                                        00194800  70.29
          ADDED          180 CONTINUE                                         00194900  70.29
          ADDED          190 CONTINUE                                         00195000  70.29
          ADDED              BRRES=BRRES+RESIST(MEM,QB,INIT)                  00195100  70.29
DEBUG01   ADDED        C     WRITE(6,8001) IB,BRRES                           00195200  70.29
          ADDED        C8001 FORMAT(1X,'DEBUG01  IB=',I4,' BRRES=',G13.6)     00195300  70.29
          ADDED          200 CONTINUE                                         00195400  70.29
          ADDED              IF(ABS(BRRES).LT.1.0E-20)  BRRES=SIGN(1.0E-20,BRRES) 00195500  70.29
          ADDED              BRCON(IB)=1.0/BRRES                              00195600  70.29
          ADDED          250 CONTINUE                                         00195700  70.29
          ADDED              INIT=2                                           00195800  70.29
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         OLD VOL=SER=004783                    DRC UPDATE                    NEW VOL=SER=007208

OLD SEQ   MESSAGE       FILENAME=MUFAN                     DECKNAME=MUFAN                               YY.DD

DEBUG02   ADDED      C       WRITE(6,8002) (ID,BRCON(ID),ID=1,NBRAN)                            00195900  70.29
          ADDED      C8002 FORMAT(1X,'DEBUG02  BRANCH  BRCON'/(11X,I4,4X,G13.6))                00196000  70.29
          ADDED            IF(LEVEL.EQ.1)  GO TO 750                                            00196100  70.29
          ADDED      C                                                                          00196200  70.29
          ADDED      C                   SET UP MATRIX OF BRANCH CONDUCTANCES FOR               00196300  70.29
          ADDED      C                   NODE EQUATIONS AND VECTOR OF INFLOWS TO                00196400  70.29
          ADDED      C                   EACH NODE.  THE NODES ARE THE REAL BRANCH              00196500  70.29
          ADDED      C                   POINTS IN THE NETWORK.                                 00196600  70.29
          ADDED      C                                                                          00196700  70.29
          ADDED            NFIN=0                                                               00196800  70.29
          ADDED            DO 650 IBRPT=1,NBRPTS                                                00196900  70.29
          ADDED            FLINBP(IBRPT)=0.0D0                                                  00197000  70.29
          ADDED            NST=NFIN+1                                                           00197100  70.29
          ADDED            NFIN=NFIN+IABS(NBCON(IBRPT))                                         00197200  70.29
          ADDED        280 CONTINUE                                                             00197300  70.29
          ADDED            DO 600 N=NST,NFIN                                                    00197400  70.29
          ADDED            J=JBRPT(N)                                                           00197500  70.29
          ADDED            JBC=IBCON(N)                                                         00197600  70.29
          ADDED            IBC=IABS(JBC)                                                        00197700  70.29
          ADDED            SGN=JBC/IBC                                                          00197800  70.29
DEBUG05   ADDED      C     WRITE(6,8005) J, JBC, NBCON(IBRPT)                                   00197900  70.29
          ADDED      C8005 FORMAT(1X,'DEBUG05  J=',I4,' JBC=',I4,' NBCON(IBRPT)=',I4)           00198000  70.29
          ADDED        300 CONTINUE                                                             00198100  70.29
          ADDED            IF(J.LE.NBRPTS) GO TO 400                                            00198200  70.29
          ADDED            IF(NPTS(IBC).GT.0)  GO TO 350                                        00198300  70.29
          ADDED            FLINBP(IBRPT)=FLINBP(IBRPT)-DBLE(SGN*QBR(IBC))                       00198400  70.29
          ADDED            GO TO 600                                                            00198500  70.29
          ADDED        350 CONTINUE                                                             00198600  70.29
          ADDED      C                   THIS BRANCH HAS A FIXED PRESSURE AT ONE END.           00198700  70.29
          ADDED      C                   CALCULATE THE FORCING TERM (INFLOW) DUE TO             00198800  70.29
          ADDED      C                   THE FIXED PRESSURE.                                    00198900  70.29
          ADDED      C                                                                          00199000  70.29
          ADDED            FLINBP(IBRPT)=FLINBP(IBRPT)                                          00199100  70.29
          ADDED          1     + DBLE(BRCON(IBC)*(PBRPT(J) -SGN*(POTHED(IBC)+DPUMP(IBC))))     00199200  70.29
          ADDED            GO TO 500                                                            00199300  70.29
          ADDED        400 CONTINUE                                                             00199400  70.29
          ADDED            IF(NPTS(IBC).GT.0) GO TO 450                                         00199500  70.29
          ADDED            IF(DPUMP(IBC).NE.0.0)  GO TO 450                                     00199600  70.29
          ADDED            FLINBP(IBRPT)=FLINBP(IBRPT)-DBLE(SGN*QBR(IBC))                       00199700  70.29
          ADDED            GO TO 600                                                            00199800  70.29
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LD SEQ   MESSAGE       FILENAME=MUFAN                  DECKNAME=MUFAN                                     YY.DD

         ADDED          450 CONTINUE                                                          00199900  70.29
         ADDED              BMATRX(IBRPT,J)=-DBLE(BRCON(IBC)) + BMATRX(IBRPT,J)               00200000  70.29
         ADDED              FLINBP(IBRPT)=FLINBP(IBRPT)                                       00200100  70.29
         ADDED             1                -DBLE(SGN*BRCON(IBC)*(POTHED(IBC)+DPUMP(IBC)))    00200200  70.29
         ADDED          500 CONTINUE                                                          00200300  70.29
         ADDED              BMATRX(IBRPT,IBRPT)=BMATRX(IBRPT,IBRPT)+DBLE(BRCON(IBC))          00200400  70.29
         ADDED          600 CONTINUE                                                          00200500  70.29
         ADDED          650 CONTINUE                                                          00200600  70.29
EBUG06   ADDED         C    CALL MPRINT(NBRPTS,NBRPTS,100,100,BMATRX)                         00200700  70.29
EBUG07   ADDED         C    WRITE(6,8007) (IF,FLINBP(IF),IF=1,NBRPTS)                         00200800  70.29
         ADDED         C8007 FORMAT(1X,'DEBUG07  IBRPT  FLINBP'/(10X,I4,3X,G13.6))            00200900  70.29
         ADDED         C                                                                      00201000  70.29
         ADDED         C                SOLVE THE SIMULTANEOUS NODE EQUATIONS                 00201100  70.29
         ADDED         C                FOR THE PRESSURES AT THE BRANCH POINTS                00201200  70.29
         ADDED         C                                                                      00201300  70.29
         ADDED              CALL SOLF4(BMATRX,FLINBP,PDUBL,NBRPTS, 70,NOGOOD)                 00201400  70.29
         ADDED              IF(NOGOOD.NE.1)  RETURN                                           00201500  70.29
         ADDED         C                                                                      00201600  70.29
EBUG07A  ADDED         C    WRITE(6,8107) (IP,PBRPT(IP),IP=1,NBRPTS)                          00201700  70.29
         ADDED         C8107 FORMAT(1X,'DEBUG07A  BRANCH PT.  PRESSURE'/(12X,I4,8X,G13.6))    00201800  70.29
         ADDED              DO 700 IBRPT=1,NBRPTS                                             00201900  70.29
         ADDED              PBRPT(IBRPT)=SNGL(PDUBL(IBRPT))                                   00202000  70.29
         ADDED          700 CONTINUE                                                          00202100  70.29
         ADDED          750 CONTINUE                                                          00202200  70.29
         ADDED         C                                                                      00202300  70.29
         ADDED         C                UPDATE THE FLOW RATES IN ALL BRANCHES                 00202400  70.29
         ADDED         C                      USING THE PRESSURES COMPUTED ABOVE              00202500  70.29
         ADDED         C                                                                      00202600  70.29
         ADDED              NFIN=0                                                            00202700  70.29
         ADDED              DO 950 IBRPT=1,NBRPTS                                             00202800  70.29
         ADDED              NST=NFIN+1                                                        00202900  70.29
         ADDED              NFIN=NFIN+IABS(NBCON(IBRPT))                                      00203000  70.29
         ADDED              DO 950 N=NST,NFIN                                                 00203100  70.29
         ADDED              J=JBRPT(N)                                                        00203200  70.29
         ADDED              IF(IBCON(N).GT.0) GO TO 800                                       00203300  70.29
         ADDED              IF(J.LE.NBRPTS) GO TO 950                                         00203400  70.29
         ADDED              JBC=IBCON(N)                                                      00203500  70.29
         ADDED              IBC=IABS(JBC)                                                     00203600  70.29
         ADDED              SGN=JBC/IBC                                                       00203700  70.29
         ADDED              GO TO 850                                                         00203800  70.29
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LD SEQ   MESSAGE      FILENAME=MUFAN                   DECKNAME=MUFAN                                  YY.DD

