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AIRCRAFT HYDRAULIC SYSTEMS DYNAMIC ANALYSIS

COMPONENT DATA HANDBOOK

McDonnell Aircraft Company
McDonnell Douglas Corporation
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The component data handbook has been developed to aid users of the aircraft hydraulic system dynamic analysis computer programs HSFR, SSFAN, and HYTRAN in selecting input data.
The handbook provides brief descriptions of the general usage components modeled by these computer programs, tabulates the necessary input data for each program and catalogs typical data trends or actual input data of components that have been simulated.

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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 Wright Aeronautical Laboratories, 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. F. Deshazer, R. E. Young, M. J. Stevens, and L. E. Clements.

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INTRODUCTION

The Component Data Handbook was written to assist the Aircraft Hydraulic Dynamic Analysis Computer program users in obtaining the necessary input data for the programs mathematical models. The handbook is a catalog of essential component data parameters for the Hydraulic System Frequency Response (HSFR) computer program, the Steady State Flow Analysis (SSFAN) computer program, and the Hydraulic Transient Analysis (HYTRAN) computer program.

The component data reflects hardware used in aircraft hydraulic systems. Adequate component commonality exists to allow the user to apply the data to other types of hydraulic systems. However, the user should review the computer simulation to assure anticipated system performance.

Many of the component input variables were chosen to simplify the models and reduce computer running time. In a few cases, the program input data is not an easily measured parameter. For these situations the input data reflects desired performance characteristics. The user must be aware that the component data is specialized to perform a defined task and adjust it accordingly.

1. Purpose

The component data handbook provides a catalog of input data on existing components from computer simulations. The data can provide valid results to judge hydraulic system performance and define potential problem areas.

2. Organization

The data requirements for the SSFAN, HSFR, and HYTRAN programs are listed for the modeled components. Data common to more than one program is noted. Appropriate figures are included which show where the dimensional data should be taken. The data items are explained either by a figure, a short explanation of the item, or a reference to the appropriate section in the user or technical manual.

After the data requirements list, a data bank for each component by computer program is presented. The data was acquired by MCAIR during aircraft hydraulic system dynamic analysis verification tests, the Space Shuttle Orbiter Hydraulic System Simulation, and F-4, F-15 and F-18 Hydraulic System simulations. This provides the user with representative data for components modeled in the Hydraulic System Performance Analysis programs. The data bank is intended to be a source of component data for simulations when the exact component data is unavailable.

Additional component data can be obtained from the final reports of the Aircraft Hydraulic Systems Dynamic Analysis Program and the Advanced Fluid System Simulation Program (Ref. (1), (2) and (3)). Further data can be found in the HYTRAN (Ref. 4), HSFR (Ref. 5), and SSFAN (Ref. 6) user manuals.

SECTION II
COMPONENT DATA

1. TUBES

Hard metallic tubes are the primary power carriers in aircraft hydraulic systems. Such tubes are used to interconnect all of the system components to provide the desired flow paths.

Many different tube sizes, materials, and wall thicknesses exist to cover the many requirements of aircraft hydraulic systems. Figure 1 shows two hydraulic tube parameters. Figures 2 , 3 , and 4 provide hydraulic tubing information for three fighter aircraft with 3000 psi hydraulic systems.

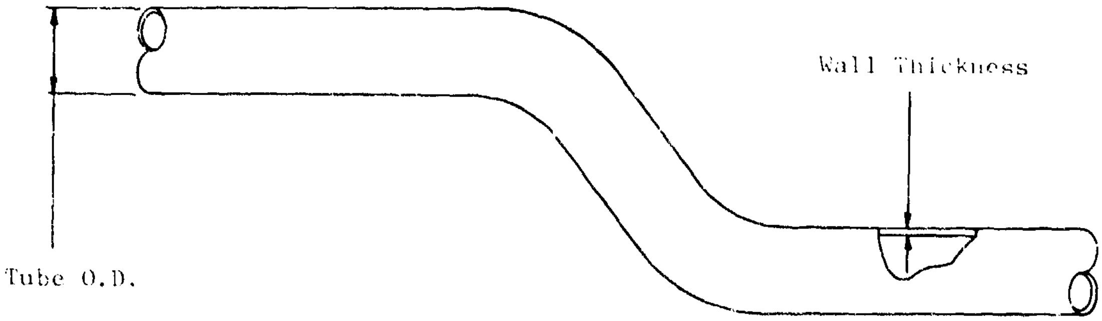


FIGURE 1 HYDRAULIC TUBE PARAMETERS

Element Type: TUBE

	Program	SSFAN	HSFR	HYTRAN
	Element Type	1	NTYPE 1 KTYPE 0	[1]
Data Parameter	Dimensions	▨	▨	▨
Outside Diameter	IN	[2]		
Wall Thickness	IN			
Bends	DEG		▨	
Length	IN			
Length Increase Due to Fittings	%	▨	▨	
Modulus of Elasticity	LB/IN^2	▨		

Notes: [1] TYPE 0 - Normal Line
TYPE 2 - Lossless Line
TYPE 10- Dead Ended Line

[2] Option of O.D. or Tube Dash Size

TUBE O.D. (INCHES)	MATERIAL	WALL THICKNESS (INCHES)	MODULUS OF ELASTICITY (LB/IN^2)	NOTES
.250	Aluminum	.035	$9.9x10^6$	
.250	St. Steel	.020	$29x10^6$	
.3125	Aluminum	.042	$9.9x10^6$	
.3125	St. Steel	.020	$29x10^6$	
.375	Aluminum	.049	$9.9x10^6$	
.375	St. Steel	.022	$29x10^6$	
.500	Aluminum	.028	$9.9x10^6$	Return Only
.500	Aluminum	.065	$9.9x10^6$	
.500	St. Steel	.028	$29x10^6$	
.625	Aluminum	.028	$9.9x10^6$	Return Only
.625	St. Steel	.035	$29x10^6$	
.750	Aluminum	.035	$9.9x10^6$	Return Only
.750	St. Steel	.020	$29x10^6$	Return/Suct.
.750	St. Steel	.042	$29x10^6$	
1.000	Aluminum	.035	$9.9x10^6$	Return Only
1.000	St. Steel	.020	$29x10^6$	Return/Suct.
1.000	St. Steel	.058	$29x10^6$	
1.250	St. Steel	.020	$29x10^6$	Suction Only

FIGURE 2 F-4 TUBING DATA

TUBE O.D. (INCHES)	MATERIAL	WALL THICKNESS (INCHES)	MODULUS OF ELASTICITY (LB/IN^2)	NOTES
.250	Aluminum	.020	9.9×10^6	Return Only
.250	Titanium	.016	15×10^6	
.250	Titanium	.028	15×10^6	Coiled Tube
.375	Aluminum	.028	9.9×10^6	Return Only
.375	Titanium	.019	15×10^6	
.375	Titanium	.042	15×10^6	Coiled Tube
.500	Aluminum	.028	9.9×10^6	Return Only
.500	Titanium	.026	15×10^6	
.500	Titanium	.056	15×10^6	Coiled Tube
.625	Aluminum	.035	9.9×10^6	Return Only
.625	Titanium	.032	15×10^6	
.625	Titanium	.071	15×10^6	Coiled Tube
.750	Aluminum	.035	9.9×10^6	Return Only
.750	Titanium	.039	15×10^6	
1.000	Aluminum	.042	9.9×10^6	Return Only
1.000	Titanium	.051	15×10^6	
1.250	Aluminum	.049	9.9×10^6	Return Only
1.250	Titanium	.065	15×10^6	
1.500	Titanium	.032	15×10^6	Suction Only

FIGURE 3 F-15 TUBING DATA

TUBE O.D. (INCHES)	MATERIAL	WALL THICKNESS (INCHES)	MODULUS OF ELASTICITY (LB/IN^2)	NOTES
.250	Titanium	.016	$15x10^6$	
.250	Titanium	.028	$15x10^6$	Coiled Tube
.375	Titanium	.019	$15x10^6$	
.375	Titanium	.042	$15x10^6$	Coiled Tube
.500	Titanium	.026	$15x10^6$	
.500	Titanium	.056	$15x10^6$	Coiled Tube
.625	Titanium	.032	$15x10^6$	
.625	Titanium	.071	$15x10^6$	Coiled Tube
.750	Titanium	.039	$15x10^6$	
1.000	Titanium	.026	$15x10^6$	Return Only
1.000	Titanium	.051	$15x10^6$	
1.250	Titanium	.032	$15x10^6$	Suction Only
1.250	Titanium	.065	$15x10^6$	
1.500	Titanium	.032	$15x10^6$	Suction Only

FIGURE 4 F-18 TUBING DATA

2. HOSES

Flexible hydraulic hoses are multi-layered (Figure 5), fluid carrying, high pressure hoses used to connect moving hydraulic components (such as moving body actuators) to rigidly clamped supply and return tubes.

In general, usage of flexible hoses is discouraged in aircraft hydraulic systems because of their weight and short service life. Their advantage over rigid lines and design motion tubing is in high vibration (gun drives, engine mounted pumps) environments and quick change applications.

Design and construction of hoses varies from one manufacturer to another. As a result of this, there is no hard relationship between a hose's dash size and the data needed to model it in HSFR, SSFAN, or HYTRAN. Figure 6 tabulates data of some hoses that have been modeled and Figures 7 and 8 show how inside diameter and hose bulk modulus vary with dash size for these hoses. All of these hoses were utilized in 3000 psi hydraulic system applications.

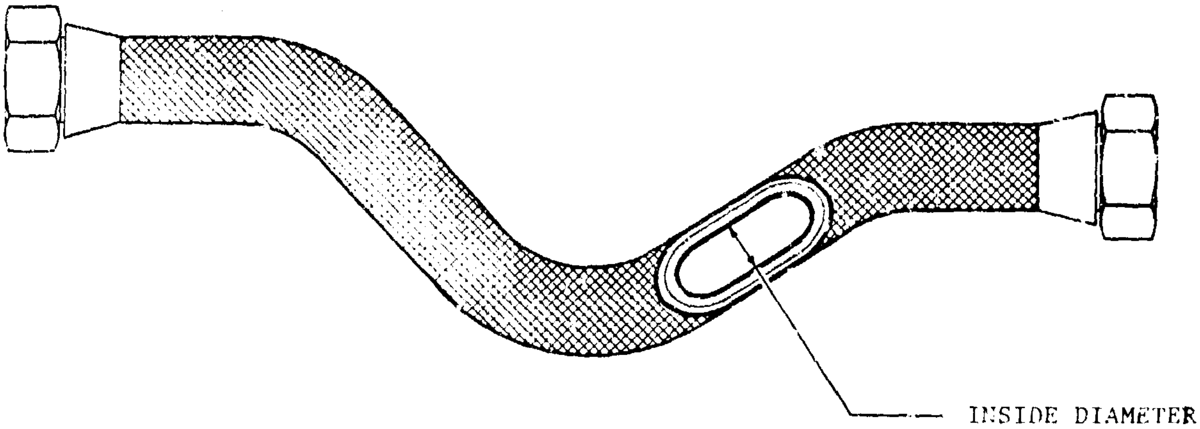


FIGURE 5 HIGH PRESSURE HYDRAULIC HOSE

Element Type: FLEXIBLE HOSE

	Program	SSFAN	HSFR	HYTRAN
	Element Type	11	NTYPE 1 KTYPE 1	1
Data Parameter	Dimensions	▨	▨	▨
Size	Dash #		▨	▨
Inside Diameter	IN			
Length	IN			
Bends	Degrees		▨	
Bulk Modulus	PSI	▨		△1
Type & Number of Fittings	-	▨	▨	

NOTES: △1 Function of Hose Bulk Modulus (Figure 6) and Simulation Fluid Properties. Refer to User's Manual (Ref. 4)

HOSE SIZE	INSIDE DIAMETER (INCHES)	BULK MODULUS (PSI)
-4	.195	59312
-10	.540	166201
-12	.602	236129
-16	.875	328461

FIGURE 6 HYDRAULIC HOSE DATA

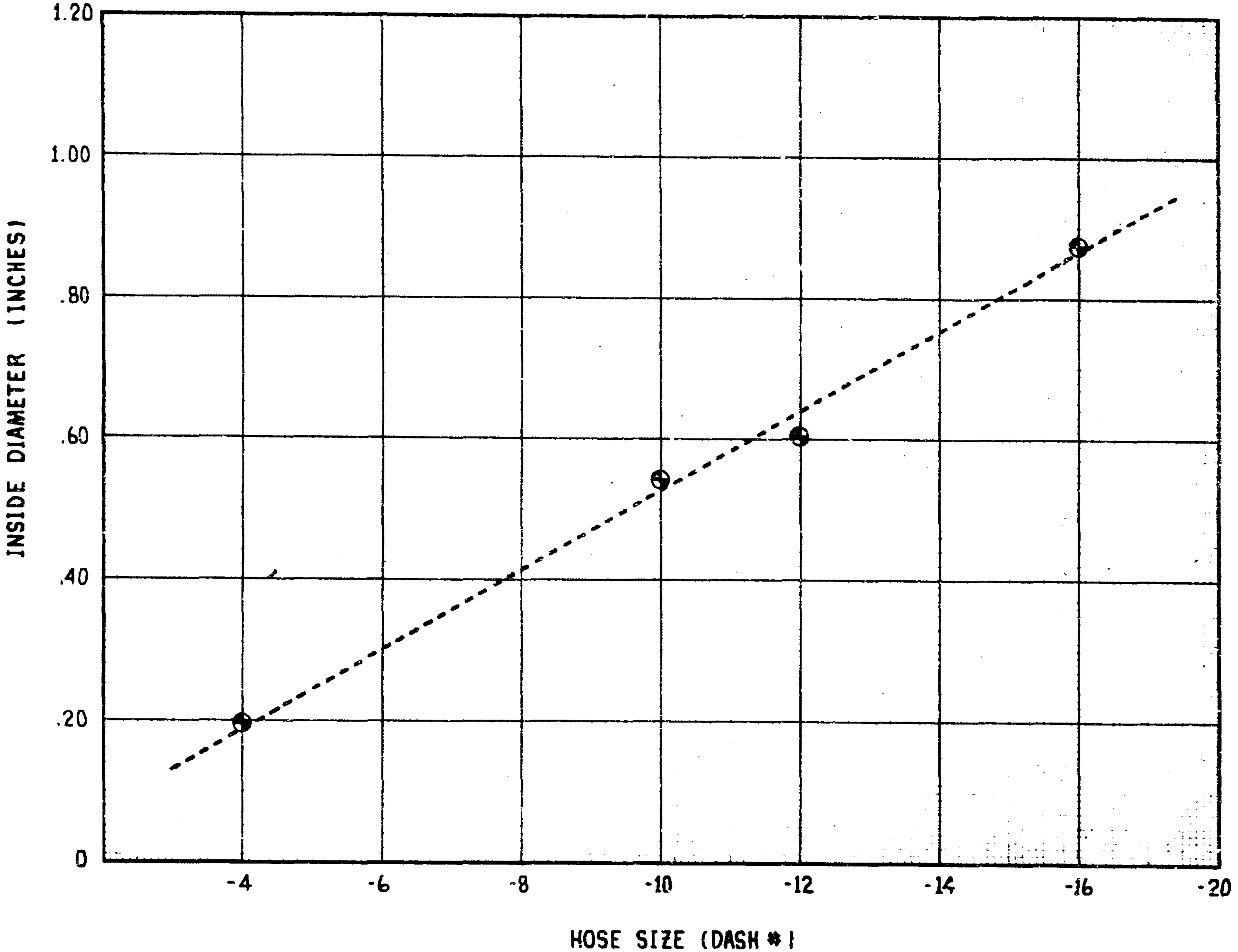


Figure 7 HOSE I.D. VS DASH SIZE FOR 3000 PSI HOSES

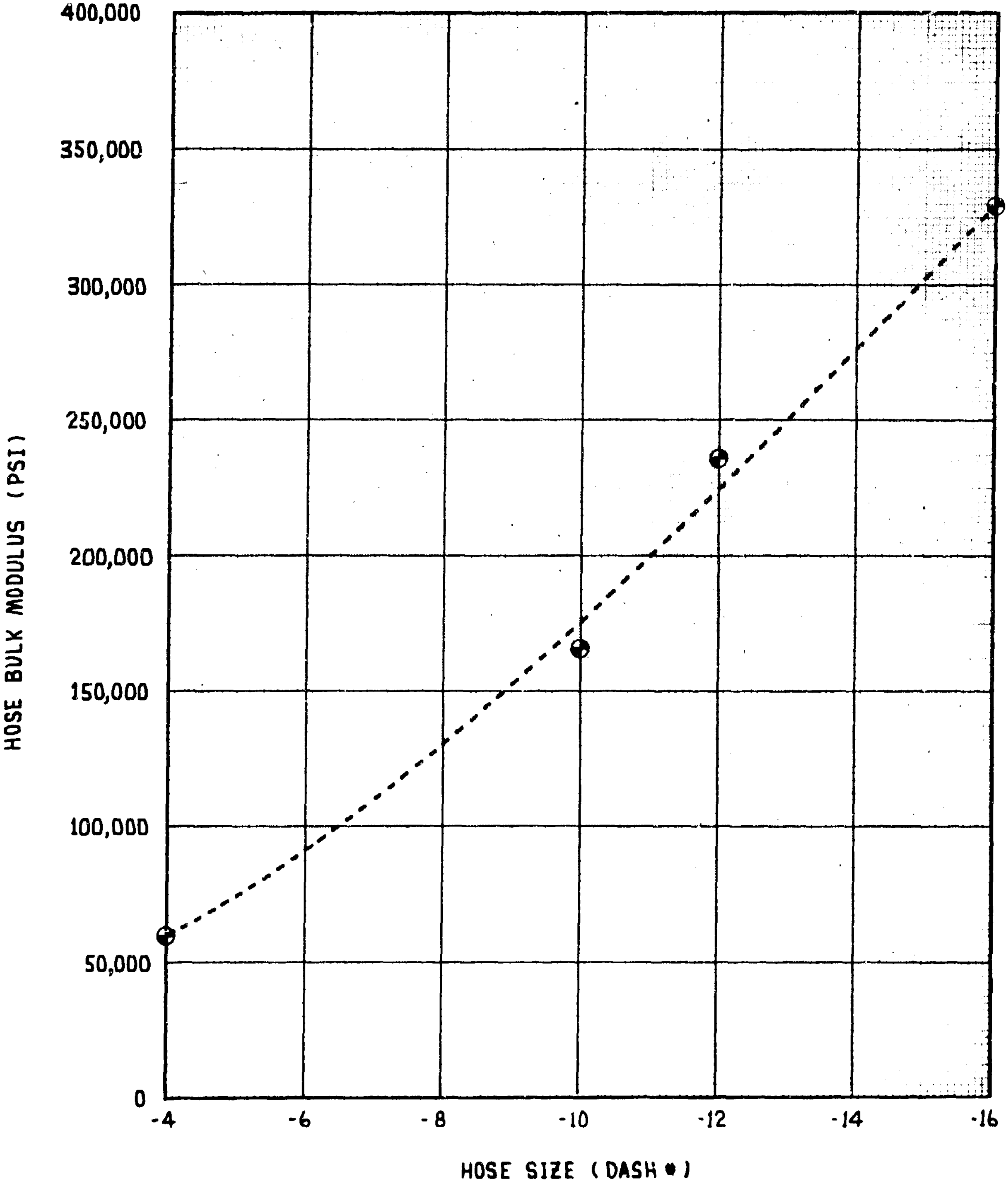


FIGURE 8 HOSE BULK MODULUS VS DASH SIZE FOR 3000 PSI HOSES

3. VARIABLE DELIVERY PISTON PUMPS

Variable delivery axial piston pumps see widespread use in aircraft hydraulic systems as main flow sources. Such pumps, as illustrated by Figure 9 , respond to varying system flow demands by increasing or decreasing the pumping piston stroke.

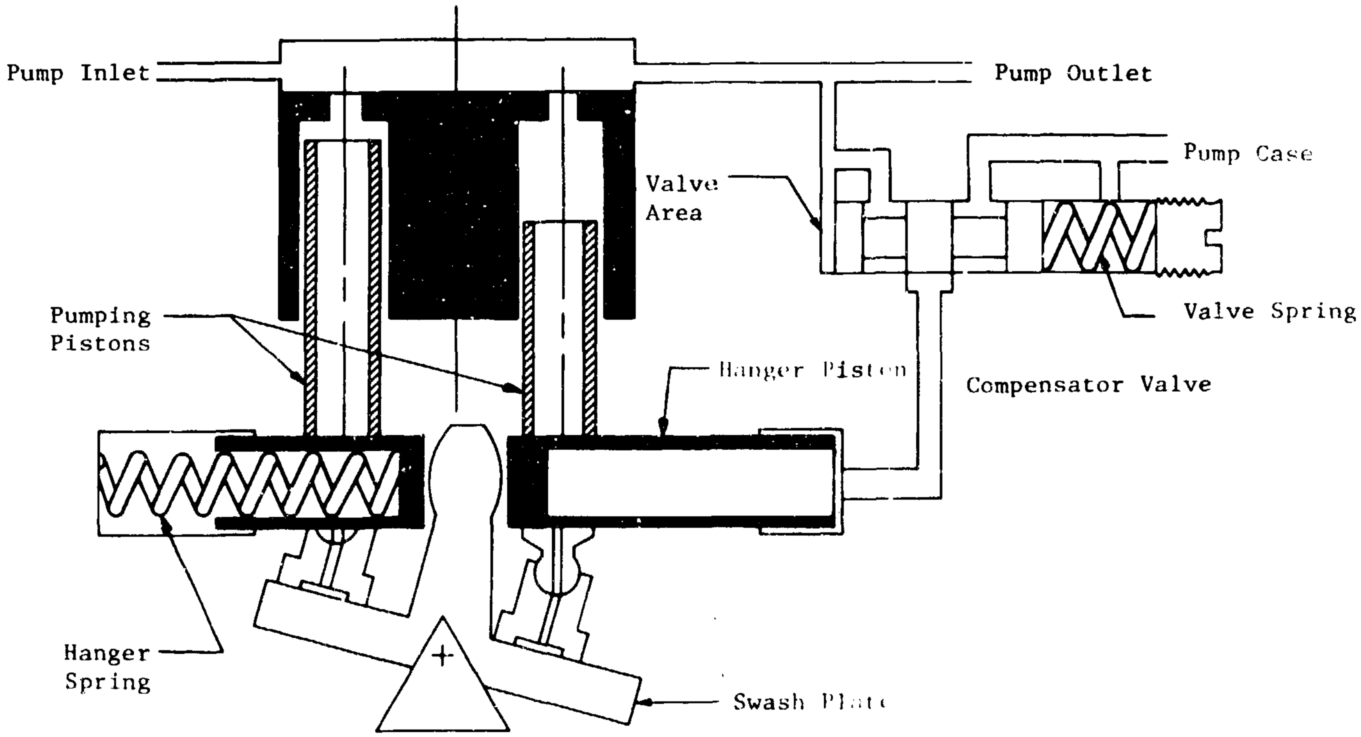


FIGURE 9 PRESSURE COMPENSATED, VARIABLE DELIVERY, AXIAL PISTON PUMP

The compensator valve/spring combination is sized to balance at the desired pump outlet pressure. When the outlet pressure drops below the desired value because of increased flow demand, the compensator valve ports the fluid trapped in the hanger piston into the pump case and the hanger spring increases the swash plate angle, thereby increasing the stroke of the pumping pistons. If this increased flow capability is sufficient enough to raise the outlet pressure above the desired level, the compensator valve ports high pressure fluid to the hanger piston which decreases the swash plate angle and thereby decreases the outlet flow. In this way, the compensator valve is able to maintain the desired outlet pressure and vary its flow output to supply system demands.

