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FAIRCHILD
STRATOS DIVISION

Contract NAS 8-28518

Report No. ER 966-25

LONG LIFE VALVE DESIGN CONCEPTS

FINAL REPORT

March 10, 1975

Prepared for:

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Fairchild Industries, Stratos Division
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Project Manager

FOREWORD

This report was prepared by Fairchild Industries, Stratos Division, under NAS 8-28518, Long Life Valve Design Concepts for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration.

The Principal Investigator during the Phase I was Mr. David T. Feldman, and during the subsequent phases was Mr. John R. Jones; the Contract Administrator was Mr. John Q. Adams; the Project Manager was Mr. M. (Ben) Baniadam; and the Cognizant NASA Engineer was Mr. Kenneth G. Anthony. This final report was prepared by Mr. Archer H. Hall, Jr.

Other personnel who made significant contributions include Messrs. Roger E. Demaree, William M. Hull, Richard G. Thomas, and Iwao Tokuda.

ABSTRACT

The long life valve design concepts study program included valve concept evaluation; final candidate selection; design, manufacture and demonstration testing of a pneumatically actuated 10-inch hybrid poppet butterfly shutoff valve; and conclusions and recommendations regarding those valve characteristics and features which would serve to guide in the formulation of future valve procurements. The pertinent design goals were temperature range of plus 200° to minus $423^{\circ}F$, valve inlet pressure 35 psia, actuation pressure 750 psia, main seal leakage 3×10^{-5} SCCS at 35 psia valve inlet pressure, and a storage and operating life of 10 years. The valve was designed to be compatible with RP-1, Propane, LH_2, LO_2, He, and N_2.

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SECTION 1

INTRODUCTION

The purpose of this study was to develop criteria for the design of cryogenic long life shutoff valves.

This program consisted of the following phases:

I Design Concept Investigation

II Detail Design.

III Manufacture and Test.

IV Final Report Including Recommendations and Conclusions.

During Phase I, a method of "forced decision configuration optimization" was developed and was utilized to rate the design concept candidates. The final selected configuration was a pneumatically actuated hybrid poppet butterfly valve.

Phase II covered the detail design and analysis of the 10-inch hybrid poppet butterfly valve.

Phase III consisted of the manufacture and the demonstration testing of the 10-inch valve. The tests consisted of the following:

Examination of Product

Initial Testing

Low Temperature Life Cycling

High Temperature Life Cycling

Vibration

Flow Capacity

Nondestructive Burst

Final Disassembly and Inspection (Wear Analysis)

Phase IV consisted of formulating the recommendations and conclusions, and preparation of this final report.

SECTION 2

PHASE I DESIGN CONCEPT INVESTIGATION

The objective of Phase I was the identification and evaluation of various valve, actuator, controller,and seal concepts, considered feasible for incorporating into long life cryogenic shutoff valves. At the end of this phase, the most promising concept for a 10-inch valve was selected along with an alternate valve. The selection was accomplished through definition of requirements, literature search, analytical techniques, and Fairchild Stratos' own experience record and that of other suppliers.

2.1 REQUIREMENTS AND DESIGN GOALS

The preliminary requirements and design goals for the design concept investigation phase of the program are presented in Table 2-1. These requirements were later revised as described in paragraph 3.1

2.2 LITERATURE SEARCH

A literature search was conducted, including an updated search of recent valve patents.

The key words for the literature search are listed below:

Valve, Shutoff, Cryogenic

- Leakage
- Endurance
- Seals
- Bearings
- Bellows
- Actuators
- Materials
- Processes
- Contamination
- Maintainability
- Reliability

A primary Bibliography is presented in Table 2-2.

Table 2-1

Preliminary Requirements and Design Goals for Shutoff Valve

SIZE (cm)	0.64 to 50.8
(inches)	1/4 to 20
MEDIA	RP-1, Propane, LH_2, LO_2, He, N_2
TEMPERATURE RANGE ^{o}F	$+200^{o}$ to -423^{o}
^{o}K	366.49 to 20.38
PRESSURE	
OPERATIONAL	
PSIA	$10^{-8} \longrightarrow 100$
$\frac{\text{NEWTONS}}{\text{meter}^2}$ absolute	$6.895 \times 10^{-5} \longrightarrow 6.895 \times 10^{5}$
PROOF	
PSIA	200
$\frac{\text{NEWTONS}}{\text{meter}^2}$ absolute	1.379×10^{6}
BURST	
PSIA	400 min.
$\frac{\text{NEWTONS}}{\text{meter}^2}$ absolute	2.758×10^{6} min.
LEAKAGE	1×10^{-7} SCCS He
CYCLE LIFE	10,000 ∽ @ Low Temperature
	10,000 ∽ @ High Temperature
STORAGE & OPERATIONAL LIFE	10 Years
VIBRATION	Per Scope of Work listed under Phase III
PRESSURE DROP, WEIGHT, ENVELOPE, RESPONSE	Minimum consistent with other requirements

Table 2-2

Primary Bibliography

1. Fairchild Stratos Experience Record

2. Advanced Valve Technology NASA SP-5019, 1967

3. Advanced Spacecraft Valve Technology, TRW Final Report 12411-6011-R000, July 1970

4. Advanced Spacecraft Valve Technology Compilation Volume 1, Mechanical Controls TRW Report No. 12411-6012-R000, July 1970

5. Liquid Rocket Valve Assemblies, NASA Lewis, April 1972, NASA SP-8XXX, Review Copy

6. Liquid Rocket Valve Components, NASA Lewis, February 1972, NASA SP-8XXX, Review Copy

7. Long-Life, Space-Maintainable Nuclear Stage Regulators and Shut Off Valves Aerojet Nuclear Systems RN-A-71007, March 1972

8. Aerospace Fluid Component Designers Handbook Volume 1 and Volume 2

9. Industry (other suppliers)

10. U.S. Government Patents

11. Quarterly Progress Reports - Space Shuttle Auxiliary Propellant Valves Marquardt NAS 3-14349

12. Quarterly Progress Reports - Space Shuttle Auxiliary Propulsion (APS) Valves Rocketdyne NAS 3-14350

13. Seal Material and Design Development Program TRW NAS 9-12500; Monthly Progress Reports

2.3 INDUSTRY SUPPLIERS

Industry suppliers were contacted by letter in regard to applicable hardware which would meet the requirements and design goals of the study program. Available information such as sketches, test data, test reports, and cutaways in any or all of the following areas were requested.

a. Concepts for actuation: motor driven pneumatic and electromechanical

b. Concepts for sealing

c. Static seals

d. Dynamic seals

e. Maintainability

f. Reliability

Out of 67 suppliers contacted, there were 6 helpful replies, 30 negative replies, and 31 no replies.

Fairchild would like to acknowledge the following suppliers for their helpful contributions:

- Aeroquip Corporation
  Marman Division
  Los Angeles, California

- Belfab Corporation
  Northridge, California

- Cryolab Division
  San Luis Obispo, California

- Lafnir Bearing
  Newington, Connecticut

- Royal Industries
  Santa Ana, California

- TRW
  One Space Park
  Redondo Beach, California

2.4 DESIGN CONCEPT CANDIDATES

2.4.1 Potential Candidate List

Utilizing the results of the literature search, supplier contact, and suggestions of Fairchild Industries personnel, a list of design concepts was compiled. These potential candidates were grouped as follows:

- Valve Concepts
- Actuator Concepts
- Controller Concepts
- Unique and Novel Actuator Concepts
- Seal Concepts

In addition, the valve concepts were categorized by type as follows:

- Visor Valves
- Ball Valves
- Flapper Valves
- Butterfly Valves
- Plug Valves
- Poppet Valves
- Swing Valves
- Rotary Valves

The design concepts are listed by groups in Tables 2-3 through 2-7.

2.4.2 Candidate Selection

An analysis and tradeoff study was conducted to rate the concepts as to desirability and to reduce their number. The selection was based on a schematic representation of the concepts. The selected candidates were grouped as follows:

- Large Valves
- Small Valves or Controllers for Large Valves
- Actuator Candidates
- Unique and Interesting Devices

Table 2-3

Valve Concepts

Visor Valve - Simultaneous Retraction of Seal and Rotation of Visor

Visor Valve - Retractable Sequenced Seal

Ball Valve - Simultaneous Retraction of Seal and Rotation of Ball

Ball Valve - Retractable Dual Seat, Sequence Controlled, Single Actuator

Dual Flapper - Single Actuator

Dual Flapper - Dual Actuator

Butterfly - Simultaneous Retraction of Seal and Rotation of Blade

Butterfly - Poppet Hybrid, Sequenced Can Motion and then Rotation

Butterfly - Poppet Hybrid, Sequenced Poppet Motion and then Rotation

Plug Valve - Retractable Sequenced Seal

Plug Valve - Retractable Sequenced Primary Seal; Secondary Seal

Coaxial Poppet

Poppet - Motor Driven thru Ball Screw

Poppet - Motor Driven thru Planitary Gear

Poppet - Radial Loaded Seal

Plug - Poppet Hybrid

Swing Gate

Rotary - 90° ON-OFF, Seals Pressure Balanced

Poppet - Hermetic Sealed Actuator

Table 2-4

Actuator Concepts

Motor-valve Direct Drive

Motor-valve Driven thru Linkage

Single Acting Piston, Solenoid Operated

Solenoid-bellows Linkage Drive Poppet

Solenoid-bellows Linkage-rack Driven

Double Acting Piston Torque Motor Actuated

Redundant Solenoid Motor Bellows Linkage Driven

Double Acting, Double Solenoid, Direct Drive

Single Acting Bellows - Solenoid Operated

Double Acting - Double Solenoid Direct Drive Detent Held

Table 2-5

Controller Concepts

Hermetic Sealed Motion Transmitter

Solenoid Actuated Bellows Sealed Poppet

Bimetallic Operated Poppet

Diffusion Controller

Bimetallic Torque Tube

Bimetallic Poppet

Expansion Bellows

Redundant Differential Expansion Poppet Controller

Piezoelectric Disks

Piezoelectric Spring

Diaphragm Controller

Electro-pyrotechnic Cartridge

Table 2-6

Unique and Novel Actuator (or Transmitter) Concepts

Hermetic Sealed Actuator

Hermetic Sealed Motion Transmitter

Differential Expansion Actuated Valve

Fluid Expansion Actuated Valve

Snap Action Differential Expansion Actuated Valve

State Change Actuator for Single Cycle Operation

Diffusion Valve Concept for Use with a Microthruster

Piezoelectric Actuator

Electrodynamic Actuator (Magnetic)

Dual Two-Way Thermally Actuated Microvalve

Three-Way Snap Action Thermally Actuated Valve

Piezoelectrical Three-Way Valve

Mechanical Linkages Used to Convert Actuator Motion from Linear to Rotary

Table 2-7

Seal Concepts

Flat Faced Poppet - Contamination Resistant

Pressurized Seal

Retainer Sealing Aids

Installed Position of M-1 Sleeve-Type Valve Lip Seal

Invar Spacer

Seal Loading Diameter Relationship

Belleville-Spring Loaded Seal Retainer

LMDE Ball Valve Seal Configuration

Bellows-Type Seal Retainer

Lip Seals - Molded Packings

Wiper Configurations

Butterfly Valves Sealing Techniques

Cone Labyrinth Valve

Elastic-Plastic Poppet and Seat

Boxed in Pressurized Ring Cryo-Seal and Double-Area Seat for Plastic Seals

Main Poppet Seal

Bi-Directional Seal

Laminating Technique for Fabricating Composite at Cryogenic Temperatures

Seat Geometry - Conical-on-Conical

Seat Geometry - Flat-on-Flat

Seat Geometry - Spherical-on-Conical

Seat Geometry - Flexible Disk/Hard Seat Valve

Sphere Seating on Sharp Corner of Soft Seat

Flat Poppet Seating on Beveled, Soft Seat

Teflon Seal - Invar Expander Ring/Aluminum Compressor Ring

Self-Aligning Flat Disk Poppet

Ball-Section Poppet with Rod End Retainer

Valve Seat with Expanding and Scrubbing Action

For this study, the valve concepts were divided into large valves one inch and greater, and small valves 1/4 to one inch in diameter. Seal concepts were not further analyzed during this phase due to a lack of suitable information on which to rate the seal configurations. Seals were analyzed during the design phase presented in Section 3.

The candidates are listed in Table 2-8 and are presented schematically in Figures 2-1 through 2-34. The analysis and tradeoff study is described in paragraph 2.4.3.

2.4.3 Analysis and Tradeoff Study

A method of "forced decision configuration optimization" was developed and utilized to reduce in number and to rate the previously compiled candidate list of valve, actuator and controller concepts. The results of this tradeoff study are presented in paragraph 2.4.2. The optimization technique consisted of determining the emphasis coefficient as described in paragraph 2.4.3.1 and the rating coefficient as described in paragraph 2.4.3.2. These two coefficients were multiplied together to obtain an adjusted rating. These adjusted ratings for all the parameters were totaled. Table 2-9 presents a typical total adjusted rating of a valve.

The total adjusted ratings of the valve, controller, and actuator concepts are presented in Tables 2-10 through 2-13. Table 2-10 presents the first iteration of the valve adjusted ratings. A second iteration is presented in Table 2-14. In the case of the actuators, similar types were grouped, and some concepts eliminated by inspection. Actuator ratings are presented in Table 2-13.

2.4.3.1 Emphasis Coefficient

The emphasis coefficient is the preferential weighting of each parameter with respect to a given parameter. Based on the requirements and design goals, the following valve parameters were determined to be significant:

Natural Vibration Resistance (Structural)
Contamination Resistance
Cycle Life
Leakage
Storage Life
Pressure Drop
In-Line Maintenance
Cost
Replacement Maintenance
Response Time
Actuator Adaptability
Weight
Availability of Design Information
Envelope

Table 2-8

Design Concept Candidates

LARGE VALVES

Figure No.	
2-1	Ball Valve
2-2	Ball-Dual Seal-Sequenced Retraction
2-3	Visor Valve
2-4	Visor Valve
2-5	Ball or Plug Valve - Retractable Sequenced Seal
2-6	Hybrid Butterfly
2-7	Butterfly - Poppet Hybrid
2-8	Butterfly - Poppet Hybrid
2-9	Dual Flapper
2-10	Dual Flapper
2-11	Swing Gate
2-12	Motor Driven Poppet

SMALL VALVE OR CONTROLLERS FOR LARGE VALVES

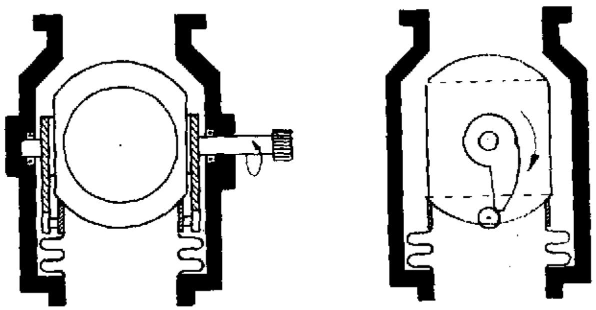
2-13	Plug - Poppet Hybrid
2-14	Coaxial Poppet
2-15	Radial Loaded Seal Poppet
2-16	Motor Driven Poppet
2-17	Solenoid Actuator Bellows Sealed Poppet
2-18	Bimetallic Operated Poppet
2-19	Motor-Valve, Direct Driven

ACTUATOR CANDIDATES

2-20	Motor-Valve,Driven Thru Linkage
2-21	Single Acting Piston, Solenoid Operated
2-22	Solenoid-Bellows, Linkage Driven Poppet
2-23	Solenoid-Bellows, Linkage - Rack Driven
2-24	Redundant System Motor or Torque Motor Actuated
2-25	*Redundant Solenoid - Motor Bellow Linkage Driven*
2-26	Double Acting, Double Solenoid, Direct Driven
2-27	Double Acting Bellows, Solenoid Operated
2-28	Double Acting, Double Solenoid, Direct Drive, Detent Held

UNIQUE AND INTERESTING DEVICES

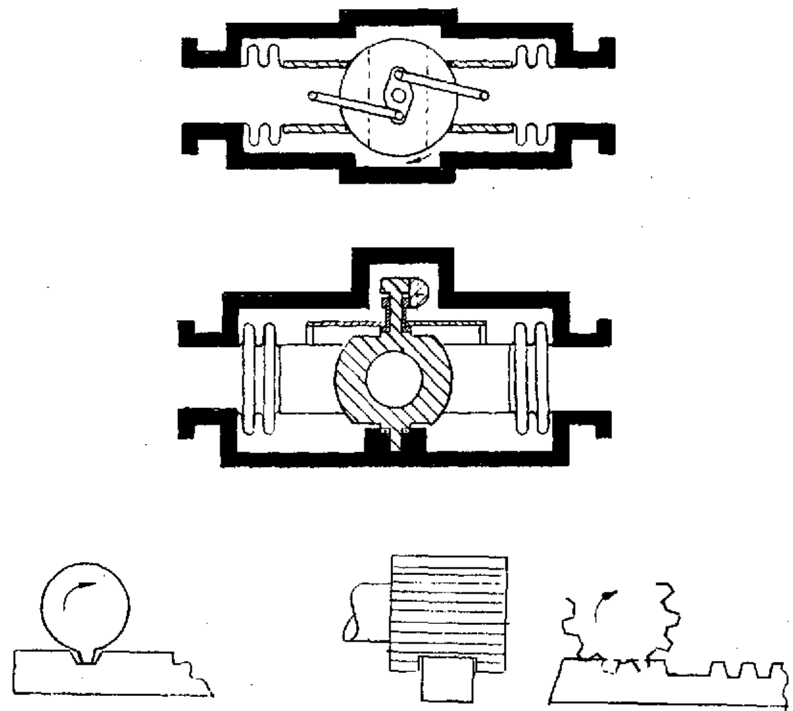
2-29	Diffusion Controller
2-30	Piezoelectric Spring
2-31	Piezoelectric Disks
2-32	Hermetic Sealed Motion Transmitter
2-33	Bimetallic Torque Tube
2-34	Hermetic Sealed Actuator



HOW IT WORKS

ACTUATOR ROTATES BALL AND THRU AN ENCLOSED CAM LIFTS BELLOWS SEAL SIMULTANEOUSLY.

Figure 2-1. Ball Valve - Simultaneous Retraction of Seal and Rotation of Ball



HOW IT WORKS

TEETH OF SPLINED ACTUATOR ENGAGE YOKE WHICH TRANSLATES BELLOWS SEAL; BALL IS RESTRAINED BY FLAT ON ACTUATOR ROD. AFTER YOKE TRANSLATES BELLOWS SEAL; BALL IS ROTATED TO OPEN POSITION; TO CLOSE-SEQUENCE IS REVERSED.

Figure 2-2. Ball Valve - Dual Seat, Sequenced Retraction

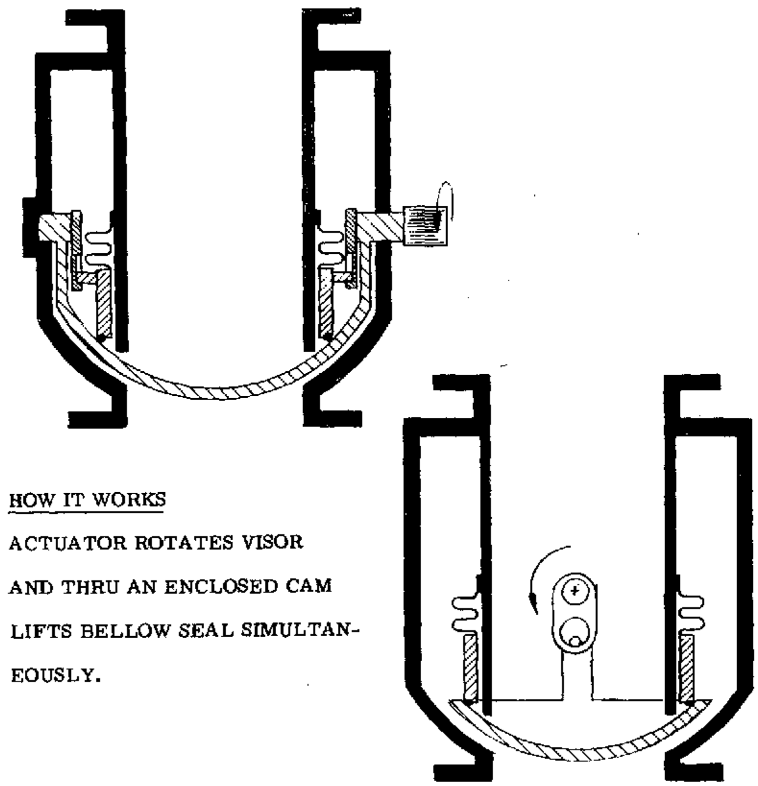
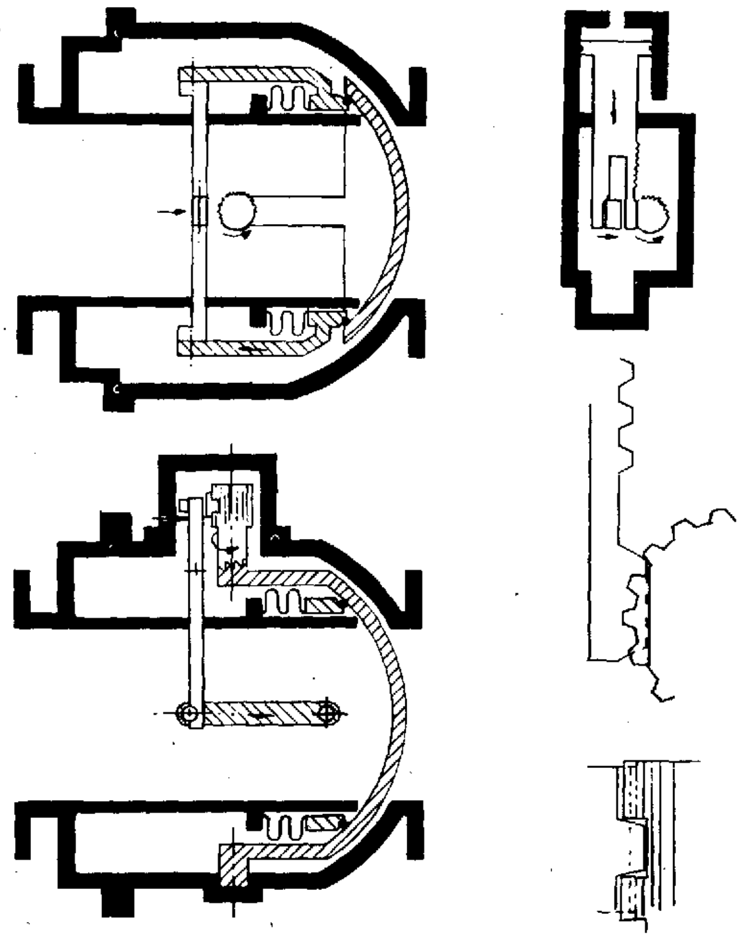


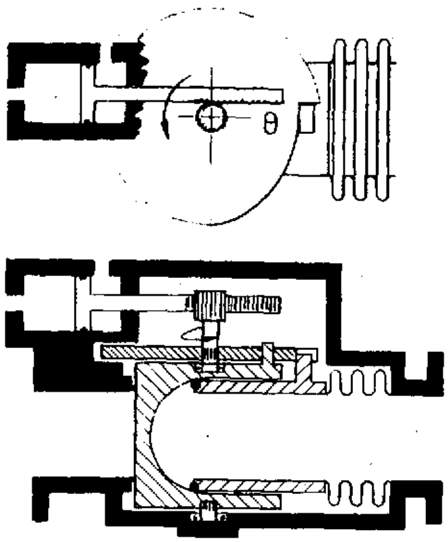
Figure 2-3. Visor Valve - Simultaneous Retraction of Seal and Rotation of Visor



HOW IT WORKS

TRANSLATION OF ACTUATOR INITIALLY LIFTS THE BELLOWS SEAL BY A CAM AND LEVER WHILE PREVENTING ROTATION OF VISOR. FURTHER TRANSLATION OF ACTUATOR CAUSES VISOR TO ROTATE.

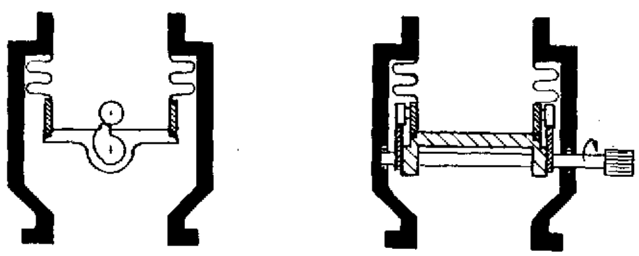
Figure 2-4. Visor Valve - Retractable Sequenced Seal



HOW IT WORKS

ACTUATOR ROTATES CAM WHICH CAUSES PRIMARY SEAL TO RETRACT; FURTHER CAM MOTION PICKS UP PIN IN SLOT WHICH CAUSES CYLINDER TO ROTATE TO OPEN POSITION. TO CLOSE, SEQUENCE IS REVERSED.

Figure 2-5. Plug Valve - Retractable Sequenced Seal



HOW IT WORKS

ACTUATOR ROTATES BLADE AND SIMULTANEOUSLY THRU A CAM LIFTS THE BELLOWS SEAL.

Figure 2-6. Hybrid Butterfly Valve - Simultaneous Seal Retraction

HOW IT WORKS

ROTATION OF ACTUATOR CAUSES BLADE TO TRANSLATE; CAM ACTION AGAINST GROUND POINT THEN CAUSES ROTATION OF BLADE.

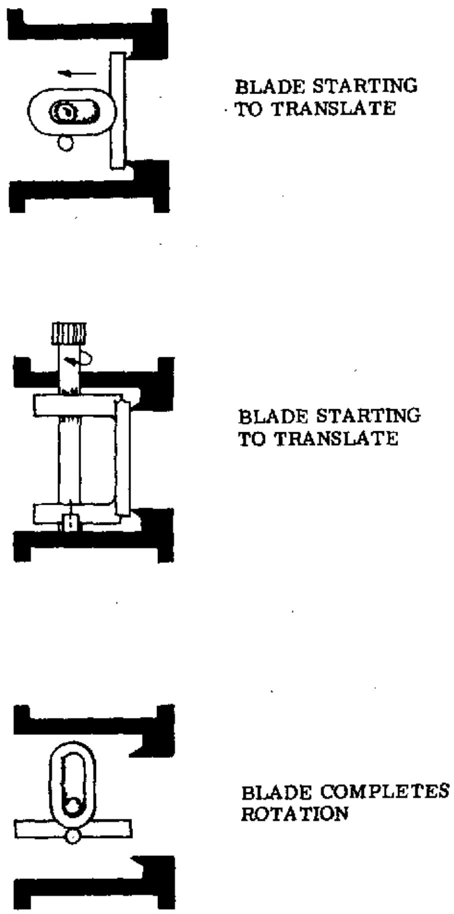
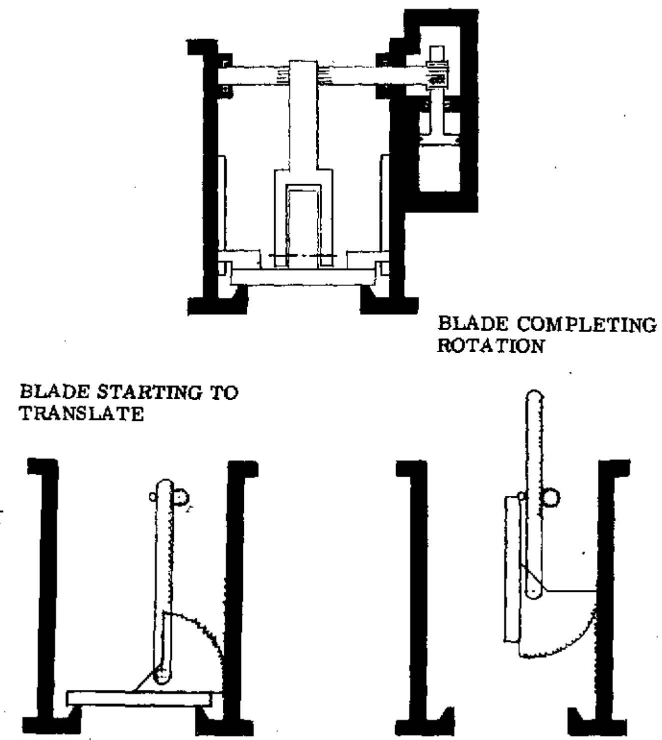


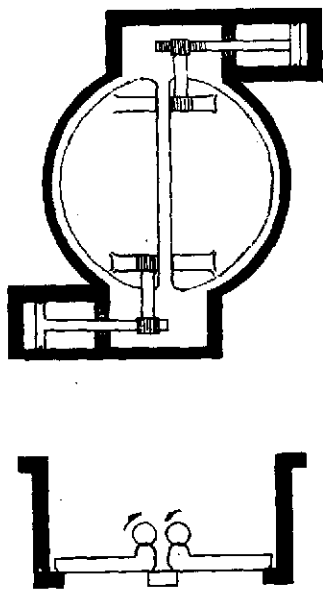
Figure 2-7. Butterfly Valve - Poppet Hybrid, Sequenced Motion and then Rotation



HOW IT WORKS

ROTATION OF ACTUATOR CAUSES TRANSLATION OF BLADE AND THEN IN SEQUENCE ROTATION AND TRANSLATION OF BLADE.

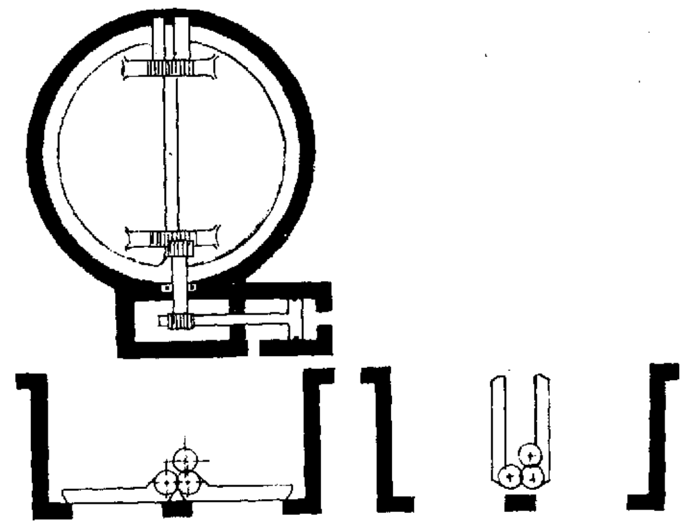
Figure 2-8. Butterfly Valve - Poppet Hybrid Sequenced Poppet Motion and then Rotation



HOW IT WORKS

EACH ACTUATOR OPENS AND CLOSES ONE FLAPPER.

Figure 2-9. Dual Flapper Valve, Single Actuator



HOW IT WORKS

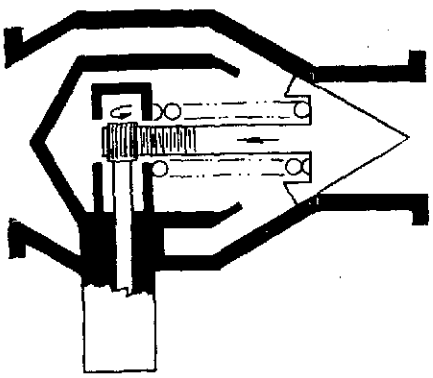
ACTUATOR DRIVES ONE FLAPPER WHICH IN TURN DRIVES SECOND FLAPPER.

Figure 2-10. Dual Flapper Valve, Dual Actuator

HOW IT WORKS

TRANSLATION OF ACTUATOR CAUSES GATE TO ROTATE; PISTON ACTUATED; RACK AND PINION DRIVE.

Figure 2-11. Swing Gate Valve



HOW IT WORKS

ACTUATOR MAY BE REMOVED WITHOUT AFFECTING VALVE; VALVE-MOTOR DRIVEN PLANETARY GEAR TRANSMISSION; RACK AND PINION LINEAR DRIVE; SPRING LOADED OVERRIDE; NORMALLY CLOSED.