         ADDED        800 CONTINUE                                                          00203900  70.29
         ADDED            IBC=IBCON(N)                                                      00204000  70.29
         ADDED            SGN=1.0                                                           00204100  70.29
         ADDED        850 CONTINUE                                                          00204200  70.29
         ADDED            IF(NPTS(IBC).LE.0)  GO TO 950                                     00204300  70.29
         ADDED        870 CONTINUE                                                          00204400  70.29
         ADDED            DP=SNGL(PDUBL(IBRPT)-PDUBL(J))+SGN*(POTHED(IBC)+DPUMP(IBC))       00204500  70.29
         ADDED        900 CONTINUE                                                          00204600  70.29
         ADDED            QOLD=QBR(IBC)                                                     00204700  70.29
         ADDED            QBR(IBC)=SGN*BRCON(IBC)*DP                                        00204800  70.29
         ADDED            IF(DPUMP(IBC).GT.0.0) QBR(IBC)=(QOLD+QBR(IBC))/2.0                00204900  70.29
EBUG08   ADDED      C     WRITE(6,8008) IBC, QBR(IBC), IBRPT, J, DP                         00205000  70.29
         ADDED      C8008 FORMAT(1X,'DEBUG08  IBC=',I4,' QBR(IBC)=',G13.6,' IBRPT=',I4,     00205100  70.29
         ADDED      C    1   ' J=',I4,' DP=',G13.6)                                         00205200  70.29
         ADDED        920 CONTINUE                                                          00205300  70.29
         ADDED            ABSERR=ABS(QOLD-QBR(IBC))                                         00205400  70.29
         ADDED            DIV=AMIN1(ABS(QOLD),ABS(QBR(IBC)))                                00205500  70.29
         ADDED            IF(ABSERR.LE.TOLABS.OR.DIV.LE.TOLABS)  GO TO 950                  00205600  70.29
         ADDED            RELERR=ABSERR/DIV                                                 00205700  70.29
         ADDED            IF(RELERR.LE.RELMAX) GO TO 950                                    00205800  70.29
         ADDED            MAXERR=IBC                                                        00205900  70.29
         ADDED            RELMAX=RELERR                                                     00206000  70.29
         ADDED        950 CONTINUE                                                          00206100  70.29
         ADDED            ITER8=ITER8+1                                                     00206200  70.29
         ADDED            IF(RELMAX.LE.TOLERR) RETURN                                       00206300  70.29
         ADDED        980 CONTINUE                                                          00206400  70.29
         ADDED            IF(ITER8.LT.LIMIT) GO TO 100                                      00206500  70.29
         ADDED            NFIN=0                                                            00206600  70.29
         ADDED            DO 1000 IB=1,MAXERR                                               00206700  70.29
         ADDED            NST=NFIN+1                                                        00206800  70.29
         ADDED            NFIN=NFIN+IABS(NPTS(IB))                                          00206900  70.29
         ADDED       1000 CONTINUE                                                          00207000  70.29
         ADDED            WRITE(6,9000) RELMAX, LIMIT, (IBRAN(I),I=NST,NFIN)                00207100  70.29
         ADDED       9000 FORMAT(1H1////1X,49(1H*),' WARNING ',49(1H*)//4X,    'THE FLOW ', 00207200  70.29
         ADDED          1 'RATE IN THE BRANCH DESCRIBED BELOW HAS A RELATIVE ERROR OF ',    00207300  70.29
         ADDED          2  1PE12.5,' AFTER ',I3,' ITERATIONS'//1X,107(1H*)//(1H0,4X,25I4))  00207400  70.29
         ADDED            RETURN                                                            00207500  70.29
         ADDED            END                                                               00207600  70.29
         ADDED            SUBROUTINE  SOLF4(B,Y,X,N,NMAX,NOGOOD)                            00207700  70.29
         ADDED            REAL*8     B,     Y,     X,     C                                 00207800  70.29
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OLD SEQ   MESSAGE        FILENAME=MUFAN                  DECKNAME=MUFAN                                   YY.DD

          ADDED             DIMENSION B(NMAX,NMAX), Y(NMAX), X(NMAX)                     00207900  70.29
          ADDED       C     THIS PROGRAM SOLVES A SET OF SIMULTANEOUS LINEAR ALGEBRAIC   00208000  70.29
          ADDED       C     EQUATIONS BY OPTIMIZED NORMALIZED ELIMINATION                00208100  70.29
          ADDED       C     THE COEFFICIENTS AND RIGHT HAND SIDES ARE LOST               00208200  70.29
          ADDED             M=N                                                          00208300  70.29
          ADDED          10 MM=M-1                                                       00208400  70.29
          ADDED       C     NORMALIZE COEFFICIENTS                                       00208500  70.29
          ADDED             DO 20 I=1,M                                                  00208600  70.29
          ADDED             C=0.0D0                                                      00208700  70.29
          ADDED             DO 12 J=1,M                                                  00208800  70.29
          ADDED          12 C=DMAX1(C,DABS(B(I,J)))                                      00208900  70.29
          ADDED             IF (C) 200,200,13                                            00209000  70.29
          ADDED          13 IF (C-1.0D0) 14,20,14                                        00209100  70.29
          ADDED          14 DO 16 J=1,M                                                  00209200  70.29
          ADDED          16 B(I,J)=B(I,J)/C                                              00209300  70.29
          ADDED             Y(I)=Y(I)/C                                                  00209400  70.29
          ADDED          20 CONTINUE                                                     00209500  70.29
          ADDED       C     OPTIMIZE ROW SELECTION                                       00209600  70.29
          ADDED             IM=0                                                         00209700  70.29
          ADDED             C=0.0D0                                                      00209800  70.29
          ADDED             DO 25 I=1,M                                                  00209900  70.29
          ADDED             IF (DABS(B(I,M))-C) 25,25,22                                 00210000  70.29
          ADDED          22 IM=I                                                         00210100  70.29
          ADDED             C=DABS(B(I,M))                                               00210200  70.29
          ADDED          25 CONTINUE                                                     00210300  70.29
          ADDED             IF (C) 200,200,27                                            00210400  70.29
          ADDED          27 IF (MM) 100,100,28                                           00210500  70.29
          ADDED          28 DO 29 J=1,M                                                  00210600  70.29
          ADDED             C=B(IM,J)                                                    00210700  70.29
          ADDED             B(IM,J)=B(M,J)                                               00210800  70.29
          ADDED          29 B(M,J)=C                                                     00210900  70.29
          ADDED             C=Y(IM)                                                      00211000  70.29
          ADDED             Y(IM)=Y(M)                                                   00211100  70.29
          ADDED             Y(M)=C                                                       00211200  70.29
          ADDED       C     REDUCE ORDER OF SET                                          00211300  70.29
          ADDED             DO 40 I=1,MM                                                 00211400  70.29
          ADDED             IF (B(I,M)) 32,40,32                                         00211500  70.29
          ADDED          32 Y(I)=B(M,M)*Y(I)-B(I,M)*Y(M)                                 00211600  70.29
          ADDED             DO 35 J=1,MM                                                 00211700  70.29
          ADDED          35 B(I,J)=B(M,M)*B(I,J)-B(I,M)*B(M,J)                           00211800  70.29
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LD SEQ   MESSAGE        FILENAME=MUFAN                      DECKNAME=MUFAN                                              YY.DD