These pumps have three ports. The suction port, through which the fluid enters the pump; the pressure port, through which fluid (at high pressure) leaves the pump, and the case drain port, which provides a path for compensator valve discharge and any internal pump leakages to return to the low pressure portion of the system.

Figures 10 , 11 and 12 show some of the data parameters necessary for the HSFR pump model. Specific pump data for all three programs is given by Figures 13 , 14, and 15.

Element Type: Variable Delivery
Piston Pump
(Page 1 of 4)

	Program	SSFAN	HSFR	HYTRAN
	Element Type	5	N Type 9 K Type 1	51,53,54
Data Parameter	Dimensions	▨	▨	▨
Suction Port Size	IN or Dash #		▨	▨
Pressure Port Size	IN or Dash #		▨	▨
Case Drain Port Size	IN or Dash #		▨	▨
Pump Operating Speed	RPM		▨	
Rated Pump Speed	RPM		▨	▨
Rated Output Flow	GPM		▨	▨
Rated Pressure at Zero Flow	PSI		▨	▨
Rated Pressure at Full Flow	PSI		▨	▨
Rated Minimum Suction Pressure	PSIA		▨	▨
Rated Maximum Case to Inlet ΔP	PSID		▨	▨
Rated Case Drain Flow	GPM		▨	▨
Rated Case Pressure	PSIG		▨	▨
Cylinder Slot Radius (R1)	IN	▨	Fig. 12	▨
Cylinder Slot Width (SLOTW)	IN	▨	Fig. 12	▨
Cylinder and Valve Plate Slot Centerline Radius (RV)	IN	▨	Fig. 12	▨
Cylinder Centerline Radius (RBORC)	IN	▨	Fig. 12	▨
Piston Diameter (DIAPIS)	IN	▨	Fig. 12	▨
Oil Volume - Piston @ Midstroke to Port Face (POVOL)	IN^3	▨	Fig. 12	▨
Valve Plate Pressure Slot Radius (R2)	IN	▨	Fig. 11	▨
Valve Plate Suction Slot Radius (R4)	IN	▨	Fig. 11	▨

Element Type: Variable Delivery
Piston Pump
(Page 2 of 4)

	Program	SSFAN	HSFR	HYTRAN
	Element Type	5	N Type 9 K Type △1	51,53,54
Data Parameter	Dimensions	▨	▨	▨
Maximum Swash Angle	DEG	▨		▨
Internal Leakage @ Input Steady State Pressure	CIS	▨		▨
Swash Plate Fixed Cross Angle (ANGCR)	DEG	▨	Fig. 10	▨
Valve Plate Pressure Slot Start Angle (THPRS)	DEG	▨	Fig. 11	▨
Valve Plate Pressure Slot End Angle (THPRE)	DEG	▨	Fig. 11	▨
Valve Plate Suction Slot Start Angle (THSUCS)	DEG	▨	Fig. 11	▨
Valve Plate Suction Slot End Angle (THSUCE)	DEG	▨	Fig. 11	▨
Suction Port Steady State Pressure	PSI	▨		▨
Swash Plate Centerline Offset (HOFF)	IN	▨	Fig. 10	▨
Maximum Swash Plate Actuator Displacement	IN	▨		▨
Swash Plate Actuator Lever Arm @ Zero Angle	IN	▨		▨
Pumping Piston Mass	$LB*SEC^2/IN$	▨		▨
Steady State Case Pressure	PSI	▨		▨
Case to Inlet ΔP at Zero Case Flow	PSI	▨		▨
Swash Plate Actuator Diameter	IN	▨		▨
Outlet to Actuator Valve Opening Pressure	PSI	▨	▨	△2
Valve Spring Rate	LB/IN	▨	▨	
Compensator Valve Area	IN^2	▨	▨	
Slot Width	IN	▨	▨	△3
Flow Force On Spool	LB	▨	▨	△4

Element Type: Variable Delivery
Piston Pump
(Page 3 of 4)

	Program	SSFAN	HSFR	HYTRAN
	Element Type	5	N Type 9 K Type △1	51,53,54
Data Parameter	Dimensions	▨	▨	▨
Valve Overlap	IN	▒	▒	
Discharge Coefficient Outlet to Actuator	-	▒	▒	△2
Discharge Coefficient Actuator to Case	-	▒	▒	△2
Actuator Area	IN^2	▒	▒	
Actuator Pressure Due to Spring Force at Zero Pump Displacement	PSI	▒	▒	
Actuator Pressure Due to Spring Force at Maximum Pump Displacement	PSI	▒	▒	
Actuator Pressure Due to Piston Acceleration @ 3600 RPM	IN^2/SEC	▒	▒	
Actuator Pressure Input at 3600 RPM and Zero Pump Displacement	PSI	▒	▒	
Actuator Pressure at 3600 RPM and Maximum Pump Displacement	PSI	▒	▒	
Slope of Pressure vs. RPM Curve	PSI/RPM	▒	▒	
Hanger Damping	PSI/IN/SEC	▒	▒	
Theoretical Maximum Pump Displacement	IN^3/REV	▒	▒	
Maximum Actuator Displacement @ Maximum Flow	IN	▒	▒	
Minimum Actuator Displacement @ Minimum Pump Flow	IN	▒	▒	
Coefficient of Actuator Leakage @ Zero Pump Displacment	CIS/PSI	▒	▒	△2
Coefficient of Actuator Leakage @ Maximum Pump Displacement	CIS/PSI	▒	▒	△2
Coefficient of Pump Leakage - Outlet to Case	CIS/PSI	▒	▒	
Coefficient of Pump Leakage - Case to Inlet	CIS/PSI	▒	▒	
Case Volume	IN^3	▒	▒	
Minimum Inlet Pressure	PSIA	▒	▒	

Element Type. Variable Delivery
Piston Pump
(Page 4 of 4)

	Program	SSFAN	HSFR	HYTRAN
	Element Type	5	N Type 9 K Type △1	51,53,54
Data Parameter	Dimensions	▨	▨	▨
Coefficient of Offset Outlet Flow Due to Actuator Motion	CIS/IN/SEC	▒	▒	△2
Maximum Valve Displacement	IN	▒	▒	△4
Pressure at Which Valve is Open From Outlet to Actuator	PSI	▒	▒	△3
Hanger Inertia Referred to the Actuator	$LB*SEC^2/IN$	▒	▒	△4
Actuator Volume	IN^3	▒	▒	△4
Outlet Volume	IN^3	▒	▒	△3
Piston Area	IN^2	▒	▒	△5
Hanger Actuator Lever Arm from Hanger Pivot at Mid Stroke	IN	▒	▒	△5
Flat Depth	IN	▒	▒	△5
Minimum Actuator Engagement	IN	▒	▒	△5
Case Drain Port Area	IN^2	▒	▒	△5
Rotating Group Mass	$LB*SEC^2/IN$	▒	▒	△5
Radius of Valve Port	IN	▒	▒	△6
Hanger Offset	IN	▒	▒	△5

NOTES:
△1 KTYPE 21 For Pressure Acoustics
KTYPE 22 For Pressure Acoustics & Hanger Torque
KTYPE 23 For Pressure and Return Acoustics & Hanger Torque
△2 TYPES 51 & 54 Only
△3 TYPES 51 & 53 Only

NOTES:

△4 TYPE 51 Only

△5 TYPE 53 Only

△6 TYPE 54 Only

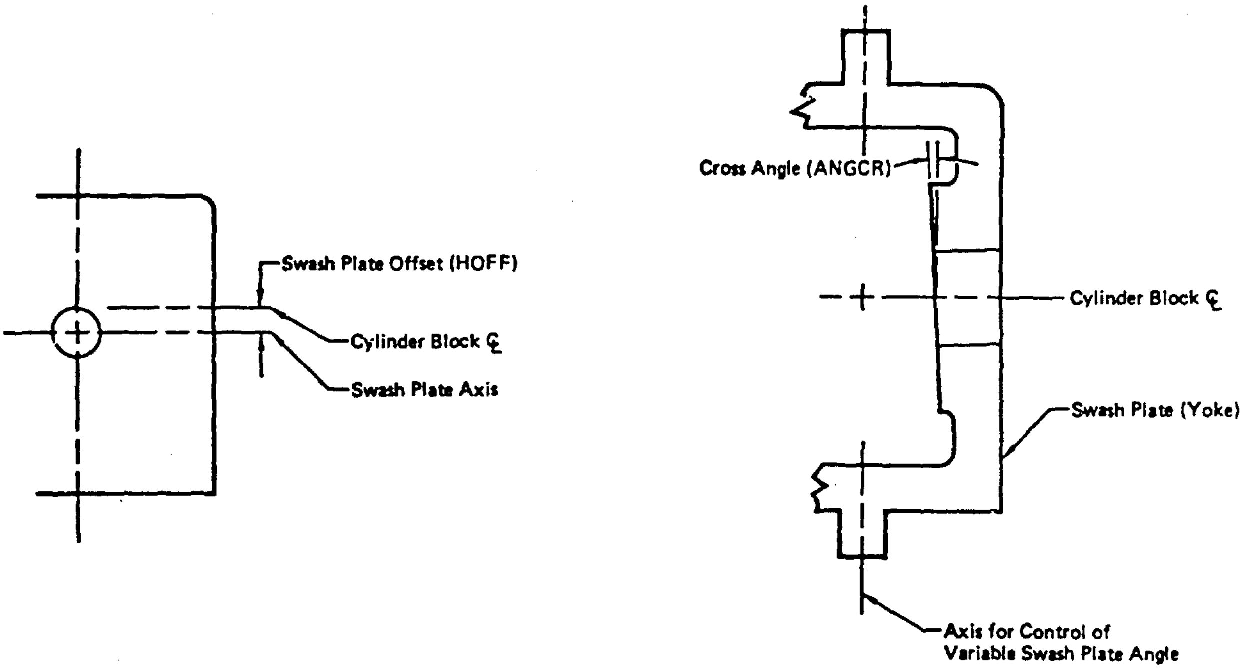


FIGURE 10 PUMP HANGER PARAMETERS

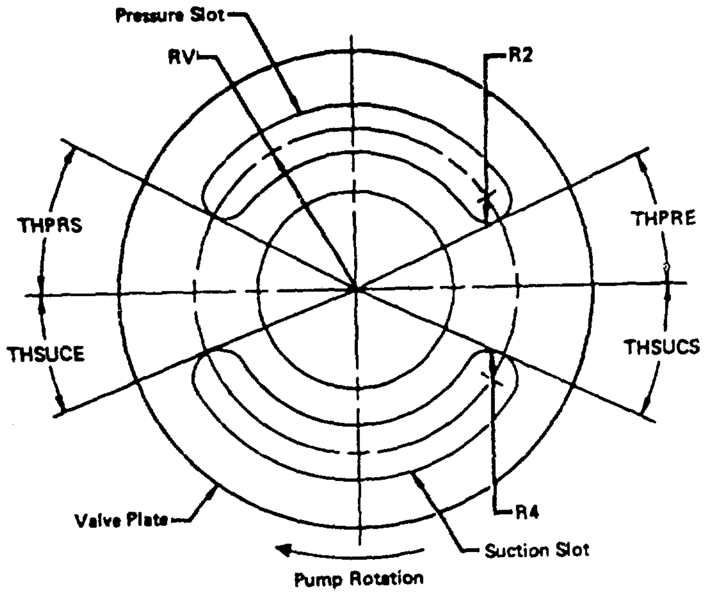
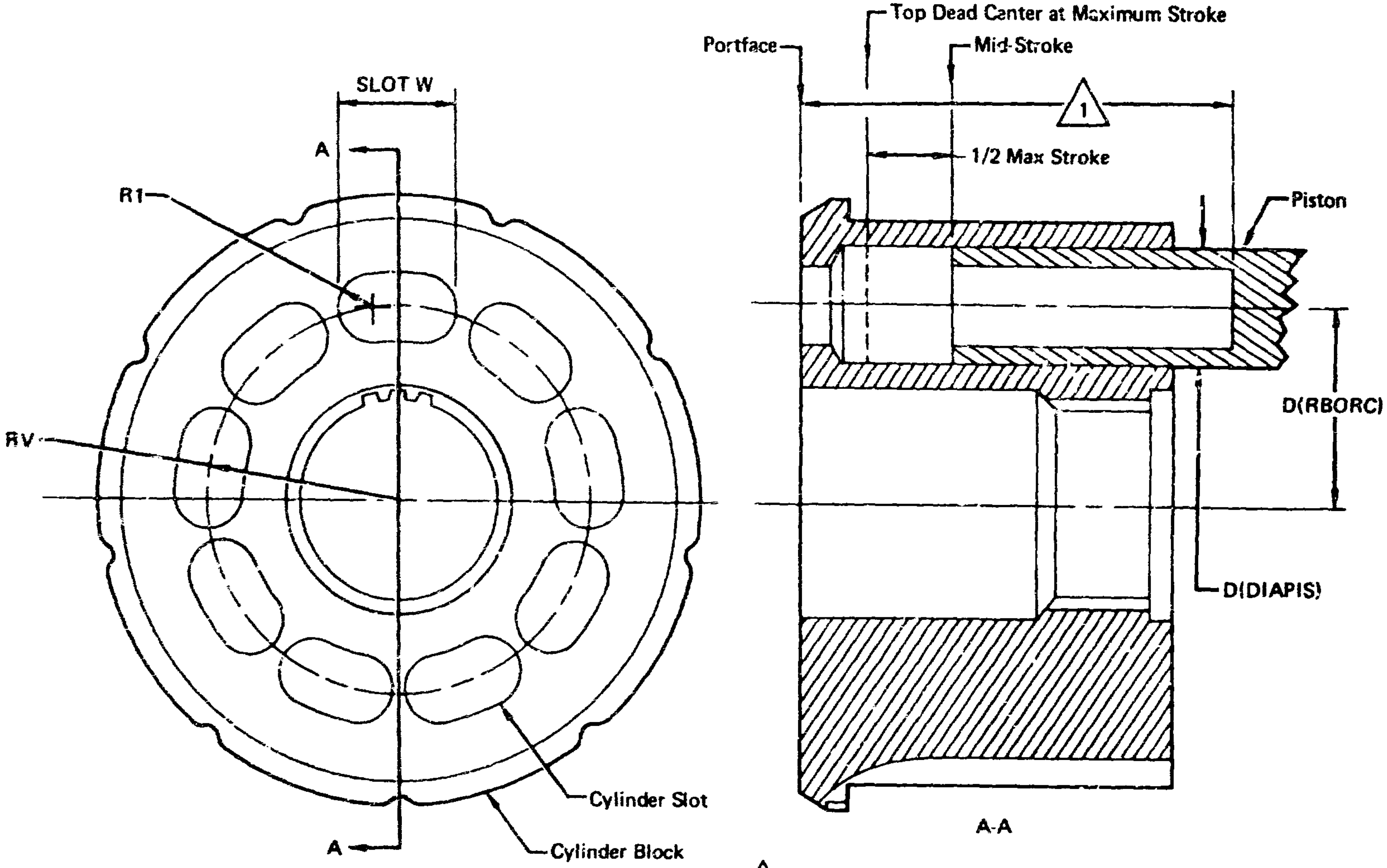


FIGURE 11 PUMP VALVE PLATE PARAMETERS



1 Mid-stroke oil volume (POVOL) is the volume between the port face and the bottom of the hollow piston.

FIGURE 12 **PUMP CYLINDER BLOCK PARAMETERS**

Data Parameter	Units	F-4 (Vickers)	F-15 (Abex)	F-18 (Abex)	HAOA ⚠1 (ABEX)
Suction Port Size	Dash #	-16	-20	-20	-16
Pressure Port Size	Dash #	-12	-16	-16	-12
Case Drain Port Size	Dash #	-4	-4	-4	-6
Rated Pump Speed	RPM	3750.	4600.	4600.	3750.
Rated Output Flow	GPM	26.	56.	56.	6.50
Rated Pressure @ Zero Flow	PSI	3000.	3050.	3050.	2600.
Rated Pressure @ Full Flow	PSI	2950.	2850.	2850.	2500.
Rated Minimum Suction Pressure	PSIA	25.	42.	42.	*
Rated Maximum Case to Inlet ΔP	PSID	300.	300.	300.	*
Rated Case Drain Flow	GPM	1.5	2.12	2.12	*
Rated Case Pressure	PSIG	50.	85.	85.	*

NOTES: * Subroutine Default Values

⚠1 Electric Motor Driven Emergency Pump Used in F-15 Streak Eagle and F-15/F-18 High Angle of Attack (HAOA) Test Aircraft

FIGURE 13 SSFAN PUMP DATA

DATA PARAMETER	Units	F-4 (Abex)	F-15/F-18	F-14 (Abex)	HAOA △1
Cylinder Slot Radius	IN		.190	.203	.121
Cylinder Slot Width	IN		.666	.7455	.476
Cyl & Valve Plate Slot Centerline Rad.	IN		1.120	1.381	.8435
Cylinder Centerline Radius	IN		1.172	1.381	.8435
Piston Diameter	IN		.698	.786	.480
Oil Vol.-Piston @ Midstroke to Port Face	IN^3		.570	.742	.201
Valve Plate Pressure Slot Radius	IN		.180	.202	.091
Valve Plate Suction Slot Radius	IN		.200	.2395	.157
Maximum Swash Angle	DEG		19.500	19.700	19.00
Int. Leakage @ Input Steady State Press	CIS		3.600	11.500	1.92
Swash Plate Fixed Cross Angle	DEG		3.375	3.125	2.75
Valve Plate Pressure Slot Start Angle	DEG		25.750	22.530	29.06
Valve Plate Pressure Slot End Angle	DEG		26.250	22.330	23.0
Valve Plate Suction Slot Start Angle	DEG		26.000	20.460	27.0
Valve Plate Suction Slot End Angle	DEG		21.750	18.160	20.0
Suction Port Steady State Pressure	PSI		△2	△2	△2
Swash Plate Centerline Offset	IN		.060	.072	.049
Max. Swash Plate Actuator Displacement	IN		.780	.800	.40
Swash Plate Act. Lever Arm @ Zero Angle	IN		2.070	2.500	1.10
Pumping Piston Mass	LB*SEC^2/IN		.00042	.000572	.0003
Steady State Case Pressure	PSI		△2	△2	△2
Case to Inlet ΔP @ Zero Case Flow	PSI		150.0	200.0	200.0
Swash Plate Actuator Diameter	IN		.690	.935	.74

NOTES: △1 Electric Motor Driven Emergency/Back-up Pump used in F-15 Streak Eagle & F-15/F-18 High Angle of Attack (HAOA) Test Aircraft

△2 Dependent on System Simulation

FIGURE 14 HSFR PUMP DATA

DATA PARAMETER	Units	F-14 (Type 54)	F-15 (Type 53)	F-18 (Type 51)	HAOA 1 (Typ 51)
Outlet to Actuator Valve Opening Press.	PSI	2925.	-	2985.	2446.
Valve Spring Rate	LB/IN	248.	2000.	2000.	248.
Compensator Valve Area	IN^2	.0191	.15	.15	.0191
Slot Width	IN	-	.25	.25	.137
Flow Force on Spool	LB	-	-	-	-
Valve Overlap	IN	.001	.016	.016	.016
Discharge Coefficient - Outlet to Act.	-	.65	-	.65	.65
Discharge Coefficient - Act. to Case	-	.65	-	.65	.65
Actuator Area	IN^2	.69	.307	.307	.69
Act Press From Spring @ Zero Pump Disp	PSI	400.	498.	400.	400.
Act Press From Spring @ Max Pump Disp	PSI	70.	80.7	70.	70.
Act Press From Piston Accel @ 3600 RPM	IN^2/SEC	130.	143.8	130.	130.
Act Press @ 3600 RPM & Zero Pump Disp	PSI	470.	574.3	470.	470.
Act Press @ 3600 RPM & Max Pump Disp	PSI	220.	296.7	215.	220.
Slope of Pressure vs. RPM Curve	PSI/RPM	.035	.035	.035	.035
Hanger Damping	PSI/IN/SEC	25.	50.	45.	25.
Theoretical Maximum Pump Displacement	IN^3/REV	4.3	3.0	3.0	.4004
Max Act Displacement @ Max Flow	IN	.8	.795	.75	.80
Min Act Displacement @ Min Pump Flow	IN	-.1	-.3	-.3	-.1
Coeff of Act Leakage @ Zero Pump Disp	CIS/PSI	.001	-	.002	.001
Coeff of Act Leakage @ Max Pump Disp	CIS/PSI	.002	-	.001	.002
Coeff of Pump Leakage - Outlet to Case	CIS/PSI	.003	.003	.00128	.00128
Coeff of Pump Leakage - Case to Inlet	CIS/PSI	.02	.1097	.0366	.02
Case Volume	IN^3	50.0	48.0	48.0	50.0
Minimum Inlet Pressure	PSIA	5.0	5.0	5.0	5.0

FIGURE 15 HYTRAN PUMP DATA

DATA PARAMETER	Units	F-14 (Type 54)	F-15 (Type 53)	F-18 (Type 51)	HAOA (Type 51)
Coeff of Offset Outlet Flow From Act.	CIS/IN/SEC	.069	-	.036	.069
Maximum Valve Displacement	IN	-	.08	.05	.05
Press at Which Valve Opens-Act to Case	PSI	-	2822.	-	-
Hanger Inertia Referred to Actuator	$LB*SEC^2/IN$	-	-	.0035	.0035
Actuator Volume	IN^3	-	10.0	1.0	1.0
Outlet Volume	IN^3	-	8.0	8.0	8.0
Piston Area	IN^2	-	.3826	-	-
Hanger Actuator Lever Arm @ Midstroke	IN	-	.277	-	-
Flat Depth	IN	-	.003	-	-
Minimum Actuator Engagement	IN	-	2.1	-	-
Case Drain Port Area	IN^2	-	.04455	-	-
Rotating Group Mass	$LB*SEC^2/IN$	-	.0104	-	-
Radius of Valve Port	IN	.0468	-	-	-
Hanger Offset	IN	-	.06	-	-

NOTES: 1 Electric Motor Driven Emergency/Back-up Pump used on F-15 Streak Eagle & F-15/F-18 High Angle of Attack (HAOA) Test Aircraft.

FIGURE 15 HYTRAN PUMP DATA (CONTINUED)

4. RESERVOIRS

Flow-through bootstrap and constant pressure are the two basic types of reservoirs modeled with the HYTRAN and SSFAN programs. In the HSFR program the reservoir is represented by a simple volume.

The bootstrap reservoir shown in Figure 16 is the type used in various aircraft hydraulic systems. System return fluid passes through the reservoir before going to the pump suction port. A variation of the bootstrap reservoir incorporates a two circuit, level sensing capability. Such reservoirs shown in Figure 17 are used on the F-15 and F-18 aircraft.

The input data requirements for the flow through and constant pressure reservoirs are listed. The appendix reservoir models in SSFAN and HYTRAN require the same input data.

SSFAN and HYTRAN bootstrap reservoir data are listed in Figures 18 and 19 .

