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Steady State	Actuator	Accumulator
User Manual	Hydraulic Filter	Restrictor
Variable Delivery Pump	Solenoid Valve	Quasi-Transient

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

SSFAN is a steady state hydraulic flow and pressure analysis computer program. Its primary purpose is to analyze non-linear resistance aircraft hydraulic systems. The program handles complex flow networks containing flow and/or pressure discontinuities such as unbalanced area actuators and check valves. Solutions for a combination of simultaneously operating subsystems are easily obtained. The program is designed using a building block approach so that new component or element models may be added with minimum change to

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the main program. The solution method is a Matrix type, using iteration to obtain a final flow and pressure balance. The program internally corrects viscosities for pressure, determines whether flow is laminar, transition or turbulent for use of appropriate resistance factors and corrects reservoir pressure for altitude effects. A Quasi-transient section has been added to allow multiple steady state calculations when simulating subsystem operations. The data is stored and can be printed in either tabular form or computer plot form.

The program was written with the aircraft hydraulic system designer in mind. The terminology and units are commonly used terms such as fluid viscosity in centistokes, temperatures in degrees Fahrenheit and flow in gallons per minute. Conversion of units for calculation is accomplished internally in the program.

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PREFACE

The final report was prepared by the McDonnell Aircraft Company, Design Engineering Power and Fluid System Department, McDonnell Douglas Corporation under contract F33615-78-C-2026, with supplemental agreement P0003.

The effort was sponsored by the Aero Propulsion Laboratory, Air Force Systems Command, Wright-Patterson AFB, Ohio under Project No. 3145-30-27 with AFWAL/POOS, and was under the direction of Paul Lindquist and William Kinzig.

The final report covers work conducted from 1 June 1978 through 31 January 1980. At McDonnell, Neil Pierce directed the program and was Principal Investigator. Special acknowledgement is also given to J. B. Greene, R. J. Levek, R. E. Young, B. G. Nolan, and P. C. McAvoy.

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SECTION I

INTRODUCTION

SSFAN is a computer program developed to analyze the steady state flows in a closed aircraft hydraulic system; i.e., where the fluid leaving the pump circulates through the system and returns to the suction inlet of the pump, either via a reservoir, or by direct line return, or both. However, the program has been expanded to allow single point pressure and flow inputs which may be used to simplify systems and isolate subsystems for preliminary analyses. The fluid temperature may be specified as constant throughout the system or temperature at various points may be specified. In the Quasi-transient mode, the program can be used to predict the steady state subsystem performance, such as flight control surface rates (under load as well as no load), flap and landing gear extend and retract times, hydraulic-motor driven gatling-gun firing rate, flows and pressures at any point in the system, etc. The performance is predicted based on operating any combination of subsystems simultaneously.

The solution method used in SSFAN is based on a one dimensional steady state flow throughout the network of branch legs in the system.

SSFAN is coded in FORTRAN IV and currently operable on the CDC 6500/6600.

SSFAN may be used as an analytical program to analyze an existing system with all the detail components accounted for in the analysis.

It may also be used as an advanced design or preliminary design tool to analyze and update new system designs as they are established.

Section 2 describes the required program input. Section 3 gives examples of program output for a single point run. Section 4 describes the additional input required for Quasi-transient operation with examples of output.

This update changed the input for element types 1,4,7 and 32 and added element types 8,13,14,15,16,17 and 18.

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1.1 General System Description

The system to be analyzed is first diagrammed as shown in Figure 1. Junction points are added and numbered. Each component or element in the system is defined by its physical characteristics and junction point numbers for input into SSFAN.

1.2 Solution Technique

SSFAN sorts the input data into branch legs from the junction point numbers and establishes continuity throughout the system. There is a branch point or end point at the end of each leg. Branch leg resistances are calculated and summed for all the elements within the leg.

Pressure points are established at each end of the leg. Fluid viscosity is internally corrected for pressure in each leg by taking the average leg pressure and using this for the viscosity correction pressure.

The Reynolds number is calculated for each leg. Flow is determined to be laminar, transition or turbulent. Appropriate resistance factors are used for each flow condition to calculate the pressure drop or resistances of each leg.

This resistance is temporarily assumed to be linear to use the Matrix solution technique in calculating pressures at all branch points in the system

where $R_{12} = \frac{P_{12}}{Q}$

R_{12} = Resistance from end 1 to end 2 of the leg

P_{12} = Pressure drop from end 1 to end 2 of the leg

Q = Flow in the leg

Conductance is then defined as

$$G_{12} = \frac{1}{R_{12}}$$

where G_{12} = Conductance from end 1 to end 2 of the leg

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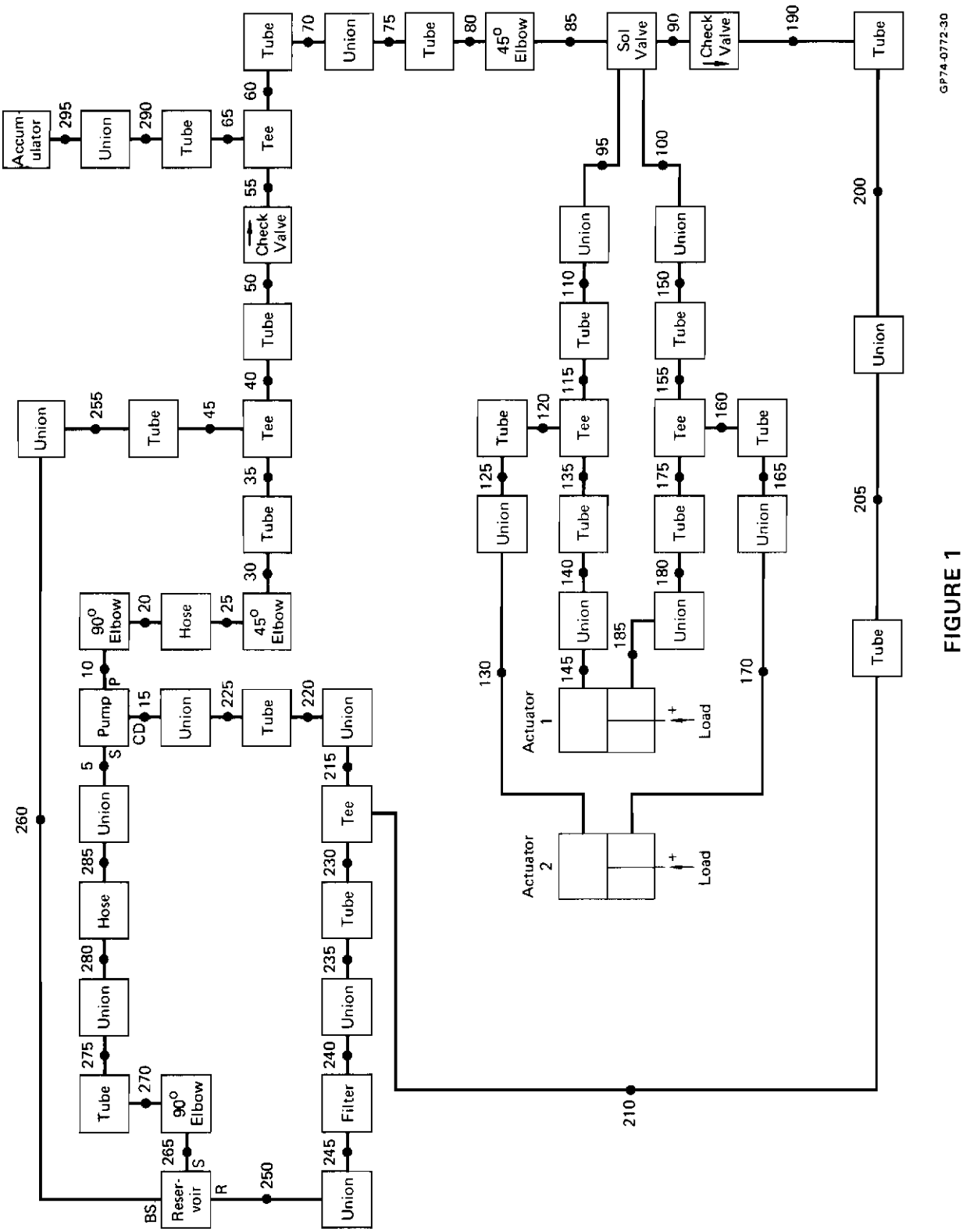

FIGURE 1
EXAMPLE HYDRAULIC SYSTEM

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then $Q = G_{12} P_{12}$

The net flow at any branch point (where three or more legs come together) must be zero.

Therefore the flow requirement is satisfied if

$$\sum_J G_{IJ} [P_I - P_J \pm \Delta P_{IJ}] - \sum_K \pm Q_{IK} = 0$$

where

P_I = pressure at branch point I

P_J = pressure at branch point J

ΔP_{IJ} = a pressure rise or loss (from a pump or actuator) in branch leg IJ

Q_{IK} = Fixed flow in branch leg IK connected to branch point I

Equations of the above form are input to the Matrix for solution of pressures at branch points. These matrix solution pressures are used in conjunction with the calculated conductance(G) to calculate a new flow guess in each leg. When two successive flow guesses for all branch legs in the system are within a specific tolerance such as .001 gpm, the solution has converged. See Volume VI Technical Description for a detailed discussion of the solution technique.

1.3 General Program Operation Description

The general SSFAN flow chart is shown in Figure 2 . As the data is read into the program, it is sorted and stored in the appropriate element array. Some element data such as tubing bends are calculated for energy loss coefficients as the data is read in. The energy loss coefficients of the bends for the tube are then stored in the array.

The pump is established as the first component in the system, unless an accumulator is designated as the pressure source. A search routine then searches the element data arrays and establishes system continuity for the total system. If system continuity cannot be established, error messages are output and the run stops. The branch leg resistances are

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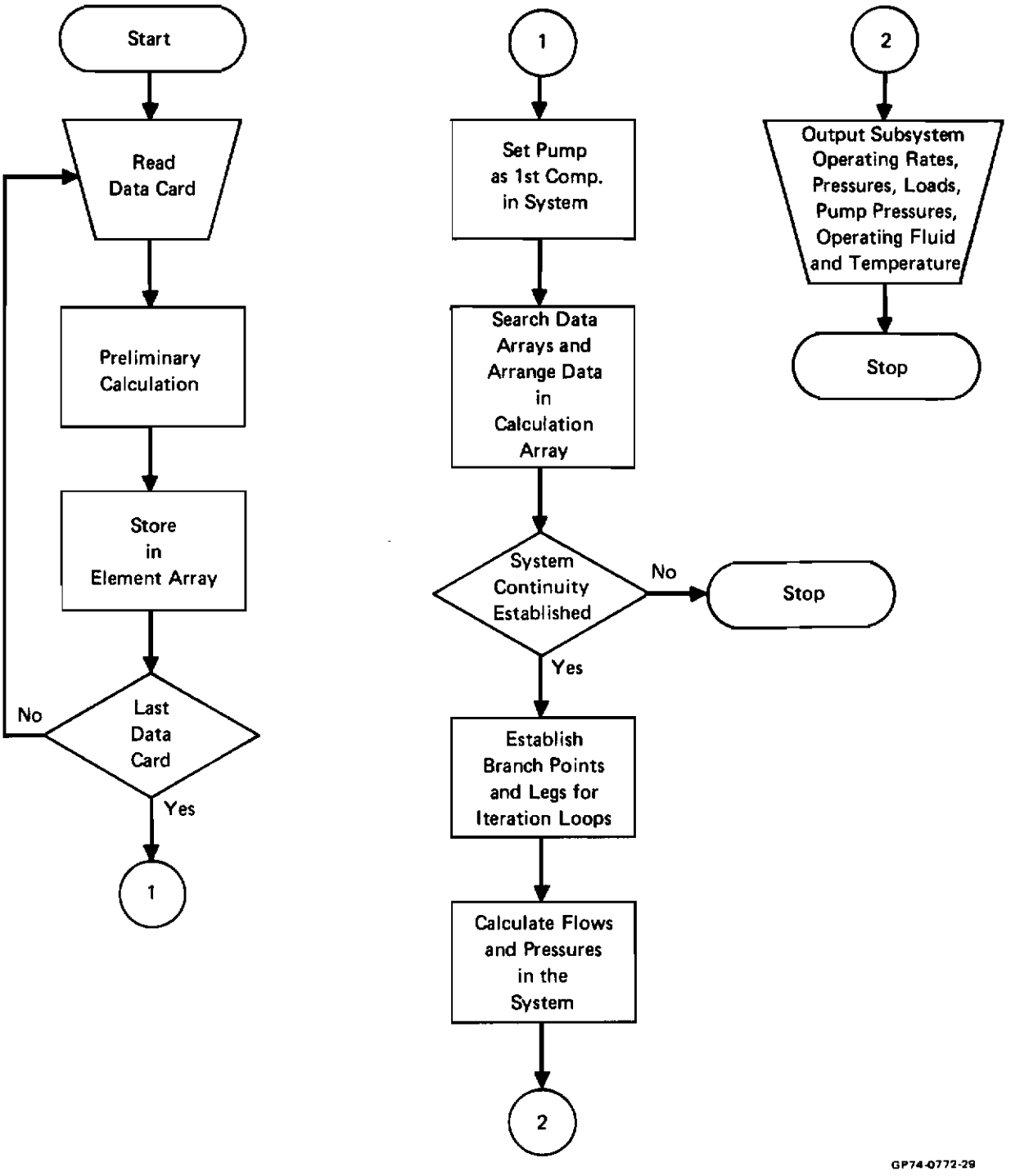

FIGURE 2
SSFAN FLOW CHART

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established as the continuity search is made.

A branch leg array is established containing all the active branch legs. An initial flow guess is made for each leg in the system and pressures are then calculated at each branch point in the system using a Matrix solution. A new flow is calculated using the previous guessed flow and the new flow calculated using the matrix solution pressures. This iteration procedure continues until the flows in all the system legs have converged to the desired tolerance.

The data is then output in one more of the available output types.

1.4 Program Limitations

The following limitations apply to the current SSFAN program.

(1) Maximum tube and fitting size·4 inch

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SECTION II

PROGRAM INPUT

Preparation of data for input into SSFAN consists of four basic steps: (1) The user must draw a schematic block diagram of his system with all elements shown; (2) the schematic is numbered at all "in" and "out" junctions of the elements; (3) the system and fluid parameters such as fluid name, viscosity, density, system operating temperature along with the program title and data output are selected: and (4) each element is described with appropriate "in" and "out" junctions along with other physical data describing the element.

2.1 Data Preparation

2.1.1 Schematic Block Diagram

The partial system schematic block diagram of Figure 3 shows how the system is to be diagrammed. It may be desirable to make the diagram blocks large enough to add additional reference data such as tube wall thickness, check valve cracking pressure, etc.

The system to be described may be visualized as shown in Figure 4 . The elements of the system are looked at as if they are disassembled for preparation of the schematic block diagram.

2.1.2 Junction Point Numbering

The point at which two elements meet is called a junction or junction point. These junctions are numbered using the series of numbers from 1 to 9999. It is recommended that an orderly sequence of numbering be used, preferably skipping numbers, so that if changes are made later, the new element numbers can be inserted in the corresponding sequence and will be easy to locate. It should be noted that this is not required for the computer program, but is recommended for the users own benefit.

Figure 2-1 illustrates a typical numbering of junction points. There are three junction points for the hydraulic pump (5, 10 and 15), two junction

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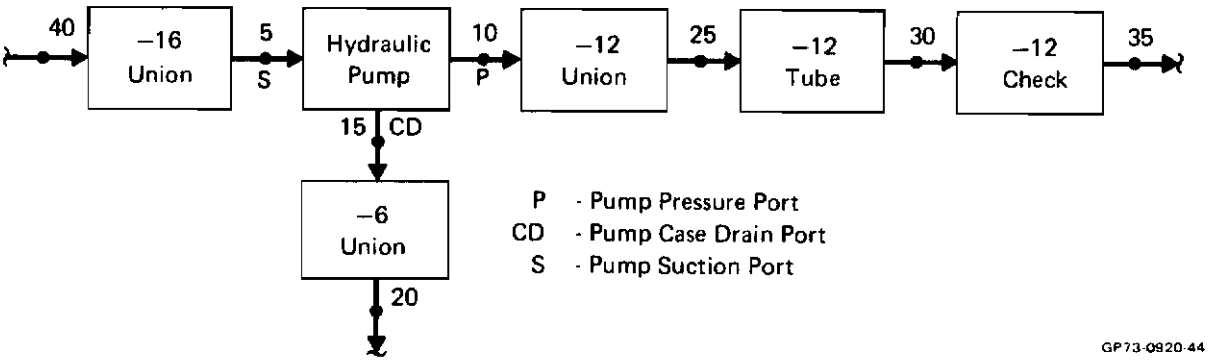

FIGURE 3
SSFAN PROGRAM - PARTIAL SYSTEM BLOCK DIAGRAM

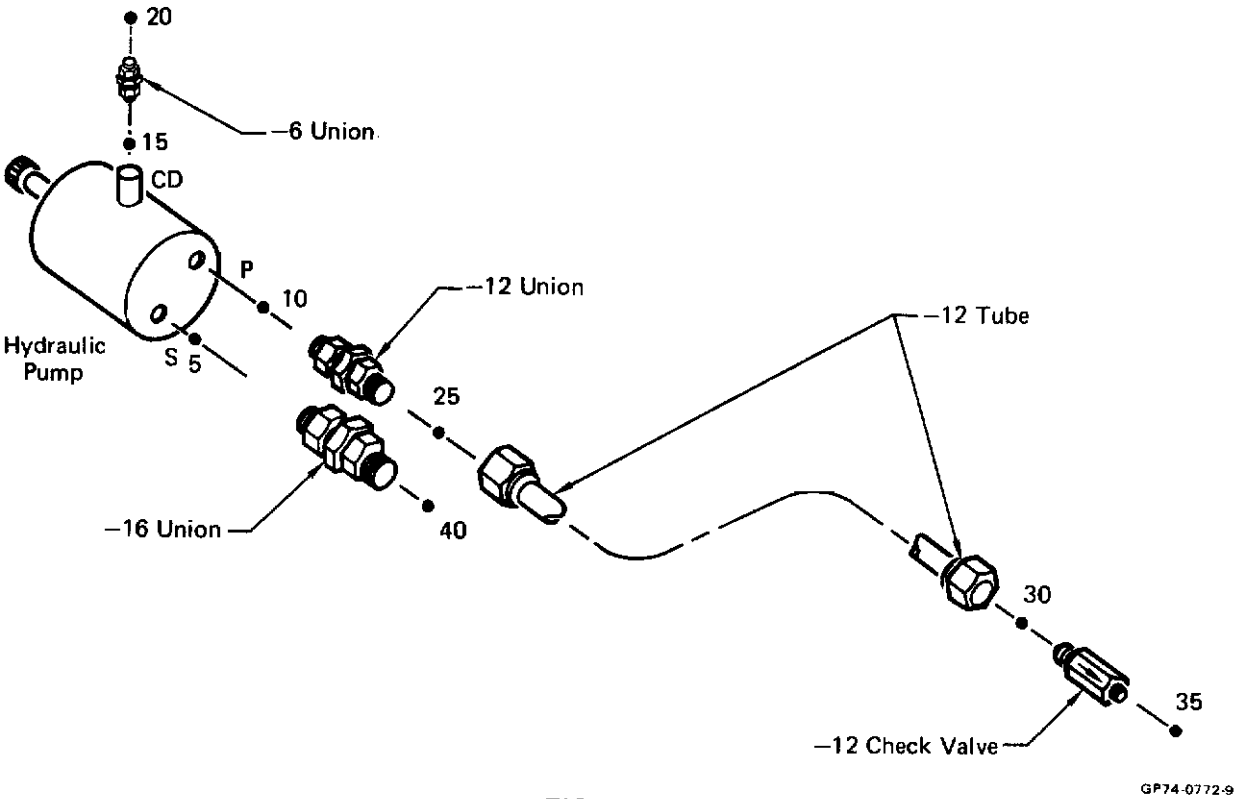

FIGURE 4
PARTIAL SYSTEM

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points for the -12 union at the pump pressure port (10 and 25) and two junction points for the -12 check valve (30 and 35).

It is required that all junction points be numbered and that no two junction points have the same number.

These "in" and "out" junction points are required data for the individual element data inputs described later.

The program uses these junction points to internally locate each element, assemble the system and assemble the resistances for each branch leg in the system.

2.1.3 System Parameters

The system parameters are the first data cards to be assembled in the data deck, and these six cards are required to be in a particular order as noted below.

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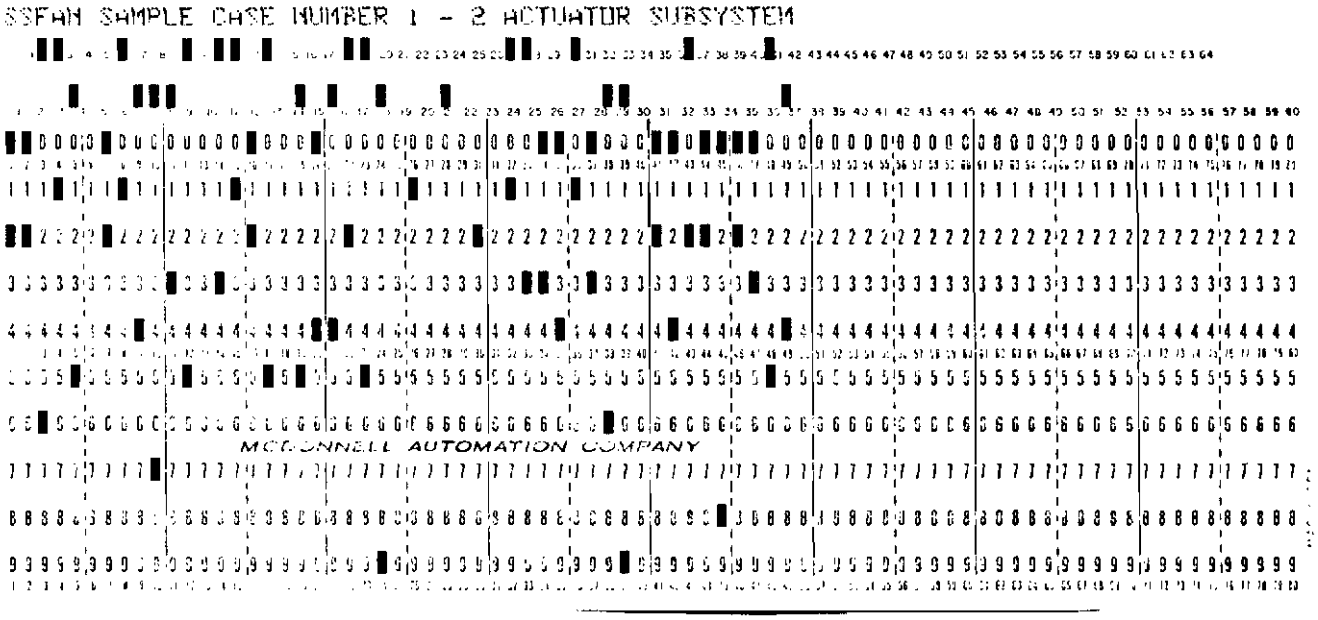
2.1.3.1 Card 1 - Title Card

The title card allows 80 characters to name the system being analyzed. This title will appear on all pages of output data. If a title is not given, a blank card must be inserted.

COLUMNS	FORMAT	DATA	DIMENSIONS
1 - 80	8A10	(NAME OF SYSTEM)	---

EXAMPLE CARD 1

Title Card Data



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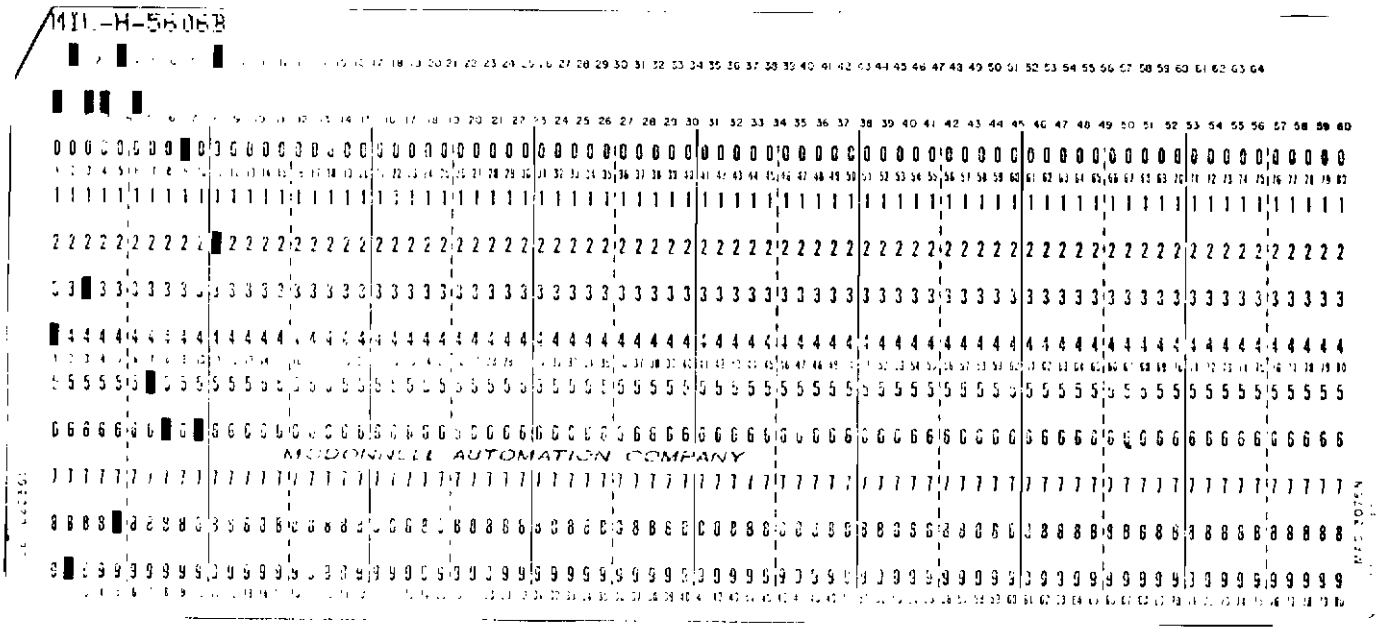
2.1.3.2 Card 2 - Fluid Name

This card is used to name the particular type fluid to be printed on the output data. Fluid names typically are MIL-H-5606A, MIL-H-5606B, MIL-H-83282, SKYDROL 500B, etc. If a fluid name is not given, a blank card must be inserted.

COLUMNS	FORMAT	DATA	DIMENSIONS
1 - 80	8A10	(NAME OF FLUID)	---

EXAMPLE CARD 2

Fluid Name Data



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2.1.3.3 Cards 3 and 4 - Viscosity-Temperature

The selected fluid of 2.1.3.2 requires appropriate viscosity-temperature data. Table 1 gives some suggested viscosities for typical aircraft hydraulic fluids. Input viscosities to SSFAN are at atmospheric pressure. Viscosity and temperature units are centistokes and degrees Fahrenheit respectively. It should be noted that viscosity values are not consistent between literature sources, therefore the user is free to select and use his own desired viscosity data.

TABLE 1
Viscosity-Temperature Data

TEMPERATURE	VISCOSITY (CENTISTOKES)				
(DEG F)	MIL-H-5606A	MIL-H-83282	SKYDROL 500B	MIL-H-5606B	
-65	2000.0	11500.0	3500.0	2000.0	
-40	385.0	2022.0	600.0	488.0	
0	130.0	270.0	155.0	135.0	
50	36.0	49.0	36.0	35.0	
100	14.6	16.0	11.75	14.5	
150	7.7	7.5	7.0	7.5	
200	4.8	4.3	4.2	4.6	
250	3.4	2.85	2.9	3.2	
300	2.4	2.05	2.15	2.4	

Input Data on Cards 3 and 4 are used to describe the viscosity-temperature points. Column 1 on Card 3 and Card 4 contain the same integer number which is the number of viscosity-temperature points to be input with a minimum of 2 and a maximum of 9.

Card 3 contains a viscosity at a point while Card 4 contains the corresponding temperature at the point.

Viscosities and temperatures must be in corresponding fields on their respective cards. The temperatures must be input in ascending order.

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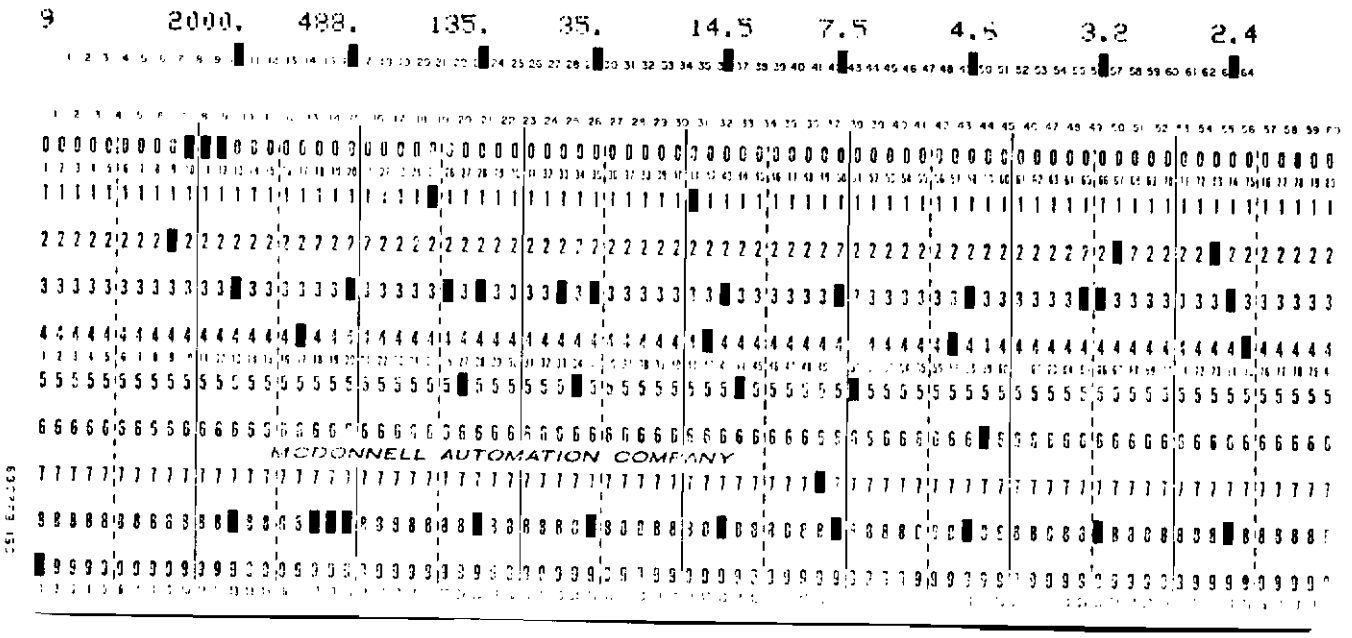
COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	NUMBER OF DATA PTS 2 MIN 9 MAX	---
2-8	7X	BLANK	---
9-16	F8.3	VISCOSITY 1	CENTISTOKES
17-24	F8.3	" 2	"
25-32	F8.3	" 3	"
33-40	F8.3	" 4	"
41-48	F8.3	" 5	"
49-56	F8.3	" 6	"
57-64	F8.3	" 7	"
65-72	F8.3	" 8	"
73-80	F8.3	" 9	"

EXAMPLE CARD 3

Viscosity Data



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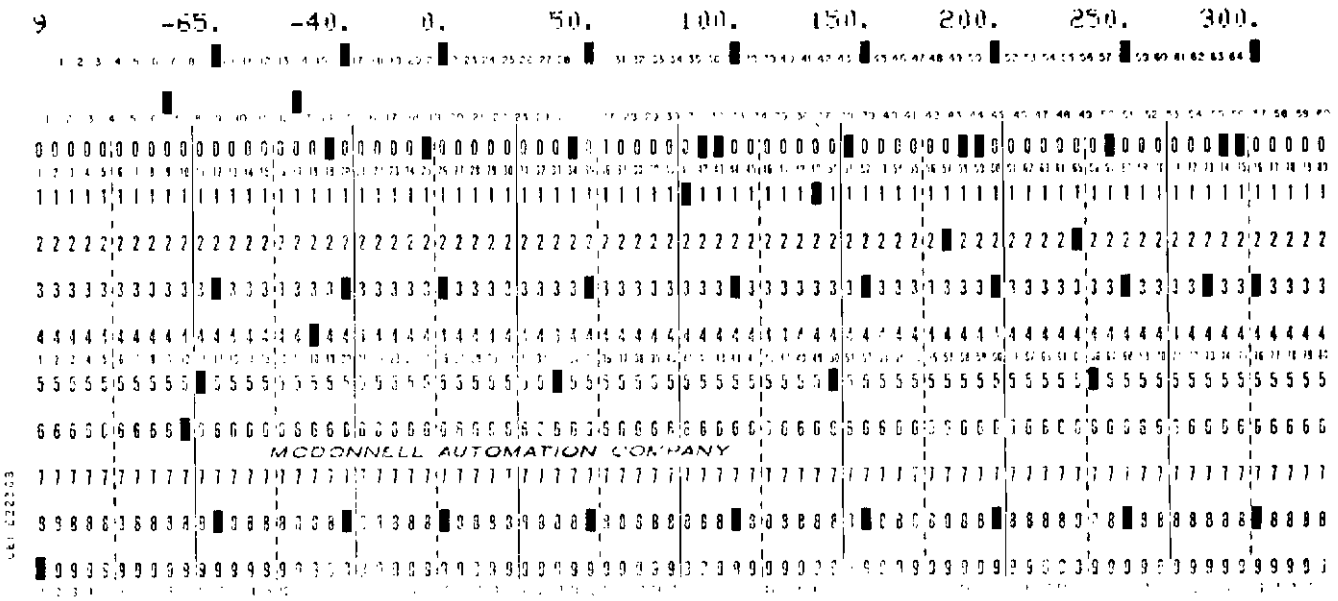
COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	NUMBER OF DATA PTS. 2 MIN / 9 MAX	---
2-8	7X	BLANK	---
9-16	F8.3	TEMPERATURE 1	DEG F
17-24	F8.3	" 2	"
25-32	F8.3	" 3	"
33-40	F8.3	" 4	"
41-48	F8.3	" 5	"
49-56	F8.3	" 6	"
57-64	F8.3	" 7	"
65-72	F8.3	" 8	"
73-80	F8.3	" 9	"

EXAMPLE CARD 4

Temperature Data



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2.1.3.4 Card 5 - Density-Temperature and Viscosity

Density-Temperature - The density of the selected fluid is input for 2 points only since density is considered to change linearly with temperature. Usually these are given at extreme temperatures, but any 2 reasonably spaced temperatures will do since interpolation is linear and linear extrapolation is allowed. Table 2 gives some suggested aircraft hydraulic fluid densities at atmospheric pressure.

TABLE 2

Density-Temperature

TEMPERATURE	DENSITY (LB/FT^3)				
(DEG F)	MIL-H-5606A	MIL-H-83282	SKYDROL 500B	MIL-H-5606B	
-65	56.1	56.6	68.8	57.2	
275	49.9	48.6	59.5	51.0	

The input densities for Card 5 are weight densities. The first data field density corresponds with the third data field temperature and the second data field density corresponds with the fourth data field temperature.

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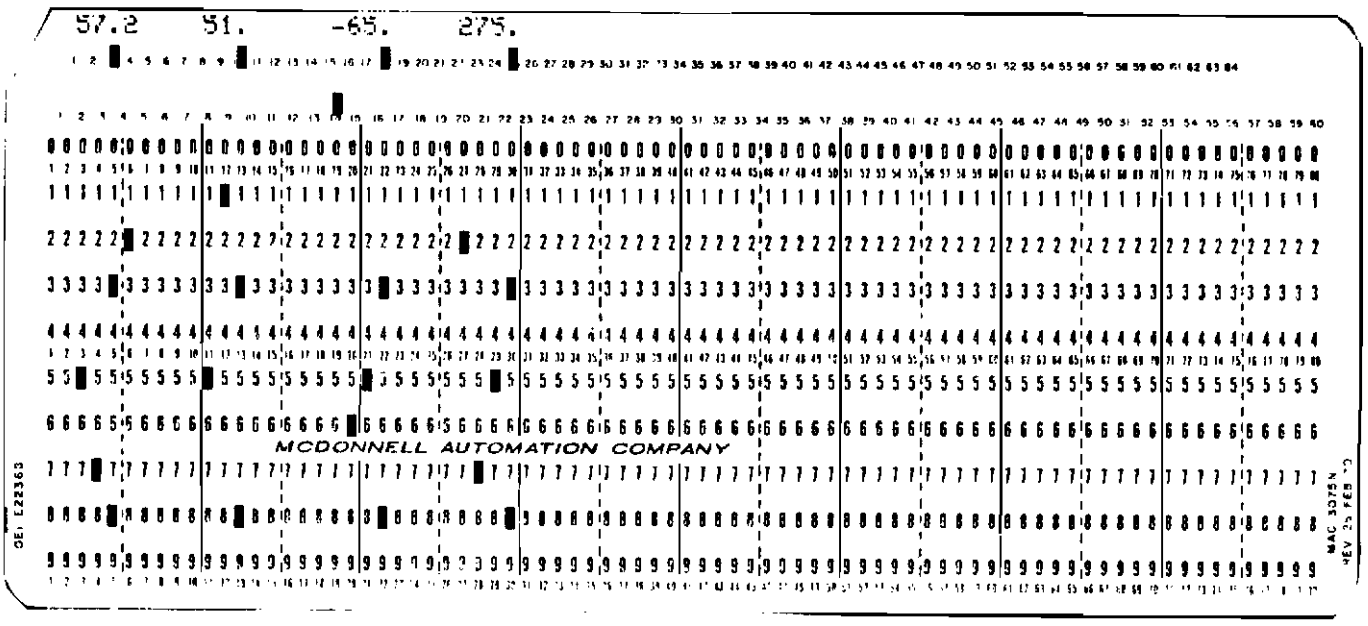
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	DENSITY 1	LB/FT^3
9-16	F8.3	DENSITY 2	LB/FT^3
17-24	F8.3	TEMPERATURE 1	DEG F
25-32	F8.3	TEMPERATURE 2	DEG F
33-80	--	BLANK	--

EXAMPLE CARD 5

DENSITY-TEMPERATURE DATA



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2.1.3.5 Card 6 - System Temperature Flight Altitude and Data Output

The desired operating fluid temperature and flight altitude are input on this card. Temperature is in Degrees Fahrenheit and flight altitude is in feet. A zero flight altitude is sea level. The SSFAN program is also capable of running at temperature increments specified by the user.

Array Output Code Number (Columns 33-40)		
1	=	Leg assembly data, ILEP array, calculation parameters (number of nodes, number of legs), PQL array, BLEG array
2	=	PQL and BLEG arrays
3	=	BLEG array

The ILEP array contains the system leg numbers with their up and downstream node numbers. The PQL array has the system pressures and any external flows to or from a node. The BLEG array is used in the steady state computation and it contains all the leg flow and pressure drop information. If 2 and 3 are selected from the array output code, PQL and BLEG will be printed for each iteration of the steady state program. Volume VI of AFAPL-TR-76-43 contains a further description of how these arrays are used and their contents.

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Data field 1 contains the system operating temperature. Field 2 and 3 are for the final temperature and temperature increment. These may be left blank if not used. Field 4 is for the flight altitude in feet. A blank or zero indicates sea level altitude.

The fifth data field contains the output code for the arrays listed above.

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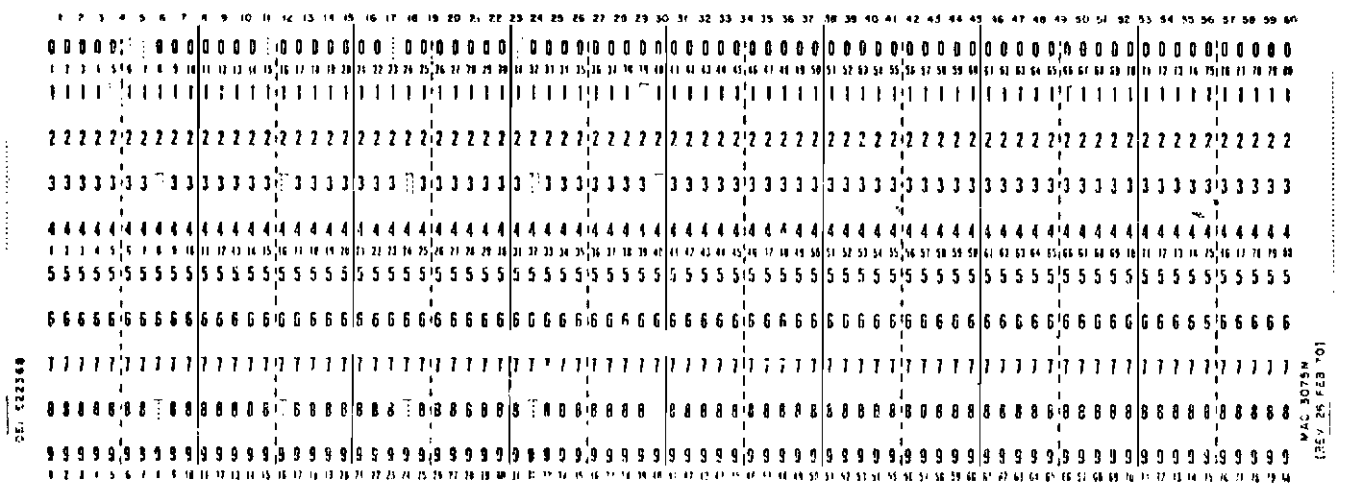
COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	TEMPERATURE	DEG F
9-16	F8.3	FINAL TEMPERATURE	DEG F
17-24	F8.3	TEMPERATURE INCREMENT	DEG F
25-32	F8.3	ALTITUDE	FEET
33-40	F8.3	ARRAY CODE NUMBER (OPTIONAL 1, 2 AND 3)	---
41-80	F8.3	BLANK	---

EXAMPLE CARD 6

System Fluid Temperature - Altitude - Output Data Type

100. 0. 0. 0. 1.