         ADDED          40 CONTINUE                                                                     00211900  70.29
         ADDED             M=MM                                                                         00212000  70.29
         ADDED             GO TO 10                                                                     00212100  70.29
         ADDED        C    READY TO CALCULATE X VALUES                                                  00212200  70.29
         ADDED         100 X(1)=Y(1)/B(1,1)                                                             00212300  70.29
         ADDED             DO 120 I=2,N                                                                 00212400  70.29
         ADDED             C=Y(I)                                                                       00212500  70.29
         ADDED             IM=I-1                                                                       00212600  70.29
         ADDED             DO 110 J=1,IM                                                                00212700  70.29
         ADDED         110 C=C-B(I,J)*X(J)                                                              00212800  70.29
         ADDED         120 X(I)=C/B(I,I)                                                                00212900  70.29
         ADDED        122  NOGOOD=1                                                                     00213000  70.29
         ADDED             RETURN                                                                       00213100  70.29
         ADDED         200 WRITE(6,901)                                                                 00213200  70.29
         ADDED             NOGOOD=2                                                                     00213300  70.29
         ADDED             RETURN                                                                       00213400  70.29
         ADDED         901 FORMAT (31H0EQUATION SET SINGULAR IN SOLVE)                                  00213500  70.29
         ADDED             END                                                                          00213600  70.29
         ADDED             SUBROUTINE OUTPUT                                                            00213700  70.29
         ADDED             COMMON  /MUFCOM/                                                             00213800  70.29
         ADDED            1    A(3),          COERR,         CONSTS(3,600), GC,                         00213900  70.29
         ADDED            2    IBCON(600),    IBRAN(850),    IFLUID,        IOPT(10),                   00214000  70.29
         ADDED            3    ITEMP,         ITYPE(600),    JBRPT(600),    LABEL(20,3),                00214100  70.29
         ADDED            4    LEVEL,         MBRAN(850),    NBCON(250),    NBRAN,                      00214200  70.29
         ADDED            5    NBRPTS,        NNMAX,          NPTS(150),     PBRPT(250),                00214300  70.29
         ADDED            6    QBR(150),      QERR,          RHO(600),      TBULK(500),                 00214400  70.29
         ADDED            7    TOLERR,        VISC(600),     XDOTA(500)                                 00214500  70.29
         ADDED             COMMON  /MUFCOM/     INOUT(100),   NINOUT,    NDUMBP,  LOOP                  00214600  70.29
         ADDED             COMMON /PUNT/ MMEM, MNODES,  DATE                                            00214700  70.29
         ADDED             COMMON /PUNT/  TIME                                                          00214800  70.29
         ADDED             DIMENSION     IFIND(150),    NODE(500),     NSKIP(150),                      00214900  70.29
         ADDED            1              PCON(500),     PRESS(500)                                      00215000  70.29
         ADDED             DIMENSION     ICONST(3,600)                                                  00215100  70.29
         ADDED             DIMENSION     RTAB(5),       R2KTAB(5)                                       00215200  70.29
         ADDED             EQUIVALENCE  (ICONST(1,1), CONSTS(1,1))                                      00215300  70.29
         ADDED             REAL*8          DATE                                                         00215400  70.29
         ADDED             DATA  RTAB/ 0.4, 0.5, 0.6, 0.7, 0.8 /                                        00215500  70.29
         ADDED             DATA  BLANK/4H    /, X/4HX    /, OPAREN/4H (   /, CPAREN/4H)    /            00215600  70.29
         ADDED             IFIND(1)=1                                                                   00215700  70.29
         ADDED             NBR=NBRAN+1                                                                  00215800  70.29
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OLD SEQ  MESSAGE   FILENAME=MUFAN                    DECKNAME=MUFAN                        YY.DD

         ADDED           DO 20 IB=2,NBR                                          00215900  70.29
         ADDED           IFIND(IB)=IFIND(IB-1)+IABS(NPTS(IB-1))                  00216000  70.29
         ADDED        20 CONTINUE                                                00216100  70.29
         ADDED           NPAGES=0                                                00216200  70.29
         ADDED           KOUNTR=0                                                00216300  70.29
         ADDED           NDO=NBRPTS+NDUMBP                                       00216400  70.29
         ADDED           LINE=28                                                 00216500  70.29
         ADDED           NB2=0                                                   00216600  70.29
         ADDED           DO 80 IBP=1,NDO                                         00216700  70.29
         ADDED           NB1=NB2+1                                               00216800  70.29
         ADDED           NB2=NB2+IABS(NBCON(IBP))                                00216900  70.29
         ADDED           DO 80 NB=NB1,NB2                                        00217000  70.29
         ADDED           IF(IBCON(NB).LE.0)  GO TO 80                            00217100  70.29
         ADDED           IB=IBCON(NB)                                            00217200  70.29
         ADDED           LINE=LINE+3                                             00217300  70.29
A-55     ADDED           NP=IABS(NPTS(IB))-1                                     00217400  70.29
         ADDED           IF(LINE+NP.LE.23)  GO TO 70                             00217500  70.29
         ADDED           IF(NP.LT.6)  GO TO 60                                   00217600  70.29
         ADDED           IF(LINE.GT.20)  GO TO 40                                00217700  70.29
         ADDED           NP=NP-3                                                 00217800  70.29
         ADDED           KOUNTR=KOUNTR+3                                         00217900  70.29
         ADDED           LINE=0                                                  00218000  70.29
         ADDED           GO TO 45                                                00218100  70.29
         ADDED        40 CONTINUE                                                00218200  70.29
         ADDED           LINE=3                                                  00218300  70.29
         ADDED        45 CONTINUE                                                00218400  70.29
         ADDED           NPAGES=NPAGES+1                                         00218500  70.29
         ADDED           NSKIP(NPAGES)=KOUNTR                                    00218600  70.29
         ADDED           IF(NP+LINE.LE.23)  GO TO 50                             00218700  70.29
         ADDED           NPSAV=NP                                                00218800  70.29
         ADDED           NP=NP-28+LINE                                           00218900  70.29
         ADDED           IF(NP.LT.3)  NP=3                                       00219000  70.29
         ADDED           KOUNTR=KOUNTR+NPSAV-NP                                  00219100  70.29
         ADDED           LINE=0                                                  00219200  70.29
         ADDED           GO TO 45                                                00219300  70.29
         ADDED        50 CONTINUE                                                00219400  70.29
         ADDED           KOUNTR=KOUNTR+NP                                        00219500  70.29
         ADDED           LINE=NP+5                                               00219600  70.29
         ADDED           GO TO 80                                                00219700  70.29
         ADDED        60 CONTINUE                                                00219800  70.29
```

OLD VOL=SER=004783 DRC UPDATE NEW VOL=SER=007208

```
LD SEQ  MESSAGE      FILENAME=MUFAN                         DECKNAME=MUFAN                               YY.DD

        ADDED           NPAGES=NPAGES+1                                                     00219900  70.29
        ADDED           NSKIP(NPAGES)=KOUNTR                                                00220000  70.29
        ADDED           LINE=NP+9                                                           00220100  70.29
        ADDED           GO TO 75                                                            00220200  70.29
        ADDED        70 CONTINUE                                                            00220300  70.29
        ADDED           LINE=LINE+NP+5                                                      00220400  70.29
        ADDED        75 CONTINUE                                                            00220500  70.29
        ADDED           KOUNTR=KOUNTR+NP                                                    00220600  70.29
        ADDED        80 CONTINUE                                                            00220700  70.29
        ADDED           NSKIP(NPAGES+1)=0                                                   00220800  70.29
        ADDED           INODE=0                                                             00220900  70.29
        ADDED           NB2=0                                                               00221000  70.29
        ADDED           NFIN=0                                                              00221100  70.29
        ADDED           INIT=2                                                              00221200  70.29
        ADDED           LINE=0                                                              00221300  70.29
        ADDED           IPAGE=1                                                             00221400  70.29
        ADDED           DO 300 IBP=1,NDD                                                    00221500  70.29
        ADDED           NB1=NB2+1                                                           00221600  70.29
        ADDED           NB2=NB2+IABS(NBCON(IBP))                                            00221700  70.29
        ADDED           IFOUND=1                                                            00221800  70.29
        ADDED           DO 300 NB=NB1,NB2                                                   00221900  70.29
        ADDED           IF(IBCON(NB).LE.0)  GO TO 300                                       00222000  70.29
        ADDED           IB=IBCON(NB)                                                        00222100  70.29
        ADDED           JBP=JBRPT(NB)                                                       00222200  70.29
        ADDED           GO TO (90,95), IFOUND                                               00222300  70.29
        ADDED        90 CONTINUE                                                            00222400  70.29
        ADDED           IFOUND=2                                                            00222500  70.29
        ADDED           INODE=INODE+1                                                       00222600  70.29
        ADDED           PRESS(INODE)=PBRPT(IBP)                                             00222700  70.29
        ADDED           INDEX=IFIND(IB)                                                     00222800  70.29
        ADDED           NODE(INODE)=IBRAN(INDEX)                                            00222900  70.29
        ADDED           PCON(INODE)=BLANK                                                   00223000  70.29
        ADDED           IF(IBP.GT.NBRPTS)   PCON(INODE)=X                                   00223100  70.29
        ADDED        95 CONTINUE                                                            00223200  70.29
        ADDED           CUMFPD=0.0                                                          00223300  70.29
        ADDED           CUMEPD=0.0                                                          00223400  70.29
        ADDED           CUMPD=0.0                                                           00223500  70.29
        ADDED       100 CONTINUE                                                            00223600  70.29
        ADDED           QB=ABS(QBR(IB))                                                     00223700  70.29
        ADDED           NUNDP=0                                                             00223800  70.29
```

A-56