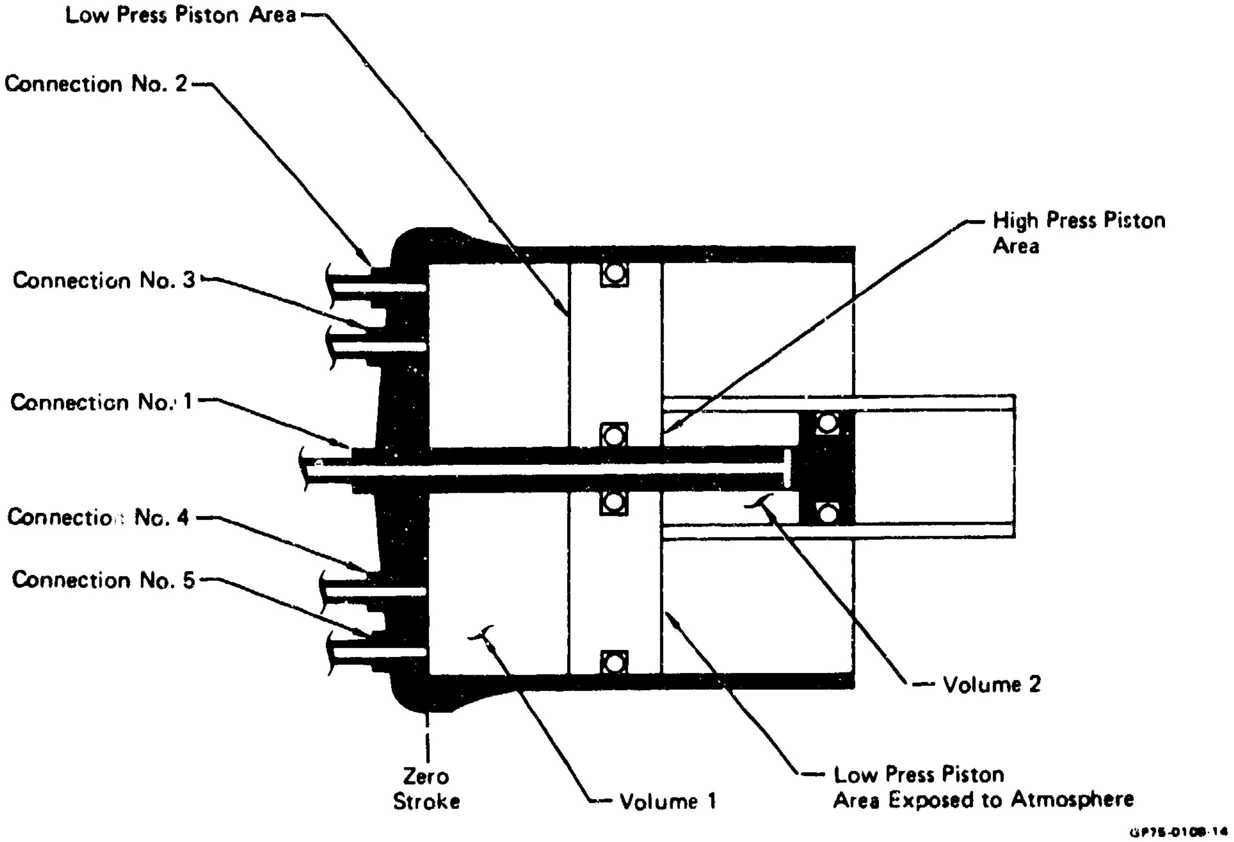


FIGURE 16 FLOW-THROUGH BOOTSTRAP RESERVOIR

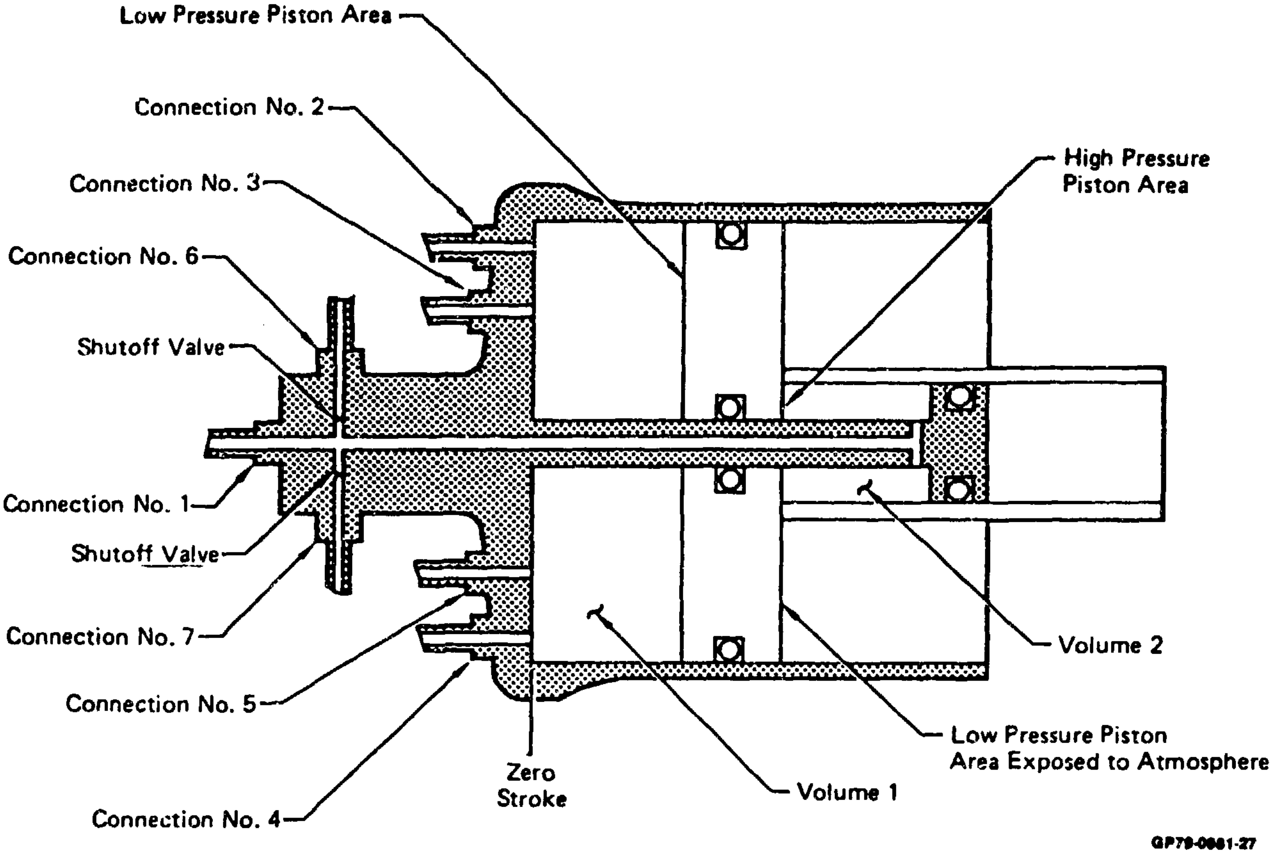


FIGURE 17 LEVEL SENSING BOOTSTRAP RESERVOIR

Element Type: Reservoir

Data Parameter	Program	SSFAN	HSFR	HYTRAN
	Element Type	△1	▨	△2
Data Parameter	Dimensions	▨	▨	▨
Return Port Size	IN or Dash #		░	░
Bootstrap Port Size	IN or Dash #		░	░
Suction Port Size	IN or Dash #		░	░
High Pressure Area	IN^2	Fig. 16	░	Fig16,17
Low Pressure Area	IN^2	Fig. 16	░	Fig16,17
Seal Friction	LB		░	░
High Pressure Volume at Zero Stroke	IN^3	░	░	Fig16,17
Low Pressure Volume at Zero Stroke	IN^3	░	░	Fig16,17
Maximum Piston Stroke	IN	░	░	Fig16,17
Initial Piston Position	IN	░	░	Fig16,17
Shut-Off Valve Orifice Diameter (Circuit A)	IN	░	░	Fig. 17
Shut-Off Valve Discharge Coefficient (Circuit A)	-	░	░	Fig. 17
Shut-Off Valve Orifice Diameter (Circuit B)	IN	░	░	Fig. 17
Shut-off Valve Discharge Coefficient (Circuit B)	-	░	░	Fig. 17
Reference Pressure	PSI	△3	░	3

Notes: 1 TYPE 9 - Flow Through Bootstrap
91 - Appendix
92 - Constant Pressure

2 TYPE 61 - Constant Pressure
62 - Bootstrap
63 - Two Circuit, Level Sensing, Bootstrap

3 For Constant Pressure Reservoirs Only

DATA PARAMETER	UNITS	F-4 POWER CONTROL	F-18 SYSTEM #1	F-18 SYSTEM #2
Return Port Size	IN	1.00	.625	.625
Bootstrap Port Size	IN	.25	.875	.875
Suction Port Size	IN	1.00	.844	.844
High Pressure Area	IN^2	1.558	2.527	2.527
Low Pressure Area	IN^2	93.41	88.734	88.734
Seal Friction	LBS	180	176	176

FIGURE 18 SSFAN BOOTSTRAP RESERVOIR DATA

DATA PARAMETER	UNITS	F-4 POWER CONTROL	F-18 SYSTEM #1	F-18 SYSTEM #2
High Pressure Area	IN^2	1.558	2.527	2.527
Low Pressure Area	IN^2	93.41	88.73	88.73
High Pressure Volume at Zero Stroke	IN^3	5.467	21.94	12.95
Low Pressure Volume at Zero Stroke	IN^3	4.67	10.36	13.54
Maximum Piston Stroke	IN	3.50	8.681	5.125
Initial Piston Stroke	IN	1.75	4.34	2.00
Shut-off Valve Orifice Diameter (Circuit A)	IN	-	.32	.32
Shut-Off Valve Discharge Coefficient (Circuit A)	-	-	.65	.65
Shut-Off Valve Orifice Diameter (Circuit B)	IN	-	.32	.32
Shut-Off Valve Discharge Coefficient (Circuit B)	-	-	.65	.65

FIGURE 19 HYTRAN BOOTSTRAP AND RLS BOOTSTRAP RESERVOIR DATA

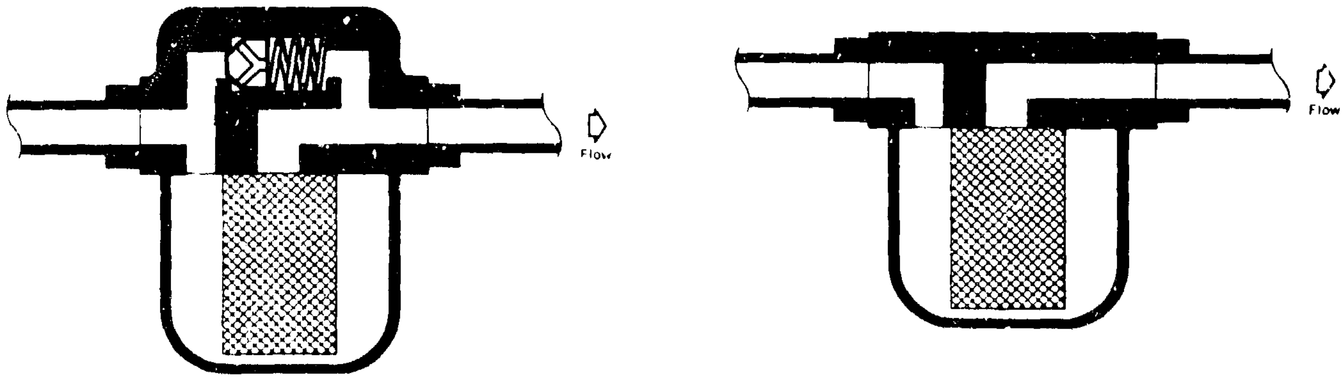
5. FILTERS

Hydraulic system filters are used to trap particle contaminants in the fluid. Such particles, if allowed to circulate, often cause system failures by plugging orifices, binding valve spools, and scoring moving surfaces.

HSFR, HYTRAN, and SSFAN model bowl type filters with renewable elements (either throw-away or cleanable). Such filters are often used in central power system applications to filter pump case drain flow, and system flow in both the supply and return circuits. These type filters are also occasionally used upstream of components that are especially sensitive to particle contamination. In central system applications, supply, return and case drain filters are often manifolded together to reduce weight and improve maintainability. The HYTRAN component #82 is a model of just such a filter manifold.

HYTRAN and SSFAN allow the capability of modelling either bypass type filters or non-bypass filters (Figure 20). HSFR is concerned only with the volume effects of the filter, not what type of filter it is.

Figure 21 provides specific data on existing filters that have been modelled and Figure 22 illustrates the contamination factor relationships necessary to model these filters in HYTRAN.



Bypass Filter

Non-Bypass Filter

FIGURE 20 BYPASS AND NON-BYPASS FILTERS

Element Type: Filter

	Program	SSFAN	HSFR	HYTRAN △1
	Element Type	6	NTYPE 3 KTYPE 0	81,82,83
Data Parameter	Dimensions	▧	▧	▧
Inlet Size	Dash #		▨	▨
Outlet Size	Dash #		▨	▨
Internal Fluid Volume	IN^3			▨
Rated Flow of Clean Element	GPM		▨	▨
Rated Pressure Drop of Clean Element	PSI		▨	▨
Fluid Viscosity @ Rated Conditions	Centistokes		▨	▨
Contamination Factor	-		▨	▨
Relief Valve Cracking Pressure	PSI		▨	△2
Bypass Pressure Drop @ Rated Flow	PSI		▨	▨
Inlet Volume	IN^3	▨	▨	
Exit Volume	IN^3	▨	▨	
Linear Flow Constant	PSI/CIS	▨	▨	
Non-Linear Flow Constant	PSI/CIS^2	▨	▨	
Relief Valve Flow Constant	CIS/PSI	▨	▨	△2

Notes: △1 Type 81 - Non Bypass

Type 82 - Three Filter Manifold with System Relief Valve

Type 83 - Bypass

△2 Type 83 Only

FILTER	TYPE	INLET SIZE	OUTLET SIZE	FLUID VOLUME (IN^3)	RATED FLOW OF CLEAN ELEMENT (GPM)	RATED ΔP OF CLEAN ELEMENT (PSI)	RATED VISCOSITY (CENTISTOKES)	RELIEF SETTING (PSI)	BYPASS ΔP AT RATED FLOW (PSI)
F-18 Pressure	Bypass Manifold	-16	-16	30.02	56	23	16.0	3600	3850
F-18 Return	Bypass Manifold	-10	-12	34.40	56	23	16.0	150	210
F-18 Case Drain	Bypass In-Line	-6	-4	3.3	3.5	7.75	16.0	100	160
F-4 Case Drain	Bypass In-Line	-6	-4	2.984	4.5	6.07	14.6	130	200
F-18 HAOA Pressure	Non-Bypass In-Line	-16	-16	24.775	29	8	14.5	-	-
F-18 HAOA Case Drain	Non-Bypass In-Line	-6	-6	5.662	3.5	10	14.5	-	-

HSFR FILTER DATA

FILTER	TYPE	TOTAL VOLUME (IN^3)
F-18 Pressure	Bypass Manifold	30.02
F-18 Return	Bypass Manifold	34.40
F-18 Case Drain	Bypass In-Line	3.3
F-4 Case Drain	Bypass In-Line	2.984
F-18 HAOA Pressure	Non-Bypass In-Line	24.775
F-18 HAOA Case Drain	Non-Bypass In-Line	5.662

HYTRAN FILTER DATA

FILTER	TYPE	INLET VOL. (IN^3)	EXIT VOL. (IN^3)	LINEAR FLOW CONST. (PSI/CIS)	NON-LINEAR FLOW CONST (PSI/CIS^2)	RELIEF VALVE CONST. (CIS/PSI)	RELIEF VALVE CRACKING PR. (PSI)
F-18 Pressure	Bypass Manifold	20.47	9.55	Figure	.0004517746	.8624	3600
F-18 Return	Bypass Manifold	16.77	17.63	Figure	.0015704544	3.593	150
F-18 Case Drain	Bypass In-Line	2.1	1.2	Figure	.0674650025	.2246	100
F-4 Case Drain	Bypass In-Line	1.89	1.094	Figure	.0190900097	.2475	130
F-18 HAOA Pressure	Non-Bypass In-Line	14.433	10.342	Figure	.0012032996	--	-
F-18 HAOA Case Drain	Non-Bypass In-Line	3.263	2.339	Figure	.0826102071	--	-

FIGURE 21 FILTER DATA

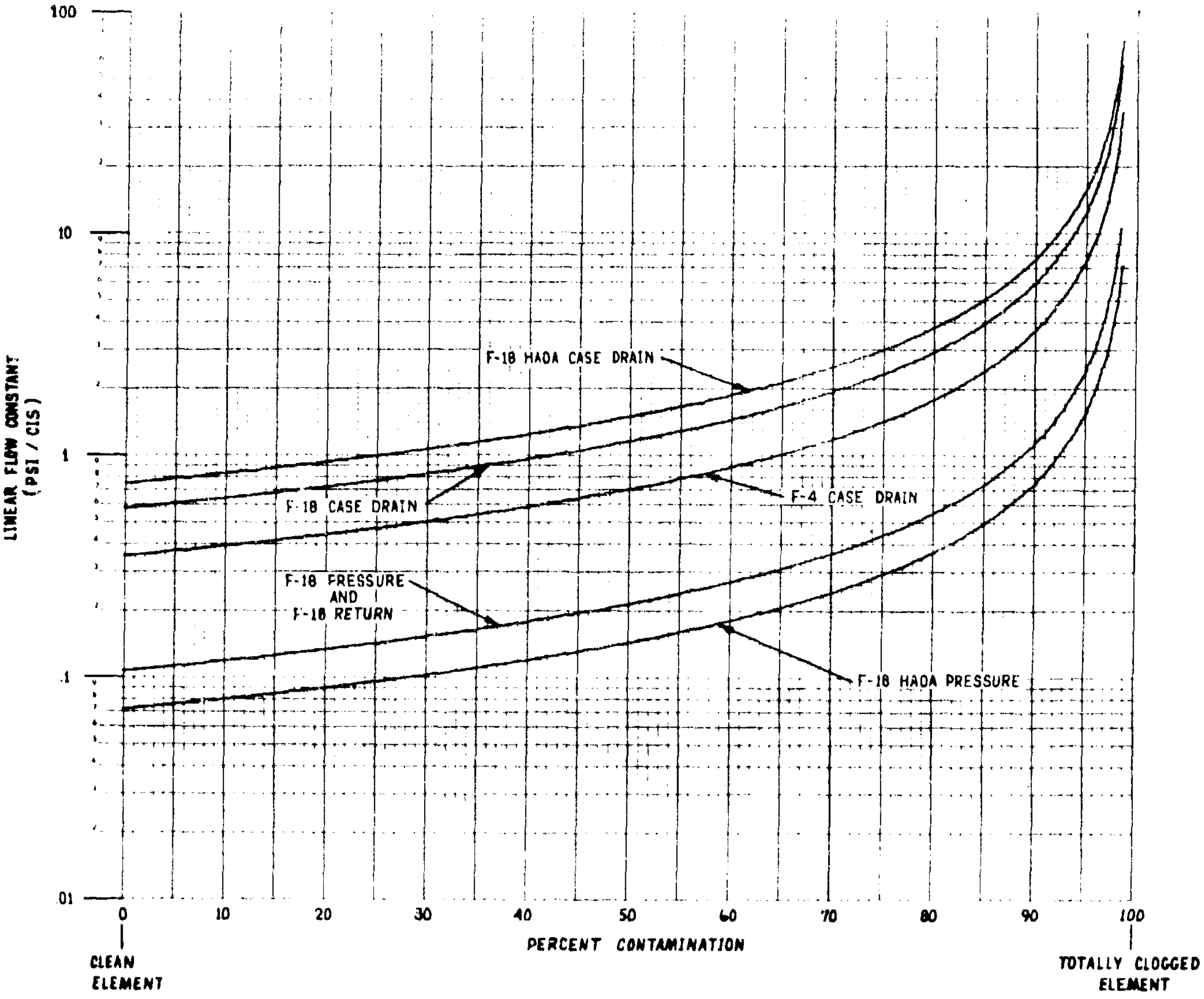
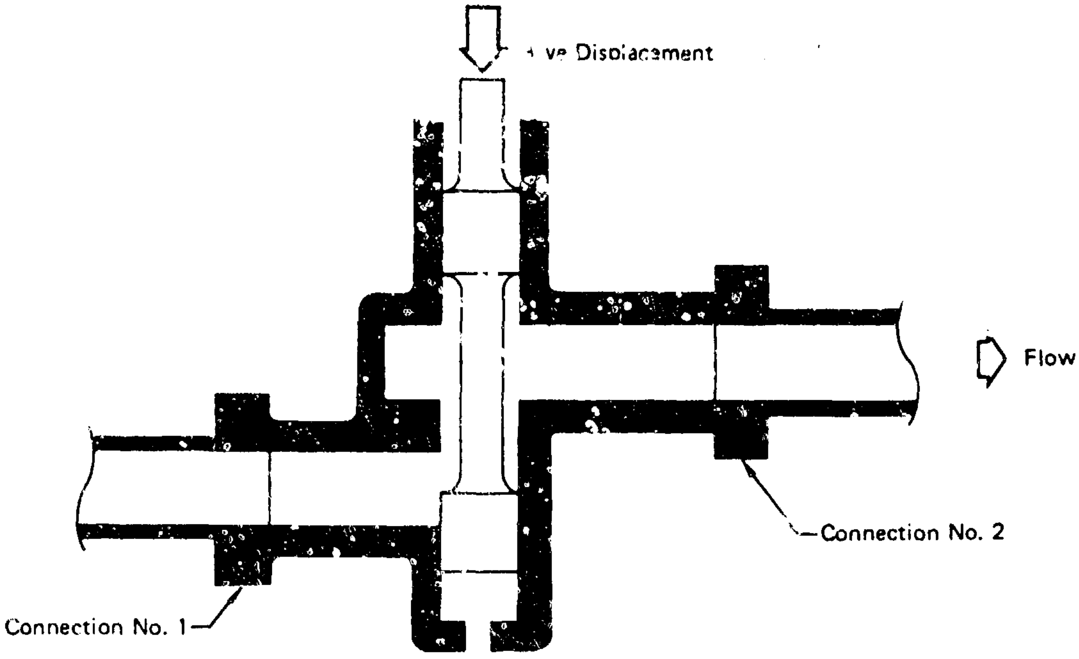


FIGURE 22 HYTRAN FILTER ELEMENT FACTORS

6. UTILITY CONTROL VALVES

a. Two-Way

The two-way control valve has a direct path from pressure to return and a null mode with leakage from high to low pressure. A typical two-way valve schematic is shown in Figure 23.



GP75-0099-19

FIGURE 23 TWO-WAY CONTROL VALVE

Valve specifications usually give the internal pressure drops as a function of flow for a given fluid and temperature. In addition to these inputs the HYTRAN and SSFAN programs let the user specify the viscosity of the rated fluid. Figure 24 presents SSFAN two-way control valve data.

The HYTRAN valve routine uses an externally controlled time history input. The valve opening versus time is derived from tabulated input data. The valve slot width is multiplied by the input values to arrive at the rectangular slot area. The discharge coefficient for a sharp-edged orifice is typically 0.6. Valve operating times depend on actual system pressures and flows. The Marotta valve (Figure 24) operating time is approximately 10 milliseconds for turn-off transients and up to 30 milliseconds for turn-on transients. The modified Victor valve operating time was 0.2 milliseconds for both turn-on and turn-off transients. The F-18 sequence valve is mechanically controlled. The operating time is tied to landing gear movement.

The valve input data for the HSFR program is not limited to two-way control valves. Typical valves which may also be modeled are electro-hydraulic servo valves, mechanical servo-valves, and combinations of electro-mechanical servo-valves, such as may be found in an integrated actuator package.