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2.1.4 Element Data

Elements are identified by numbers 1 through 99 in SSFAN. The most commonly used components are established as the lowest numbers. The general system of identification numbers is shown below. As noted, there are unused numbers which are reserved for development of future element models.

Element Type	Description	Element Type	Description
1	Tube	32	Restrictor-2 Way
2	Union	33	Relief Valve
3	Check Valve	34	Valve (4W-3P)
4	Simple Actuator	35	Valve (3W-2P)
5	Pump Variable Del.	36	Valve (2W-2P)
6	Filter Assy	37	Flow Regulator
7	Accumm,Press or Flow Source	38	Restrictor Sizer
8	Hyd Motor	39	
9	Reservoir-Flow Through	40	
10	Special (Flow vs. ΔP)	41	
11	Hose	42	
12	Heat Exchanger	43	
13	Floating Branch Point	44	
14	Jct Point Temperature	45	
15	Q-T Timestep Data	46	
16	Q-T Component Data	47	
17	Q-T Control Data	48	
18	Q-T Output Data	49	
19		50	
20		51	(Reserved for Pumps)
21	45^{0} Elbow	52	
22	90° Elbow	53	
23	Reducer	54	
24	Tee	55	
25	Cross	56	
26	(Reserved for Fittings)	57	
27		58	
28		59	
29		60	(Reserved for Filter
30		61	Manifolds)
31	Restrictor-1 Way	62	

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Element Type	Description	Element Type	Description
63	(Reserved)	81	(Reserved)
64		82	
65		83	
66		84	
67		85	
68		86	
69		87	
70		88	
71		89	
72		90	
73		91	Reservoir-Appendix
74		92	Reservoir-Constant Pressure
75		93	
76		94	
77		95	
78		96	
79		97	
80		98	

Individual element data cards do not have to be arranged in any particular order, except that if 2 or more data cards are required to describe one element. These cards do have to be in order. SSFAN sorts the element data and establishes continuity using the junction point numbers.

In the interest of using terminology which is familiar to aircraft hydraulic system designers and minimizing standard data input, the convention of using equivalent tube size is available as an option. For example the user may input for a tube either the actual tube O.D. in inches or the equivalent tube size in 16ths of an inch. The same is true for a fitting internal bore. The actual fitting internal bore may be input or the equivalent tube size may be input. The sizes and diameters listed below are currently used in SSFAN. The reference internal fitting bores established are the MS33649 and MS33656 series. The program algorithm approximates these values.

The system tubing and fittings are limited to a 4 inch maximum diameter or size.

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SIZE OPTION 1

The diameters listed under the "Program Algorithm" column below are currently programmed into SSFAN and will be used for calculation when the equivalent tube size option is used. The equivalent tube size is input in the size column for element data. For example, when the user inputs 4. into a size column, the program uses a .25 diameter for a tube or a .172 diameter for a fitting bore and an internal port diameter. An equivalent tube size less than 4 may not be used, but the acutal size may be input, see size option 2. The program algorithm will calculate sizes for any other input size such as 7, 23, 61, etc. - see Volume VI Technical Description.

Equivalent Tube Size (16ths In.)	Actual Tube O.D. (In)	Program Algorithm Calculated Tube I.D.(In)	Reference (MS) Internal FTG Bore (In.)
4	.25	.172	.172
5	.3125	.2345	.234
6	.375	.297	.297
8	.50	.391	.391
10	.625	.484	.484
12	.75	.609	.609
16	1.00	.843	.844
20	1.25	1.078	1.078
24	1.50	1.313	1.312
28	1.75	1.547	1.547
32	2.00	1.781	1.781
40	2.50	2.281	2.281
48	3.00	2.781	2.781

SIZE OPTION 2

The user may input directly a tube outside diameter or internal bore diameter up to but not including 4 inches.

The format for all element input data has been established as follows:

(1) Column 1 of the first data card describing an element contains the number of cards (limit of 9) required to describe the element. This is always an Integer (no decimal point following the number).

(2) All other element input data requires a decimal point following the number regardless of whether or not the number is a whole number.

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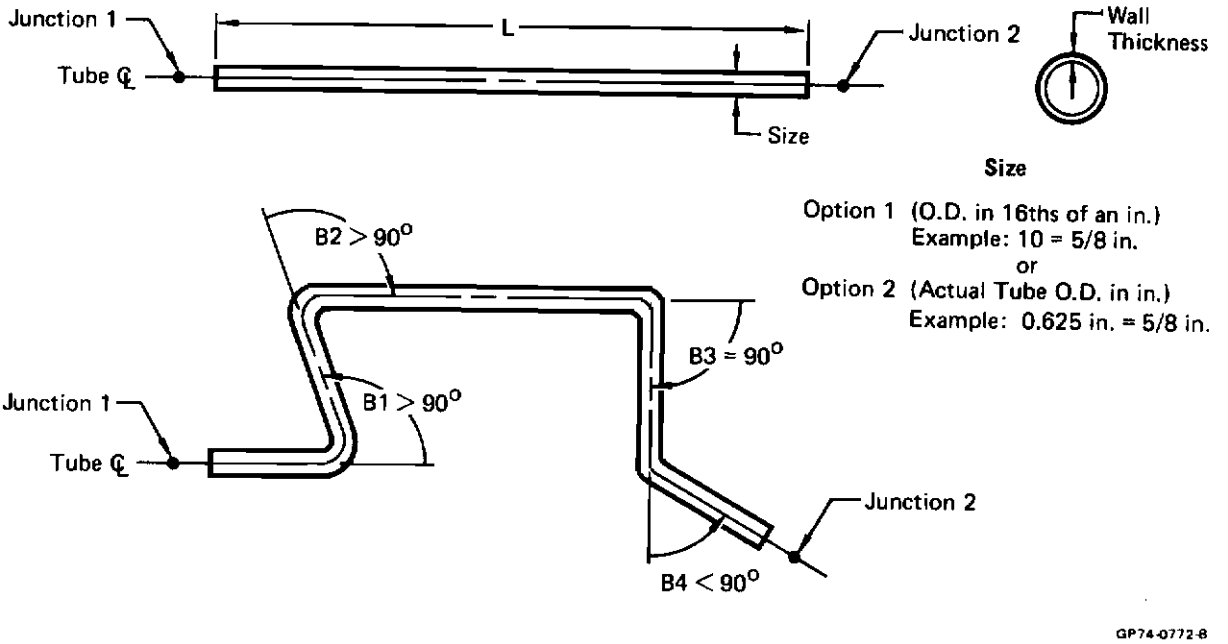
2.1.4.1 Type 1 - Tube



ELEMENT TYPE 1 - TUBE

A tube element is a rigid pipe and may have bends and flared ends. Also, end nuts or "B" nuts may be attached. The tube element parameters are input on 1 to 9 data cards depending on the number of bends in the tube. A total of 9 data cards may be used to input data and bend angles.

Junction point numbers are the assigned numbers from the block diagram. (Example: 230. and 235.). Size is the tube outside diameter and may be input as either option 1 or 2 shown above.

Wall thickness and tube length are in inches. Tube length is the length of the unbent tube. Bend angles are in degrees and are measured at the tube center line using the straight section after a bend as a zero reference for the next bend.

NOTE: Bend angles are converted to energy loss coefficients as the data is read into the program. Output Type 1, see Figure 3-3, shows these bends as a total energy loss for the bends.

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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1 to 9	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 1.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE	IN. (See Options)
41-48	F8.3	WALL THICKNESS	IN.
49-56	F8.3	LENGTH	IN.
57-64	F8.3	BEND 1	DEG
65-72	F8.3	BEND 2	"
73-80	F8.3	BEND 3	"

2ND,3RD,ETC. CARD FORMAT (IF REQUIRED)

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	BEND	DEG
9-16	F8.3	BEND	"
17-24	F8.3	BEND	"
25-32	F8.3	BEND	"
33-40	F8.3	BEND	"
41-48	F8.3	BEND	"
49-56	F8.3	BEND	"
57-64	F8.3	BEND	"
65-72	F8.3	BEND	"
73-80	F8.3	BEND	"

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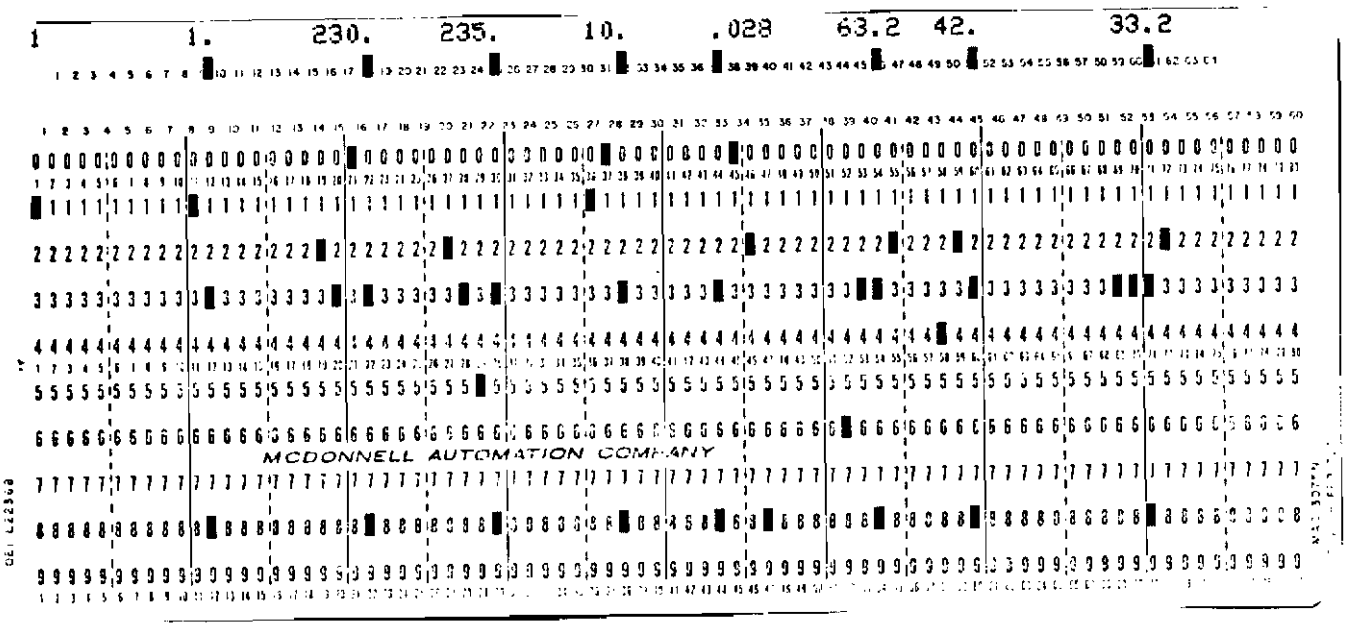
EXAMPLE 1

TYPE 1 TUBE INPUT DATA

1 DATA CARD REQUIRED



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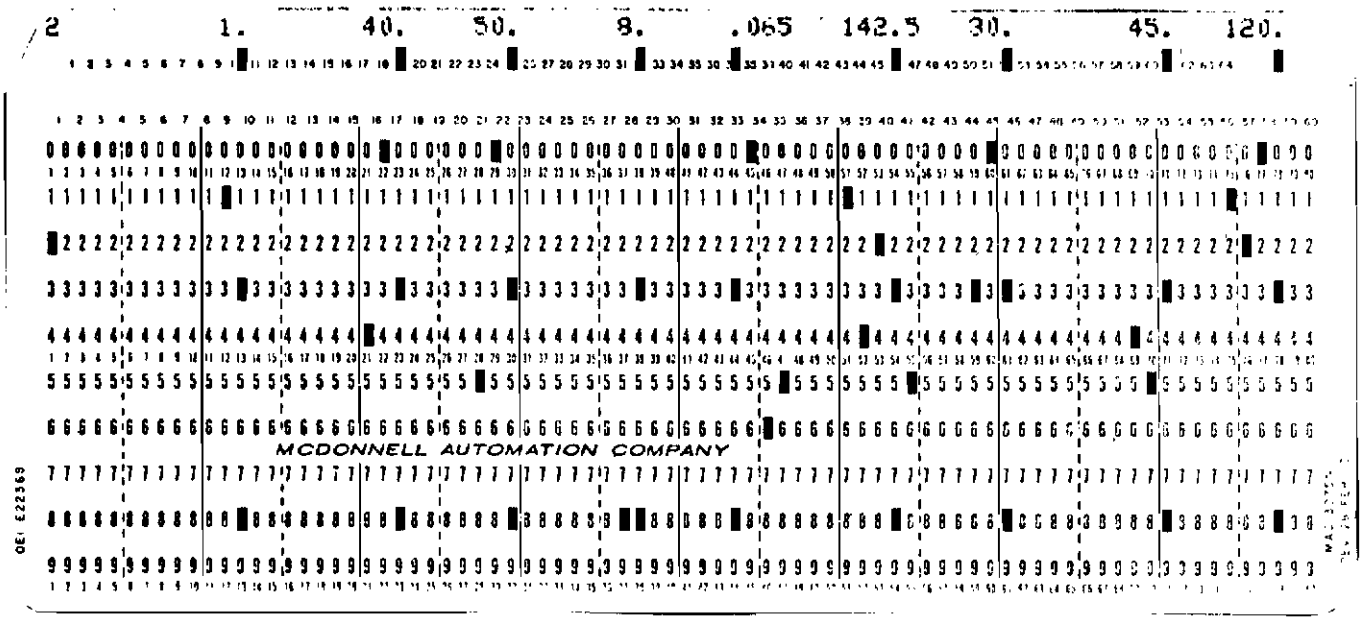
EXAMPLE 2

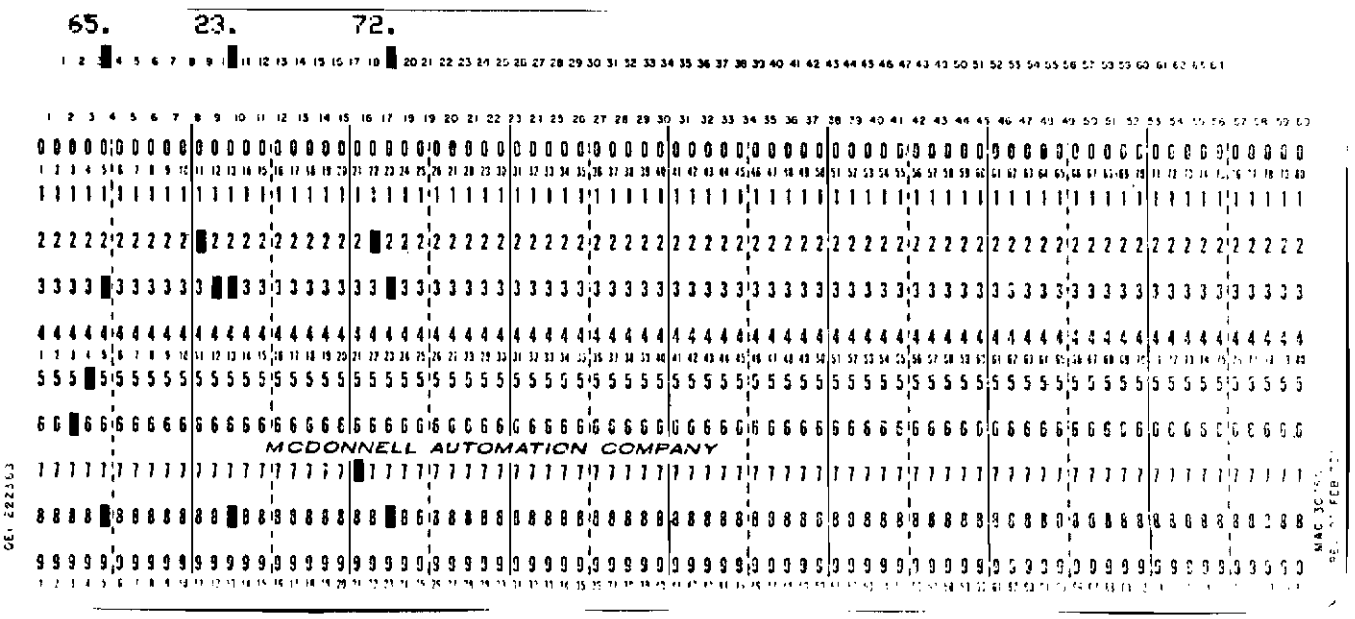
TYPE 1 TUBE INPUT DATA

2 DATA CARDS REQUIRED

CARD 1



CARD 2



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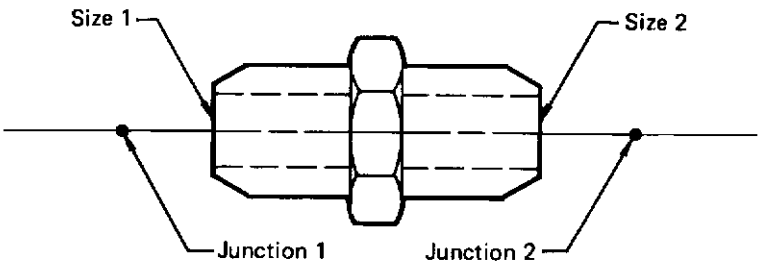
2.1.4.2 Type 2 - Union



Size 1 and Size 2

Option 1 (Fitting End for Tube Size in 16ths of an in.)
Example: 4 = 0.172 I.D.
or
Option 2 (Actual Fitting I.D. at End for Size 1 and Size 2)
Example: 0.172 in.

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ELEMENT TYPE 2 - UNION

A union is a connector commonly used to join 2 tubes or join a tube to a component such as a valve. The union may be a threaded or permanent type and is considered to be a constant diameter throughout its length. It should not be confused with the Type 23 reducer fitting.

The number of data cards required is always 1. Junction point numbers 1 and 2 are the assigned numbers from the block diagram (Example: 245. and 250.). Size 1 and Size 2 are equal and reflect the fitting internal diameter as option 1 or 2 shown in the above sketch.

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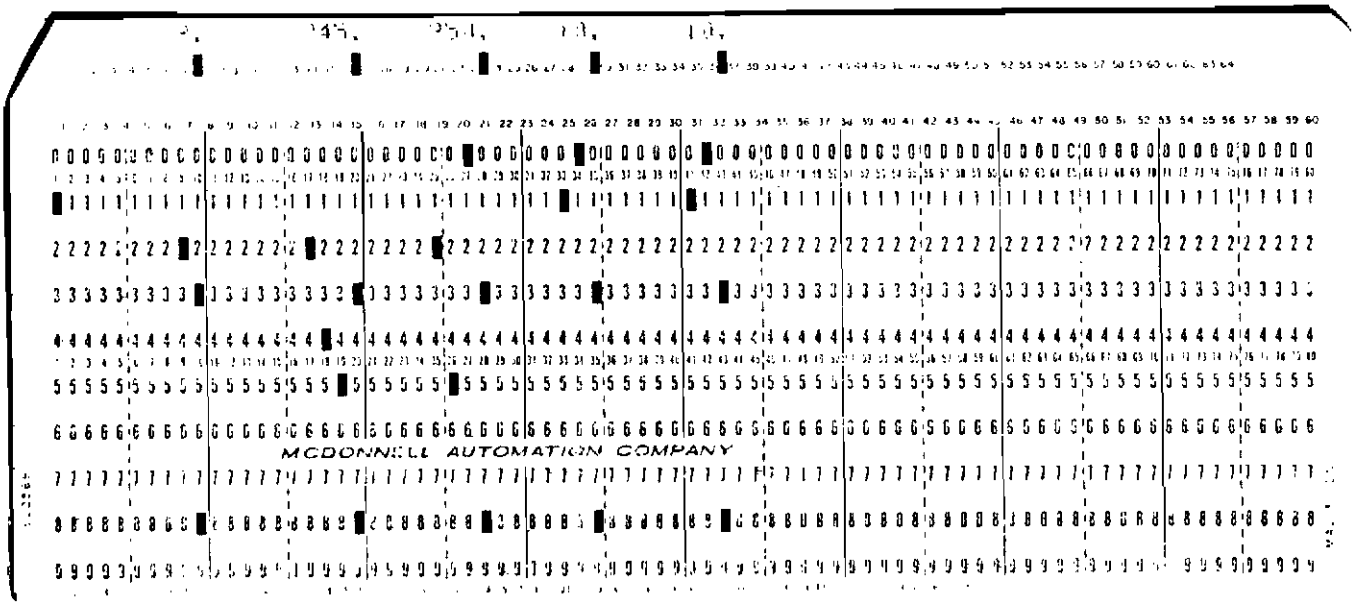
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 2.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	
49- 80		BLANK	---

EXAMPLE

TYPE 2 UNION INPUT DATA



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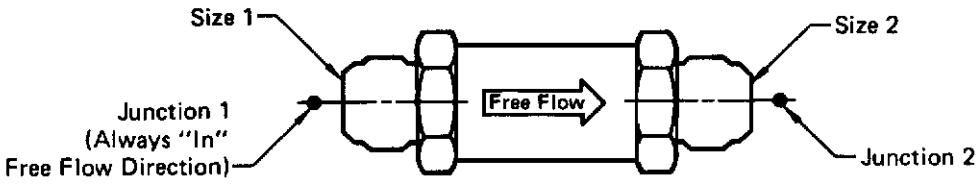
2.1.4.3 Type 3 - Check Valve



Size 1 and Size 2

Option 1 (Fitting End for Tube Size in 16ths of an in.)
Example: 8 = 8/16 in.
or
Option 2 (Actual Fitting I.D. at End for Size 1 and Size 2)
Example: 0.391 in.

GP74-0772-1

ELEMENT TYPE 3 - CHECK VALVE

A check valve may be a ball type, guided poppet type or any other type. Its main purpose is to permit flow in one direction only. In the "free flow" direction as shown above, the pressure drop is normally low. The check valve should not be confused with the Type 31 one-way restrictor which allows a smaller restricted flow in the direction opposite "free flow."

One data card is required for the check valve input. Junction point numbers 1 and 2 are assigned numbers from the block diagram. (Example: 90. and 190.) Junction point 1 is always at the "in" port with flow going in the "Free flow" direction. Sizes 1 and 2 are the fitting end internal bore diameters, see options 1 and 2 above. The nominal check valve cracking pressure is normally input, but minimum or maximum cracking pressure could be used if desired.

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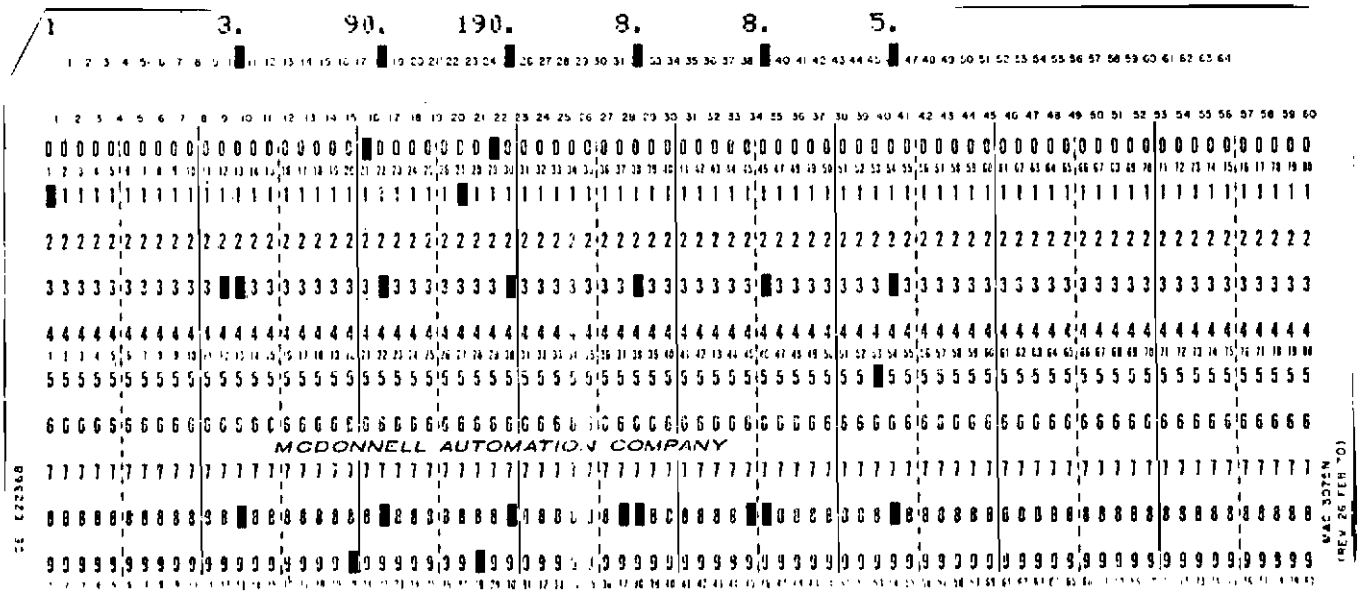
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 3.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-56	F8.3	CRACKING PRESSURE	PSI
57-80	-	BLANK	---

EXAMPLE

TYPE 3 CHECK VALVE INPUT DATA



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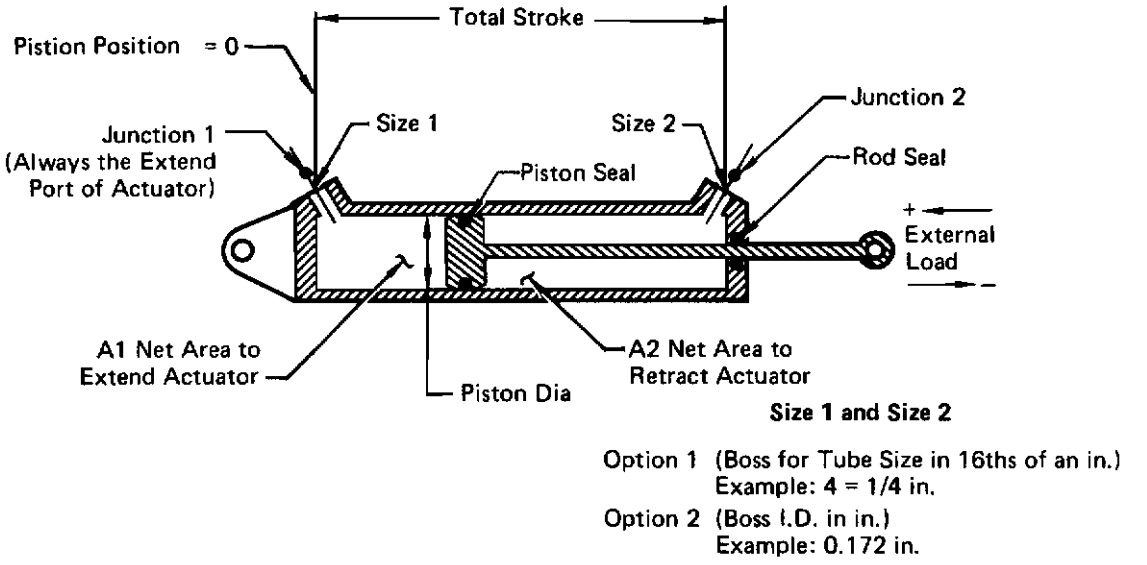
2.1.4.4 Type 4 - Simple Actuator



ELEMENT TYPE 4 - SIMPLE ACTUATOR

The simple linear actuator is used to convert the system fluid power to linear mechanical motion, and is usually controlled by a valve. The piston and rod seals provide a viscous drag or damping force always opposing the direction of motion of the piston. There are several types of simple linear actuators all of which are Type 4. The above sketch shows an unbalanced (unequal areas) type. Other Type 4 actuators are balanced (areas same both sides of piston), partially balanced, parallel and tandem. (See Volume II) Two data cards are required for input parameters. Junction 1 is always assigned to the extend port. Sizes 1 and 2 are noted as optional input. The net areas acting to extend and retract the piston are input along with an external load. A positive (+) load resists actuator extension and aids actuator retraction. The net seal friction force is calculated as: SEAL FRICTION FORCE(LB) = 10X(SUM OF THE DYNAMIC SEAL O.D.S). Piston diameter, total actuator stroke and initial piston position are also input. A piston postion of 0 is when the actuator in the full retracted position. A

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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 4.	---
17-24	F8.3	EXTEND JUNCTION 1	---
25-32	F8.3	RETRACT JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-56	F8.3	EXTEND AREA	IN^2
57-64	F8.3	RETRACT AREA	IN^2
65-72	F8.3	SEAL FRICTION	LB
73-80	F8.3	EXTERNAL LOAD	LB

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	TOTAL STROKE	IN
9-16	F8.3	PISTON POSITION	IN
17-24	F8.3	PISTON DIAMETER	IN
25-32	F8.3	CONTROL VALVE JCT TO EXTEND ACTR	--
33-80	F8.3	BLANK	--

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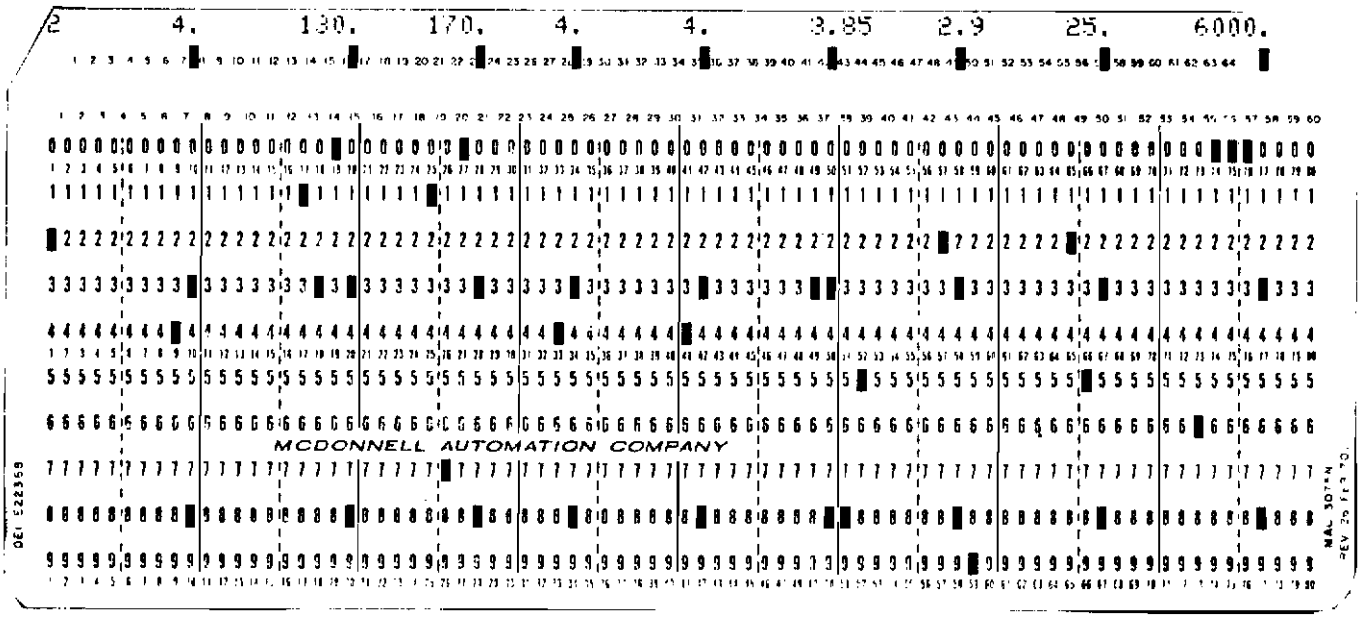
EXAMPLE

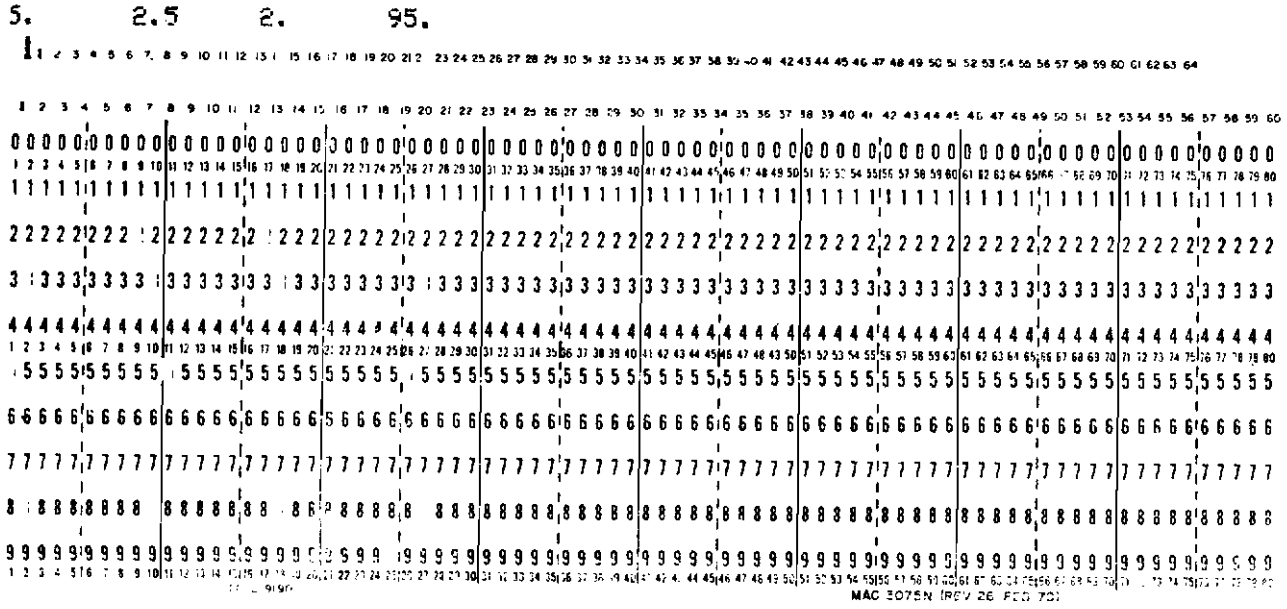
TYPE 4 SIMPLE ACTUATOR INPUT DATA

2 DATA CARDS REQUIRED

CARD 1



CARD 2



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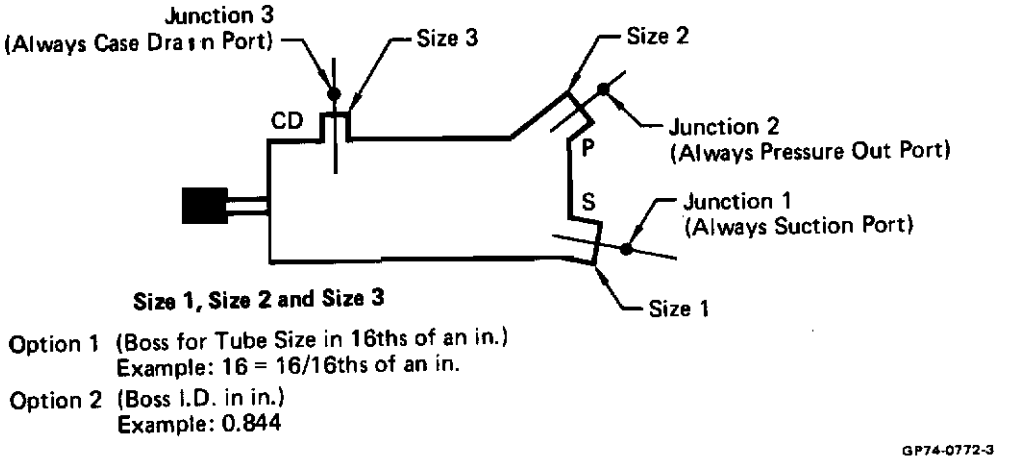
2.1.4.5 Type 5 - Variable Delivery Pump



ELEMENT TYPE 5 - VARIABLE DELIVERY HYDRAULIC PUMP

The variable displacement pump outputs flow in response to the load demands of the system. The pump has a basic flow pressure characteristic curve which is described by its rated flows and pressures. There is some internal leakage flow from the high pressure side back to the case drain port and also internal leakage from the pump case back to the inlet or suction port.

Two data cards are required for the pump input. The suction, pressure "out" and case drain junctions are numbered 1, 2 and 3 respsectively. Sizes are input corresponding to junction points with options as noted. The pump actual RPM and rated RPM along with the rated pressures and the rated flow at rated pressure are also input.

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The following pump characteristics are optional input parameters. These are noted in Figure 2-3.

PSMIN - Rated minimum suction or inlet pressure. Default value is 25 psia.

RCDP - Rated maximum pressure difference between the pump case and inlet. Default value is 300 psid.

RCDL - Rated flow out the case drain port under pump rated conditions. Default value is 1 gpm.

PSET - The pump case pressure when setting the rated flow and pressure. The default value is 50 psig.

If the columns are left blank on the data cards, the default values will be used.

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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 2	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 5.	---
17-24	F8.3	JUNCTION 1 (S)	---
25-32	F8.3	JUNCTION 2 (P)	---
33-40	F8.3	JUNCTION 3 (CD)	---
41-48	F8.3	SIZE 1	IN. (See Options)
49-56	F8.3	SIZE 2	IN. (See Options)
57-64	F8.3	SIZE 3	IN. (See Options)
65-72	F8.3	ACTUAL PUMP RPM	REV. PER MIN.
73-80	F8.3	RATED PUMP RPM	REV. PER MIN.