```
LD SEQ  MESSAGE       FILENAME=MUFAN                    DECKNAME=MUFAN                              YY.DD

        ADDED            DPUNK=BLANK                                                    00223900  70.29
        ADDED            ORFD=0.0                                                       00224000  70.29
        ADDED            NST=IFIND(IB)                                                  00224100  70.29
        ADDED            NFIN=IFIND(IB+1)-1                                             00224200  70.29
        ADDED            FLOCON=BLANK                                                   00224300  70.29
        ADDED            IF(NPTS(IB).LT.0)  FLOCON=X                                    00224400  70.29
        ADDED            IF(QBR(IB).GE.0.0)  GO TO 150                                  00224500  70.29
        ADDED            PBP1=PBRPT(JBP)                                                00224600  70.29
        ADDED            PBP2=PBRPT(IBP)                                                00224700  70.29
        ADDED            MEMF=0                                                         00224800  70.29
        ADDED            IFROM=1                                                        00224900  70.29
        ADDED            ITO=0                                                          00225000  70.29
        ADDED            N=NFIN-1                                                       00225100  70.29
        ADDED            NSTOP=NST                                                      00225200  70.29
        ADDED            INC=-1                                                         00225300  70.29
        ADDED            GO TO 160                                                      00225400  70.29
        ADDED        150 CONTINUE                                                       00225500  70.29
        ADDED            PBP1=PBRPT(IBP)                                                00225600  70.29
        ADDED            PBP2=PBRPT(JBP)                                                00225700  70.29
        ADDED            IFROM=0                                                        00225800  70.29
        ADDED            ITO=1                                                          00225900  70.29
        ADDED            N=NST                                                          00226000  70.29
        ADDED            NSTOP=NFIN-1                                                   00226100  70.29
        ADDED            INC=1                                                          00226200  70.29
        ADDED        160 CONTINUE                                                       00226300  70.29
        ADDED            IF(NSKIP(IPAGE).NE.LINE)  GO TO 165                            00226400  70.29
        ADDED            WRITE(6,6000) DATE,ITIME,IPAGE,NPAGES,((LABEL(I,J),I=1,19),J=1,3) 00226500  70.29
        ADDED       6000 FORMAT(1H1//1H0,32(1H*),' MUFAN FLOW AND PRESSURE DROP PRINTOUT',00226600  70.29
        ADDED          1       ' * ',A8,2X,I4,' ** PAGE',I3,' OF',I3,' *'//17X,19A4/17X,  00226700  70.29
        ADDED          2       19A4/17X,19A4//1H0,57X,11(1H-),'CUMULATIVE',13(1H-)/     00226800  70.29
        ADDED          3       28X,'ELEVATION',4X,'FRICTION',22X,'ELEVATION',4X,        00226900  70.29
        ADDED          4     'FRICTION' /10X,3(5X,8HPRESSURE),4X,3(5X,8HPRESSURE)/4X,   00227000  70.29
        ADDED          5       'MEMBER ',3(4X,9HDROP, PSI),4X,3(4X,9HDROP, PSI),4X,     00227100  70.29
        ADDED          6       'REYNOLDS NO' /1X,107(1H-)/2X)                           00227200  70.29
        ADDED            IPAGE=IPAGE+1                                                  00227300  70.29
        ADDED        165 CONTINUE                                                       00227400  70.29
        ADDED            WRITE(6,6001) QB, FLOCON                                       00227500  70.29
        ADDED       6001 FORMAT(    1H0,32(1H.),' BEGINNING OF BRANCH - FLOW=',G12.5,A2, 00227600  70.29
        ADDED          1       34(1H.)/1X,1H.,106X,1H. )                                00227700  70.29
        ADDED            GO TO 172                                                      00227800  70.29
```

```
OLD SEQ  MESSAGE     FILENAME=MUFAN                    DECKNAME=MUFAN                      YY.DD

         ADDED      170 CONTINUE                                               00227900  70.29
         ADDED          IF(NSKIP(IPAGE).NE.LINE)  GO TO 172                    00228000  70.29
         ADDED          WRITE(6,6000) DATE,ITIME,IPAGE,NPAGES,LABEL            00228100  70.29
         ADDED          IPAGE=IPAGE+1                                          00228200  70.29
         ADDED      172 CONTINUE                                               00228300  70.29
         ADDED          INDEX1=N+IFROM                                         00228400  70.29
         ADDED          INDEX2=N+ITO                                           00228500  70.29
         ADDED          MEM=MBRAN(N)                                           00228600  70.29
         ADDED          IF(ITYPE(MEM)-100000000) 180,176,178                   00228700  70.29
         ADDED      176 CONTINUE                                               00228800  70.29
         ADDED          DPCON=X                                                00228900  70.29
         ADDED          REYNO=-1.0E20                                          00229000  70.29
         ADDED          GO TO 187                                              00229100  70.29
         ADDED      178 CONTINUE                                               00229200  70.29
         ADDED          IF(ITYPE(MEM).NE.300000000)  GO TO 179                 00229300  70.29
         ADDED          REYNO=-1.0E20                                          00229400  70.29
         ADDED          FPDROP=-CONSTS(2,MEM)                                  00229500  70.29
         ADDED          DPCON=X                                                00229600  70.29
         ADDED          GO TO 190                                              00229700  70.29
         ADDED      179 CONTINUE                                               00229800  70.29
         ADDED          IF(NUNDP.NE.0)  GO TO 190                              00229900  70.29
         ADDED          NUNDP=N                                                00230000  70.29
         ADDED          SAVCPD=CUMPD                                           00230100  70.29
         ADDED          FPDROP=0.0                                             00230200  70.29
         ADDED          GO TO 190                                              00230300  70.29
         ADDED      180 CONTINUE                                               00230400  70.29
         ADDED          DPCON=BLANK                                            00230500  70.29
         ADDED          IT=MOD(ITYPE(MEM),10000000)                            00230600  70.29
         ADDED          IF(IT.LT.1000000)  GO TO 182                           00230700  70.29
         ADDED          IT=IT/1000000+41                                       00230800  70.29
         ADDED           FPDROP=-PTABLE(IT,QB)                                 00230900  70.29
         ADDED          REYNO=-1.0E20                                          00231000  70.29
         ADDED          GO TO 190                                              00231100  70.29
         ADDED      182 CONTINUE                                               00231200  70.29
         ADDED          IF(IT.LT.10000)  GO TO 185                             00231300  70.29
         ADDED          REYNO=-1.0E20                                          00231400  70.29
         ADDED          GO TO 187                                              00231500  70.29
         ADDED      185 CONTINUE                                               00231600  70.29
         ADDED          REYNO=4.2441317E-3*QB/(VISC(MEM)*CONSTS(1,MEM))        00231700  70.29
         ADDED      187 CONTINUE                                               00231800  70.29
```

```
OLD SEQ  MESSAGE     FILENAME=MUFAN                      DECKNAME=MUFAN                                          YY.DD