Figure 2-12. Poppet Valve - Motor Driven Thru Planetary Gear

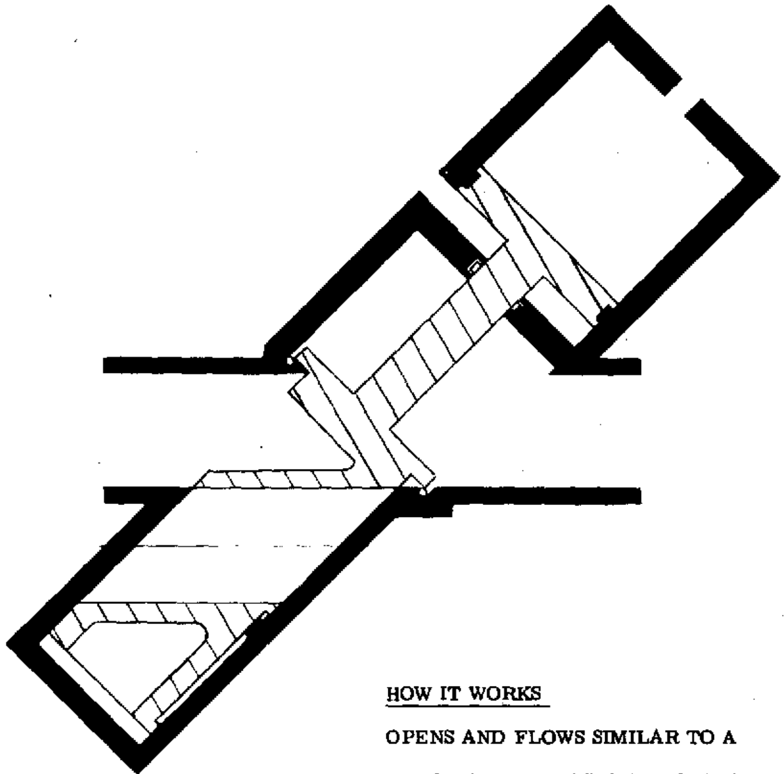
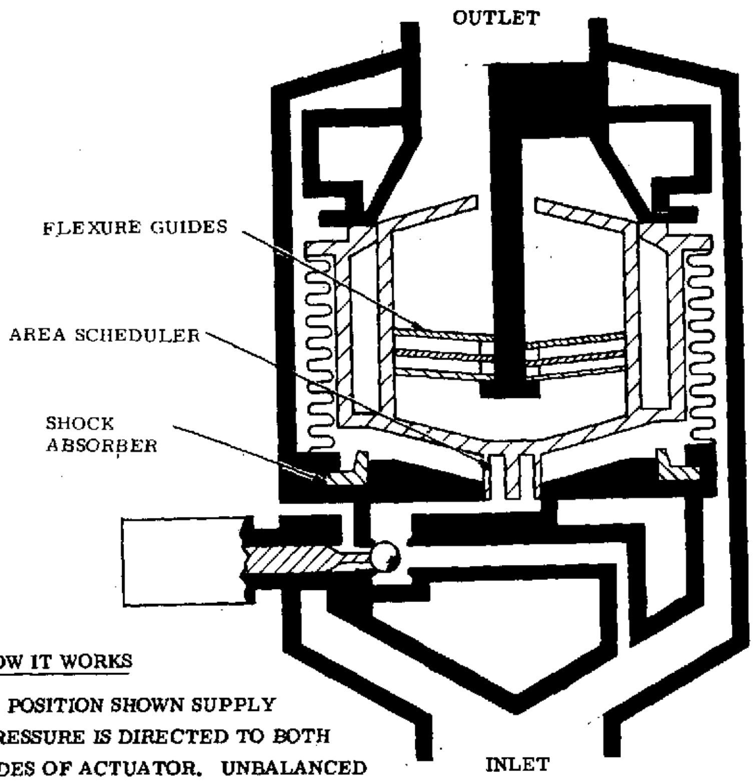


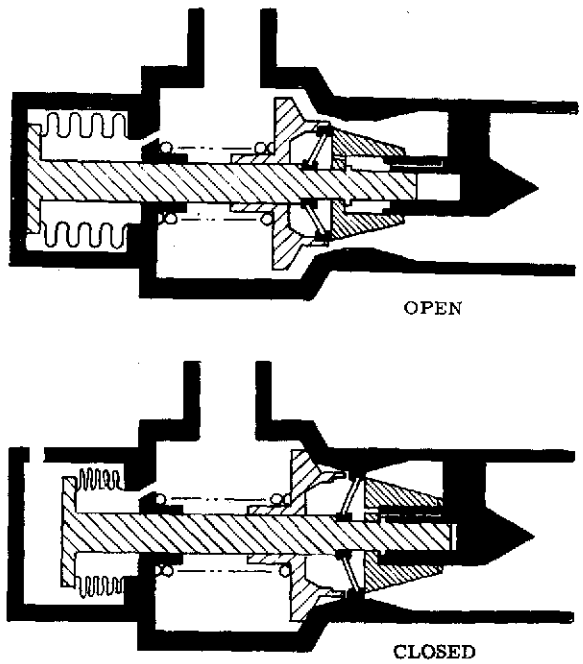
Figure 2-13. Plug Valve - Poppet Hybrid



HOW IT WORKS

IN POSITION SHOWN SUPPLY PRESSURE IS DIRECTED TO BOTH SIDES OF ACTUATOR. UNBALANCED FORCE KEEPS VALVE CLOSED.
ENERGIZING SOLENOID VENTS ONE SIDE OF PISTON, CAUSING VALVE TO OPEN. CONCEPT ALSO DEPICTS AREA SCHEDULER TO REDUCE IMPACT ON SEAT AND SHOCK ABSORBTION IN OPEN DIRECTION.

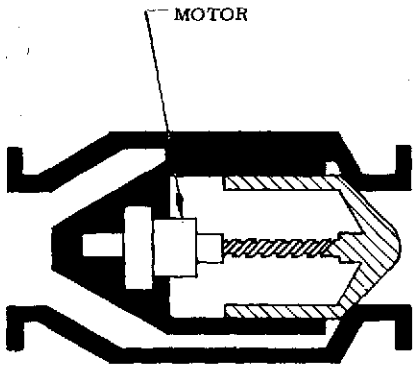
Figure 2-14. Coaxial Poppet Valve (or Controller)



HOW IT WORKS

VALVE CLOSES AND STOPS AGAINST PRIMARY STOP AND SEAL; CONTINUED ACTUATOR MOTION CAUSES EXPANSIVE FORCE AGAINST SECONDARY SEAL WHICH HAS BEEN IN A PROTECTIVE DOWNSTREAM POSITION.

Figure 2-15. Radial Loaded Seal Poppet Valve (or Controller)



HOW IT WORKS

BRUSHLESS MOTOR; EXTERNAL SOLID STATE COMMUTATOR SWITCHING; LEAD ANGLE TO BALL SCREW IS LESS THAN 12° TO PREVENT POPPET FROM BACK DRIVING DUE TO HIGH SEALING FORCE.

Figure 2-16. Poppet Valve - Motor Driven thru Ball Screw (or Controller)

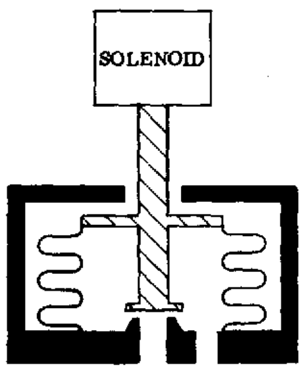
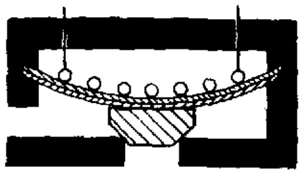


Figure 2-17. Solenoid Actuated Bellows Sealed Poppet Valve (or Controller)



HOW IT WORKS

SNAP ACTION DIFFERENTIAL EXPANSION ACTUATED CONTROLLER.

Figure 2-18. Bimetallic Operated Poppet Valve (or Controller)

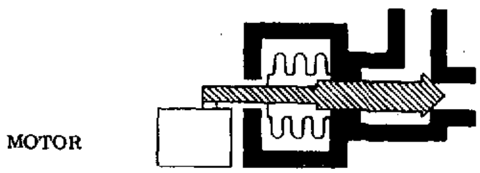


Figure 2-19. Valve (or Controller), Motor-Valve, Direct Driven

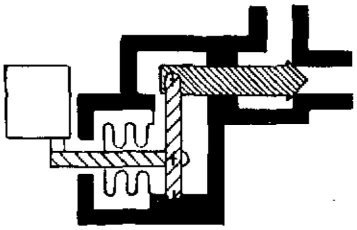
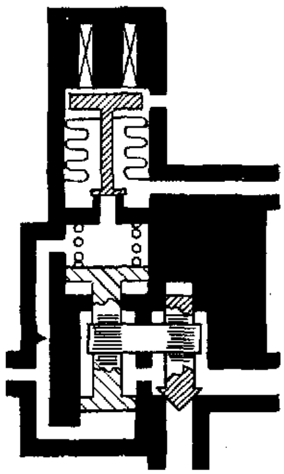


Figure 2-20. Actuator, Motor-Valve Driven Thru Linkage



HOW IT WORKS

WITH SOLENOID CLOSED SUPPLY PRESSURE ACTS ON BOTH SIDES OF PISTON. UNBALANCED AREAS CAUSE PISTON TO MOVE VALVE TO CLOSED POSITION. WHEN SOLENOID OPENS, PRESSURE DRAINS FROM ONE SIDE OF PISTON, CAUSING VALVE TO OPEN.

Figure 2-21. Actuator, Single Acting Piston, Solenoid Operated

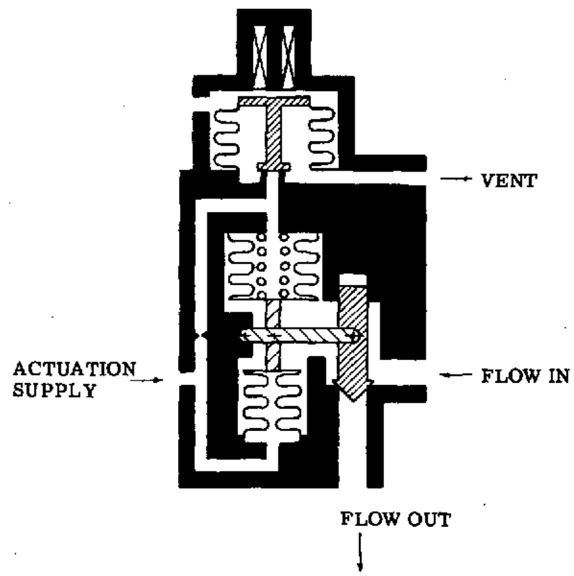


Figure 2-22. Actuator, Solenoid-Bellows, Linkage Driven Poppet

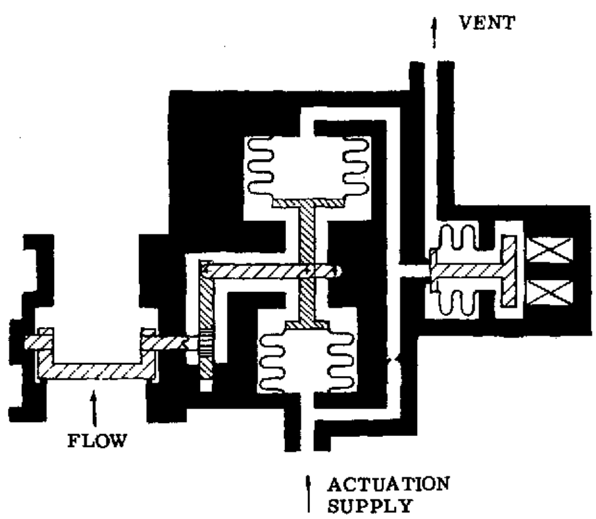
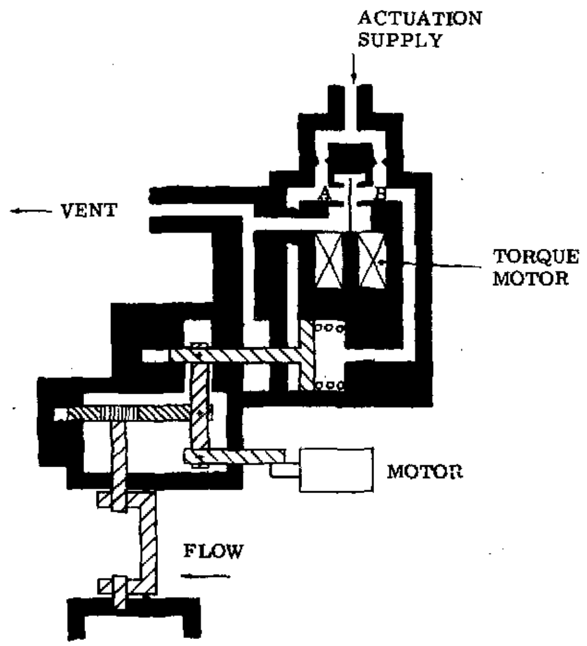


Figure 2-23. Actuator, Solenoid-Bellows, Linkage - Rack Driven



HOW IT WORKS

TORQUE MOTOR CLOSES PORT A OR B; WITH B PORT CLOSED, 'A' SIDE OF PISTON VENTS - VALVE CLOSES; WITH A PORT CLOSED, B SIDE OF PISTON VENTS - VALVE OPENS. EITHER TORQUE MOTOR OR MOTOR MAY ACTUATE VALVE

Figure 2-24. Actuator, Redundant System, Motor or Torque Motor Actuated

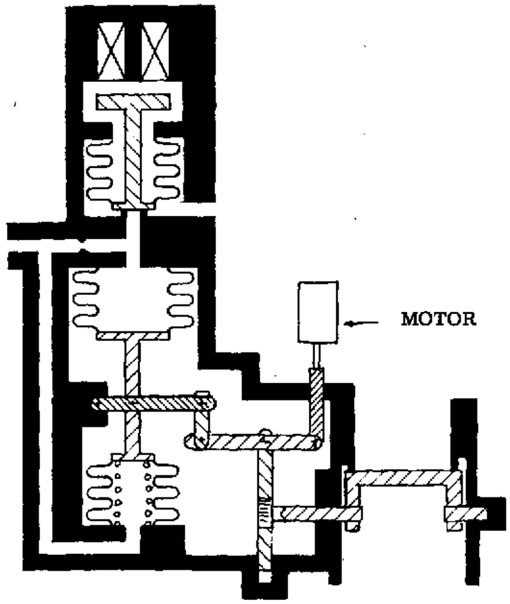


Figure 2-25. Actuator, Redundant Solenoid-Motor Bellows Linkage Driven

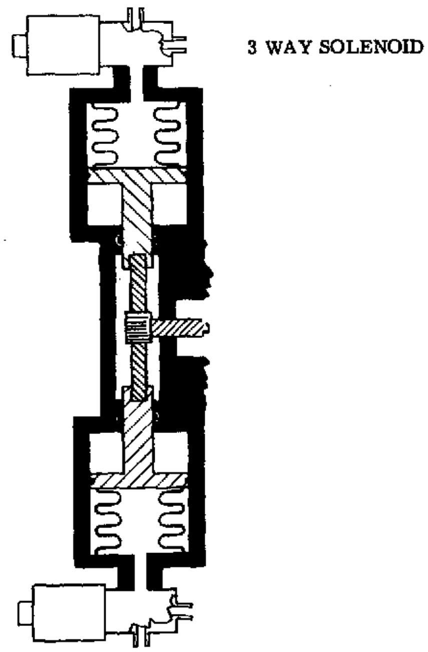


Figure 2-26. Actuator, Double Acting, Double Solenoid Direct Driven

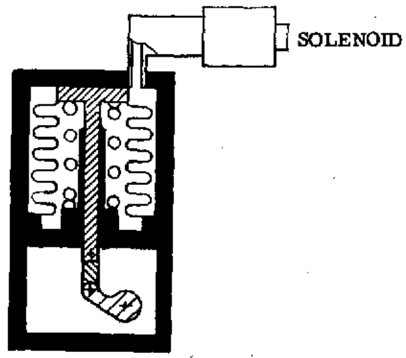


Figure 2-27. Actuator, Double Acting Bellows, Solenoid Operated

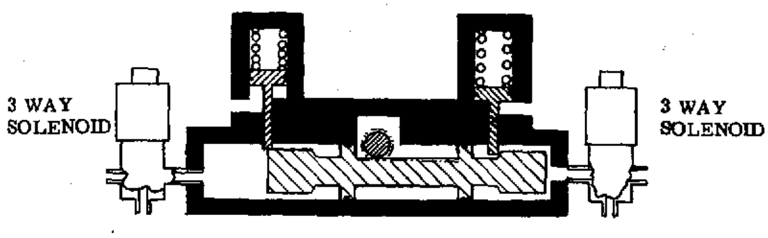
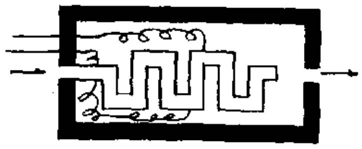


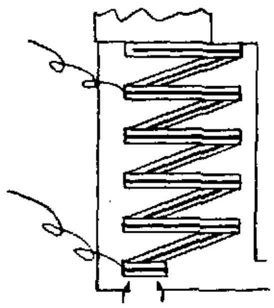
Figure 2-28. Actuator, Double Acting, Double Solenoid, Direct Drive, Detent Held



HOW IT WORKS

TUBES ARE SEALED WITH HYDROGEN GAS; HEATING OF TUBES DIFFUSES GAS THRU PALLADIUM-SILVER TUBING.

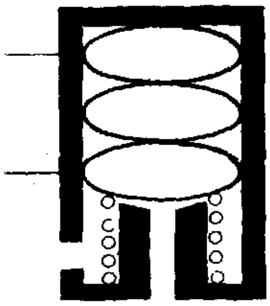
FIGURE 2-29. DIFFUSION CONTROLLER



HOW IT WORKS

ELECTRIC FIELD CAUSES DEFLECTION OF PIEZOELECTRIC SPRING OPENING AND CLOSING OF SEAT.

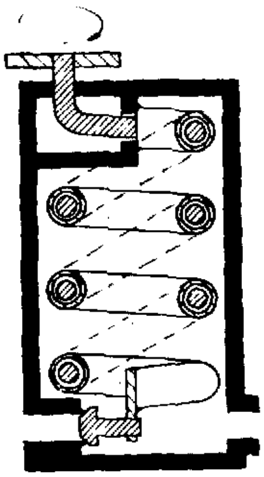
FIGURE 2-30. PIEZOELECTRIC SPRING



HOW IT WORKS

ELECTRIC FIELD CAUSES DEFLECTION OF PIEZOELECTRIC DISKS.

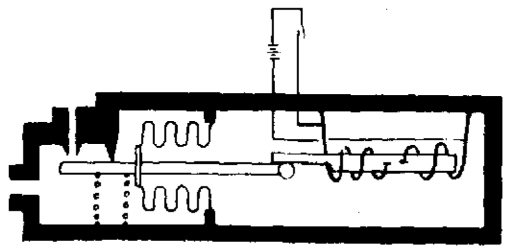
FIGURE 2-31. PIEZOELECTRIC DISKS



HOW IT WORKS

THE END OF THE TUBULAR MEMBER WHICH EXTENDS INTO THE ENCLOSURE IS HERMETICALLY SEALED, WHILE THE OUTER SURFACE OF THE TUBULAR MEMBER IS HERMETICALLY SEALED TO THE WALL OF THE ENCLOSURE, WHERE IT PENETRATES THE WALL. TORQUE APPLIED TO THE INNER MEMBER FROM AN EXTERNAL LOCATION IS TRANSMITTED TO THE OUTER MEMBER WHICH IS THE HERMETIC SEALED CHAMBER.

FIGURE 2-32. HERMETIC SEALED MOTOR TRANSMITTER



HOW IT WORKS

HEATING OF BIMETALLIC TORQUE TUBE CAUSES ROTATION WHICH IN TURN CAUSES PIVOTING OF POPPET SEAL.

Figure 2-33. Bimetallic Torque Tube

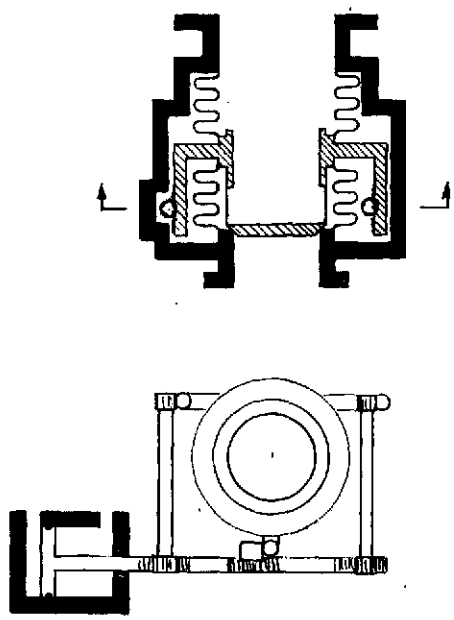


Figure 2-34. Hermetic Sealed Actuator

Table 2-9

Typical Large Valve Adjusted Ratings

4- VERY GOOD 3- GOOD 2- FAIR 1- POOR	FIG 2-3 VISOR VALVE SIMULTANEOUS RETRACTION OF SEAL AND ROTATION OF VISOR			FIG 2-4 VISOR VALVE SEAL RETRACTION AND THEN VALVE ROTATED			FIG 2-1 BALL VALVE SIMULTANEOUS RETRACTION AND ROTATION OF BALL		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	4	.0879	.3516	4	.0879	.3516	4	.0879	.3516
RESPONSE TIME	2	.0549	.1098	1	.0549	.0549	2	.0549	.1098
WEIGHT	4	.0220	.0880	2	.0220	.0440	3	.0220	.0660
CYCLE LIFE	2	.1209	.2418	4	.1209	.4836	2	.1220	.2418
LEAKAGE	2	.1209	.2418	4	.1209	.4836	2	.1220	.2418
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	3	.0549	.1647	3	.0549	.1647	3	.0549	.1647
IN LINE MAINTENANCE	3	.0659	.1977	2	.0659	.1318	3	.0659	.1977
COST	3	.0659	.1977	2	.0659	.1318	3	.0659	.1977
STORAGE LIFE	4	.0989	.3966	4	.0989	.3966	4	.0989	.3966
ACTUATOR ADAPTABILITY	4	.0275	.1000	2	.0275	.0550	4	.0275	.1000
VIBRATION RESISTANCE	3	.1374	.4022	2	.1374	.2748	3	.1374	.4122
CONTAMINATION RESISTANCE	3	.1264	.3792	3	.1264	.3792	2	.1264	.2528
AVAILABILITY OF DESIGN INFO	3	.0165	.0495	1	.0165	.0165	3	.0165	.0495
		TOTAL	2.9206		TOTAL	2.9681		TOTAL	2.7822

Table 2-10

Large Valve Concept Ratings
Adjusted Rating by Groups - First Iteration

Figure		Rating
2-3	Visor	2.9206
2-4	Visor	2.9681
2-1	Ball	2.7822
2-2	Ball	2.8197
2-6	Butterfly	2.4790
2-7	Butterfly	3.1824
2-8	Butterfly	2.8692
2-14	Poppet	3.1703
2-16	Poppet	2.6878
2-12	Poppet	2.9717
2-15	Poppet	2.9505
2-9	Dual Flapper	3.0943
2-10	Dual Flapper	2.8790
(1)	Rotary	3.1155
2-5	Plug Valve	2.8241
(2)	Plug Valve	2.9836
2-34	Hermetic Seal Actuator	3.3407
2-11	Swing	3.0714

(1) 90° on-off, seals pressure balanced (small valves only)

(2) Retractable sequenced primary seal, secondary seal

Table 2-11

Small Valve Concept Ratings

Figure		Rating
2-13	Plug, Poppet Hybrid	3.6562
2-33	Bimetallic Poppet	3.5733
(1)	Rotary	3.2467
2-19	Poppet Direct Motor Driven	3.2334
2-34	Hermetic Sealed Poppet	3.1724

(1) 90° on-off, seals pressure balanced.

Table 2-12

Controller Concept Ratings

Figure		Rating
2-29	Paladium Silver Alloy Tube	4.8204
2-17	Hermetic Sealed Bellows	4.7881
2-32	Hermetic Sealed Tubular	4.5703
2-18	Snap Action Differential Expansion	4.3009
2-31	Piezoelectric Disks	3.9869
-	Heat Sensitive Thermal	3.3331

Table 2-13

Large Valve Actuator Ratings

Figure		Rating
2-27	Single Acting, Bellows Solenoid Operated	3.6151
2-28	Double Acting, Double Solenoid Direct Drive Detent Held	3.3333
2-26	Double Acting Double Solenoid, Direct Drive	3.1729
2-24	Hydraulic Redundant Motor-Torque Motor	2.3973
2-24	Pneumatic Redundant Motor-Torque Motor	2.3846
2-21	Piston Rack Pinion	2.1091

Table 2-14

Large Valve Concept Ratings
Adjusted Rating - Second Iteration

Figure		Rating
2-4	Visor	3.2858
2-5	Plug	3.2803
2-7	Butterfly	3.2802
2-2	Ball	3.2144
2-14	Poppet	3.1923
2-19	Hermetic Poppet	2.8965
2-9	Dual Flapper	2.5329

For the controllers and actuators, the parameters were the same, except that "pressure drop" was eliminated as a consideration. As a result, the emphasis coefficients for the controllers and actuators were different from the valve emphasis coefficients.

The parameter weight assignment and resultant emphasis coefficient for the valves are shown in Figure 2-35. The parameters were weighted, accordingly, to the prescribed order of importance, by methodically comparing each parameter with each of the others. Only two parameters were compared at a time. In each comparison, the preferred parameter was assigned a numerical value of 1, the less preferred by comparison received a zero.

In a few cases where the two compared parameters were about equal, each was given a numerical value of 1/2.

The ratio of the positive responses to the total number of comparisons yields a weighting factor referred to as an emphasis coefficient of the parameter.

The emphasis coefficients for the actuators and controllers are presented in Table 2-15.

2.4.3.2 Rating Coefficient

The rating coefficient is the preferential weighting of each concept with respect to a given parameter. The coefficient was based on previous experience and preliminary calculations. The large valve configuration ratings range from 4, awarded to the best, to 1, awarded to the least suited to the particular parameter. See Table 2-9 for typical ratings for a large valve. The range of the ratings was 4 to 1, 5 to 1, and 6 to 1 for large valve actuators, small valves and controllers-transmitters, respectively.

2.4.4 Final Candidate Design Concepts (Based on Schematic Representation)

The design concepts based on schematic representation were reduced to four large valves, four small valves, and four actuator candidates. The concepts are listed in the order of their rating in Table 2-16.

PARAMETER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
PRESSURE DROP	1	1	0	0	1	1	1	1	0	1	0	0	1										
RESPONSE TIME	0													1	0	0	1	0	0	1	0	1	0
WEIGHT		0												0									
CYCLE LIFE			1												1								
LEAKAGE				1												1							
ENVELOPE					0												0						
REPLACEMENT MAINTENANCE						0												1					
IN LINE MAINTENANCE							0												1				
COST								0												0			
STORAGE LIFE									1												1		
ACTUATOR ADAPTABILITY										0												0	
NATURAL VIBRATION RESISTANCE (STRUCTURAL)											1												1
CONTAMINATION RESISTANCE												1											
AVAILABILITY OF DESIGN INFORMATION													0										

PARAMETER	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
PRESSURE DROP																							
RESPONSE TIME	0	1																					
WEIGHT			0	0	1	0	0	0	0	0	0	0	1										
CYCLE LIFE			1											1/2	1	1	1	1	1	1	0	1/2	1
LEAKAGE				1										1/2									
ENVELOPE					0										0								
REPLACEMENT MAINTENANCE						1										0							
IN LINE MAINTENANCE							1										0						
COST								1										0					
STORAGE LIFE									1										0				
ACTUATOR ADAPTABILITY										1										0			
NATURAL VIBRATION RESISTANCE (STRUCTURAL)											1										1		
CONTAMINATION RESISTANCE	1											1										1/2	
AVAILABILITY OF DESIGN INFORMATION		0											0										0

PARAMETER	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
PRESSURE DROP																							
RESPONSE TIME																							
WEIGHT																							
CYCLE LIFE																							
LEAKAGE	1	1	1	1	1	1	0	1/2	1														
ENVELOPE	0									0	0	0	0	0	0	0	0						
REPLACEMENT MAINTENANCE		0								1								0	0	0	1	0	0
IN LINE MAINTENANCE			0								1							1					
COST				0								1							1				
STORAGE LIFE					0								1							1			
ACTUATOR ADAPTABILITY						0								1							0		
NATURAL VIBRATION RESISTANCE (STRUCTURAL)							1								1							1	
CONTAMINATION RESISTANCE								1/2								1							1
AVAILABILITY OF DESIGN INFORMATION									0								1						

PARAMETER	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL POSITIVE RESPONSES M	EMPHASIS COEFFICIENT M/91
PRESSURE DROP																							8	0.0879
RESPONSE TIME																							5	0.0549
WEIGHT																							2	0.0220
CYCLE LIFE																							11	0.1209
LEAKAGE																							11	0.1209
ENVELOPE																							0	0
REPLACEMENT MAINTENANCE	1																						5	0.0549
IN LINE MAINTENANCE		0	0	1	0	0	1																6	0.0659
COST		1						0	1	0	0	1											6	0.0659
STORAGE LIFE			1					1					1	0	0	1							9	0.0989
ACTUATOR ADAPTABILITY				0					0				0				0	0	1/2				2.5	0.0275
NATURAL VIBRATION RESISTANCE (STRUCTURAL)					1					1				1			1			1/2	1		12.5	0.1374
CONTAMINATION RESISTANCE						1					1				1			1		1/2		1	11.5	0.1264
AVAILABILITY OF DESIGN INFORMATION	0						0					0				0			1/2		0	0	1.5	0.0165
TOTAL																							91	1.000

Figure 2-35. Parameter Weight Assigned for Forced Decision Optimization of Valve Concepts (Emphasis Coefficient Determination)

A

B

Table 2-15

Parameter Weight Assigned for Forced Decision Optimization of Controller Concepts

Parameters *	Total Positive Responses	Emphasis Coefficient
Response Time	5	0.0641
Weight	2	0.0256
Cycle Life	10	0.1282
Leakage	10	0.1282
Envelope	0	0
Replacement Maintenance	5	0.0641
In-Line Maintenance	6	0.0769
Simplicity/Cost	6	0.0769
Storage Life	8	0.1026
Actuator Adaptability	2.5	0.0321
Vibration	11.5	0.1474
Contamination Resistance	10.5	0.1346
Availability of Design Information	1.5	0.0192
	78	

* Parameters are the same as for valves except pressure drop has been eliminated.