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	RATED OUTPUT FLOW	GPM
9-16	F8.3	RATED PRESSURE (0 FLOW)	PSI
17-24	F8.3	RATED PRESSURE (FULL FLOW)	PSI
25-32	F8.3	PSMIN	PSIA
33-40	F8.3	RCDP	PSID
41-48	F8.3	RCDL	GPM
49-56	F8.3	PSET	PSIG
57- 80	-	BLANK	-

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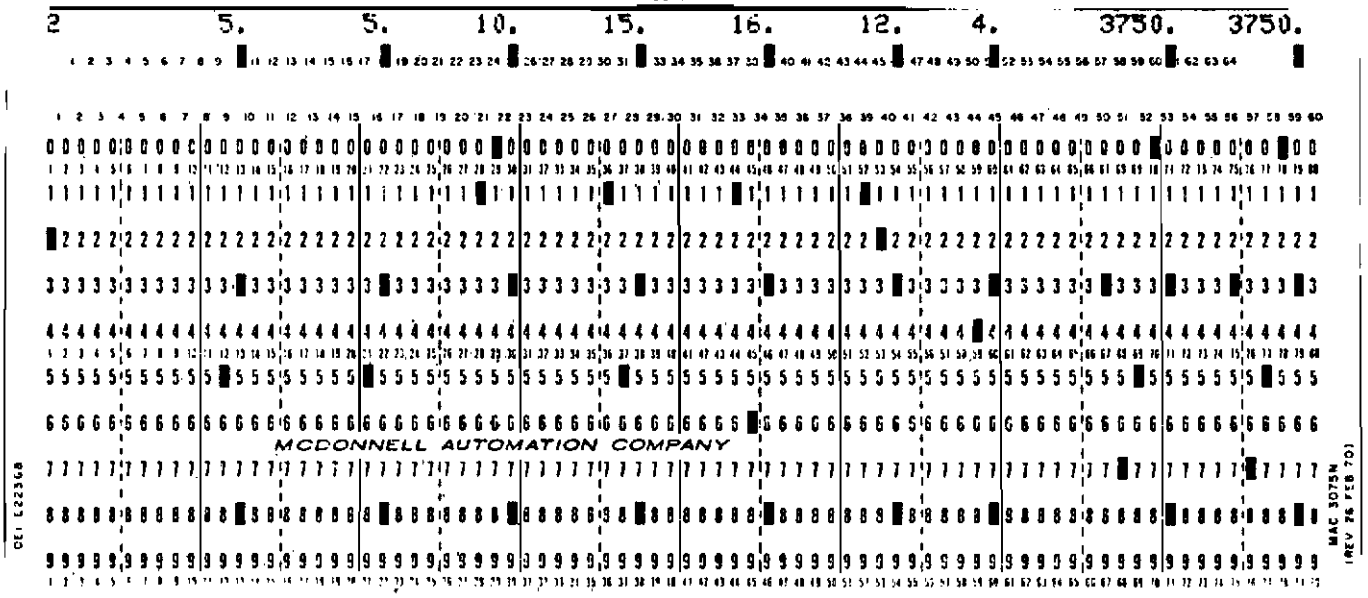
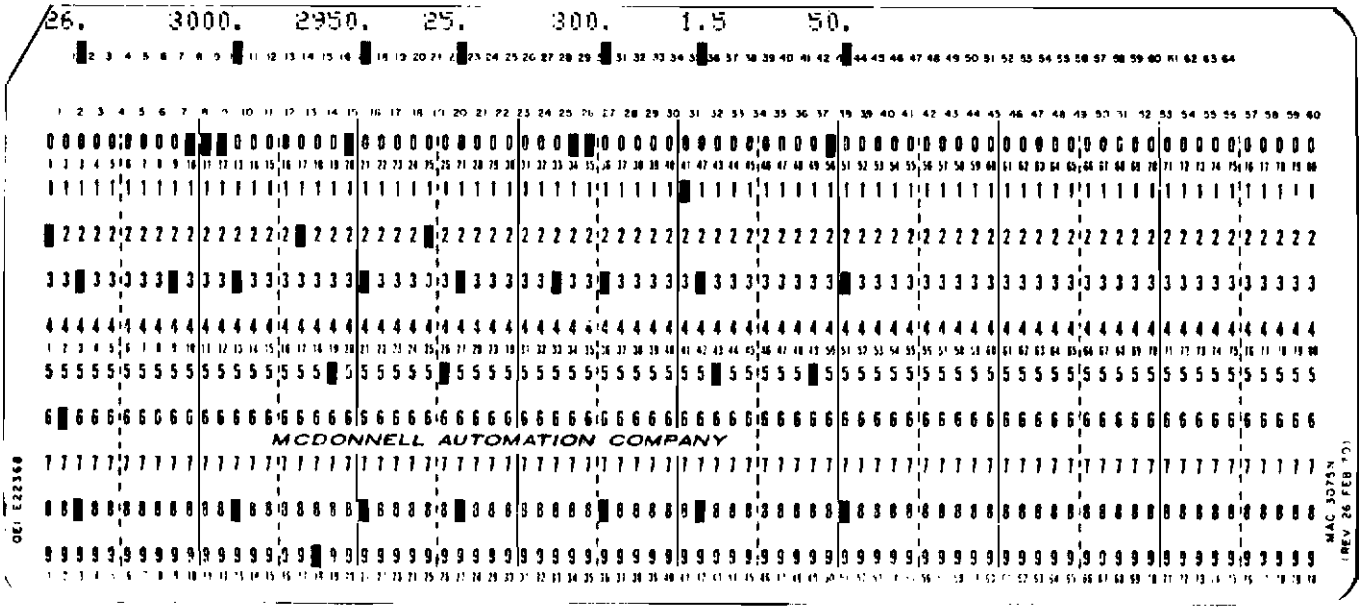
EXAMPLE
TYPE 5 VARIABLE DELIVERY PUMP

2 DATA CARDS REQUIRED

CARD 1



CARD 2



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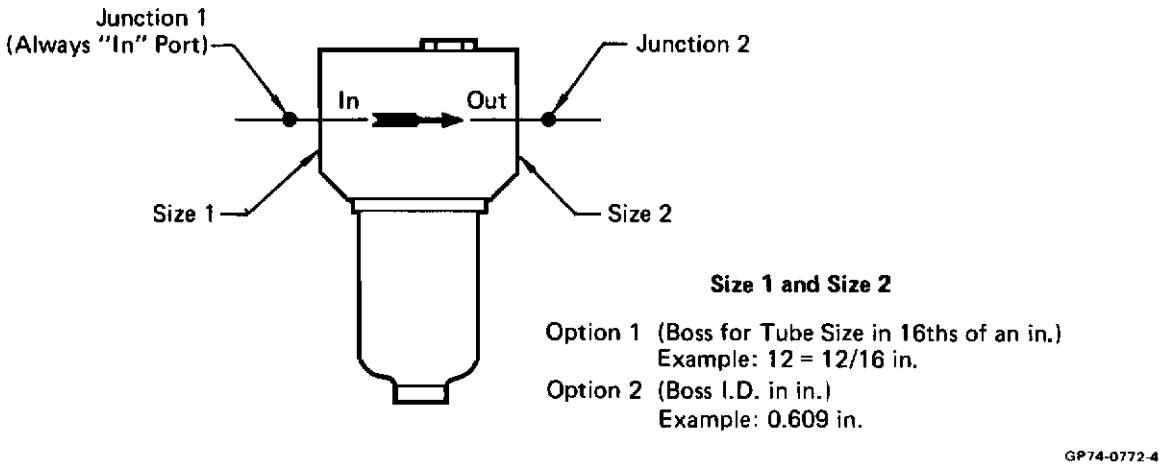
2.1.4.6 Type 6 - Filter



ELEMENT TYPE 6 - FILTER ASSEMBLY

Filters are an essential part of all aircraft hydraulic systems. They are installed in strategic locations to protect components which are sensitive to contamination. Some filters have bypass relief valves. Type 6 filter is either a bypass or non-bypass type.

Two cards are required for input data. Junction 1 is always input as the inlet flow port. Sizes 1 and 2 correspond to junctions 1 and 2 with options as noted. The internal fluid volume is input along with the rated flow and pressure drop of a clean element. The next column contains the viscosity for the clean element at the rated conditions. The contamination factor is optional. A blank or 0. is a clean element. A value between 0. and 1. is the percent the element is contaminated. A value of 1. is a full contaminated element. A factor is input when the user wants to simulate a partially contaminated element and not a clean element. If there is a bypass relief, the nominal relief cracking pressure is input along with the bypass pressure drop at the same rated flow as the clean element.

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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 2	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 6.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-56	F8.3	INTERNAL FLUID VOLUME	IN^3
57-64	F8.3	RATED FLOW OF CLEAN ELEMENT	GPM
65-72	F8.3	RATED PRESSURE DROP OF CLEAN ELEMENT	PSI
73-80	F8.3	VISCOSITY AT RATED CONDITIONS	CENTISTOKES

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	CONTAMINATION FACTOR	PSI
9-16	F8.3	RELIEF VLV CRACKING PRESSURE	PSI
17-24	F8.3	BYPASS PRESSURE DROP AT RATED FLOW	PSI
25-80	--	BLANK	--

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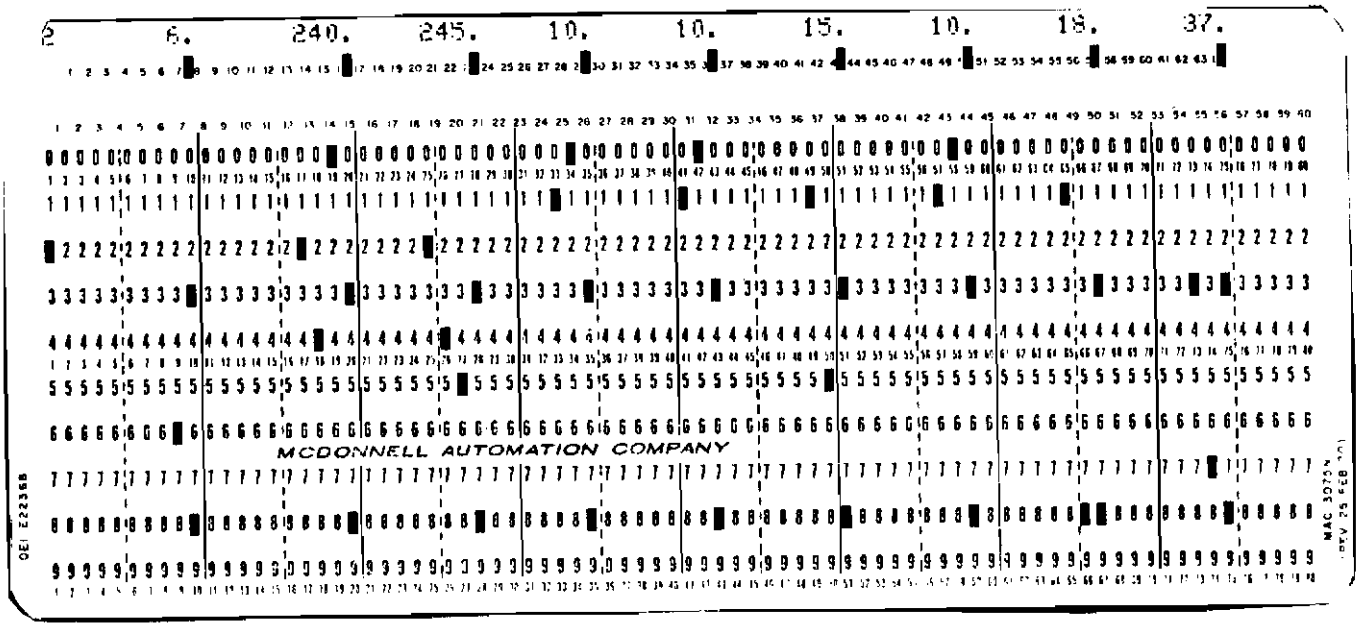
EXAMPLE

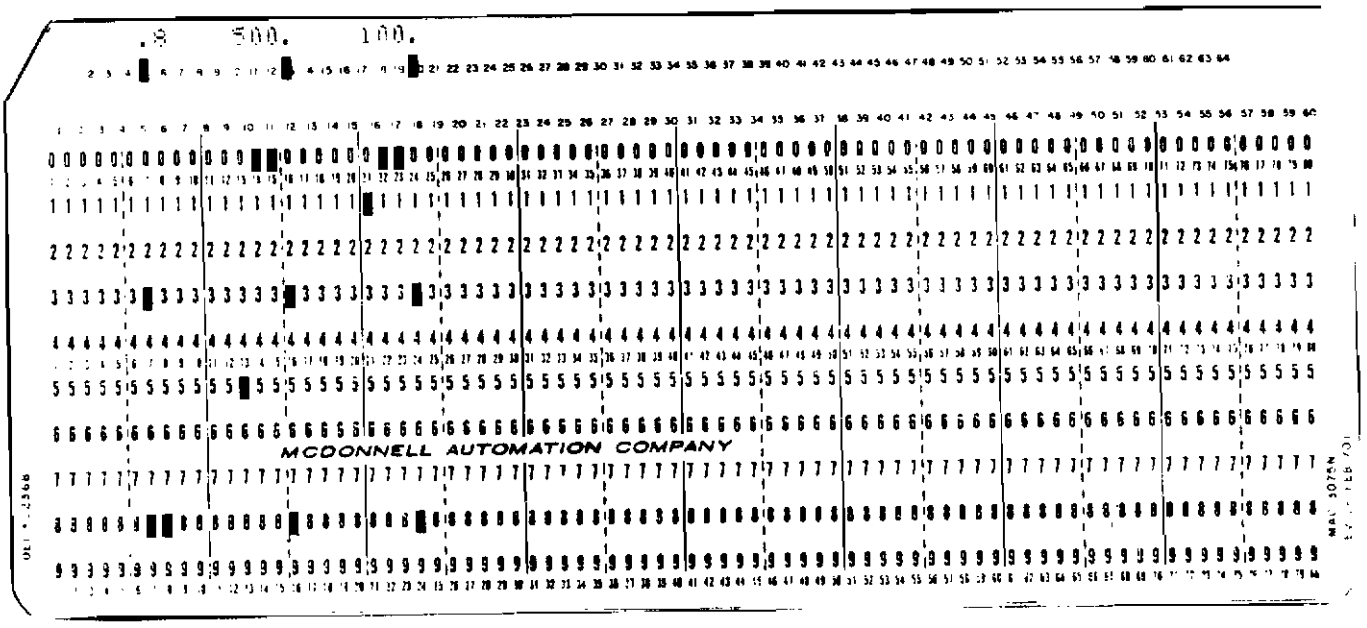
TYPE 6 FILTER INPUT DATA

2 DATA CARDS REQUIRED

CARD 1



CARD 2



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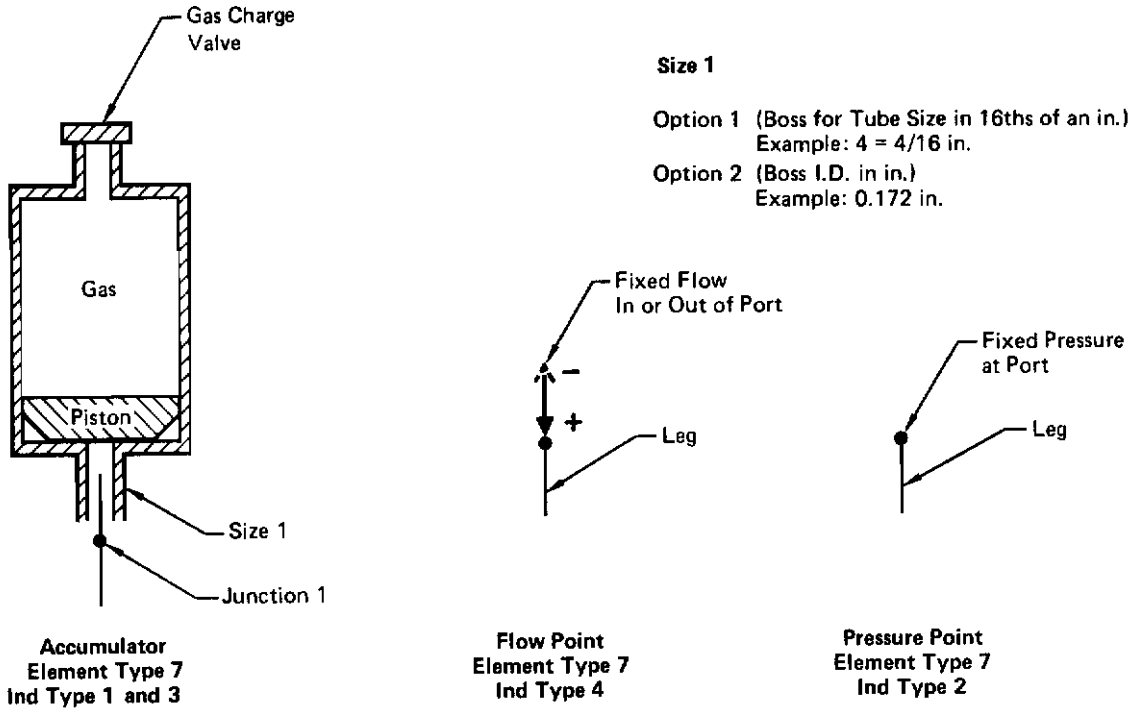
2.1.4.7 Type 7 - Accumulator - Fixed Pressure Point - Fixed Flow Point



ELEMENT TYPE 7 - ACCUMULATOR

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There are 4 subtypes under element type 7. Subtype 1. is a passive (static) accumulator where no flow is considered to be in the leg to the accumulator and the accumulator pressure is the same as the pressure at the point where the leg branches off to go to the accumulator. Subtype 2. is a fixed pressure point and maintains this pressure regardless of the flow in the leg leading to or away from the point. This point has to be an end point in the system and cannot be an intermediate point between 2 elements. Subtype 3. is a dynamic accumulator. An accumulator may be a piston type, bladder type, or an air to oil type. Any of these types can be input as Type 7 because an accumulator power capability is based on the precharge gas volume, pressure and temperature. The columns for precharge gas pressure and volume, fluid minimum and maximum volume and initial pressure or initial fluid volume are used only when the dynamic accumulator is used. Subtype 4. is a fixed flow point with similar restrictions as the Subtype 2. This point will

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maintain the constant flow regardless of system conditions or changes in system conditions.

SUMMARY OF ELEMENT TYPE 7. SUBTYPE OPTIONS

SUBTYPE		DESCRIPTION
1.	STATIC PRESSURE POINT	PRESSURE WILL BE CALCULATED AT PRESSURE POINT
2.	FIXED PRESSURE POINT	SETS PRESSURE AT PRESSURE POINT
3.	DYNAMIC PRESSURE POINT	PRESSURE AND/OR VOLUME IS SET AT PRESSURE POINT AND UPDATED DURING PROGRAM CALCULATION
4.	FIXED FLOW POINT	FLOW IS SET AT PRESSURE POINT

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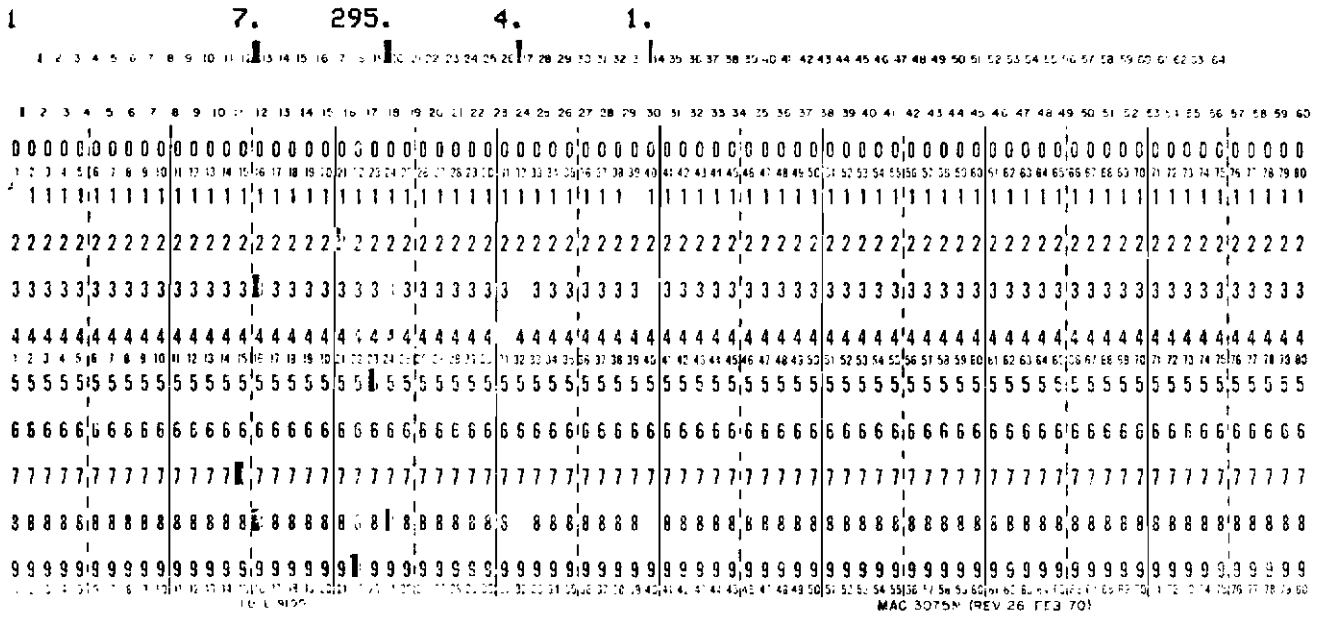
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1	--
2-8	7X	Blank	--
9-16	F8.3	(Element Type) 7.	--
17-24	F8.3	Junction	--
25-32	F8.3	Size	IN (See Options)
33-40	F8.3	(Static Pressure Accum) 1.	--
41-80		Blank	

EXAMPLE

TYPE 7 STATIC PRESSURE ACCUMULATOR INPUT DATA



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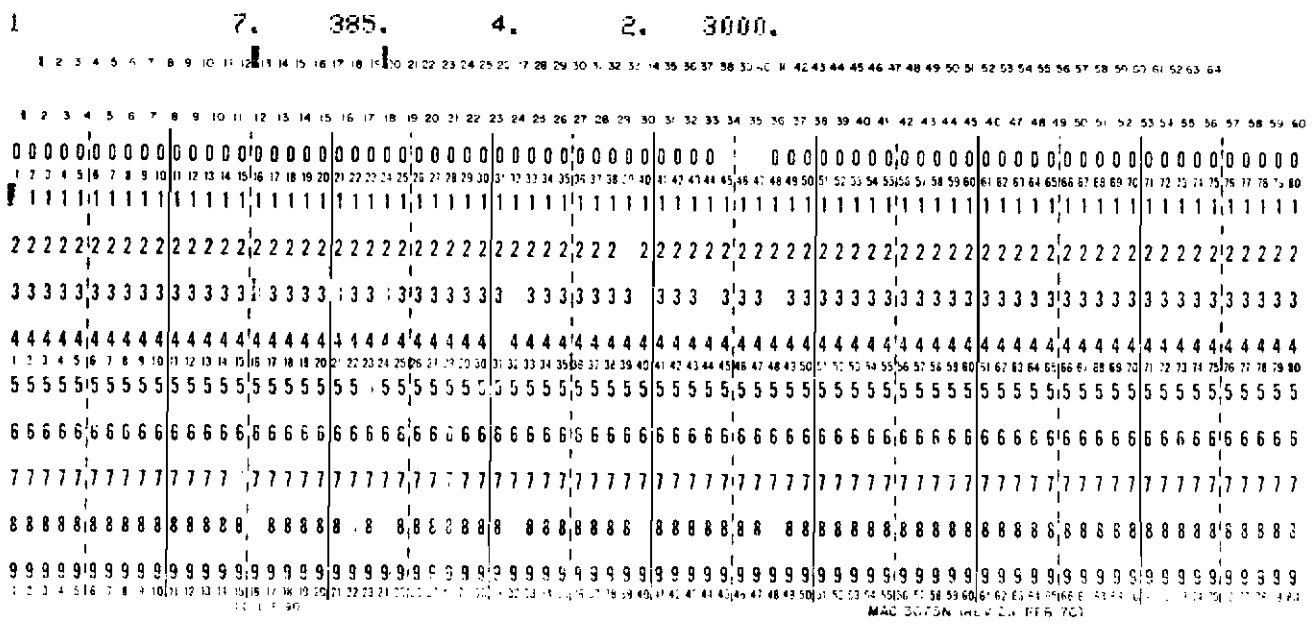
Contrails

CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1	--
2-8	7X	Blank	--
9-16	F8.3	(Element Type) 7.	--
17-24	F8.3	Junction	--
25-32	F8.3	Size	IN. (See Options)
33-40	F8.3	(Fixed Pressure Point) 2.	--
41-48	F8.3	Pressure	PSI
49-80		Blank	

EXAMPLE

TYPE 7 FIXED PRESSURE POINT INPUT DATA



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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 2	--
2-8	7X	Blank	--
9-16	F8.3	(Element Type) 7.	--
17-24	F8.3	Junction	--
25-32	F8.3	Size	IN.(See options)
33-40	F8.3	(Dynamic Pressure Accum) 3.	--
41-48	F8.3	Precharge Gas Pressure	PSIG
49-56	F8.3	Minimum Gas Volume	IN^3
57-64	F8.3	Precharge (Max) Gas Volume	IN^3
65-72	F8.3	Precharge Gas Temperature	DEG F
73-80	F8.3	Maximum Oil Volume	IN^3

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	Minimum Oil Volume	IN^3
9-16	F8.3	Initial Gas/Fluid Pressure	PSIG
17-80		Blank	--

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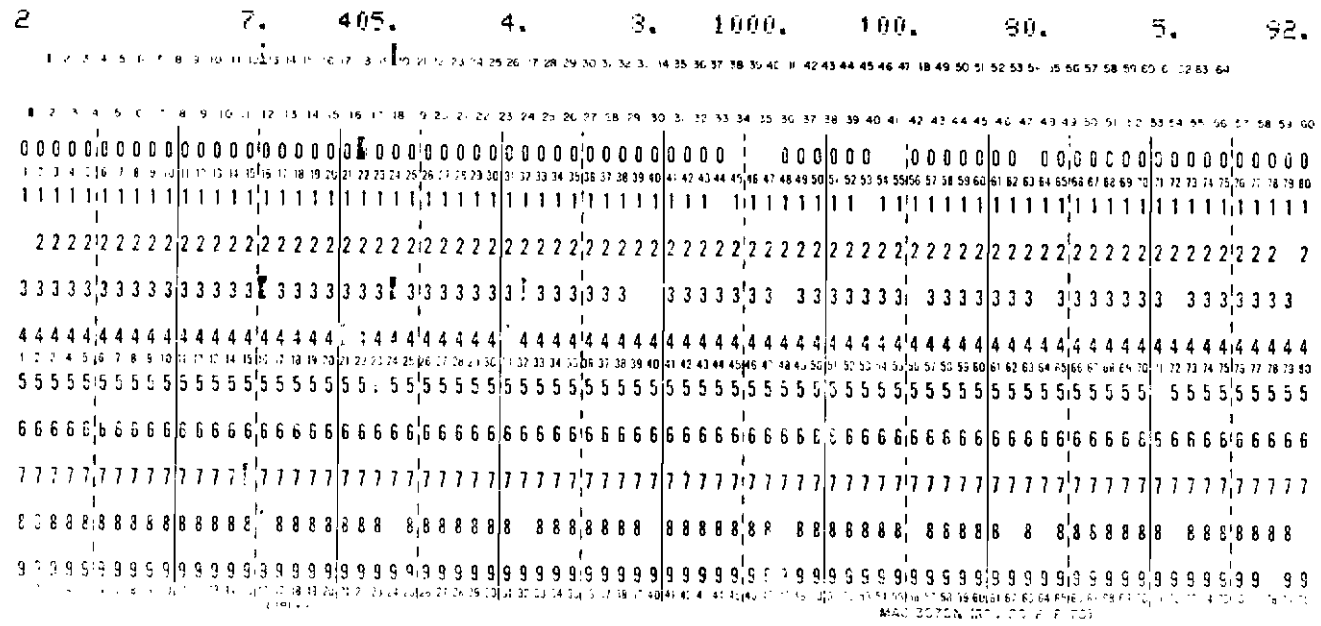
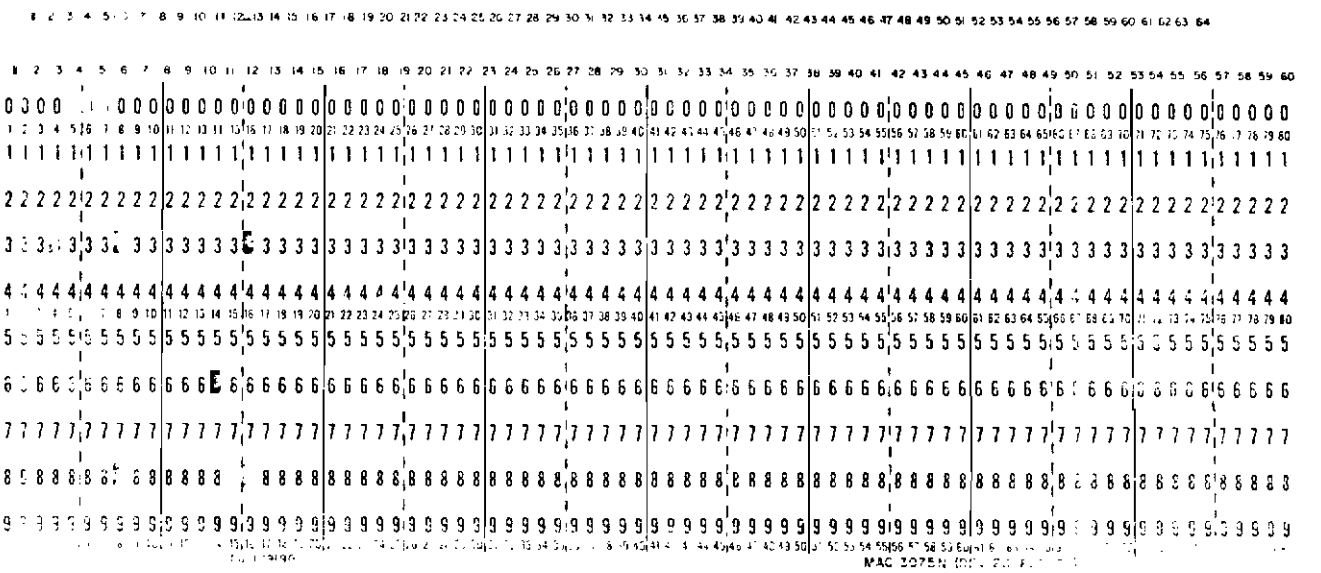
EXAMPLE
TYPE 7 DYNAMIC ACCUMULATOR SUBTYPE 3
2 DATA CARDS REQUIRED

CARD 1



CARD 2



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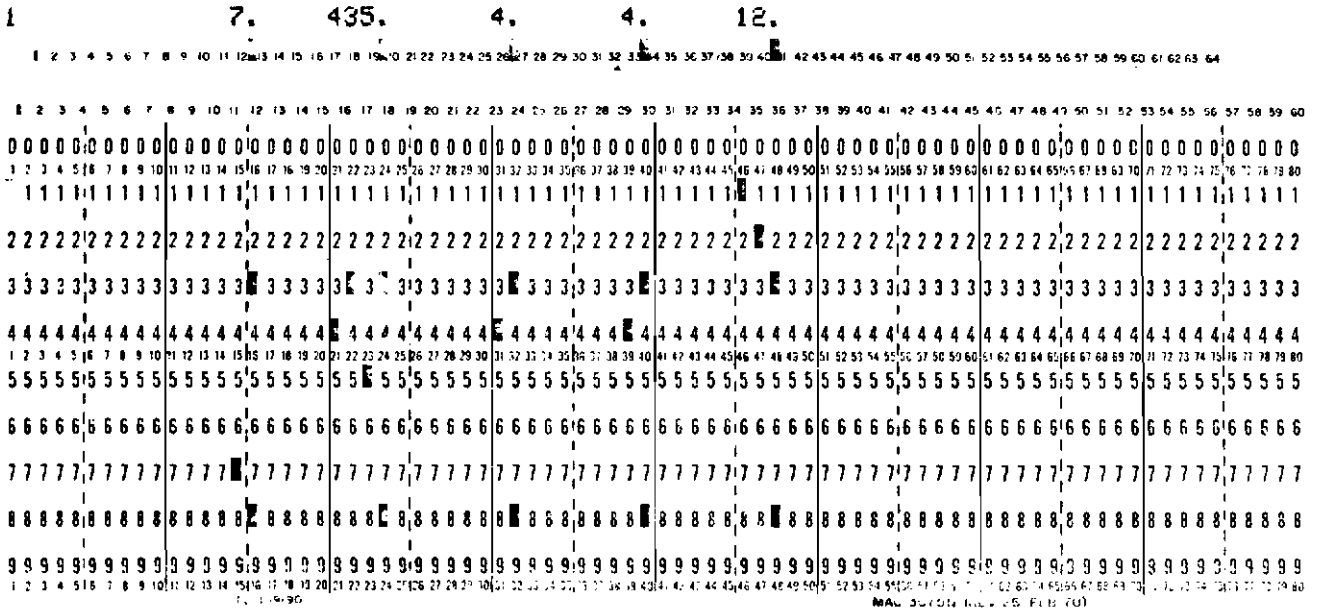
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1	--
2-8	7X	Blank	--
9-16	F8.3	(Element Type) 7.	--
17-24	F8.3	Junction	--
25-32	F8.3	Size	IN. (See Options)
33-40	F8.3	(Fixed Flow Point) 4.	--
41-48	F8.3	Flow Rate	GPM
49-80		Blank	

EXAMPLE

TYPE 7. FIXED FLOW POINT INPUT DATA



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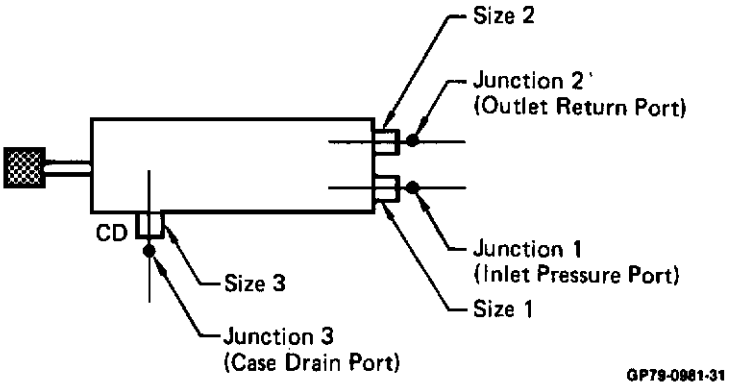
2.1.4.8 Type 8 - Fixed Displacement Hydraulic Motor



ELEMENT TYPE 8 - HYDRAULIC MOTOR

Hydraulic motors are used to convert fluid power to rotating mechanical power. The fluid flow is changed to rotational velocity or speed and the pressure is converted to torque to move the load. Torque losses are a combination of breakaway torque, coulomb friction and viscous drag losses. Input values are motor displacement, load torque and overall efficiency. The case drain leakage is an optional input with a default value of 1 cubic in per second per 1000 psi. The motor model can be used as a 2 port model (with no case drain port) or a 3 port model.

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COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 2.	---
2-8	7X	Blank	---
9-16	F8.3	(Element Type) 8.	---
17-24	F8.3	Junction 1 (IN)	---
25-32	F8.3	Junction 2 (OUT)	---
33-40	F8.3	Junction 3 (CD) Optional	---
41-48	F8.3	Size 1	IN (See Options)
49-56	F8.3	Size 2	IN (See Options)
57-64	F8.3	Size 3	IN (See Options)
65-72	F8.3	Displacement	IN^3/REV
73-80	F8.3	Load Torque	IN-LB

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	Efficiency	Decimal % 0.→1.
9-16	F8.3	CD Leakage (Optional)	IN^3/SEC/1000 PSI
17-80		Blank	---

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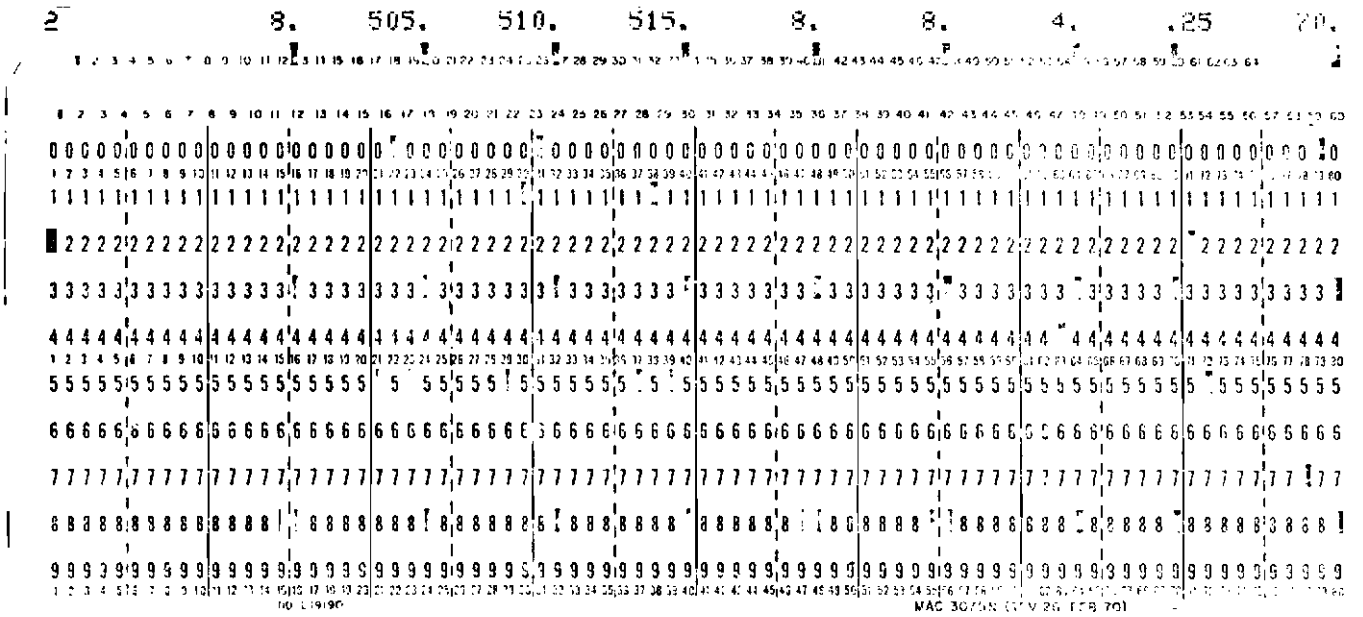
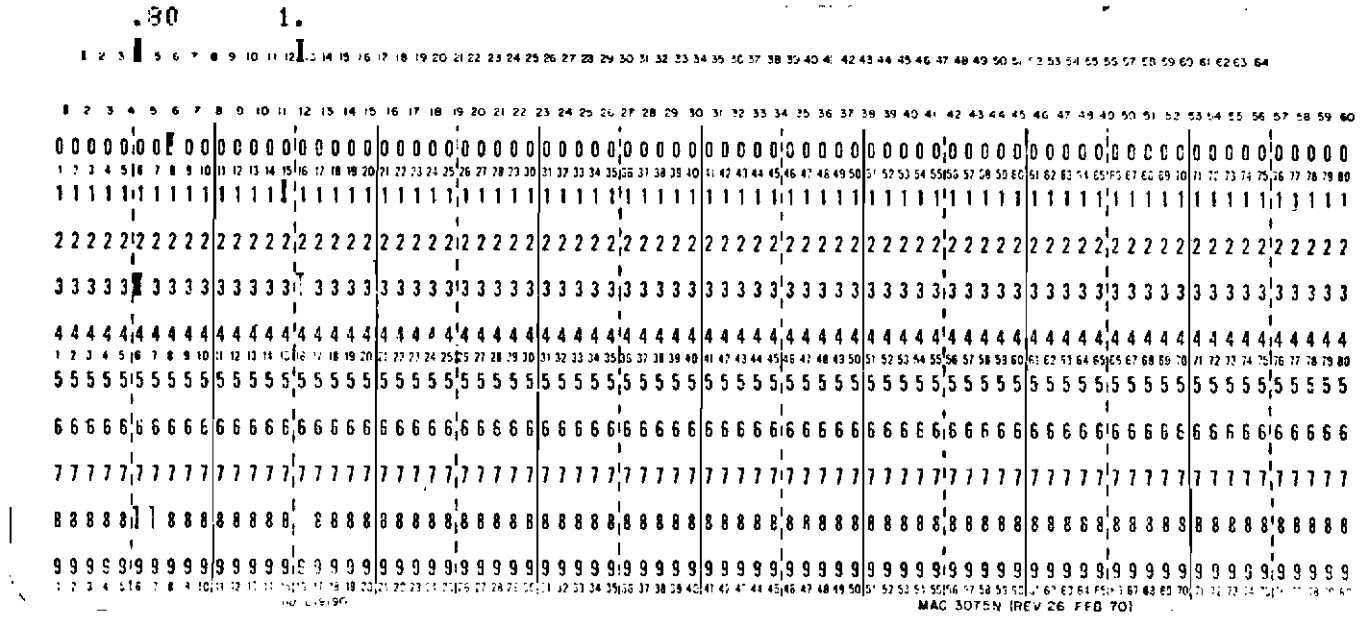
EXAMPLE
TYPE 8 HYDRAULIC MOTOR INPUT DATA

CARD 1



CARD 2



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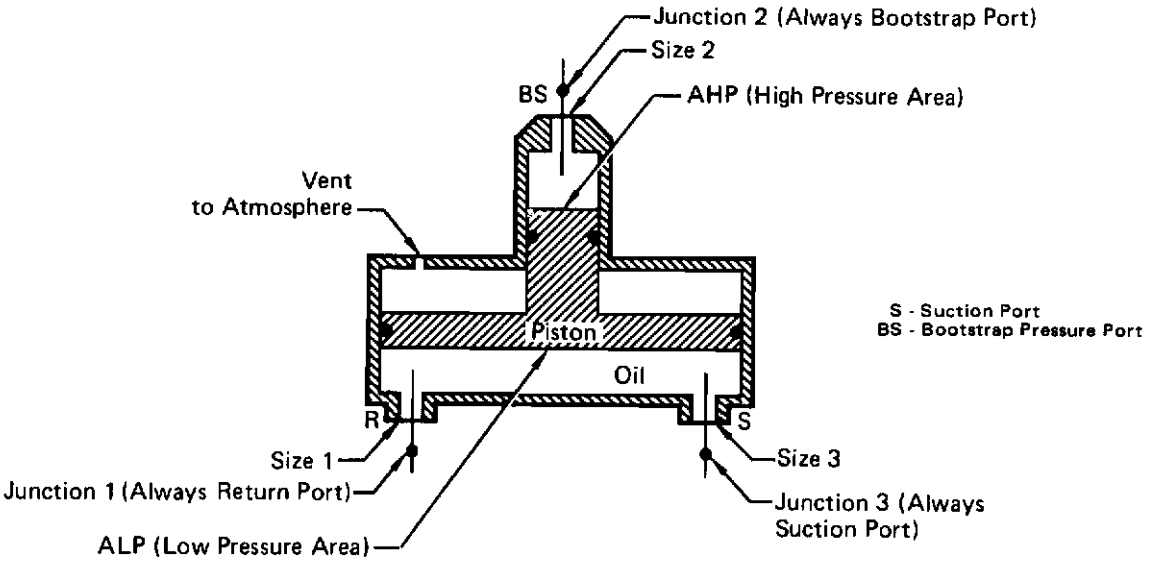
2.1.4.9 Type 9 - Flow Through Reservoir



Size 1, Size 2 and Size 3

Option 1 (Boss for Tube Size in 16ths of an in.)
Example: 12 = 12/16 in.
Option 2 (Boss I.D. in in.)
Example: 0.609 in.