         ADDED           FPDROP=RESIST(MEM,QB,INIT)*QB                                                00231900  70.29
         ADDED       190 CONTINUE                                                                     00232000  70.29
         ADDED           EPDROP=RHO(MEM)*(XDOTA(INDEX1)-XDOTA(INDEX2))                                00232100  70.29
         ADDED           PDROP=FPDROP+EPDROP                                                          00232200  70.29
         ADDED           CUMPD=CUMPD+PDROP                                                            00232300  70.29
         ADDED           IF(NUNDP.GT.0)  GO TO 210                                                    00232400  70.29
         ADDED           LINE=LINE+1                                                                  00232500  70.29
         ADDED           CUMFPD=CUMFPD+FPDROP                                                         00232600  70.29
         ADDED           CUMEPD=CUMEPD+EPDROP                                                         00232700  70.29
         ADDED           INODE=INODE+1                                                                00232800  70.29
         ADDED           NODE(INODE)=IBRAN(INDEX2)                                                    00232900  70.29
         ADDED           PRESS(INODE)=PBP1-CUMPD                                                      00233000  70.29
         ADDED           PCON(INODE)=BLANK                                                            00233100  70.29
         ADDED       200 CONTINUE                                                                     00233200  70.29
         ADDED           WRITE(6,6002) IBRAN(INDEX1), IBRAN(INDEX2), PDROP,    EPDROP,                00233300  70.29
         ADDED          1               DPUNK, FPDROP, DPCON, CUMPD, CUMEPD, CUMFPD, REYNO            00233400  70.29
         ADDED      6002 FORMAT(1X,2H. ,I3,2H -,I3,2G14.4,A2,G11.4,A4,3G13.4,2X,G10.5,2H .)           00233500  70.29
         ADDED           DPUNK=BLANK                                                                  00233600  70.29
         ADDED       210 CONTINUE                                                                     00233700  70.29
         ADDED           IF(N.EQ.NSTOP)  GO TO 220                                                    00233800  70.29
         ADDED           N=N+INC                                                                      00233900  70.29
         ADDED           GO TO 170                                                                    00234000  70.29
         ADDED       220 CONTINUE                                                                     00234100  70.29
         ADDED           IF(NUNDP) 236,240,221                                                        00234200  70.29
         ADDED       221 CONTINUE                                                                     00234300  70.29
         ADDED           N=NUNDP                                                                      00234400  70.29
         ADDED           NUNDP=-1                                                                     00234500  70.29
         ADDED           DPUNK=UPAREN                                                                 00234600  70.29
         ADDED           DPCON=CPAREN                                                                 00234700  70.29
         ADDED           FPDROP=PBP1-PBP2-CUMPD                                                       00234800  70.29
         ADDED           CUMPD=SAVCPD                                                                 00234900  70.29
         ADDED           REYNO=-1.0E20                                                                00235000  70.29
         ADDED           IF(FPDROP.LE.0.0)  GO TO 170                                                 00235100  70.29
         ADDED           IF(CONSTS(1,MEM).LE.0.0)  GO TO 170                                          00235200  70.29
         ADDED      C                     CALCULATE REQUIRED ORFICE DIAMETER                          00235300  70.29
         ADDED           MEM=MBRAN(N)                                                                 00235400  70.29
         ADDED           REYNO=4.2441317E-3*QB/(VISC(MEM)*CONSTS(1,MEM))                              00235500  70.29
         ADDED           R2K=QB/(900.0*3.14159*CONSTS(1,MEM)**2*SQRT(64.4*FPDROP))                    00235600  70.29
         ADDED           DO 224 L=1,5                                                                 00235700  70.29
         ADDED           R2KTAB(L)=RTAB(L)**2*ORFICE(RTAB(L),REYNO)                                   00235800  70.29
```

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```
OLD SEQ   MESSAGE    FILENAME=MUFAN                      DECKNAME=MUFAN                                YY.DD

          ADDED      224 CONTINUE                                                            00235900  70.29
          ADDED          IF(R2K-R2KTAB(1)) 234,226,228                                       00236000  70.29
          ADDED      226 CONTINUE                                                            00236100  70.29
          ADDED          ORFD=RTAB(1)*CONSTS(1,MEM)                                          00236200  70.29
          ADDED          GO TO 233                                                           00236300  70.29
          ADDED      228 CONTINUE                                                            00236400  70.29
          ADDED          IF(R2K-R2KTAB(5)) 232,230,234                                       00236500  70.29
          ADDED      230 CONTINUE                                                            00236600  70.29
          ADDED          ORFD=RTAB(5)*CONSTS(1,MEM)                                          00236700  70.29
          ADDED          GO TO 233                                                           00236800  70.29
          ADDED      232 CONTINUE                                                            00236900  70.29
          ADDED          CALL INT4(R2KTAB,RTAB,R2K,R)                                        00237000  70.29
          ADDED          ORFD=R*CONSTS(1,MEM)                                                00237100  70.29
          ADDED      233 CONTINUE                                                            00237200  70.29
          ADDED          CONSTS(2,MEM)=ORFD                                                  00237300  70.29
          ADDED          GO TO 170                                                           00237400  70.29
          ADDED      234 CONTINUE                                                            00237500  70.29
          ADDED          ORFD=-1.0                                                           00237600  70.29
          ADDED          GO TO 170                                                           00237700  70.29
          ADDED      236 CONTINUE                                                            00237800  70.29
          ADDED          IF(ORFD)  238,240,242                                               00237900  70.29
          ADDED      238 CONTINUE                                                            00238000  70.29
          ADDED          WRITE(6,6006)  QB, FLOCON                                           00238100  70.29
          ADDED     6006 FORMAT(1X,1H.,106X,1H./1X,16(1H.),' END OF BRANCH - FLOW=',G12.5,  00238200  70.29
          ADDED        1          A2,38H, REQ'D ORFICE DIAM OUT OF TABLE RANGE, 17(1H.)///2X)00238300  70.29
          ADDED          GO TO 244                                                           00238400  70.29
          ADDED      240 CONTINUE                                                            00238500  70.29
          ADDED          WRITE(6,6003)  QB, FLOCON                                           00238600  70.29
          ADDED     6003 FORMAT(1X,1H.,106X,1H./1X,35(1H.),' END OF BRANCH - FLOW=',G12.5,  00238700  70.29
          ADDED        1          A2,36(1H.)///2X)                                           00238800  70.29
          ADDED          GO TO 244                                                           00238900  70.29
          ADDED      242 CONTINUE                                                            00239000  70.29
          ADDED          WRITE(6,6007)  QB, FLOCON, ORFD                                     00239100  70.29
          ADDED     6007 FORMAT(1X,1H.,106X,1H./1X,19(1H.),' END OF BRANCH - FLOW=',G12.5,  00239200  70.29
          ADDED        1          A2,20H, REQ'D ORFICE DIAM=,G11.3,20(1H.)///2X)             00239300  70.29
          ADDED      244 CONTINUE                                                            00239400  70.29
          ADDED          IF(QBR(IB).GE.0.0)  GO TO 246                                       00239500  70.29
          ADDED          IF(IABS(NBCON(JBP)).GE.2)  GO TO 260                                00239600  70.29
          ADDED          PRESS(INODE)=PBRPT(JBP)                                             00239700  70.29
          ADDED          NODE(INODE)=IBRAN(NFIN)                                             00239800  70.29
```

OLD VOL=SER=004783 DRC UPDATE NEW VOL=SER=007208

```
OLD SEQ  MESSAGE       FILENAME=MUFAN                      DECKNAME=MUFAN                                    YY.DD

         ADDED            GO TO 250                                                              00239900  70.29
         ADDED        246 CONTINUE                                                               00240000  70.29
         ADDED            IF(IABS(NBCON(JBP)).GE.2)  GO TO 260                                   00240100  70.29
         ADDED        250 CONTINUE                                                               00240200  70.29
         ADDED            PCON(INODE)=BLANK                                                      00240300  70.29
         ADDED            IF(JBP.GT.NBRPTS)  PCON(INODE)=X                                       00240400  70.29
         ADDED            GO TO 300                                                              00240500  70.29
         ADDED        260 CONTINUE                                                               00240600  70.29
         ADDED            INODE=INODE-1                                                          00240700  70.29
         ADDED        300 CONTINUE                                                               00240800  70.29
         ADDED            CALL SORT(3,INODE,NODE,PRESS,PCON)                                     00240900  70.29
         ADDED            NPAGES=( INODE-1)/170+1                                                00241000  70.29
         ADDED            NFIN=0                                                                 00241100  70.29
         ADDED            DO 800 IPAGE=1,NPAGES                                                  00241200  70.29
         ADDED            NST=NFIN+1                                                             00241300  70.29
         ADDED            NFIN=NFIN+170                                                          00241400  70.29
         ADDED            IF(IPAGE.EQ.NPAGES)  NFIN=INODE                                        00241500  70.29
         ADDED            WRITE(6,6005) DATE,ITIME,IPAGE,NPAGES,((LABEL(I,J),I=1,19),J=1,3),00241600  70.29
         ADDED           1             (NODE(K),PRESS(K),PCON(K),K=NST,NFIN)                     00241700  70.29
         ADDED       6005 FORMAT(1H1//1H0,41(1H*),' MUFAN PRESSURE PRINTOUT ',7(1H*),1X,         00241800  70.29
         ADDED           1          A8,I6,' ** PAGE',I3,' OF',I3,' *'//17X,19A4/17X,19A4/        00241900  70.29
         ADDED           2          17X,19A4//1H0,5('NODE    PRESSURE ',5X)//                    00242000  70.29
         ADDED           3          (1X,5(I4,3X,G10.4,A1,4X)))                                   00242100  70.29
         ADDED        800 CONTINUE                                                               00242200  70.29
         ADDED            RETURN                                                                 00242300  70.29
         ADDED            END                                                                    00242400  70.29

                   2,424 RECORDS, HIGHEST ERROR CODE 00
```