Table 2-16

Candidate Design Concepts (Based on Schematic Representation)

Figure	Large Valves	Figure	Small Valves	Figure	Actuators
2-4	Visor	2-13	Plug Poppet Hybrid	2-27	Double Acting Bellows-Solenoid
2-5	Plug	2-18	Bimetallic Poppet	2-28	Double Acting Double Solenoid Direct Drive Detent Held
2-7	Butterfly	2-19	Poppet Direct Motor Driven	2-26	Double Acting Double Solenoid Direct Drive
2-2	Ball	2-17	Hermetic Sealed Bellows	2-24	Hydraulic or Pneumatic Redundant Motor-Torque Motor

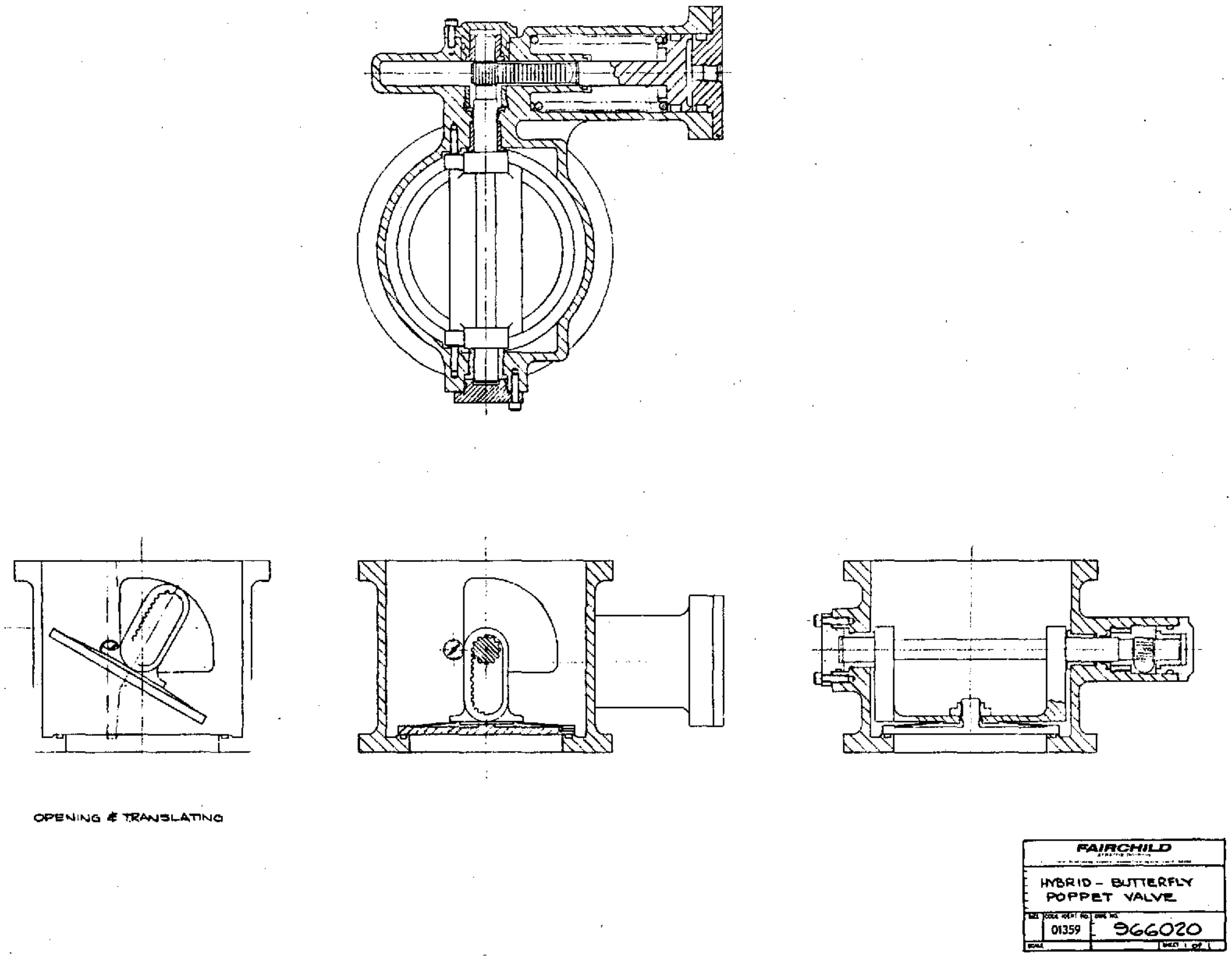


Figure 2-36. Hybrid - Butterfly Poppet Valve

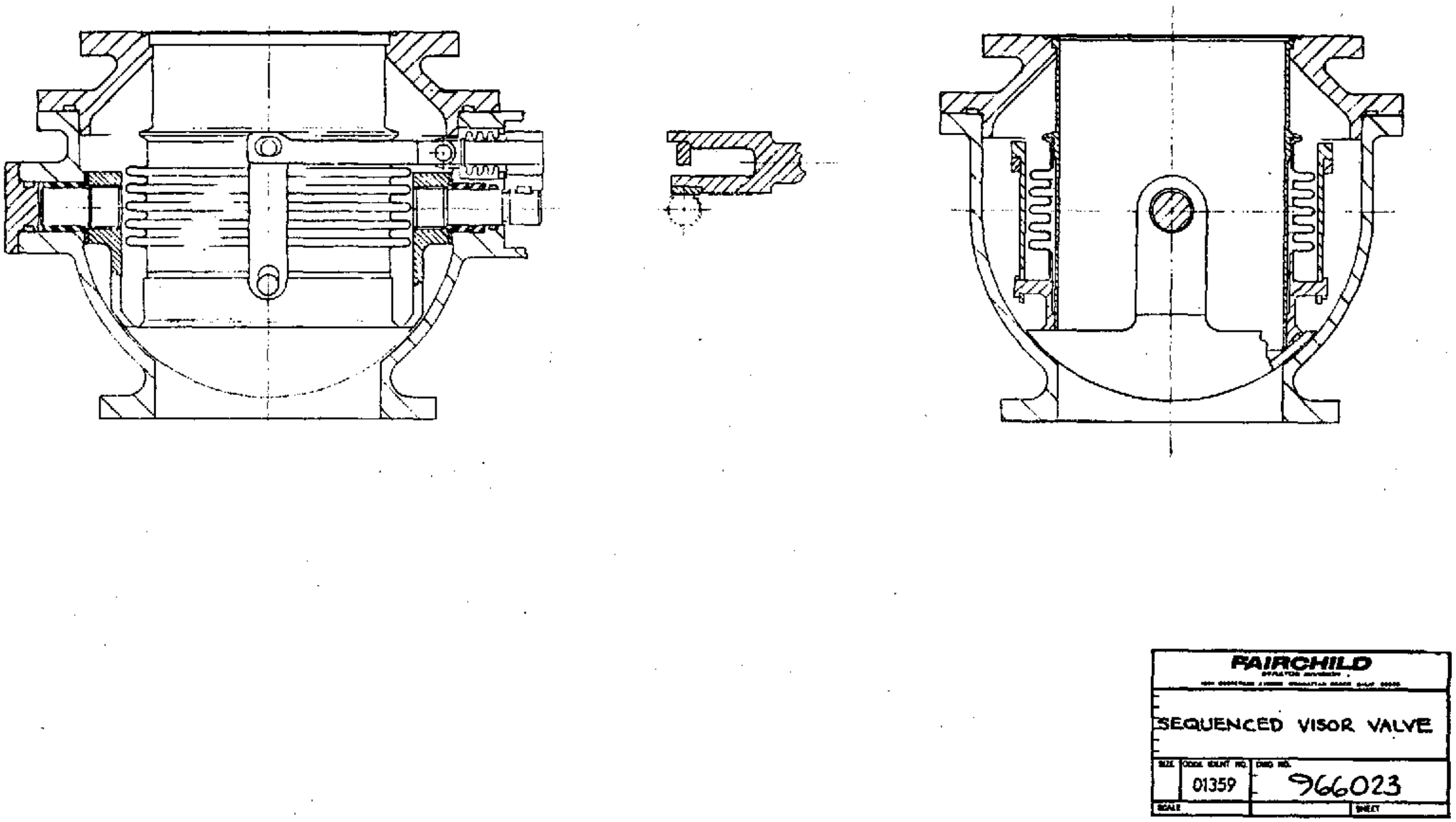


Figure 2-37. Sequenced Visor Valve

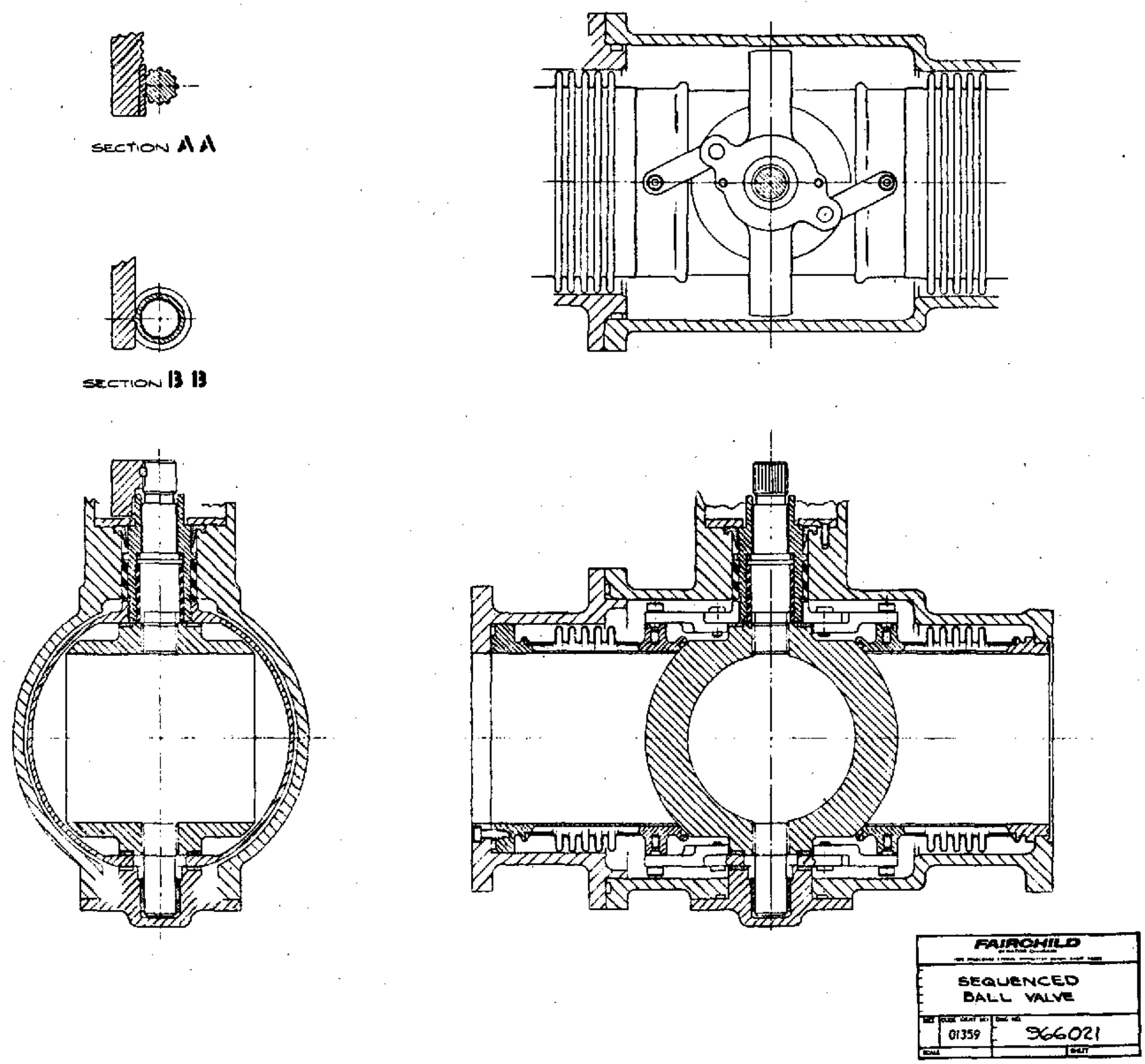


Figure 2-38. Sequenced Ball Valve

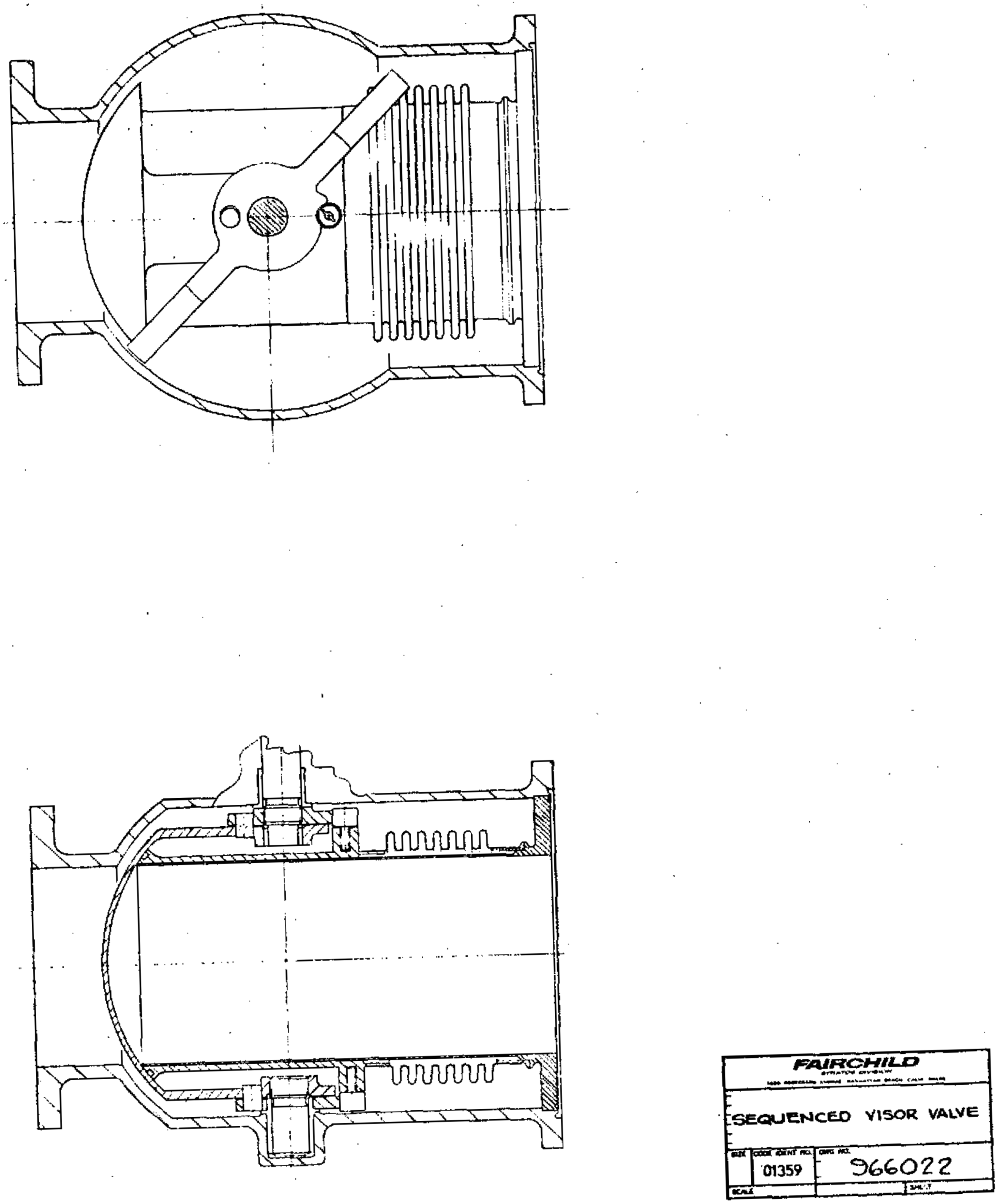
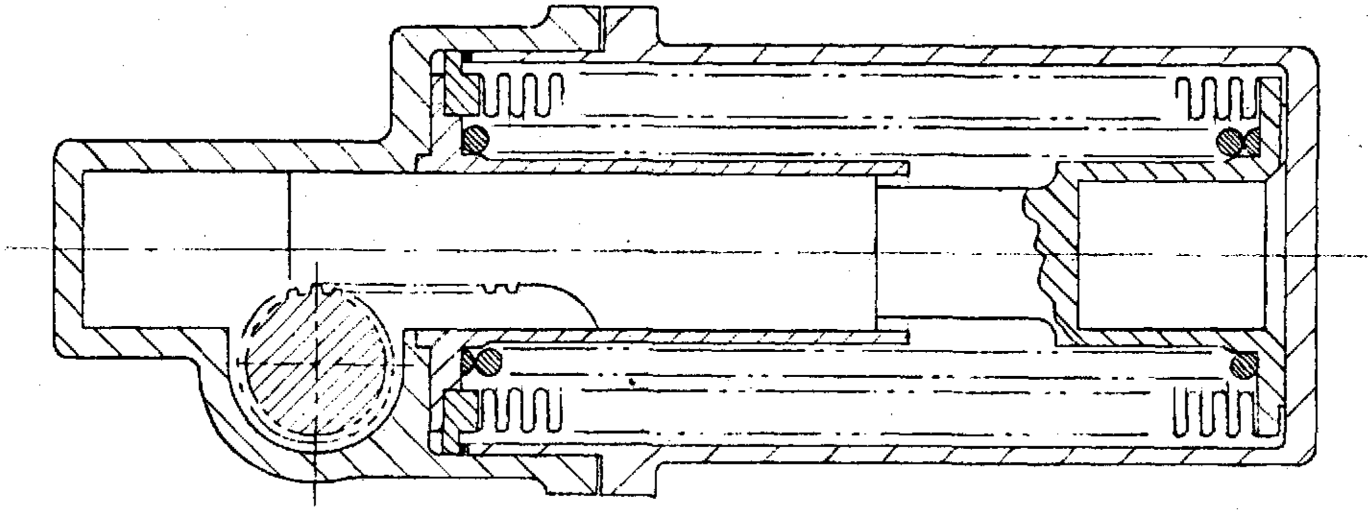


Figure 2-39. Sequenced Visor Valve



FAIRCHILD STRATOS DIVISION 1800 ROSECRANS AVENUE, MANHATTAN BEACH, CALIF. 90266			
ACTUATOR - DOUBLE ACTING			
SIZE	CODE IDENT NO. 01359	DWG NO. 966024	
SCALE			SHEET

Figure 2-40. Actuator - Double Acting

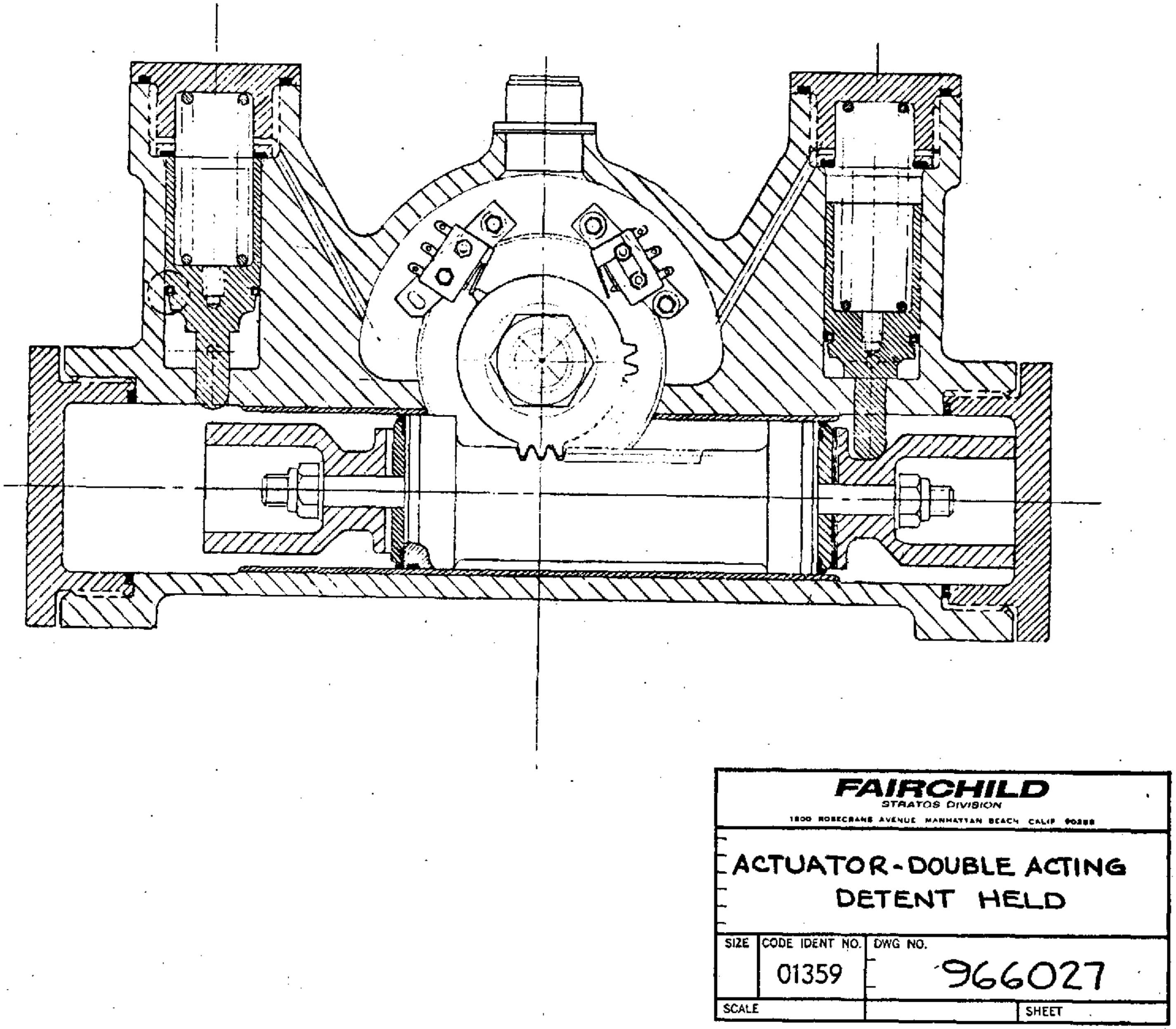


Figure 2-41. Actuator - Double Acting, Detent Held

2.5 FINAL CANDIDATES

The final candidate design concepts based on layout representation are presented in Table 2-17. These large valves and large valve actuator concepts are listed in the order of adjusted ratings. The layouts were drawn for each of the concepts and then evaluated using the technique of forced decision optimization. The ratings are indicated in the Table. The basis for the layouts were the concepts based on the schematic representations previously listed in Table 2-16. The layout drawings are shown in Figures 2-36 through 2-41.

2.6 FINAL DESIGN CONCEPT SELECTION

Final valve and actuator design concepts were selected utilizing the results of the rated candidate design concepts based on layout representation and the results of the breadboard evaluation. The hybrid poppet-butterfly, PN 966020, was selected as the primary candidate for a valve design, and sequenced visor valve, PN 966023, was selected as an alternate in the event of serious design obstacles. A double acting actuator similar to PN 966025 was selected for final design. Bellows piston actuation was preferred.

Table 2-17

Candidate Design Concepts
(Based on Layout Representation)

Figure	Large Valves	Rating
2-36	966020, Hybrid Butterfly Poppet	3.6045
2-37	966023, Visor-Lever Sequenced	3.0221
2-38	966021, Ball-Dual Seal Sequenced	2.7913
2-39	966022, Visor-Cam Sequenced	3.0770

Figure	Large Actuators	Rating
2-40	966024, Double Acting Bellows-Solenoid Operated	3.9996
	Redundant, Single Acting Bellows Solenoid Operated	3.6151
2-41	966027, Double Acting Direct Drive Detent Held	2.9935
	Redundant Motor-Bellows	2.4870

SECTION 3

PHASE II FINAL DESIGN

3.1 FINAL REQUIREMENTS AND DESIGN GOALS

The final requirements and design goals for the 10-inch shutoff valve were updated based on the best available information for possible mission use. These requirements and goals are listed in Table 3-1. The updated parameters were operational pressure, proof pressure, burst pressure, and leakage. The design factors of safety for the valve and actuator, the design flow mach number for the valve, and the closing time for the valve were established. These are as follows:

a.	Proof Factor	1.50
b.	Ultimate Factor	2.50
c.	Design Valve Flow Rate, Mach	0.5
d.	Closing Time, Milliseconds	500

3.2 VALVE DESIGN CONCEPT

The design features of the hybrid poppet butterfly concept, shown schematically in Figure 3-1, are as follows:

a. No actuation shaft leakage when the valve is closed. The actuation linkage,which causes the rotary actuation of the butterfly poppet, is located downstream of the valve enclosure.

b. Butterfly poppet out of the flow stream. The butterfly poppet is lifted off its seat by rollers on the edge of the butterfly, which are guided by slots in the housing. Continued rotary motion of the actuator linkage causes the butterfly to pivot along the axis of the cam rollers.

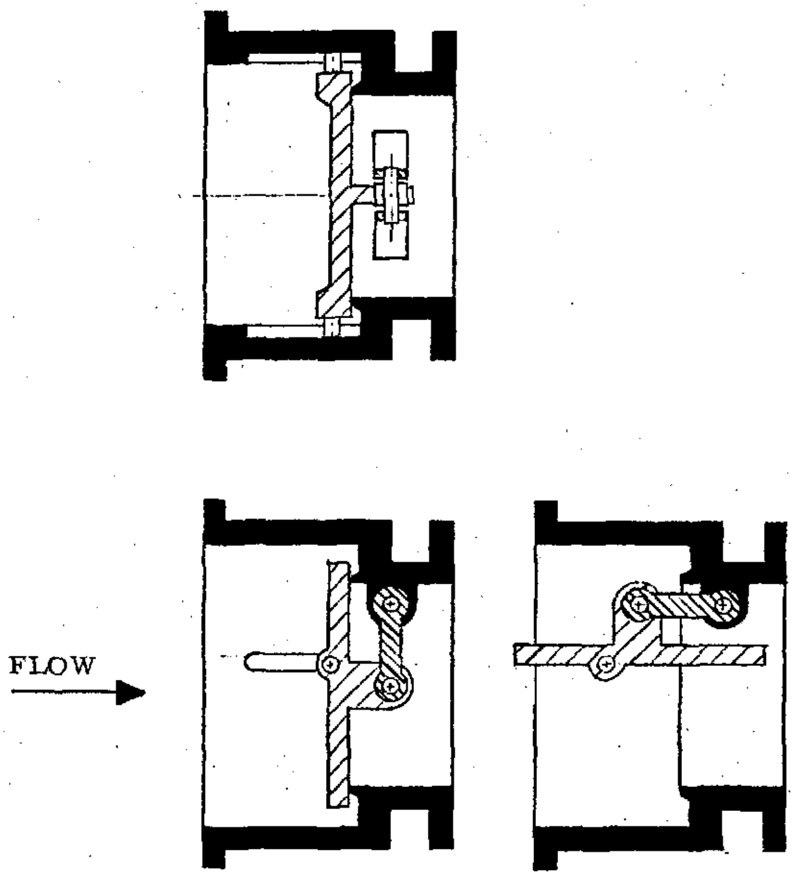
c. Seal-to-seat misalignment forgiveness is obtained without necessity of a bellows. The lever from the rotary actuator is connected at the butterfly to a uniball, which will allow a $\pm 1^{o}$ of freedom along any axis (except for full rotation in the pivoted direction). This freedom allows for 0.175 inch of forgiveness at the 10-inch diameter.

d. Seal seat loading is handled by a seal limit stop, actuator, and pressure load. No thermal or Belleville spring loads at the seal are required.

Table 3-1

Requirements and Design Goals
10-In. (25.4 CM) Shutoff Valve

Media	RP-1, Propane, LH_2, LO_2, He, N_2
Temperature	-423^{o} to $+200^{o}F$ 20.38^{o} to $366.49^{o}K$
Ambient Pressure	10^{-8} to 14.7 psia 6.895×10^{-5} to $1.013 \times 10^{5}\ \frac{N}{m^2}$ abs
Valve Pressure	
Operating	35 psia (+3.5, -0) $24.13 \times 10^{4}\ \frac{N}{m^2}$ abs ($+2.41 \times 10^{4}$, -0)
Proof	52.5 psia (+5.25, -0) $36.2 \times 10^{4}\ \frac{N}{m^2}$ abs ($+3.62 \times 10^{4}$, -0)
Burst	87.5 psia (+8.75, -0) $60.3 \times 10^{4}\ \frac{N}{m^2}$ abs ($+6.03 \times 10^{4}$, -0)
Actuator Pressure (He or N_2)	
Operating	750 ± 50 psia $5.17 \pm 3.45 \times 10^{6}\ \frac{N}{m^2}$ abs
Proof	1125 ± 75 psia $7.75 \pm 5.17 \times 10^{6}\ \frac{N}{m^2}$ abs
Burst	1875 ± 125 psia $12.92 \pm 8.62 \times 10^{6}\ \frac{N}{m^2}$ abs
Valve Pressure Drop	2 psi ($1.379 \times 10^{4}\ \frac{N}{m^2}$) maximum with 43 lb/sec (25.8 kg/sec) air or N_2 at room ambient temperature and pressure, and 35 psia ($24.13 \times 10^{4}\ \frac{N}{m^2}$) at valve inlet.
Valve Leakage Goal	3×10^{-5} SCCS at 35 psia ($24.13 \times 10^{4}\ \frac{N}{m^2}$ abs)



HOW IT WORKS

BUTTERFLY LIFTS OFF SEAT AXIALLY BECAUSE OF COMBINED ROTARY MOTION FROM ACTUATING LINK AND LINEAR MOTION FROM ROLLERS IN CAM SLOT. CONTINUED ROTARY MOTION CAUSES BUTTERFLY TO PIVOT ALONG AXIS OF CAM ROLLERS.

Figure 3-1. Schematic Diagram, Hybrid Poppet Butterfly

3.3 HARDWARE STUDIES AND SELECTION

3.3.1 Main Seal Selection

3.3.1.1 Main Seal Concepts

Several main seal concepts were sketched and evaluated. The four configurations, which are discussed below, are identified as the TRW, Rocketdyne and McDonnell Douglas concepts.

3.3.1.1.1 TRW Concepts

The two TRW main seal concepts that use TRW material AF-E-124D are shown in Figures 3-2 and 3-3. This material is reported to behave like an elastomer at room temperature and like improved teflon at cryogenic temperatures. The stress required for sealing at cryogenic temperatures is reported to be less than that required with Teflon. This material was developed by TRW under NASA Contract NAS 9-11866.

The configuration shown in Figure 3-2 features a flat mating plate with a relatively large circumferential area relative to the seal. The needed stress is developed across the seal lip. The configuration shown in Figure 3-3 features a sealing plate with a 0.016 to 0.02 lip which mates with a relatively large flat seal.

3.3.1.1.2 Rocketdyne Concept

The Rocketdyne trapped seal configuration, which was developed under NASA Contract NAS 3-14350, is shown in Figure 3-4. In this main seal configuration the Teflon seal is continually trapped by two annular rings which minimizes the tendency of the Teflon to cold flow.

3.3.1.1.3 McDonnell Douglas Concept

The McDonnell Douglas seal concept, which was developed under NASA Contract NAS 3-14375, uses Teflon S coated A-286 CRES material. The configuration is shown in Figure 3-5.

3.3.1.2 Seal Selection

The seal configuration depicted in Figure 3-2 was selected to be used in the 10-inch long life valve. The material selected was Plaskon CTFE 2400 manufactured by Allied Chemical. This material had been used successfully in applications at Fairchild Stratos for liquid hydrogen valve applications.

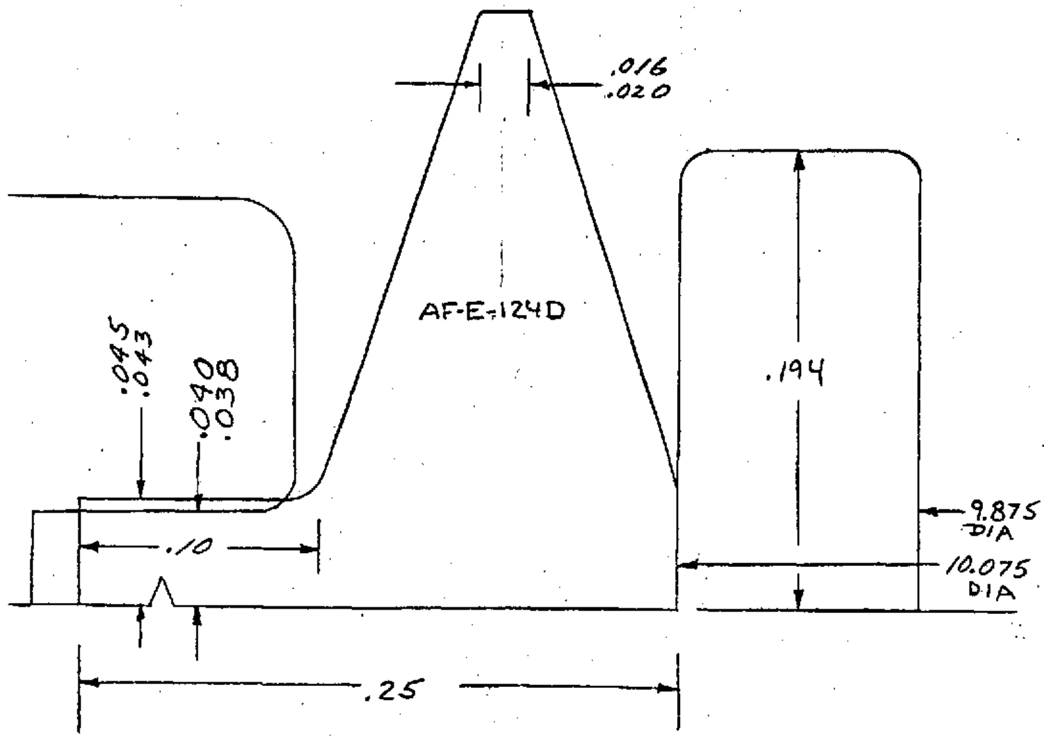


Figure 3-2. TRW Seal Concept (Tapered)

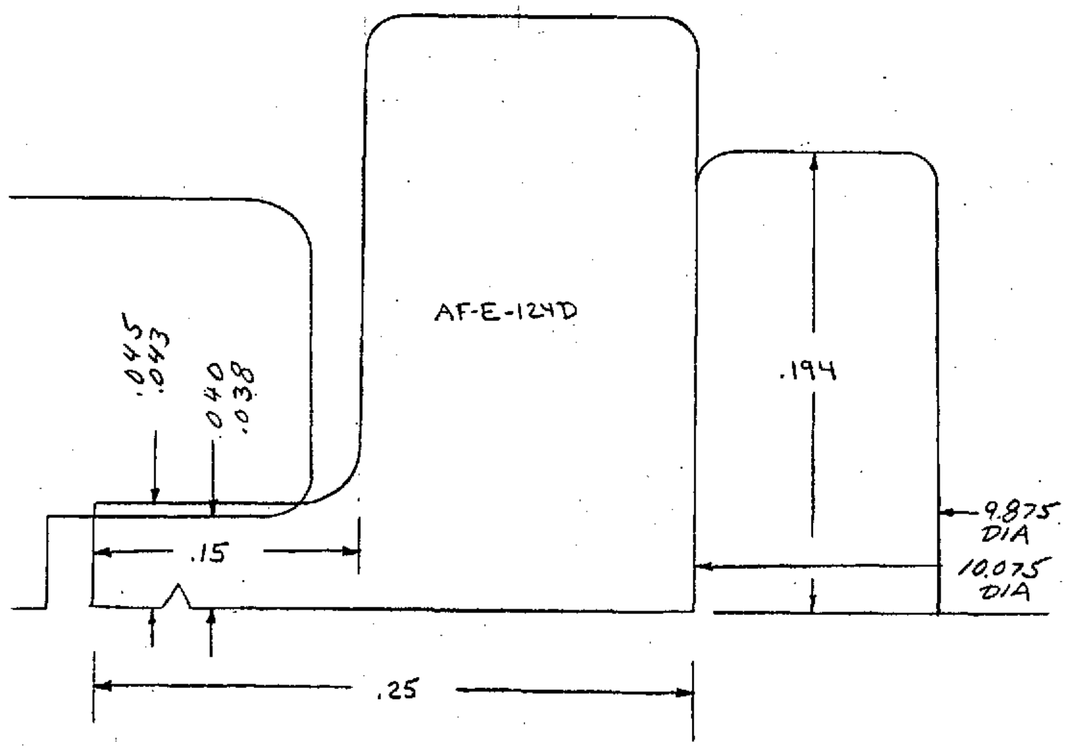


Figure 3-3. TRW Seal Concept (Square)

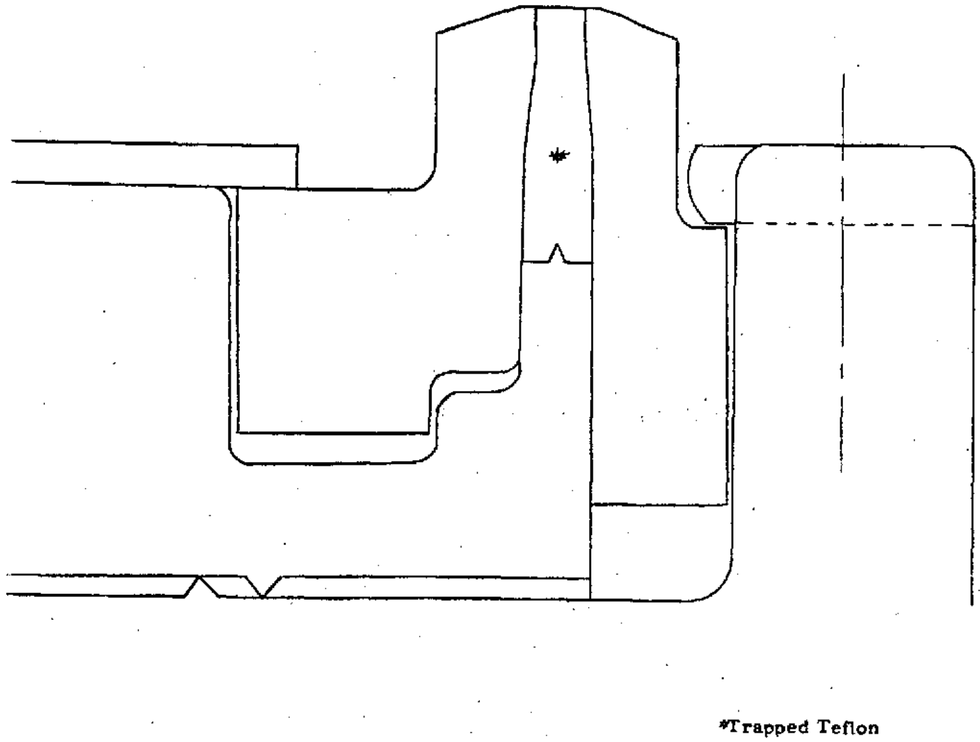


Figure 3-4. Rocketdyne Seal Concept

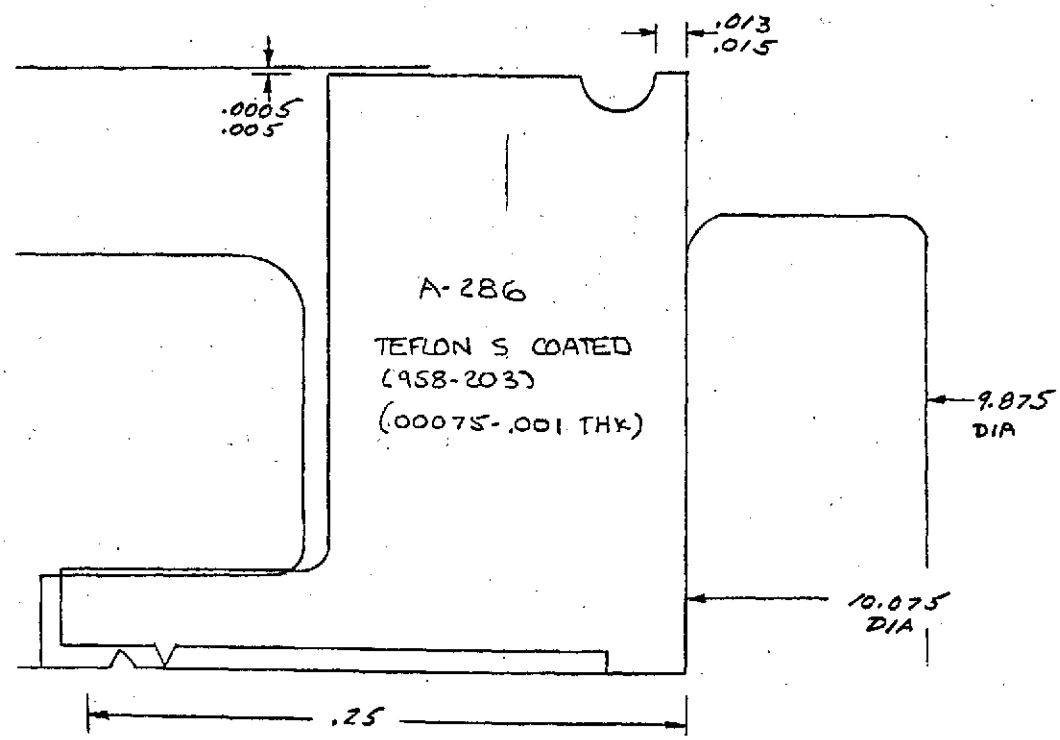


Figure 3-5. McDonnell Douglas Seal Concept

3.3.2 Actuation Mechanism Selection

3.3.2.1 Mechanism Requirements

The poppet actuation mechanisms were studied, and the following requirements were determined to be desirable:

a. Valve pressure drop to be used to assist in sealing. This requires that the initial disk motion be against the flow.

b. The disk lift at the point of rotation through the plane of the seat to be minimized (1) by locating the rotation points upstream of the valve, and (2) by translating the disk in the direction of increasing lateral clearance after the initial normal lift off the seat.

c. Maintain a consistent closing torque level to permit the control of the closing transient with the pneumatic actuator.

d. Maintain constant torque in order to simplify the actuator design.