The input data for a valve element includes the valve gain linearized at the steady state circuit flow through the valve. Valve gain is expressed as pressure drop (psi) per unit flow rate (cubic inches per second). Flow out of the circuit being analyzed is input for terminating valve elements. This "overboard flow" is the steady state flow through the terminating valve at the input steady state system pressure. Determination of the valve gain is given below:

For a valve pressure/flow relationship of the form

$P = KQ^n$ Where: P = pressure drop (psi)

Q = flow rate (cis)

K = constant

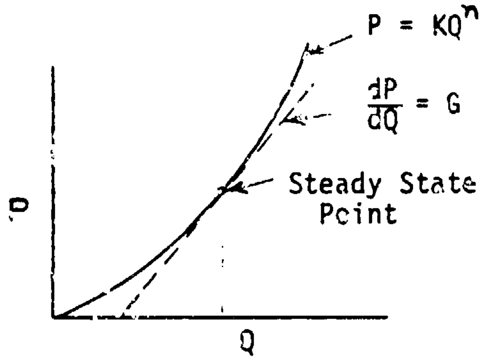
n = flow exponent

the linearized valve gain (G) may be determined from

$$G = \frac{dP}{dQ} = nKQ^{n-1}$$

but $K = \frac{P}{Q^n}$

therefore $G = \frac{nP}{Q}$.



PRESSURE-VALVE FLOW RELATIONSHIP

If the valve flow can be characterized as an orifice ($n = 2$), then the gain is $G = {}^{2P}/_{Q}$. The orifice relationship is typical of electrohydraulic servo valve steady state control flow. If the valve flow can be characterized as laminar for the steady state condition, then $n = 1$ and the gain is $G = {}^{P}/_{Q}$. The laminar relationship is typical for null leakage flow across lapped spool valves, e.g. mechanical servovalves, and the second stage of an electrohydraulic valve.

Parallel valve elements, for instance those within an electro-mechanical integrated servoactuator, may be combined for modeling as a single valve element by computing an equivalent gain (G_e) for all the parallel flow paths.

$$\frac{1}{G_e} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3} \quad . \; . \; .$$

Empirical pressure drop/flow data, if available, should be used to calculate the gain at the steady state flow condition. The flow relationship may be assumed unless the flow exponent is available from empirical data.

Element Type: TWO-WAY CONTROL VALVE

	Program	SSFAN	HSFR	HYTRAN
	Element Type	36	NTYPE ⚠ NTYPE 0	21
Data Parameter	Dimensions	▨	▨	▨
Inlet Port Size	IN or DASH #		▨	▨
Outlet Port Size	IN or DASH #		▨	▨
Rated Flow (Inlet to Outlet)	GPM		▨	▨
Rated Pressure Drop (Inlet to Outlet)	PSI		▨	▨
Fluid Viscosity at Rated Conditions	Centistokes		▨	▨
Leakage Flow (Inlet to Outlet)	GPM		▨	▨
Pressure Drop for Leakage Conditions	PSI		▨	▨
Valve Gain	PSI/CIS	▨	See P. 36	▨
Circuit Overboard Glow	CIS	▨		▨
Valve Slot Width	IN	▨	▨	
Valve Discharge Coefficient	-	▨	▨	
Valve Positions (From Time = 0.0)	IN	▨	▨	
Operating Time (From Time = 0.0)	SEC	▨	▨	

NOTES: ⚠ NTYPE = 4 Non-Terminating Valve

NTYPE = 14 Terminating Valve

DATA PARAMETER	UNITS	MARROTA VALVE P/N 205883-1	MODIFIED VICTOR SV 41S-9021	F-18 SEQUENCE VALVE
INLET PORT SIZE	DASH #	-6	-6	-4
OUTLET PORT SIZE	DASH #	-6	-6	-4
RATED FLOW	GPM	28.6	40	1.2
RATED PRESSURE DROP	PSI	3000.	3000	25
FLUID VISCOSITY AT RATED CONDITIONS	CENTISTOKES	12.0	12.0	12.0
LEAKAGE FLOW	GPM		.001	-
PRESSURE DROP FOR LEAKAGE CONDITIONS	PSI		3000.	-

FIGURE 24 SSFAN TWO-WAY CONTROL VALVE DATA

b. Three Way

Only the SSFAN program has a three way valve model. The 2 positions for a 3 way 2 position valve are (1) pressure to C3 port and, (2) the valve in the null or closed position with leakage from high to low pressure.

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.

SSFAN input data for several three-way control valves is shown in Figure 25.

Element Type: THREE-WAY CONTROL VALVE

	Program	SSFAN	HSFR	HYTRAN
	Element Type	35	▨	▨
Data Parameter	Dimensions	▨	▨	▨
Junction 1 (Pressure) Port Size	IN or DASH #		░	░
Junction 2 (Return) Port Size	IN or DASH #		░	░
Junction 3 (C3) Port Size	IN or DASH #		░	░
Rated Flow from JCT 1 to JCT 3	GPM		░	░
Rated Pressure Drop for Rated Flow	PSI		░	░
Fluid Viscosity at Rated Conditions	Centistokes		░	░
Leakage Flow from JCT 1 to JCT 3	GPM		░	░
Pressure Drop for Leakage Conditions	PSI		░	░

DATA PARAMETER	UNITS	F-18 ISOLATION VALVE	F-18 SHUTTLE VALVE	F-18 PARKING BRAKE	F-18 EMERGENCY IN-FLIGHT REFUEL	F-18 EMERGENCY LANDING GEAR
PRESSURE PORT SIZE	DASH #	-6	-4	-4	-4	-6
RETURN PORT SIZE	DASH #	-4	-4	-6	-6	-4
C3 PORT SIZE	DASH #	-8	-4	-4	-4	-6
RATED FLOW FROM PRESSURE TO C3	GPM	9.6	1.5	.325	1.0	2.0
RATIO PRESSURE DROP FOR RATED FLOW	PSI	48	14	300	30	33
FLUID VISCOSITY AT RATED CONDITIONS	CENTISTOKES	22	15.1	15.1	15.1	15.1
LEAKAGE FLOW FROM PRESSURE TO C3	GPM	.0012	-	00004	.00001	-
PRESSURE DROP FOR LEAKAGE CONDITIONS	PSI	4000	-	3000	3000	-

FIGURE 25 SSFAN THREE WAY CONTROL VALVE DATA

c. Four-Way

Four-way valves (Figure 26) are the components generally used to control reversible utility functions in aircraft hydraulic systems. As illustrated by the SSFAN operating code, Figure 27, a single four-way valve can be used to command an actuator (or group of actuators) to either extend, retract, or hold their position.

The utility four-way valves that have been modelled in HYTRAN thus far are usually full-trail configuration valves. As such, when the valve spool is in the null position (position = 0.0), the pressure port is blocked and both cylinder ports are connected to return (Figure 28). Such a valve prevents possible hardware damage that can result if pressure is applied to one side of an unequal area actuator before the other side is ported to return, or when thermal expansion or contraction of the subsystem fluid does not have a relief path.

As with the two-way and three-way valves, data presentation for the four-way valve in Figures 29 and 30 consists of data parameters that have been used to model specific F-18 and F-15 valves in HYTRAN and SSFAN. No four-way valve exists in HSFR, but it can be approximated by combinations of two-way valves. See Section 6a for a discussion of two-way valve simulation in HSFR.

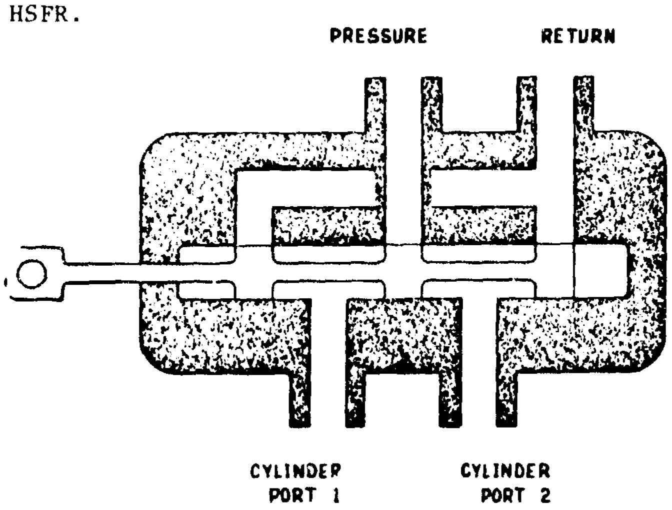


FIGURE 26 ZERO LAP, FOUR-WAY VALVE

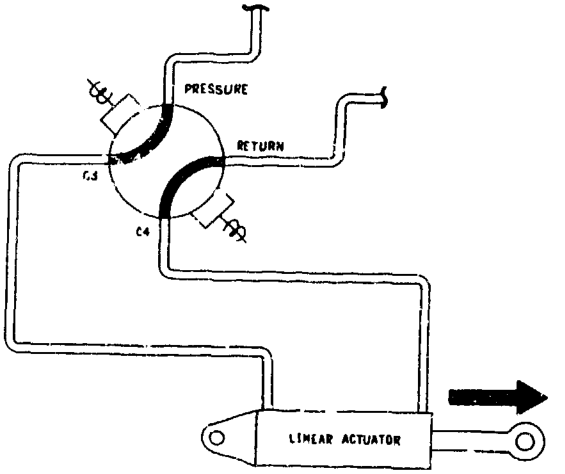
Element Type: Four-Way Control Valve

	Program	SSFAN	▨	HYTRAN
	Element Type	34	▨	22
Data Parameter	Dimensions	▨	▨	▨
Pressure Port Size	IN or Dash #		░	░
Return Port Size	IN or Dash #		░	░
Cylinder Port #1 Size	IN or Dash #		░	░
Cylinder Port #2 Size	IN or Dash #		░	░
Rated Flow from "Pressure" to Either "Cylinder" Port	GPM		░	░
Rated Pressure Drop for Rated Flow	PSI		░	░
Fluid Viscosity for Rated Conditions	CENTISTOKES		░	░
Leakage from "Pressure" to Either Cylinder Port (Valve Closed)	GPM		░	░
Pressure Drop for Rated Leakage	PSI		░	░
Operating Control Code	-	△1	░	░
Con #1-2 Projected Cutoff Position	IN	░	░	
Con #1-2 Projected Max Open Pos.	IN	░	░	
Con #1-2 Max Effective Valve Area	IN^2	░	░	
Con #1-2 Characteristic Curvature Coefficient	-	░	░	
Con #2-3 Projected Cutoff Position	IN	░	░	
Con #2-3 Projected Max Open Pos.	IN	░	░	
Con #2-3 Max Effective Valve Area	IN^2	░	░	
Con #2-3 Characteristic Curvature Coefficient	-	░	░	
Con #3-4 Projected Cutoff Position	IN	░	░	
Con #3-4 Projected Max Open Pos.	IN	░	░	

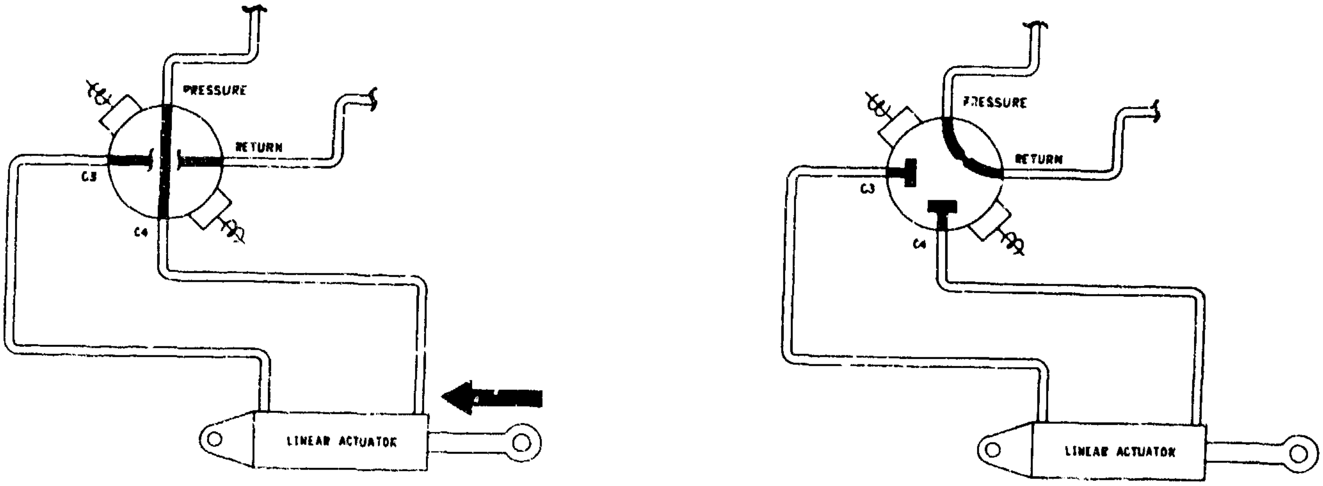
Element Type: Four-Way Control
Valve (Continued)

	Program	SSFAN	▨	HYTRAN
	Element Type	34	▨	22
Data Parameter	Dimensions	▨	▨	▨
Con #3-4 Max Effective Valve Area	IN^2	▒	▒	
Con #3-4 Characteristic Curvature Coefficient	-	▒	▒	
Con #4-1 Projected Cutoff Position	IN	▒	▒	
Con #4-1 Projected Max Open Pos.	IN	▒	▒	
Con #4-1 Max Effective Valve Area	IN^2	▒	▒	
Con #4-1 Characteristic Curvature Coefficient	-	▒	▒	
Valve Position Table	IN	▒	▒	△1
Valve Time Table	SEC	▒	▒	△1

Notes: △1 Dependent on Simulation



CONTROL CODE 1



CONTROL CODE 2

CONTROL CODE 3

(HIGH RESISTANCE FROM
PRESSURE TO RETURN)

FIGURE 27 SSFAN FOUR-WAY CONTROL
VALVE OPERATION CODE

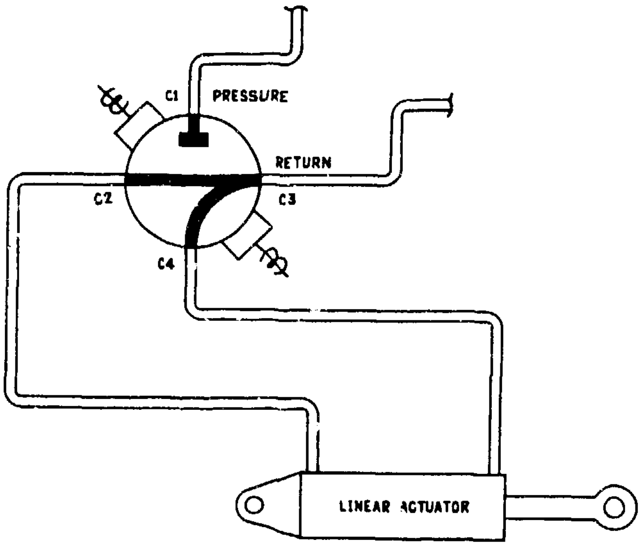
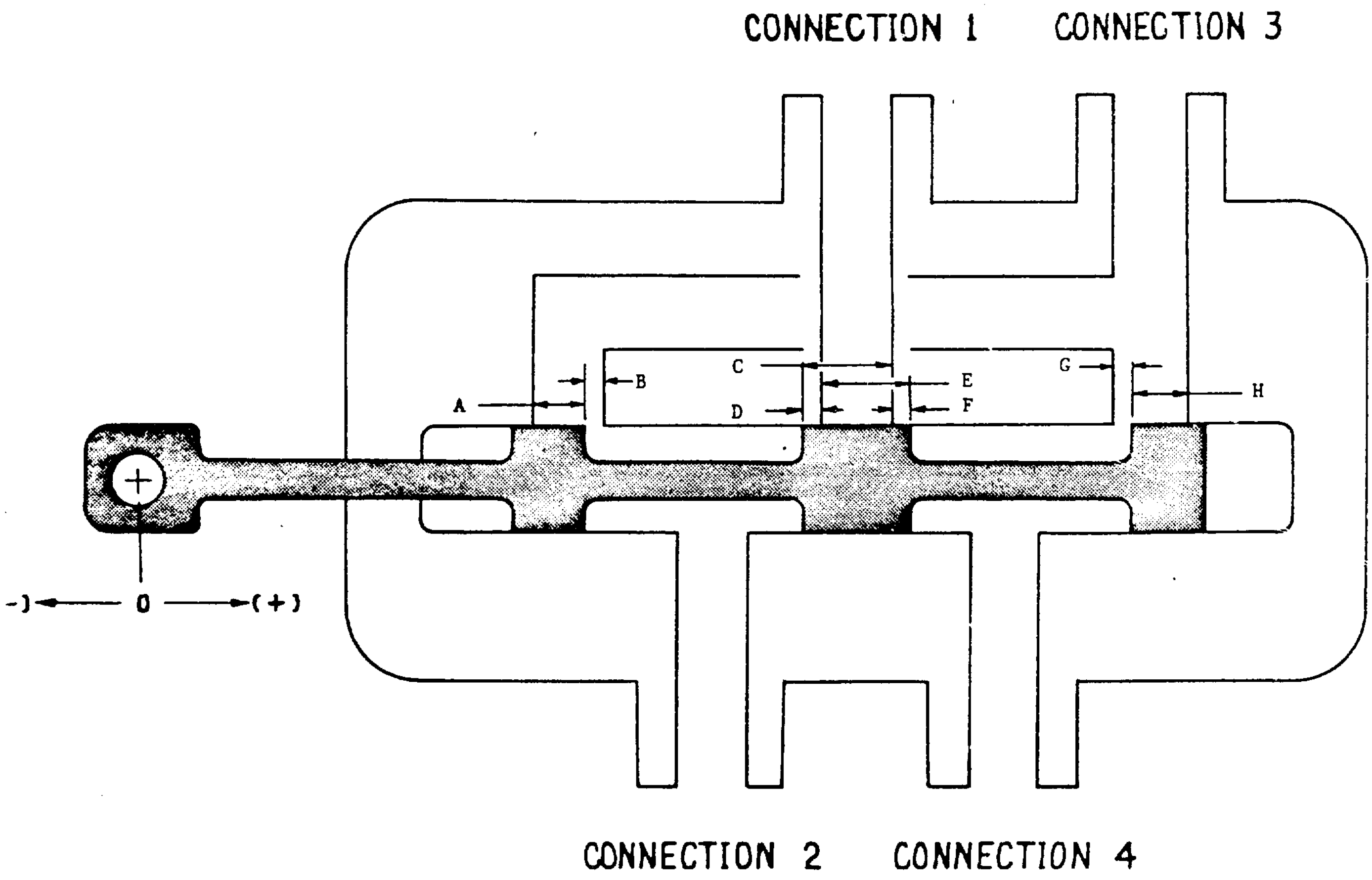


FIGURE 28 Full Trail Configuration
Four-Way Valve @ Null Position

	Units	F-18 Landing Gear	F-18 In-Flight Refuel	F-15 Speedbrake	F-18 Speedbrake
Pressure Port Size	Dash #	-6	-4	-10	-8
Return Port Size	Dash #	-6	-6	-8	-8
#1 Cylinder Port Size	Dash #	-6	-6	-8	-8
#2 Cylinder Port Size	Dash #	-8	-4	-10	-8
"Pressure" to C1 or C2 Rated Flow	GPM	8.5	.5	25.	15.
Rated Pressure Drop	PSI	48.	3000.	230.	100.
Fluid Viscosity for Rated Conditions	CENTISTOKES	16.0	18.0	14.6	16.0
Rated Leakage (Valve Closed)	GPM	.004	.0006	.003	.002
Rated ΔP For Leakage	PSI	3000.	3000.	3000.	3000.

Figure 29 SSFAN Four-Way Valve Data



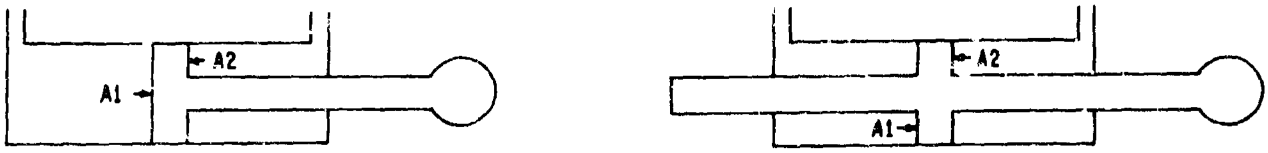
	Units	F-18 Land. Gr.	F-18 IFR	F-15 Spdbrake	F-18 Spdbrake
Con. 1-2 Projected Cutoff (D)	IN	+.145	+.11	+.0025	+.1954
Con 1-2 Projected Max. Opening (C)	IN	+.3198	+.235	+.125	+.4241
Con 1-2 Max Effective Valve Area	IN^2	.0693	.0003365	.062	.056
Con 1-2 Characteristic Curvature	-	32.	32.	32.	32.
Con 2-3 Projected Cutoff (B)	IN	+.1395	+.09	-.0025	-.0499
Con 2-3 Projected Max Opening (A)	IN	-.0465	-.035	-.12	-.3202
Con 2-3 Max Effective Valve Area	IN^2	.0367	.0003365	.063	.056
Con 2-3 Characteristic Curvature	-	32.	32.	32.	32.
Con 3-4 Projected Cutoff (G)	IN	-.1395	-.09	+.0025	+.0416
Con 3-4 Projected Max Opening (H)	IN	+.0407	+.035	+.12	+.2661
Con 3-4 Max Effective Valve Area	IN^2	.0372	.0003365	.062	.056
Con 3-4 Characteristic Curvature	-	32.	32.	32.	32.
Con 1-4 Projected Cutoff (F)	IN	-.1686	-.11	-.0025	-.0499
Con 1-4 Projected Max Opening (E)	IN	-.3372	-.235	-.125	-.2661
Con 1-4 Max Effective Valve Area	IN^2	.0662	.0003365	.063	.056
Con 1-4 Characteristic Curvature	-	32.	32.	32.	32.

Figure 30 HYTRAN Four-Way Valve Data

7. LINEAR ACTUATORS

Linear actuator models exist in only HYTRAN and SSFAN. In both computer programs, the models are based on differential pressure acting on a piston. The piston may be of equal or unequal area configuration (see Figure 31).

If the actuator has more than one piston (either in tandem or parallel arrangement) but receives power from only one hydraulic system, the piston areas and chamber volumes must be summed to give an equivalent single piston actuator. HYTRAN allows modelling of a dual system, two piston, valve controlled actuator, but SSFAN does not have this capability. A single system, valve controlled actuator model exists in HYTRAN and can be approximated in SSFAN by combining a simple actuator and four-way valve. Single piston, utility actuator models exist in both HYTRAN and SSFAN.



$A1 \neq A2$

Unequal Area Actuator

$A1 = A2$

Equal Area Actuator

FIGURE 31 UNEQUAL AND EQUAL AREA ACTUATORS

a. Utility

Simple, linear, piston type actuators are the most common method of hydraulic actuation of utility functions. In such applications, these devices are generally located remotely from the valve which controls them and are not required to hold any position intermediate to their stops.

The SSFAN and HYTRAN models of this type of actuator are based on the single piston, dual acting concept illustrated by Figure 32 . Multiple piston designs may be modeled if total piston areas and chamber volumes are summed to give an equivalent single piston actuator.