ELEMENT TYPE 9 - FLOW THRU BOOTSTRAP RESERVOIR

The type 9 reservoir is a bootstrap pressurized flow through type with system return fluid normally passing through the reservoir before going to the pump suction port. The reservoir model is corrected for altitude from sea level.

Two cards are required for input data. The return port, bootstrap port and pump suction port must be numbered junctions 1, 2, and 3 respectively. Sizes 1, 2, and 3 correspond to the junction numbers. The area of the piston upon which boostrap pressure is acting is input along with the area of the piston exposed to the low pressure fluid. Card 2 contains the equivalent seal friction force where: SEAL FRICTION FORCE(LB) = 10.X(SUM OF THE DYNAMIC SEAL ODS).

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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 2	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 9.	---
17-24	F8.3	JUNCTION 1 (R)	---
25-32	F8.3	JUNCTION 2 (BS)	---
33-40	F8.3	JUNCTION 3 (S)	---
41-48	F8.3	SIZE 1	IN. (See Options)
49-56	F8.3	SIZE 2	IN. (See Options)
57-64	F8.3	SIZE 3	IN. (See Options)
65-72	F8.3	HIGH PRESSURE AREA	IN^2
73-80	F8.3	LOW PRESSURE AREA	IN^2

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	SEAL FRICTION	LBS
9-80		BLANK	---

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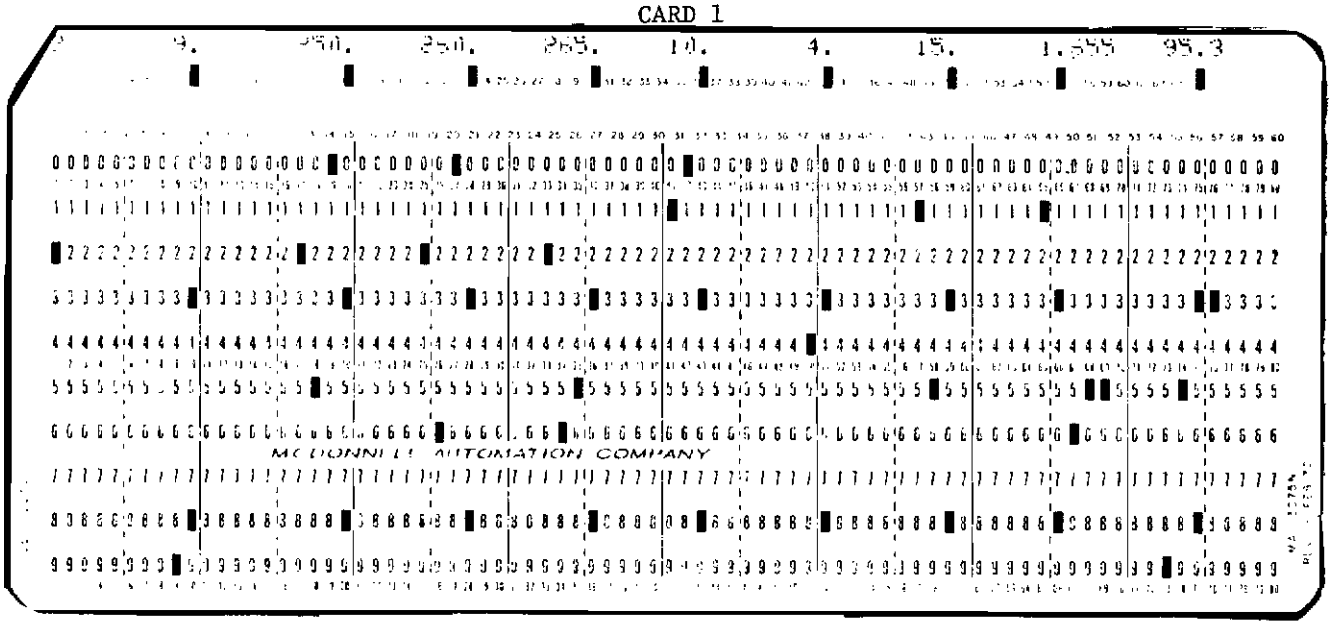
EXAMPLE

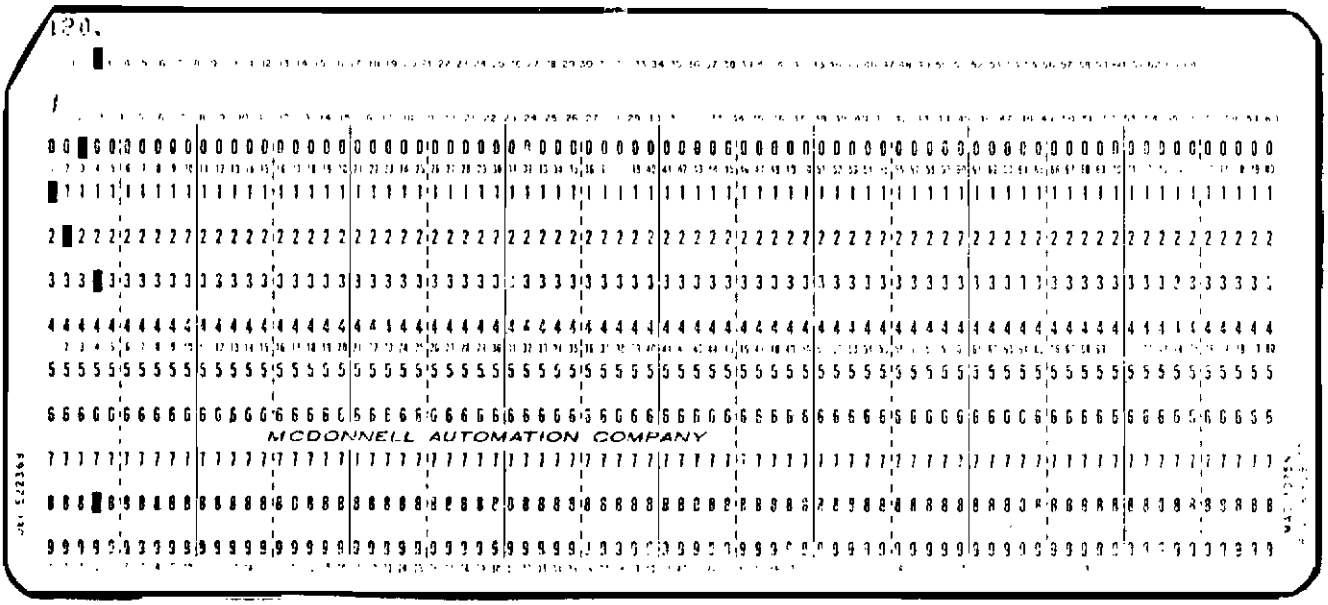
TYPE 9 FLOW THROUGH RESERVOIR INPUT DATA

2 DATA CARDS REQUIRED

CARD 1



CARD 2



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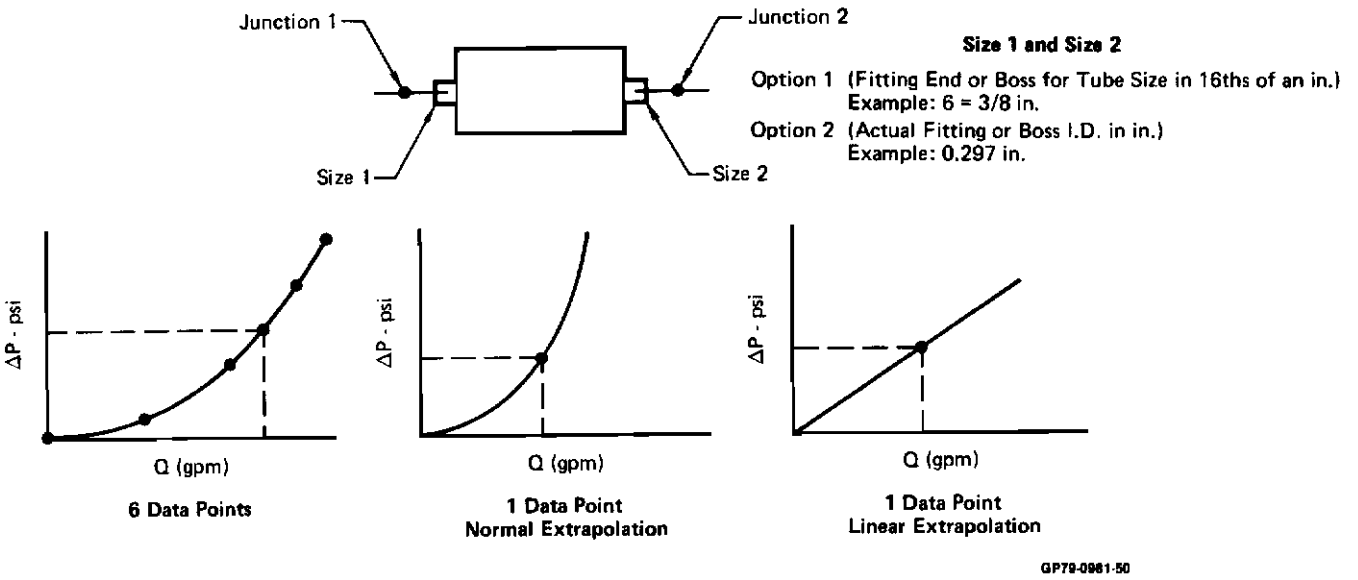
2.1.4.10 Type 10 - Special (Flow vs ΔP)



ELEMENT TYPE 10 - SPECIAL (FLOW vs ΔP)

The special category is used for elements which have 1 to 6 known measured flow versus pressure drop points. These may be input as ΔP and Q values with up to six points used to describe the characteristic curve. The element is considered to have one inlet and one outlet port. The viscosity of the fluid for which the data was taken is also required.

One or two cards are used for input data. Junction points 1 and 2 are the assigned numbers from the block diagram (Example: 1050. and 1060.). Sizes 1 and 2 are the fitting end or internal port inside diameters. All pressure drop data points are input before the first flow data point. Input data points should be in ascending order. If a number greater than 0 is placed after the last flow value, linear interpolation will be used, except for 6 data points.

NOTE: Flow points are input directly after pressure points. For example, if 2 data points are input, the 2 flow points are input in the first 2 columns of Card 2.

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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1 or 2	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 10.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-56	F8.3	FLUID DATA VISCOSITY	CENTISTOKES
57-64	F8.3	NUMBER OF POINTS	---
65-72	F8.3	PRESSURE DROP 1	PSI
73-80	F8.3	PRESSURE DROP 2	PSI

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	PRESSURE DROP 3	PSI
9-16	F8.3	PRESSURE DROP 4	PSI
17-24	F8.3	PRESSURE DROP 5	PSI
25-32	F8.3	PRESSURE DROP 6	PSI
33-40	F8.3	FLOW 1	GPM
41-48	F8.3	FLOW 2	GPM
49-56	F8.3	FLOW 3	GPM
57-64	F8.3	FLOW 4	GPM
65-72	F8.3	FLOW 5	GPM
73-80	F8.3	FLOW 6	GPM

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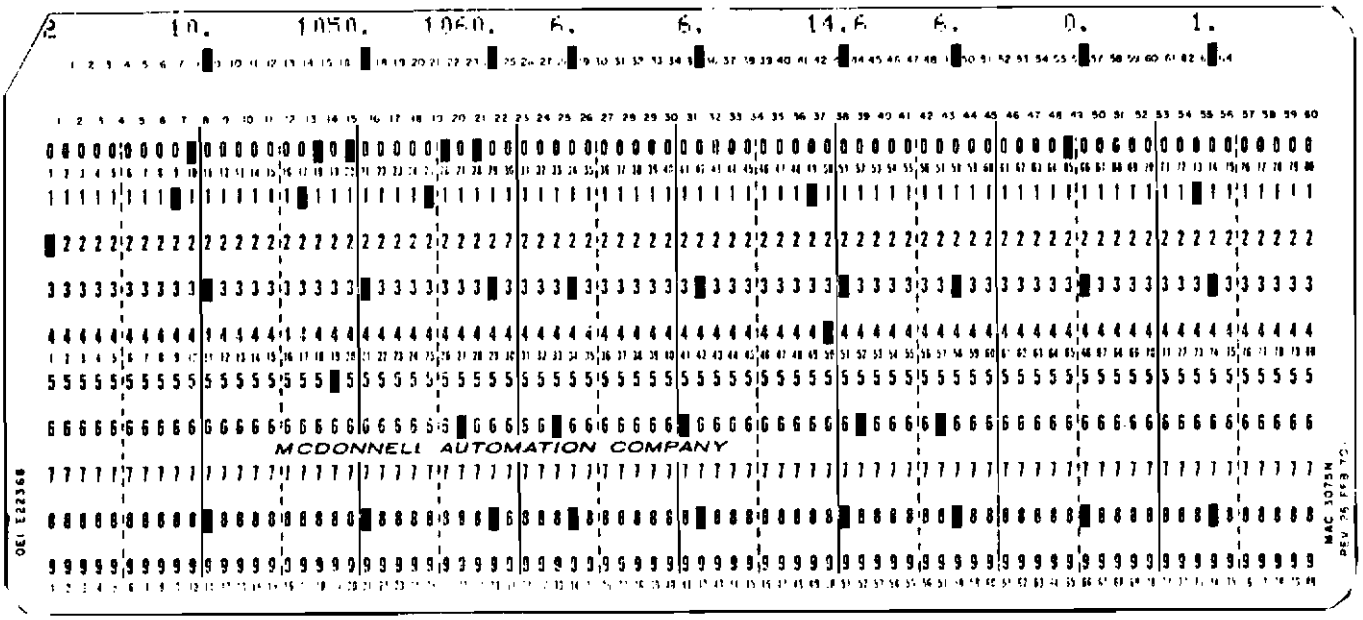
EXAMPLE

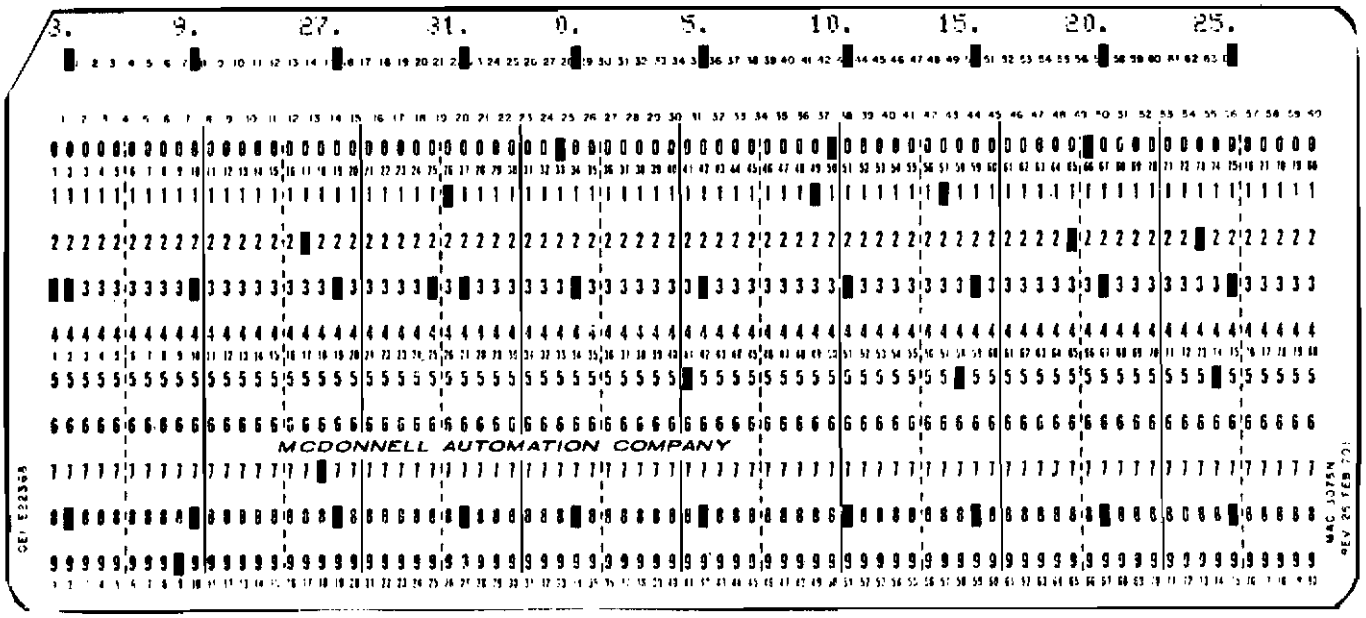
TYPE 10 SPECIAL (FLOW VS. ΔP) INPUT DATA

2 DATA CARDS REQUIRED

CARD 1



CARD 2



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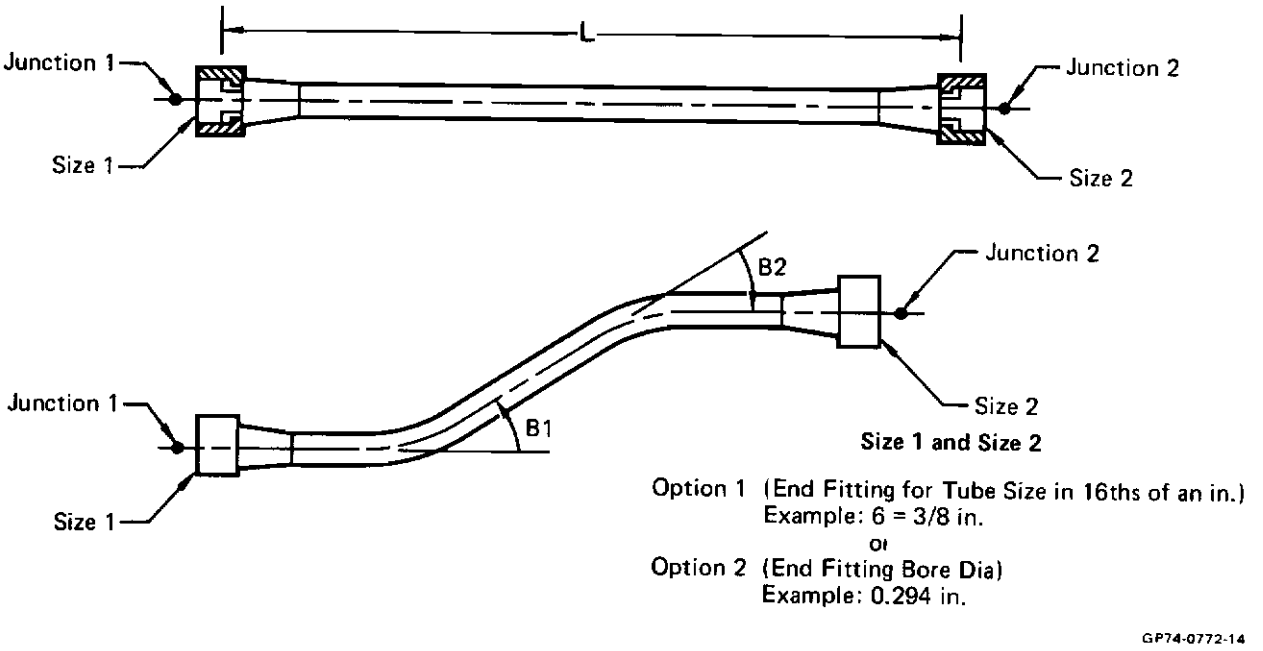
2.1.4.11 Type 11 - Flexible Hose



ELEMENT TYPE 11 - FLEXIBLE HOSE

The flexible hose is used in applications where a rigid tube will not allow required motion or misalignment. The length of the hose is its straight length measured between the ends of the nipple assemblies.

One card is required for input data. A maximum of 3 bend angles are allowed. Bend angles are measured in degrees. Junction point numbers 1 and 2 are the assigned numbers from the block diagram (Example: 20. and 25.). Size is the equivalent tube size, but does not have the equivalent tube size options. For calculation the internal diameter is a required input.

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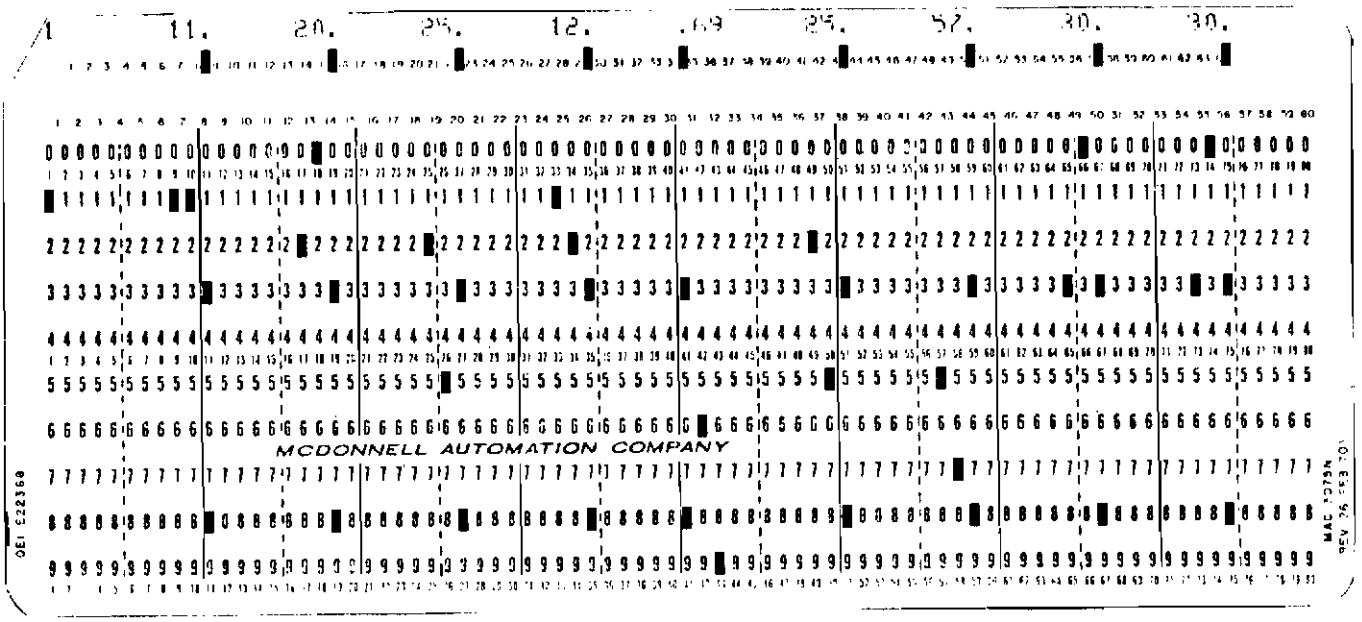
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSION
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 11.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE	IN. (16ths)
41-48	F8.3	HOSE INSIDE DIA.	IN.
49-56	F8.3	LENGTH	IN.
57-64	F8.3	BEND ANGLE	DEG
65-72	F8.3	BEND ANGLE	DEG
73-80	F8.3	BEND ANGLE	DEG

EXAMPLE

TYPE 11 FLEXIBLE HOSE INPUT DATA



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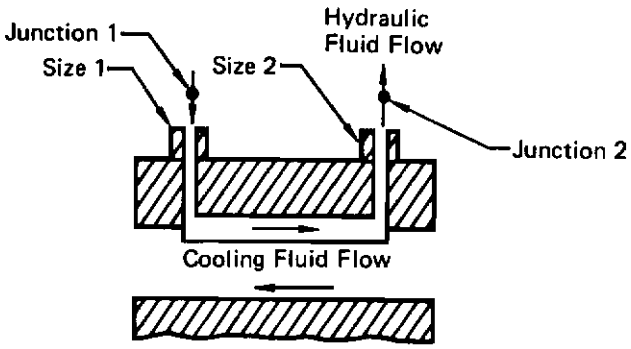
2.1,4.12 Type 12 - Heat Exchanger or Radiator



Size 1 and Size 2

Option 1 Fitting End or Boss for Tube Size in 16ths of an in.)
Example: 4 = 1/4 in.

or

Option 2 (Actual Fitting or Boss I.D. in in.)
Example: 0.172 in.

GP74-0772-12

ELEMENT TYPE 12 - HEAT EXCHANGER OR RADIATOR

A heat exchanger is used to remove excess heat from the hydraulic fluid. The common type used in aircraft uses the engine fuel as a heat sink; however some usage is made of air as a cooling fluid.

One card is required for heat exchanger input data. Junction 1 is normally the inlet port and junction 2 the outlet port. Sizes 1 and 2 correspond with options noted. A rated flow and a rated pressure drop are input along with the fluid viscosity for the rated conditions.

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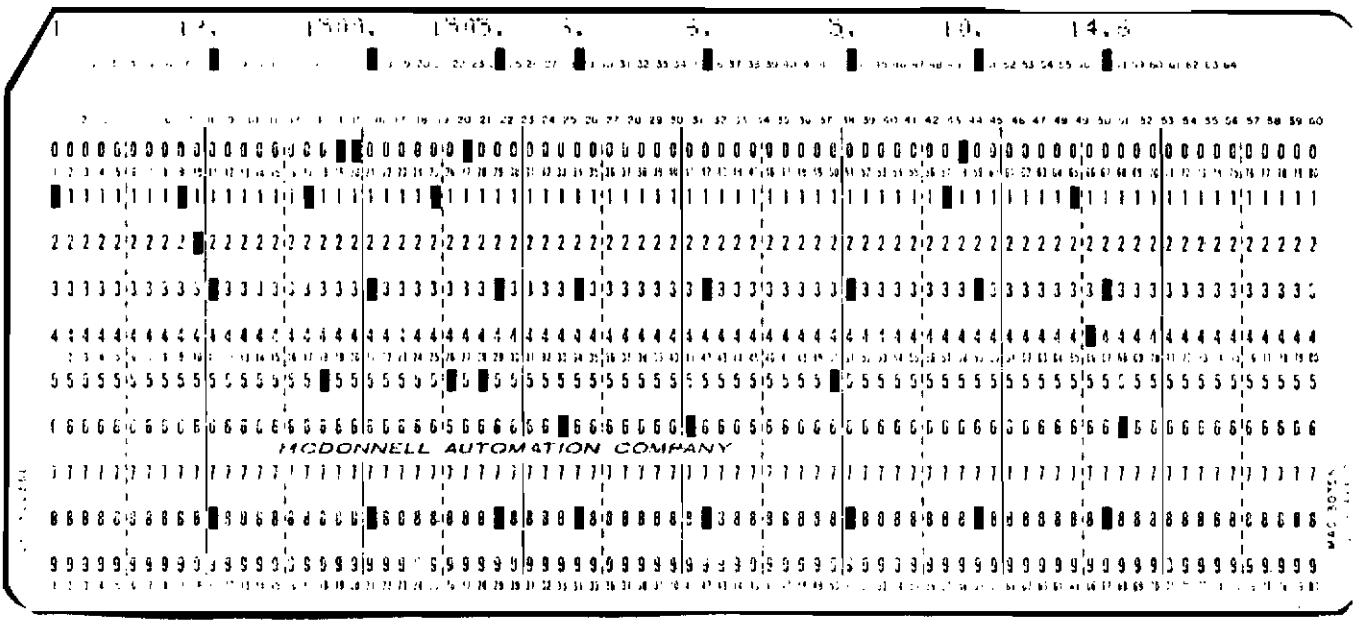
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 12.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-56	F8.3	RATED FLOW	GPM
57-64	F8.3	RATED PRESSURE DROP	PSI
65-72	F8.3	RATED VISCOSITY	CENTISTOKES
73-80		BLANK	---

EXAMPLE

TYPE 12 HEAT EXCHANGER OR RADIATOR INPUT DATA



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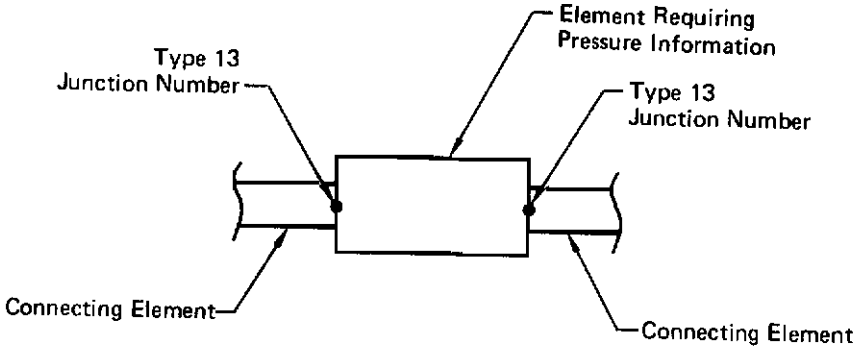
2.1.4.13 Type 13 - Floating Branch Point



GP79-0981-32

ELEMENT TYPE 13 - FLOATING BRANCH POINT

The floating branch point input is used to specify points in the system where additional calculated pressures are desired. Element types 1, 2, 3, 6, 10, 11, 12, 21, 22, 23, 31, 32 and 33 do not have a pressure calculated at their junctions unless they are connected directly to a branch point element. If it is desired to have the pressure calculated at the inlet and outlet of a type 6 filter for example, each junction number is input on a type 13 data card in addition to the normal data input. This applies to all of the elements listed above. A tube for another example could be modeled as several sections with type 13 junctions included at the end of each section. Pressures would then be calculated at intermediate points in the tube.

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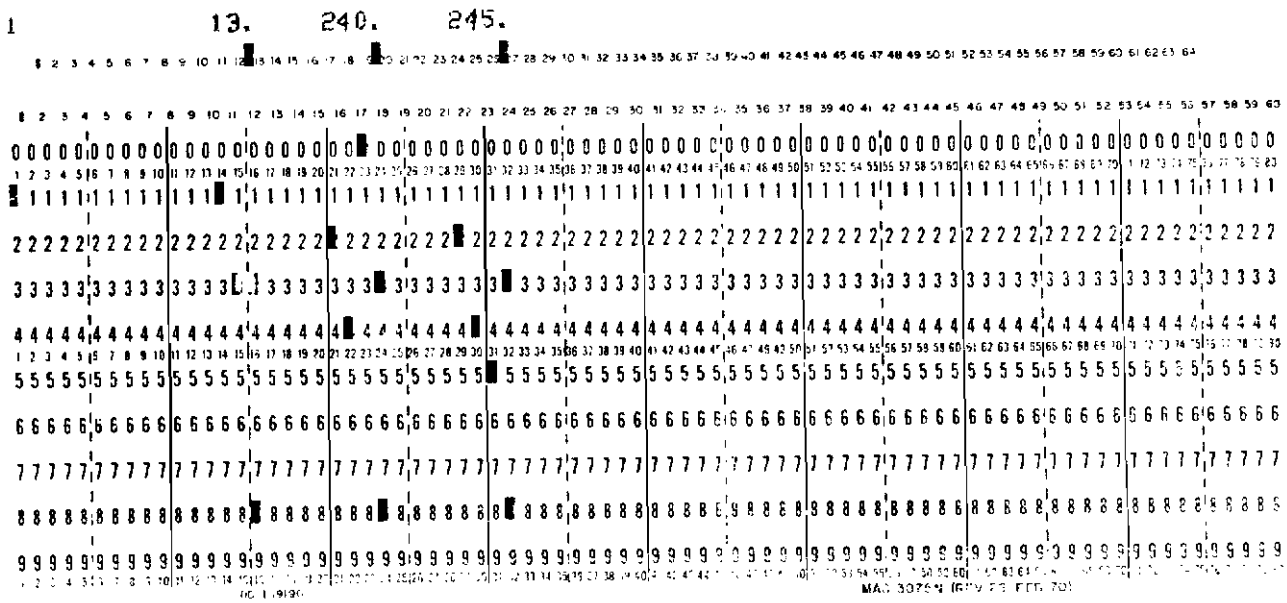
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1	---
2-8	7X	Blank	---
9-16	F8.3	(Element Type) 13.	---
17-24	F8.3	Junction No.	---
25-32	F8.3	Junction No.	---
33-40	F8.3	Junction No.	---
41-48	F8.3	Junction No.	---
49-56	F8.3	Junction No.	---
57-64	F8.3	Junction No.	---
65-72	F8.3	Junction No.	---
73-80	F8.3	Junction No.	---

EXAMPLE
TYPE 13 FLOATING BRANCH POINT INPUT DATA



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2.1.4.14 Type 14 - Junction Point Temperature Input

The junction point temperature input is used to specify temperatures at junctions which are branch points in the system. Any junction of the following components may be input for element types 4, 5, 7, 8, 9, 13, 24, 25, 34, 35, 36, 37, 91 and 92.

This input is used in conjunction with the system temperature input of Card 6. Card 6 temperature initializes all junctions to the system temperature. The type 14 input overrides the initialized temperatures.

For example if a temperature of 100°F was input on Card 6, all junctions will initially be at 100°F. Before the calculation program is run a check is made to determine if any Type 14 temperatures have been input. If a Type 14 temperature of 40°F was input for 3 junctions, these 3 values will be input at the specific points for calculation of the leg viscosities. A maximum of 100 points may be input.

CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1	---
2-8	7X	Blank	---
9-16	F8.3	(Element Type) 14.	---
17-24	F8.3	Temperature	DEG F
25-32	F8.3	Junction No.	---
33-40	F8.3	Junction No.	---
41-48	F8.3	Junction No.	---
49-56	F8.3	Junction No.	---
57-64	F8.3	Junction No.	---
65-72	F8.3	Junction No.	---
73-80	F8.3	Junction No.	---

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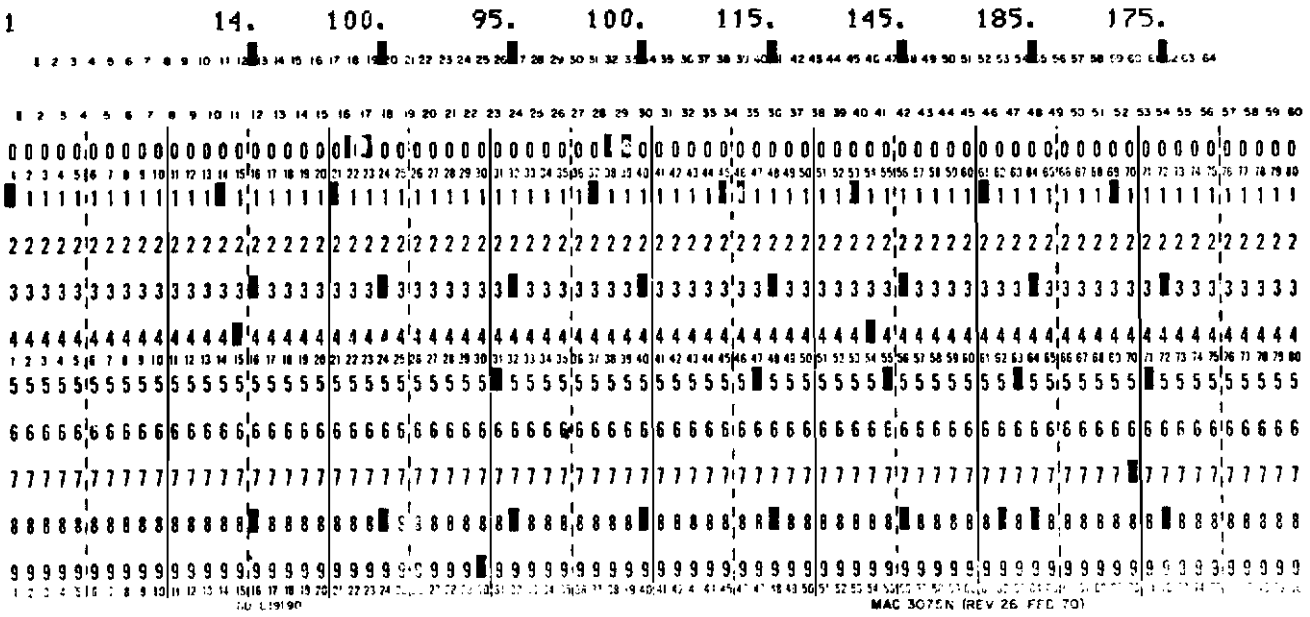
EXAMPLE

TYPE 14 JUNCTION POINT TEMPERATURE INPUT DATA



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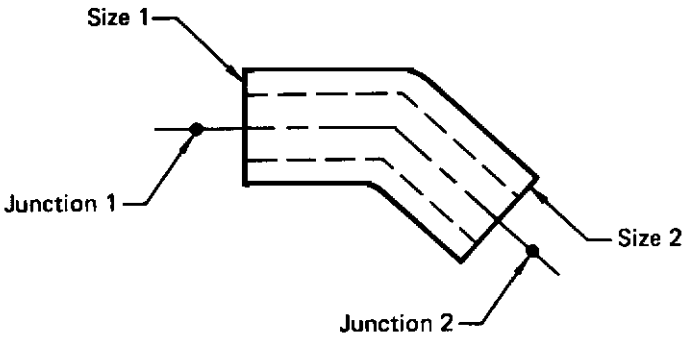
2.1.4.15 Type 21 - 45° Elbow



Size 1 and Size 2

Option 1 (Fitting End or Boss for Tube Size in 16ths of an in.)
Example: 8 = 8/16 in.)
or
Option 2 (Actual Fitting or Boss I.D.)
Example: 0.391 in.

GP74-0772-15

ELEMENT TYPE 21 - 45° ELBOW

The 45° elbow like the union is also a connector to join 2 tubes or join a tube to a component. The elbow may be a threaded or permanent type. The ends may be internally or externally threaded.

The number of data cards required is always 1. Junction point numbers 1 and 2 are the assigned numbers from the block diagram (Example: 80. and 85.). Size 1 and Size 2 reflect the internal fitting diameters at each end (see options 1 and 2 in above sketch). These do not have to be identical.

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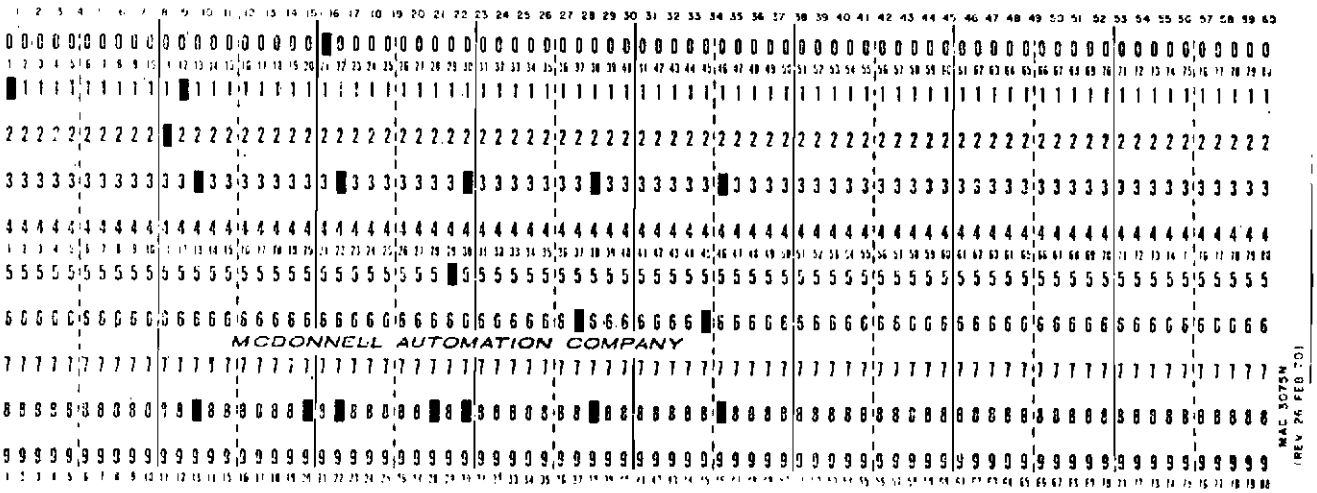
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	
9-16	F8.3	(ELEMENT TYPE) 21.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-80		BLANK	---

EXAMPLE

TYPE 21 45° ELBOW DATA INPUT

1 21. 80. 85. 6. 6.



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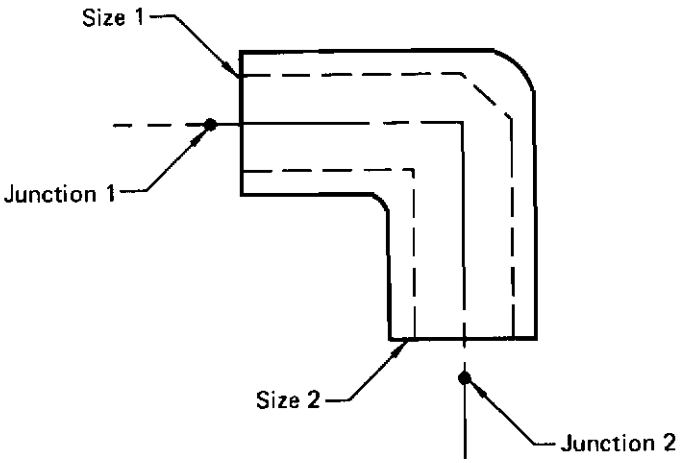
2.1.4.16 Type 22 - 90° Elbow



Size 1 and Size 2

Option 1 (Fitting End or Boss for Tube Size in 16ths of an in.)
Example: 8 = 8/16 in.
or
Option 2 (Actual Fitting or Boss I.D.)
Example: 0.391 in.

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ELEMENT TYPE 22 - 90° ELBOW

The 90° elbow is a connector commonly used to change the piping run direction in a minimum distance. It may be a threaded or permanent type where the ends may be internally or externally threaded.