3.3.2.2 Design No. 1 (Gear Rack Cam)

The hybrid butterfly utilizing the gear rack cam mechanism, identified here as Design No. 1, was studied. The study was concerned with the feasibility of the gear rack cam concept, especially in relation to accumulated tolerances, method of guidance and support, and affect of load unbalance.

Analysis indicated that the execution of a cam gear mechanism would be difficult to implement because of the precision manufacture required for the wide temperature limits. Design No. 1 was abandoned. Three other designs (Design No. 2, 3 and 4) were considered.

3.3.2.3 Design No. 2 (Lever Driven, Cam Positioned)

Design No. 2, shown schematically in Figure 3-6, is a lever-driven, cam-positioned valve. This configuration features an initial axial motion of the valve disk to eliminate seal scuffing, followed by a combined rotation and translation to provide the final low drag axial orientation of the disk.

The actuator torque requirements were calculated as a function of disk angle using aerodynamic load and center of pressure locations on the disk. The torque requirements plotted in Figure 3-7 show that the driving torque changes sign prior to the completion of the stroke. This causes the disk to be self-driven to the fully open position. This characteristic is undesirable for use with a pneumatic actuator which does not permit snubbing to the degree

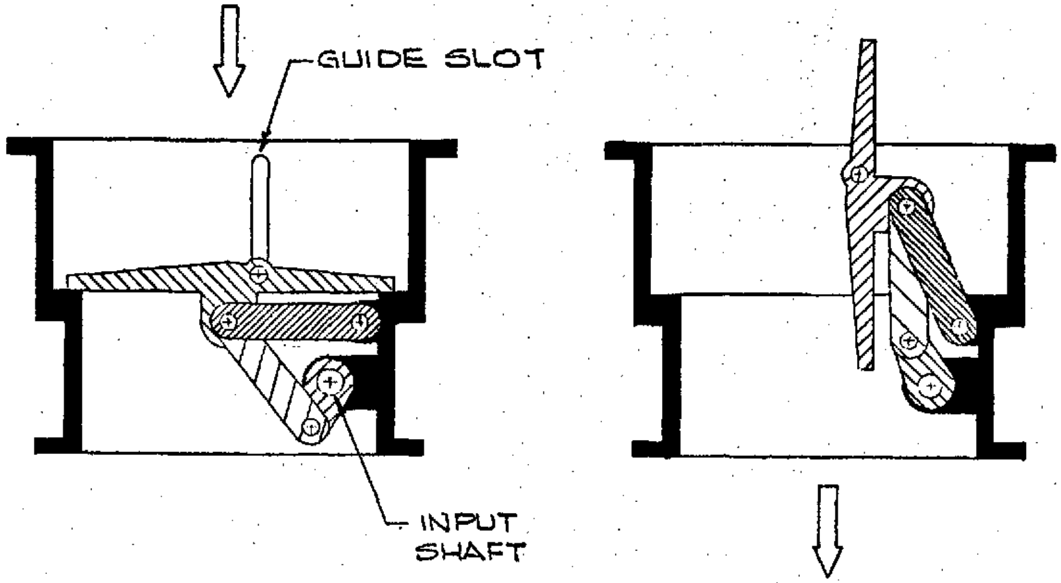


Figure 3-6. Design No. 2-Hybrid Butterfly

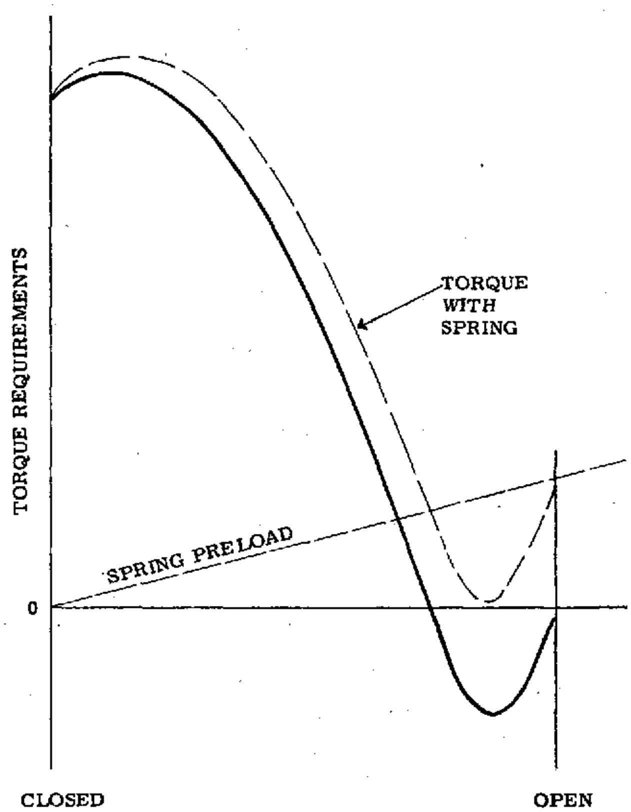


Figure 3-7. Operating Torque Requirements-Design No. 2

permitted by the hydraulic counterpart. The negative torque could be counteracted by the addition of an actuator spring, but the overall torque pattern would be undesirable for pneumatic operation with the large unbalanced disk force.

3.3.2.4 Actuation System Characteristics

Actuation systems may be designed with increasing or decreasing actuator demand pressure with the opening stroke. A system with an increasing demand pressure with opening stroke has the capability of controlling the rate of closure in a flow situation by the use of an orifice in the actuator inlet. See Figure 3-8. This scheme does not fully utilize the work capability of the bellows and therefore involves an actuator penalty.

A system with a decreasing demand pressure with stroke calls for a recompression of the pneumatic pressure to balance the force demand. This can be accomplished by minimizing the head clearance volume and using an orifice, as long as the actuation pressure at the point of closure is sufficiently high.

3.3.2.5 Overall Design Requirements

The overall design requirements were reviewed and the following was concluded:

a. The poppet should be supported in the central area of the disk to permit a uniform outer disk thickness. This requirement minimizes distortion of the sealing surface during temperature transients and permits uniform load distribution to the seal.

b. The demand pneumatic actuation pressure must be sufficiently high at the open position to permit snubbing of the closing transient.

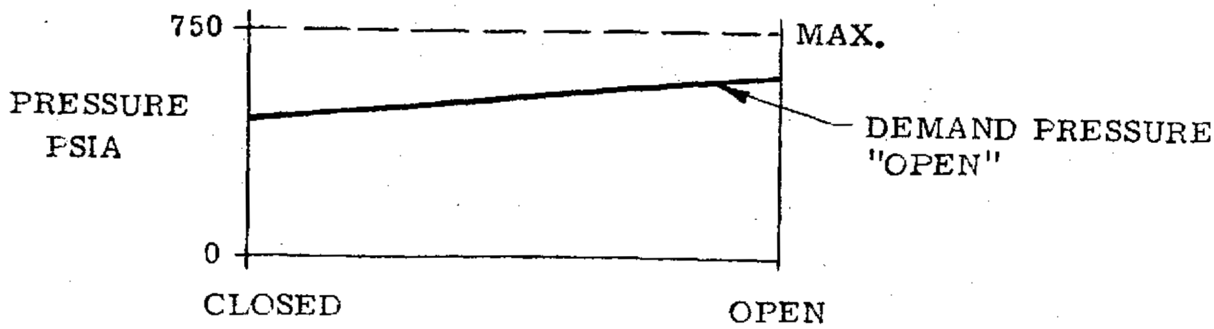
c. The disk support and guidance members should be on the same side of the disk to reduce the effects of differential expansion.

3.3.2.6 Four-Bar Linkages

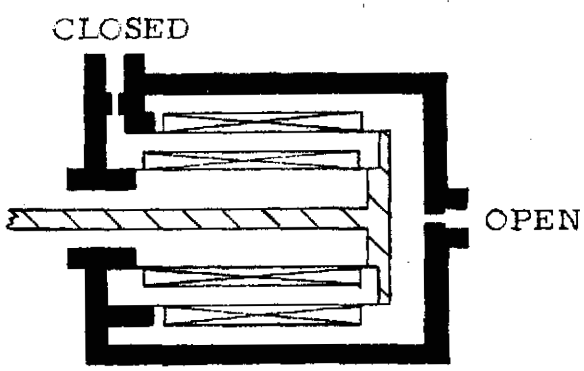
A study of four-bar linkages indicated that insufficient blade motion resulted when the overall design requirements listed in paragraph 3.3.2.5 were imposed. After defining the lowest disk trajectory for clearance, the Design No. 3 was selected.

3.3.2.7 Design No. 3 (Lever Driven, Lever Positioned)

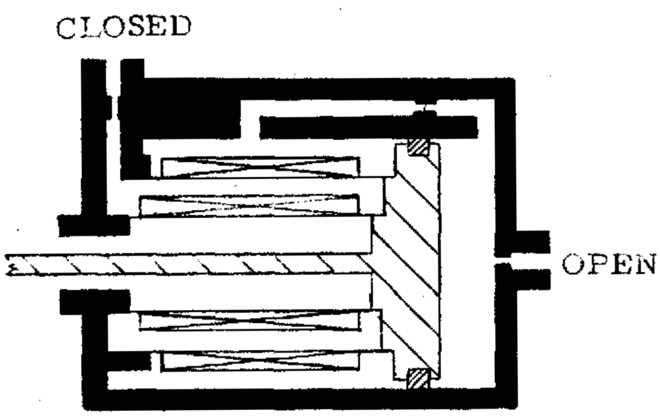
Design No. 3 is a lever driven, lever positioned valve with the fulcrum of the disk support lever located outside the flow stream for minimum pressure drop.



(A) Desirable Demand Characteristic



(B) Orifice Controlled Actuator



(C) Piston Head Controlled Actuator

Figure 3-8. Actuator Variables - Design No. 2

The valve mechanism is shown in schematic form and preliminary layout form in Figures 3-9 and 3-10, respectively. The lever mounted on the actuator shaft is link connected to the support lever and to the valve disk.

This lever system results in a favorable pressure drop configuration in the open position at the expense of higher bearing loads in the mechanism. A disk load at the valve cracking point of 2830 pounds results in a beam link load of 9000 pounds and a fulcrum load of 12, 200 pounds for the compact arrangement shown in Figures 3-9 and 3-10. The bearing loads can be reduced by increasing the driving arm dimensions with an envelope and weight penalty.

The design of the pivot joints is based on the permissible loading of the sleeve bearings rather than the structural strength of the members. The overall sizing dictates the use of the polyimide compound SP-21 rather than the low friction compound SP-211, having the lower bearing allowables.

The design opening torque characteristics are shown in Figure 3-11. The valve demand torque is well matched to the available actuator linkage torque as seen in the Figure. Although the demand torque drops with the actuator shaft angle, a final demand pressure of 300 psi is indicated.

The upstream location of the shaft seal is a disadvantage for a long life low leakage requirement.

3.3.2.8 Design No. 4 (Lever Driven and Lever Positioned)

Design No. 4 is a lever driven, lever positioned valve with the actuation mechanism located downstream of the valve disk. The lever attachment points are in the central area of the disk. A support spanning the valve body provides the pivot points for the actuation shaft and the upper support lever. Preliminary and final designs are shown in Figures 3-12 and 3-13, respectively. The preliminary mechanism illustrated in Figure 3-12 provides the initial motion normal to the seat by the parallel arrangement of the linkage. The short support lever permits a rigid lateral positioning of the open disk.

The final design shown in Figure 3-13 eliminates the ironing of the linkage during actuation, permitting a symmetrical arrangement of the linkage. The valve disk is supported by both driving links which further reduces the bearing loads. The selected linkage maintains valve disk-seat parallelism for an initial lift of 0.70 inch and gives a valve seat clearance in excess of 0.50 inch at the point of entry of the disk through the plane of the seat.

The torque characteristic for the final design is shown in Figure 3-14. The initial rise in the torque is a desirable feature but the drop-off is undesirable. The torque drop-off in the last 10^{o} of motion is corrected by spring action to the level shown. The resulting curve is easily matched by the actuator and is satisfactory for the closing dynamic requirement.

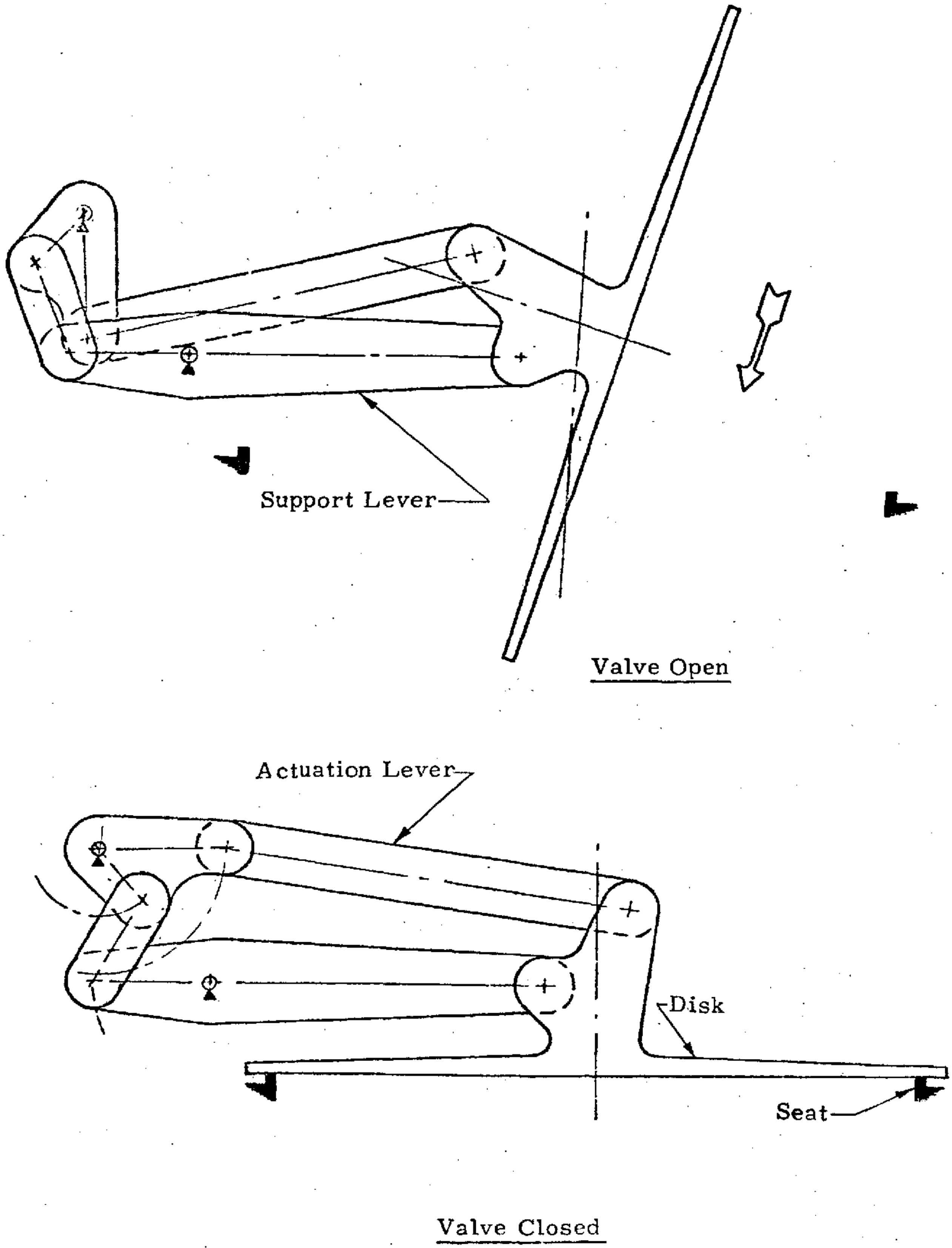


Figure 3-9. Design No. 3 - Hybrid Butterfly

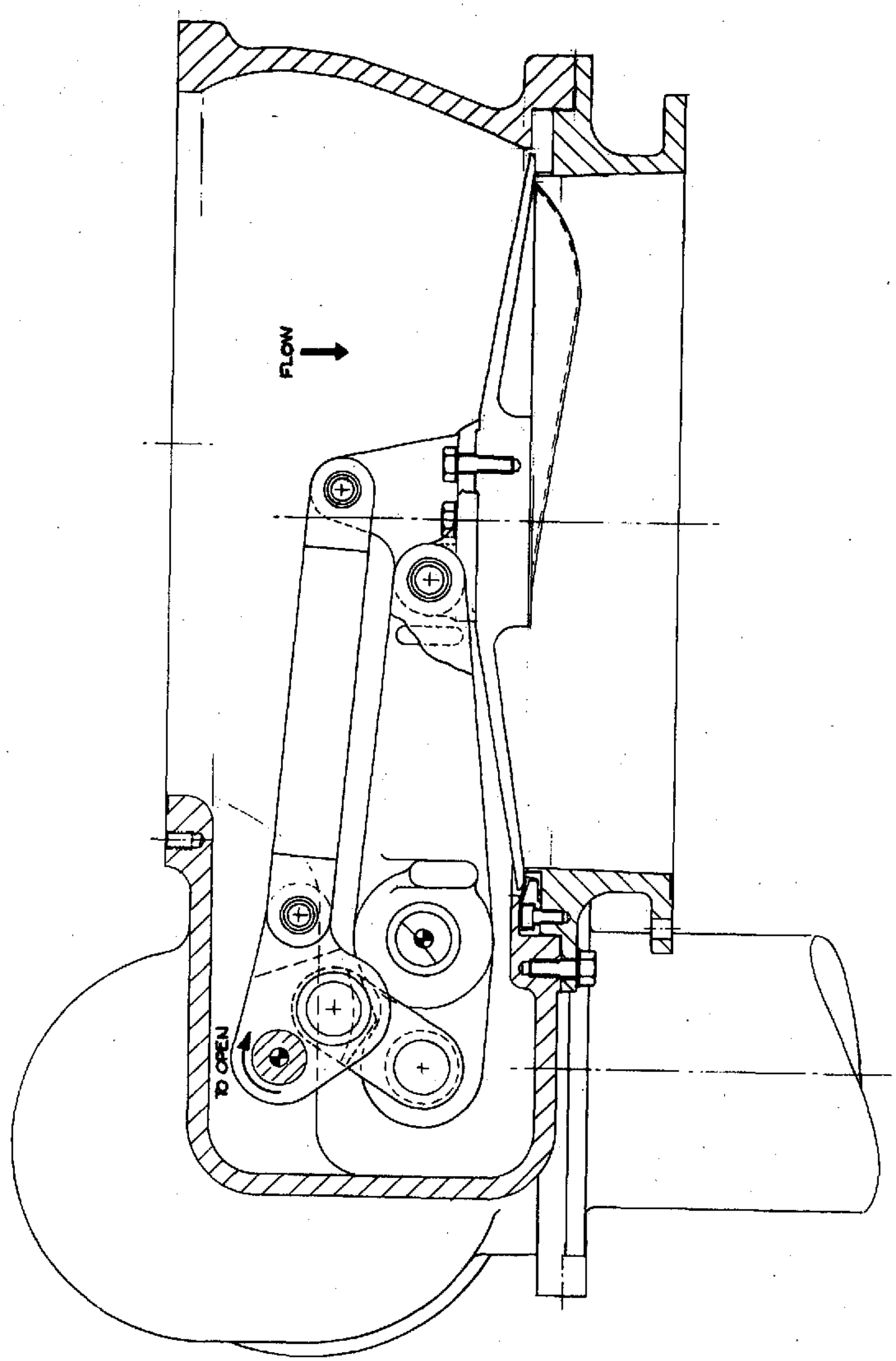


Figure 3-10. Detail Design No. 3

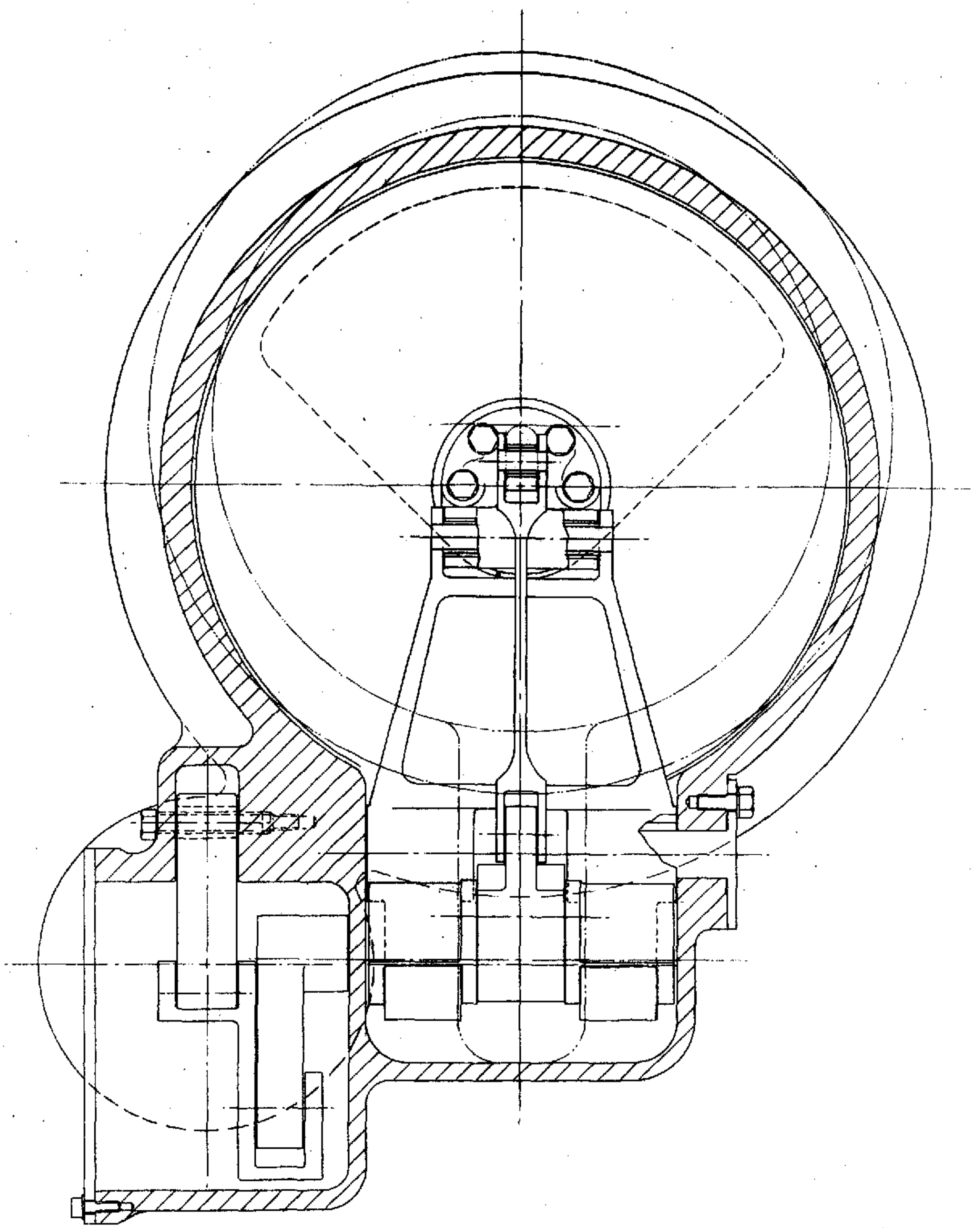


Figure 3-10. Detail Design No. 3 (continued)

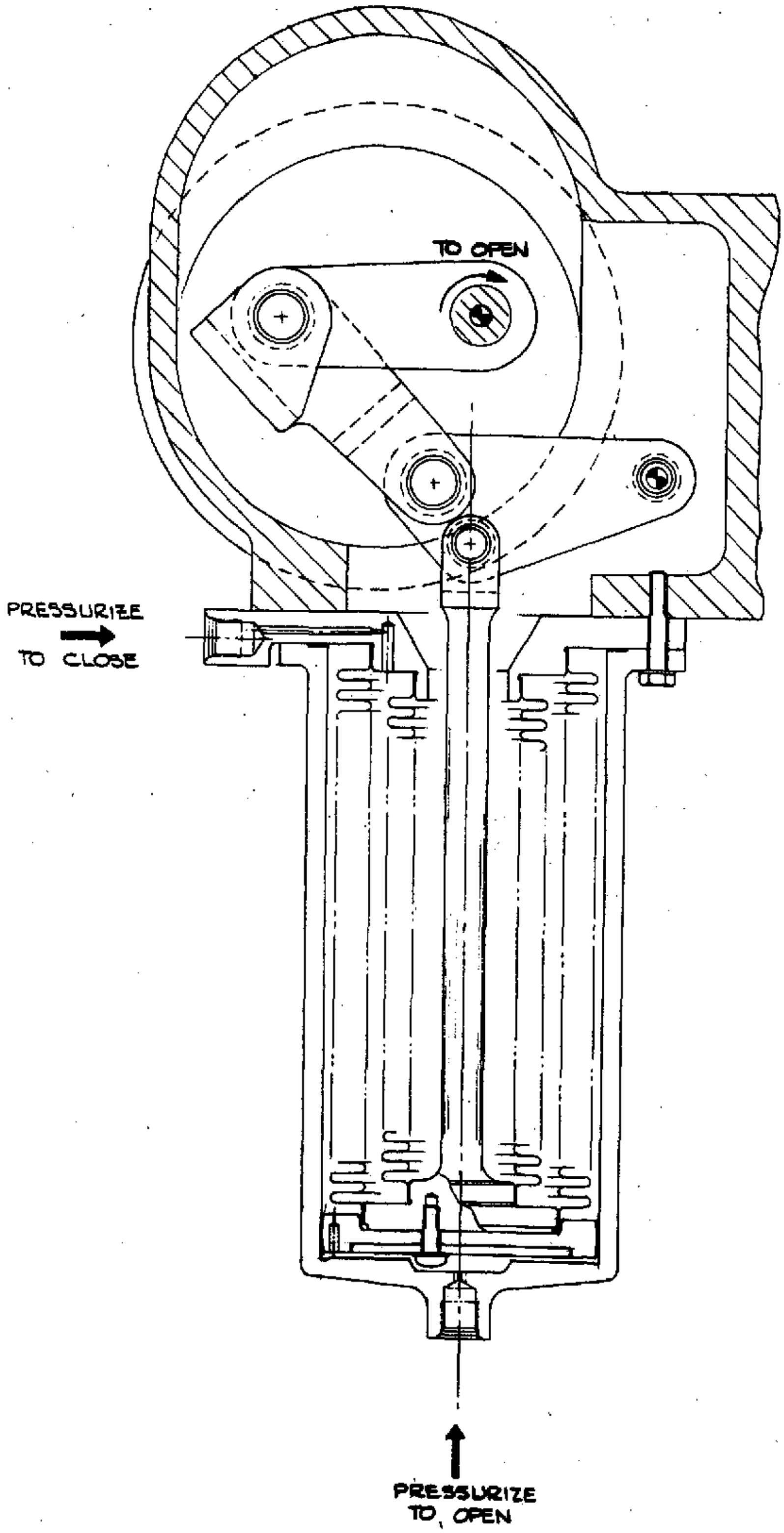


Figure 3-10. Detail Design No. 3 (concluded)