Since these actuators see widespread and varied application, they are usually sized to perform the specific function required of them. This does not encourage the concept of a "multi purpose" utility actuator to perform several different jobs on an aircraft. In view of this, what has been done in this section is to tabulate actual data of actuators that have been modeled (Figure 33) and present a piston/rod mass trend exhibited by these actuators (Figure 34). All of these actuators are used in utility system operations on a 22,000 pound strike fighter with 3000 psi hydraulic systems.

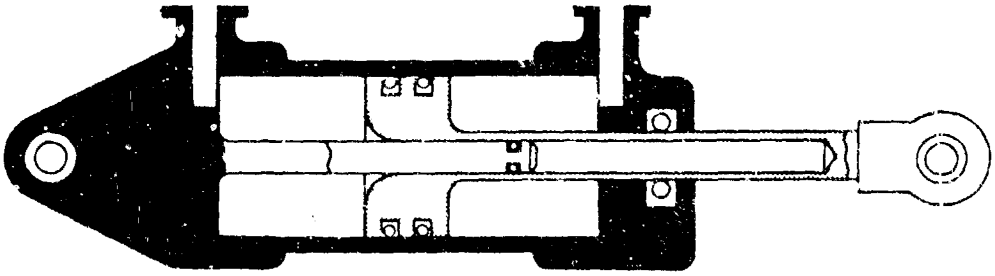


FIGURE 32 UTILITY ACTUATOR

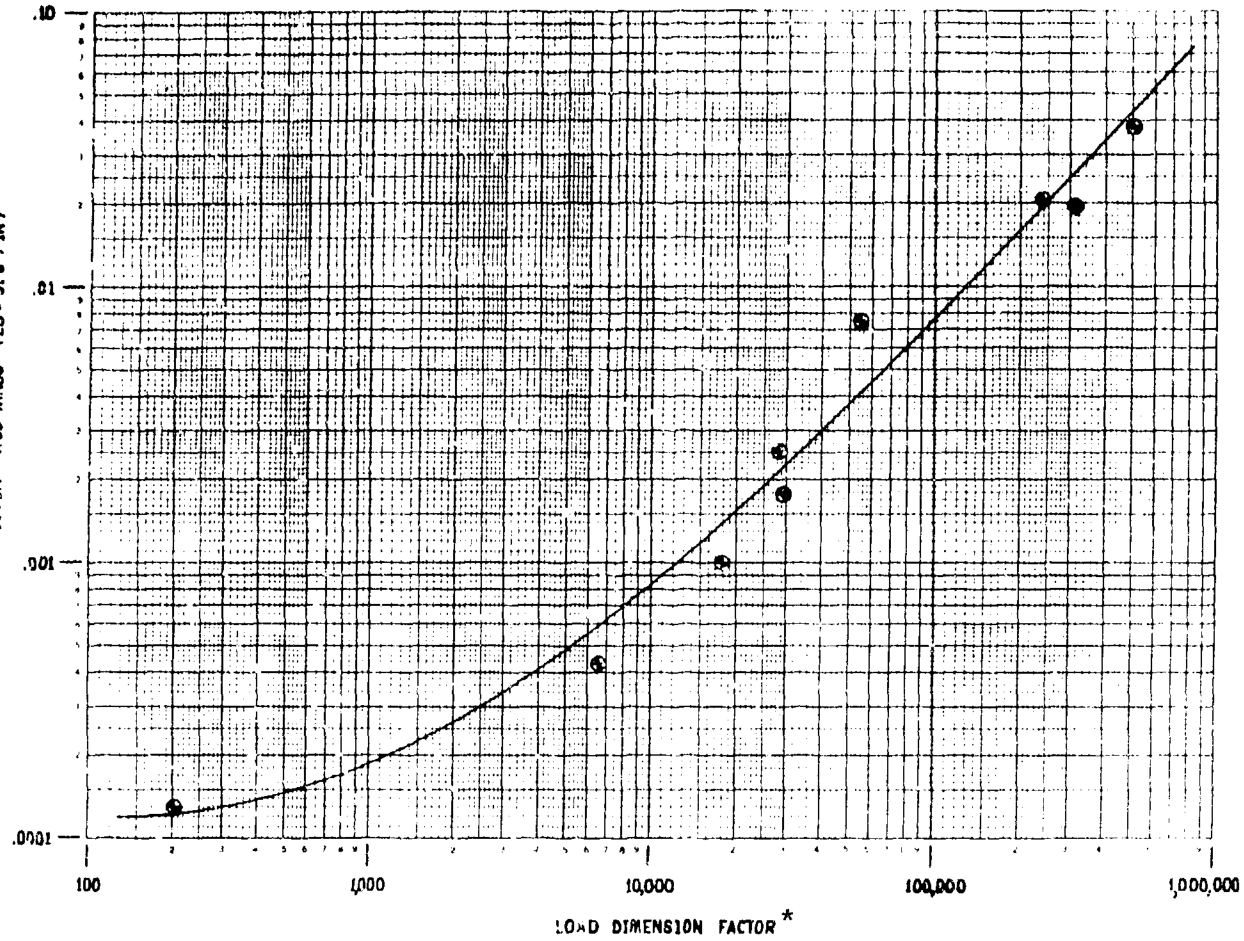
Element Type: Linear Utility Actuator

	Program	SSFAN	▨	HYTRAN
	Element Type	4	▨	102
Data Parameter	Dimensions	▨	▨	▨
Extend Port Size	IN or Dash #		▨	▨
Retract Port Size	IN or Dash #		▨	▨
Extend Piston Area	IN^2		▨	
Retract Piston Area	IN^2		▨	
Seal Friction	LB		▨	▨
External Load	LB	△1	▨	△1
Total Stroke	IN		▨	▨
Piston Position	IN	△1	▨	△1
Piston Diameter	IN		▨	▨
Control Valve Junction #	-	△2	▨	▨
Extend Chamber Vol @ Zero Stroke	IN^3	▨	▨	△1
Retract Chamber Vol @ Zero Stroke	IN^3	▨	▨	△1
Stroke from Zero to Max Position	IN	▨	▨	△1
Stroke from Zero to Min Position	IN	▨	▨	△1
Velocity Damping Factor	LB*SEC/IN	▨	▨	△3
Mass of Piston + Rod	$LB*SEC^2/IN$	▨	▨	

Notes:
△1 Dependent on Simulation
△2 Dependent on System Configuration
△3 Dependent on Design Velocity of Actuator

Actuator Function	Extend Port Size (Dash #)	Retract Port Size (Dash #)	Piston Extend Area (IN^2)	Piston Retract Area (IN^2)	Seal Friction (LB)	Operating Stroke (IN)	Piston Diameter (IN)	Velocity Damping Factor (LB*SEC/IN)	Piston & Rod Mass ($LB*SEC^2/IN$)
MLG Strut Extend & Retract	-6	-6	9.34	8.10	55	7.64	3.493	37.43	.0204
Landing Gear Door Capture Lock	-4	-4	.102	.102	7.2	.68	.36	1.06	.00013
Main Landing Gear Uplock	-4	-6	.873	.627	16	1.851	1.054	.864	.0004379
Main Landing Gear Door	-4	-4	1.90	1.46	23	3.889	1.554	5.323	.0025
Main Landing Gear Side Brace	-4	-4	2.05	.57	25	2.5	1.616	52.	.007514
Speedbrake	-8	-8	5.61	4.67	52	25.75	2.744	5.05	.0308
In-Flight Refuel Probe	-4	-4	2.38	1.94	25	3.47	1.741	36.03	.001744
NLG Strut Extend & Retract	-6	-6	10.28	8.80	50	8.756	3.618	25.69	.0195
NLG Door and Uplock	-4	-6	1.21	.908	19	3.796	1.242	4.505	.001

FIGURE 33 UTILITY ACTUATOR DATA



* A pseudo-parameter inter-relating actuator force capability, working stroke and area ratio through the equation:

$$\text{Load Dimension Factor} = \frac{(3000 * \text{Extend Area} - 100 * \text{Retract Area}) * \text{Working Stroke} * \text{Extend Area}}{\text{Retract Area}}$$

where all areas are in inches^2 and working stroke is in inches.

NOTE: For all steel piston/rod combinations in 3000 psi applications

FIGURE 34 PISTON/ROD MASS TRENDS OF UTILITY ACTUATORS

b. Valve Controlled

The linear valve controlled actuator is essentially a piston actuator/ four-way valve combination that's manifolded together.

In aircraft hydraulic systems, these devices are primarily used for flight control surface actuation. The close proximity of the valve and actuator is ideal for the feedback linkages often necessary in this application, and the manifolding of control valve and actuator provides a more compact and lighter weight method of actuation than a remote actuator/valve configuration.

Since flight control surface actuation is so critical to aircraft operation, hydraulic actuators that perform this function are often multi-system devices. As such, they can maintain their function even with the failure of one of their hydraulic systems. The HYTRAN component type #108 is a model of just such a two system actuator. Figure 35 illustrates the tandem actuator concept that can be modelled with component type #108. A parallel, dual system actuator (where the pistons are side-by-side and the rods are yoked together outside of the actuator barrel) may also be modelled by component type 108. No SSFAN or HSFR dual system actuator model exists at this time.

The single piston valve controlled actuator, Figure 36 , exists in HYTRAN as a type #101 component and may be modelled in SSFAN by combining a simple actuator (type #4) and a four-way, three position valve (type #34). No provisions exist for modelling this component in HSFR.

As with utility actuators, valve controlled actuators are highly specific and generally do not exist for "general purpose" applications. Since this does not lead to any universal data trends, what has been done here is to tabulate specific data of actuators that have been modelled and provide a graph for estimating piston + rod mass based on these actuators (Figures 37, 38 and 39). Again, as with the utility actuators, all of this data comes from components used on a 22,000 pound strike fighter with 3000 psi hydraulic systems.

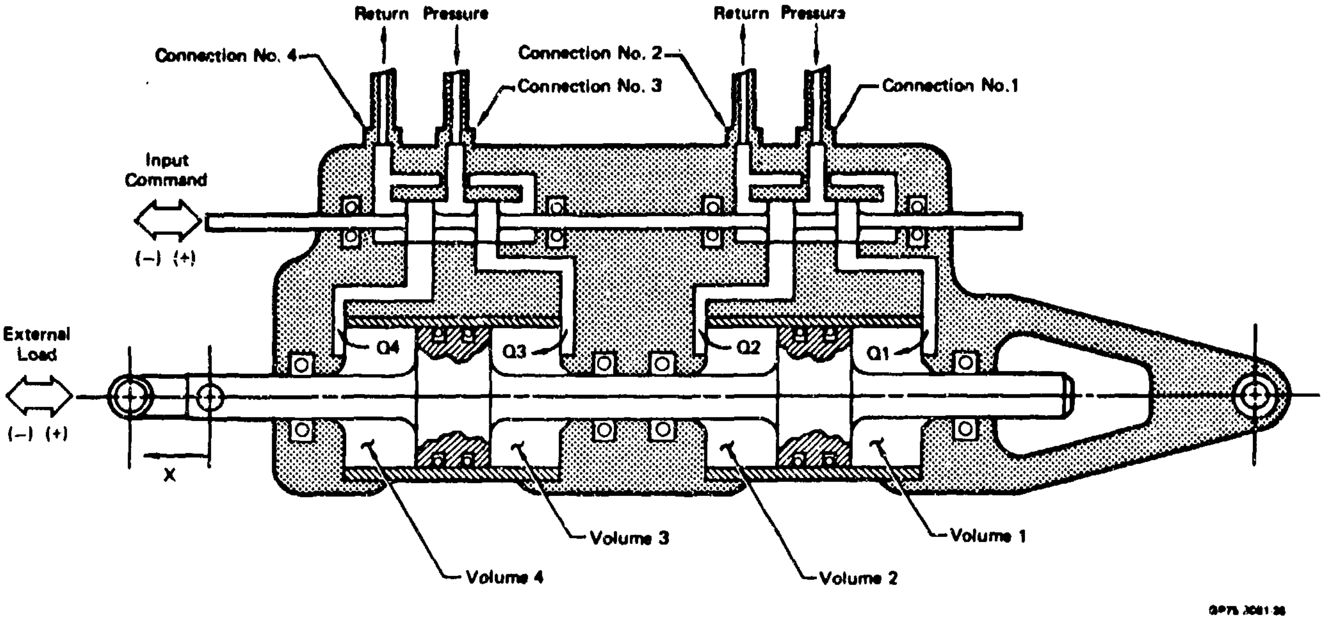


FIGURE 35 TANDEM ACTUATOR

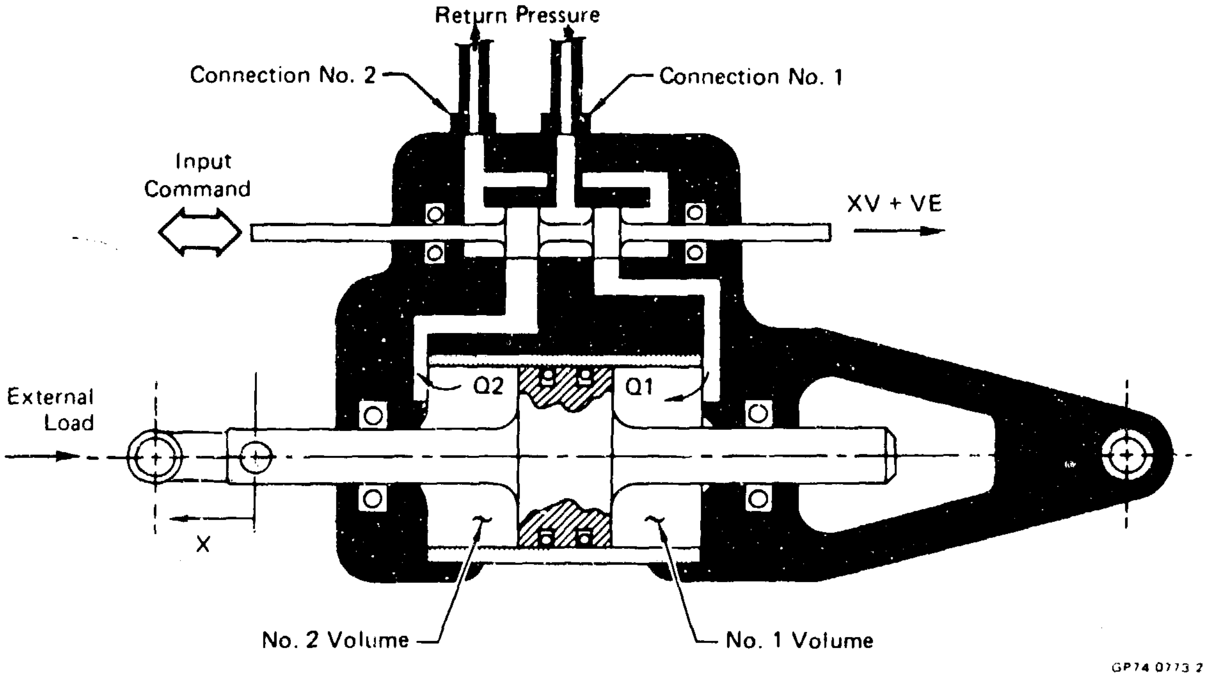


FIGURE 36 SINGLE PISTON, VALVE CONTROLLED ACTUATOR

Element Type: Linear Valve Controlled Actuators

	Program	SSFAN	▨	HYTRAN
	Element Type	34 + 4	▨	101,108
Data Parameter	Dimensions	▨	▨	▨
Pressure Port Size	IN or Dash #		▒	▒
Return Port Size	IN or Dash #		▒	▒
Valve Cylinder Port Sizes	IN or Dash #	△1	▒	▒
Actuator Port Sizes	IN or Dash #	△1	▒	▒
Rated Valve Flow From "Pressure" to Either Cylinder Port (Full Open Valve)	GPM	△2	▒	▒
Rated Pressure Drop for Rated Flow (Full Open Valve)	PSI	△3	▒	▒
Fluid Viscosity at Rated Conditions	Centistokes		▒	▒
Valve Leakage From "Pressure" to Either Cylinder Port (Valve Closed)	GPM		▒	▒
Pressure Drop for Leakage Conditions	PSI		▒	▒
Valve Operating Control Code	-	△4	▒	▒
Piston #1 Extend Area	IN^2		▒	
Piston #1 Retract Area	IN^2		▒	
Piston #2 Extend Area	IN^2	▒	▒	△5
Piston #2 Retract Area	IN^2	▒	▒	△5
Seal Friction	LB		▒	▒
External Load	LB	△4	▒	
Total Stroke	IN		▒	▒
Piston Position	IN	△4	▒	
Piston Diameter	IN		▒	▒
Control Valve Junction #	-	△6	▒	▒

Element Type: Linear Valve Controlled Actuators (Continued)

	Program	SSFAN	▨	HYTRAN
	Element Type	34 + 4	▨	101,108
Data Parameter	Dimensions	▨	▨	▨
Slot Width: Conn #1 to Chamber #1	IN	░	░	
Slot Width: Conn #1 to Chamber #2	IN	░	░	
Slot Width: Conn #2 to Chamber #1	IN	░	░	
Slot Width: Conn #2 to Chamber #2	IN	░	░	
Slot Width: Conn #3 to Chamber #3	IN	░	░	△5
Slot Width: Conn #3 to Chamber #4	IN	░	░	△5
Slot Width: Conn #4 to Chamber #3	IN	░	░	△5
Slot Width: Conn #4 to Chamber #4	IN	░	░	△5
Chamber #1 Volume @ Zero Stroke	IN^3	░	░	
Chamber #2 Volume @ Zero Stroke	IN^3	░	░	
Chamber #3 Volume @ Zero Stroke	IN^3	░	░	△5
Chamber #4 Volume @ Zero Stroke	IN^3	░	░	△5
Stroke From Zero to Max Position	IN	░	░	△4
Stroke From Zero to Min Position	IN	░	░	△4
Velocity Damping Factor	LB*SEC/IN	░	░	△7
Mass of Pistons + Rod	LB*SEC^2/IN	░	░	
Valve Position History	IN	░	░	△4
Valve Time History	SEC	░	░	△4

NOTES: △1 Make same as pressure port size unless manifold passages are known

△2 Obtainable from piston areas and maximum ram velocity

NOTES: (Continued)

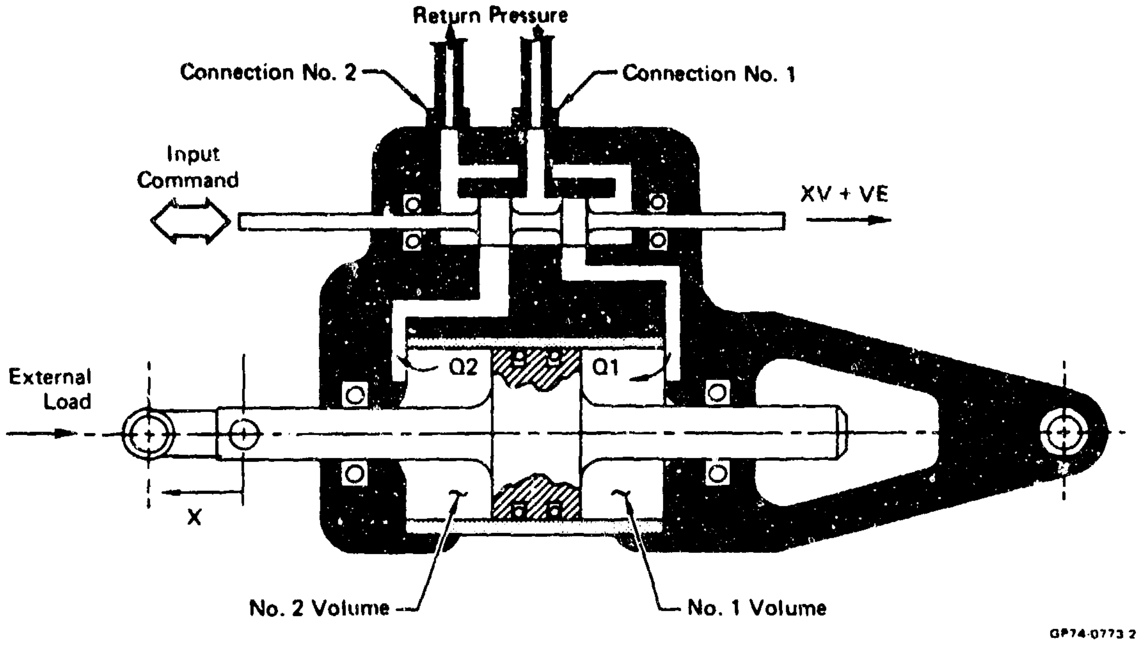
△3 One half of port-to-port pressure drop @ max ram velocity