The number of data cards required is always 1. Junction point numbers are the assigned numbers from the block diagram (Example: 10. and 20.). Size 1 and Size 2 reflect the internal fitting diameters at each end (see options 1 and 2 in the above sketch). These do not have to be identical.

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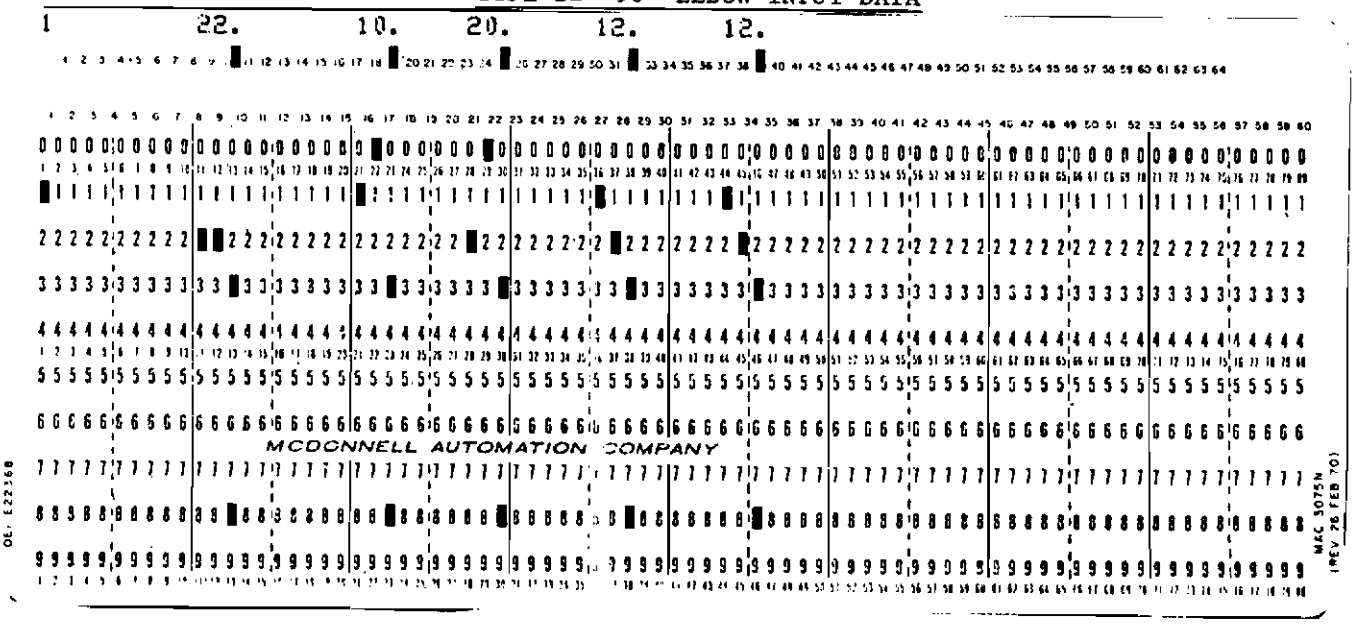
Contrails

CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	
9-16	F8.3	(ELEMENT TYPE) 22.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-80		BLANK	---

EXAMPLE

TYPE 22 90° ELBOW INPUT DATA



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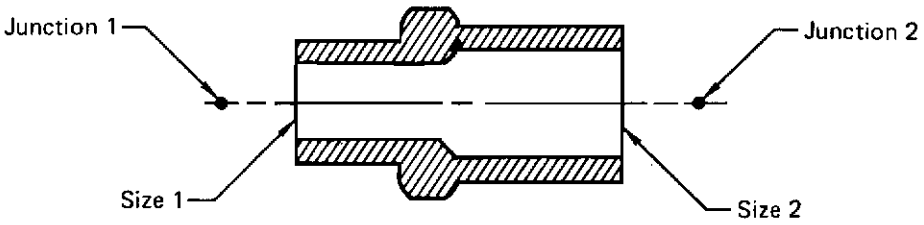
2.1.4.17 Type 23 - Reducer



Size 1 and Size 2

Option 1 (Fitting End or Boss for Tube Size in 16ths of an in.)
Example: Size 1 = 8 = 8/16 in.
Size 2 = 10 = 10/16 in.
or
Option 2 (Fitting End or Boss I.D.)
Example: Size 1 = 0.391 in.
Size 2 = 0.484 in.

GP74-0772-16

ELEMENT TYPE 23 - REDUCER

The reducer fitting is commonly used to connect a tube or fitting to a different size fitting, tube or component port. These are commonly a threaded type.

One data card is required for input data. Junction point numbers 1 and 2 are the assigned numbers from the block diagram (Example: 900. and 905). Size 1 and Size 2 are generally not equal and reflect the internal diameters at each end. This fitting could also be an adapater which changes from an external thread at one end to an internal thread at the other. See the above sketch for Size 1 and Size 2 options.

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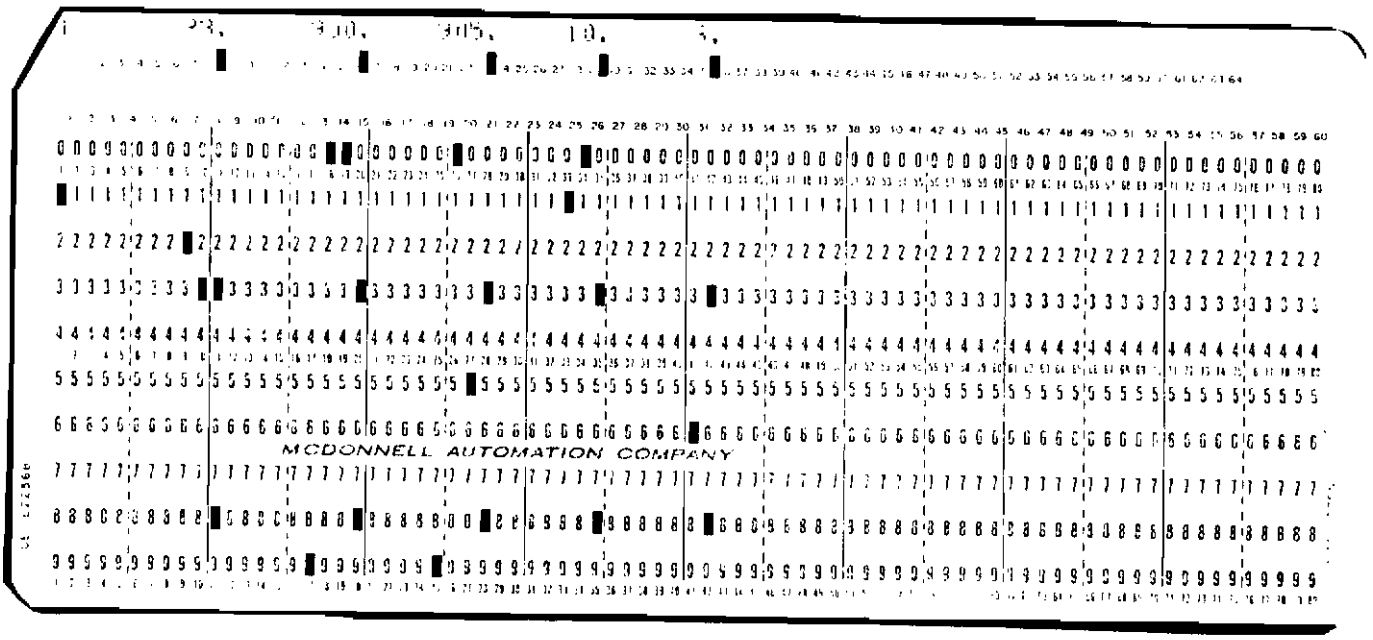
Contrails

CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 23.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-80		BLANK	---

EXAMPLE

TYPE 23 REDUCER INPUT DATA



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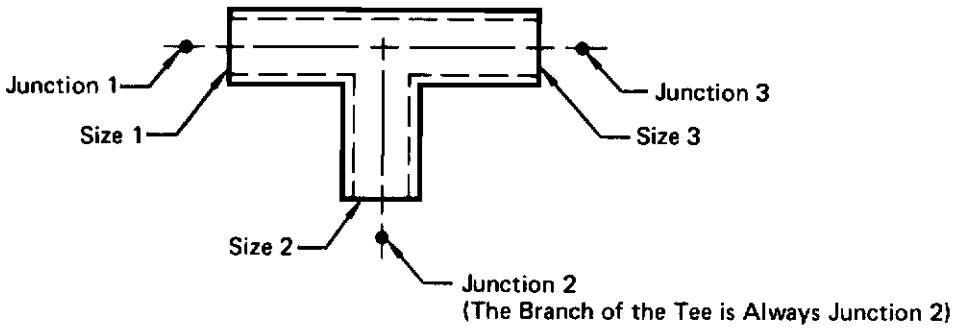
2.1.4.18 Type 24 - Tee



Size 1, Size 2 and Size 3

Option 1 (Fitting End or Boss for Tube Size in 16ths of an in.)
Example: 8 = 8/16 in.
or
Option 2 (Actual Fitting or Boss I.D.)
Example: 0.391 in.

GP74-0772-18

ELEMENT TYPE 24 - TEE

The tee is a connector commonly used to connect three elements which may be a combination of tubes, fittings or components. These are either a threaded or permanent type. The branch is considered to be at a 90° angle to the run.

One data card is required for input. Junction point numbers are the assigned numbers from the block diagram (Example: 35., 45., and 40.). It should be noted that junction point 2 has to be input as the branch of the tee. Size 1, Size 2 and Size 3 correspond to the ends with junction points of the same number. The sizes can be different and the ends internally or externally threaded. See the above sketch for size options.

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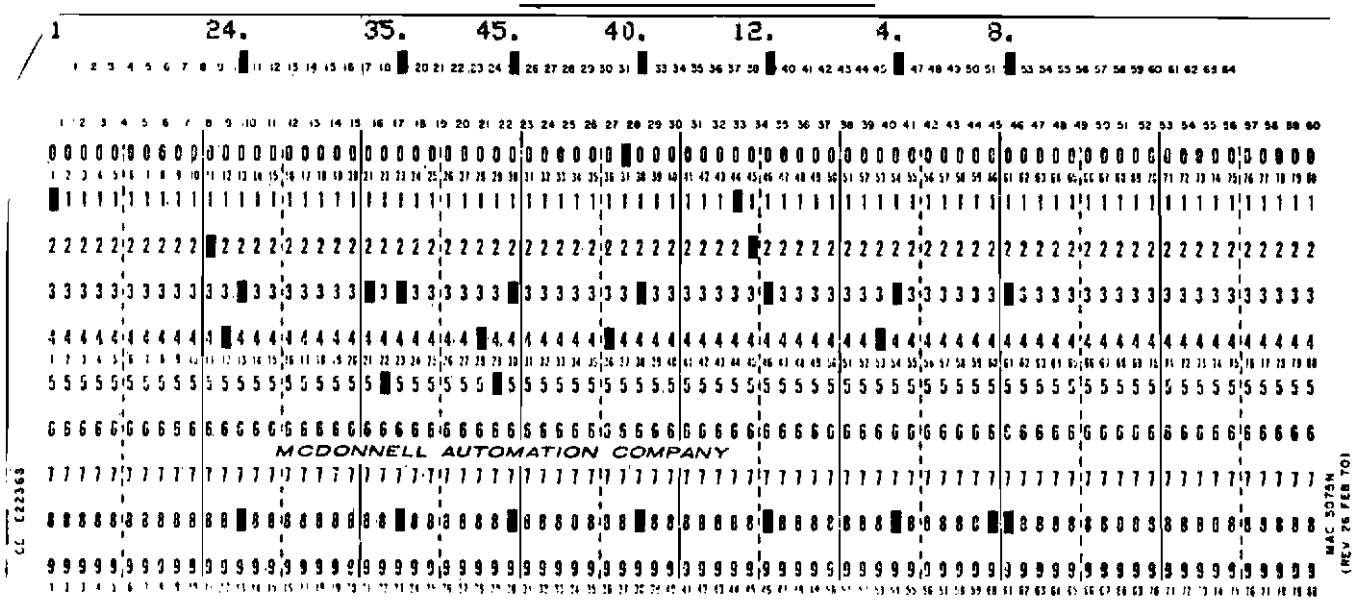
Contrails

CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 24.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	JUNCTION 3	---
41-48	F8.3	SIZE 1	IN. (See Options)
49-56	F8.3	SIZE 2	IN. (See Options)
57-64	F8.3	SIZE 3	IN. (See Options)
65-80		BLANK	---

EXAMPLE

TYPE 24 TEE INPUT DATA



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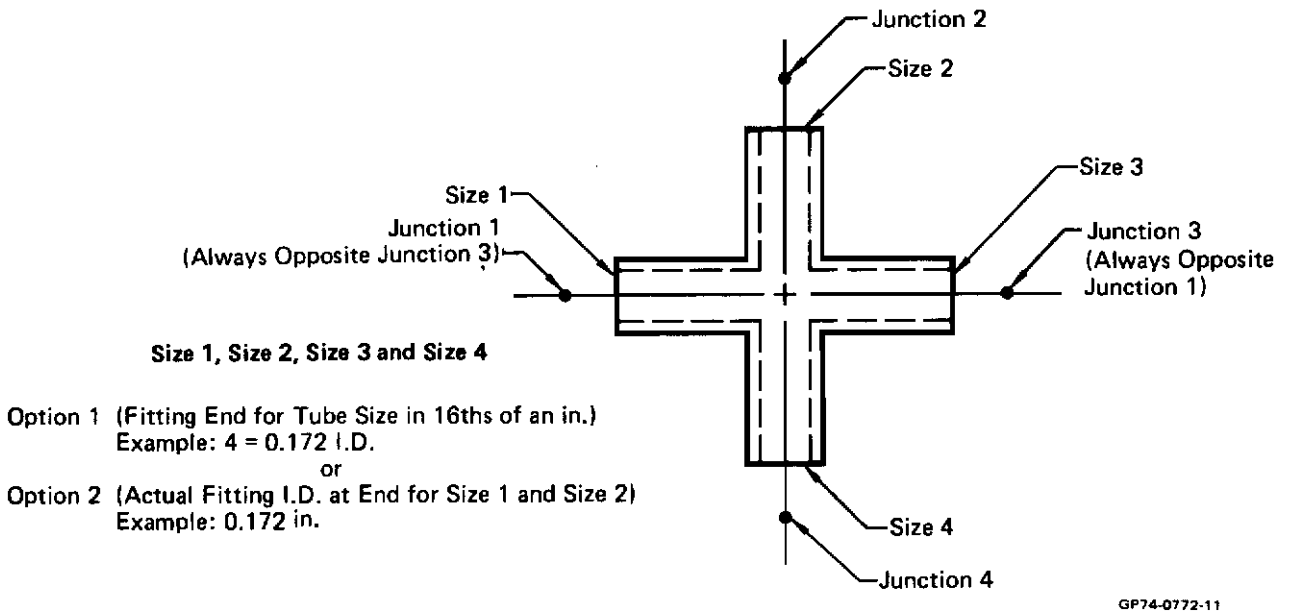
2.1.4.19 Type 25 - Cross



ELEMENT TYPE 25 - CROSS

The cross fitting is used sparingly in hydraulic system design because it requires considerable space to connect 4 elements (probably tubes) at one point. The cross is a connector which may be a threaded or permanent type. Each port is at a 90° angle with each adjacent port.

One data card is required for input. Junction point numbers are the assigned numbers from the block diagram (Example: 920., 925., 930., and 935.). Note that junction point 3 is considered to be opposite junction 1 and the junction point and size data have to be input in the correct order. The sizes can be different and the ends internally or externally threaded. See the above sketch for size options and junction point numbering.

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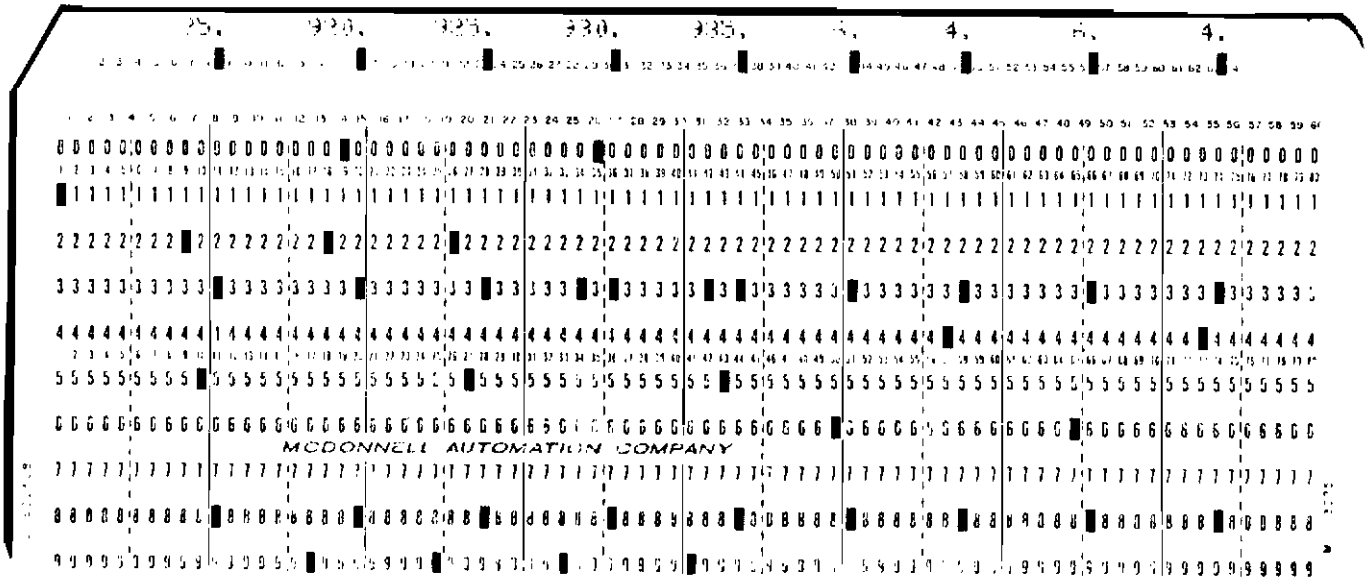
Contrails

CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	
9-16	F8.3	(ELEMENT TYPE) 25.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	JUNCTION 3	---
41-48	F8.3	JUNCTION 4	---
49-56	F8.3	SIZE 1	IN. (See Options)
57-64	F8.3	SIZE 2	IN. (See Options)
65-72	F8.3	SIZE 3	IN. (See Options)
73-80	F8.3	SIZE 4	IN. (See Options)

EXAMPLE

TYPE 25 CROSS INPUT DATA



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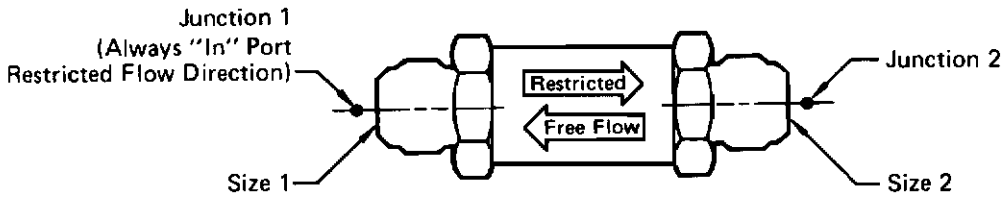
Contrails

2.1.4.20 Type 31 - 1 Way Restrictor



Size 1 and Size 2

Option 1 (Fitting End or Boss for Tube Size in 16ths of an in.)
Example: 8 = 8/16 in.)
or
Option 2 (Actual Fitting or Boss I.D.)
Example: 0.391 in.

GP74-0772-25

ELEMENT TYPE 31 - ONE WAY RESTRICTOR

The 1 way restrictor restricts flow in one direction and allows free flow in the other direction. The orifice flow is a function of orifice size, Reynolds number and the coefficient of discharge.

One card is required for input data. Junction 1 always starts at the restricted port for flow in the restricted direction. Size 1 and Size 2 correspond to junction 1 and junction 2 with options as noted. The orifice diameter is input along with a coefficient of discharge. If the coefficient of discharge is not input, the element model will select one.

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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 2	--
2-8	7X	BLANK	--
9-16	F8.3	31. (ELEMENT TYPE)	--
17-24	F8.3	JUNCTION 1	--
25-32	F8.3	JUNCTION 2	--
33-40	F8.3	SIZE 1	IN.(SEE OPTIONS)
41-48	F8.3	SIZE 2	IN.(SEE OPTIONS)
49-56	F8.3	ORIFICE DIA OR RATED DP (RESTRICTED)	IN. OR PSI
57-64	F8.3	DISCHARGE COEF OR RATED Q (RESTRICTED)	-- OR GPM
65-72	F8.3	FREE FLOW CRACKING PRESSURE (OPTIONAL)	PSI
73-80	F8.3	F.F. RATED DP (OPTIONAL)	PSI

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	F.F. RATED Q (OPTIONAL)	GPM
9-80	F8.3	BLANK	--

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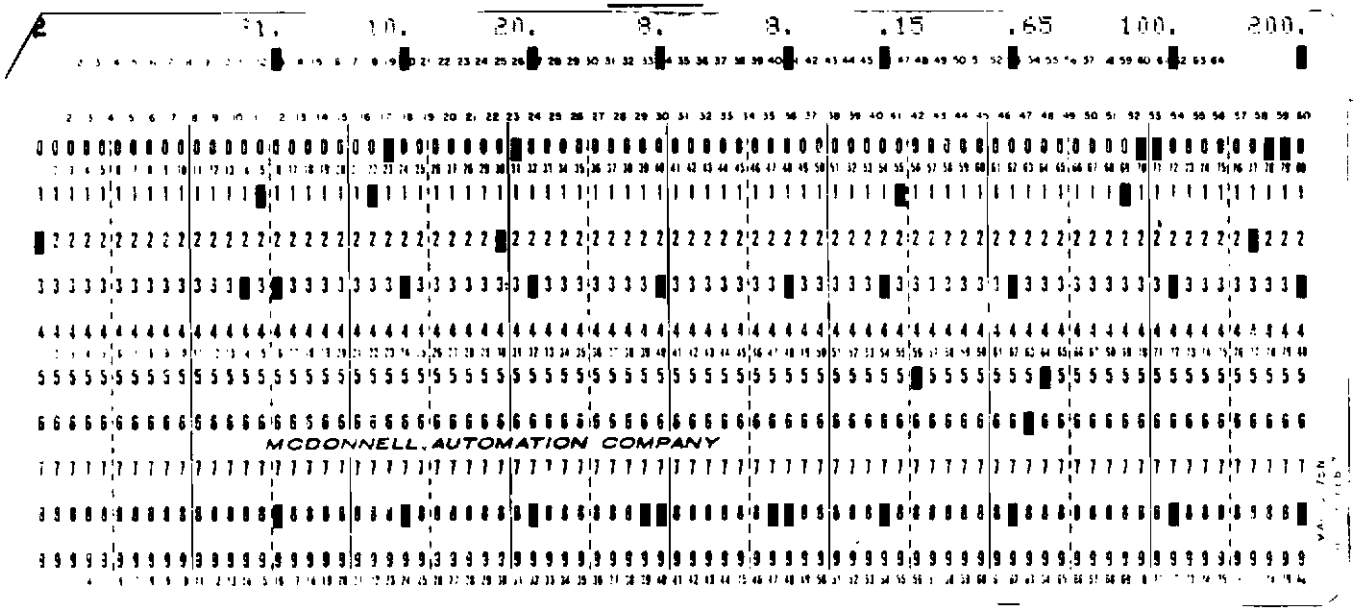
Contrails

EXAMPLE

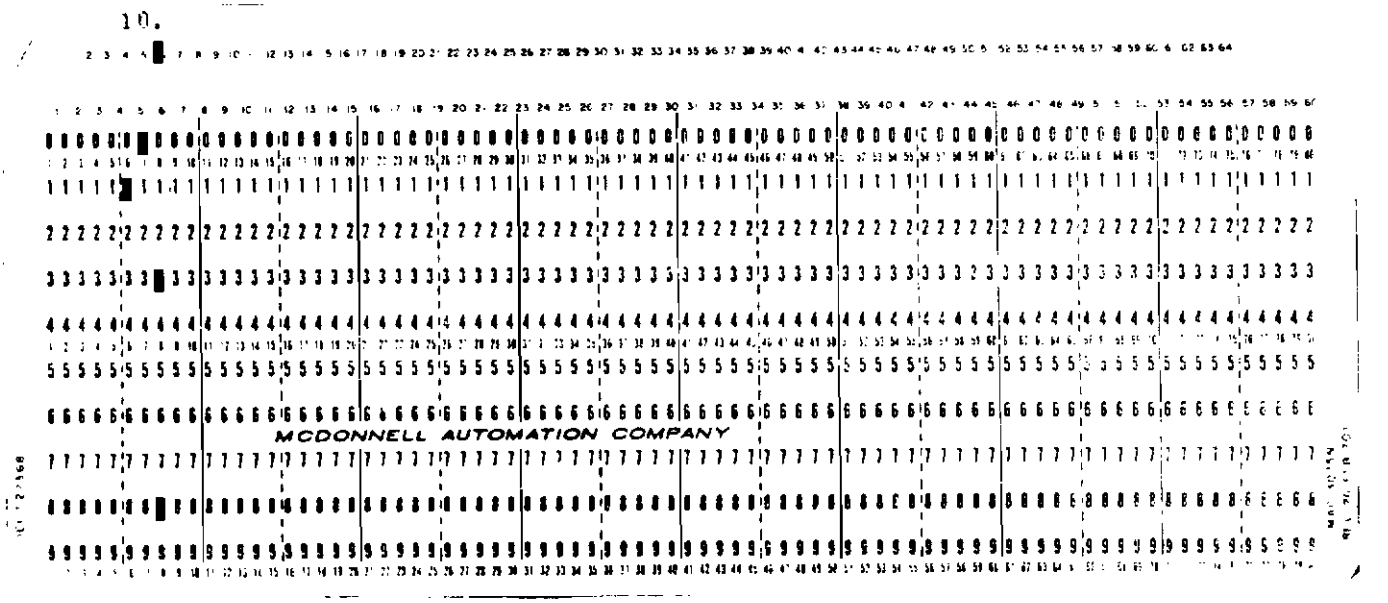
TYPE 31 1 WAY RESTRICTOR INPUT DATA

2 DATA CARDS REQUIRED

CARD 1



CARD 2



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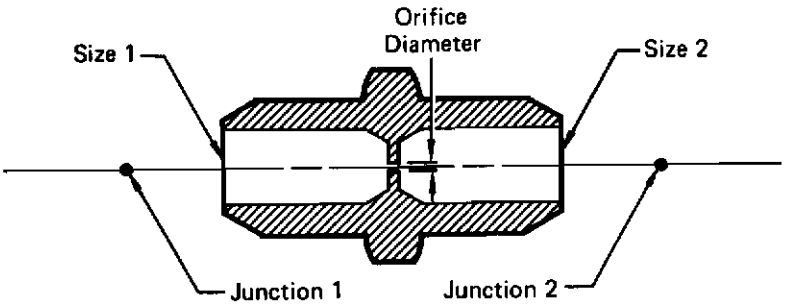
2.1.4.21 Type 32 - 2 Way Restrictor



Size 1 and Size 2

Option 1 (Fitting End or Boss for Tube Size in 16ths of an in.)
Example: 8 = 8/16 in.
or
Option 2 (Actual Fitting of Boss I.D.)
Example: 0.391 in.

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ELEMENT TYPE 32 - TWO WAY RESTRICTOR

The two way restrictor restricts flow in both directions and is an orifice type element. The orifice flow is a function of the orifice diameter, Reynolds number and the coefficient of discharge.

One card is required for input data. Junctions 1 and 2 correspond to Size 1 and 2 respectively. The orifice diameter and coefficient of discharge or the rated flow and rated pressure drop may be input. If no coefficient of discharge is input, the element model selects 0.6.

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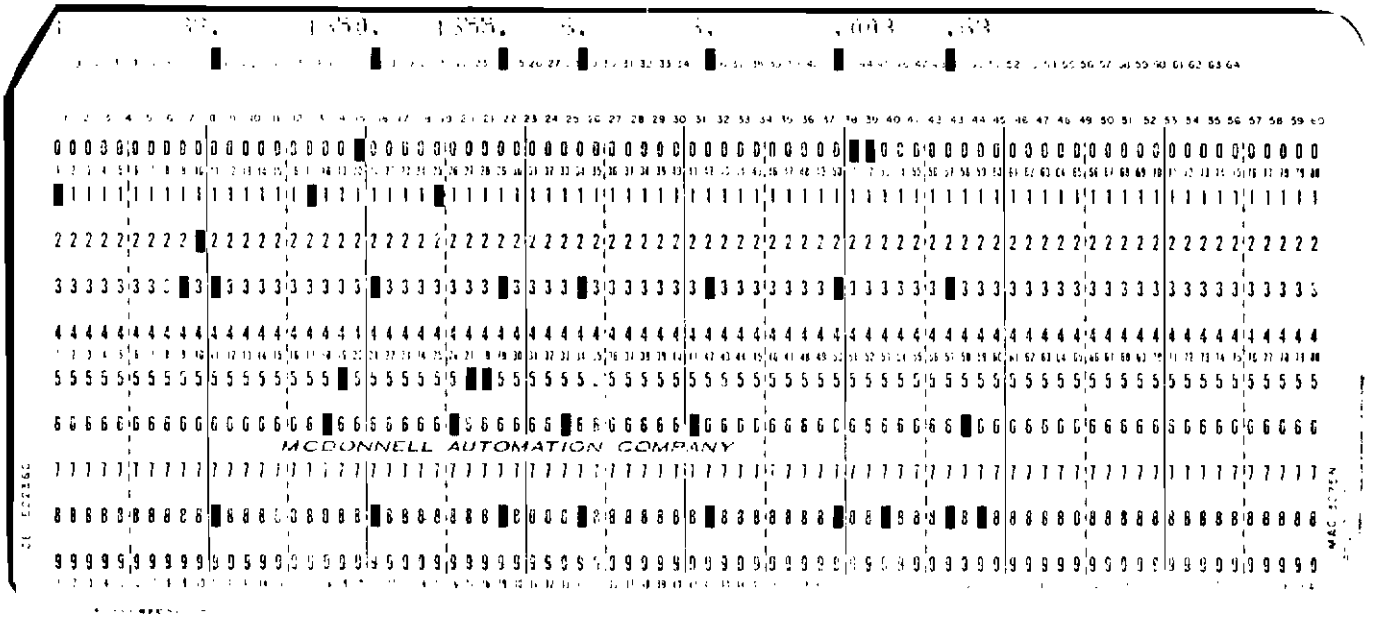
Contrails

CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 32.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-56	F8.3	RATED PRESSURE DROP OR ORIFICE DIA.	IN.
57-64	F8.3	RATED FLOW OR DISCHARGE COEFFICIENT	---
65-80		BLANK	---

EXAMPLE

TYPE 32 2 WAY RESTRICTOR INPUT DATA



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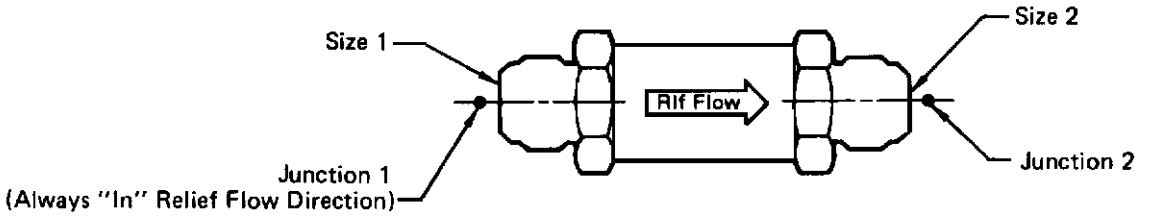
Contrails

2.1.4.22 Type 33 - Relief Valve



Size 1 and Size 2

Option 1 (Fitting End for Tube Size in 16ths of an in.)
Example: 8 = 8/16 in.
or
Option 2 (Actual Fitting I.D. at End for Size 1 and Size 2)
Example: 0.391 in.

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ELEMENT TYPE 33 - RELIEF VALVE

The relief valve acts in much the same manner as a Type 3 check valve. It is normally used to keep the system pressure or a component pressure from exceeding an upper limit.

One card is required for input data. Junction 1 is the "in" port to the relief flow direction. Junction 2 is the "out" flow port. Sizes 1 and 2 correspond to junctions 1 and 2. The nominal relief pressure is also input.

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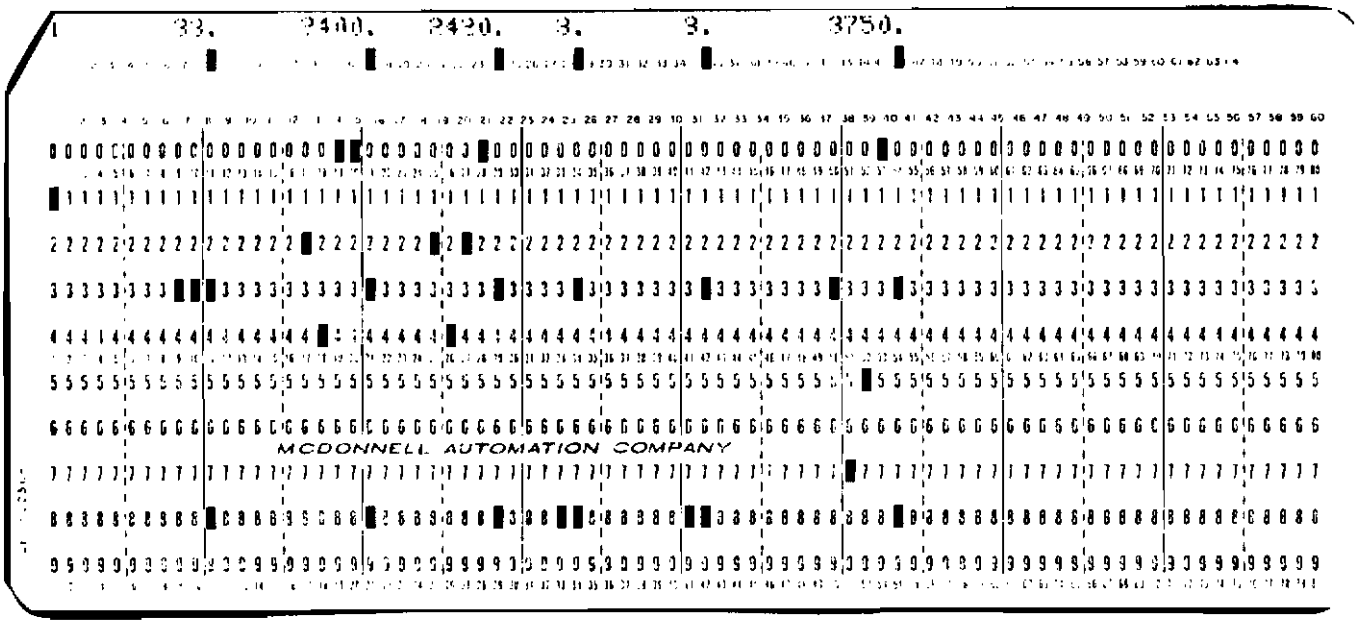
Contrails

CARD FORMAT

COLUMN	FORMAT	DATA	DIMENSION
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 33.	---
17-24	F8.3	JUNCTION 1	---
25-32	F8.3	JUNCTION 2	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-56	F8.3	RELIEF VALVE PRESSURE SETTING	PSI
57-80		BLANK	---

EXAMPLE

TYPE 33 RELIEF VALVE INPUT DATA



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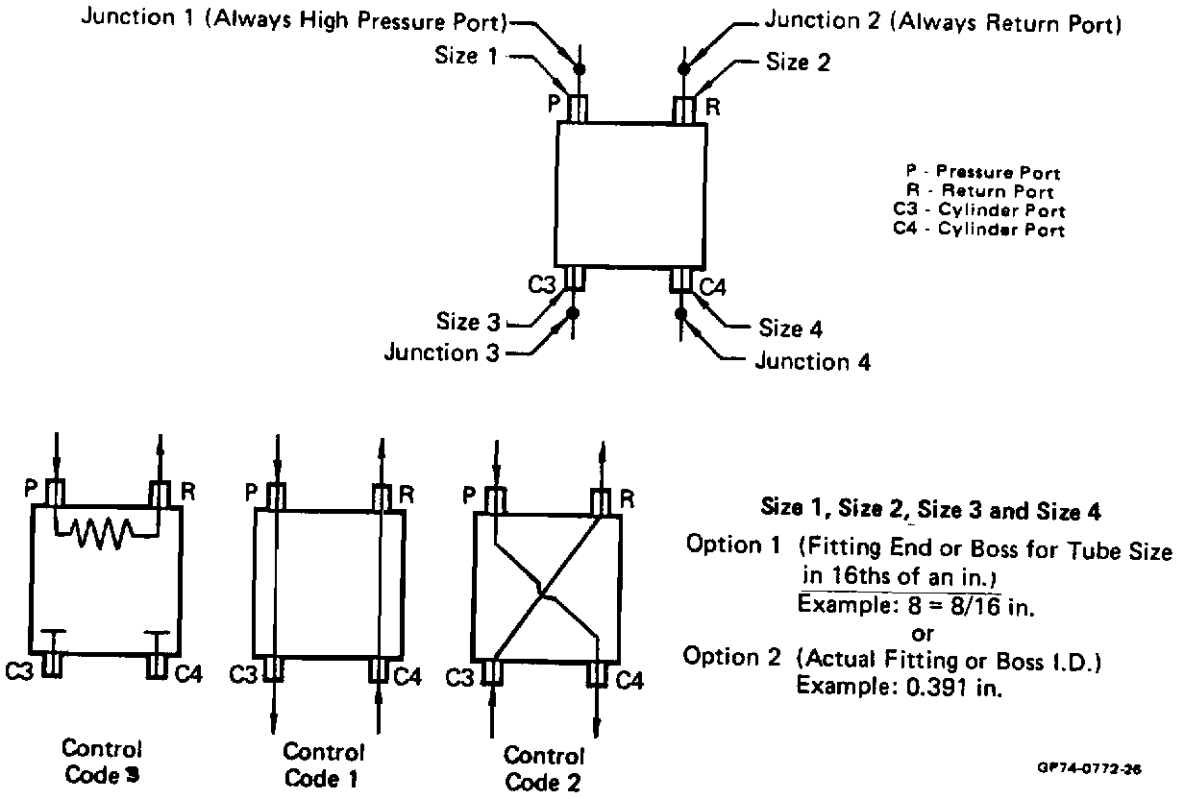
2.1.4.23 Type 34 - Valve (4W - 3P)



ELEMENT TYPE 34 - VALVE (4-WAY - 3 POSITION)

For a 4 way 3 position type valve the 3 positions are (1) pressure to C3 port with C4 ported to return - control code 1, (2) pressure to C4 port with C3 ported to return - control code 2, and (3) the valve in the null or closed position with leakage from high to low pressure - control code 3.

Two cards are required as input data. The junctions 1, 2, 3 and 4 ports are identified. Sizes 1, 2, 3 and 4 correspond with the same junction number with options noted. Valve specifications usually give the internal pressure drops as a function of flow for a specific fluid and temperature. The viscosity for the fluid at these conditions is input to allow for other type fluids and temperatures. The rated pressure drops at rated flows are input.