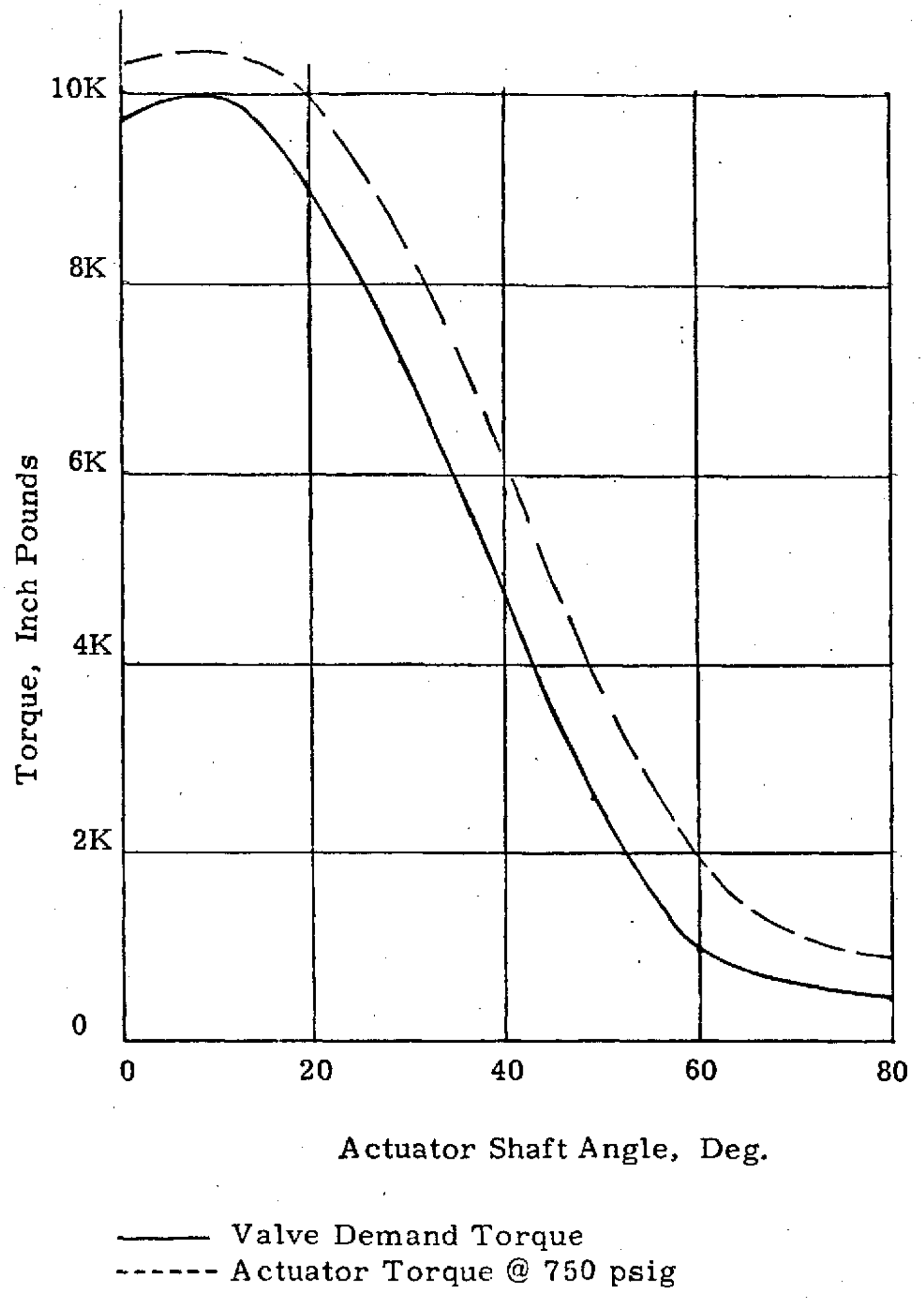


Figure 3-11. Torque Characteristics - Design No. 3

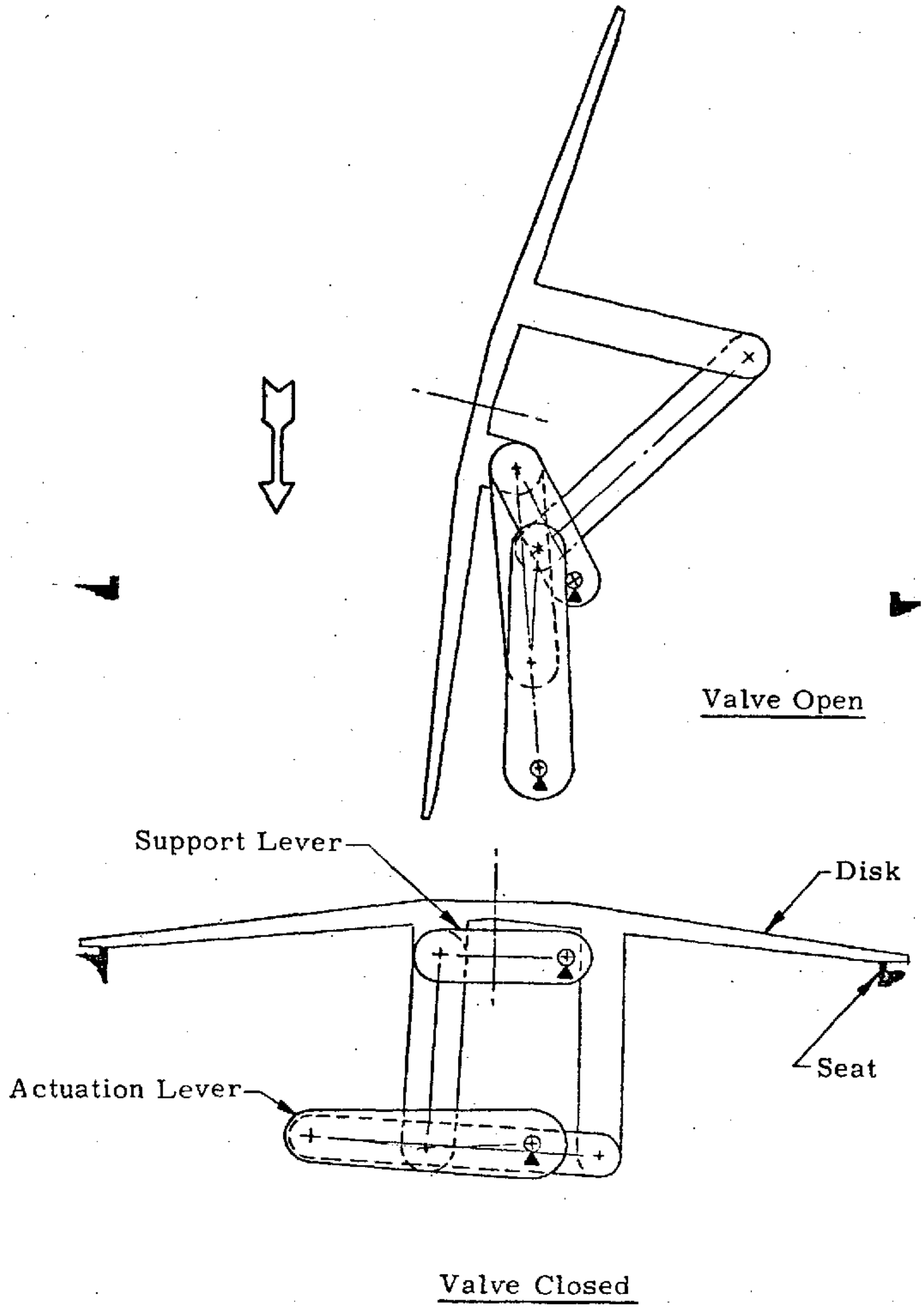


Figure 3-12. Preliminary Design No. 4 - Hybrid Butterfly

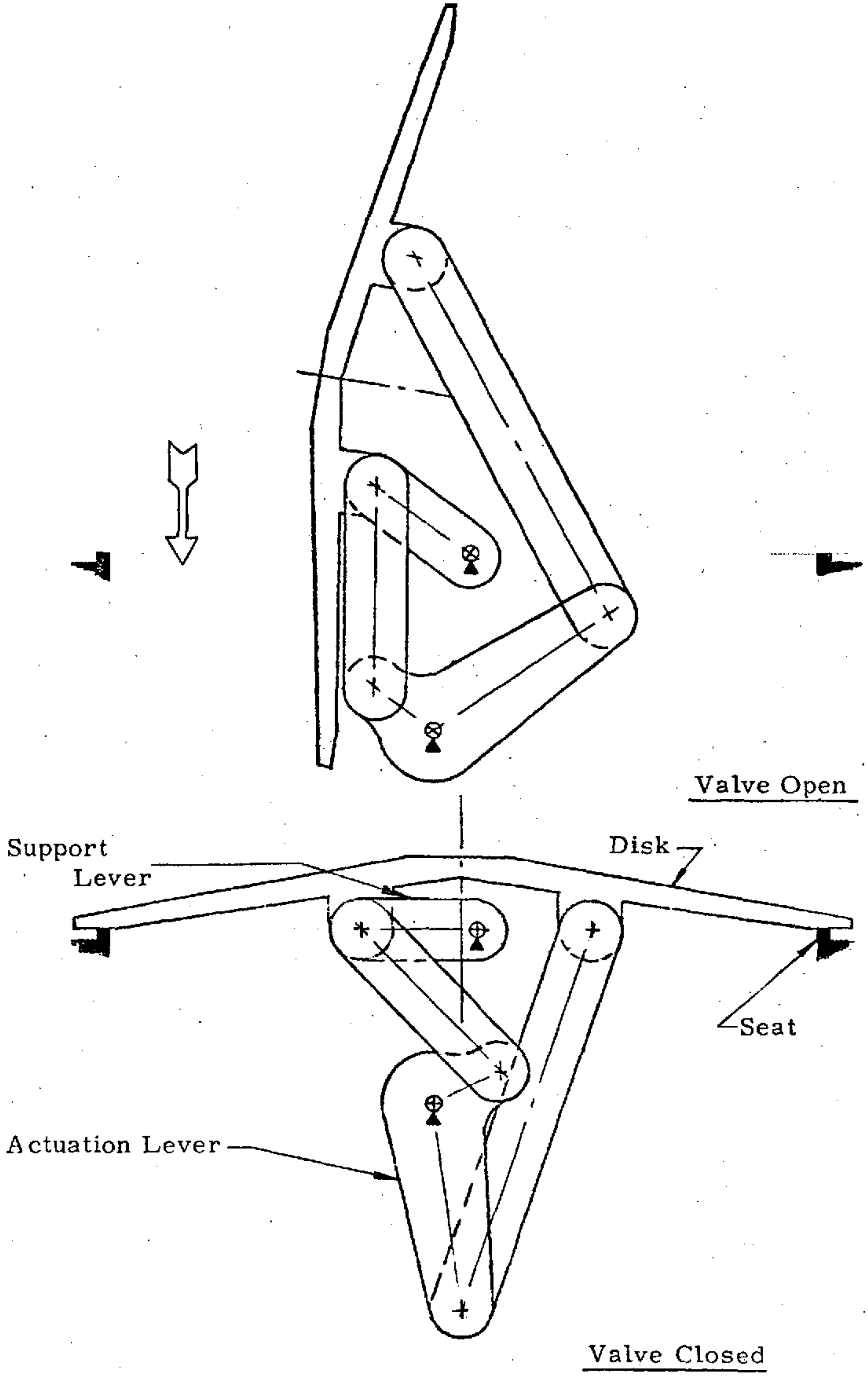


Figure 3-13. Final Design No. 4 - Hybrid Butterfly

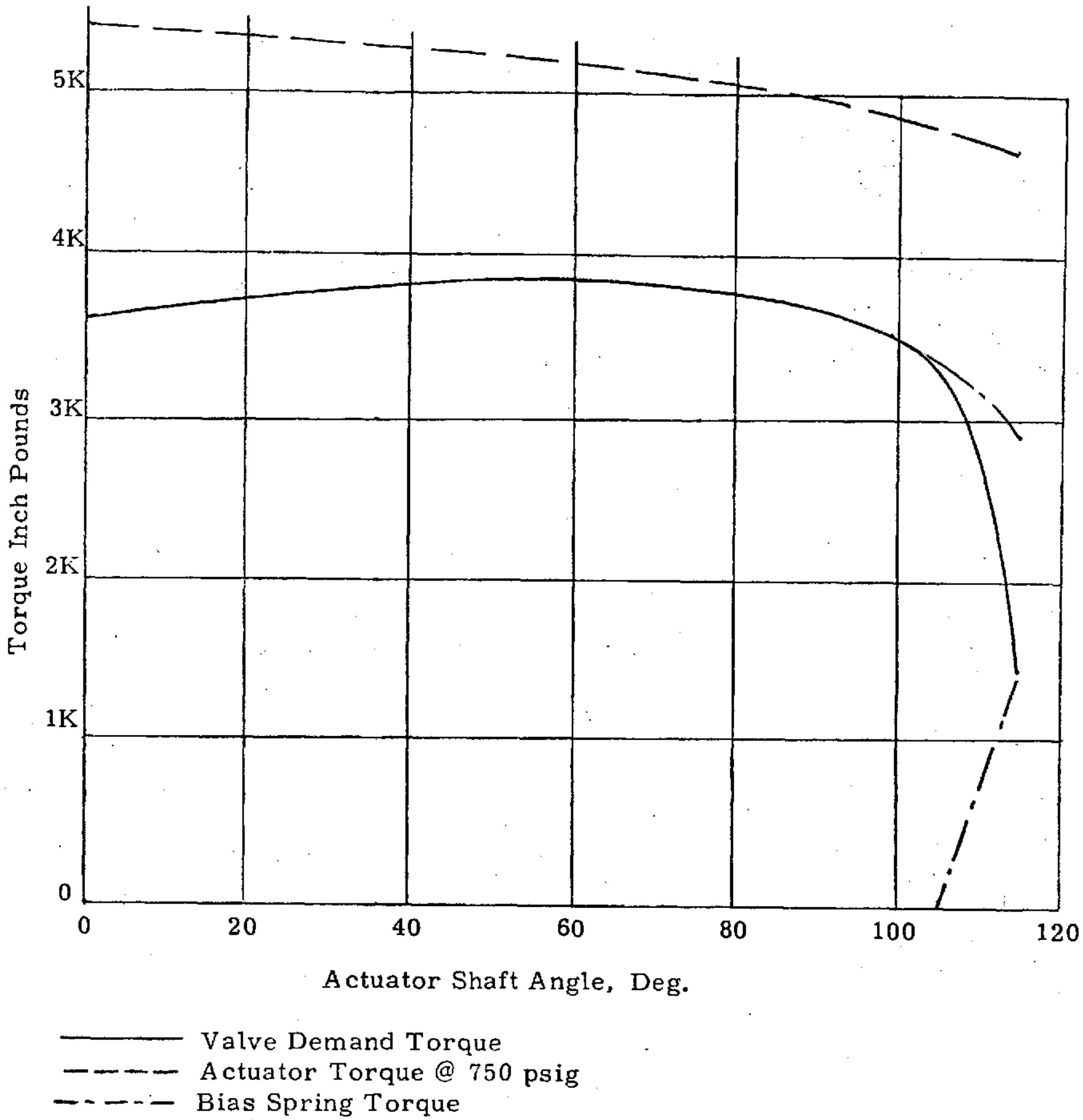


Figure 3-14. Torque Characteristic - Design No. 4

This design provides the desired downstream location of the shaft seal. However, the pressure drop will be increased from that in Design No. 3 because of the additional members in the flow stream.

3.4 FINAL DESIGN SELECTION

The final design was selected based on the functional characteristics of the three design candidates (Designs No. 2, No. 3 and No. 4). The three designs are compared in Table 3-2. Design No. 4 was selected on the basis of minimum system leakage, rapid response capability, and extended life capability.

Table 3-2

Design Concept
Functional Characteristics
Comparison

	Design Concept		
	No. 2	No. 3	No. 4
Characteristics	Lever Driven Cam Positioned	Lever Driven Lever Positioned	Lever Driven Lever Positioned
Uniform Blade Rigidity	No	Yes	Yes
Maintains Positive Closing Torque	No	Yes	Yes
Actuation Requirement	High	Medium	Low
Valve Pressure Drop	Medium	Low	Medium
Actuator Shaft Downstream	Yes	No	Yes
Rigid Support	No	Yes	Yes
Low Actuation Friction	Yes	No	Yes
Low Mechanical Weight	Yes	No	Yes

3.5 DETAIL DESIGN

3.5.1 Configuration

The final shutoff valve configuration is shown in Figure 3-15, Assembly Drawing 966001. A common factor of all sequentially operated valves is the increase in actuator stroke requirements where the initial poppet translation occurs with the full poppet pneumatic loading. The actuation motion of the poppet linkage illustrated in Figure 3-15 limits the translation to that required for poppet-seat clearance in the open position. The actuation linkage employed in this design was selected to provide a relatively constant design actuation force with stroke and therefore minimize the bellows displacement.

The main seal configuration is similar to that shown in Figure 3-2 and was fabricated from CTFE plastic. A redundant metallic seal member was incorporated in the design to reduce the valve discharge rate at the main seal engagement to a leakage level which would reduce the seal surface wear by erosion. A detail of the seal arrangement and a description of the sealing sequence are presented in Figure 3-16. The hard surface identified on the poppet is a 0.003 to 0.005-inch thickness of flame plated Tribaloy No. 120. This DuPont blend of 80 percent Tribaloy 100 plus 20 percent nickel was chosen for its maximum mechanical wear resistance. Tribaloy 100 is 55 percent Colbalt, 35 percent Molybdenum, and 10 percent Silicon. The final finish, after grinding, was specified to be 1 to 2 RMS.

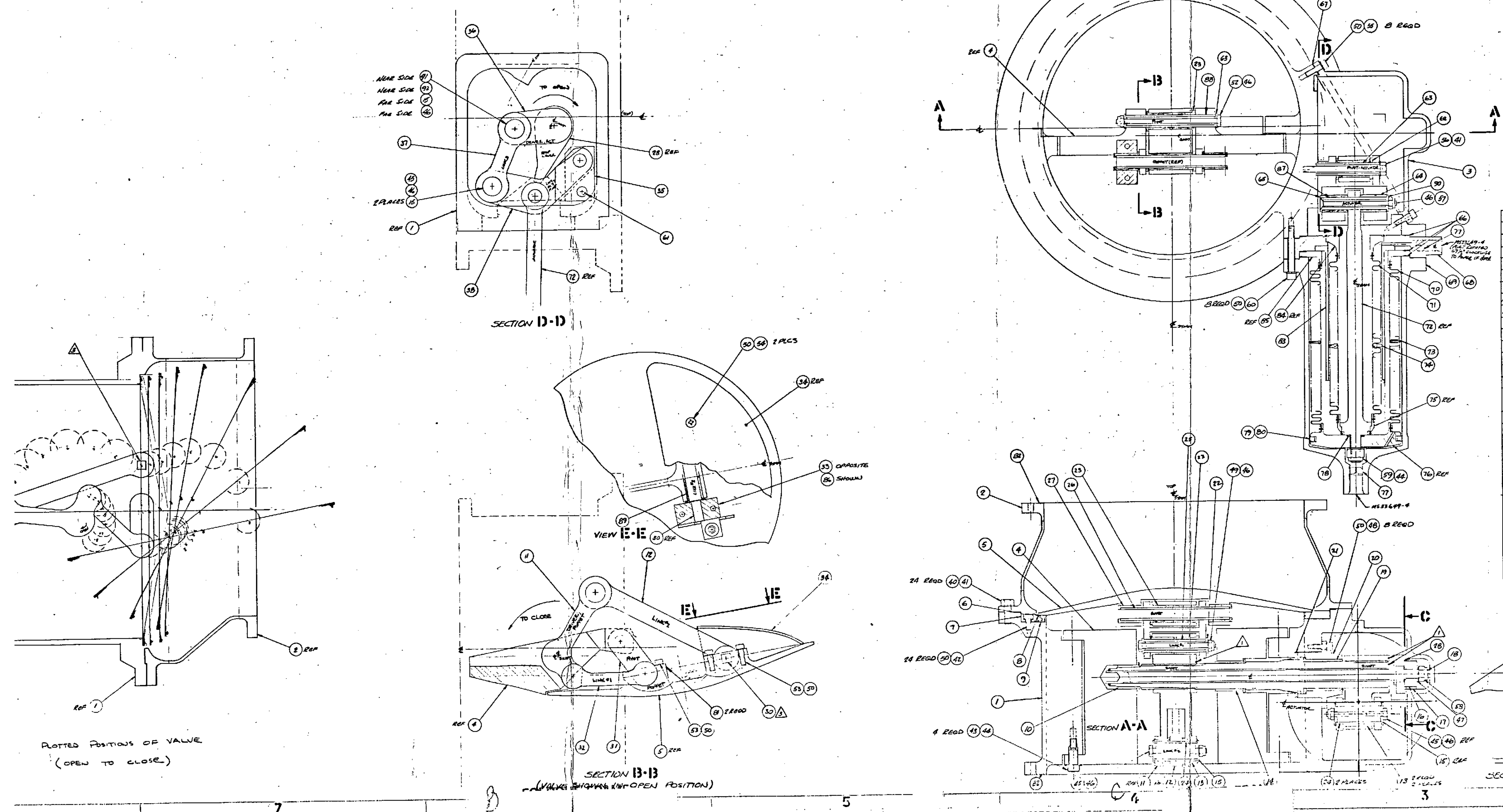
The valve actuator was a bellows type as shown in Figure 3-15. This configuration featured an inner bellows assembly, PN 966056, and an outer bellows assembly, PN 966057, which are shown in Figures 3-17 and 3-18 respectively. Complete bellows design requirements are presented in these figures. The actuator was designed with a maximum stroke of 2.12 inches.

3.5.2 Material Selection

A general breakdown of the metallic and the non-metallic materials used in the construction of the final shutoff valve is presented in Table 3-3. Aluminum was selected for the poppet and all linkage members as appropriate for design loading as well as low inertia. Alloy 6061-T6 was selected for the primary valve components because of the desirable fracture toughness of the alloy at cryogenic temperatures as well as adequate physical properties at plus 200°F.

DuPont polyimide bearings were selected on the basis of low wear rate and tolerance to impact loading. The bearings were sized on the basis of 5000 psi bearing stress using the SP211 compound.

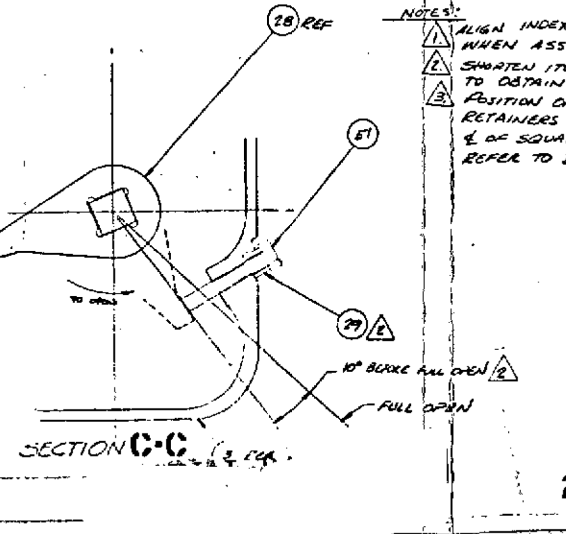
REVISIONS			
LTR	DESCRIPTION	DATE	APPD
A	ITEM 19: 966031-7 WAS 966033-7	9-73	
B	ITEM 43: 4441 WAS MS51975-9; ADDED ITEM 91 & 92; [illegible]		



1		SCREW, 100° FLAT	MS24693-76			92
1		KEEPER	966032-6			91
1		KEEPER	966032-1			90
2		BEARING	966031-3			89
1		SLEEVE	966035-3			88
1		SLEEVE	966035-4			87
1		SUPPORT, DEFLECTOR R.H.	966065			86
REF		FIXED END BELLOWS OUTER BELLOWS	966060	PART OF 70		85
REF		FIXED END FITTING INNER BELLOWS	966059	PART OF 71		84
1		SUPPORT GUIDE	966042			83
2		SEAL, FACE INLET & OUTLET	966070-3	SHIPPED AS LOOSE ITEMS		82
2		BLOCK, ALLOW	966069			81
1		RING	966079			80
1		EXPANDER	966078			79
1		SEAL, FACE (BELLOWS)	966070-1			78
2		ORIFICE	966073			77
REF		FREE END FITTING OUTER BELLOWS	966043	PART OF 70		76
REF		FREE END FITTING INNER BELLOWS	966058	PART OF 71		75
1		GUIDE, INNER	966055			74
1		GUIDE, OUTER	966054			73
REF		SHAFT, ACTUATOR	966049	PART OF 71		72
1		BELLOWS ASSY-INNER	966056			71
1		BELLOWS ASSY-OUTER	966057			70
1		HOUSING	966050			69
1		MANIFOLD	966061			68
1		GASKET, COVER	966066			67
3		SEAL, FACE, ACT.	966070-4			66
1		KEEPER, MODIFIED	966032-5			65
2		BEARING	966033-2			64
2		KEEPER	966032-5			63
2		BEARING	966031-4			62

NOTES:

1. ALIGN INDEX MARKS AS NOTED WHEN ASSEMBLING.
2. SHORTEN ITEM 29 AS REQD TO OBTAIN 10° DIMENSION.
3. POSITION OF SQUARE IN RETAINERS ACTS AS ADJUSTMENT ℄ OF SQUARE IS OFF CENTER REFER TO DETAIL DWG TO ASSEMBLE.



QTY REQD	CODE IDENT	DESCRIPTION	PART NO.	SPECIFICATION	MATERIAL	ZONE	ITEM NO.
1		BOLT, HEX 3/8-24 × 2.88	AN3C27A				61
8		SCREW, CAP 10-32 × 3.00	NAS1351C3-32				60
1		NUT SELF LOCK 3/8-24	MS21083-C6				59
1		NUT, SELF LOCK 5/16-24	MS21083-C5				58
1		SCREW, 100° FLAT 10-32 × 3.00	MS24693-288				57
1		BOLT, HEX 1/4-28 × 3.03	ANC30A				56
8		SCREW, CAP 10-32 × .62	NAS1351C3-10				55
2		SCREW, PAN 10-32 × .50	MS51958-63				54
8		SCREW, CAP 10-32 × .62	NAS1351C3-10				53
1		BOLT, HEX 10-32 × 3.90	AN3C37A				52
1		BOLT, HEX 1/4-28 × 1.53	AN4C14A				51
58		WASHER #10	NAS620C10L				50
1		BOLT, HEX 10-32 × 2.90	AN3C27A				49
8		SCREW, CAP 10-32 × .50	NAS1351C3-8				48
1		WASHER 5/16	AN960C516L				47
6		NUT, SELF LOCK 10-32	MS21083-C3				46
3		BOLT, HEX 10-32 × 2.15	AN3C21A				45
5		WASHER 3/8	AN960C616L				44
4		BOLT-SHOULDER 1/4-20, 5/16 DIA × .62 LONG	P/N 4441	AC DESIGN CORP VAN NUYS CA			43
24		SCREW, CAP 10-32 × .38	NAS1351C3-6				42
25		WASHER 1/4	AN960C416L				41
24		BOLT, HEX 1/4-28 × .78	AN4C6A				40
1		LINK, ACT. PIVOT	966046				38
1		LINK #3	966045				37
1		DRIVER, ACTUATOR	966047				36
1		PIVOT BLOCK	966077				35
1		DEFLECTOR	966063				34
1		SUPPORT, DEFLECTOR L.H.	966064				33
1		LINK #1	966037				32
1		LINK, POPPET PIVOT	966044				31
1		SHAFT, ADJUSTABLE (POPPET)	966062				30
1		SPACER, STOP	966071				29
1		STOP LEVER	966036				28
2		BEARING	966052				27
2		SLEEVE	966035-5				26
2		SLEEVE	966035-1				25
4		SLEEVE	966035-2				24
6		BEARING	966031-5				23
2		KEEPER	966032-4				22
1		LIP SEAL	966076				21
1		RETAINER, LIP SEAL	966040				20
1		BEARING	966031-7				19
1		TORSION SHAFT ASSY	966067				18
1		BEARING	966033-1				17
1		BUSHING, COVER	966074				16
6		KEEPER	966032-2				15
1		BEARING	966031-6				14
6		BEARING	966031-2				13
1		LINK #2	966034				12
1		DRIVER, POPPET	966048				11
1		BEARING	966031-1				10
1		SEAT	966072				9
1		DISC SPRING	966075				8
1		RETAINER, SEAT	966039				7
1		FLANGE SEAL, MAIN	966070-2				6
1		POPPET ASSY	966053				5
1		SUPPORT	966038				4
1		COVER	966051				3
1		DUCT ASSY	966068				2
1		BODY ASSY	966041				1

LIST OF MATERIALS OR PARTS LIST

EXCEPT AS SPECIFIED
A. DIM. ARE IN INCHES
B. DIM. APPLY AFTER PLATING
C. BREAK EDGES .015R MAX
D. INTERNAL CORNERS .015R MAX
E. CONCENTRICITIES .010 TIR
F. PARALLELISMS .010 IN./IN.
G. SQUARENESS .010 IN./IN.
H. ANGLES ± 0° 30'
I. MACHINED SURFACES ASA 63 ✓
L. DIMENSIONS PER [illegible]
L. THREADS PER MIL-S-7742
M. REMOVE ALL BURRS

FINAL — P-1000
QTY | NEXT ASSY | USED ON
APPLICATION

FINISH | HEAT TREAT

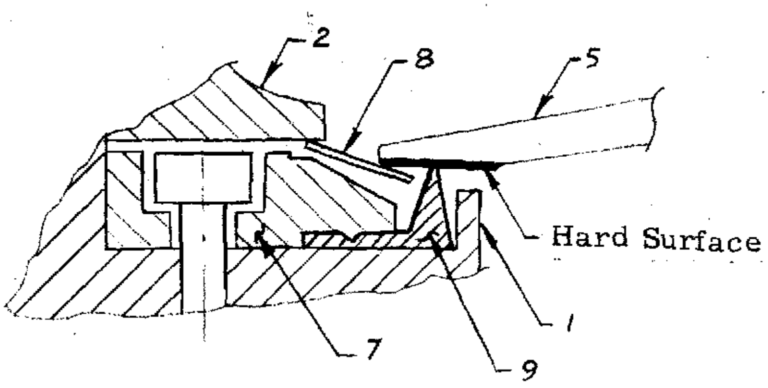
FAIRCHILD

10" VALVE

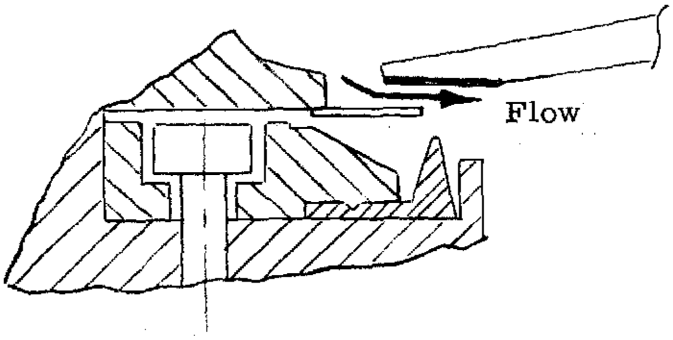
SIZE J | CODE IDENT NO. 01359 | DWG NO. 966001

68

2 — 3 — 5 — 7



Closed Position



Partially Open Position

LEGEND

Item Number *	Part Number	Nomenclature
1	966041	Body Assembly
2	966068	Duct Assembly
5	966053	Poppet Assembly
7	966039	Seat (Seal) Retainer
8	966075	Disk Spring
9	966072	Seat (Seal)

* Item numbers are those found on Drawing 966001

SEALING SEQUENCE

The disk spring (Item 8) is retained by the duct (Item 2) and the seal retainer (Item 7). In closing, contact is first made between the disk spring and the outer poppet (Item 5) periphery; then contact is made between the seal (Item 9) and the poppet (Item 5).