△4 Dependent on simulation

△5 Type #108 only

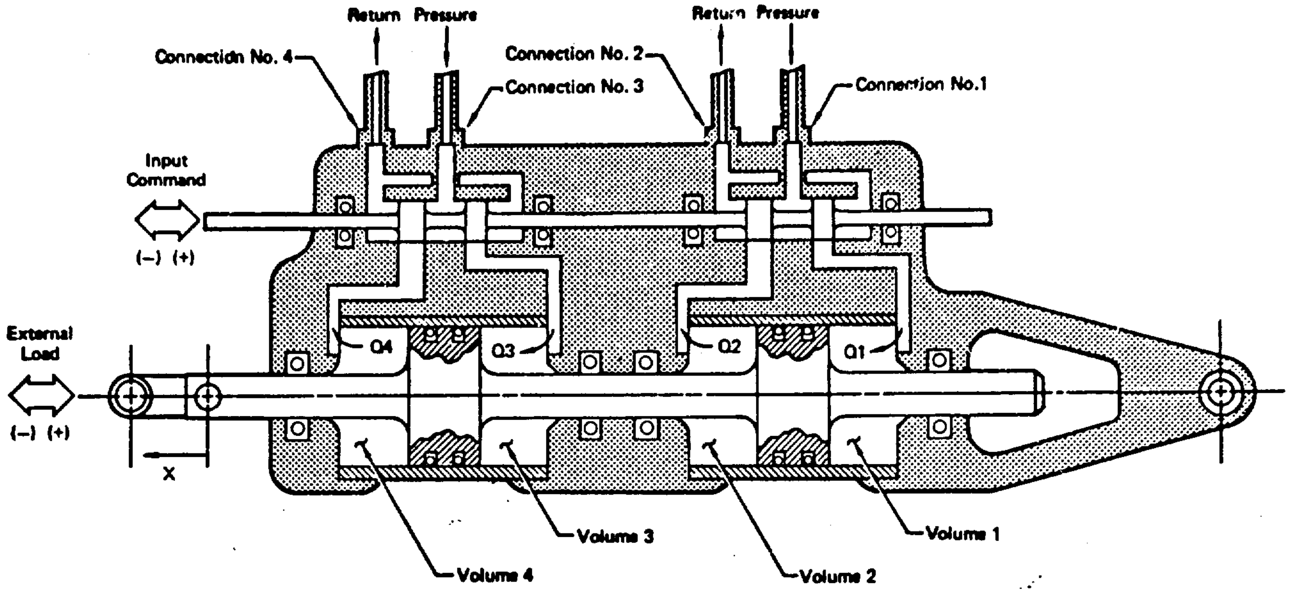
△6 Dependent on system configuration

△7 Dependent on design velocity of actuator



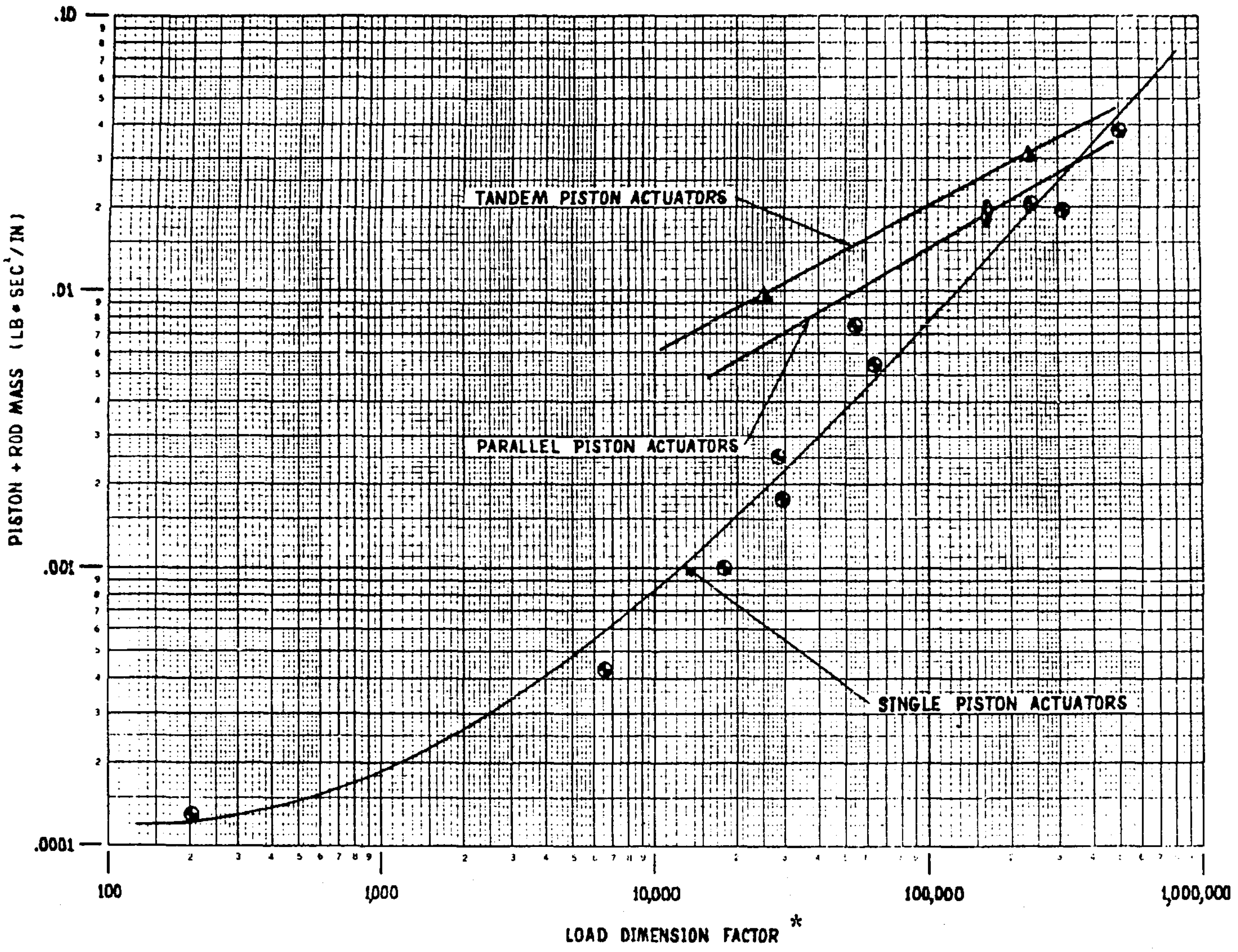
	Units	F18 Rudder	Aileron
Piston Configuration	-	Tandem	Single
Min Ram Velocity	IN/SEC	1.33	7.13
Port to Port ΔP @ Min Ram Velocity	PSI	2000	2000
Total Piston Extend Area	IN^2	5.64	4.71
Total Piston Retract Area	IN^2	5.07	4.40
Extend Chamber Vol. @ Zero Stroke	IN^3	4.44	10.3
Retract Chamber Vol. @ Zero Stroke	IN^3	3.98	9.64
Stroke from Zero to Full Retracted	IN	-.715	-2.19
Stroke from Zero to Full Extended	IN	+.715	+2.19
Velocity Damping Factor	LB*SEC/IN	75.19	14.03
Mass of Pistons + Rod	$LB*SEC^2/IN$	.0095574	.005439
Slot Width: Conn #1 to Volume #1	IN	.092	.3565
Slot Width: Conn #1 to Volume #2	IN	.092	.3565
Slot Width: Conn #2 to Volume #1	IN	.092	.3565
Slot Width: Conn #2 to Volume #2	IN	.092	.3565
Valve Metering Stroke	IN	+.030	+.030
Seal Friction	LB	100	100
Pressure Port Size	Dash #	-4	-6
Return Port Size	Dash #	-4	-6
Fluid Viscosity @ Rated Conditions	Centistokes	7.5	7.5

FIGURE 37 SINGLE SYSTEM VALVE CONTROLLED ACTUATORS



	Units	Stabilizer	Trail. Edge Flap
Piston Configuration .	-	Tandem	Parallel
Rated Max Ram Velocity	IN/SEC	7.1	3.248
Port to Port ΔP @ Max Ram Velocity	PSI	2000	2000
Fluid Viscosity for Rated Conditions	Centistokes	7.5	7.5
Piston Area #1	IN^2	5.639	2.654
Piston Area #2	IN^2	4.86	2.048
Piston Area #3	IN^2	4.86	2.654
Piston Area #4	IN^2	4.86	2.048
Volume #1 @ Zero Stroke	IN^3	21.07	2.0
Volume #2 @ Zero Stroke	IN^3	18.3	18.63
Volume #3 @ Zero Stroke	IN^3	18.3	2.0
Volume #4 @ Zero Stroke	IN^3	18.3	18.63
Slot Width: Conn #1 to Volume #1	IN	.272	.110
Slot Width: Conn #1 to Volume #2	IN	.252	.082
Slot Width: Conn #2 to Volume #1	IN	.272	.110
Slot Width: Conn #2 to Volume #2	IN	.252	.082
Slot Width: Conn #3 to Volume #3	IN	.252	.110
Slot Width: Conn #3 to Volume #4	IN	.252	.082
Slot Width: Conn #4 to Volume #3	IN	.252	.110
Slot Width: Conn #4 to Volume #4	IN	.252	.082
Stroke From Zero to Fully Extended	IN	+3.56	+8.12
Stroke From Zero to Fully Retracted	IN	-3.56	0.0
Velocity Damping Factor	LB*SEC/IN	17.60	30.79
Mass of Pistons + Rod	LB*SEC^2/IN	.03005	.019
Valve Metering Stroke	IN	± .06	±.0305
Seal Friction	LB	125	100
Pressure Port Size	Dash #	-6	-4
Return Port Size	Dash #	-8	-6

FIGURE 38 DUAL SYSTEM VALVE CONTROLLED ACTUATORS.



* - A pseudo-parameter defined as:

$$\text{Load Dimension Factor} = \frac{(3000 * \text{TOTEXA} - 100 * \text{TOTRETA}) * \text{STROKE} * \text{TOTEXA}}{\text{TOTRETA}}$$

Where: TOTEXA = Total extend area of all pistons (IN^2)
TOTRETA = Total retract area of all pistons (IN^2)
STROKE = Working stroke of actuator (IN)

NOTES: For all steel piston/rod combinations

FIGURE 39 PISTON/ROD MASS TRENDS OF VALVE CONTROLLED LINEAR ACTUATORS

8. CHECK VALVES

Check valves are simple pressure operated, spring biased devices used in hydraulic systems to allow flow in only one direction. Several different types exist, but the kind most often used in aircraft hydraulic systems is the poppet type, illustrated by Figure 40 . Though other types may be modelled, the data in this section is based on poppet type check valves.

When modeled with the appropriate data, the check valve can also be used to simulate high pressure single stage relief valves.

Figures 41 , 42 and 43 provide representative check valve data for all three programs.

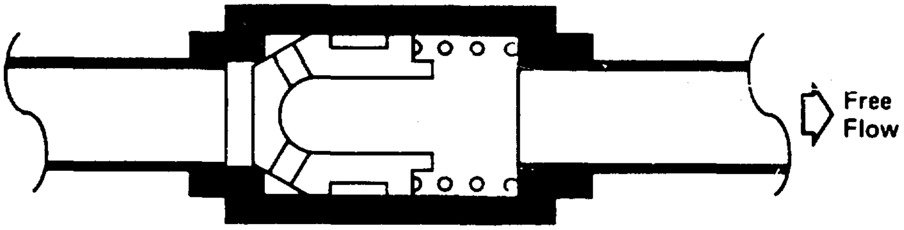


FIGURE 40 POPPET TYPE CHECK VALVE

Element Type: Check Valve

	Program	SSFAN	HSFR*	HYTRAN
	Element Type	3	N Type 4 K Type 0	31
Data Parameter	Dimensions	▨	▨	▨
Cracking Pressure	PSID		▨	▨
Poppet Mass	LB*SEC^2/IN	▨	▨	
Spring Constant	LB/IN	▨	▨	
Maximum Poppet Stroke	IN	▨	▨	
Spring Preload	LB	▨	▨	
Inlet Size	IN or Dash #		▨	▨
Outlet Size	IN or Dash #		▨	▨
Valve Gain	PSI/CIS	▨		▨
Overboard Flow	CIS	▨		▨
Poppet Area	IN^2	▨	▨	
Full Flow Area	IN^2	▨	▨	
Damping Factor	LB*SEC/IN	▨	▨	

NOTES:
* - HSFR NTYPE 14 if Terminating Element

Check Valve Dash Size	-4	-6	-8	-10	-12	-16	-20
Inlet Size	-4	-6	-8	-10	-12	-16	-20
Outlet Size	-6	-8	-10	-12	-16	-20	-24
Cracking Pressure*(PSID)	5	5	5	5	5	5	5

FIGURE 41 SSFAN CHECK VALVE DATA

* Typical for simple line mounted check valves

INLET TUBE SIZE	POPPET AREA (IN^2)	FULL FLOW AREA(IN^2)	POPPET MASS (LB SEC^2/IN)	SPRING PRE-LOAD(LB)	SPRING CON-STANT(LB/IN)	DAMPING FACTOR	POPPET DIS-PLAC. (IN)
-4	.01966	.020608	.0000041967	.0983	.6052	0.1	.11829
-6	.0455	.051084	.0000112242	.2275	.6859	0.1	.12915
-8	.0825	.086524	.000022557	.4125	.7905	0.1	.14221
-10	.1310	.148283	.000038763	.655	.9328	0.1	.1582
-12	.1910	.252803	.000060331	.955	1.1377	0.1	.17824
-16	.3465	.382608	.000121247	1.7325	2.0287	0.1	.23872
-20	.5498	.622028	.000208355	2.7475	9.3564	0.1	.36132

FIGURE 42 HYTRAN CHECK VALVE DATA (5 PSID CRACKING PRESSURE)

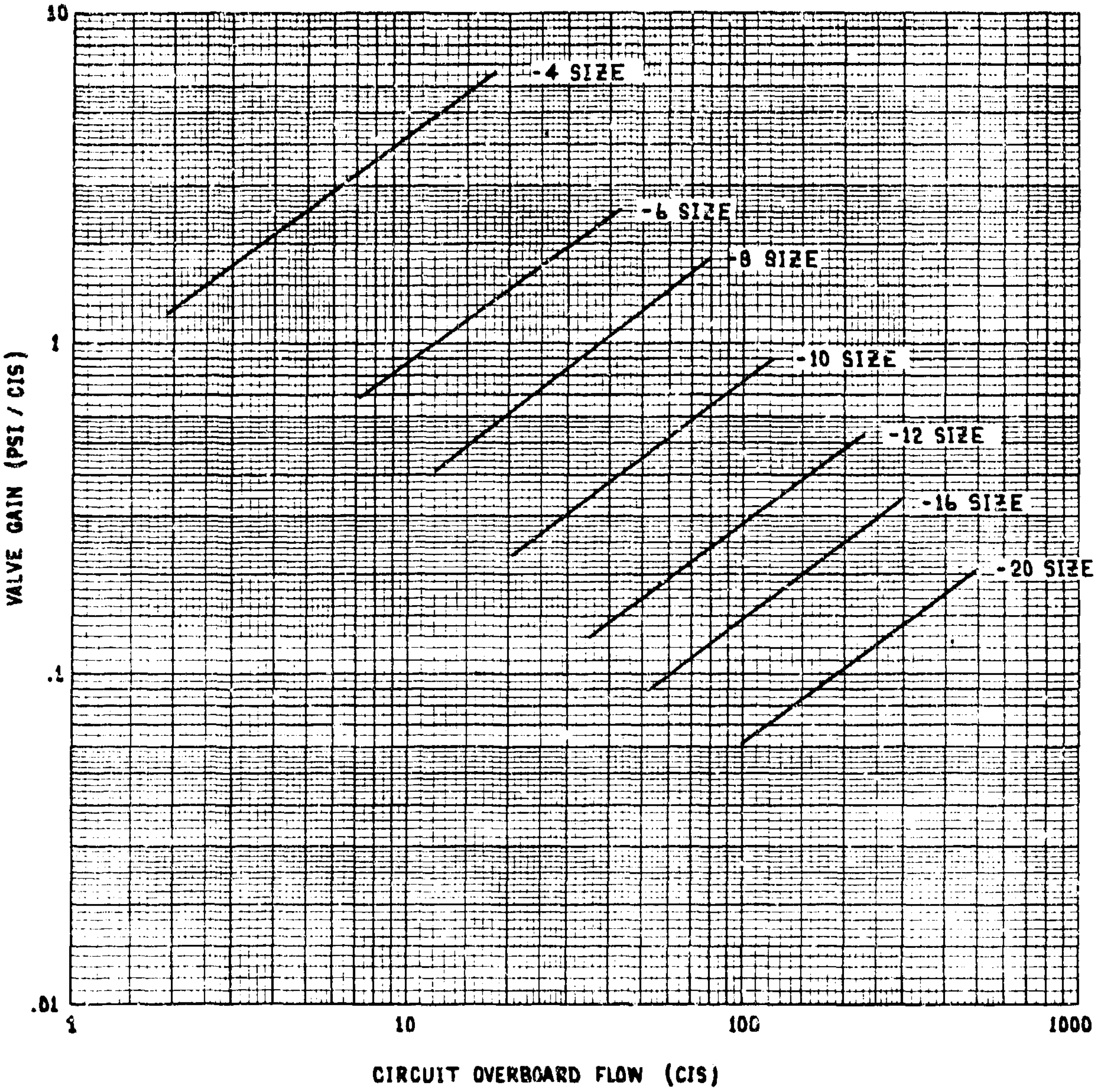


FIGURE 43 HSFR CHECK VALVE DATA

9. RESTRICTORS

a. One-Way

The one-way restrictors modeled by SSFAN, HYTRAN, and HSFR are simple pressure operated, spring biased devices which allow free flow in one direction while restricting flow in the opposite direction.

As shown by Figure 44 , these devices are essentially poppet type check valves with a metering orifice drilled through the poppet. Since the flow/pressure drop characteristics of one-way restrictors are dependent on the flow direction, their major usage is as timing devices in subsystems where the desired actuator extend rate is different from the desired actuator retract rate.

Due to their purpose, one-way restrictors do not exhibit any relationship between fitting size and rated restricted flow. Since they are, however, very similar to check valves, there is a correlation between fitting size and free flow characteristics. Figures 45 and 46 provide information on the check valve characteristics of different size one way restrictors, while Figures 47, 48, 49, 50 , and 51 show orifice size/pressure drop relationships that should exist for the restricted flow direction.

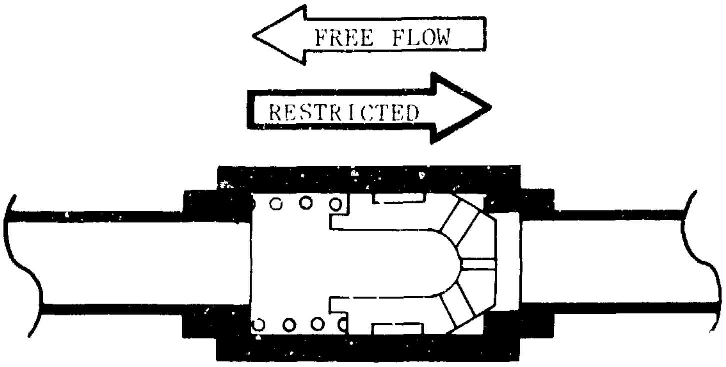


FIGURE 44 POPPET TYPE ONE-WAY RESTRICTOR

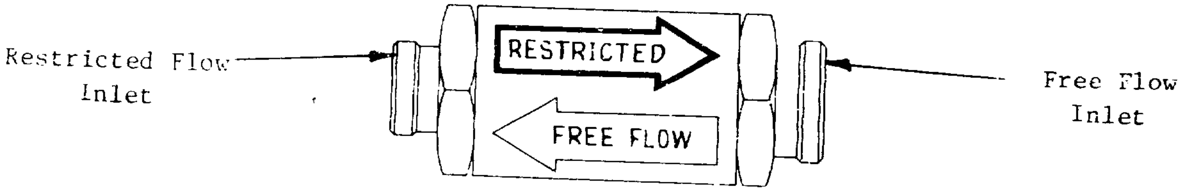
Element Type: One-Way Poppet
Type Restrictor

Data Parameter	Program	SSFAN	HSFR △1	HYTRAN
	Element Type	31	NTYPE 4 KTYPE 0	33
Data Parameter	Dimensions	▨	▨	▨
Free Flow Inlet Size	IN or Dash #		▨	▨
Restricted Inlet Size	IN or Dash #		▨	▨
Orifice Diameter	IN	△2	▨	
Discharge Coefficient	-	△3	▨	
Free Flow Cracking Pressure	PSID		▨	▨
Free Flow Rated Pressure Drop	PSID		▨	▨
Free Flow Rated Q	GPM		▨	▨
Valve Gain	PSI/CIS	▨		▨
Overboard Flow	CIS	▨		▨
Inlet (Poppet) Diameter	IN	▨	▨	
Outlet (Free Flow) Diameter	IN	▨	▨	
Poppet Mass	LB*SEC^2/IN	▨	▨	
Spring Constant	LB/IN	▨	▨	
Poppet Stroke	IN	▨	▨	
Spring Preload	LB	▨	▨	

NOTES: △1 HSFR NTYPE 14 if Terminating Element

△2 Option for Rated Pressure Drop (PSID)

△3 Option for Rated Flow (GPM)



SSFAN One-Way Restrictor Free Flow Data

Restricted Inlet Size (Dash #)	Free Flow Inlet Size (Dash #)	Cracking Pressure (PSID)	Free Flow Pressure Drop (PSID)	Free Flow at Pressure Drop (GPM)
-4	-6	5	20	4.12
-6	-8	5	40	7.95
-8	-10	5	50	15.0

HYTRAN One-Way Restrictor Free Flow Data (5 PSID Cracking)

Free Flow Inlet Size (Dash #)	Inlet (Poppet) Diameter (IN)	Outlet (Free Flow) Diameter (IN)	Poppet Mass $LB*SEC^2/IN$	Spring Constant (LB/IN)	Poppet Stroke (IN)	Spring Preload (LB)
-6	.271	.208	.0000030778	.4388	.064	.288
-8	.351	.243	.0000149888	.5151	.115	.483
-10	.424	.316	.0000443568	.5913	.165	.705