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4 WAY - 3 POSITION

CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 2	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 34.	---
17-24	F8.3	JUNCTION 1 (P)	---
25-32	F8.3	JUNCTION 2 (R)	---
33-40	F8.3	JUNCTION 3 (C3)	---
41-48	F8.3	JUNCTION 4 (C4)	---
49-56	F8.3	SIZE 1	IN. (See Options)
57-64	F8.3	SIZE 2	IN. (See Options)
65-72	F8.3	SIZE 3	IN. (See Options)
73-80	F8.3	SIZE 4	IN. (See Options)

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	RATED FLOW FROM JCT 1 TO JCT 3 OR JCT 4	GPM
9-16	F8.3	RATED PRESSURE DROP FOR RATED FLOW	PSI
17-24	F8.3	VISCOSITY OF FLUID FOR RATED CONDITIONS	CENTISTOKES
25-32	F8.3	LEAKAGE FLOW FROM JCT 1 TO JCT 3	GPM
33-40	F8.3	PRESSURE DROP FOR LEAKAGE CONDITIONS	PSI
41-48	F8.3	OPERATING CONTROL CODE	---
49-80	F8.3	BLANK	---

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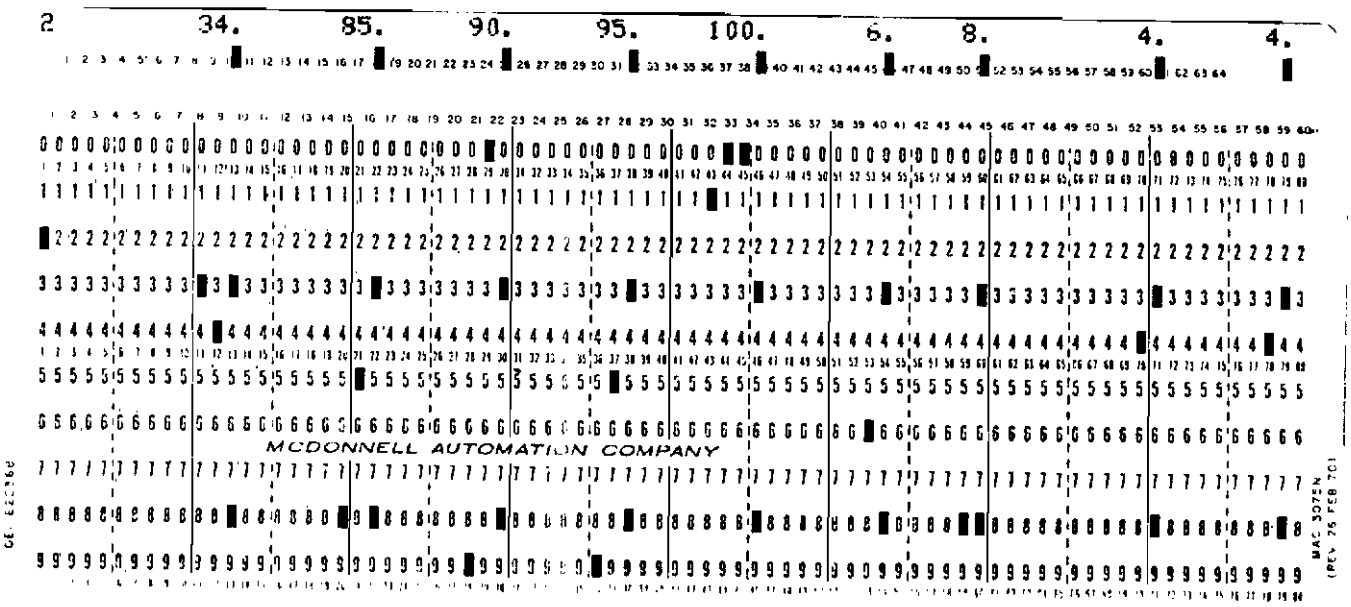
EXAMPLE

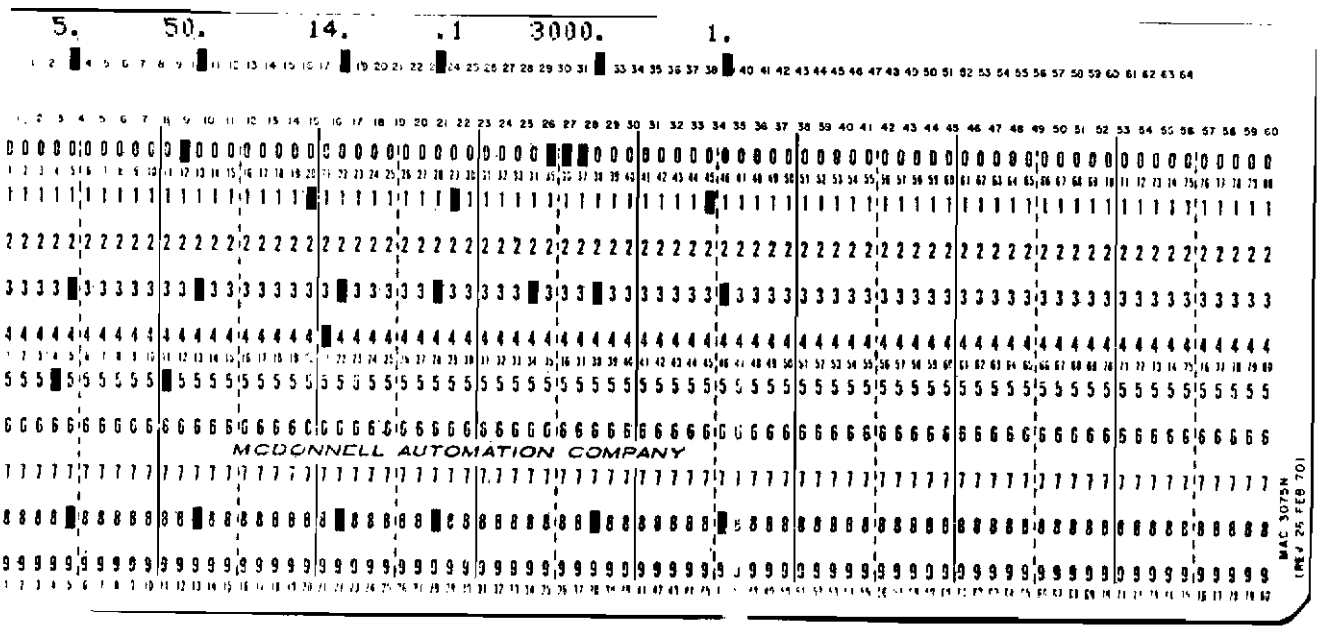
TYPE 34 VALVE (4W-3P) INPUT DATA

2 CARDS REQUIRED

CARD 1



CARD 2



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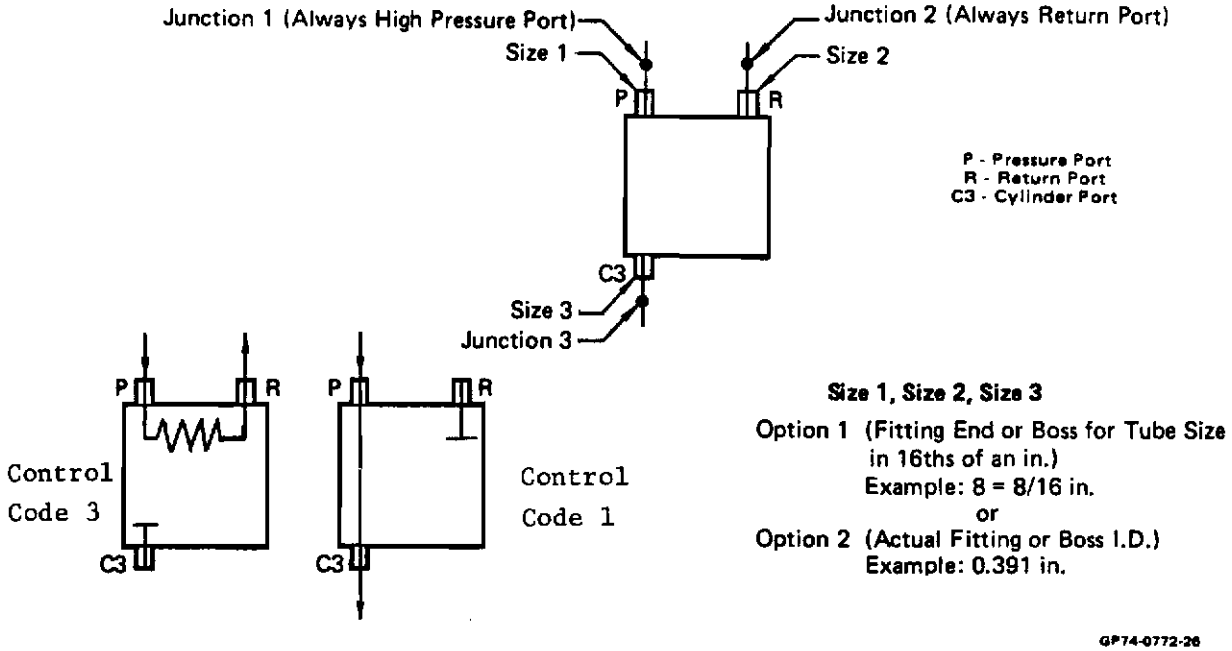
2.1.4.24 Type 35 - Valve (3W - 2P)



ELEMENT TYPE 35 - VALVE (3-WAY - 2 POSITION)

The 2 positions for a 3 way 2 position valve are (1) pressure to C3 port - control code 1, and (2) the valve in the null or closed position with leakage from high to low pressure - control code 3.

Two cards are required as input data. The junctions 1, 2 and 3 ports are identified. Sizes 1, 2 and 3 correspond with the same junction number with options as noted. Valve specifications usually give the internal pressure drops as a function of flow for a specific fluid and temperature. The viscosity for the fluid at these conditions is input to allow for other type fluids and temperatures. The rated pressure drops at rated flows are input.

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3 WAY - 2 POSITION

CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 2	--
2-8	7X	Blank	--
9-16	F8.3	(Element Type) 35.	--
17-24	F8.3	Junction 1(P)	--
25-32	F8.3	Junction 2 (R)	--
33-40	F8.3	Junction 3 (C3)	--
41-48	F8.3	Blank	--
49-56	F8.3	Size 1	In.(See options)
57-64	F8.3	Size 2	In.(See options)
65-72	F8.3	Size 3	In.(See options)
73-80	F8.3	Blank	--

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	Rated flow from JCT 1 to JCT 3	GPM
9-16	F8.3	Rated pressure drop for rated flow	PSI
17-24	F8.3	Viscosity of Fluid for rated conditions	Centistokes
25-32	F8.3	Leakage flow from JCT 1 to JCT 3	GPM
33-40	F8.3	Pressure drop for leakage conditions	PSI
41-48	F8.3	Operating control code	--
49-80	F8.3	Blank	--

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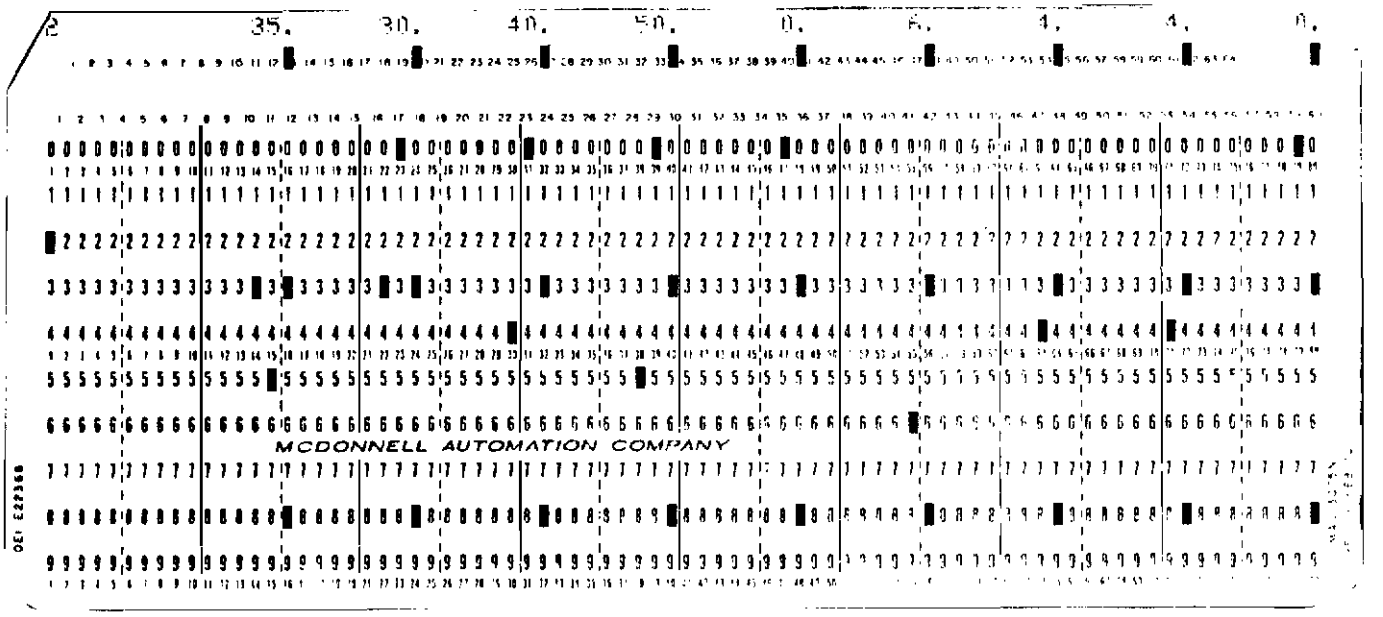
EXAMPLE

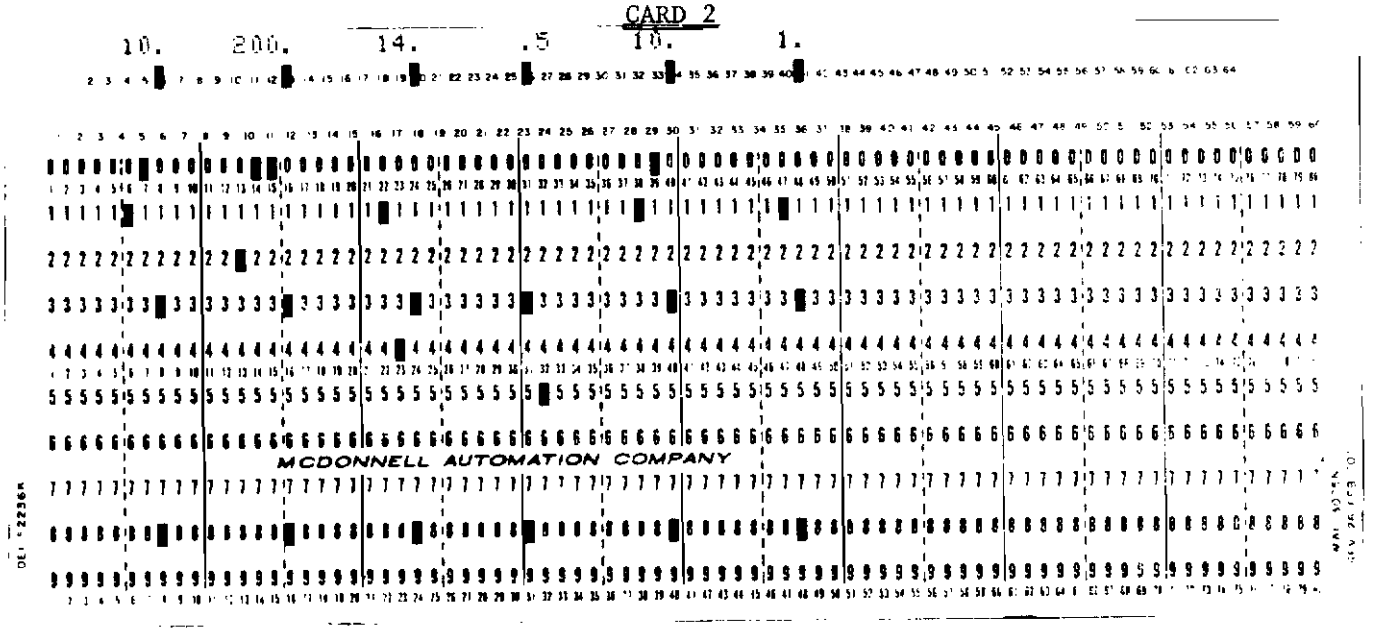
TYPE 35 VALVE (3W-2P) INPUT DATA

2 CARDS REQUIRED

CARD 1



CARD 2



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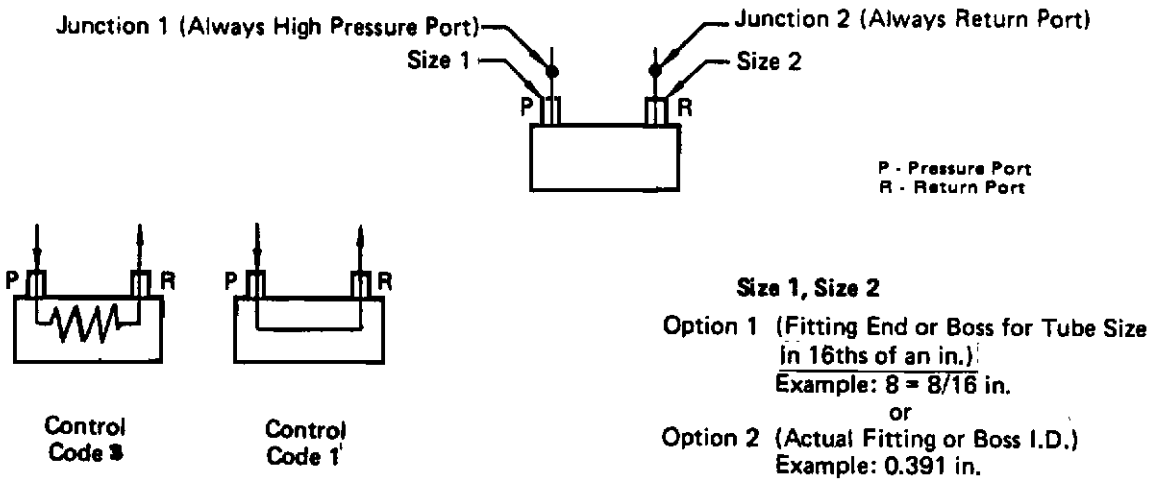
2.1.4.25 Type 36 - Valve (2W - 2P)



ELEMENT TYPE 36 - VALVE (2-WAY - 2 POSITION)

The 2 way 2 position valve has (1) direct path from pressure to return - control code 1 and (2) the valve in the null position with leakage from the high to low pressure - control code 3.

Two cards are required as input data. The junctions 1 and 2 ports are identified. Sizes 1 and 2 correspond with the same junction number with options as noted. Valve specifications usually give the internal pressure drops as a function of flow for a specific fluid and temperature. The viscosity for the fluid at these conditions is input to allow for other type fluids and temperatures. The rated pressure drops at rated flows are input.

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2 WAY - 2 POSITION
CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of cards) 2	--
2-8	7X	Blank	--
9-16	F8.3	(Element type) 36.	--
17-24	F8.3	Junction 1 (P)	--
25-32	F8.3	Juntion 2 (R)	--
33-40	F8.3	Blank	--
41-48	F8.3	Blank	--
49-56	F8.3	Size 1	IN (See options)
57-64	F8.3	Size 2	IN (See options)
65-72	F8.3	Blank	--
73-80	F8.3	Blank	--

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	Rated flow from JCT 1 to JCT 2	GPM
9-16	F8.3	Rated pressure drop for rated flow	PSI
17-24	F8.3	Viscosity of fluid for rated conditions	Centistokes
25-32	F8.3	Leakage flow from JCT 1 to JCT 2	GPM
33-40	F8.3	Pressure drop for leakage conditions	PSI
41-48	F8.3	Operating Control Code	--
49-80	F8.3	Blank	--

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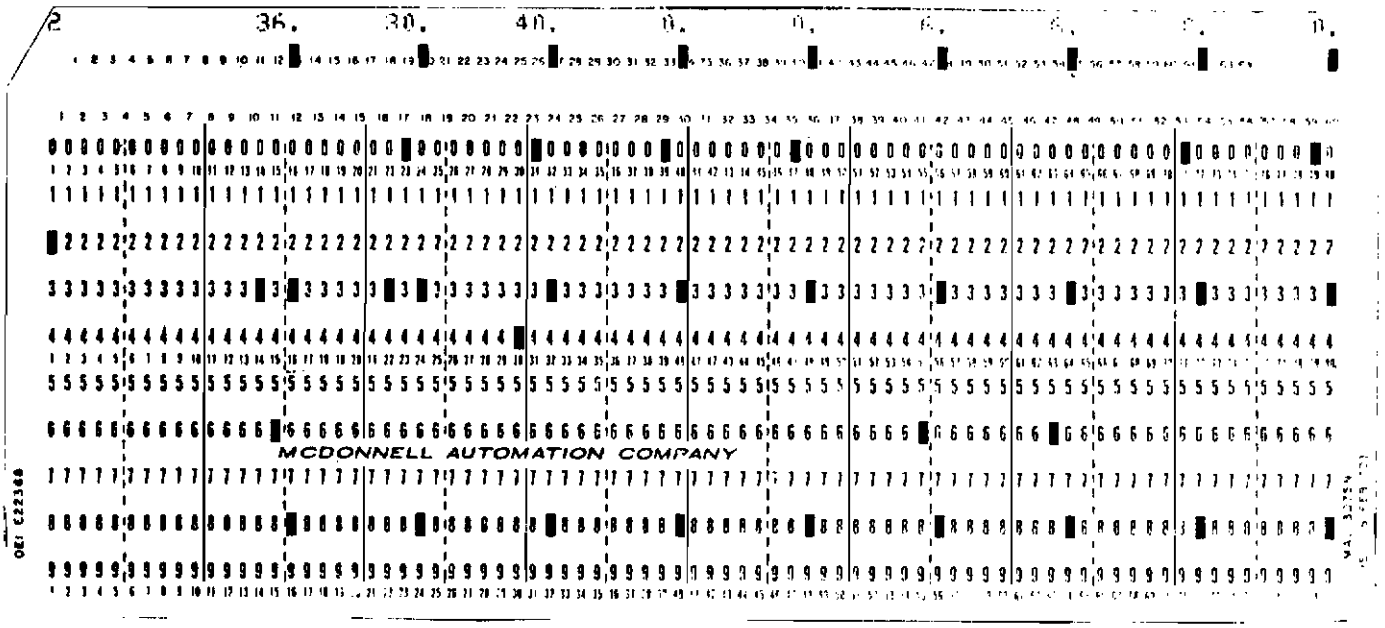
EXAMPLE

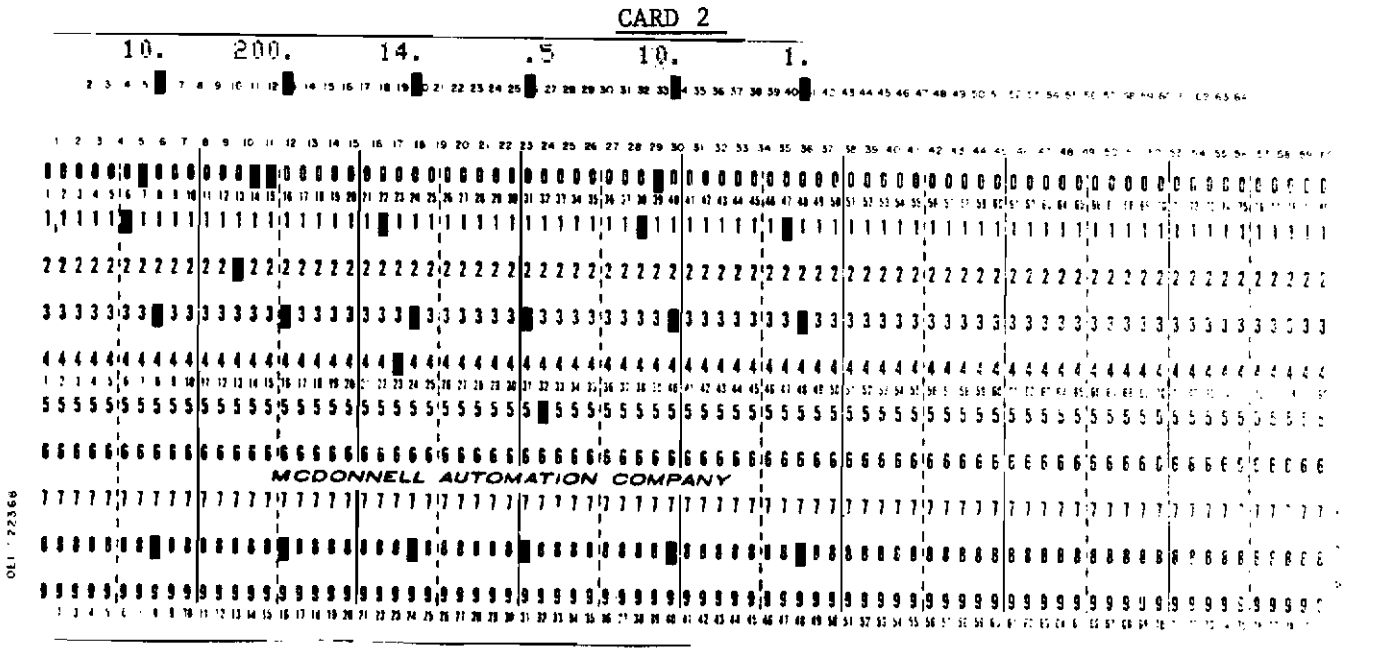
TYPE 36 VALVE (2W-2P) INPUT DATA

2 CARDS REQUIRED

CARD 1



CARD 2



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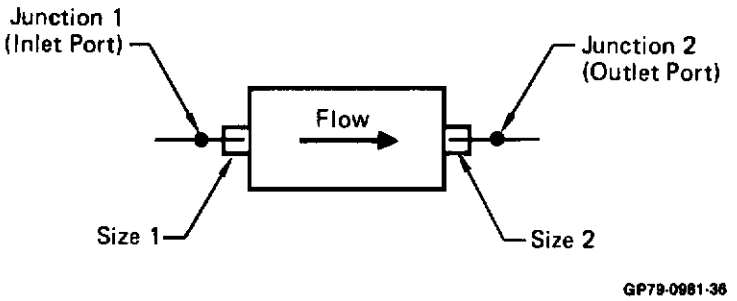
2.1.4.26 Element Type 37 Flow Regulator



ELEMENT TYPE 37 · FLOW REGULATOR

The flow regulator is used to establish a constant flow rate in a system leg regardless of the upstream or downstream pressure. Input data are the inlet and outlet junction numbers, sizes, the regulated flow rate and the minimum pressure drop across the valve to obtain the regulated flow rate.

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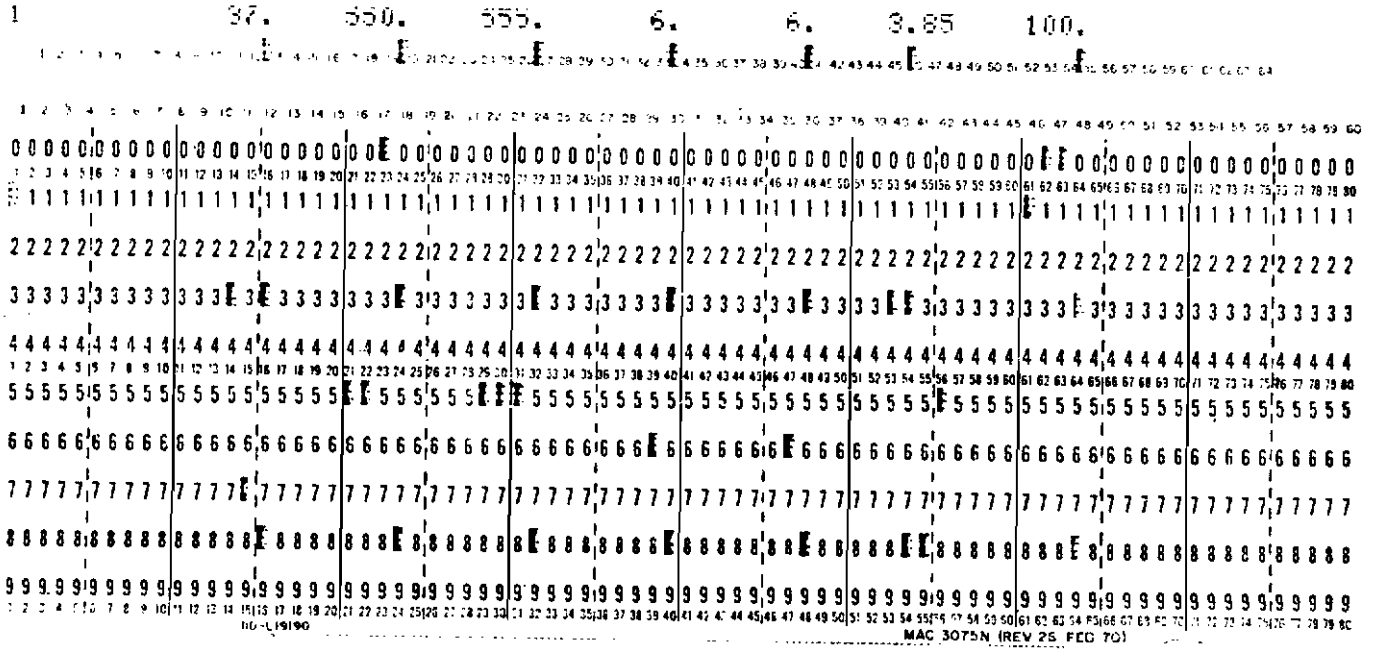
COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1	---
2-8	7X	Blank	---
9-16	F8.3	(Element Type) 37.	---
17-24	F8.3	Junction 1	---
25-32	F8.3	Junction 2	---
33-40	F8.3	Size 1	IN. (See Options)
41-48	F8.3	Size 2	IN. (See Options)
49-56	F8.3	Rated Flow	GPM
57-64	F8.3	Minimum Pressure	PSI
65-72	F8.3	Blank	---
73-80	F8.3	Blank	---

EXAMPLE

Element Type 37 - Flow Regulator



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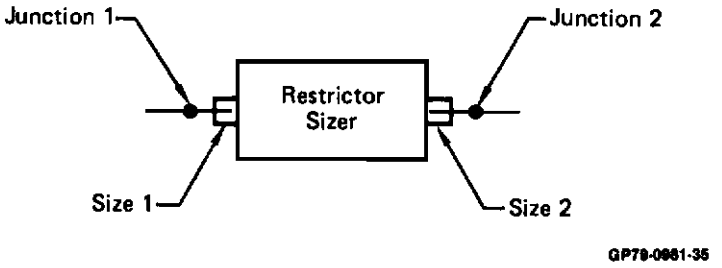
2.1.4.27 Element Type 38 - Restrictor Sizer



ELEMENT TYPE 38 - RESTRICTOR SIZER

The restrictor sizer (orifice sizer) calculates an orifice diameter for a given flow rate in a leg. For example, in a multiple leg system it is desired to operate a subsystem from one position to another position in 3 seconds. The required average flow rate for 3 seconds operation is calculated and input as a type 38. The math model sets the flow rate in the leg at the input flow rate and calculates the inlet and outlet pressures. These pressures are determined during the dynamic balance which calculates the flow balance in all legs of the system. The difference in pressure is then used for calculating the orifice diameter. See Appendix D, Volume VI Technical Description for discussion of the orifice sizing technique.

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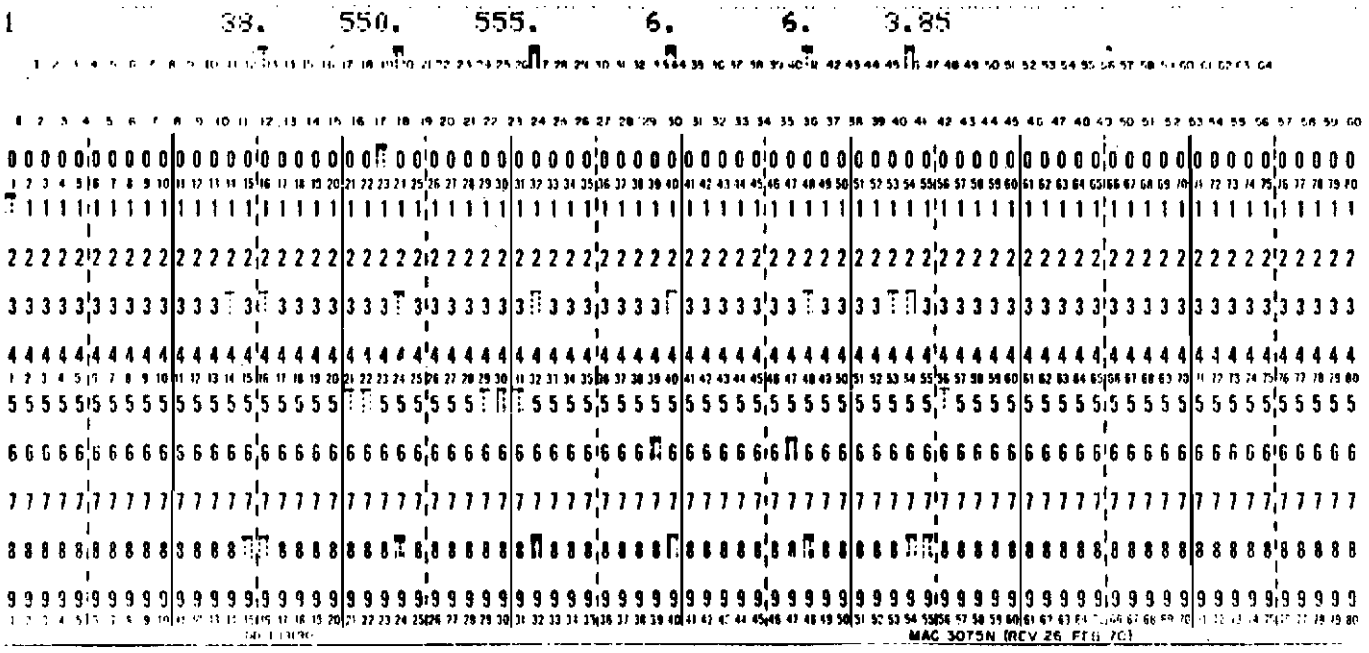
COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1	---
2-8	7X	Blank	---
9-16	F8.3	(Element Type) 38.	---
17-24	F8.3	Junction 1	---
25-32	F8.3	Junction 2	---
33-40	F8.3	Size 1	IN. (See Options)
41-48	F8.3	Size 2	IN. (See Options)
49-56	F8.3	Rated Flow	GPM
57-64	F8.3	Blank	---
65-72	F8.3	Blank	---
73-80	F8.3	Blank	---

EXAMPLE

Element Type 38 - Restrictor Sizer



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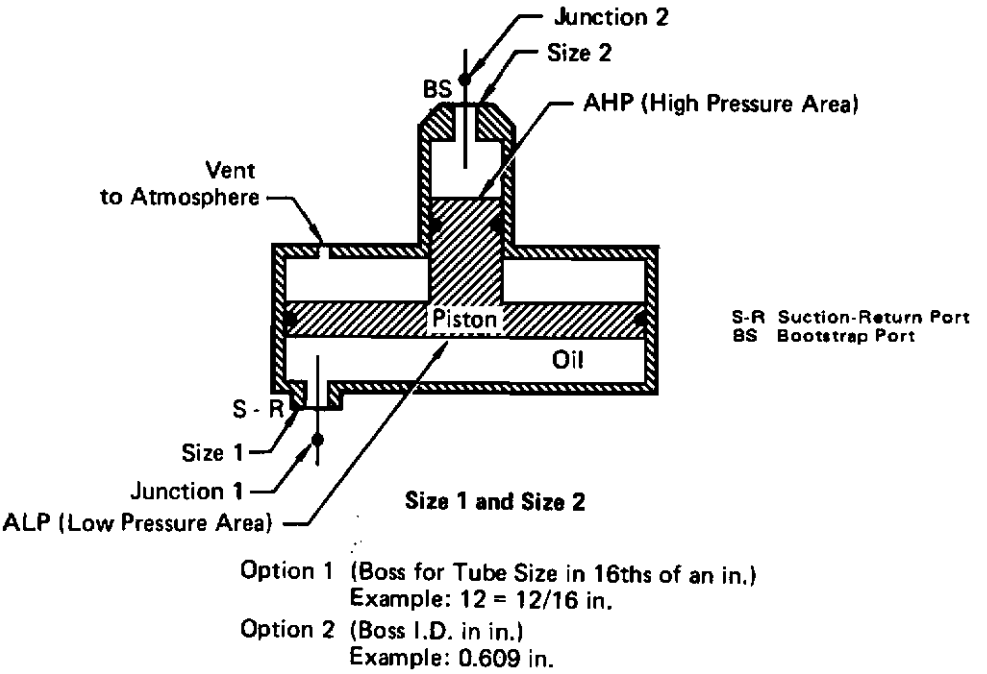
2.1.4.28 Type 91 - Appendix Reservoir



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ELEMENT TYPE 91 - APPENDIX BOOTSTRAP RESERVOIR

Type 91 reservoir is a boostrap pressurized appendix type. Its purpose is to make up system volume differences that occur with fluid temperature changes and the volume exchange with differential area actuators in the subsystems. The reservoir model is corrected for altitude using sea level as a 0 reference point.

One card is required for data input. The appendix port (S-R) and the bootstrap port must be input as junctions 1 and 2 respectively. The high pressure (bootstrap pressure) area of the reservoir piston along with the low pressure area are input. The seal friction force is calculated as shown for the type 9 reservoir.

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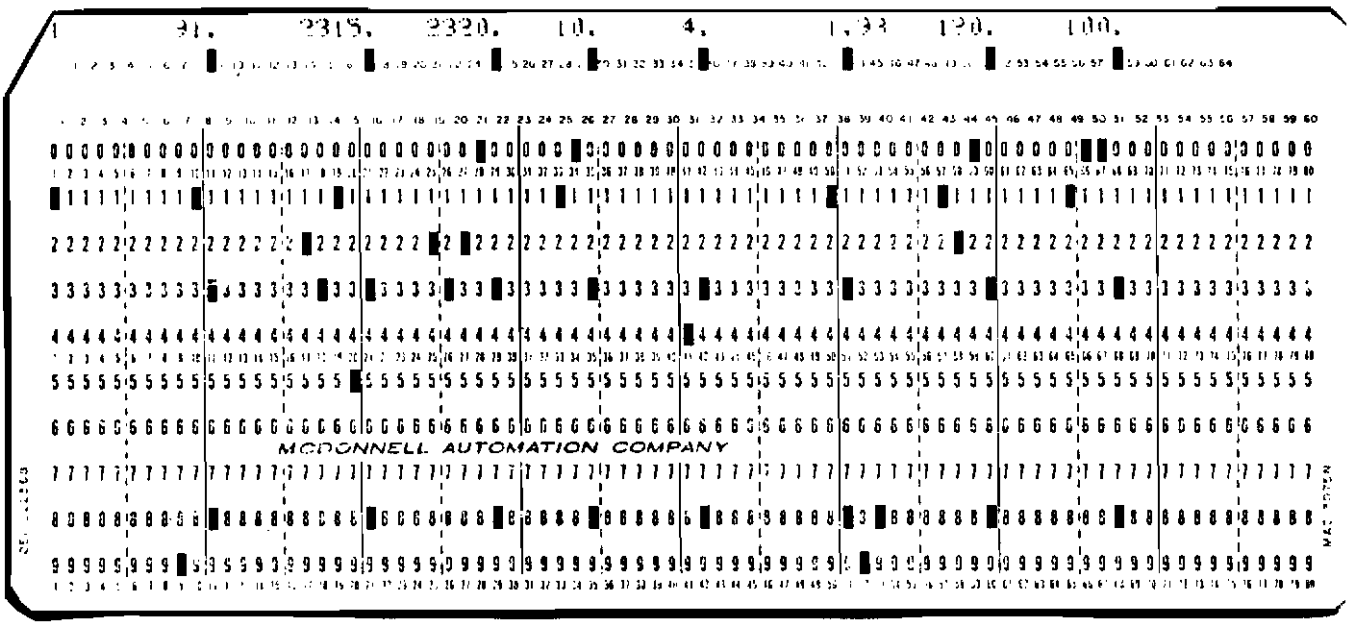
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	(ELEMENT TYPE) 91.	---
17-24	F8.3	JUNCTION 1 (R-S)	---
25-32	F8.3	JUNCTION 2 (BS)	---
33-40	F8.3	SIZE 1	IN. (See Options)
41-48	F8.3	SIZE 2	IN. (See Options)
49-56	F8.3	HIGH PRESSURE AREA	IN^2
57-64	F8.3	LOW PRESSURE AREA	IN^2
65-72	F8.3	SEAL FRICTION	LB.
73-80		BLANK	---

EXAMPLE

TYPE 91 APPENDIX RESERVOIR DATA INPUT



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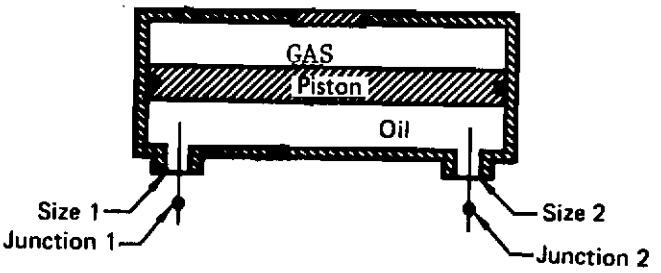
2.1.4.29 Type 92 - Constant Pressure Reservoir



Size 1, Size 2

Option 1 (Boss for Tube Size in 16ths of an in.)
Example: 12 = 12/16 in.
Option 2 (Boss I.D. in in.)
Example: 0.609 in.

ELEMENT TYPE 92 - CONSTANT PRESSURE RESERVOIR

The Type 92 reservoir is a constant pressure flow through reservoir. Its purpose is to provide a constant reference pressure flow through reservoir. Its purpose is to provide a constant reference pressure regardless of the changing flow rate caused by a system demand.

One card is required for data input. The in and out junction numbers and port sizes are entered along with the constant pressure value on this card.