OLD VOL=SER=004783 DRC UPDATE NEW VOL=SER=007208

FILE	TYPE	DECK	LANGUAGE	ADD YY.DDD HHMM JOBNAME	CHG YY.DDD HHMM JOBNAME	RECO
MUFAN	SOURCE					
		MUFAN	FORT	70.295 2211 D247USEF	70.295 2211 D247USEF	2
				70.295 2211 D247USEF	70.295 2211 D247USEF	2

APPENDIX B

K-Factors

01-071-002

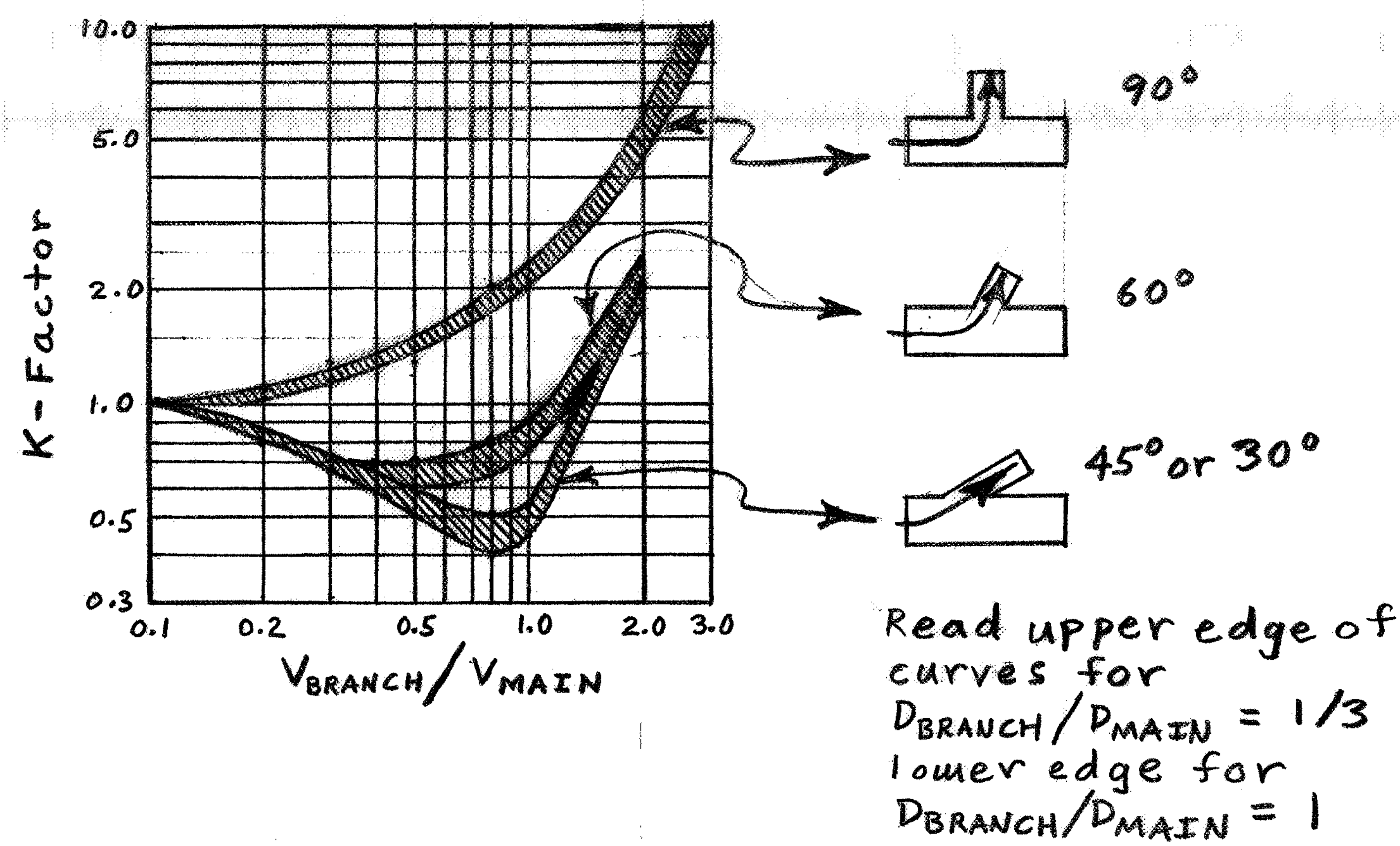
AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