FIGURE 45 SSFAN AND HYTRAN ONE-WAY RESTRICTOR DATA

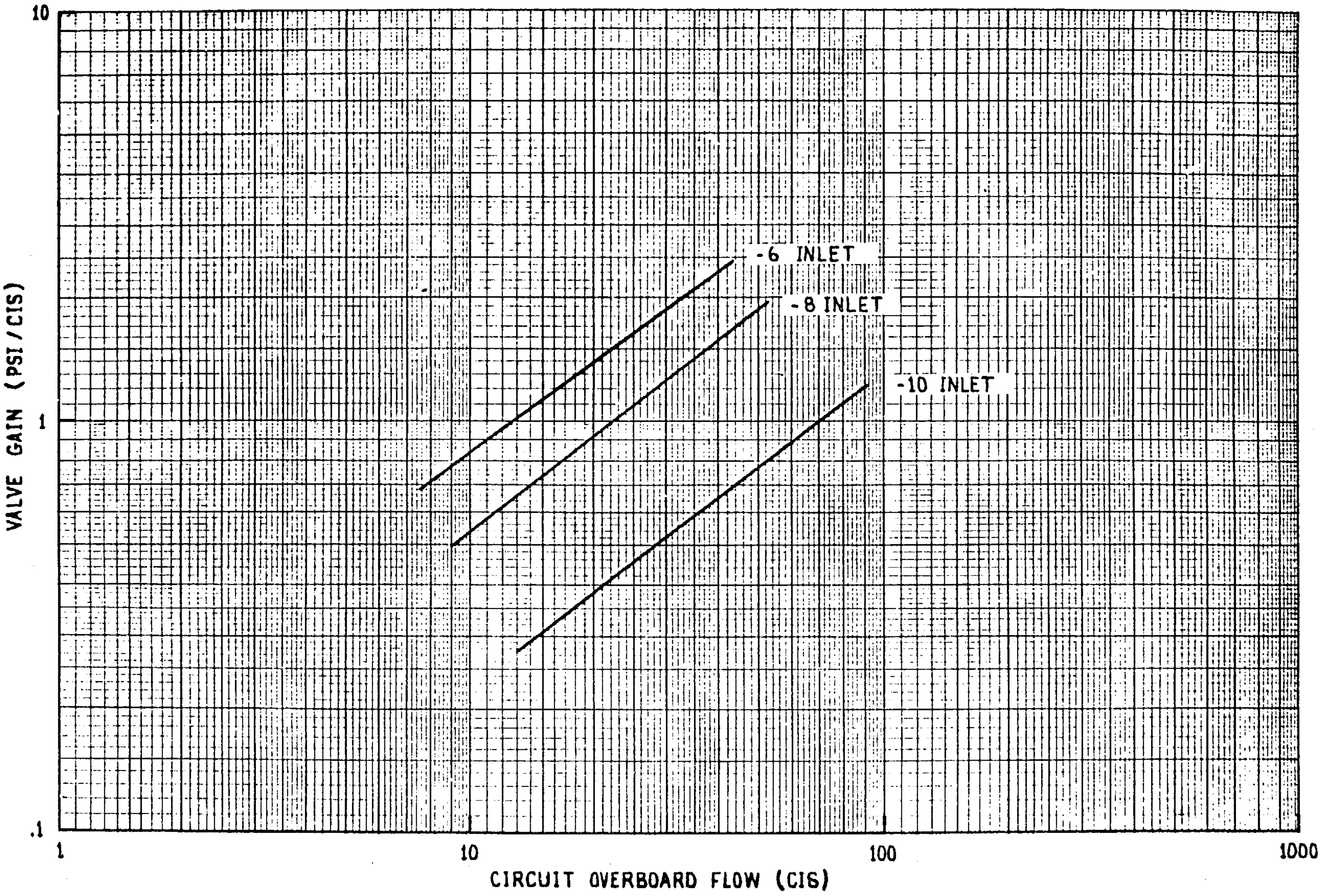


FIGURE 46 HSFR ONE-WAY RESTRICTOR FREE FLOW DATA

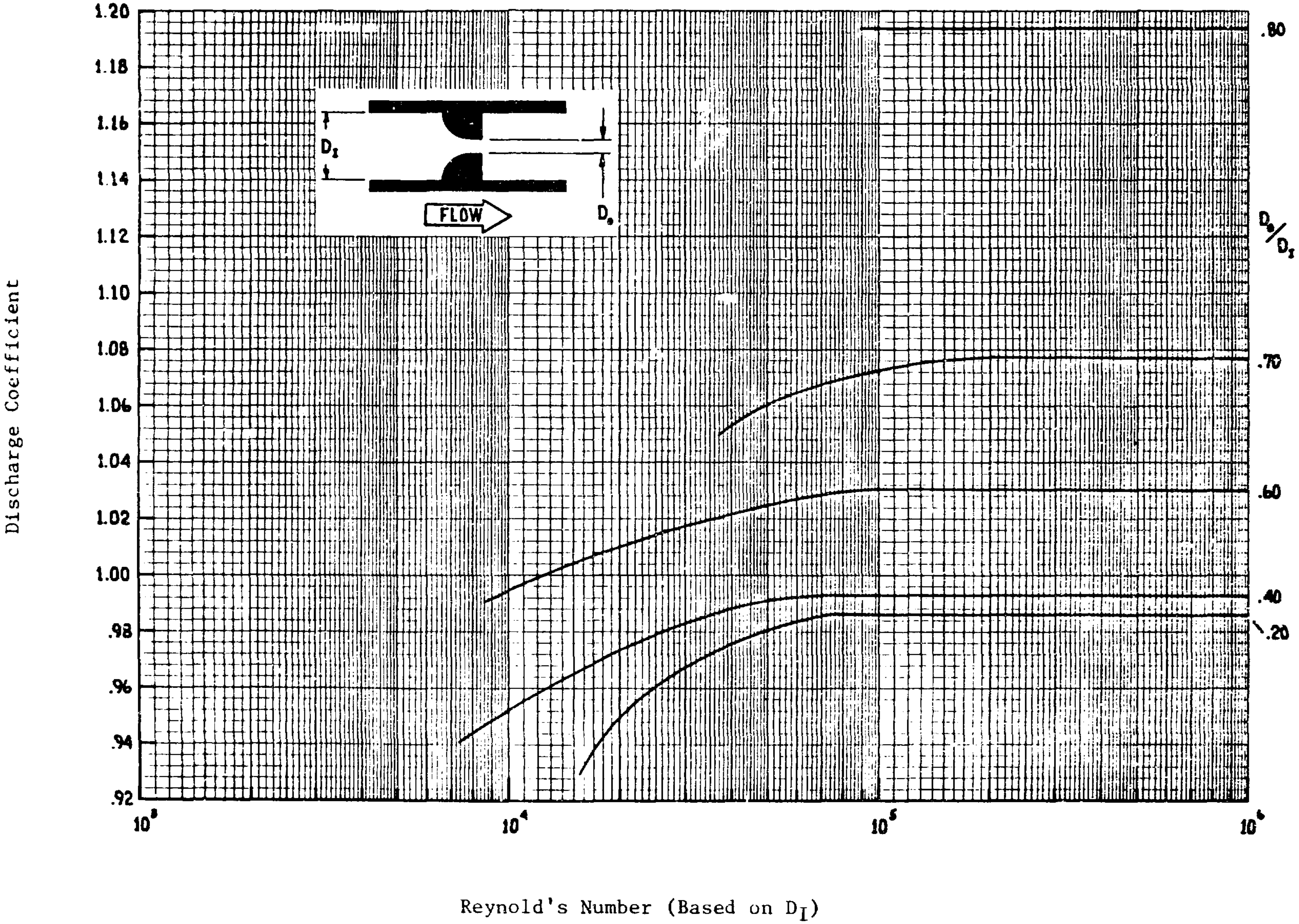


FIGURE 47 DISCHARGE COEFFICIENT TRENDS OF NOZZLED ORIFICES

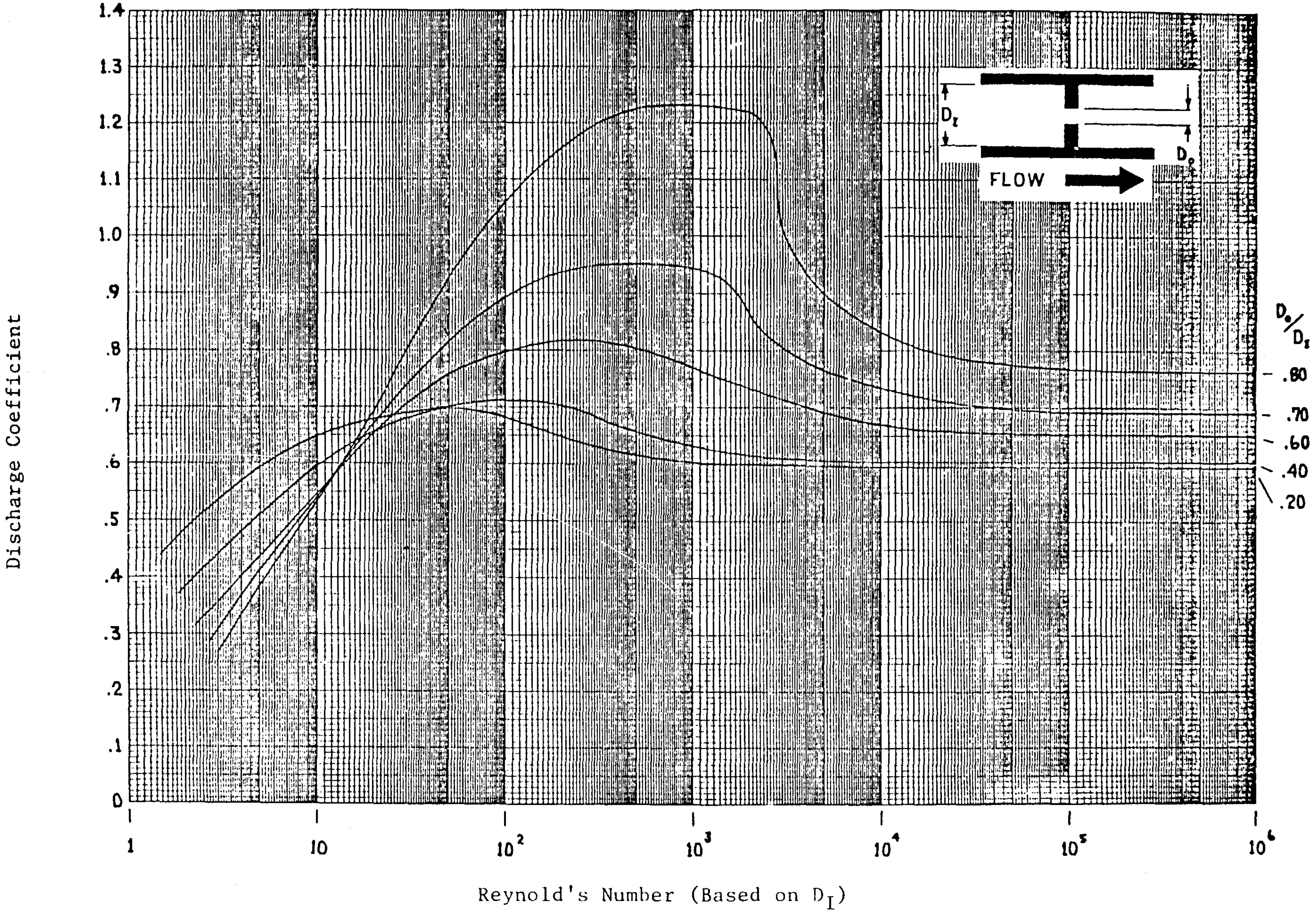


FIGURE 48 DISCHARGE COEFFICIENT TRENDS OF SHARP EDGED ORIFICES

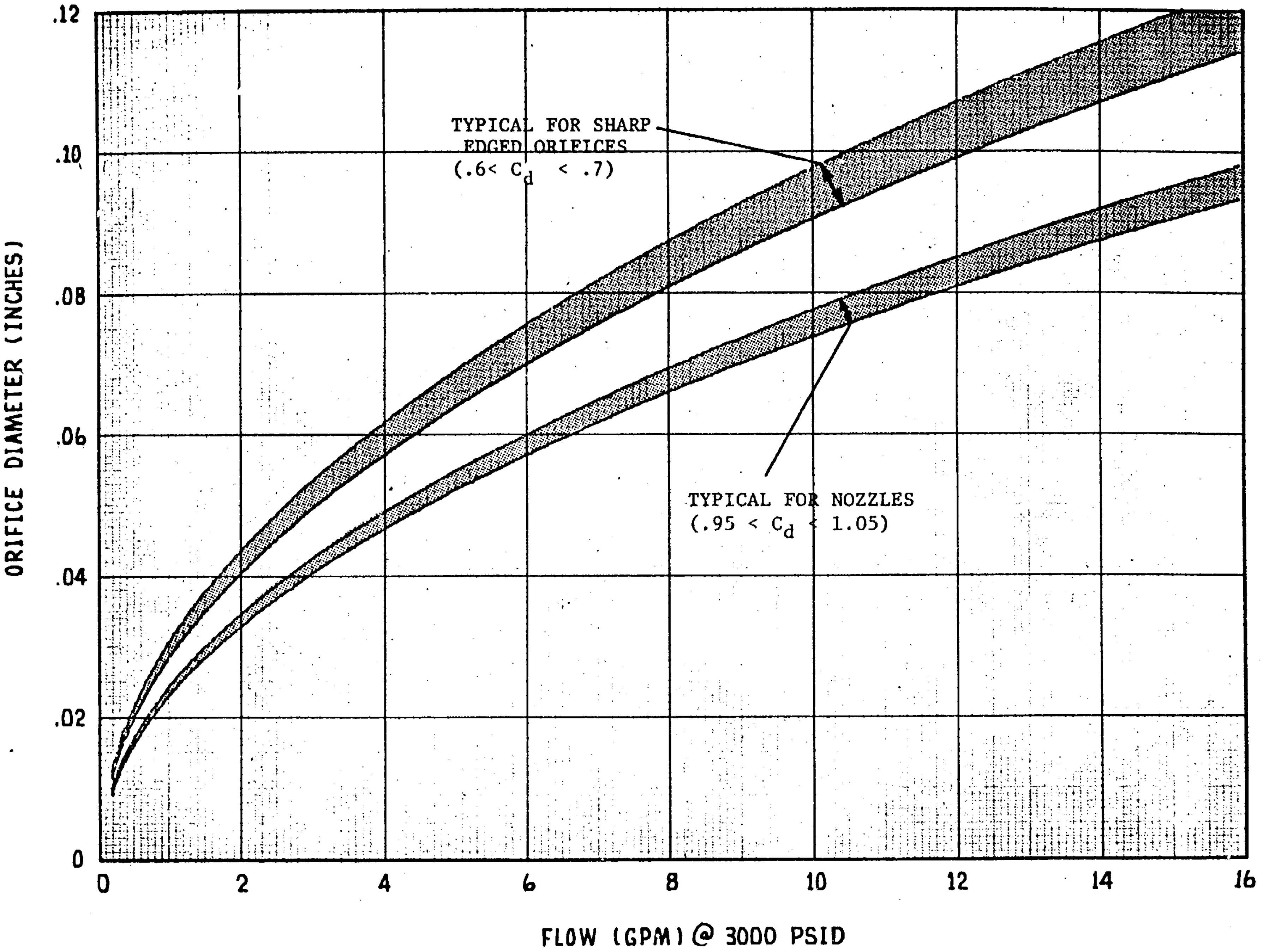


FIGURE 49 ORIFICE FLOW RELATIONSHIPS WITH MIL-H-5606B AT 100°F

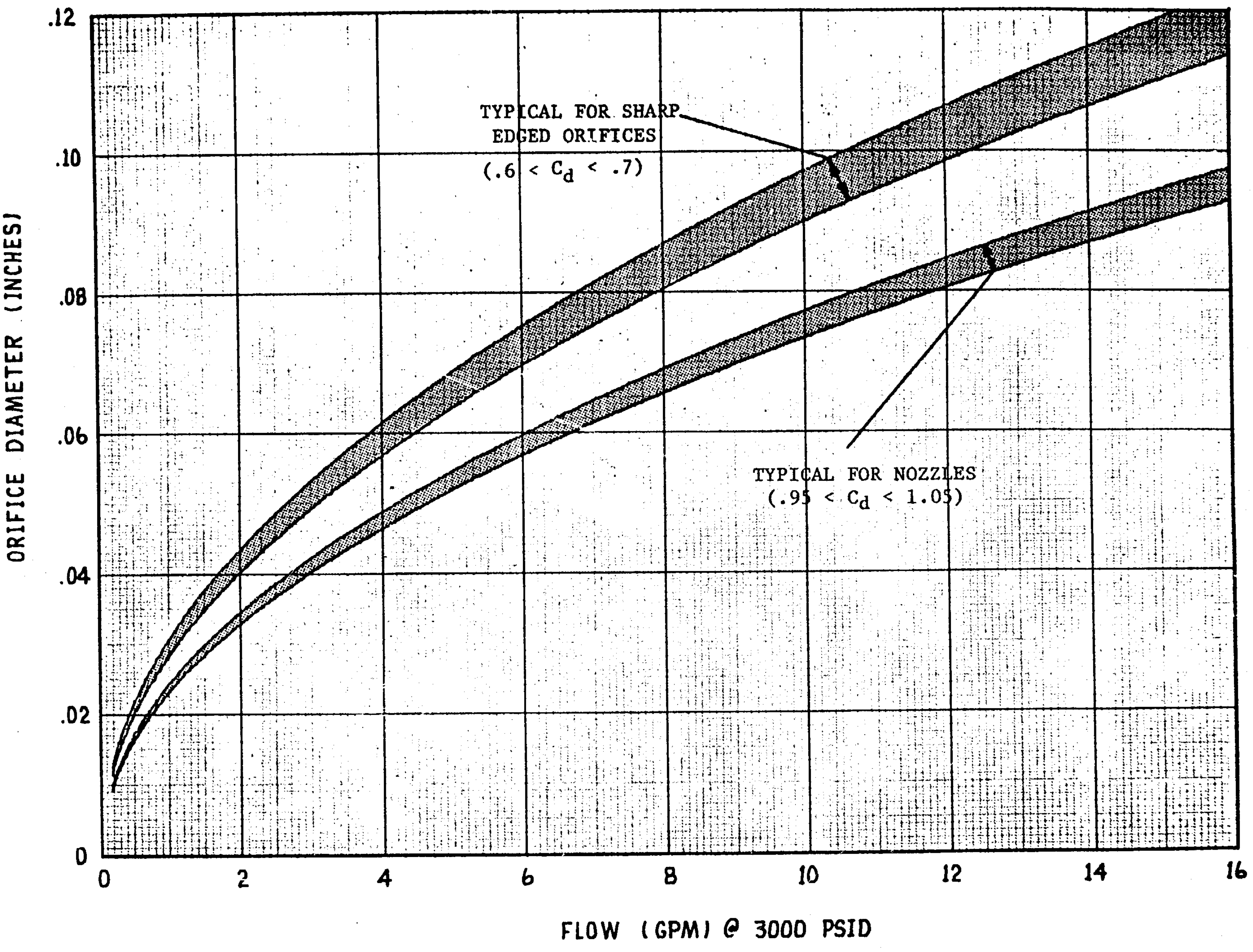


FIGURE 50 ORIFICE FLOW RELATIONSHIPS WITH MIL-H-83282 AT 100°F

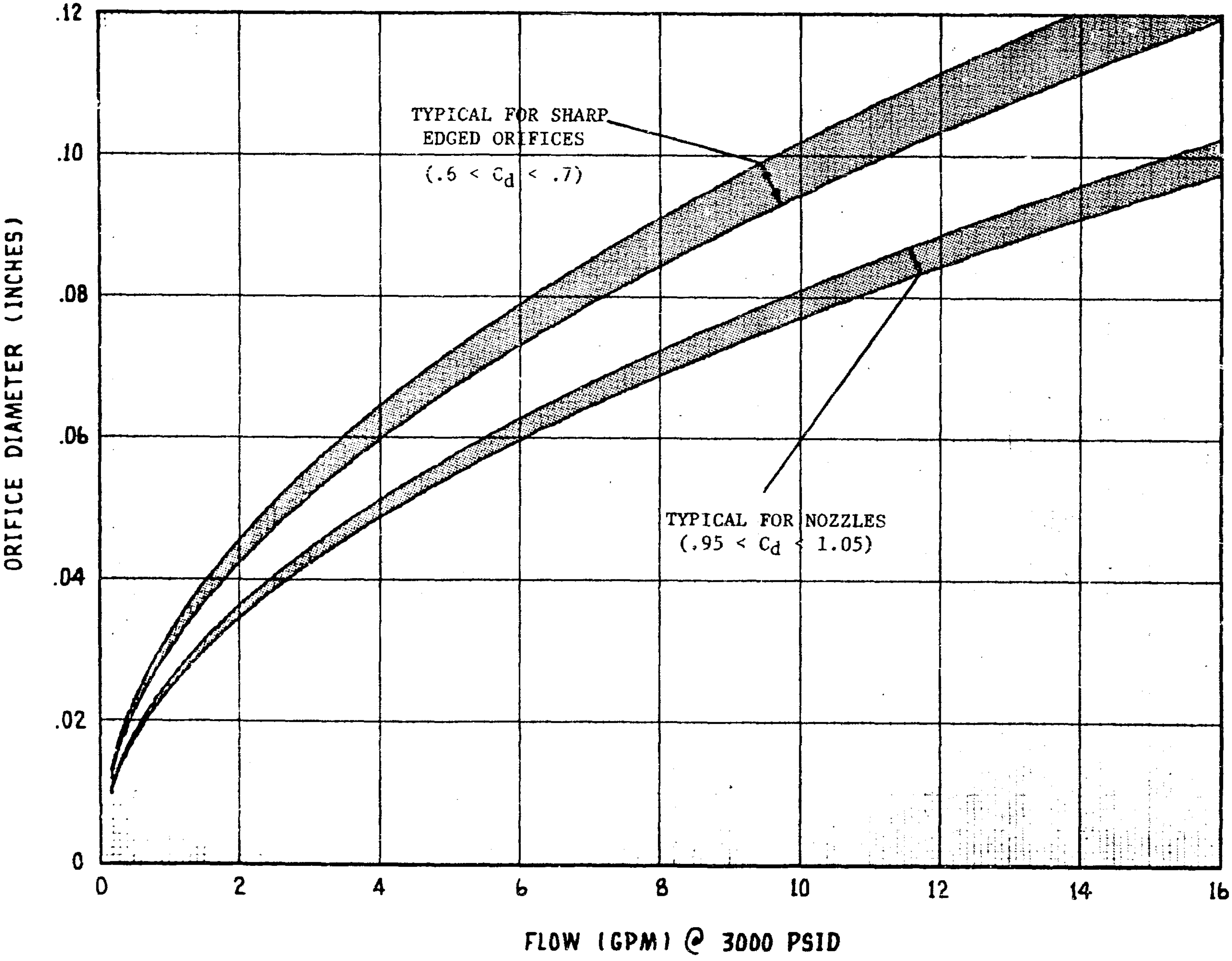


FIGURE 51 ORIFICE FLOW RELATIONSHIPS WITH SKYDROL 500B AT 100°F

b. Two-Way

Two-way restrictors are simple, flow limiting devices normally used to obtain desired system operating times. Apart from some very specialized units, a two-way restrictor is simply a single orifice or nozzle placed in the flow path (be it a line, port, or internal component passage) that is to be controlled (Figure 52).

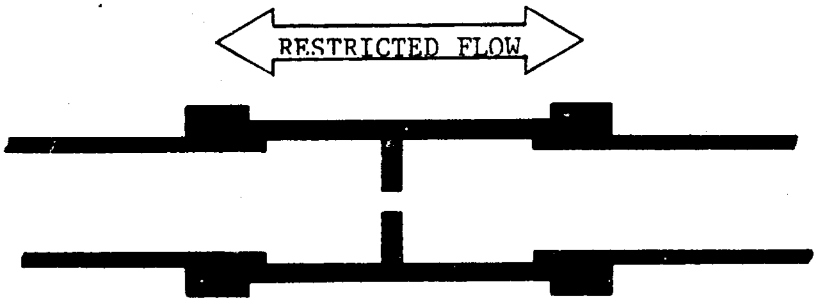


FIGURE 52 TWO-WAY ORIFICE TYPE RESTRICTOR

The computer models of a two-way restrictor are based on the square law (i.e. $Q \alpha \sqrt{\Delta P}$) relationship exhibited by nozzles and orifices, and assume that the flow/pressure drop characteristic is the same for flow in either direction.

Due to their purpose, restrictors don't exhibit any relationship between their inlet dash size and flow rating. To present data of actual restrictors that have been modelled would be of little value to the user, since the chance that he will encounter the same restrictor in his system simulations is small. In view of this, what has been done for this component is to provide graphs of basic restrictor relations, which the user may utilize to select restrictor data based on the system being modelled and the restrictor in question. Figures 47,48,49,50 and 51 provide this information.

Element Type: Two-Way Orifice Restrictor

	Program	SSFAN	HSFR[1]	HYTRAN
	Element Type	32	NTYPE 4 KTYPE 0	41
Data Parameter	Dimensions	▨	▨	▨
Inlet Size	IN or Dash #		▨	▨
Outlet Size	IN or Dash #		▨	▨
Orifice Diameter	IN	[2]	▨	[2]
Discharge Coefficient	-	[2]	▨	[2]
Rated Flow	[3]	[4]	▨	[4]
Rated Pressure Drop	PSID	[4]	▨	[4]
Rated Fluid	-	▨	▨	[4]
Rated Fluid Temperature	°F	▨	▨	[4]
Valve Gain	PSI/CIS	▨		▨
Overboard Flow	CIS	▨		▨

NOTES:

[1] NTYPE 14 IF Terminating Element

[2] Necessary for Orifice Dimension Input Option

[3] GPM for SSFAN, CIS for HYTRAN

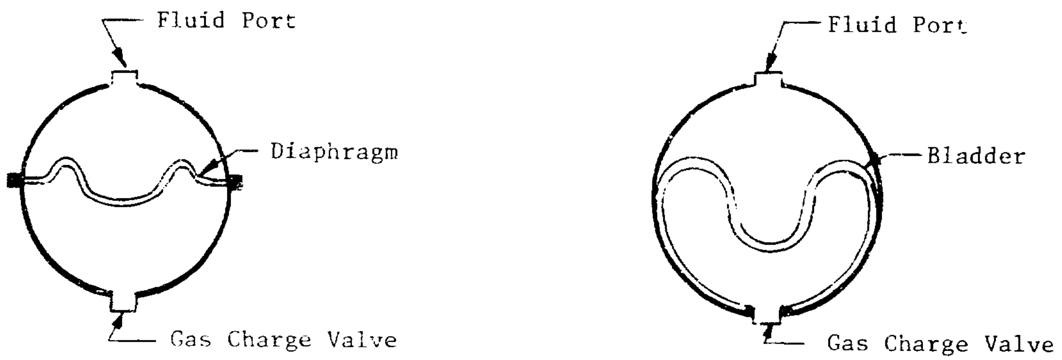
[4] Necessary for Rated Condition Input Option

10. ACCUMULATORS

Accumulators are used for the purpose of storing fluid energy. In order to prevent direct contact between the gas and the fluid, the accumulators are made with diaphragms, bladders or pistons, see Figure 53. Using a self-displacing accumulator requires no additional reservoir capacity, as all the fluid stored in the pressure side of the accumulator is returned to the low pressure side of the accumulator during the discharge cycle. Figure 54 provides SSFAN and HYTRAN data.