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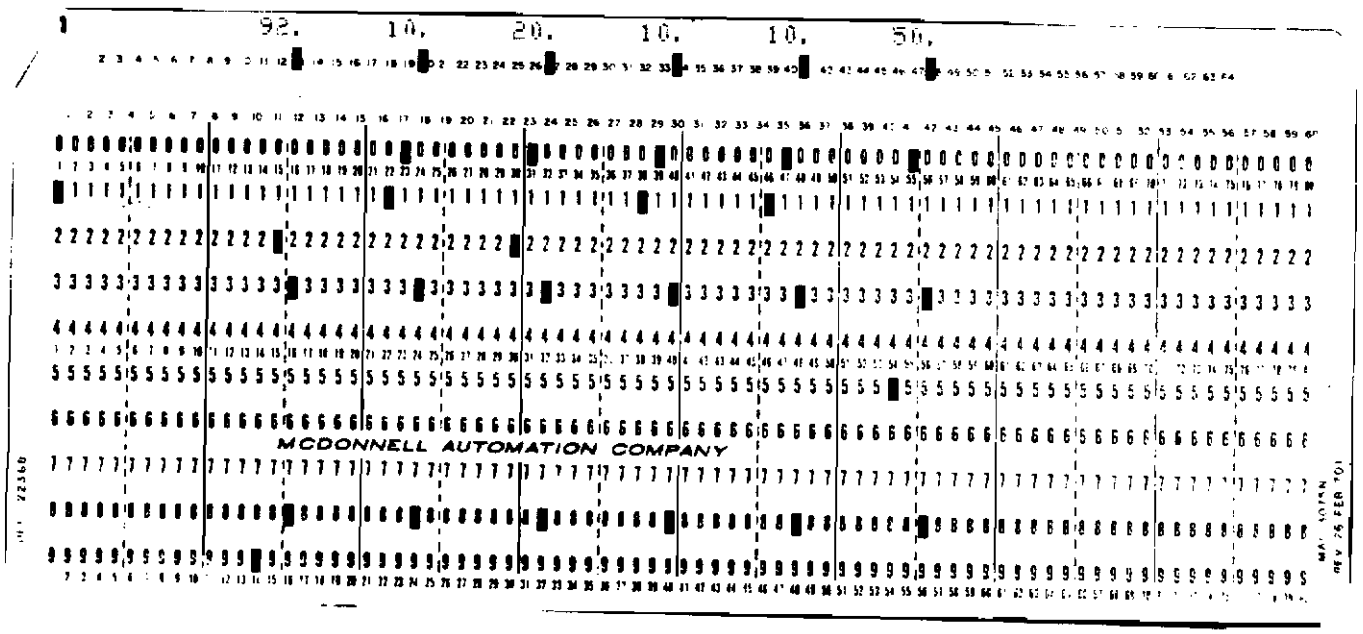
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	--
2-8	7X	BLANK	--
9-16	F8.3	(ELEMENT TYPE) 92.	--
17-24	F8.3	JUNCTION 1	--
25-32	F8.3	JUNCTION 2	--
33-40	F8.3	SIZE 1	IN.(SEE OPTIONS)
41-48	F8.3	SIZE 2	IN.(SEE OPTIONS)
49-56	F8.3	PRESSURE	PSI
57-80	F8.3	BLANK	--

EXAMPLE

TYPE 92 CONSTANT PRESSURE RESERVOIR DATA INPUT



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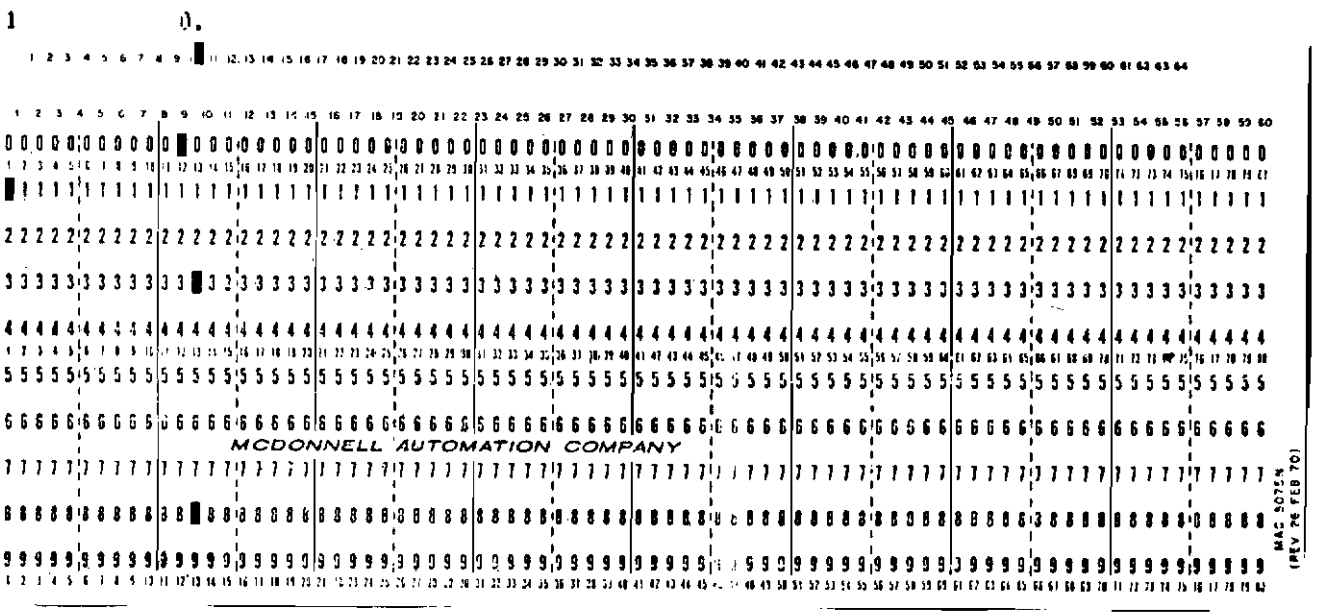
2.1.5 End Card

The end card for the data deck is the last data card. An integer 1 is placed in Column 1 and the 0. in column 9 indicates the end of data.

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	ENTER 1	---
2-8	7X	BLANK	---
9-16	F8.3	ENTER 0.	---
17-80		BLANK	---

EXAMPLE END CARD



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2.1.6 Program Deck and Input Data

The program deck and data cards are assembled as shown in Figure 5. The first six cards and the end card must be in order in the data deck. The element cards may be in random order.

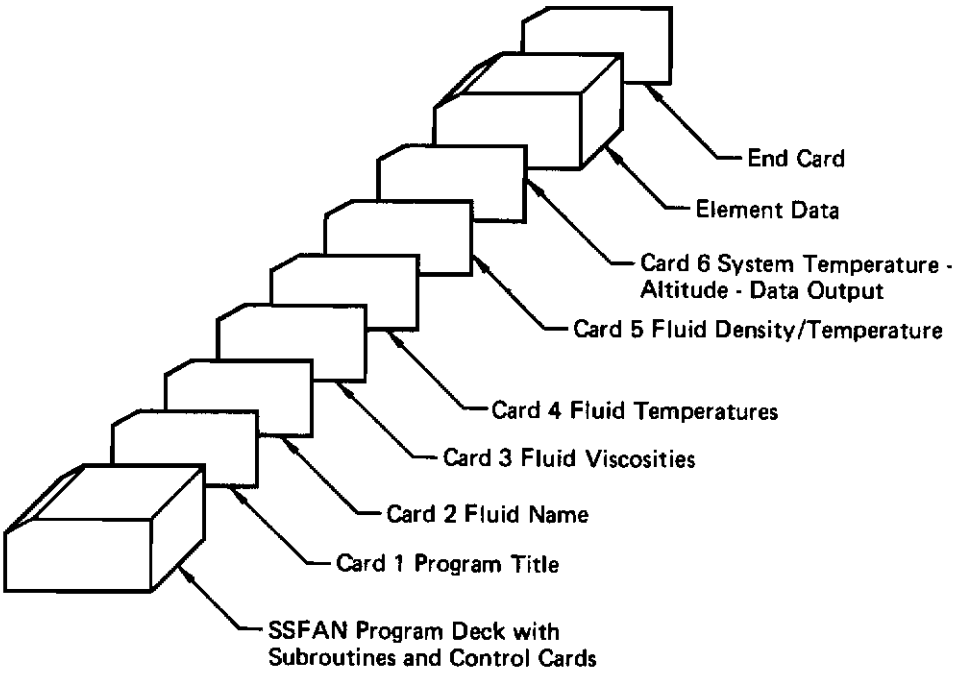

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FIGURE 5
SSFAN PROGRAM DECK AND INPUT DATA

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SECTION III

PROGRAM OUTPUT

For illustration, simple hydraulic systems of the types shown in Figures 6 and 11 are modelled to indicate the output which may be obtained with SSFAN. Normal input parameters set the system characteristics or resistances in each leg for the input conditions of fluid type and temperature and fluid altitude. The network flow balance, pressures at branch points and leg pressure drops are calculated for this one set of conditions.

Program Output is of 4 basic types. The first output is the individual element data, output exactly as it was read into the program. This may be used for reference when first setting up the system to ensure that the data was input correctly. The second output is the road map or system assembly. This gives the junction numbers and the corresponding computer assigned pressure point number. Also, each leg number and the corresponding junction number and computer assigned pressure point number at each end of the leg are output. The third output prints the pressures at each junction point or end point in the system along with the flows in each leg. This output corresponds directly with the system assembly road map described above. The fourth output is a special quasi-transient type output and is described in Section 4.

3.1 SSFAN Sample Case Number 1

Sample case number 1 is the simple hydraulic system shown in Figure 6. This is a 2 actuator load system with the solenoid valve in position to extend the actuators each against a 1000 pound load. The actuators are the unbalanced area type and are of different sizes. The pump is a variable delivery type operating at 3750 RPM with a rated flow of 50 gpm at this RPM. The reservoir is a flow through type with bootstrap pressure.

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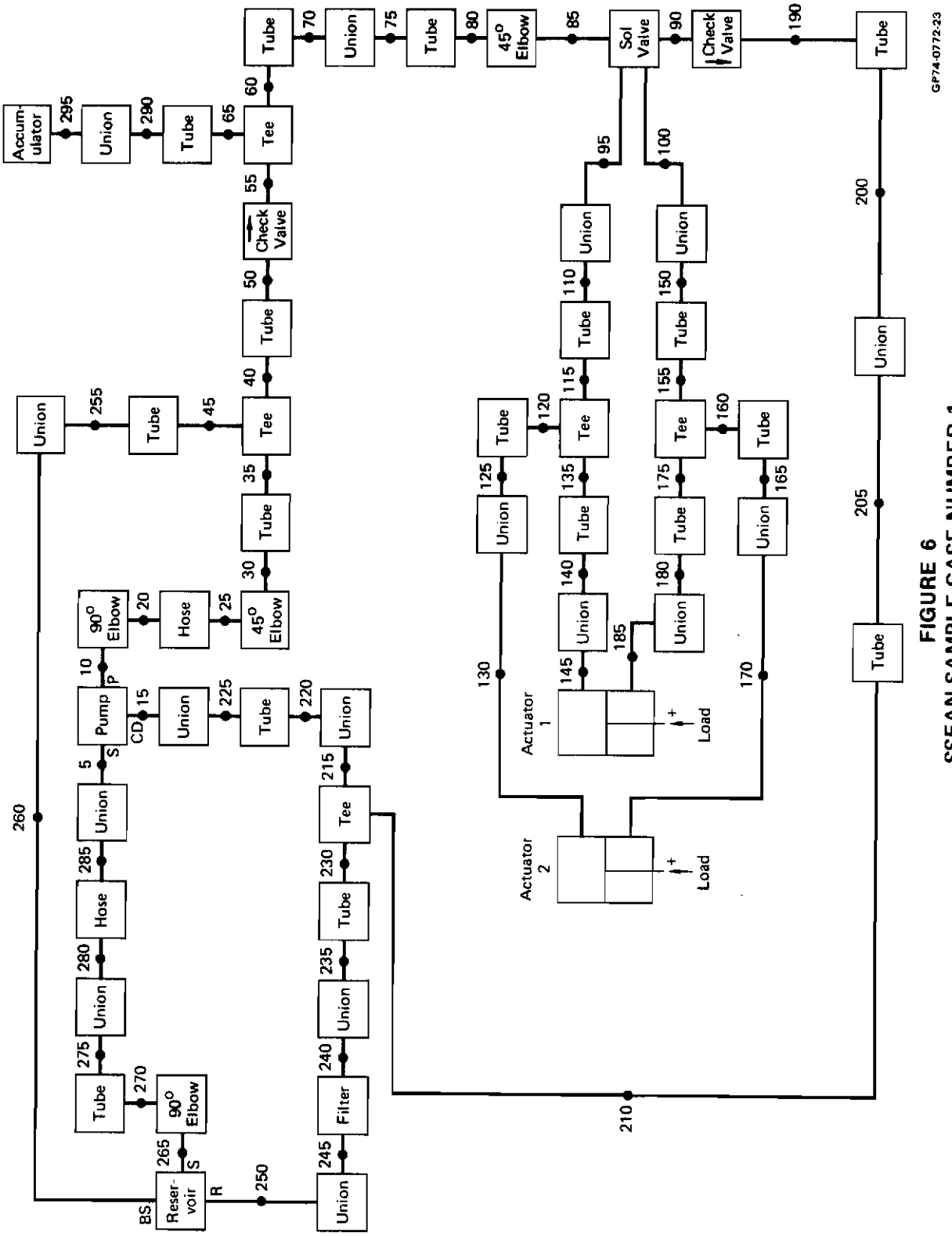

FIGURE 6
SSFAN SAMPLE CASE NUMBER 1
2 Actuator Subsystem

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Figure 7 shows a typical first page data output page giving the system data parameters exactly as they were input.

Figure 8 shows the individual element data exactly as it was input.

Figure 9 is an example of the pressure point number and leg assembly number assignments. The junction numbers at leg ends correspond to the numbers of Figure 6 block diagram. For example, for leg 10-35, this is the leg that starts at the pump pressure out port and ends at the downstream tee (reservoir bootstrap pressure tee). It may be noted that the bootstrap pressure line (260-45) and the accumulator line (65-295) have 0. flow and 0. pressure drop. Also, looking at the reservoir return line (250-230) and the pump suction line (5-265), system flow is being made up for the system from the reservoir because the unbalanced area actuators are extending. If the leg is assembled opposite to the direction of the actual flow, the flow is printed out as negative (-), see Figure 10.

Addition of flows will show that the flows are balanced within .01 gpm. Of course the flow changes across the pistons of the unbalanced area actuators.

The flow at the pump is balanced where the flow out the pressure port (12.84 gpm) plus the case drain flow (.66 gpm) equals the flow in the suction port (13.50 gpm).

Figure 10 also gives the pressure point data. The pump case pressure (junction 3) is seen to be 135.85 psi which is established at this level because of the return system flow gradient and the restricted case drain line. The overall effect is to increase the 3000 psi rated pump pressure out to 3075.88 because the pump compensator is referenced to the case drain pressure. The reservoir interval pressure may be seen to be 53.07 PSI and the suction pressure at the pump is 50.56 PSI.

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```
*****************************************************************************
*********************************SSFAN PROGRAM*******************************
*****************************************************************************

DATA DECK---------------SSFAN  --  SAMPLE CASE NUMBER 1

*******************************COLUMN NUMBERS********************************
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
++++++++$$$$$$$$++++++++$$$$$$$$++++++++$$$$$$$$++++++++$$$$$$$$++++++++$$$$$$$$

CARD 1 ++++++++++++++++++++++TITLE+++++++++++++++++++++++++++++++++++++++++++
SSFAN  --  SAMPLE CASE NUMBER 1

CARD 2 ++++++++++++++++++++++FLUID+++++++++++++++++++++++++++++++++++++++++++
MIL-H-5606A

CARDS 3&4 ++++++++VISCOSITY-TEMPERATURE DATA++++++++++++++++++++++++++++++++
9          2000.00  385.00  130.00   36.00   14.60    7.70    4.80    3.40    2.40
9           -65.00  -40.00    0.00   50.00  100.00  150.00  200.00  250.00  300.00

CARD 5 +++++++++++++DENSITY-TEMPERATURE DATA++++++++++++++++++++++++++++++++++
  56.200  49.900 -65.000 275.000

CARD 6 +++++INITIAL TEMP-FINAL TEMP-TEMP INCR-ALTITUDE-PRINT-OPTIONS++++++++++++
 100.000 100.000   0.000   0.000   1.000   2.000   3.000   4.000
```

FIGURE 7

EXAMPLE SSFAN FIRST SIX CARDS INPUT DATA

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```
CARDS 7 & ON ++++++++++++++++++++++++++++++ELEMENT DATA++++++++++++++++++++++++++++++
*****************************COLUMN NUMBERS*****************************
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
++++++++$$$$$$$$++++++++$$$$$$$$++++++++$$$$$$$$++++++++$$$$$$$$++++++++$$$$$$$$
2          4.000  145.000  195.000    4.000    4.000    4.500    3.250   35.000 1000.000
   5.000   2.500    2.000   95.000    0.000    0.000    0.000    0.000    0.000    0.000
2          4.000  130.000  170.000    4.000    4.000    3.850    2.900   25.000 1000.000
   5.000   2.500    2.000   95.000    0.000    0.000    0.000    0.000    0.000    0.000
2          1.000   40.000   50.000    0.000     .065  142.500   30.000   45.000  120.000
  65.000  23.000   72.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
1          1.000  230.000  235.000   10.000     .028   63.200   42.000   33.200    0.000
2         34.000   85.000   90.000   95.000  100.000    6.000    8.000    4.000    4.000
  25.000  200.000   14.000     .100 3000.000    1.000    0.000    0.000    0.000    0.000
2          9.000  250.000  260.000  265.000   10.000    4.000   16.000    1.655   95.300
   2.000   0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
2          1.000  205.000  210.000    4.000     .023  147.300   23.000   38.000   90.000
  63.000 121.000  150.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
2          5.000    5.000   10.000   15.000   16.000   12.000    4.000 3750.000 3750.000
  50.000 3000.000 2250.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
1          2.000  245.000  250.000   10.000   10.000    0.000    0.000    0.000    0.000
1          2.000  235.000  240.000   10.000   10.000    0.000    0.000    0.000    0.000
1          2.000  220.000  215.000    4.000    4.000    0.000    0.000    0.000    0.000
1          1.000  225.000  220.000    4.000     .020   78.200   97.000   [illegible]    0.000
1                  [illegible]  225.000    4.000    4.000    [illegible]    0.000    [illegible]    0.000
                   [illegible]  205.000    [illegible]    [illegible]    [illegible]    [illegible]    [illegible]    [illegible]
                   [illegible]  [illegible]    [illegible]    [illegible]    [illegible]    [illegible]    [illegible]    [illegible]
1          [illegible]  270.000  [illegible]    [illegible]    [illegible]    [illegible]    [illegible]    [illegible]    [illegible]
1          2.000  275.000  [illegible]  [illegible]   16.000    0.000    0.000    0.000    0.000
1         21.000   25.000   30.000   12.000   12.000    0.000    0.000    0.000    0.000
1          2.000  235.000    5.000   16.000   16.000    0.000    0.000    0.000    0.000
1          7.000  295.000    4.000    1.000   50.000  100.000    4.000    6.000    0.000
1          0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
```

FIGURE 8
EXAMPLE SSFAN SAMPLE CASE NUMBER 1
ELEMENT INPUT DATA - CARDS 7 AND ON

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SSFAN — SAMPLE CASE NUMBER 1

LEG NO-LEG END PRESSURE PT NO-JUNCTION PT NO & ELEMENT TYPE

LEG NO.	PRESSURE PT (UP)	PRESSURE PT (DN)	BRANCH/END PT (UP)	BRANCH/END PT (DN)	*	PRESS PT NO	ELEMENT	JUNCTION NUMBERS
1	2	15	10.	35.	*	1	PUMP	5.
2	1	11	5.	265.	*	2	PUMP	10.
3	3	12	15.	215.	*	3	PUMP	15.
4	9	12	250.	230.	*	4	ACCUM	295.
5	10	15	260.	45.	*	5	ACTR	145.
6	12	18	210.	90.	*	6	ACTR	185.
7	15	14	40.	55.	*	7	ACTR	130.
8	14	4	65.	295.	*	8	ACTR	170.
9	14	17	60.	85.	*	9	RESV	250.
10	19	13	95.	115.	*	10	RESV	260.
11	13	7	120.	130.	*	11	RESV	265.
12	8	16	170.	160.	*	12	TEE	210.- 215.- 230.
13	13	5	135.	145.	*	13	TEE	115.- 120.- 135.
14	6	16	185.	175.	*	14	TEE	55.- 65.- 60.
15	16	20	155.	100.	*	15	TEE	35.- 45.- 40.
16	5	6	145.	185.	*	16	TEE	175.- 160.- 155.
17	7	8	130.	170.	*	17	VLV	85.
18	17	18	85.	90.	*	18	VLV	90.
19	17	19	85.	95.	*	19	VLV	95.
20	19	18	95.	90.	*	20	VLV	100.
21	17	20	85.	100.	*			
22	20	18	100.	90.	*			

FIGURE 9

EXAMPLE SSFAN SAMPLE CASE NUMBER 1
SYSTEM ASSEMBLY DATA

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LEG NO.	FLOW (GPM)	**	PRESSURE PT NO.	PRESSURE (PSIG)	TEMPERATURE (DEG F)
1	12.84	**	1	50.56	100.00
2	-13.50	**	2	3075.38	100.00
3	.66	**	3	135.85	100.00
4	-9.86	**	4	2906.82	100.00
5	-.41	**	5	976.46	100.00
6	-9.20	**	6	1044.30	100.00
7	12.44	**	7	1155.98	100.00
8	.00	**	8	1189.82	100.00
9	12.44	**	9	53.07	100.00
10	12.36	**	10	3056.95	100.00
11	6.45	**	11	53.07	100.00
12	4.86	**	12	130.66	100.00
13	5.91	**	13	1294.73	100.00
14	4.27	**	14	2906.82	100.00
15	9.13	**	15	3063.18	100.00
16	5.91	**	16	846.30	100.00
17	6.45	**	17	2499.28	100.00
18	.07	**	18	206.08	100.00
19	12.36	**	19	2449.85	100.00
20	.00	**	20	233.03	100.00
21	.00	**			
22	9.13	**			

FIGURE 10

EXAMPLE SSFAN SAMPLE CASE NUMBER 1
LEG FLOW RATES
AND
PRESSURE AT BRANCH POINTS & END POINTS

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Contrails

Contrails

3.2 SSFAN Sample Case Number 2

Sample case number 2 is similar to sample case number 1, except that a third actuator has been added. The configuration in Figure 11 illustrates a more complex circuit for analysis because it is not just another parallel load to the original 2 actuators. It ties into the actuator 2 return loop before actuator 2 completes its circuit with actuator 1. This type of network cross-branching is readily handled by the SSFAN solution technique.

Figures 12 and 13 show the system assembly and output flows and pressure drops respectively. These results show data very similar to the sample case 1 data except there are more legs and branch points.

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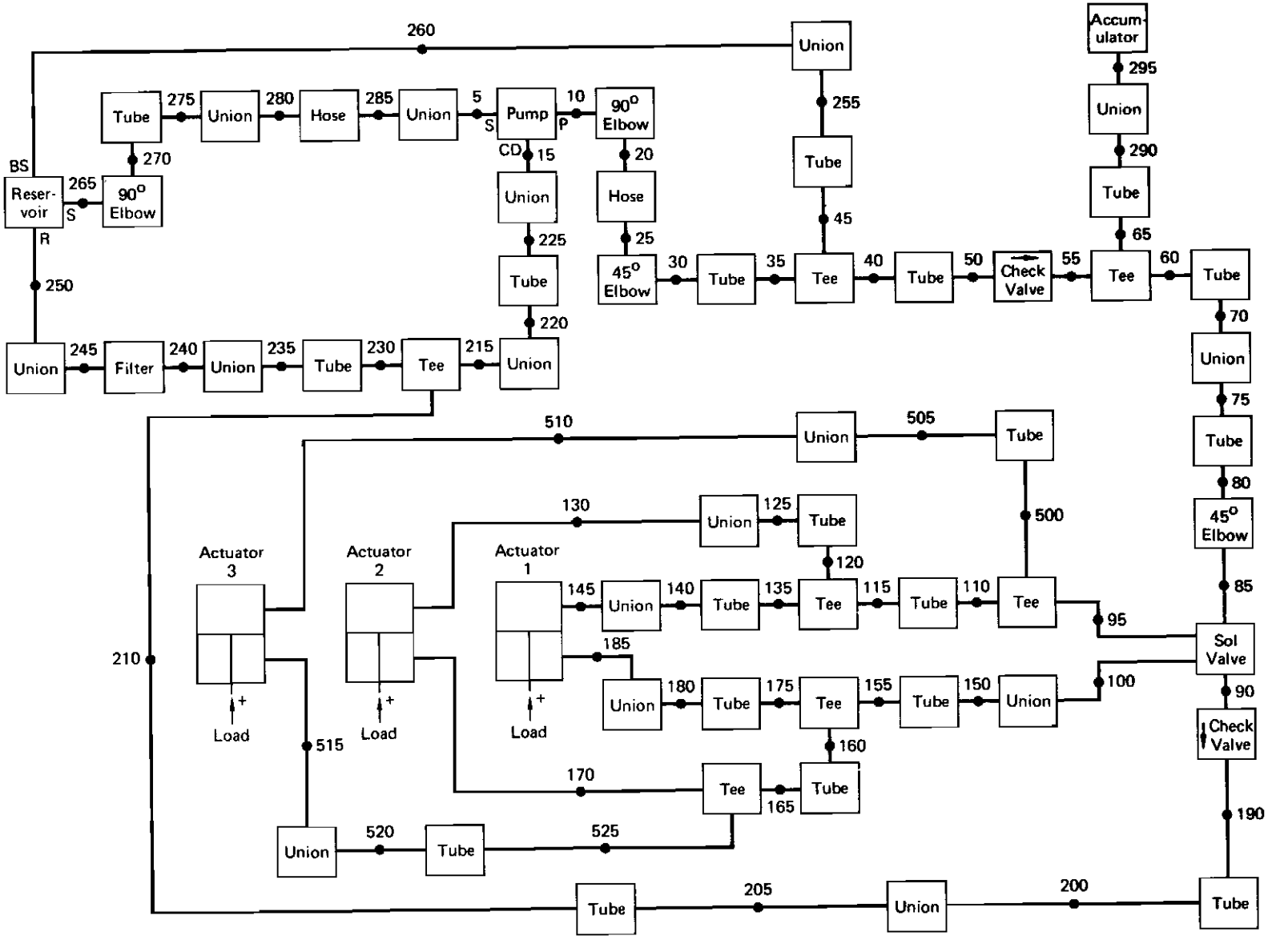

FIGURE 11
SSFAN SAMPLE CASE NUMBER 2
3 Actuator Subsystem

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SSFAN -- SAMPLE CASE NUMBER 2

LEG NO-LEG END PRESSURE PT NO-JUNCTION PT NO & ELEMENT TYPE

LEG NO.	PRESSURE PT (UP)	(DN)	BRANCH/END PT (UP)	(DN)	*	PRESS PT NO	ELEMENT	JUNCTION NUMBERS
1	2	19	10.	35.	*	1	PUMP	5.
2	1	13	5.	265.	*	2	PUMP	10.
3	3	16	15.	215.	*	3	PUMP	15.
4	11	16	250.	230.	*	4	ACCUM	295.
5	12	19	260.	45.	*	5	ACTR	145.
6	16	22	210.	90.	*	6	ACTR	185.
7	19	15	40.	55.	*	7	ACTR	510.
8	15	4	65.	295.	*	8	ACTR	515.
9	15	21	60.	85.	*	9	ACTR	130.
10	23	18	95.	96.	*	10	ACTR	170.
11	18	17	110.	115.	*	11	RESV	250.
12	17	9	120.	130.	*	12	RESV	260.
13	10	14	170.	170.	*	13	RESV	265.
14	14	8	525.	515.	*	14	TEE	170.- 525.- 165.
15	7	18	510.	500.	*	15	TEE	55.- 65.- 60.
16	14	20	165.	160.	*	16	TEE	210.- 215.- 230.
17	17	5	135.	145.	*	17	TEE	115.- 120.- 135.
18	6	20	185.	175.	*	18	TEE	96.- 110.- 500.
19	20	24	155.	100.	*	19	TEE	35.- 45.- 40.
20	5	6	145.	185.	*	20	TEE	175.- 160.- 155.
21	9	10	130.	170.	*	21	VLV	85.
22	21	22	85.	90.	*	22	VLV	90.
23	21	23	85.	95.	*	23	VLV	95.
24	23	22	95.	90.	*	24	VLV	100.
25	21	24	85.	100.	*			
26	24	22	100.	90.	*			
27	7	8	510.	515.	*			

FIGURE 12

EXAMPLE SSFAN SAMPLE CASE NUMBER 2
SYSTEM ASSEMBLY DATA

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LEG NO.	FLOW (GPM)	** **	PRESSURE PT NO.	PRESSURE (PSIG)	TEMPERATURE (DEG F)
1	15.01	**	1	49.85	100.00
2	-15.64	**	2	3083.84	100.00
3	.62	**	3	146.00	100.00
4	-11.20	**	4	2861.31	100.00
5	-.47	**	5	1130.47	100.00
6	-10.58	**	6	1257.51	100.00
7	14.55	**	7	1475.46	100.00
8	.00	**	8	1735.14	100.00
9	14.55	**	9	1421.01	100.00
10	14.48	**	10	1541.61	100.00
11	7.74	**	11	53.13	100.00
12	1.95	**	12	3060.49	100.00
13	1.47	**	13	53.13	100.00
14	-4.87	**	14	1545.98	100.00
15	-6.75	**	15	2861.31	100.00
16	6.34	**	16	142.21	100.00
17	5.78	**	17	1437.77	100.00
18	4.18	**	18	1906.07	100.00
19	10.52	**	19	3067.56	100.00
20	5.78	**	20	1064.51	100.00
21	1.95	**	21	2325.96	100.00
22	.07	**	22	238.96	100.00
23	14.48	**	23	2258.15	100.00
24	.00	**	24	274.73	100.00
25	.00	**			
26	10.52	**			
27	6.75	**			

FIGURE 13

EXAMPLE SSFAN SAMPLE CASE NUMBER 2
LEG FLOW RATES
AND
PRESSURE AT BRANCH POINTS & END POINTS

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SECTION IV

QUASI-TRANSIENT INPUT AND OUTPUT

SSFAN may be run in the quasi-transient mode. With an input of time interval, time step and some additional component element data, the quasi-transient model may be used to predict subsystem operating times. Calculated data may be output in tabular form and in computer graph plot form. The following element types are used for quasi-transient input and output data. These data are placed with the normal SSFAN data.

ELEMENT TYPE	DESCRIPTION
15	Time Interval and Time Step
16	Additional Component Element Data
17	Valve Position vs Time Data
18	Valve Position vs Other Component Position Data
19	Output Data

4.1 Quasi-Transient Input

4.1.1 Time Interval and Time Step

The initial time, final time and desired time step are all input values. The time step is optional. If the time step is not input, a default value of 100 is used. 100 steps provide the steps needed for a complete graph output.

4.1.2 Additional Component Element Data

Additional data may be supplied for actuators, accumulators, motors and valves.

4.1.2.1 Actuator

The additional data for an actuator consists of the quasi-transient element type (16.), element type (4.), actuator extend port junction number, number of points on load-stroke curve and the load versus stroke points. All piston position values are input and then load values are input in corresponding order. One or two data cards are used depending on the number of points input. A piston position of 0. is when the actuator rod is full retracted. All piston positions are positive from this point. A compression load on the rod is a positive load and a tension load on the rod is a negative load.

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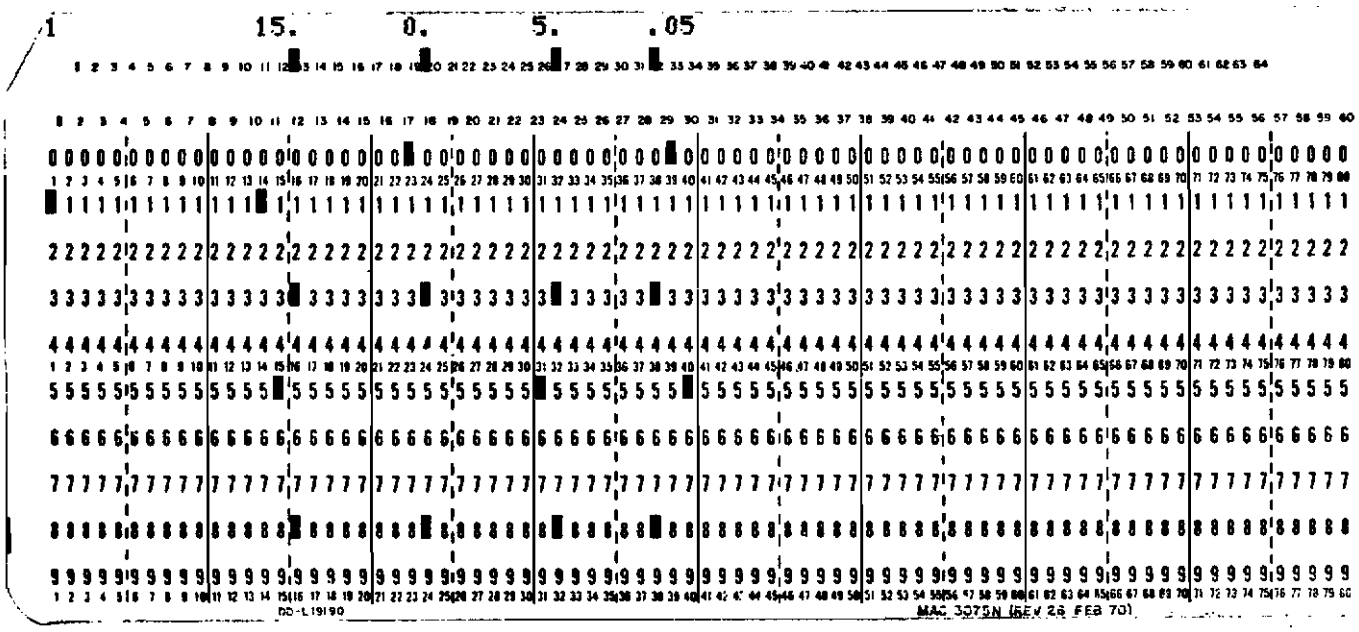
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1	---
2-8	7X	Blank	---
9-16	F8.3	(Element Type) 15.	---
17-24	F8.3	Initial Time	SEC
25-32	F8.3	Final Time	SEC
33-40	F8.3	Time Step (Optional)	SEC
41-48	F8.3	Blank	

EXAMPLE
TIME INTERVAL AND TIME STEP INPUT DATA



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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1 OR 2	- - -
2-8	7X	BLANK	- - -
9-16	F8.3	QUASI-TRANSIENT ELEMENT TYPE 16.	- - -
17-24	F8.3	ACTUATOR ELEMENT TYPE 4.	- - -
25-32	F8.3	ACTUATOR EXTEND JUNCTION NO.	- - -
33-40	F8.3	NUMBER OF LOAD VS STROKE POINTS	- - -
41-48	F8.3	PISTON POS 1	IN
49-56	F8.3	PISTON POS 2	IN
57-64	F8.3	PISTON POS 3	IN
65-72	F8.3	PISTON POS 4	IN
73-80	F8.3	PISTON POS 5	IN

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	PISTON POS 6	IN
9-16	F8.3	PISTON POS 7	IN
17-24	F8.3	ACTUATOR LOAD 1	LB
25-32	F8.3	ACTUATOR LOAD 2	LB
33-40	F8.3	ACTUATOR LOAD 3	LB
41-48	F8.3	ACTUATOR LOAD 4	LB
49-56	F8.3	ACTUATOR LOAD 5	LB
57-64	F8.3	ACTUATOR LOAD 6	LB
65-72	F8.3	ACTUATOR LOAD 7	LB

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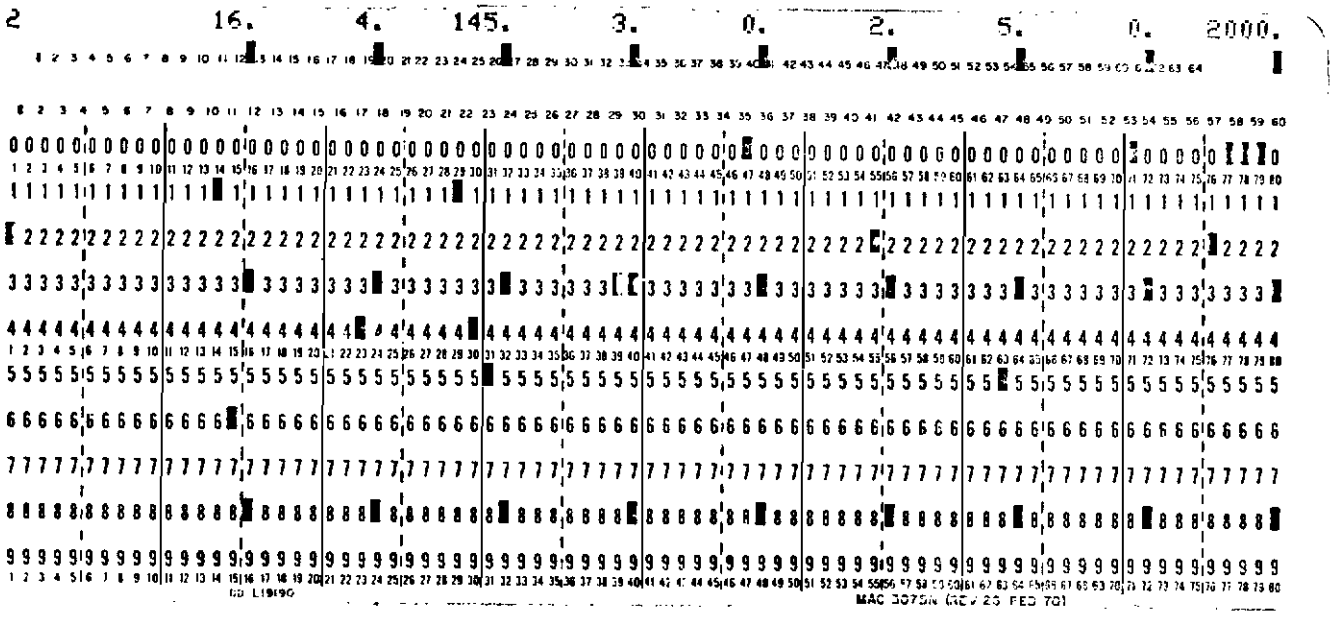
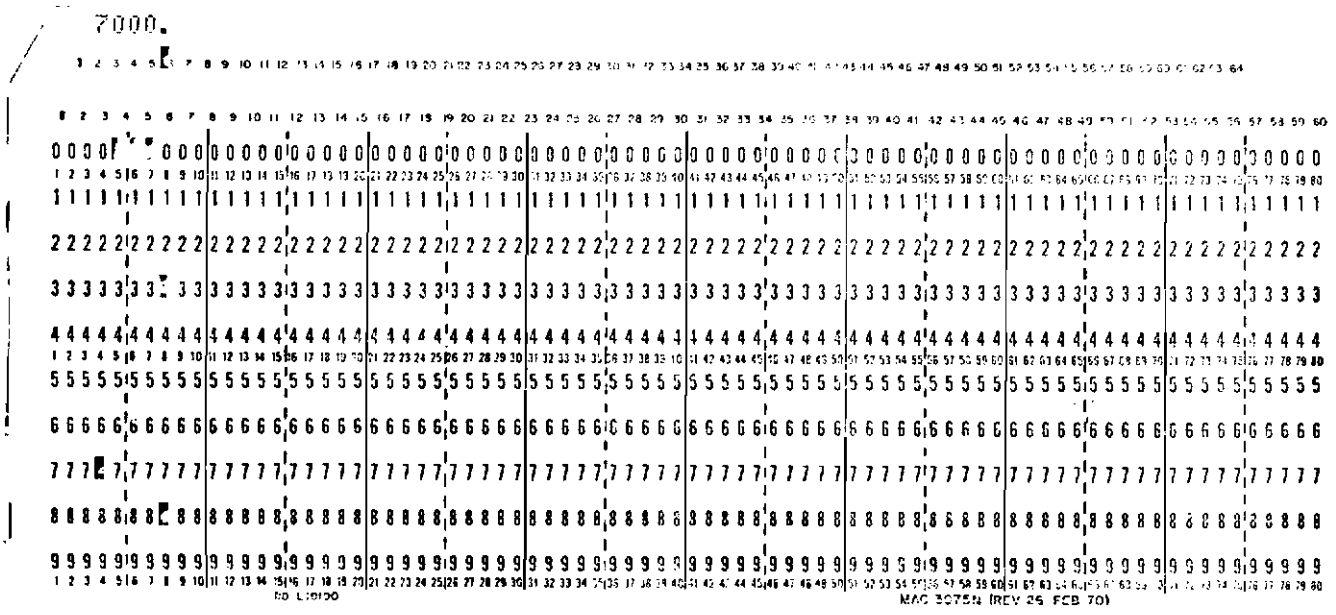
EXAMPLE
TYPE 16 ACTUATOR LOAD VS. STROKE DATA
2 DATA CARDS

CARD 1



CARD 2



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4.1.2.2 Accumulator

The Quasi-transient accumulator is used in conjunction with the dynamic accumulator element type 7., subtype 3. The initial fluid volume is input and the initial gas/fluid pressure may be reset with the Quasi-transient element type 16. In the Quasi-transient mode, the dynamic accumulator gas pressure is calculated to be an adiabatic compression or expansion, using a compressibility factor correction.