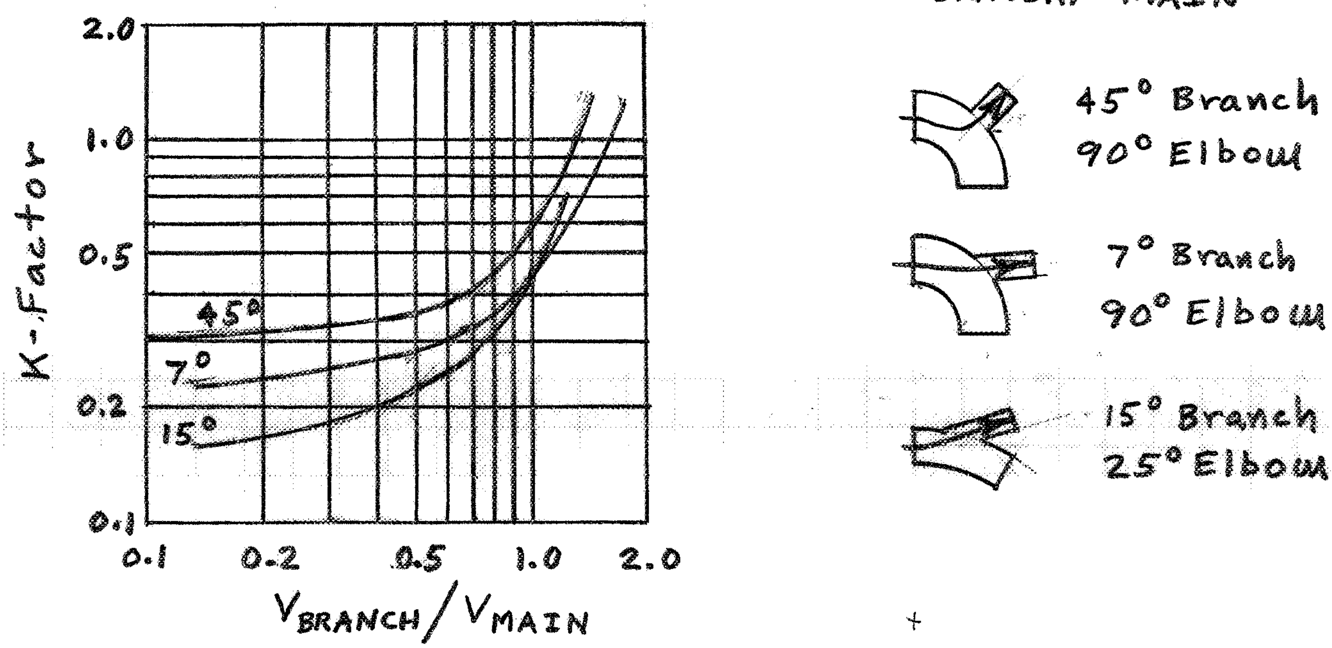
QUADRILLE WORK SHEET

DATE 9/23/70

WORK ORDER 1475-02-0183

SUBJECT K-Factors BY DGM





STK. NO. D-1-103

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

QUADRILLE WORK SHEET

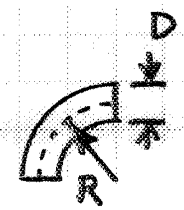
DATE 9/23/70

SUBJECT K-Factors

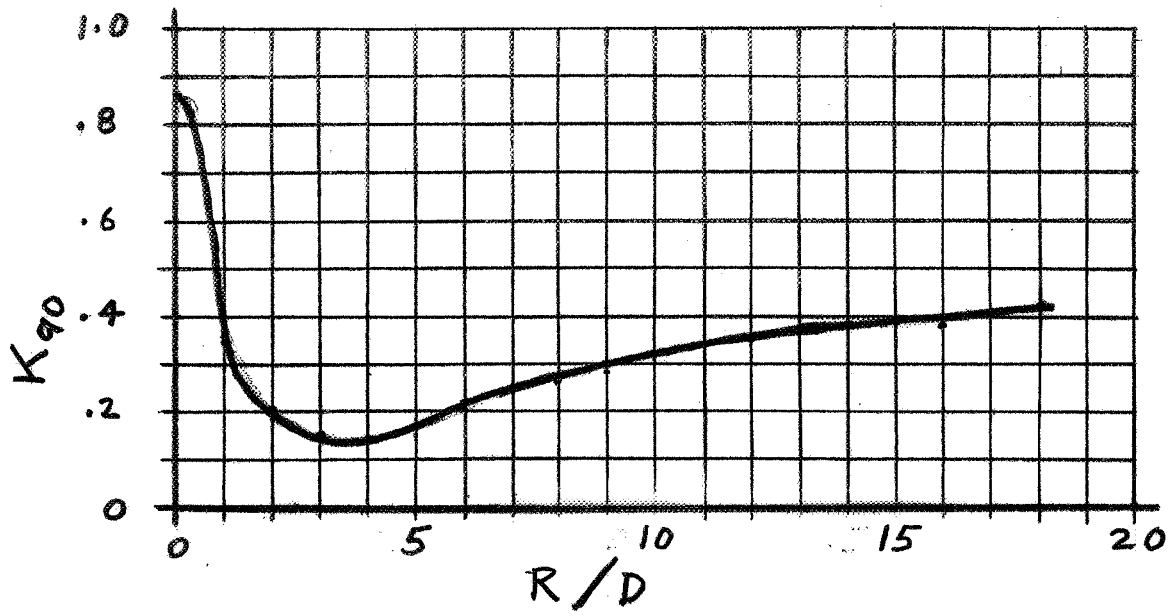
BY [signature]

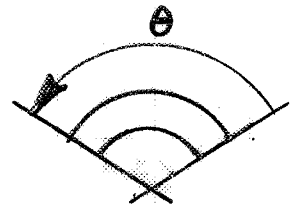
WORK ORDER 1475-02-0183

K-Factor for 90° Tubing Bend

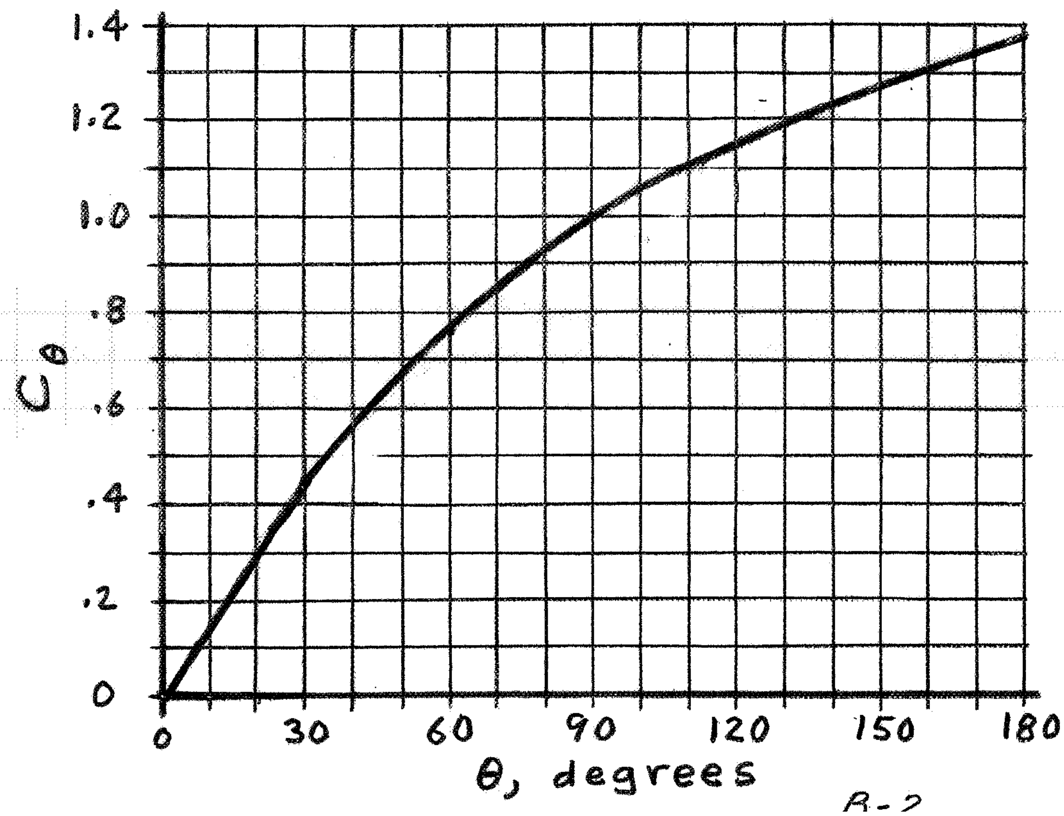


D is the inside diameter





$K_\theta = C_\theta K_{90}$



STK. NO. D-1-103

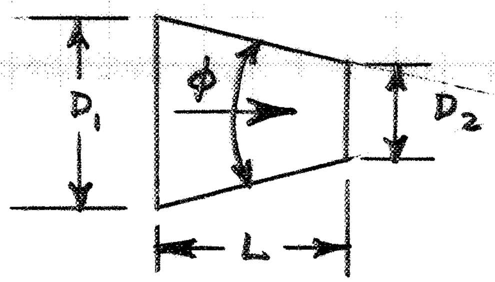
QUADRILLE WORK SHEET

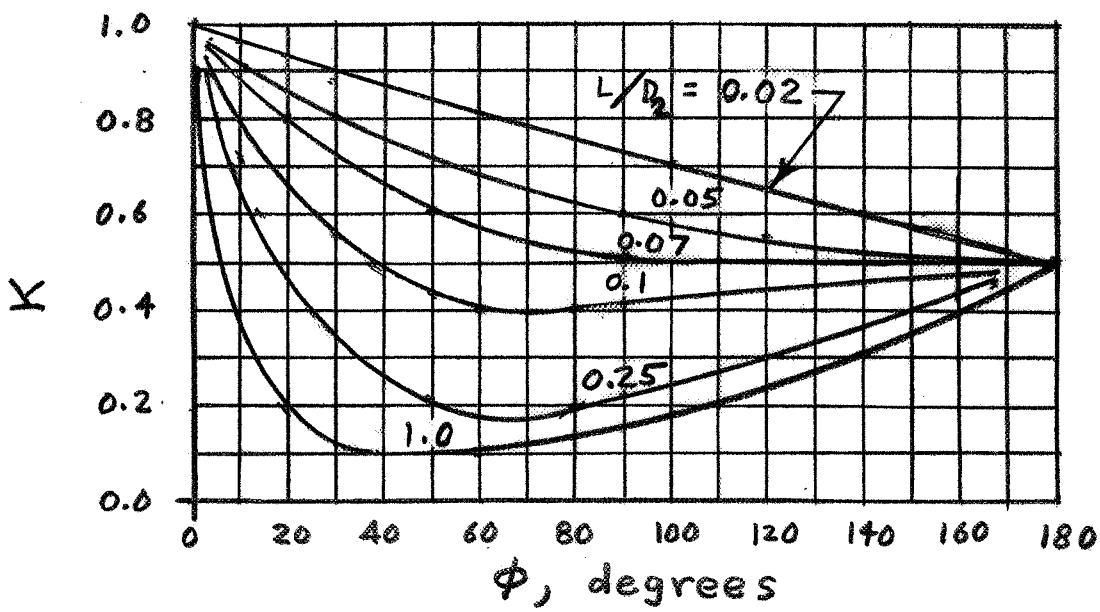
AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