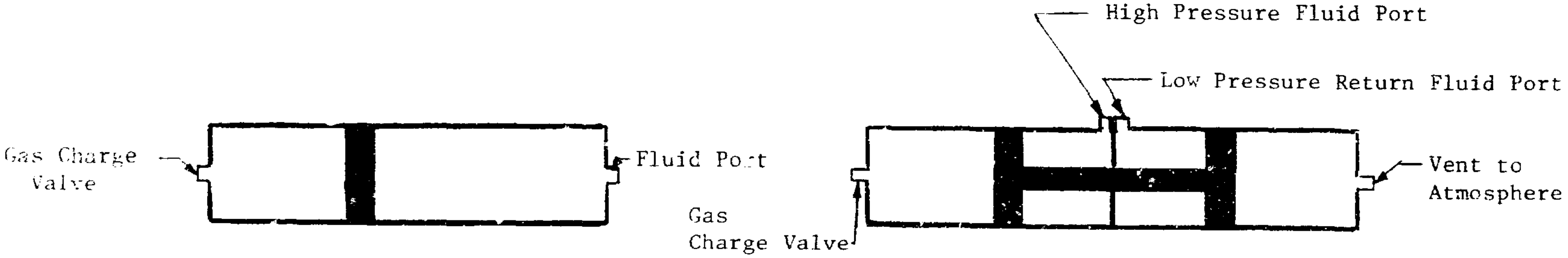
Element Type: Accumulator

	Program	SSFAN	HYTRAN
	Element Type	7	71
Data Parameter	Dimensions	▨	▨
Minimum Gas Volume	IN^3		
Precharge (Maximum) Gas Volume	IN^3		▨
Minimum Oil Volume	IN^3		
Maximum Oil Volume	IN^3		
Precharge Gas Pressure	PSIG		
Precharge Gas Temperature	DEG F		



DIAPHRAM TYPE

BLADDER TYPE



PISTON TYPE

SELF-DISPLACING TYPE

FIGURE 53 ACCUMULATORS

Data Parameter	F-18 Emergency Brake Accumulator		F-18 APU Start Accumulator		F-15 JFS Accumulator	
▨	SSFAN	HYTRAN	SSFAN	HYTRAN	SSFAN	HYTRAN
Min Gas Vol (IN^3)	42	42	152	152	70	70
Prechg (Max) Gas Vol (IN^3)	92	▨	290	▨	215	▨
Min Oil Vol (IN^3)	0	0	0	0	30	30
Max Oil Vol (IN^3)	50	50	133	133	140	140
Prechg Gas Press (PSIG)	1500	1500	1950	1950	1500	1500
Prechg Gas Temp (°F)	70	70*	70	70*	70	70*

* Precharge Temperature is given at 70°F. HYTRAN input calls for precharge temperature at 60°F. Precharge pressures may have to be converted for HYTRAN input.

FIGURE 54 ACCUMULATOR DATA FOR SSFAN AND HYTRAN

11. PRIORITY VALVES

A priority valve is modeled as a parallel check valve/relief valve combination in the HYTRAN program. As shown in Figure 55 , the priority valve allows free flow from the outlet (connection #1) to the inlet (connection #2) through the check valve, and permits reverse flow when the pressure at connection #2 is sufficient to open the relief valve.

The HYTRAN priority valve model is instantaneous and does not have the spring/mass/damping effects. Consequently, the amount of input data is reduced.

The relief valve and check valve flow characteristics are taken from the operating ranges of the respective valves. The leakage impedance is the high gain characteristic of the relief and check valves when they are closed.

HYTRAN priority valve data values are shown in Figure 56 .

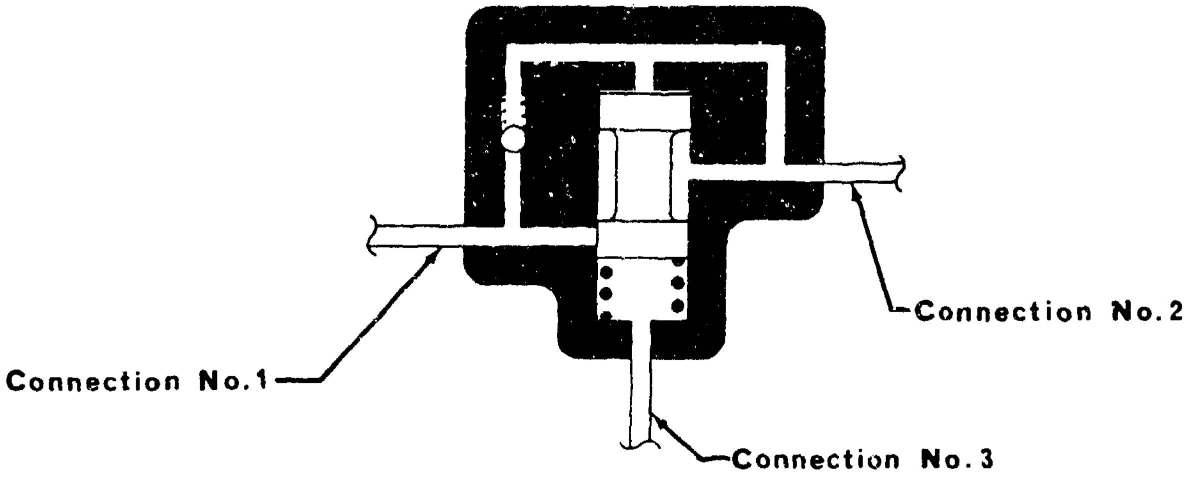


FIGURE 55 PRIORITY VALVE

Element Type: Priority Valve

	Program	SSFAN	HSFR	HYTRAN
	Element Type	▨	▨	32
Data Parameter	Dimensions	▨	▨	▨
Relief Valve Cracking Pressure	PSI	▒	▒	
Relief Valve Reseat Pressure	PSI	▒	▒	
Slope of Relief Valve Flow Characteristic	PSI/CIS	▒	▒	
Slope of Check Valve Flow Characteristic	PSI/CIS	▒	▒	
Leakage Impedance	PSI/CIS	▒	▒	
Check Valve Cracking Pressure	PSI	▒	▒	

DATA PARAMETER	UNITS	F-18 FORWARD PRIORITY VALVE	F-18 AFT PRIORITY VALVE
RELIEF VALVE CRACKING PRESSURE	PSI	2245.	2245.
RELIEF VALVE RESEAT PRESSURE	PSI	2200.	2500.
SLOPE OF RELIEF VALVE FLOW CHARACTERISTIC	PSI/CIS	.6957	1.9
SLOPE OF CHECK VALVE FLOW CHARACTERISTIC	PSI/CIS	.705	1.32
LEAKAGE IMPEDANCE	PSI/CIS	1.0E7	1.0E5
CHECK VALVE CRACKING PRESSURE	PSI	14.	14.

FIGURE 56 HYTRAN PRIORITY VALVE DATA

12. PULSCO ACOUSTIC FILTER

The Pulsco acoustic filter is a device for attenuating hydraulic system pressure pulsations.

NOTE

This device is manufactured and marketed by the

Pulsco Division
American Air Filter Company, Inc.
Louisville, Kentucky

The design and/or inventions disclosed are the property of American Air Filter Company, Inc., Pulsco Division.

The Pulsco acoustic filter consists basically of three volumes interconnected by three lines as shown in Figure 57 . Input data for a Pulsco type unit is in Figure 58.

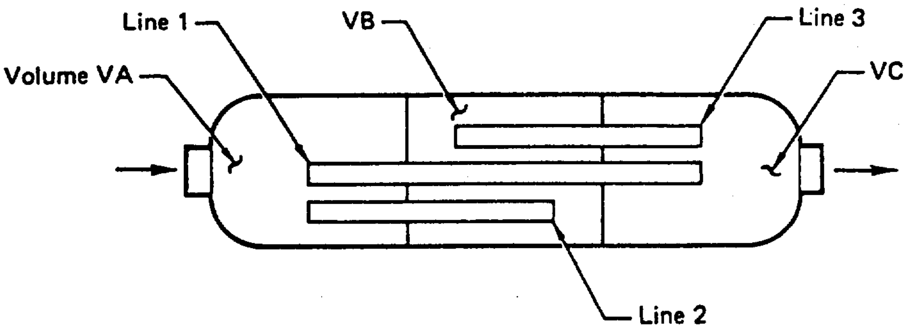


Figure 57 PULSCO ACOUSTIC FILTER

Element Type: Pulsco Acoustic Filter

	Program	SSFAN	HSFR	HYTRAN
	Element Type		NTYPE 2 KTYPE32	
Data Parameter	**Dimensions**			
Volume A (VA)	IN^3		Fig. 57*	
Volume B (VB)	IN^3			
Volume C (VC)	IN^3			
Line Length (Line 1)	IN			
Outside Diameter (Line 1)	IN			
Wall Thickness (Line 1)	IN			
Modulus of Elasticity (Line 1)	PSI			
Line Length (Line 2)	IN			
Outside Diameter (Line 2)	IN			
Wall Thickness (Line 2)	IN			
Modulus of Elasticity (Line 2)	PSI			
Line Length (Line 3)	IN			
Outside Diameter (Line 3)	IN			
Wall Thickness (Line 3)	IN			
Modulus of Elasticity (Line 3)	PSI			

* Note: All Parameters Referenced to Figure 57.

DATA PARAMETER	UNITS	FILTER
Volume A	IN^3	20
Volume B	IN^3	40
Volume C	IN^3	20
Line Length (Line 1)	IN	12
Outside Diameter (Line 1)	IN	1.0
Wall Thickness (Line 1)	IN	.051
Modulus of Elasticity (Line 1)	PSI	1.6E7
Line Length (Line 2)	IN	6.
Outside Diameter (Line 2)	IN	.50
Wall Thickness (Line 2)	IN	.028
Modulus of Elasticity (Line 2)	PSI	1.6E7
Line Length (Line 3)	IN	.10
Outside Diameter (Line 3)	IN	.75
Wall Thickness (Line 3)	IN	.042
Modulus of Elasticity (Line 3)	PSI	1.6E7

FIGURE 58 HSFR INPUT DATA FOR PULSCO TYPE ACOUSTIC FILTER

13. QUINCKE TUBE

A means to dampen acoustic noise at resonance is the helical Quincke tube. Basically an outer spiraled passage is formed by winding a solid element around the straight inner tube, which is then enclosed in another straight outer tube.

A simplified Quincke tube in Figure 59 consists of branched lines with the same cross-sectional area. If the difference in the branch line lengths follows the following relationship,

$$\ell_3 - \ell_2 = \frac{\lambda}{2}$$

where

ℓ_3, ℓ_2 = Branched Line Lengths

λ = Wavelength

then pressure waves meeting at Point B will tend to cancel each other for the selected frequency. Experimental testing has shown that the Quincke tube does have wide-band pressure attenuation characteristics in typical aircraft hydraulic circuits.

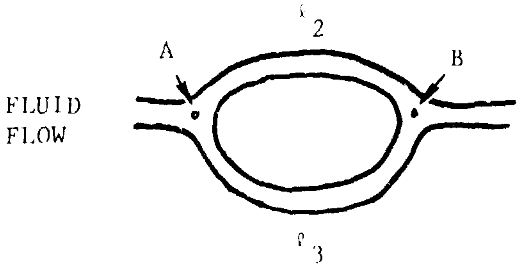


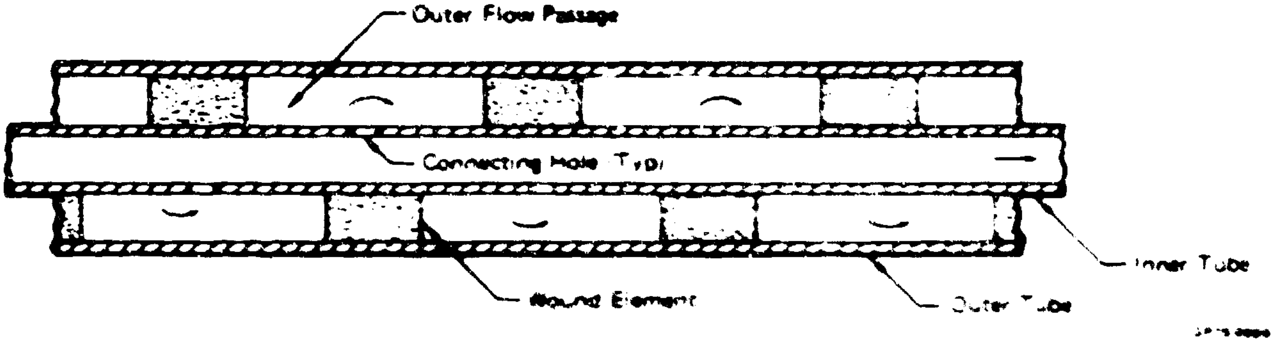
FIGURE 59 SIMPLIFIED QUINCKE TUBE

The Quincke tube configuration is shown in Figure 59

The Quincke tube can have holes connecting the inner and outer passages as a user option. Each hole must be located from the datum line shown in Figure 60 . The maximum number of holes is 16 with the existing program.

The hole length is the distance between the inner and outer tubes. For the example shown in Figure 61 , it would be the inner tube wall thickness.

The HSFR input data for a prototype Quincke tube is presented in Figure 62.



[illegible]

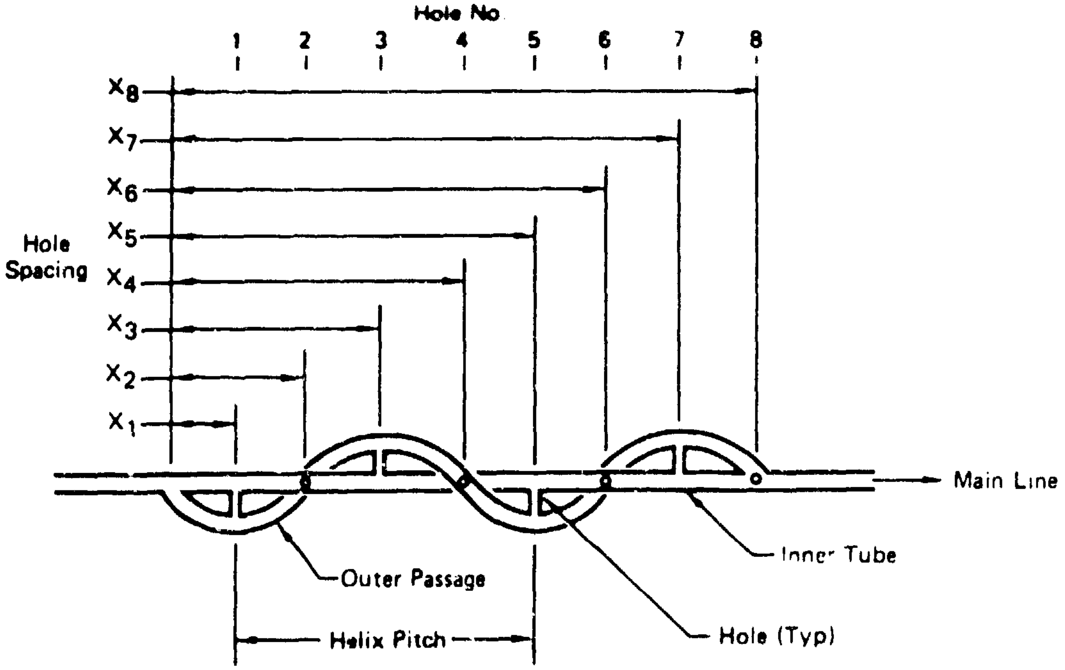


FIGURE 61 QUINCKE TUBE INPUT PARAMETERS WITH HOLE LOCATIONS

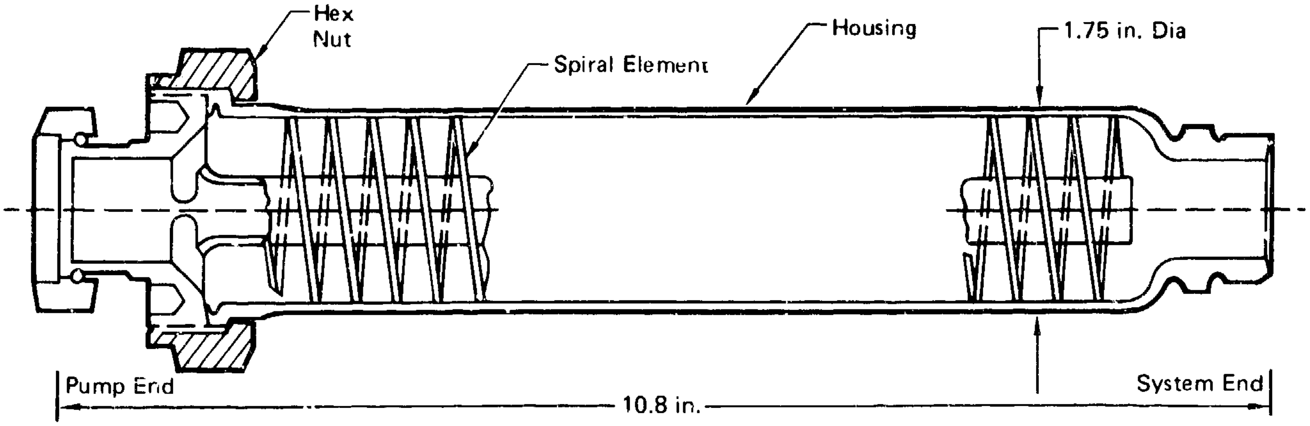
Element Type: QUINCKE TUBE
(PAGE 1 of 1)

	Program	SSFAN	HSFR	HYTRAN
	Element Type	▨	NTYPE 8 KTYPE △1	▨
Data Parameter	Dimensions	▨	▨	▨
Outer Tube Length	IN	░	FIG. 62	░
Inner Tube ID	IN	░	FIG. 61	░
Inner Tube OD	IN	░	FIG. 61	░
Outer Tube ID	IN	░	FIG. 61	░
Outer Tube OD	IN	░	FIG. 61	░
Wound Element Cross-Sectional Area	IN^2	░	FIG. 60	░
Helix Pitch	IN^2	░	FIG. 61	░
Number of Holes	-	░	FIG. 61	░
Length of Holes	IN	░	FIG. 61	░
Distance to Holes	IN	░	FIG. 61	░
Diameter of Holes	IN	░	FIG. 61	░

NOTES △1 . KTYPE 0 FOR NO HOLES

KTYPE 30 FOR 1-8 HOLES

KTYPE 50 FOR 9-16 HOLES



DATA PARAMETER	UNITS	PROTOTYPE
OUTER TUBE LENGTH	IN	7.27
INNER TUBE ID	IN	.194
INNER TUBE OD	IN	.56
OUTER TUBE ID	IN	1.604
OUTER TUBE OD	IN	1.75
WOUND ELEMENT CROSS-SECTIONAL AREA	IN^2	.05
HELIX PITCH	IN^2	.363

FIGURE 62 PROTOTYPE QUINCKE TUBE DATA

14. HEAT EXCHANGERS

Heat exchangers are used in hydraulic systems to remove excess heat from the fluid. High fluid temperatures are undesirable because of the seal damage, fluid degradation and component malfunctions they can cause. Use of heat exchangers in the hydraulic system removes the heat generated by pumps, orifices and electro-hydraulic valves (EHV's) before it can raise the fluid temperature to an undesirable level.

A common method of heat rejection in aircraft hydraulic systems is simply to circulate the fluid through a forced convection heat exchanger (Figure 63). This approach usually uses the aircraft fuel system as a heat sink, but occasionally air is used as a cooling fluid.

SSFAN is the only program of the subject three which has a heat exchanger model. Since heat exchangers are highly specific to the system they serve, no attempt has been made to arrive at any generalized data trends they might show. What has been done instead is to tabulate data on actual heat exchangers as in Figure 64. All of these heat exchangers are in use on fighter type aircraft with 3000 psi hydraulic systems.

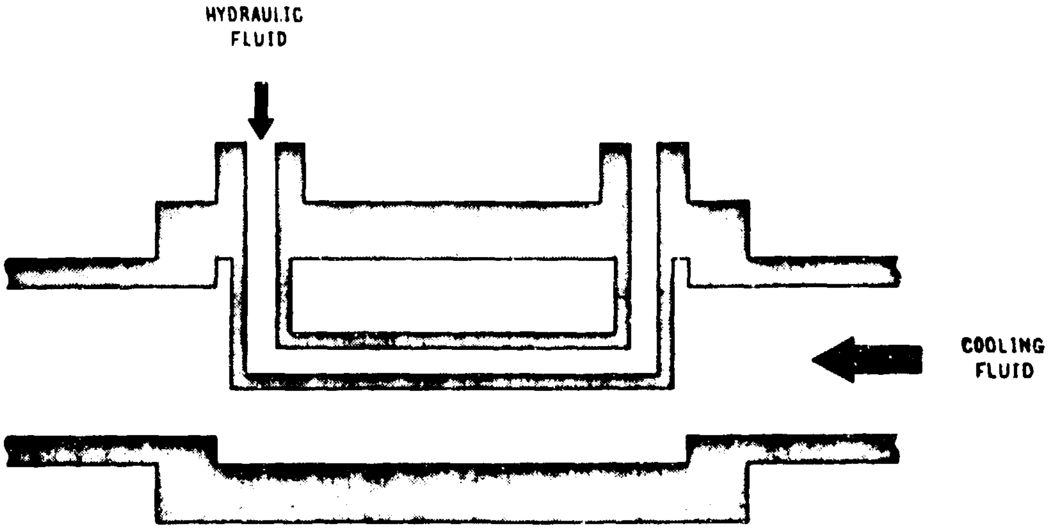


Figure 63 Forced Convection Heat Exchanger

Element Type: Heat Exchanger

	Program	SSFAN	▨	▨
	Element Type	12	▨	▨
Data Parameter	Dimensions	▨	▨	▨
Inlet Size	IN or Dash #		▒	▒
Outlet Size	IN or Dash #		▒	▒
Rated Flow	GPM		▒	▒
Rated Pressure Drop	PSID		▒	▒
Rated Viscosity	Centistokes		▒	▒

SSFAN HEAT EXCHANGER DATA

Type	Rated Heat Load	Inlet Size	Outlet Size	Rated Flow	Rated Pressure Drop	Rated Viscosity (Centistokes)
Oil - Fuel	600 BTU/MIN	-6	-6	10 GPM	20 PSID	3.9
Oil - Fuel	230 BTU/MIN	-6	-6	4.5 GPM	10 PSID	3.9
Oil - Air	125 BTU/MIN	-4	-4	2.5 GPM	20 PSID	16.0

Figure 64 HEAT EXCHANGER DATA

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2. DeGarcia, H., Greene, J. B., Levek, R. J., and Pierce, N. J., Aircraft Hydraulic Systems Dyanmic Analysis - Final Report, AFAPL-TR-78-77, McDonnell Douglas Corporation, St. Louis, Missouri, October 1978.
3. DeGarcia, H., Deshazer, R. F., Levek, R. J., Pierce, N. J., and Stevens, M. J., Advanced Fluid System Simulation - Final Report, AFWAL-TR-80-2039, McDonnell Douglas Corporation, St. Louis, Missouri, January 1980.
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5. Amies, G. E. and Greene, J. B., Aircraft Hydraulic System Dynamic Analysis Volume III, Frequency Response (HSFR) Computer Program User Manual, AFAPL-TR-76-43, Vol III, McDonnell Douglas Corporation, St. Louis, Missouri, February 1977.
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