4.1.2.3 Hydraulic Motor

Additional data may be supplied for the hydraulic motor with elemnt type 16. Data points for overall efficiency versus motor RPM at a specific pressure difference (such as 3000 PSID across the motor ports) are input. Data points for other pressure differences are extrapoloted from a set of curves taken from actual test data and programmed into the calculation subroutine, see Volume VI Technical Description. Input data are the element type 16., element type 8, the pressure port junction number, the number of efficiency versus RPM data points and the data points. All RPMS are input in ascending order followed by the efficiencies.

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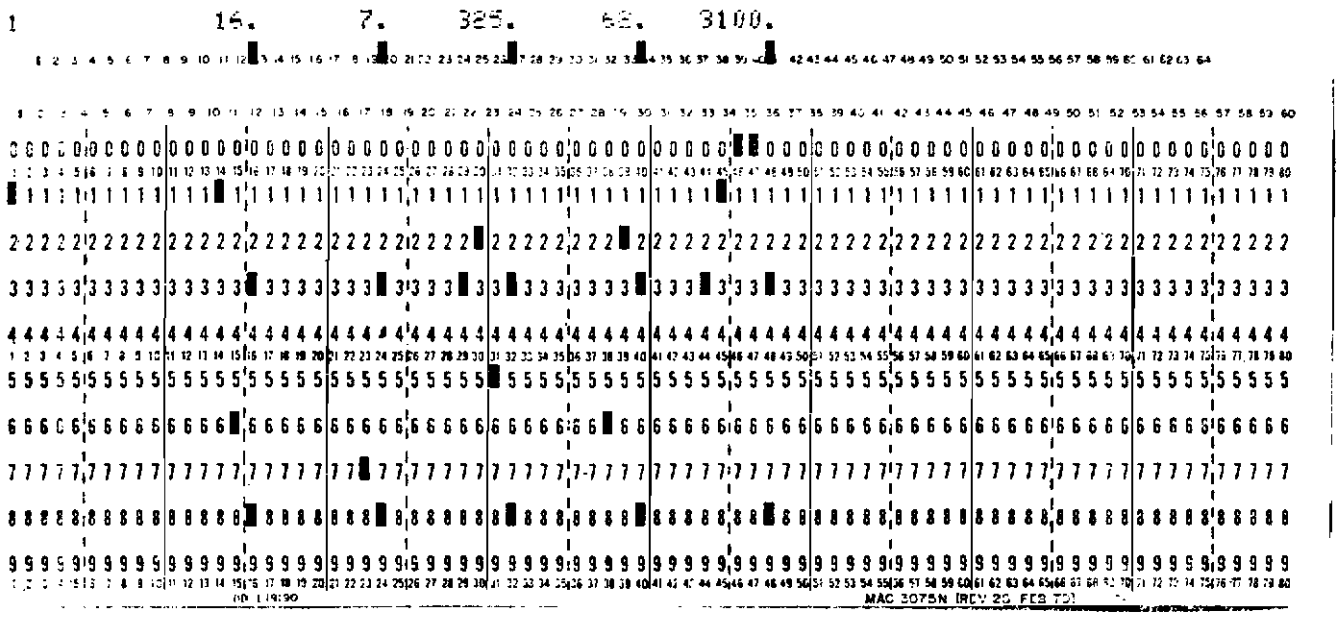
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1	---
2-8	7X	Blank	---
9-16	F8.3	Quasi-Transient Element Type 16	---
17-24	F8.3	Dynamic Accumulator Element Type 7	---
25-32	F8.3	Accumulator Port Junction No.	---
33-40	F8.3	Initial Fluid Volume	IN^3
41-48	F8.3	Initial Gas/Fluid Pressure (Optional)	PSIG
49-80	F8.3	Blank	---

EXAMPLE

TYPE 16 - ADDITIONAL COMPONENT DATA FOR DYNAMIC ACCUMULATOR

CARD 1



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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1 or 2	- - -
2-8	7X	Blank	- - -
9-16	F8.3	QUASI-Transient Element Type 16	- - -
17-24	F8.3	HYD Motor Element Type 8	- - -
25-32	F8.3	Motor Inlet Pressure Port Junction No.	- - -
33-40	F8.3	Motor PSID for Efficiencies VS RPMS	PSID
41-48	F8.3	Number of Efficiency VS RPM Points	- - -
49-56	F8.3	RPM 1	RPM
57-64	F8.3	RPM 2	RPM
65-72	F8.3	RPM 3	RPM
73-80	F8.3	RPM 4	RPM

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	RPM 5	RPM
9-16	F8.3	RPM 6	RPM
17-24	F8.3	RPM 7	RPM
25-32	F8.3	Efficiency 1	Decimal %
33-40	F8.3	Efficiency 2	
41-48	F8.3	Efficiency 3	
49-56	F8.3	Efficiency 4	
57-64	F8.3	Efficiency 5	
65-72	F8.3	Efficiency 6	
73-80	F8.3	Efficiency 7	

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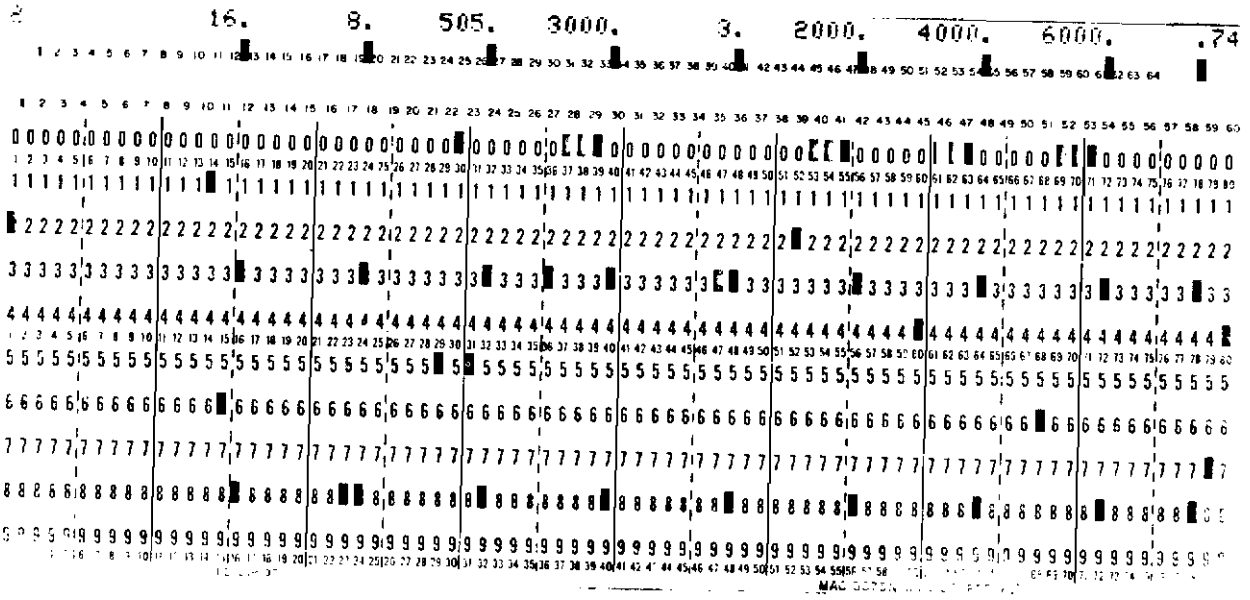
EXAMPLE

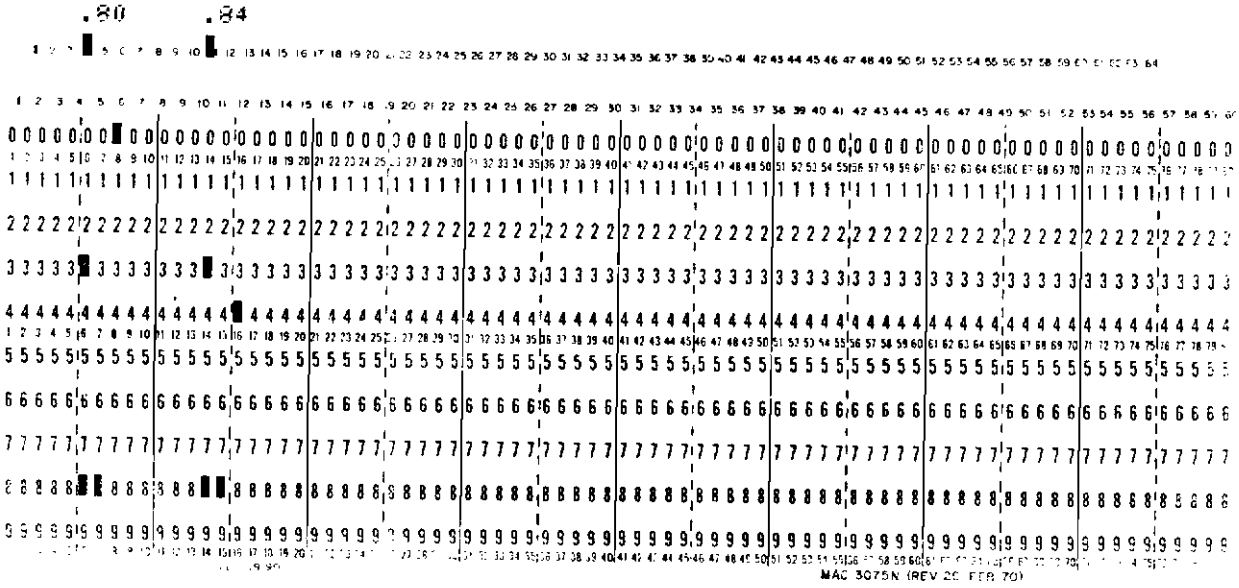
TYPE 16 - ADDITIONAL COMPONENT DATA FOR HYDRAULIC MOTOR

2 CARDS REQUIRED

CARD 1



CARD 2



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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 1 or 2	---
2-8	7X	Blank	---
9-16	F8.3	Quasi-Transient Element Type 17.	---
17-24	F8.3	Valve Element Type 34., 35., 36.	---
25-32	F8.3	Valve Inlet Pressure Port Junction No.	---
33-40	F8.3	Number of Valve Position Vs. Time Points	---
41-48	F8.3	TIME 1	SEC
49-56	F8.3	TIME 2	SEC
57-64	F8.3	TIME 3	SEC
65-72	F8.3	TIME 4	SEC
73-80	F8.3	TIME 5	SEC

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	TIME 6	SEC
9-16	F8.3	TIME 7	SEC
17-24	F8.3	Valve Position 1	Operating Code 1, 2 or 3
25-32	F8.3	Valve Position 2	
33-40	F8.3	Valve Position 3	
41-48	F8.3	Valve Position 4	
49-56	F8.3	Valve Position 5	
57-64	F8.3	Valve Position 6	
65-72	F8.3	Valve Position 7	

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4.1.3 Valve Position vs Time Data

This data input is used when the valve is operated during the time interval. The data input is designated as quasi-transient element type 17 for element types 34, 35 and 36. The element inlet pressure port junction number is also input. 1 or 2 cards are used depending on the number of valve positions input. The total number of valve position versus time points are input, then all the time values, followed by the valve position operating codes. The operating codes correspond with those described in Section II.

4.1.4 Valve Position vs Other Component Position Data

This data is input as quasi-transient element type 18 and is typically a valve, such as a sequence valve whose position is dependent on an actuator position. The actuator is considered to be the independent element with the valve the dependent element. The number of actuator stroke position vs valve position points are input followed by the actuator positions, then the valve position operating codes.

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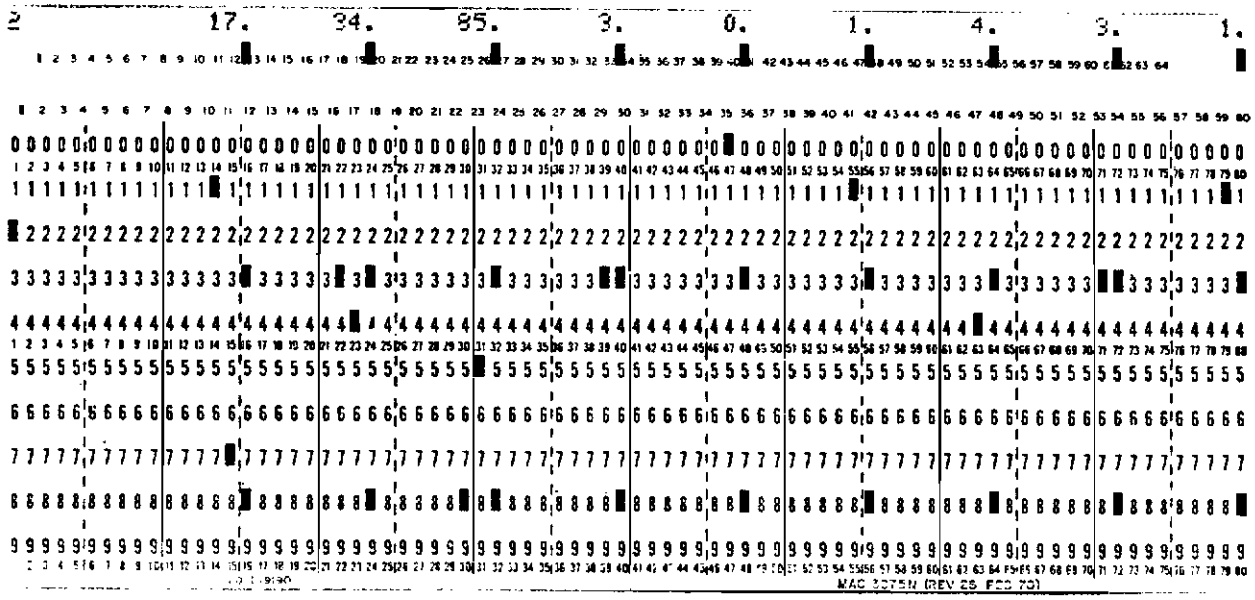
EXAMPLE

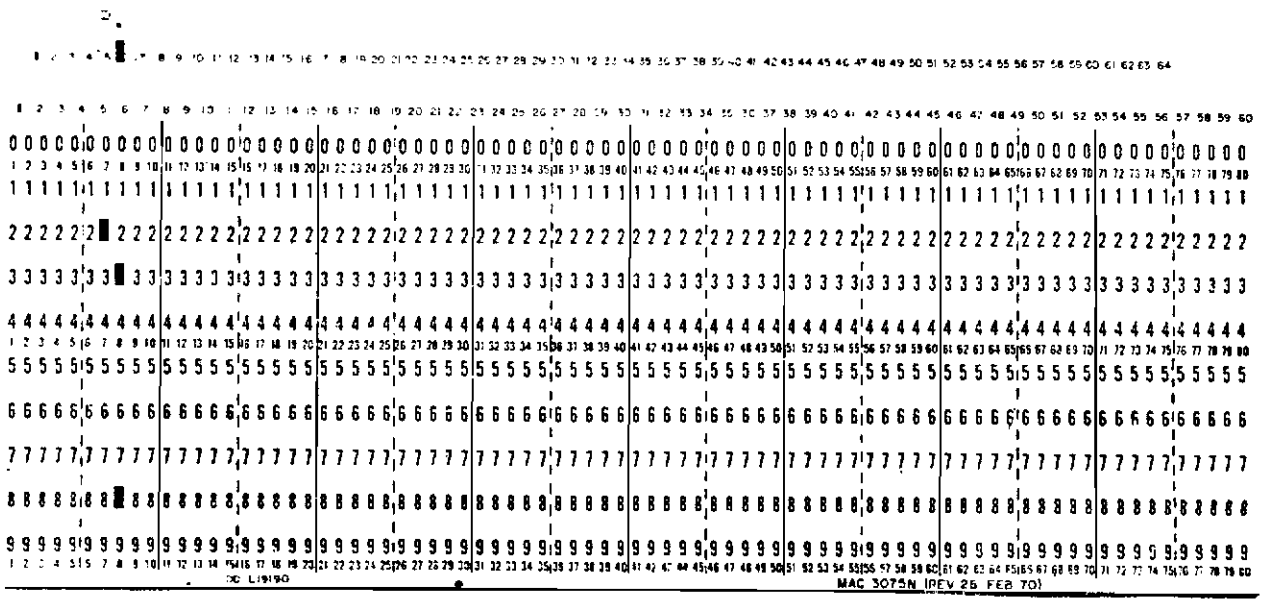
TYPE 17 - VALVE POSITION VS TIME

2 CARDS REQUIRED

CARD 1



CARD 2



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CARD 1 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(Number of Cards) 2	---
2-8	7X	Blank	---
9-16	F8.3	Quasi-Transient Element Type 18.	---
17-24	F8.3	Actuator Element Type 4. (Independent Element)	---
25-32	F8.3	Actuator Extend Port Junction Number	---
33-40	F8.3	Valve Element Type 36. (Dependent Element)	---
41-48	F8.3	Valve Inlet Pressure Junction Number	---
49-56	F8.3	Number of Position vs Position Points	---
57-64	F8.3	Actuator Stroke Pos 1	IN
65-72	F8.3	Actuator Stroke Pos 2	IN
73-80	F8.3	Actuator Stroke Pos 3	IN

CARD 2 FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1-8	F8.3	Actuator Stroke Pos 4	IN
9-16	F8.3	Actuator Stroke Pos 5	IN
17-24	F8.3	Actuator Stroke Pos 6	IN
25-32	F8.3	Valve Position 1	Operating Code 1 or 3
33-40	F8.3	Valve Position 2	
41-48	F8.3	Valve Position 3	
49-56	F8.3	Valve Position 4	
57-64	F8.3	Valve Position 5	
65-72	F8.3	Valve Position 6	

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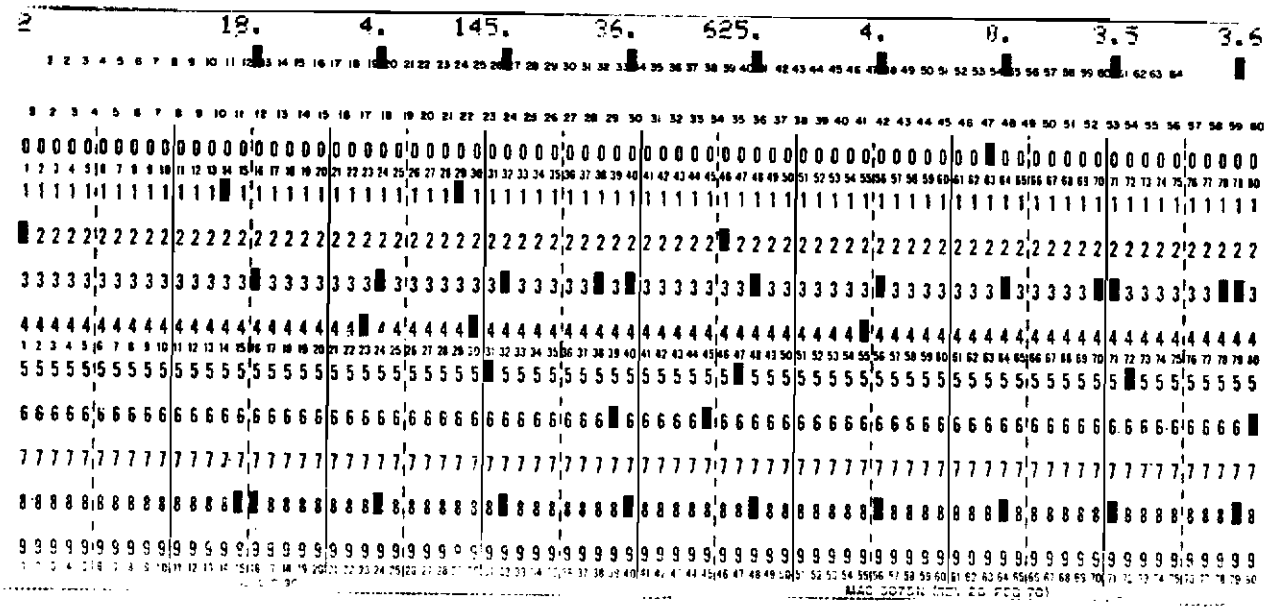
EXAMPLE

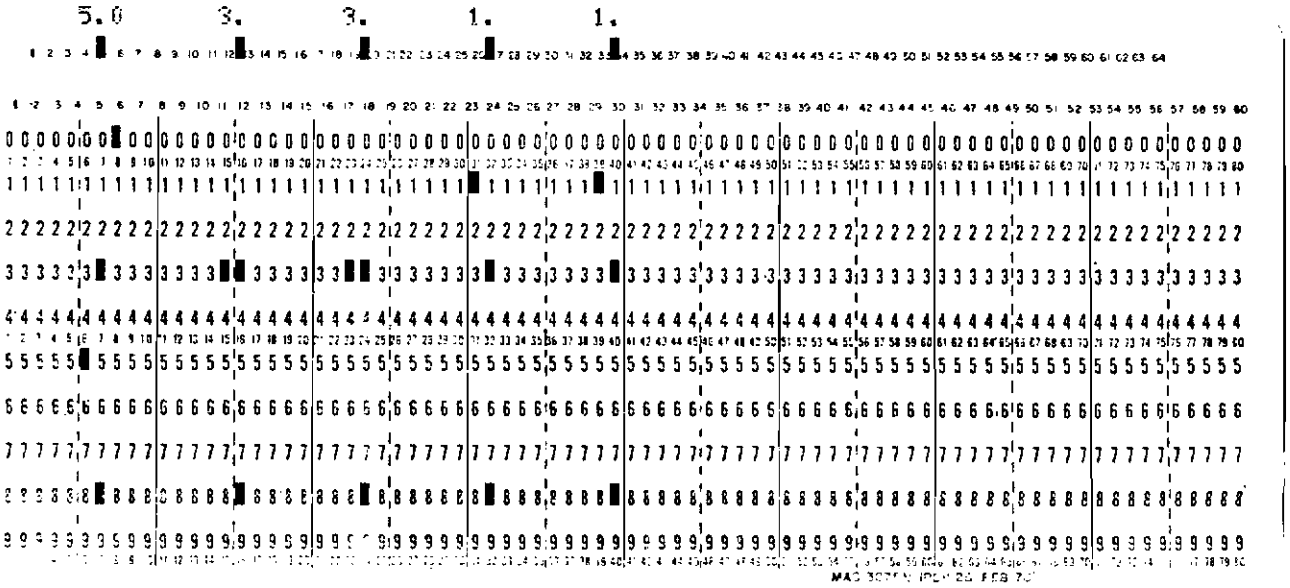
TYPE 18 - VALVE POSITION VS ACTUATOR POSITION

2 CARDS REQUIRED

CARD 1



CARD 2



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4.2 Quasi-Transient Output Data

The quasi-transient element type 19 is used for data output requirements. The junction number is used to identify the point at which output data is desired. Data output is of 3 types.

1. - pressure versus time
2. - flow versus time
3. - actuator piston position versus time

This type number is input in columns 25-32.

The initial steady state balance is printed as described in section 3. Then, tabulated data is printed for all quasi-transient type 19 input junction numbers at each time step, see Figure 14. Figures 15, 16 and 17 are computer plots of the 3 options of output types. Data output types 1 and 2 may be used at any junction. Data output type 3 is used only for actuators and plots the time history of the piston position. This plot may be used to determine subsystem operating times.

The user has the option to set the "y" scale on the computer plot if desired. A 1. placed in columns 33-40, with the minimum and maximum values in the next 2 data fields respectively will set the "y" scales. The "x" scale is established by the time interval.

Figures 14,15,16, and 17 are quasi-transient data using SSFAN Sample Case Number 1. Variable unequal increasing loads were placed on the actuators. The valve was initially closed and then opened at .5 seconds. There is initial pressure on the actuator because the actuator ports are not open to return, see Figure 15. Figure 16 actuator flow rate initially increases because of the other actuator and its increasing load. As both loads increase the actuator flow rate then decreases. At 2.25 seconds the second actuator bottoms and the flow is suddenly increased. The flow then continues to decrease as the load increases. At 2.60 seconds the actuator bottoms, but there is still leakage flow across the piston since the valve is still open.

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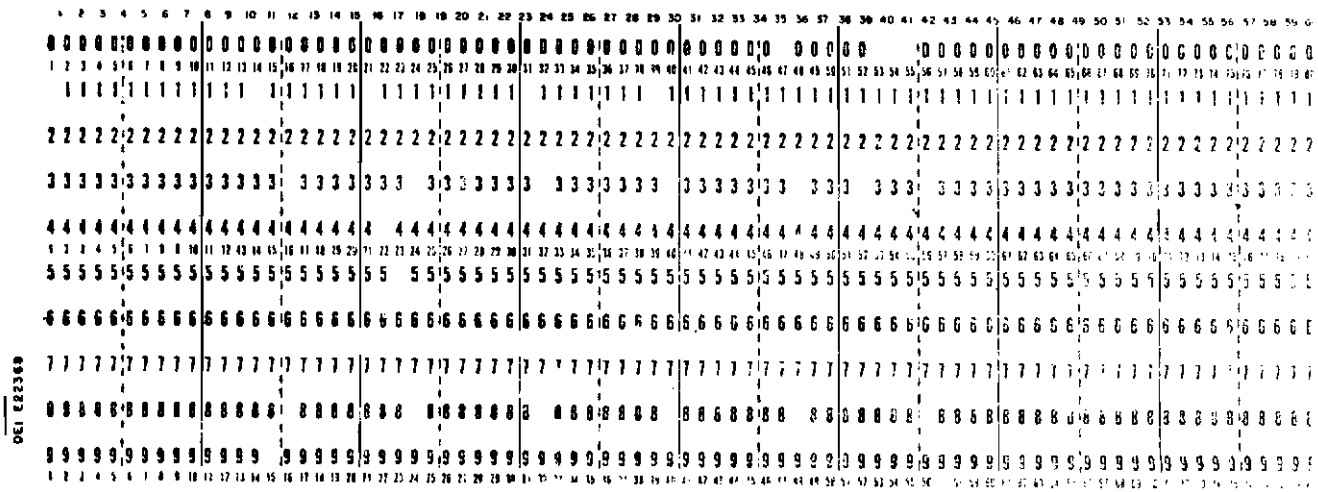
CARD FORMAT

COLUMNS	FORMAT	DATA	DIMENSIONS
1	I1	(NUMBER OF CARDS) 1	---
2-8	7X	BLANK	---
9-16	F8.3	QUASI-TRANSIENT ELEMENT TYPE 19	---
17-24	F8.3	JUNCTION NUMBER	---
25-32	F8.3	OUTPUT TYPE 1, 2 OR 3	---
33-40	F8.3	SET OWN "Y" SCALES 1 = YES 0 = NO	---
41-48	F8.3	MINIMUM "Y" (OPTIONAL)	---
49-56	F8.3	MAXIMUM "Y" (OPTIONAL)	---
57-80	---	BLANK	---

EXAMPLE

TYPE 19 - OUTPUT DATA

```
1              19.      145.       1.        1.        0.     3000.
```



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SSPAN -- SAMPLE CASE NUMBER 1

ROW 2 IND 1=PRESS PLOT 2=FLOW PLOT 3=PIST POS PLOT

TIME	JCT	JCT	JCT
	145.000	145.000	145.000
	2.000	1.000	3.000
	0.000	0.000	1.000
	0.000	0.000	0.000
	0.000	0.000	5.000
	0.000	0.000	0.000
0.0000	0.000	1540.270	0.000
.0500	0.000	1540.274	0.000
.1000	0.000	1540.274	0.000
.1500	0.000	1540.274	0.000
.2000	0.000	1540.274	0.000
.2500	0.000	1540.274	0.000
.3000	0.000	1540.274	0.000
.3500	0.000	1540.274	0.000
.4000	0.000	1540.274	0.000
.4500	0.000	1540.274	0.000
.5000	0.000	1540.274	0.000
.5500	2.155	2292.819	.092
.6000	2.344	2309.449	.193
.6500	2.443	2321.160	.297
.7000	2.533	2332.894	.405
.7500	2.613	2344.646	.517
.8000	2.683	2356.382	.632
.8500	2.744	2368.680	.749
.9000	2.796	2380.915	.869
.9500	2.840	2393.267	.990
1.0000	2.876	2405.717	1.113
1.0500	2.906	2418.246	1.238
1.1000	2.929	2430.835	1.363
1.1500	2.947	2443.467	1.489
1.2000	2.960	2456.125	1.616
1.2500	2.967	2468.793	1.743
1.3000	2.970	2481.516	1.870
1.3500	2.968	2494.230	1.997
1.4000	2.963	2506.909	2.123
1.4500	2.954	2519.540	2.250
1.5000	2.941	2532.111	2.376
1.5500	2.926	2544.610	2.501
1.6000	2.907	2557.027	2.625
1.6500	2.882	2569.347	2.748
1.7000	2.856	2581.546	2.871
1.7500	2.829	2593.625	2.992
1.8000	2.800	2605.580	3.111
1.8500	2.768	2617.403	3.230
1.9000	2.736	2629.084	3.347
1.9500	2.704	2640.622	3.463
2.0000	2.670	2652.017	3.577
2.0500	2.637	2663.244	3.690
2.1000	2.603	2674.290	3.801
2.1500	2.568	2685.212	3.911
2.2000	2.532	2695.946	4.019
2.2500	2.496	2706.526	4.126
2.3000	3.454	2713.894	4.274
2.3500	3.358	2728.575	4.417
2.4000	3.265	2742.933	4.557
2.4500	3.174	2756.993	4.693
2.5000	3.084	2770.638	4.825
2.5500	2.993	2783.844	4.953
2.6000	2.903	2796.479	5.000
2.6500	.092	3009.956	5.000
2.7000	.092	3009.956	5.000
2.7500	.092	3009.956	

FIGURE 14 QUASI-TRANSIENT TABULATED DATA

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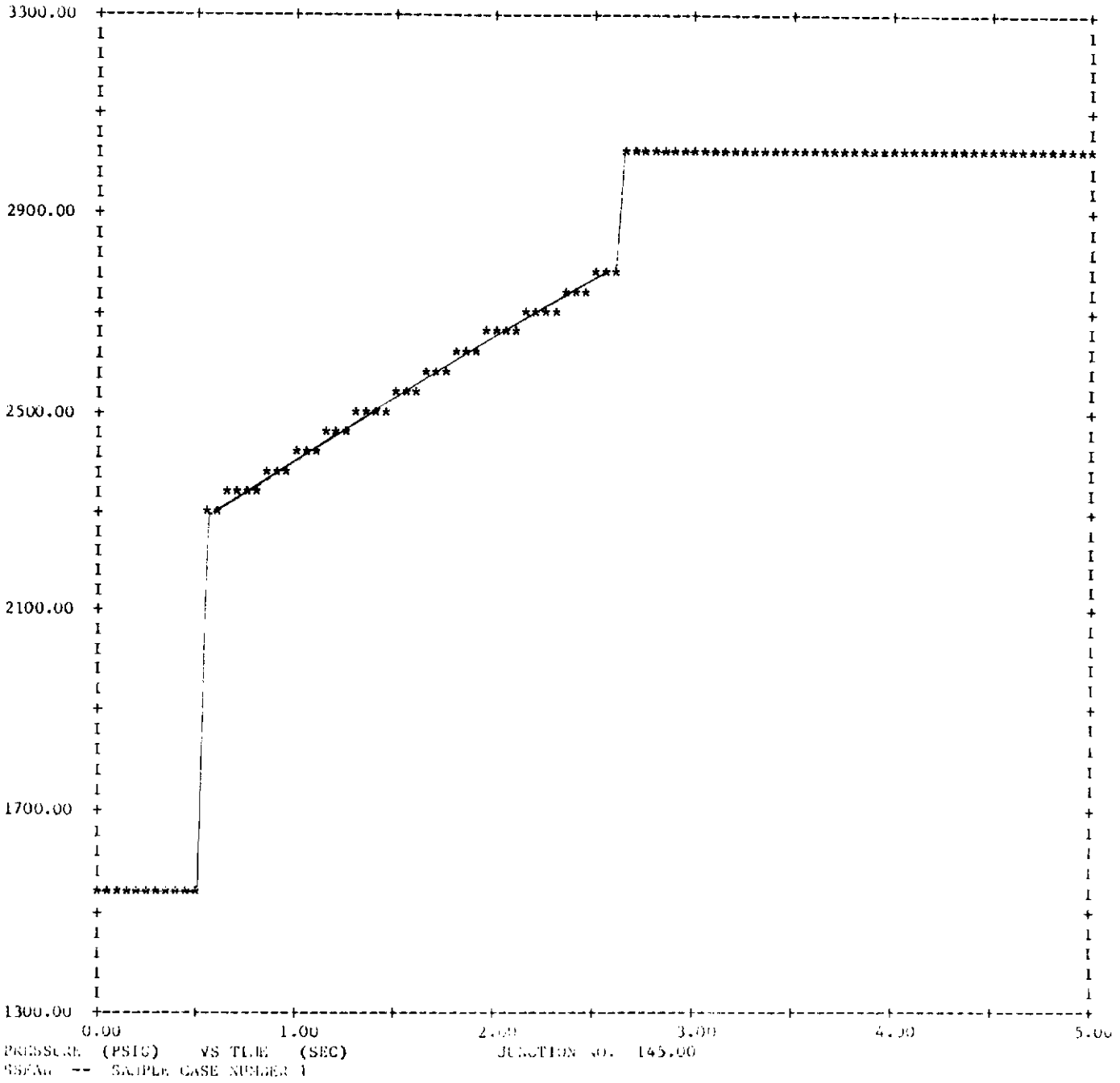

FIGURE 15 QUASI-TRANSIENT PRESSURE
VERSUS
TIME COMPUTER PLOT

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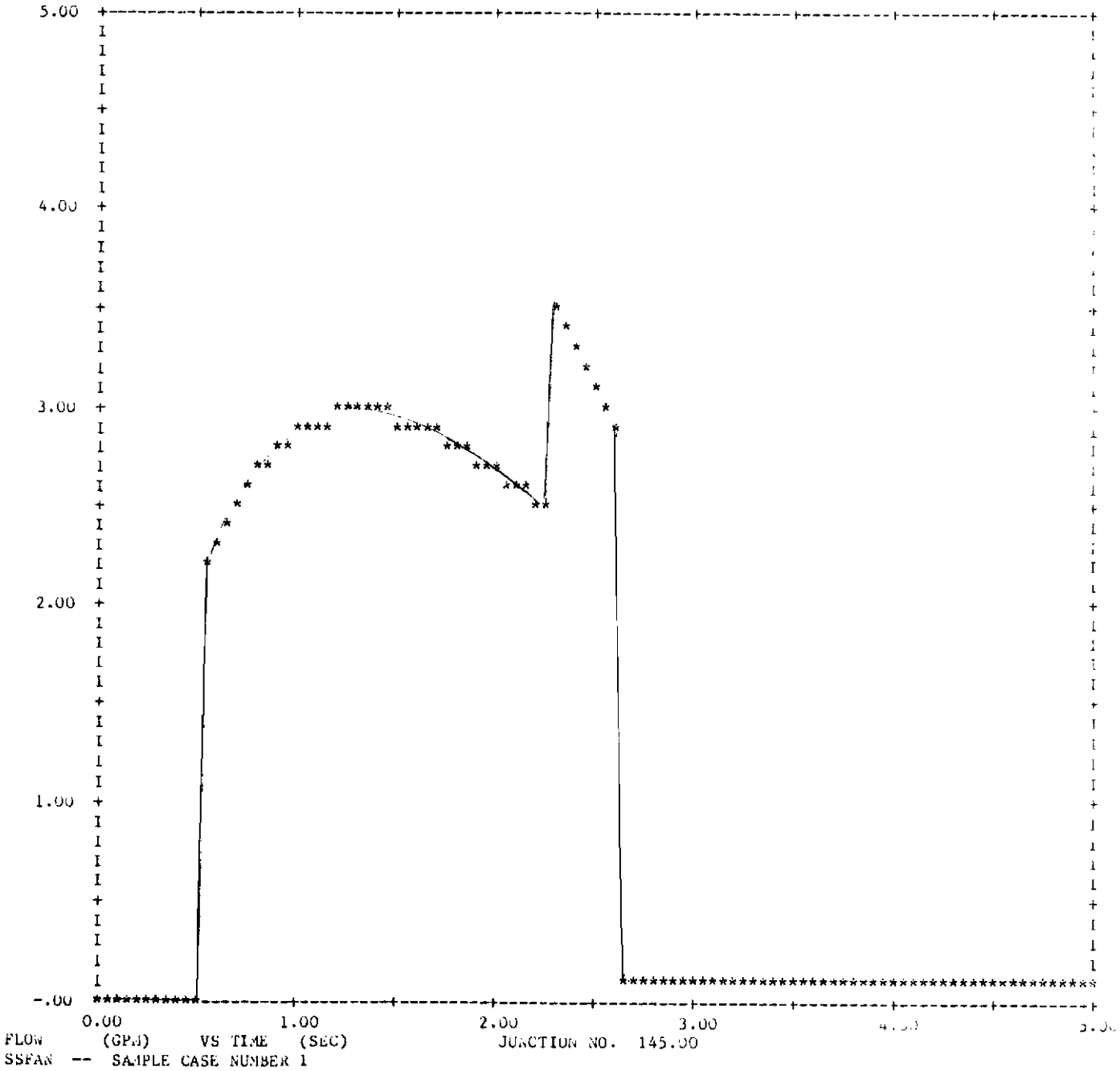

FIGURE 16 QUASI-TRANSIENT FLOW
VERSUS
TIME COMPUTER PLOT

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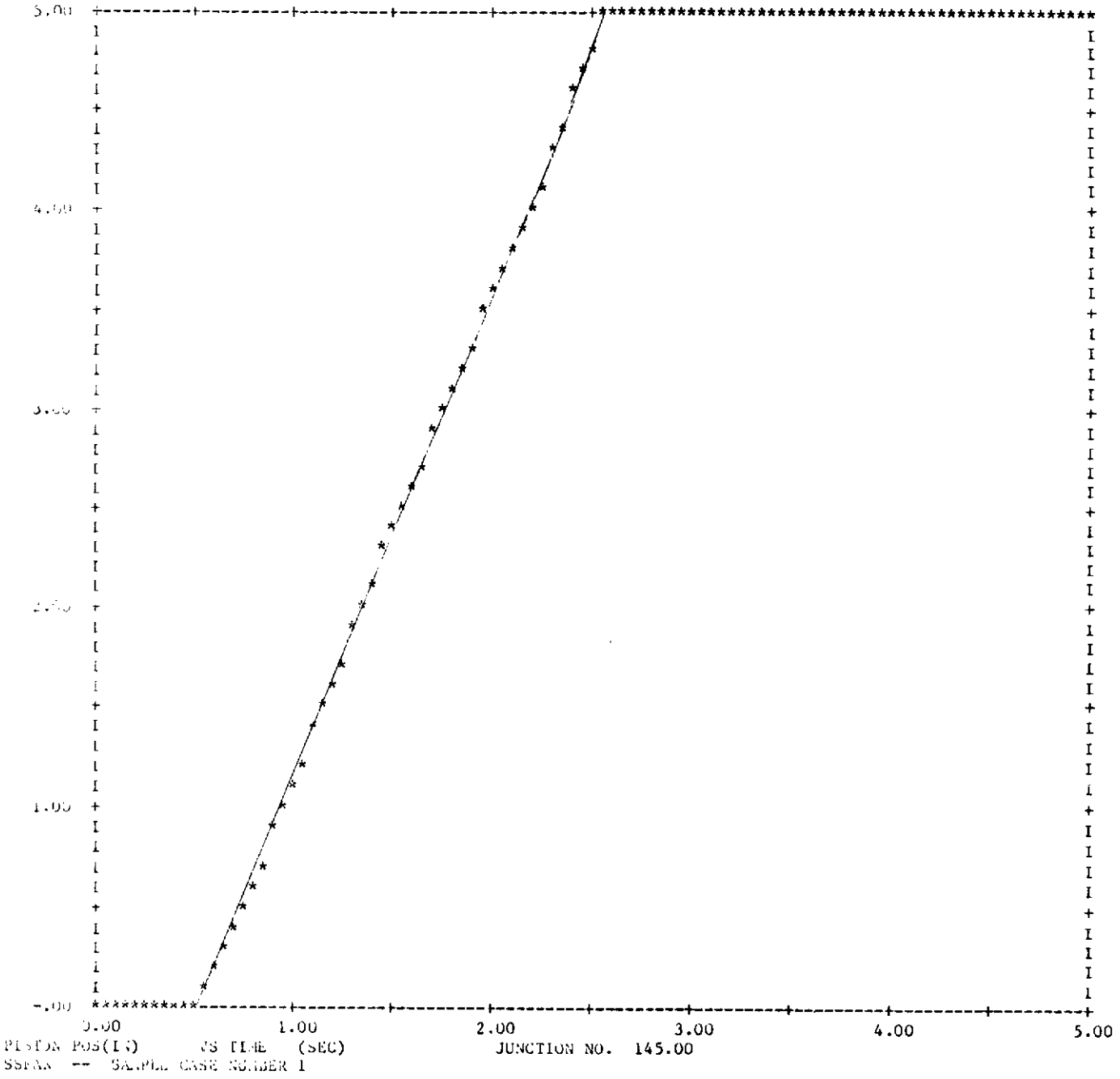

FIGURE 17 QUASI-TRANSIENT ACTUATOR POSITION
VERSUS
TIME COMPUTER PLOT

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