DATE 9/25/70
WORK ORDER 1475-02-0183

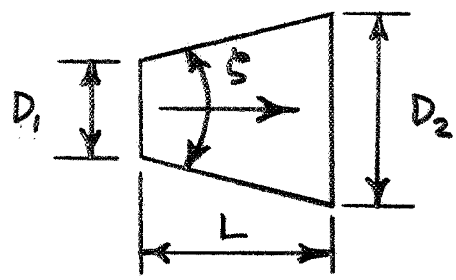
SUBJECT K- Factors BY DJM

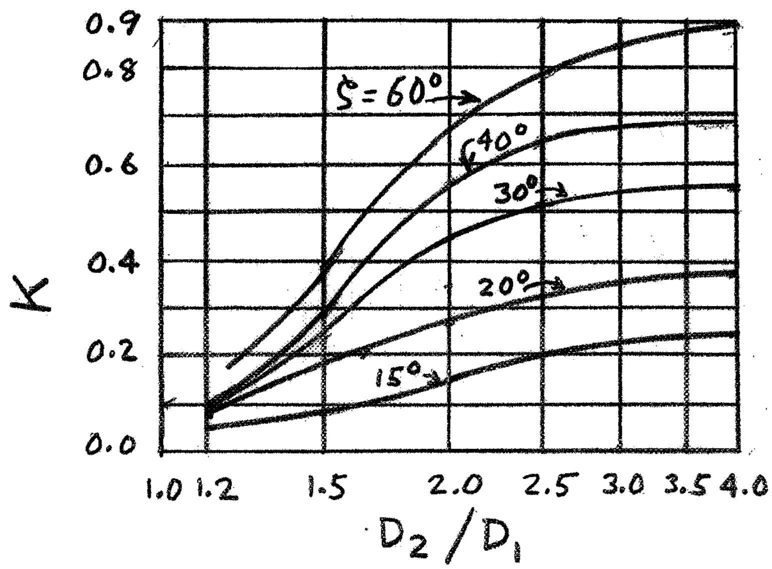
Gradual Contraction



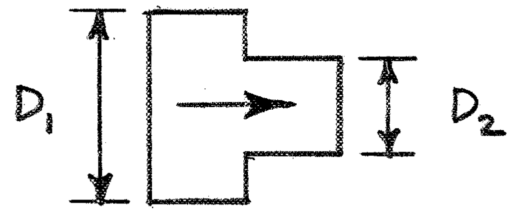


Gradual Expansion

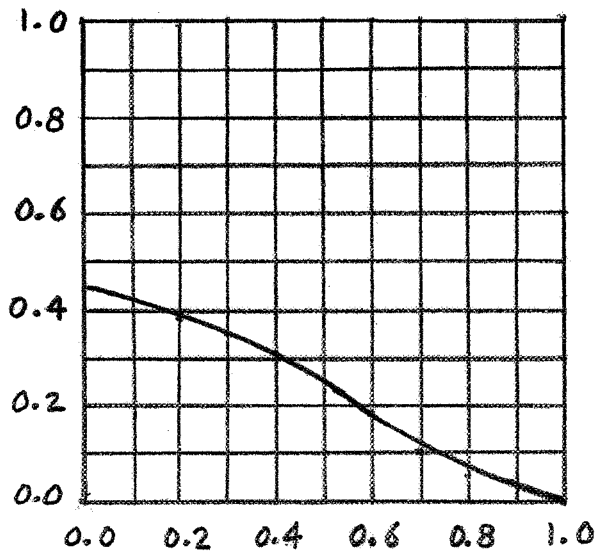




Sudden Contraction



$$A_1 = \frac{\pi D_1^2}{4} \qquad A_2 = \frac{\pi D_2^2}{4}$$



Square Edged Orifice

The flow coefficient data from reference (4) has been modified to include pressure recovery. The pressure recovery factors used (from ref. 7) are shown below.

D_0/D_1	λ
0.20	0.95
0.30	0.90
0.40	0.83
0.50	0.75
0.60	0.645
0.65	0.59
0.70	0.535
0.75	0.465
0.80	0.400

For an orifice:

$$Q = 3600 \rho C A_0 \sqrt{\frac{2g(P_1 - P_2)}{144 \rho}}$$

Where: Q = weight flow rate, lb/hr.
C = flow coefficient
$A_0 = \frac{\pi D_0^2}{576}$ = area of orifice, ft^2.
P = pressure, psi
ρ = weight density, lb/ft^3

SUBJECT K- Factors BY

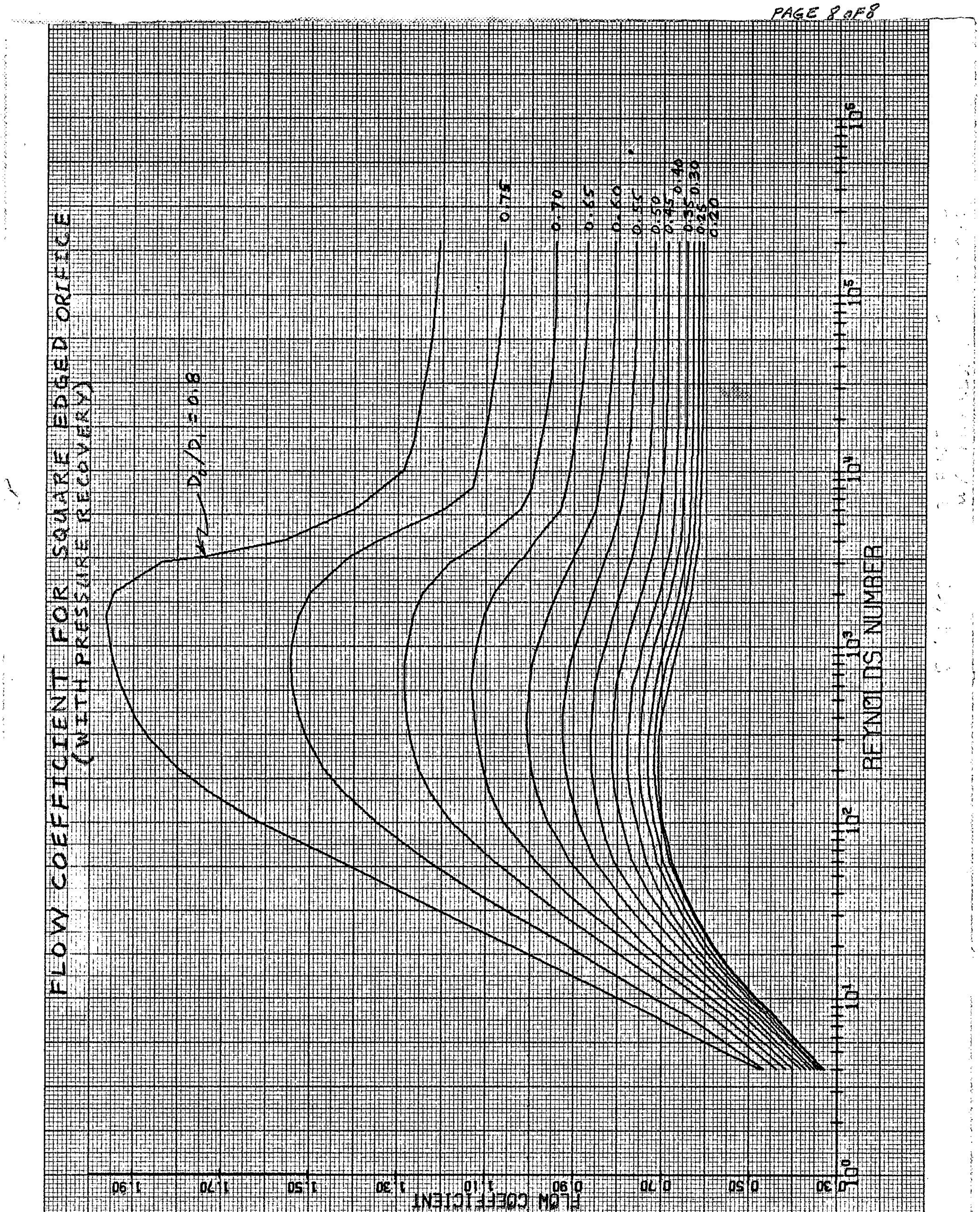
WORK ORDER 1475-02-0183

$$K = \left(\frac{D_1}{D_0}\right)^4 \frac{1}{C^2}$$

Where: K = K-factor

D_1 = pipe inside diameter

D_0 = orifice diameter


FLOW COEFFICIENT FOR SQUARE EDGED ORIFICE
(WITH PRESSURE RECOVERY)
$D_1/D = 0.8$
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
REYNOLDS NUMBER
10^0
10^1
10^2
10^3
10^4
10^5
10^6
FLOW COEFFICIENT
0.30
0.50
0.70
0.90
1.10
1.30
1.50
1.70
1.90