Figure 3-16. Detail of Valve Main Seal

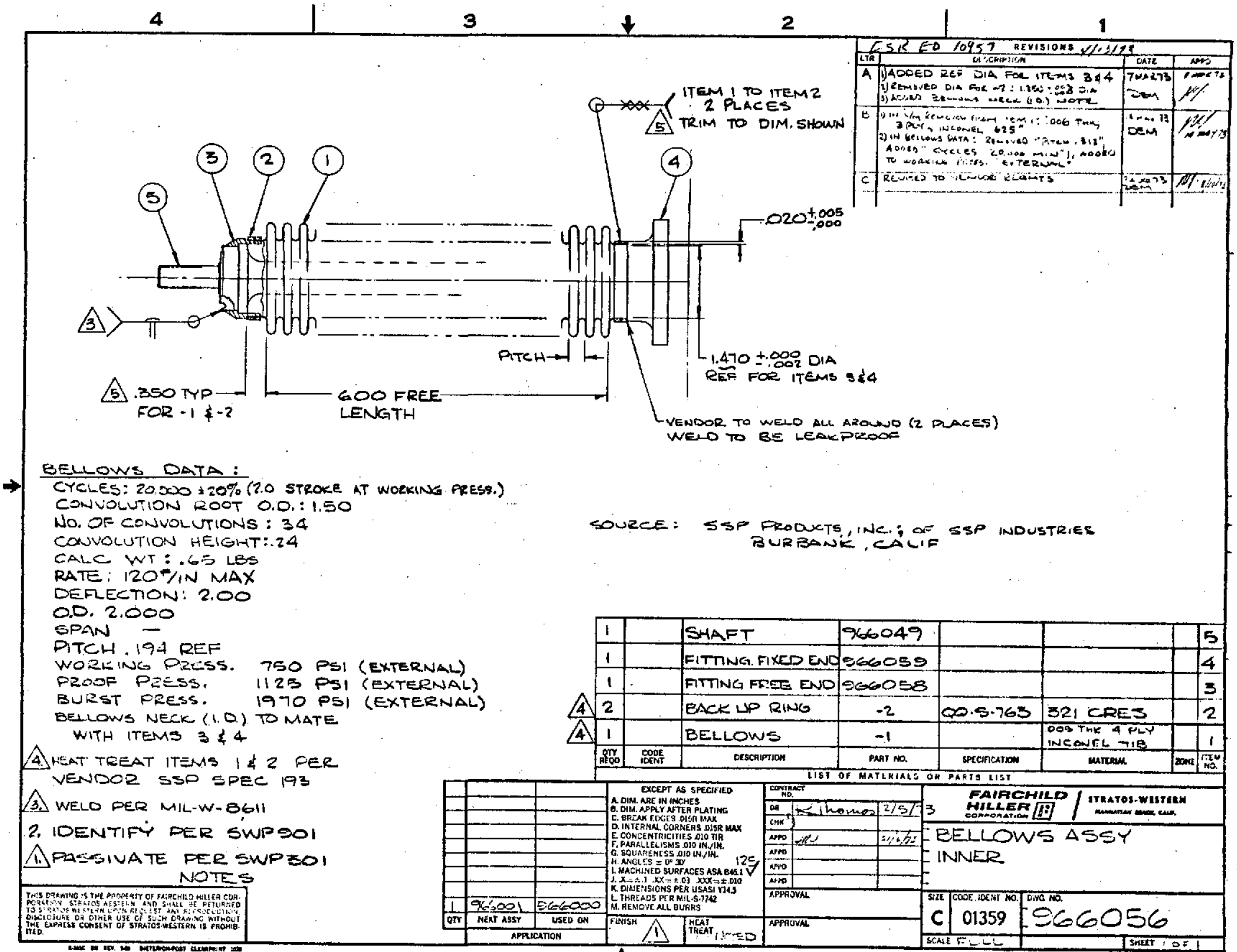


Figure 3-17 Inner Bellows Assembly PN 966056

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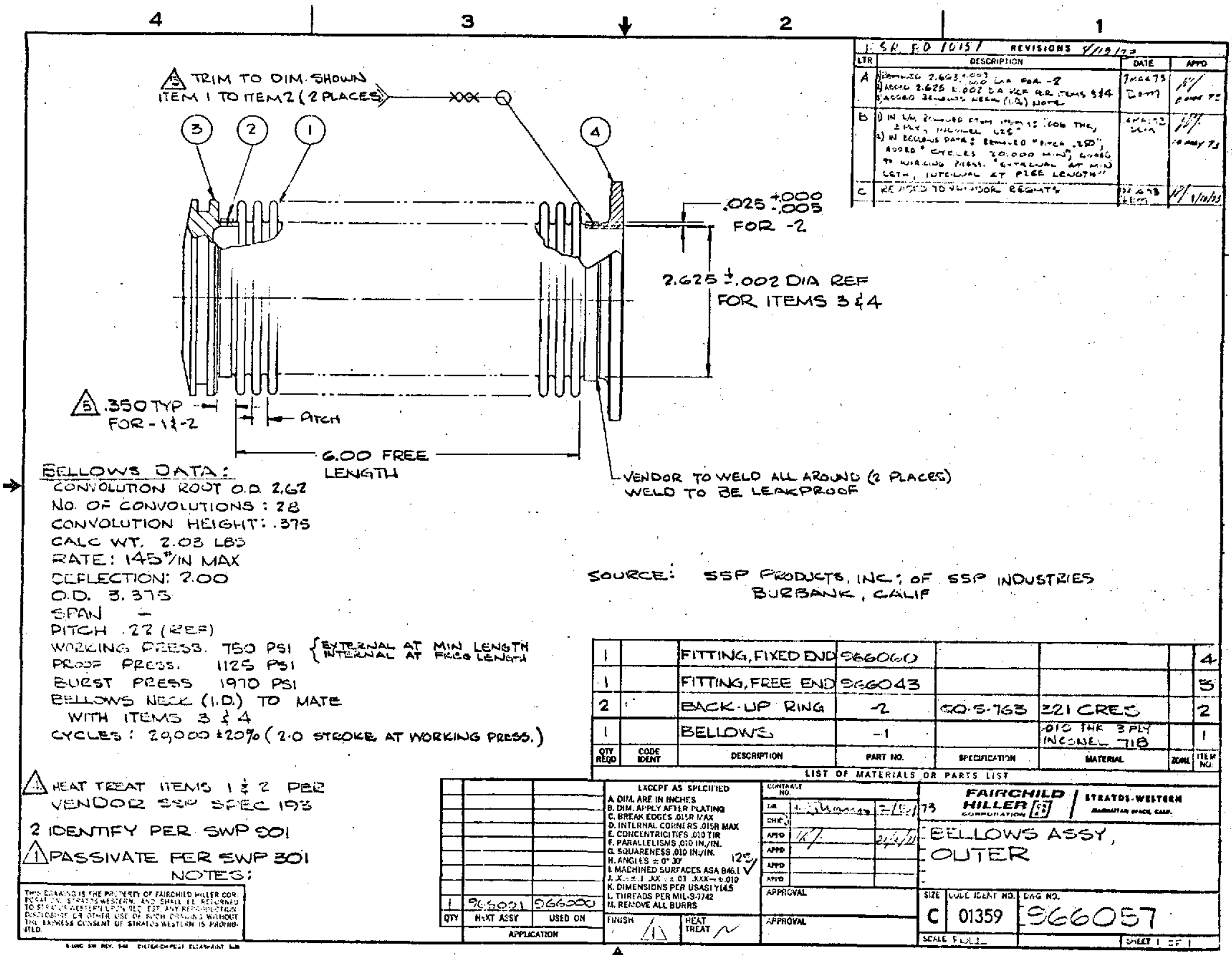

Figure 3-18 Outer Bellows Assembly PN 966057

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Table 3-3

Material Summary

10-Inch Long Life Valve

MATERIAL	SPECIFICATION	APPLICATION
6061-T6 Alum Alloy	QQ-A-200/8 QQ-A-250/11	Body assembly, lip seal retainer, flange, cover support, actuator housing, butterfly poppet assembly, valve duct flanges, actuation linkage
5052-0 Alum Alloy	WW-T-700 or QQ-A-250/8	Valve duct
Inconel 718	-	Inner and outer bellows
A286 Cres	AMS 5736	Torsion shaft assembly
300 Series Cres	QQ-S-763 and QQ-S-766	Disk spring, bearing keepers, bushing cover, stop lever and spacer, adjustment shaft, manifold, bellows fittings and backup ring, orifices, expander and support guide
TFE Teflon	AMS 3651	Main flange seal, actuator face seal, cover gasket, face seal, inner and outer bellows guide
Plaskon CTFE	2400 ASTM D1430 Grade 4	Valve Seat
SP-211 Polyimide	-	Bearings

3.5.3 Dynamic Simulation

A dynamic simulation program was written for the digital computer to solve the valve opening and closing transients and to optimize the actuator orifices. Originally, a series of actuator development tests in which the recorded pressure and stroke data would be used for orifice optimization were planned, but the dynamic simulation approach showed both cost and schedule advantage.

The correct sizing of the three actuator orifices, actuation orifices, piston orifices and deactuation orifices was necessary to provide control of the poppet at the point of closure. This problem was accentuated by the rapid closure specification and the positive flow feedback forces applied during the closure.

3.5.3.1 System Math Model

A system math model was determined for the hybrid butterfly valve configuration. The valve features the poppet opening against an applied pressure differential and closing with the assistance of fluid forces. The three actuator orifices must be selected to prevent excessive poppet-seat impact while meeting a closing time design objective of 0.5 seconds. A schematic diagram of the butterfly-poppet and the actuator is shown in Figure 3-19. System parameters are also identified on the diagram.

To simplify the program complexity, the valve inertia, the poppet forces, the spring preload, and the friction forces were referred to the actuator linear positions. Further, to minimize the cost of the digital programming, the simplest linear integration method will be used with a sufficiently small time increment (0.0005 second as an initial value to maintain accuracy).

3.5.3.1.1 Poppet-Actuator Equivalent Mass

A non-linear equivalent mass was calculated to evaluate the actuator acceleration with force unbalance. Valve actuation results in a non-linear poppet rotation and translation with respect to actuator position. A graph of the equivalent mass as a function of actuator stroke is presented in Figure 3-20. The method of calculation is presented in Appendix C.

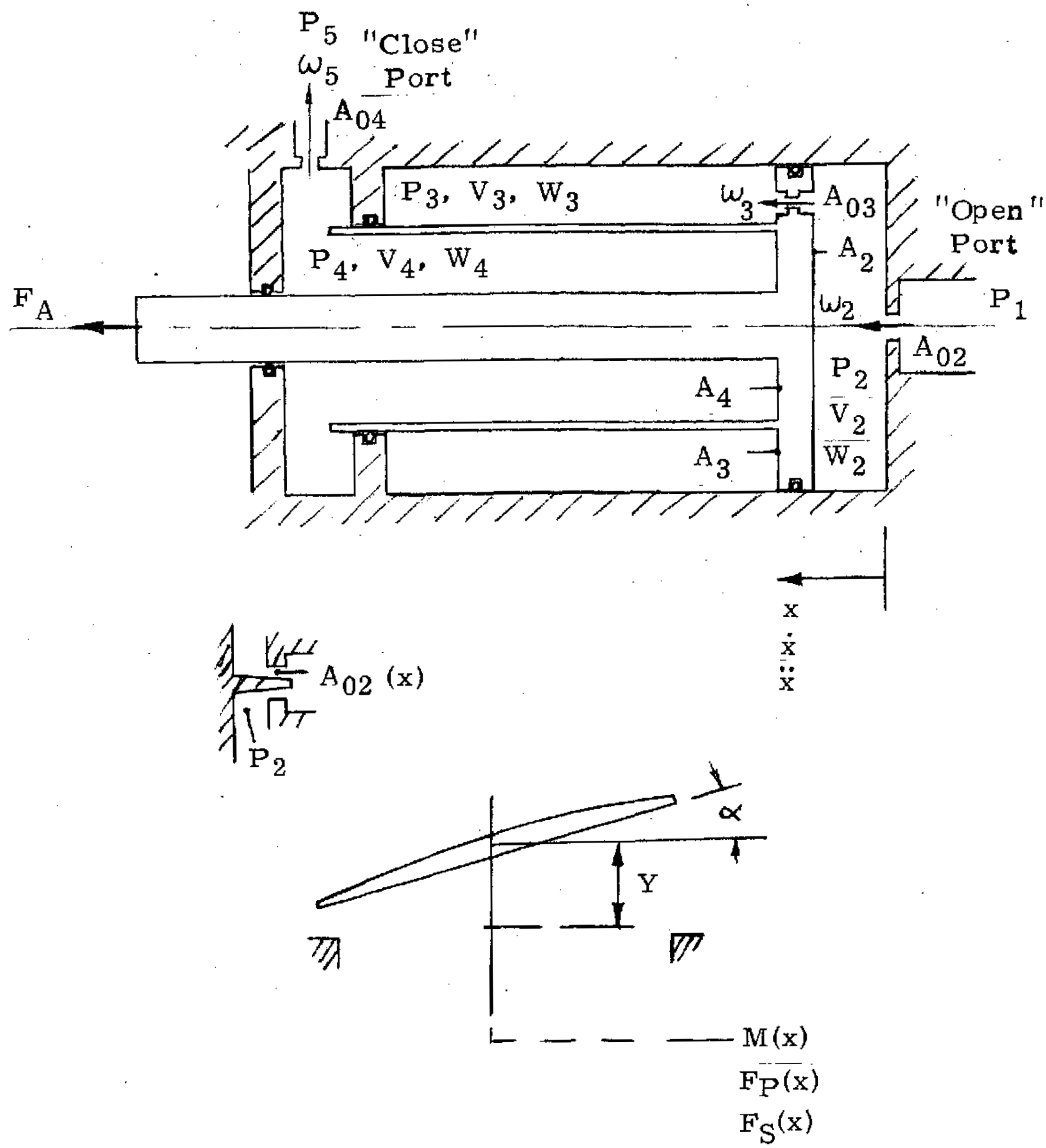

Figure 3-19. Schematic Diagram, Actuator and Poppet

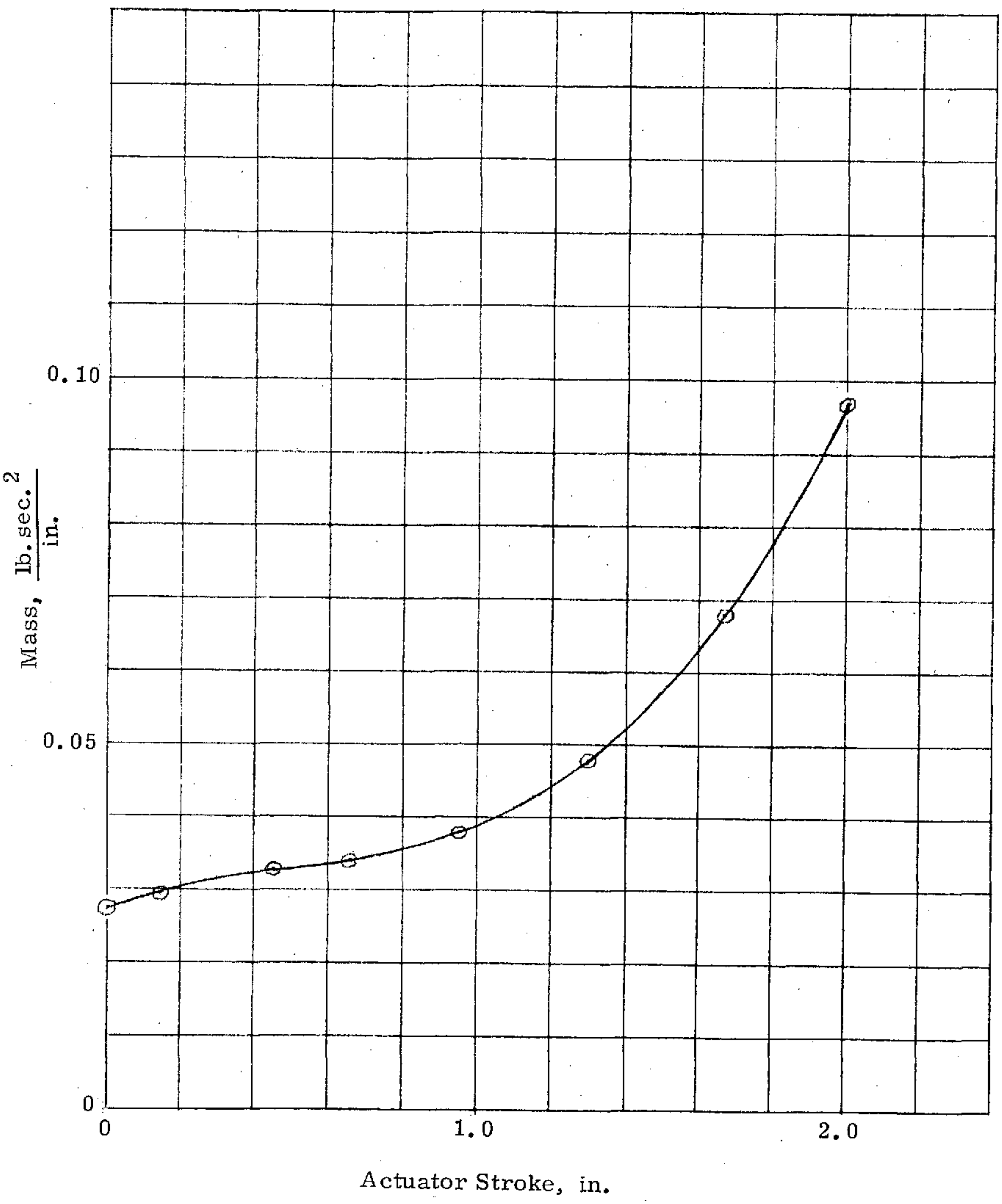

Figure 3-20. Equivalent Mass as a Function of Actuator Stroke

3.5.3.1.2 Poppet Force

The non-linear poppet force as a function of actuator stroke was calculated. The force included a fluid force (air-load), a bellows force, and a torsional spring force. Figure 3-21 presents a graph of the combined force as well as the individual components.

3.5.3.1.3 System Equations

The system equations, including the initial conditions, were written and are presented below in the computing sequence. See Figure 3-19 for parameter identification.

$t = t + \Delta t$

$P_1 \geq P_2$	$P_1 < P_2$
$R_2 = \dfrac{P_2}{P_1}$	$R_2 = \dfrac{P_1}{P_2}$

$\phi = f(R_2)$ Interpolation of ϕ Table

$\omega_2 = \dfrac{C_2 \, Ao_2 \, P_1 \, \phi}{\sqrt{T}}$	$\omega_2 = \dfrac{-C_2 \, Ao_2 \, P_2 \, \phi}{\sqrt{T}}$

Repeat for ω_3 and ω_4

$W_2 = W_2 + (\omega_2 - \omega_3) \, \Delta t$

$W_3 = W_3 + \omega_3 \, \Delta t$

$W_4 = W_4 + \omega_4 \, \Delta t$

$V_2 = V_2o + A_2 \, (X + \dot{X} \, \Delta t)$

$V_3 = V_3o - A_3 \, (X + \dot{X} \, \Delta t)$

$V_4 = V_4o - A_4 \, (X + \dot{X} \, \Delta t)$

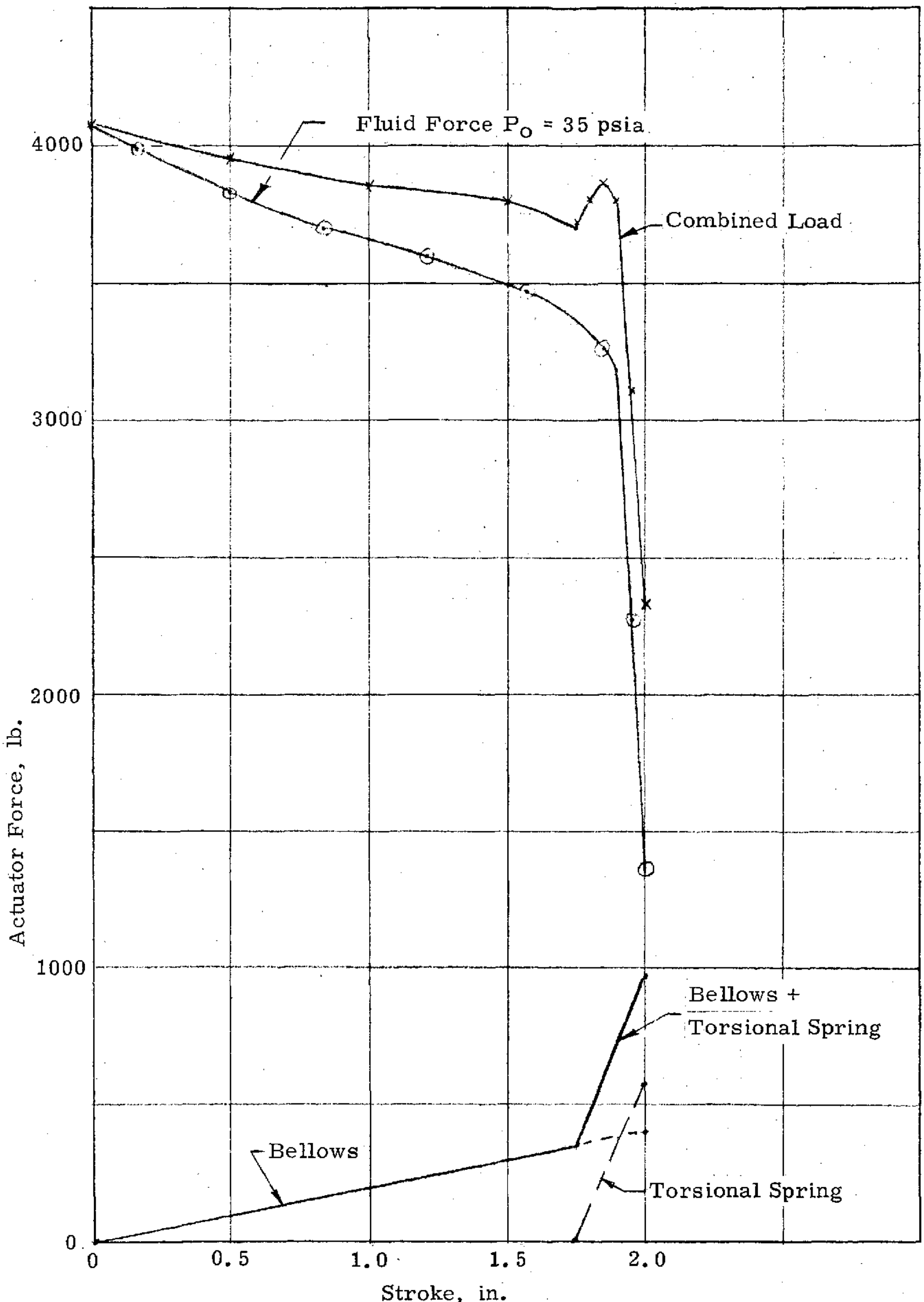

Figure 3-21. Poppet Forces as a Function of Actuator Stroke

$$P_2 = \frac{\gamma RT \ W_2}{V_2}$$

$$P_3 = \frac{\gamma RT \ W_3}{V_3}$$

$$P_4 = \frac{\gamma RT \ W_4}{V_4}$$

$$F_A = A_2 P_2 - A_3 P_3 - A_4 P_4$$

$$\ddot{X} = \frac{F_A - F_p - f + F_s}{M}$$

$Fp = f(x)$ Table (See Figure 3-21)

$f = K \ Fp$

$F_s = O \qquad X \geq O$

$=$ Subroutine when $X < O$

$=$ Subroutine when $X \geq X$ max.

$M = f(x)$ Table (See Figure 3-20)

$$\dot{X} = \dot{X} + \ddot{X} \Delta t$$

$$X = X + \dot{X} \Delta t + \frac{\ddot{X} \Delta t^2}{2}$$

INITIAL CONDITIONS

VALVE CLOSED

$P_5 = P_4 = 765$ psia

$P_1 = P_2 = P_3 = 15$ psia

$V_2 = 1.000$ In.^{3}	$A_1 = 9.787$ In.^{2}	$X = 0$
$V_3 = 21.53$ In.^{3}	$A_2 = 2.718$ In.^{2}	$\dot{X} = 0$
$V_4 = 28.82$ In.^{3}	$A_3 = 4.831$ In.^{2}	$\ddot{X} = 0$

Gas - Air

$$\gamma = 1.40$$

$$R = 639.6 \text{ In}/°F$$

$$T = 530°R$$

$$\gamma RT = 0.4746 \times 10^6 \text{ In.}$$

Flow - Discharge Coef. $C = 0.8$ All Orifices

ϕ per Chart or Graph or

$$\omega = \frac{0.530 \text{ CA Pu}}{\sqrt{T}} \sqrt{\frac{4}{3}\left[1-\left(\frac{P_D}{P_u}\right)^2\right]} \text{ Lb/Sec.}$$

3.5.3.2 Computer Program Listing

A listing of the dynamic simulation computer program is presented in Table 3-4.

3.5.3.3 Computer Program Printout

A typical computer printout is presented in Table 3-5 for valve closure at full system pressure. All of the force and inertia terms are related to the actuator position X. XDOT and ACCX are the actuator velocity and acceleration, and P_2, P_3 and P_4 are the actuator pressures at the piston, outer bellows, and inner bellows respectively. AO_2, AO_3 and AO_4 are the actuator orifice, piston orifice and deactuation orifice areas respectively. Actuator stroke and pressures are plotted as a function of time for the opening and closing transients in Figures 3-22 and 3-23 respectively. Computations for different orifice sizes and for reduced valve flow rates are presented. The computations show that the actuator was able to close within the desired 0.50 second interval without excessive closing velocities.

The computer program was also capable of evaluating the effects of system and actuation pressure variations.

Table 3-4.

Listing of Simulation Computer Program

```
C      THIS PROGRAM CALCULATES THE POSITION OF THE ACTUATOR AS A
C        FUNCTION OF TIME IN THE OPENING AND CLOSING OF THE VALVE
C        IT ALSO  CALCULATES THE ACCELERATION AND VELOCITY OF
C        THE VALVE ACTUATOR   PROGRAMED BY J.JONES & C.ALDRICH
      REAL   MOL,M,NOITER,KS1,KS2
   WD (A0,P,T1,Q) = 0.425*A0* P/SQRT(T1) * SQRT(1.33 *
&  (1.- Q** 2.0))
 P1=15.0;P5=765.0;P1NEW=765.0;P5NEW=15.0
   MOL =28.97; T1 =530.0; V20 =1.0; V30 =21.53; V40 = 28.82
      DTIME = 0.0002;A2 = 9.787;A3 = 2.718;A4 = 4.831;A02 = .0078
      A03 = .0020;A04 = .0078;X=0.000 ;XDOT =  0.000;
      FF0 = 4060.;FF1 = 3950.;FF2 = 3830.;FF3 = 3720.;FF4 = 3660.
      FF5 = 3580.;FF6 = 3500.;FF7 = 3430.;FF8 = 3350.;FF9 = 3270.
      FF10 = 3150.;FF11 = 2270.;FF12 = 1360.
      KS1 = 3300000.  ;KS2 =  100000.
      BSR =  200.  ;TSR =  2280.  ;XTS = 1.75  ;CTR = 0. ;CTR1 = 0.
       PRFREQ = 50.0 ;NOITER = 3000.0
      P2 = P1
      P3 = P1
      P4 = P5
   10 P1 = P1NEW
      CMOL = MOL / 28.97
   11 P5 = P5NEW
  V2=V20+A2*X
   V3=V30-A3*X
   V4=V40-A4*X
      DCON = DTIME
      W2 = .0015625*V2*(P2/T1)*CMOL
      W3 = .0015625 * V3 * (P3 / T1) * CMOL
      W4 = .0015625 * V4 * (P4 / T1) * CMOL
      TIME = 0
   13 DTIME=DCON
     IF(P1.GE.P2) WD2=WD(A02,P1,T1,P2/P1)
      IF(P2.GT.P1)   WD2 = - WD(A02,P2,T1,P1/P2)
      IF(P2.GE.P3)   WD3 = WD(A03,P2,T1,P3/P2)
      IF(P3.GT.P2)   WD3 = - WD(A03,P3,T1,P2/P3)
      IF(P4.GE.P5)   WD4 = - WD(A04,P4,T1,P5/P4)
      IF(P5.GT.P4)   WD4 = WD(A04,P5,T1,P4/P5)
   14 W2 = W2 + (WD2 - WD3) * DTIME
      W3 = W3 + WD3 * DTIME
      W4 = W4 + WD4 * DTIME
   16 V2 = V20+A2*X
      V3 = V30-A3*X
      V4 = V40-A4*X
      IF(V2 .LE. 0.0) V2 = .001
      IF(V3 .LE. 0.0) V3 = .001
      IF(V4 .LE. 0.0) V4 = .001
   17 P2 = 640. * W2 * T1 / V2
      P3 = 640. * W3 * T1 / V3
      P4 = 640. * W4 * T1 / V4
      IF(P2 .LE. 0.0) P2 = .01
      IF(P3 .LE. 0.0) P3 = .01
      IF(P4 .LE. 0.0) P4 = .01
```

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```
F=A2*P2-A3*P3-A4*P4
   TIME=TIME+DTIME

      FFAN=SIGN(0.1*F,XDOT)
 19 IF(X .LE. .2) M = .02756 + .0127 * X
    IF(X .LE. .4.AND.X .GT. .2) M = .0301 + .0105 * (X - .2)
    IF(X .LE. .6.AND.X .GT. .4) M = .0322 + .0075 * (X - .4)
    IF(X .LE. .8.AND.X .GT. .6) M = .0337 + .0095 * (X - .6)
    IF(X .LE. 1..AND.X .GT. .8) M = .0356 + .0165 * (X - .8)
    IF(X .LE. 1.2.AND.X .GT. 1.0) M = .0389 + .0260 * (X - 1.0)
    IF(X .LE. 1.4.AND.X .GT. 1.2) M = .0441 + .0395 * (X - 1.2)
    IF(X .LE. 1.6.AND.X .GT. 1.4) M = .0520 + .0540 * (X - 1.4)
    IF(X .LE. 1.8.AND.X .GT. 1.6) M = .0628 + .0799 * (X - 1.6)
    IF(X .GT. 1.8) M = .0788 + .09 * (X - 1.8)
 20 IF(X .LE. .25) FF=FF0-4.0*(FF0-FF1)*X
    IF(X .LE. .50.AND.X .GT. .25) FF=FF1-4.*(FF1-FF2)*(X-.25)
    IF(X .LE. .75.AND.X .GT. .50) FF=FF2-4.*(FF2-FF3)*(X-.50)
    IF(X .LE. 1.0.AND.X .GT. .75) FF=FF3-4.*(FF3-FF4)*(X-.75)
    IF(X .LE. 1.25.AND.X .GT. 1.) FF=FF4-4.*(FF4-FF5)*(X-1.0)
    IF(X .LE. 1.50.AND.X .GT. 1.25) FF=FF5-4.*(FF5-FF6)*(X-1.25)
    IF(X .LE. 1.65.AND.X .GT. 1.5) FF=FF6-20./3.*(FF6-FF7)*(X-1.5)
    IF(X .LE. 1.75.AND.X .GT. 1.65) FF=FF7-10.*(FF7-FF8)*(X-1.75)
    IF(X .LE. 1.85.AND.X .GT. 1.75) FF=FF8-10.*(FF8-FF9)*(X-1.85)
    IF(X .LE. 1.90.AND.X .GT. 1.85) FF=FF9-20.*(FF9-FF10)*(X-1.9)
     IF(X .LE. 1.95.AND.X .GT. 1.9) FF=FF10-20.*(FF10-FF11)*(X-1.95
      )
    IF(X .LE. 2..AND.X .GT. 1.95) FF=FF11-20.*(FF11-FF12)*(X-2.0)
 21 IF(X.LT.0.0) FS=KS1*X
    IF(X.GT.2.0) FS=KS2*(X-2.0)
    IF(X.GE.0.0.AND.X.LE.2.0) FS=0.0
 22 FB = BSR * X
 23 FST= TSR * (X - XTS)
    IF(X.LE.XTS)     FST =0
 24 ACCX =(F - FFAN - FF - FB - FST - FS) / M
X=X+XDOT*DTIME+0.5*ACCX*DTIME**2.0
    XDOT = XDOT + ACCX * DTIME
  IF(X.LE.0.0.AND.XDOT.LE.0.0) X=0.
   IF(X.GE.2.0.AND.XDOT.GE.0.) X=2.
      IF(X.LE.0.0.AND.XDOT.LE.0.0) XDOT=0.
      IF(X.GE.2.0.AND.XDOT.GE.0.0) XDOT=0.
 30 CTR = CTR + 1.0
    CTR1 = CTR1 + 1.0
    IF(CTR1 .EQ. 1.0) PRINT 97
    IF(CTR1 .EQ. 1.0) PRINT 98
    IF(CTR .EQ. PRFREQ) CTR = 0.0
    IF(CTR .EQ. 1.0) PRINT 99,TIME,X,XDOT,ACCX,P2,P3,P4,WD2,WD3,WD4
     IF(CTR1 .GT. NOITER) STOP
    IF(NOITER .GT. 1.) GOTO 13
 97 FORMAT(1H-/1H0,28X,"DYNAMIC SIMULATION"/1H,17X,"VALVE   "
     "P/N 966000 ACTUATION TRANSIENTS")
 98 FORMAT(1H0,1X,"TIME      X       XDOT      ACCX       P2"
    "       P3       P4       WD2      WD3      WD4")
 99 FORMAT(1H,F6.4,1X,F6.4,1X,F7.1,1X,F8.0,3(1X,F6.2),3
    (1X,F6.3))
STOP;END
```

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Table 3-5
Typical Print-Out
Simulation Computer Program

ACTS 14:18PDT 08/24/73

AO2 = 0.0056 $IN.^2$

AO3 = 0.0031 $IN.^2$

AO4 = 0.0065 $IN.^2$

DYNAMIC SIMULATION
VALVE P/N 966000 ACTUATION TRANSIENTS

TIME	X	XDOT	ACCX	P2	P3	P4	WD2	WD3	WD4
0.0002	2.0000	0.	16090.	764.70	765.00	15.37	-0.091	0.	0.106
0.0102	2.0000	0.	14022.	750.85	763.67	34.11	-0.090	-0.009	0.106
0.0202	2.0000	0.	12071.	738.01	761.38	52.82	-0.088	-0.012	0.106
0.0302	2.0000	0.	10197.	725.85	758.54	71.50	-0.087	-0.015	0.105
0.0402	2.0000	0.	8385.	714.23	755.29	90.14	-0.085	-0.016	0.105
0.0502	2.0000	0.	6626.	703.09	751.73	108.73	-0.084	-0.018	0.105
0.0602	2.0000	0.	4915.	692.36	747.91	127.25	-0.083	-0.019	0.104
0.0702	2.0000	0.	3246.	682.01	743.88	145.69	-0.081	-0.020	0.104
0.0802	2.0000	0.	1618.	672.01	739.66	164.05	-0.080	-0.020	0.103
0.0902	2.0000	0.	26.	662.31	735.29	182.30	-0.079	-0.021	0.103
0.1002	2.0000	0.	5564.	652.92	730.78	200.45	-0.078	-0.022	0.102
0.1102	1.9999	-0.3	-3072.	643.82	726.15	218.47	-0.077	-0.022	0.101
0.1202	1.9981	-0.4	1671.	635.43	721.24	236.27	-0.076	-0.023	0.101
0.1302	1.9906	-2.4	-1012.	628.88	715.62	253.56	-0.075	-0.023	0.100
0.1402	1.7683	-43.6	2332.	689.78	686.92	257.31	-0.082	-0.003	0.100
0.1502	1.6377	1.4	9254.	724.50	675.02	265.19	-0.086	0.017	0.099
0.1602	1.6388	-1.2	-6731.	704.03	678.14	281.31	-0.084	0.013	0.098
0.1702	1.6323	-1.4	523.	688.05	679.43	296.78	-0.082	0.007	0.098
0.1802	1.5933	-9.2	-1029.	685.46	676.49	309.35	-0.082	0.007	0.097
0.1902	1.5050	-3.9	1315.	703.15	669.34	318.84	-0.084	0.014	0.096
0.2002	1.4744	-7.6	-1415.	695.32	668.76	331.71	-0.083	0.012	0.095
0.2102	1.3868	-3.8	1538.	713.39	662.66	339.90	-0.085	0.017	0.095
0.2202	1.3532	-9.1	-1451.	705.48	662.45	351.87	-0.084	0.016	0.094
0.2302	1.2743	-1.2	1065.	720.49	657.91	359.87	-0.086	0.019	0.093
0.2402	1.2225	-11.6	-107.	720.47	656.44	369.87	-0.086	0.019	0.093
0.2502	1.1679	-3.8	-662.	722.97	654.84	379.06	-0.086	0.020	0.092
0.2602	1.0973	-5.8	1225.	734.16	651.94	386.81	-0.087	0.022	0.091
0.2702	1.0490	-8.7	-678.	731.83	651.37	396.04	-0.087	0.022	0.091
0.2802	0.9928	-3.5	-1037.	734.93	650.15	404.24	-0.088	0.023	0.090
0.2902	0.9240	-3.3	1355.	746.48	647.94	411.19	-0.089	0.024	0.089
0.3002	0.8662	-8.4	1354.	750.07	646.94	418.85	-0.089	0.025	0.089
0.3102	0.8183	-9.7	-1081.	746.05	646.94	427.01	-0.089	0.024	0.088
0.3202	0.7668	-6.2	-2590.	745.00	646.65	434.55	-0.089	0.024	0.087
0.3302	0.7070	-2.1	-1983.	751.11	645.71	441.14	-0.090	0.025	0.087
0.3402	0.6413	-3.7	284.	762.45	644.47	447.10	-0.091	0.027	0.086
0.3502	0.5824	-3.6	802.	768.30	643.89	453.37	-0.092	0.028	0.085
0.3602	0.5246	-3.3	1046.	773.24	643.52	459.51	-0.092	0.028	0.085
0.3702	0.4685	-2.5	726.	776.55	643.38	465.57	-0.093	0.029	0.084
0.3802	0.4149	-2.1	-981.	775.85	643.55	471.66	-0.093	0.029	0.083
0.3902	0.3620	-5.8	-3788.	772.02	643.90	477.67	-0.092	0.028	0.083
0.4002	0.2983	-7.0	57.	787.30	643.42	482.54	-0.094	0.030	0.082
0.4102	0.2410	-4.1	1107.	794.32	643.49	487.71	-0.095	0.031	0.082
0.4202	0.1872	-7.9	-1626.	790.64	643.99	493.10	-0.094	0.030	0.081
0.4302	0.1324	-2.3	-2393.	792.47	644.36	495.08	-0.095	0.031	0.080
0.4402	0.0751	-4.9	-1846.	797.78	644.70	502.83	-0.095	0.031	0.080
0.4502	0.0184	-9.6	-2186.	800.70	645.14	507.51	-0.095	0.031	0.079
0.4602	0.	0.	-93622.	601.74	646.36	515.05	-0.072	-0.015	0.078
0.4702	0.	0.	-137110.	469.14	642.59	524.20	-0.056	-0.029	0.077
0.4802	0.	0.	-162982.	400.18	637.68	533.21	-0.048	-0.033	0.076

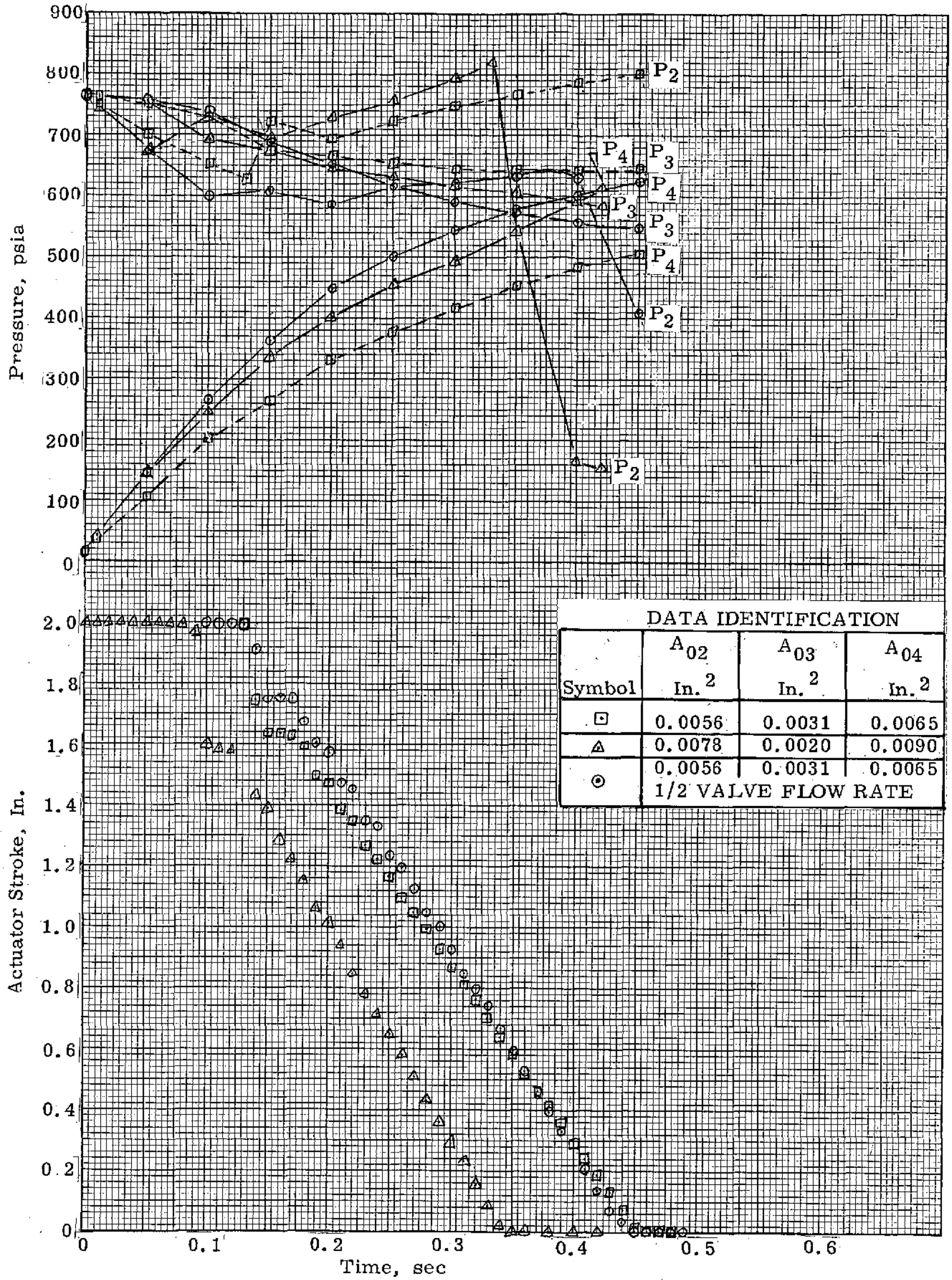
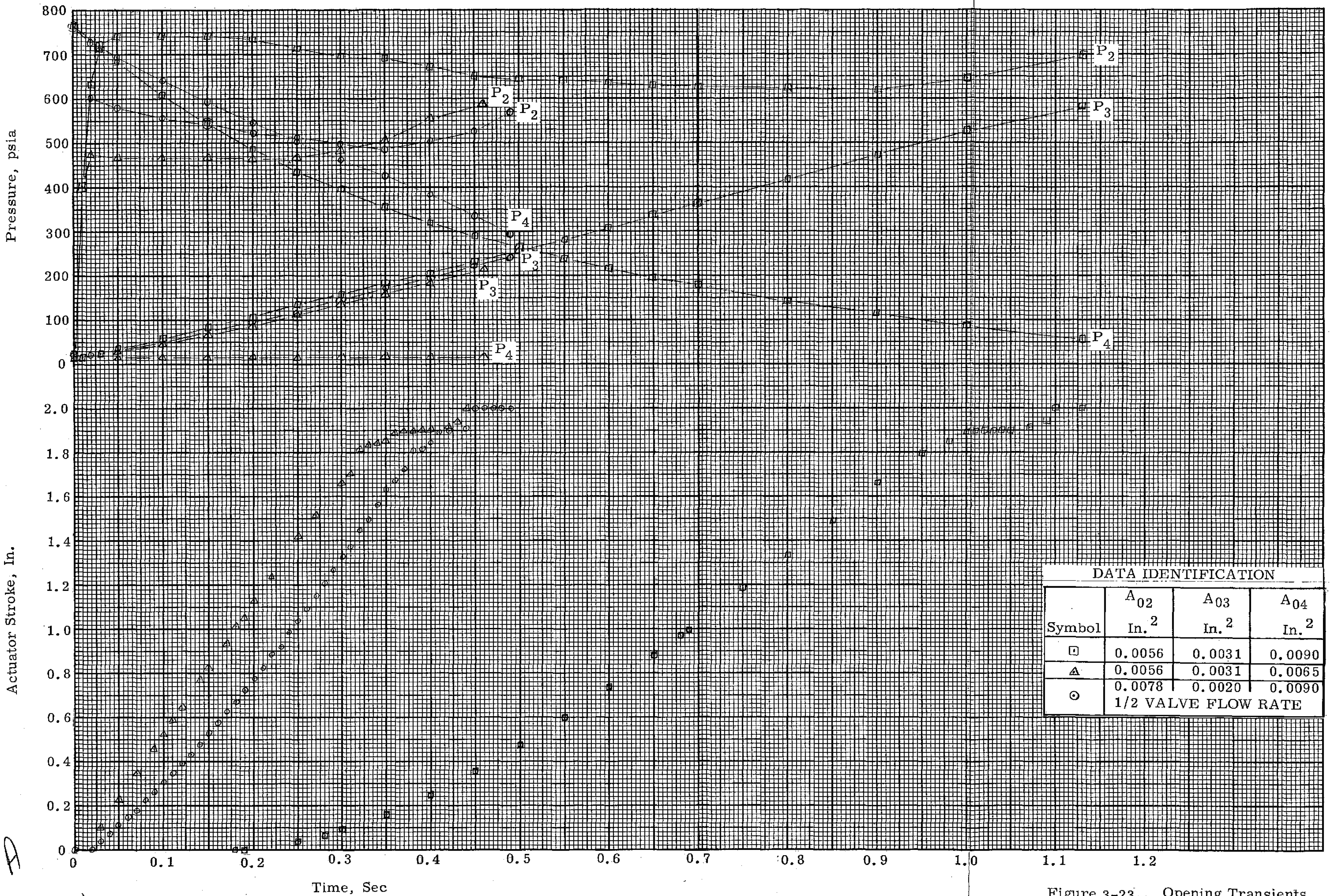


Figure 3-22. Closing Transients

C-2



DATA IDENTIFICATION

Symbol	A_{02} In.^{2}	A_{03} In.^{2}	A_{04} In.^{2}
⊡	0.0056	0.0031	0.0090
⚠	0.0056	0.0031	0.0065
⊙	0.0078	0.0020	0.0090
	1/2 VALVE FLOW RATE		

A

Figure 3-23. Opening Transients

B

SECTION 4

PHASE III MANUFACTURE AND TEST

4.1 MANUFACTURE

The 10-inch long life shutoff valve, PN 966000, was manufactured in accordance with Assembly Drawing 966001. A photograph of the unit is shown in Figure 4-1.

Hardware was manufactured by Fairchild Stratos and by numerous outside vendors. Assembly of the unit was accomplished at Fairchild. The valve components, which were manufactured by outside vendors, are listed in Table 4-1. The original bellows vendor defaulted, and a second vendor was chosen. Two sets of bellows were received and tested during the demonstration testing. The bellows proved to be unsatisfactory, and the bellows type actuator assembly was replaced with a piston type actuator assembly during the early part of the demonstration testing. See Demonstration Test Report ER-966-24, which is included as Appendix D of this report, for additional information on the bellows failure and for a detail description of the piston type actuator assembly.

The sealing surface of the poppet assembly, PN 966053 (see Figure 3-16), was sent to DuPont to be plasma sprayed with Tribaloy No. 120. Following the application of the hard coating, the surface was ground to the finished dimensions. However, the surface finish of the part, as received by Fairchild Stratos, was "out-of-spec." Subsequent lapping brought the surface finish within the 1 to 2 RMS specified on the drawing.

4.2 DEMONSTRATION TESTS

Demonstration tests were conducted on the long life valve test specimen as reported in Fairchild Stratos test report number ER 966-24, which is included in Appendix D herein. Included in the test report are sections covering the test summary, the test specimen description, the rework and change summary, the test setups and procedures, and the distortion of the testing.

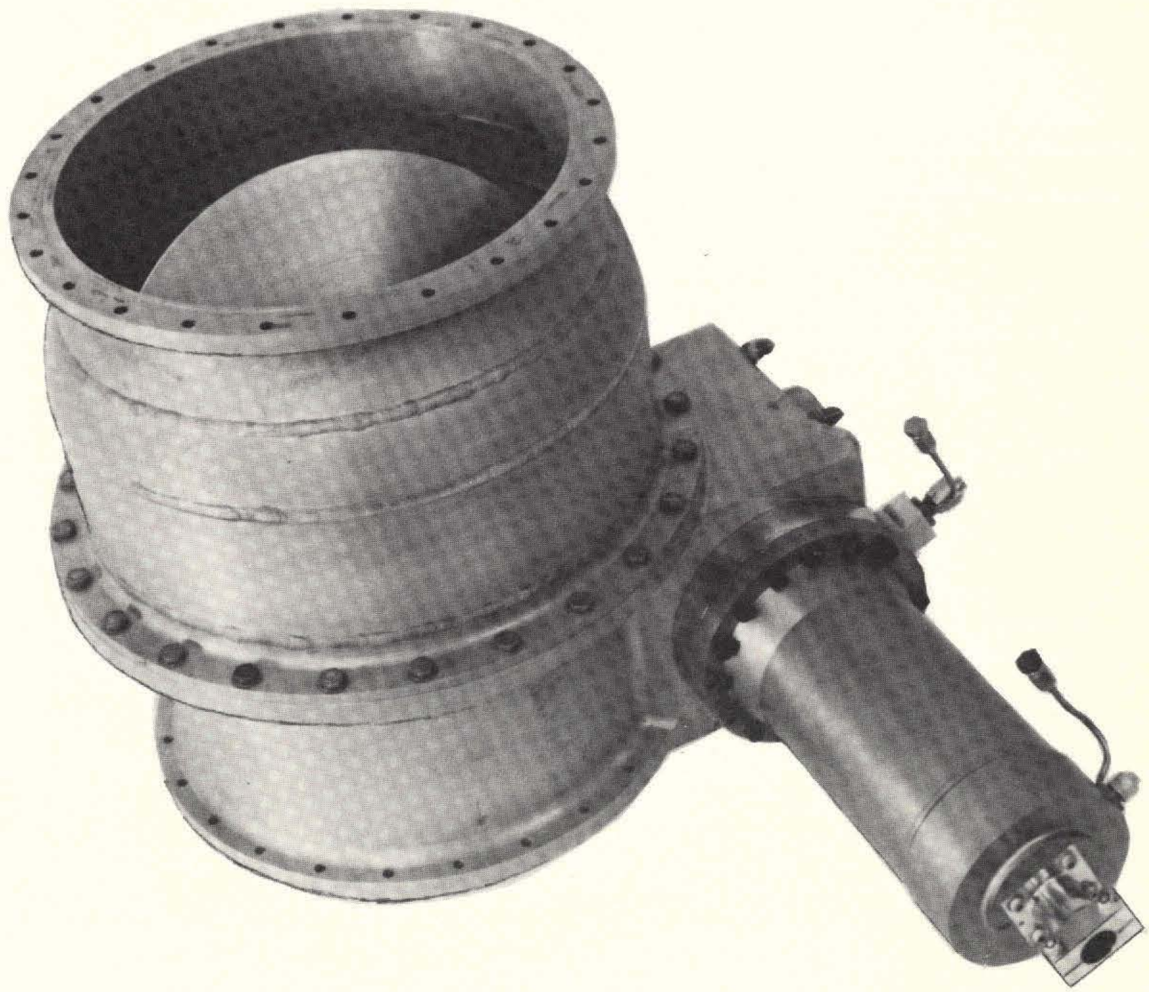


Figure 4-1. 10-Inch Long Life Shutoff Valve, P/N 966000

Table 4-1

Valve Components
Manufactured Outside Fairchild

Part Number	Description
966031-1 thru -7	Bearing
966033-1 thru -2	Bearing
966035-1 thru -5	Sleeve
966039	Seat Retainer
966041	Body Assembly
966052	Bearing
966056	Bellows Assembly, Inner
966057	Bellows Assembly, Outer
966063	Deflector
966068	Duct Assembly
966072	Seat (Seal)
966079	Ring

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

As evidenced by the configuration studies carried out in Phase I, the selection of the optimum configuration is in large part influenced by the preferential weighing factors applicable to the characteristic parameters for a specific valve application. The design selection of the 10-inch valve placed preferential weighing on minimum internal leakage for a 20,000 cycle life while meeting the opening and closing time requirements.

The study also indicated the necessity to use valve configurations which eliminate or minimize scrubbing action on the seal during engagement and further pointed to seal concepts which eliminated significant flow during final closure to prevent seal erosion or damage by high velocity contaminants. The lever positioned poppet design accomplished these objectives by providing poppet translation at the point of seal engagement with a flat seat design. In addition, the disk spring element provided a means of deflecting the fluid stream away from the critical seal surface or closure and provided for substantial flow reduction at seal-poppet engagement.

Although some of the performance objectives were not attained within the constraints of this contract, the investigation pointed to the following conclusions and recommendations:

a. Bellows: Bellows problems occurred during the demonstration test program. The long life (20,000 cycles) requirement was incompatible with the high pressure, long stroke and available envelope requirements. A failure analysis of the primary actuator bellows (outer) provided a review of the design constraints imposed by the long cyclic life objective. Imposition of the bellows stability criteria and the allowable cyclic stress level indicated a permissible bellows stroke in the order of 1.0 inch as compared to the 1.6-inch stroke employed in the test configuration. This would result in a bellows area and actuation force increase by this stroke ratio as well as modification of the actuation linkage attachment and bearing size.

b. Poppet Hard Coating: The Tribaloy Blend 120 hard coating on the poppet sealing surface proved to be very wear resistant. There was no evidence of separation of the coating from the aluminum alloy base metal as a result of the temperature extremes of minus 200° to plus 200°F. The stainless steel disk spring showed no signs of galling as a result of contact with the hard surface. The coating, not being as fine-grained as might be desired, was slightly porous in nature. This porosity contributed to the main seal leakage during the demonstration testing. The Tribaloy coating of the test hardware was thicker than specified. A thinner coating would have produced a finer grain structure and would have helped to eliminate the porous condition.

c. Polyimide Bearings: The polyimide SP 211 bearings used in the valve actuation linkage proved to stand up well under the 20,000 test cycles, and the SP 211 material is recommended for similar applications.

d. Piston Dynamic Seals: The piston dynamic seals were made of both plain TFE and filled TFE (15 percent glass, 5 percent Moly Disulphide). During the demonstration test program it was found that particles from the plain TFE seal were deposited on the cylinder wall and were then transferred to the filled seal. These flakes of contamination interfered with the proper sealing action of the filled dynamic seals. The dynamic seals of the filled material are recommended for their longer wear capabilities.

e. Shaft Seal: The shaft seal relied on interference fit and differential pressure loading to provide proper sealing action. During the demonstration testing, this lip seal provided variable sealing capabilities for both the room temperature and low temperature cycling and the room temperature and high temperature cycling. A spring loaded design is recommended for a low leakage and long life application.

APPENDIX A

Rating Sheets
(29 Sheets)

Large Valves - 1st Iteration

Large Valves - 2nd Iteration

Small Valves

Large Valve Actuators

Controllers

Transmitters

90

1ST ITERATION 4 - VERY GOOD 3 - GOOD 2 - FAIR 1 - POOR	FIG 2-3 VISOR VALVE SIMULTANEOUS RETRACTION OF SEAL & ROTATION OF VISOR			FIG 2-4 VISOR VALVE SEAL RETRACTED & THEN VALVE ROTATED			FIG 2-1 BALL VALVE SIMULTANEOUS RETRACTION AND ROTATION OF BALL		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	4	.0879	.3516	4	.0879	.3516	4	.0879	.3516
RESPONSE TIME	2	.0549	.1098	1	.0549	.0549	2	.0549	.1098
WEIGHT	4	.0220	.0880	2	.0220	.0440	3	.0220	.0660
CYCLE LIFE	2	.1209	.2418	4	.1209	.4836	2	.1209	.2418
LEAKAGE	2	.1209	.2418	4	.1209	.4836	2	.1209	.2418
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	3	.0549	.1647	3	.0549	.1647	3	.0549	.1647
IN LINE MAINTENANCE	3	.0659	.1977	2	.0659	.1318	3	.0659	.1977
COST ~~SIMPLICITY~~	3	.0659	.1977	2	.0659	.1318	3	.0659	.1977
STORAGE LIFE	4	.0989	.3966	4	.0989	.3966	4	.0989	.3966
ACTUATOR ADAPTABILITY	4	.0275	.1000	2	.0275	.0550	4	.0275	.1000
NATURAL VIBRATION RESISTANCE	3	.1374	.4022	2	.1374	.2748	3	.1374	.4122
CONTAMINATION RESISTANCE	3	.1264	.3792	3	.1264	.3792	2	.1264	.2528
AVAILABILITY OF DESIGN INFO	3	.0165	.0495	1	.0165	.0165	3	.0165	.0495
		TOTAL	2.9206		TOTAL	2.9681		TOTAL	2.7822

1ST ITERATION
4 - VERY GOOD
3 - GOOD
2 - FAIR
1 - POOR

FIG 2-2 BALL SEAL RETRACTED AND BALL ROTATED IN SEQUENCE

	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	4	.0879	.3516		.0879			.0879	
RESPONSE TIME	1	.0549	.0549		.0549			.0549	
WEIGHT	1	.0220	.0220		.0220			.0220	
CYCLE LIFE	4	.1209	.4836		.1209			.1209	
LEAKAGE	4	.1209	.4836		.1209			.1209	
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	3	.0549	.1647		.0549			.0549	
IN LINE MAINTENANCE	2	.0659	.1318		.0659			.0659	
COST ~~SIMPLICITY~~	2	.0659	.1318		.0659			.0659	
STORAGE LIFE	4	.0989	.3966		.0989			.0989	
ACTUATOR ADAPTABILITY	2	.0275	.0550		.0275			.0275	
NATURAL VIBRATION RESISTANCE	2	.1374	.2748		.1374			.1374	
CONTAMINATION RESISTANCE	2	.1264	.2528		.1264			.1264	
AVAILABILITY OF DESIGN INFO	1	.0165	.0165		.0165			.0165	
		TOTAL	2.8197		TOTAL			TOTAL	

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1ST ITERATION 4 - VERY GOOD 3 - GOOD 2 - FAIR 1 POOR	FIG 2-6 BUTTERFLY SIMULTANEOUS RETRACTION & ROTATION OF BLADE			FIG 2-7 BUTTERFLY BLADE TRANSLATES & THEN ROTATES			FIG 2-8 BUTTERFLY BLADE TRANSLATES & ROTATES		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
RESSURE DROP	3	.0879	.2637	3	.0879	.2637	3	.0879	.2637
ESPONSE TIME	3	.0549	.1647	2	.0549	.1098	2	.0549	.1098
WEIGHT	3	.0220	.0660	4	.0220	.0880	2	.0220	.0440
YCLE LIFE	2	.1209	.2418	4	.1209	.4836	4	.1209	.4836
EAKAGE	2	.1209	.2418	4	.1209	.4836	4	.1209	.4836
ENVELOPE		0			0			0	
EPLACEMENT MAINTENANCE	3	.0549	.1647	3	.0549	.1647	3	.0549	.1647
N LINE MAINTENANCE	2	.0659	.1318	3	.0659	.1977	2	.0659	.1318
COST ~~SIMPLICITY~~	2	.0659	.1318	3	.0659	.1977	2	.0659	.1318
STORAGE LIFE	4	.0989	.3956	4	.0989	.3956	4	.0989	.3956
ACTUATOR ADAPTABILITY	4	.0275	.1000	4	.0275	.1100	4	.0275	.1100
NATURAL ~~VIBRATION~~ RESISTANCE	2	.1374	.2748	3	.1374	.4122	2	.1374	.2748
CONTAMINATION RESISTANCE	2	.1264	.2528	2	.1264	.2528	2	.1264	.2528
AVAILABILITY OF DESIGN INFO	3	.0165	.0495	2	.0165	.0230	2	.0165	.0230
		TOTAL	2.4790		TOTAL	3.1824		TOTAL	2.8692

4

1ST ITERATION
4 - VERY GOOD
3 - GOOD
2 - FAIR
1 - POOR

	FIG 2-14 COAXIAL POPPET			FIG 2-16 MOTOR DRIVEN POPPET			FIG 2-12 MOTOR DRIVEN POPPET		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	2	.0879	.1758	2	.0879	.1758	2	.0879	.1758
RESPONSE TIME	4	.0549	.2196	3	.0549	.1647	3	.0549	.1638
WEIGHT	2	.0220	.0440	1	.0220	.0220	3	.0220	.0660
CYCLE LIFE	4	.1209	.4836	1	.1209	.1209	4	.1209	.4836
LEAKAGE	4	.1209	.4836	4	.1209	.4836	4	.1209	.4836
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0549	.2196	4	.0549	.2196	4	.0549	.2196
IN LINE MAINTENANCE	2	.0659	.1318	1	.0659	.0659	3	.0659	.1977
~~SIMPLICITY~~ COST	2	.0659	.1318	2	.0659	.1318	3	.0659	.1977
STORAGE LIFE	4	.0989	.3956	3	.0989	.2977	4	.0989	.3956
ACTUATOR ADAPTABILITY	1	.0275	.0275	1	.0275	.0275	3	.0275	.0825
NATURAL VIBRATION RESISTANCE	3	.1374	.4122	4	.1374	.5496	2	.1374	.2748
CONTAMINATION RESISTANCE	3	.1264	.3792	3	.1264	.3792	3	.1264	.3792
AVAILABILITY OF DESIGN INFO	4	.0165	.0660	3	.0165	.0495	3	.0165	.0495
		TOTAL	3.1703		TOTAL	2.6878		TOTAL	2.9717

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5 1ST ITERATION

4- VERY GOOD
3- GOOD
2- FAIR
1- POOR

FIG 2-15- RADIAL LOADED SEAL POPPET

	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	2	.0879	.1758		.0879			.0879	
RESPONSE TIME	4	.0549	.2196		.0549			.0549	
WEIGHT	3	.0220	.0660		.0220			.0220	
CYCLE LIFE	4	.1209	.4836		.1209			.1209	
LEAKAGE	1	.1209	.1209		.1209			.1209	
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0549	.2196		.0549			.0549	
IN LINE MAINTENANCE	2	.0659	.1318		.0659			.0659	
~~SIMPLICITY~~ COST	2	.0659	.1318		.0659			.0659	
STORAGE LIFE	4	.0989	.3956		.0989			.0989	
ACTUATOR ADAPTABILITY	2	.0275	.0550		.0275			.0275	
NATURAL VIBRATION RESISTANCE	3	.1374	.4122		.1374			.1374	
CONTAMINATION RESISTANCE	4	.1264	.5056		.1264			.1264	
AVAILABILITY OF DESIGN INFO	2	.0165	.0330		.0165			.0165	
		TOTAL	2.9505		TOTAL			TOTAL	

1ST ITERATION 4-VERY GOOD 3-GOOD 2-FAIR 1-POOR	FIG 2-9 DUAL FLAPPER SINGLE ACTUATOR			FIG 2-10 DUAL FLAPPER DUAL ACTUATOR			ROTARY		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	3	.0879	.2637	3	.0879	.2637	2	.0879	.1758
RESPONSE TIME	3	.0549	.1647	3	.0549	.1647	2	.0549	.1098
WEIGHT	3	.0220	.0660	2	.0220	.0440	3	.0220	.0660
CYCLE LIFE	3	.1209	.3627	3	.1209	.3627	2	.1209	.2418
LEAKAGE	3	.1209	.3627	3	.1209	.3627	3	.1209	.3627
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0549	.2196	4	.0549	.2196	4	.0549	.2196
IN LINE MAINTENANCE	3	.0659	.1977	3	.0659	.1977	2	.0659	.1318
~~SIMPLICITY~~ COST	4	.0659	.2636	3	.0659	.1977	3	.0659	.1977
STORAGE LIFE	4	.0989	.3956	4	.0989	.3956	4	.0989	.3956
ACTUATOR ADAPTABILITY	4	.0275	.1000	4	.0275	.1100	4	.0275	.1100
NATURAL VIBRATION RESISTANCE	3	.1374	.4122	2	.1374	.2748	4	.1374	.5496
CONTAMINATION RESISTANCE	2	.1264	.2528	2	.1264	.2528	4	.1264	.5056
AVAILABILITY OF DESIGN INFO	2	.0165	.0330	2	.0165	.0330	3	.0165	.0495
		TOTAL	3.0943		TOTAL	2.8790		TOTAL	3.1155

7 1ST ITERATION

4- VERY GOOD
3- GOOD
2- FAIR
1- POOR

	PLUG VALVE RETRACTABLE SEQUENCED SEAL			FIG. 2-5 PLUG VALVE RETRACTABLE SEQUENCED SEAL PLUS SECONDARY SEAL					
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	4	.0879	.3516	4	.0879	.3516		.0879	
RESPONSE TIME	2	.0549	.1098	1	.0549	.0549		.0549	
WEIGHT	2	.0220	.0440	1	.0220	.0220		.0220	
CYCLE LIFE	3	.1209	.3627	4	.1209	.4836		.1209	
LEAKAGE	2	.1209	.2418	3	.1209	.3627		.1209	
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0549	.2196	4	.0549	.2196		.0549	
IN LINE MAINTENANCE	3	.0659	.1977	2	.0659	.1318		.0659	
~~SIMPLICITY~~ COST	2	.0659	.1318	1	.0659	.0659		.0659	
STORAGE LIFE	4	.0989	.3956	4	.0989	.3956		.0989	
ACTUATOR ADAPTABILITY	3	.0275	.0825	3	.0275	.0825		.0275	
NATURAL VIBRATION RESISTANCE	2	.1374	.2748	2	.1374	.2748		.1374	
CONTAMINATION RESISTANCE	3	.1264	.3792	4	.1264	.5056		.1264	
AVAILABILITY OF DESIGN INFO	2	.0165	.0330	2	.0165	.0330		.0165	
		TOTAL	2.8241		TOTAL	2.9836		TOTAL	

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8 1ST ITERATION
4 - VERY GOOD
3 - GOOD
2 - FAIR
1 POOR

	FIG 2-19 HERMETIC SEAL ACTUATED POPPET			FIG 2-11 SWING					
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	2	.0879	.1758	4	.0879	.3516		.0879	
RESPONSE TIME	4	.0549	.2196	3	.0549	.1647		.0549	
WEIGHT	3	.0220	.0660	2	.0220	.0440		.0220	
CYCLE LIFE	4	.1209	.4836	3	.1209	.3627		.1209	
LEAKAGE	4	.1209	.4836	3	.1209	.3627		.1209	
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0549	.2196	4	.0549	.2196		.0549	
IN LINE MAINTENANCE	1	.0659	.0659	3	.0659	.1977		.0659	
~~SIMPLICITY~~ COST	3	.0659	.1977	2	.0659	.1318		.0659	
STORAGE LIFE	4	.0989	.3956	4	.0989	.3956		.0989	
ACTUATOR ADAPTABILITY	2	.0275	.0550	4	.0275	.1100		.0275	
NATURAL VIBRATION RESISTANCE	4	.1374	.5496	3	.1374	.4122		.1374	
CONTAMINATION RESISTANCE	3	.1264	.3792	2	.1264	.2528		.1264	
AVAILABILITY OF DESIGN INFO	3	.0165	.0495	4	.0165	.0660		.0165	
		TOTAL	3.3407		TOTAL	3.0714		TOTAL	

9

4 - VERY GOOD
3 - GOOD
2 - FAIR
1 POOR

SECOND ITERATION

	FIG 2-4 VISOR VALVE SEAL RETRACTED AND THEN VALVE ROTATED			FIG 2-2 BALL - SEAL RETRACTED AND BALL ROTATED IN SEQUENCE			FIG 2-7 BUTTERFLY BLADE TRANSLATES & THEN ROTATES		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	4	.0879	.3516	4	.0879	.3516	3	.0879	.2637
RESPONSE TIME	2	.0549	.1098	1	.0549	.0549	3	.0549	.1647
WEIGHT	1	.0220	.0220	1	.0220	.0220	4	.0220	.0880
CYCLE LIFE	4	.1209	.4836	4	.1209	.4836	4	.1209	.4836
LEAKAGE	3	.1209	.3627	4	.1209	.4836	3	.1209	.3627
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0549	.2196	4	.0549	.2196	4	.0549	.2196
IN LINE MAINTENANCE	3	.0659	.1977	3	.0659	.1977	3	.0659	.1977
COST ~~SIMPLICITY~~	1	.0659	.0659	1	.0659	.0659	4	.0659	.2636
STORAGE LIFE	4	.0989	.3956	4	.0989	.3956	4	.0989	.3956
ACTUATOR ADAPTABILITY	4	.0275	.1100	4	.0275	.1100	4	.0275	.1100
NATURAL VIBRATION RESISTANCE	3	.1374	.4122	2	.1374	.2748	3	.1374	.4122
CONTAMINATION RESISTANCE	4	.1264	.5056	4	.1264	.5056	2	.1264	.2528
AVAILABILITY OF DESIGN INFO	3	.0165	.0495	3	.0165	.0495	4	.0165	.0660
		TOTAL	3.2858		TOTAL	3.2144		TOTAL	3.2802

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10

4- VERY GOOD
3- GOOD
2- FAIR
1- POOR

SECOND ITERATION

	FIG 2-14 POPPET			FIG 2-9 DUAL FLAPPER			FIG 2-5 PLUG		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	2	.0879	.1758	2	.0879	.1758	4	.0879	.3516
RESPONSE TIME	4	.0549	.2196	3	.0549	.1647	1	.0549	.0549
WEIGHT	2	.0220	.0440	3	.0220	.0660	1	.0220	.0220
CYCLE LIFE	4	.1209	.4836	3	.1209	.3627	4	.1209	.4836
LEAKAGE	2	.1209	.2418	1	.1209	.1209	4	.1209	.4836
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0549	.2196	4	0549	.2196	4	.0549	.2196
IN LINE MAINTENANCE	2	.0659	.1318	4	.0659	.2636	4	.0659	.2636
COST ~~SIMPLICITY~~	2	.0659	.1318	1	.0659	.0659	1	.0659	.0659
STORAGE LIFE	4	.0989	.3956	4	0989	.3956	4	.0989	.3956
ACTUATOR ADAPTABILITY	1	.0275	.0275	4	.0275	.1100	4	.0275	.1100
NATURAL VIBRATION RESISTANCE	4	.1374	.5496	3	.1374	.4122	2	.1374	.2748
CONTAMINATION RESISTANCE	4	.1264	.5056	1	.1264	.1264	4	.1264	.5056
AVAILABILITY OF DESIGN INFO	4	.0165	.0660	3	.0165	.0495	3	.0165	.0495
		TOTAL	3.1923		TOTAL	2.5329		TOTAL	3.2803

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4- VERY GOOD
3- GOOD
2- FAIR
1- POOR

FIG A2-19 HERMETIC SEAL ACTUATOR

SECOND ITERATION

	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	2	.0879	.1758		.0879			.0879	
RESPONSE TIME	4	.0549	.2196		.0549			.0549	
WEIGHT	2	.0220	.0440		.0220			.0220	
CYCLE LIFE	4	.1209	.4836		.1209			.1209	
LEAKAGE	3	.1209	.3627		.1209			.1209	
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0549	.2196		.0549			.0549	
IN LINE MAINTENANCE	2	.0659	.1318		.0659			.0659	
COST ~~SIMPLICITY~~	3	.0659	.1977		.0659			.0659	
STORAGE LIFE	4	.0989	.3956		.0989			.0989	
ACTUATOR ADAPTABILITY	3	.0275	.0825		.0275			.0275	
NATURAL ~~VIBRATION~~ RESISTANCE	2	.1374	.2748		.1374			.1374	
CONTAMINATION RESISTANCE	2	.1264	.2528		.1264			.1264	
AVAILABILITY OF DESIGN INFO	4	.0165	.0660		.0165			.0165	
		TOTAL	2.8965		TOTAL			TOTAL	

SMALL VALUES 5 - SUPERIOR 4 - EXCELLENT 3 - VERY GOOD 2 - FAIR 1 - POOR	ROTARY			FIG 2-19 POPPET DIRECT MOTOR DRIVEN			FIG 2-33 BIMETALLIC POPPET		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	1	.0879	.0879	3	.0879	.2637	3	.0879	.2637
RESPONSE TIME	3	.0549	.1647	3	.0549	.1647	2	.0549	.1188
WEIGHT	2	.0220	.044	2	.0220	.044	5	.0220	.110
CYCLE LIFE	2	.1209	.2418	3	.1209	.3627	5	.1209	.6045
LEAKAGE	5	.1209	.6045	3	.1209	.3931	3	.1209	.3937
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	5	.0549	.2745	5	.0549	.2745	3	.0549	.1647
IN LINE MAINTENANCE	1	.0659	.0659	3	.0659	.1977	1	.0659	.0659
SIMPLICITY/COST	2	.0659	.1301	3	.0659	.1977	5	.0659	.3295
STORAGE LIFE	3	.0989	.2967	4	.0989	.3956	5	.0989	.4945
ACTUATOR ADAPTABILITY	5	.0275	.1375	5	.0275	.1375	1	.0275	.0275
VIBRATION	4	.1374	.5496	3	.1374	.4122	5	.1374	.6870
CONTAMINATION RESISTANCE	5	.1265	.6325	3	.1265	.3795	3	.1265	.3795
AVAILABILITY OF DESIGN INFO	3	.0165	.0495	3	.0165	.0495	2	.0165	.0330
		TOTAL	3.2467		TOTAL	3.2334		TOTAL	3.5733

ORIGINAL PAGE IS OF POOR QUALITY

SMALL VALUES 4 - VERY GOOD 3 - GOOD 2 - FAIR 1 - POOR	HERMETIC SEALED POPPET			FIG 2-13 PLUG-POPPET HYBRID					
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	3	.0879	.2637	5	.0879	.4295			
RESPONSE TIME	4	.0549	.2226	5	.0549	.2867			
WEIGHT	4	.0220	.088	3	.0220	.066			
CYCLE LIFE	3	.1209	.3627	4	.1209	.4836			
LEAKAGE	3	.1209	.3627	5	.1209	.6045			
ENVELOPE		0			0				
REPLACEMENT MAINTENANCE	4	.0549	.2196	5	.0549	.2745			
IN LINE MAINTENANCE	2	.0659	.1361	1	.0659	.0659			
SIMPLICITY/COST	3	.0659	.1977	4	.0659	.2636			
STORAGE LIFE	4	.0989	.3956	4	.0989	.3956			
~~[illegible]~~ ACTUATOR ADAPTABILITY	3	.0275	.0825	3	.0275	.0825			
VIBRATION	3	.1374	.4122	2	.1374	.2748			
CONTAMINATION RESISTANCE	3	.1265	.3795	3	.1265	.3795			
AVAILABILITY OF DESIGN INFO	3	.0165	.0495	3	.0165	.0495			
		TOTAL	3.1724		TOTAL	3.6562		TOTAL	

LARGE VALVE ACTUATORS 4 SUPERIOR 3 EXCELLENT 2 GOOD 1 POOR	FIG 2-26 DOUBLE ACTING DOUBLE SOLENOID DIRECT DRIVE			FIG 2-27 SINGLE ACTING BELLOW-SOLENOID OPERATED			FIG 2-28 - DOUBLE ACTING, DOUBLE SOLENOID DIRECT DRIVE DETENT HELD		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
RESPONSE TIME	2	.0641	.1282	2	.0641	.1282	3	.0641	.1923
WEIGHT	1	.0256	.0256	2	.0256	.0512	3	.0256	.0768
CYCLE LIFE	2	.1282	.2564	3	.1282	.3846	4	.1282	.5128
LEAKAGE	4	.1282	.5128	4	.1282	.5128	3	.1282	.3846
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0641	.2564	4	.0641	.2564	4	.0641	.2564
IN LINE MAINTENANCE	3	.0769	.2307	3	.0769	.2307	4	.0769	.3076
~~[illegible]~~/COST	2	.0769	.1538	4	.0769	.3076	3	.0769	.2307
STORAGE LIFE	4	.1026	.4104	4	.1026	.4104	3	.1026	.3078
VALVE ADAPTABILITY	4	.0321	.1284	4	.0321	.1284	4	.0321	.1284
NATURAL VIBRATION RESISTANCE	4	.1474	.5896	4	.1474	.5896	4	.1474	.5896
CONTAMINATION RESISTANCE	3	.1346	.4038	4	.1346	.5384	2	.1346	.2692
AVAILABILITY OF DESIGN INFO	4	.0192	.0768	4	.0192	.0768	4	.0192	.0768
		TOTAL	3.1729		TOTAL	3.6155		TOTAL	3.3330

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LARGE VALVE ACTUATORS 4 SUPERIOR 3 EXCELLENT 2 GOOD 1 POOR	FIG 2-21 PISTON RACK PINION			FIG 2-24 HYDRAULIC REDUNDANT MOTOR ~~[illegible]~~D-TORQUE MOTOR			FIG 2-24 PNEUMATIC REDUNDANT MOTOR ~~[illegible]~~-TORQUE MOTOR		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
RESPONSE TIME	1	.0641	.0641	4	.0641	.2564	1	.0641	.0641
WEIGHT	1	.0256	.0256	4	.0256	.1024	1	.0256	.0256
CYCLE LIFE	2	.1282	.2564	4	.1282	.5128	4	.1282	.5128
LEAKAGE	2	.1282	.2564	1	.1282	.1282	3	.1282	.3846
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0641	.2564	4	.0641	.2564	4	.0641	.2564
IN LINE MAINTENANCE	2	.0769	.1538	4	.0769	.3076	4	.0769	.3076
~~[illegible]~~/COST	2	.0769	.1538	1	.0769	.0769	1	.0769	.0769
STORAGE LIFE	3	.1026	.3078	3	.1026	.3078	3	.1026	.3078
VALVE ADAPTABILITY	4	.0321	.1284	4	.0321	.1284	4	.0321	.1284
NATURAL VIBRATION RESISTANCE	2	.1474	.2948	1	.1474	.1474	1	.1474	.1474
CONTAMINATION RESISTANCE	1	.1346	.1346	1	.1346	.1346	1	.1346	.1346
AVAILABILITY OF DESIGN INFO	4	.0192	.0768	2	.0192	.0384	2	.0192	.0384
		TOTAL	2.1091		TOTAL	2.3973		TOTAL	2.3846

CONTROLLERS
6 - EXCELLENT
5 - VERY GOOD
4 - GOOD
3 - FAIR
2 - POOR
1 - VERY POOR

	FIG 2-31 PIEZOELECTRIC DISKS			FIG 2-29 PALADIUM SILVER ALLOY TUBE			HEAT SENSITIVE THERMAL CONTROLLER		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
RESPONSE TIME	3	.0641	.1923	2	.0641	.1282	1	.0641	.0641
WEIGHT	5	.0256	.1280	3	.0256	.0768	2	.0256	.0512
CYCLE LIFE	6	.1282	.7692	6	.1282	.7692	5	.1282	.6410
LEAKAGE	4	.1282	.5128	6	.1282	.7692	4	.1282	.5128
ENVELOPE		0							
REPLACEMENT MAINTENANCE	1	.0641	.0641	6	.0641	.3846	1	.0641	.0641
IN LINE MAINTENANCE	1	.0769	.0769	6	.0769	.4614	1	.0769	.0769
SIMPLICITY/COST	2	.0769	.1538	2	.0769	.1538	3	.0769	.2307
STORAGE LIFE	6	.1026	.6156	6	.1026	.6156	5	.1026	.5130
ACTUATOR ADAPTABILITY	4	.0321	.1284	6	.0321	.1926	3	.0321	.0963
VIBRATION	6	.1474	.8844	3	.1474	.4422	5	.1474	.7370
CONTAMINATION RESISTANCE	3	.1346	.4038	6	.1346	.8076	2	.1346	.2692
AVAILABILITY OF DESIGN INFO	3	.0192	.0576	1	.0192	.0192	4	.0192	.0768
		TOTAL	3.9869		TOTAL	4.8204		TOTAL	3.3331

TRANSMITTERS	FIG 2-32 HERMETIC SEALED TUBULAR CONTROLLER			FIG 2-17 HERMETIC SEALED BELLOWS MOTION CONTROLLER			FIG 2-18 SNAP ACTION DIFFERENTIAL EXPANSION		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
RESPONSE TIME	5	.0641	.3205	5	.0641	.3205	3	.0641	.1923
WEIGHT	3	.0256	.0768	4	.0256	.1024	5	.0256	.1280
CYCLE LIFE	5	.1282	.6410	5	.1282	.6410	5	.1282	.6410
LEAKAGE	5	.1282	.6410	5	.1282	.6410	4	.1282	.5128
ENVELOPE		0							
REPLACEMENT MAINTENANCE	5	.0641	.3205	5	.0641	.3205	3	.0641	.1923
IN LINE MAINTENANCE	5	.0769	.3845	5	.0769	.3845	1	.0769	.0769
SIMPLICITY	4	.0769	.3076	6	.0769	.4614	5	.0769	.3845
STORAGE LIFE	6	.1026	.6156	6	.1026	.6156	5	.1026	.5130
ACTUATOR ADAPTABILITY	6	.0321	.1926	6	.0321	.1926	5	.0321	.1605
VIBRATION	4	.1474	.5896	4	.1474	.5896	6	.1474	.8844
CONTAMINATION RESISTANCE	3	.1346	.4038	3	.1346	.4038	4	.1346	.5384
AVAILABILITY OF DESIGN INFO	4	.0192	.0768	6	.0192	.1152	4	.0192	.0768
		TOTAL	4.5703		TOTAL	4.7881		TOTAL	4.3009

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APPENDIX B

Adjusted Rating Sheets
Based On
Layout Representation
(4 Sheets)

Large Valves

Large Actuators

LARGE VALVE PROPOSAL DRWS.	966020 HYBRID BUTTERFLY POPPET			966021 DUAL SEQUENCED BALL			966022 - DUAL LEVEL SEQUENCED		
4 SUPERIOR 3 EXCELLENT 2 GOOD 1 POOR	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	3	.0879	.2637	4	.0879	.3516	4	.0879	.3516
RESPONSE TIME	4	.0549	.2196	2	.0549	.1098	3	.0549	.1647
WEIGHT	4	.0220	.0880	1	.0220	.0220	3	.0220	.0660
CYCLE LIFE	4	.1209	.4836	2	.1209	.2418	3	.1209	.3627
LEAKAGE	4	.1209	.4836	3	.1209	.3627	3	.1209	.3627
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0549	.2196	4	.0549	.2196	4	.0549	.2196
IN LINE MAINTENANCE	4	.0659	.2636	3	.0659	.1977	3	.0659	.1977
~~SIMPLICITY~~/COST	4	.0659	.2636	2	.0659	.1318	3	.0659	.1977
STORAGE LIFE	4	.0989	.3956	4	.0989	.3956	4	.0989	.3956
~~VALVE~~ ACTUATOR ADAPTABILITY	4	.0275	.1100	2	.0275	.0550	2	.0275	.0550
NATURAL VIBRATION RESISTANCE	2	.1374	.2750	2	.1374	.2750	2	.1374	.2750
CONTAMINATION RESISTANCE	4	.1264	.5056	3	.1264	.3792	3	.1264	.3792
AVAILABILITY OF DESIGN INFO	2	.0165	.0330	3	.0165	.0495	3	.0165	.0495
		TOTAL	3.6045		TOTAL	2.7713		TOTAL	3.0770

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LARGE VALVE PROPOSAL DRWGS.
4 SUPERIOR
3 EXCELLENT
2 GOOD
1 POOR

	966023 VISOR CAM SEQUENCED								
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
PRESSURE DROP	4	.0879	.3516		.0879			.0879	
RESPONSE TIME	2	.0549	.1098		.0549			.0549	
WEIGHT	2	.0220	.0660		.0220			.0220	
CYCLE LIFE	3	.1209	.3627		.1209			.1209	
LEAKAGE	3	.1209	.3627		.1209			.1209	
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0549	.2196		.0549			.0549	
IN LINE MAINTENANCE	3	.0659	.1977		.0659			.0659	
~~SIMPLICITY~~/COST	3	.0659	.1977		.0659			.0659	
STORAGE LIFE	4	.0989	.3956		.0989			.0989	
~~VALVE~~ ACTUATOR ADAPTABILITY	2	.0275	.0550		.0275			.0275	
NATURAL VIBRATION RESISTANCE	2	.1374	.2758		.1374			.1374	
CONTAMINATION RESISTANCE	3	.1264	.3792		.1264			.1264	
AVAILABILITY OF DESIGN INFO	3	.0165	.0495		.0165			.0165	
		TOTAL	3.0221		TOTAL			TOTAL	

0111

LARGE ACTUATORS LAYOUT VIEWS 4 SUPERIOR 3 EXCELLENT 2 GOOD 1 POOR	966024 SINGLE ACTING BELLOWS - SOLENOID OPERATED			966027, DOUBLE ACTING DIRECT DRIVE DETENT HELD			REDUNDANT MOTOR BELLOWS		
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
RESPONSE TIME	4	.0641	.2564	3	.0641	.1923	2	.0641	.1282
WEIGHT	4	.0256	.1024	3	.0256	.0768	1	.0256	.0256
CYCLE LIFE	4	.1282	.5128	3	.1282	.3846	2	.1282	.2564
LEAKAGE	4	.1282	.5128	3	.1282	.3846	3	.1282	.3846
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0641	.2564	4	.0641	.2564	3	.0641	.1923
IN LINE MAINTENANCE	4	.0769	.3076	3	.0769	.1923	4	.0769	.3076
COST	4	.0769	.3076	3	.0769	.1923	1	.0769	.0769
STORAGE LIFE	4	.1026	.4104	4	.1026	.4104	3	.1026	.3078
VALVE ADAPTABILITY	4	.0321	.1284	4	.0321	.1284	2	.0321	.0642
VIBRATION RESISTANCE	4	.1474	.5896	2	.1474	.2948	1	.1474	.1474
CONTAMINATION RESISTANCE	4	.1346	.5384	3	.1346	.4038	4	.1346	.5384
AVAILABILITY OF DESIGN INFO	4	.0192	.0768	4	.0192	.0768	3	.0192	.0576
		TOTAL	3.9996		TOTAL	2.9935		TOTAL	2.4870

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	REDUNDANT SINGLE ACTING BELLOWS SOLENOID OPERATED								
	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING	RATING	EMPHASIS COEFFICIENT	ADJUSTED RATING
RESPONSE TIME	4	.0641	.2564		.0641			.0641	
WEIGHT	2	.0256	.0512		.0256			.0256	
CYCLE LIFE	4	.1282	.5128		.1282			.1282	
LEAKAGE	4	.1282	.5128		.1282			.1282	
ENVELOPE		0			0			0	
REPLACEMENT MAINTENANCE	4	.0641	.2564		.0641			.0641	
IN LINE MAINTENANCE	4	.0769	.3076		.0769			.0769	
COST	2	.0769	.1538		.0769			.0769	
STORAGE LIFE	4	.1026	.4104		.1026			.1026	
VALVE ADAPTABILITY	3	.0321	.0963		.0321			.0321	
VIBRATION RESISTANCE	3	.1474	.4422		.1474			.1474	
CONTAMINATION RESISTANCE	4	.1346	.5384		.1346			.1346	
AVAILABILITY OF DESIGN INFO	4	.0192	.0768		.0192			.0192	
		TOTAL	3.6151		TOTAL			TOTAL	

APPENDIX C

Dynamic Simulation
P/N 966000

Calculations of
Equivalent Mass and
Poppet Forces
(5 Pages)

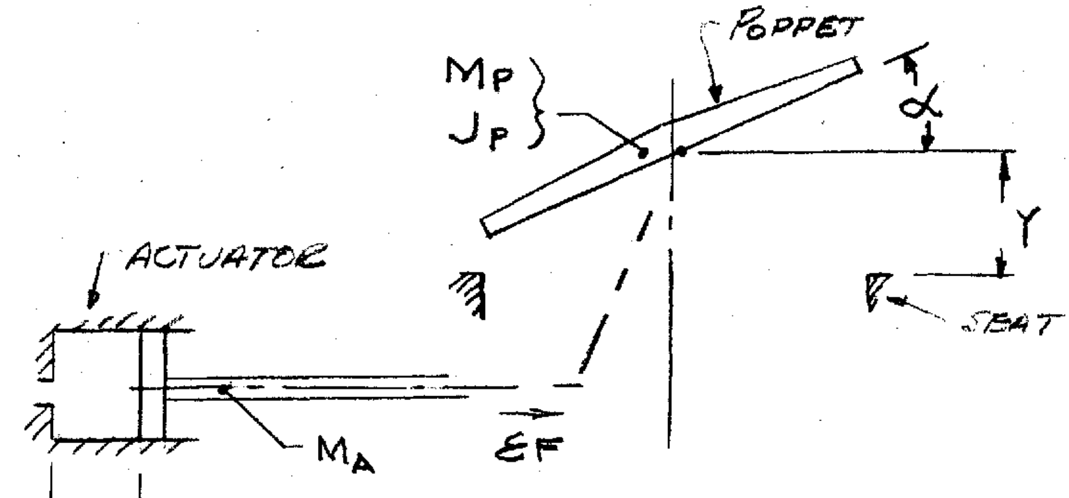
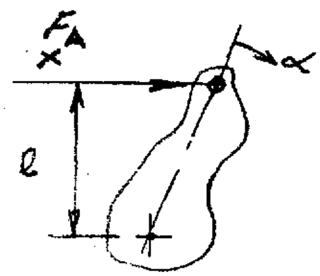


FIG 1

VALVE ACTUATION RESULTS IN A NON-LINEAR POPPET ROTATION AND TRANSLATION WITH RESPECT TO ACTUATOR POSITION SHOWN IN FIGURE 1. AN EQUIVOLENT NON-LINEAR MASS WILL BE COMPUTED TO EVALUATE ACTUATOR ACCELERATION WITH FORCE UNBALANCE.

ROTATION



T = TORQUE (IN #)
ℓ = (IN)
J = (# IN SEC²)
α = POSITION (RAD)
F_A = (#)

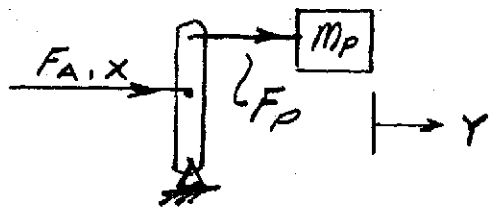
$$T = F\ell = J\ddot{\alpha}$$

$$d\alpha = \frac{dx}{\ell}$$

$$F\ell = \frac{J}{\ell}\ddot{x}$$

$$\ddot{x} = \frac{F\ell^2}{J} = \frac{F}{J}\left(\frac{dx}{d\alpha}\right)^2 = \frac{F}{J\left(\frac{d\alpha}{dx}\right)^2}$$

TRANSLATION



$F = (\#)$
$M = \left(\frac{\# \, SEC^2}{IN}\right)$
$X = (IN)$

$$F_P = M_P \ddot{Y} = M_P \left(\frac{dY}{dx}\right) \ddot{X}$$

$$F_A \, dx = F_P \, dY$$

$$F_A \frac{dx}{dY} = M_P \left(\frac{dY}{dx}\right) \ddot{X}$$

$$\ddot{X} = \frac{F_A}{M_P \left(\frac{dY}{dx}\right)^2}$$

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OF POOR QUALITY

EQUIVOLENT MASS $M_E = M_A + M_P\left(\frac{dY}{dx}\right)^2 + J\left(\frac{d\alpha}{dx}\right)^2$

$$M_A = \frac{2.5\#}{386 \text{ IN/SEC}^2} = 6.47 \times 10^{-3} \frac{\# SEC^2}{IN}$$

$$M_P = \frac{3.87\#}{386 \text{ IN/SEC}^2} = 10.03 \times 10^{-3} \frac{\# SEC^2}{IN}$$

$$J = \frac{3.00\#}{386 \text{ IN/SEC}^2} \times (2.1 \text{ IN})^2 = 3.427 \times 10^{-2} \# \text{ IN SEC}^2$$

X	$\left(\frac{dY}{dx}\right)$	$\left(\frac{d\alpha}{dx}\right)$	$M_P\left(\frac{dY}{dx}\right)^2$	$J\left(\frac{d\alpha}{dx}\right)^2$	M_A	$M_E \; \frac{\# SEC^2}{IN}$
0	1.45	0 0 RAD/IN	21.09×10^{-3}	0	6.47×10^{-3}	2.756×10^{-2}
.15	1.50	0 0	22.57×10^{-3}	0		2.904×10^{-2}
.45	1.60	2°/IN .035	25.68×10^{-3}	0.04×10^{-3}		3.219×10^{-2}
.66	1.56	17°/IN .297	24.41×10^{-3}	3.02×10^{-3}		3.390×10^{-2}
.95	1.40	33°/IN .576	19.66×10^{-3}	11.37×10^{-3}		3.750×10^{-2}
1.30	1.09	53°/IN .925	11.92×10^{-3}	29.32×10^{-3}		4.751×10^{-2}
1.66	0.48	75°/IN 1.309	2.31×10^{-3}	58.72×10^{-3}		6.750×10^{-2}
2.00	0.05	93°/IN 1.623	$.03 \times 10^{-3}$	90.27×10^{-3}	6.47×10^{-3}	9.677×10^{-2}

STOP SIMULATION

$$x < 0 \quad \begin{cases} F_S = -K_{S1}\, x & \dot{x} < 0 \\ \dot{x} = K_{V1}\, \dot{x}_{x=0} & \dot{x} \geq 0 \end{cases}$$

$$x > 2.000 \quad \begin{cases} F_S = -K_{S2}\,(x - 2.000) & \dot{x} > 0 \\ \dot{x} = -K_{V2}\, \dot{x}_{x=2.000} & \dot{x} \leq 0 \end{cases}$$

THESE RELATIONSHIPS INCLUDE THE RESPECTIVE SPRING RATES AND RECOIL FACTORS.

FOR FIRST COMPUTATION USE THE FOLLOWING VALUES:

$$K_{S1} = 3.3 \times 10^6 \ \#/IN$$

$$K_{S2} = 10^5 \ \#/IN$$

$$K_{V1} = 0.40$$

$$K_{V2} = 0.60$$

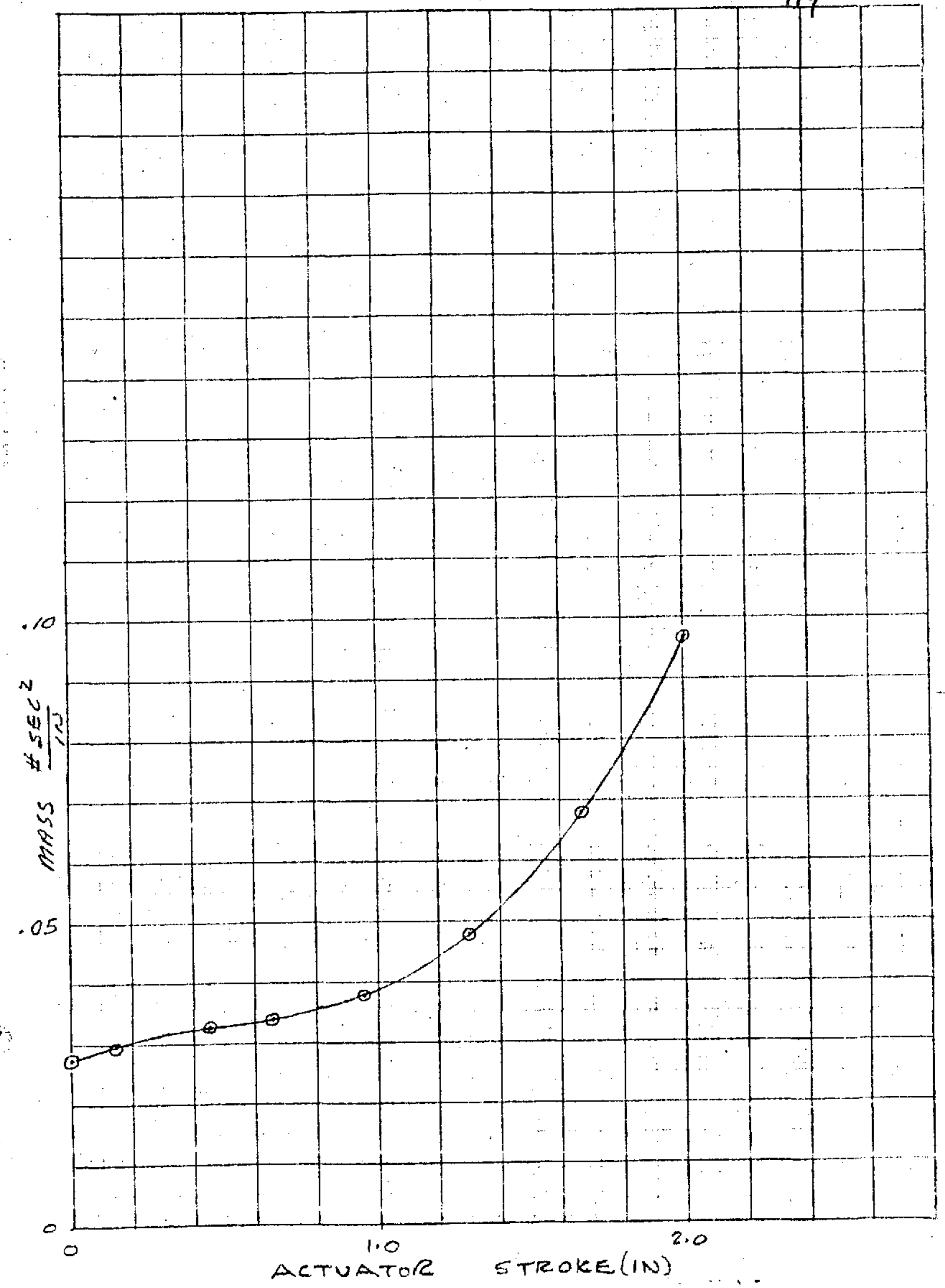
FRICTION

ASSUME $f = \pm 0.1\ F_A$

POSITIVE WHEN $\dot{x} \geq 0$
NEGATIVE WHEN $\dot{x} < 0$

POPPET FORCE

FORCE INCLUDES A TORSIONAL SPRING PLUS POPPET AIR LOADS THIS WILL BE SUPPLIED AS A GRAPH OF F_P VS x.


.10
.05
0
MASS #SEC²/IN
0
1.0
2.0
ACTUATOR STROKE(IN)

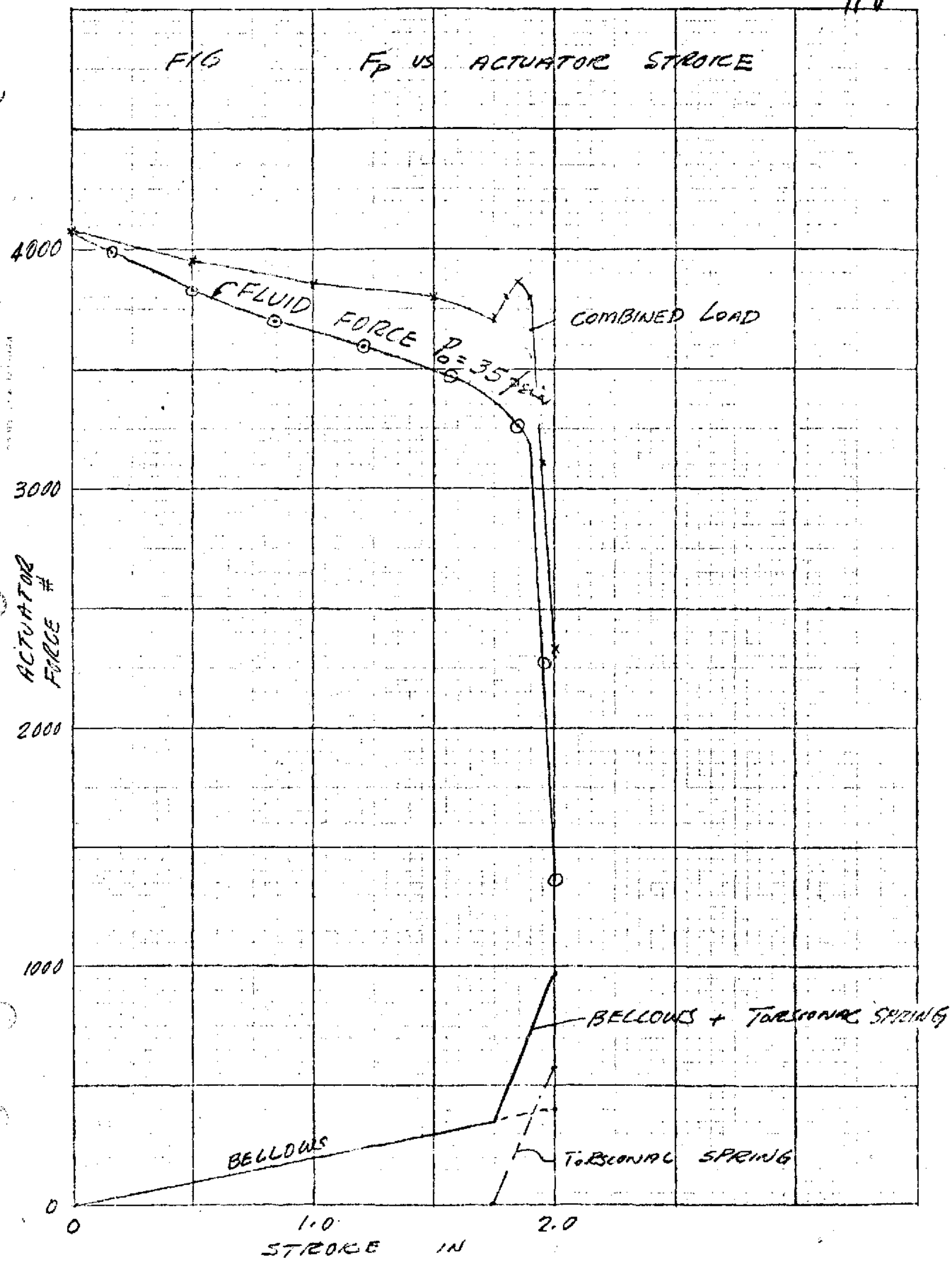


FIG F_p VS ACTUATOR STROKE
4000
3000
2000
1000
0
ACTUATOR FORCE #
FLUID FORCE $P_0 = 35$ PSIA
COMBINED LOAD
BELLOWS + TORSIONAL SPRING
BELLOWS
TORSIONAL SPRING
0
1.0
2.0
STROKE IN

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APPENDIX D

Demonstration Test Report
ER 966-24

Long Life Valve Design Concepts
(153 Pages)

FAIRCHILD
STRATOS DIVISION
1800 ROSECRANS AVENUE
MANHATTAN BEACH, CALIF., 90266

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DEMONSTRATION TEST REPORT

ER 966-24

LONG LIFE VALVE DESIGN CONCEPTS

CONTRACT NAS 8-28518

NASA CONTROL NO. PR-M-28518

Prepared by: A. H. Hall
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Approved by: J R Jones.
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J.Q. Adams, Contract Administrator

Approved by: M. Baniadam
M. Baniadam, Project Manager

20 December 1974

FOREWORD

This report was prepared by Fairchild Industries, Stratos Division, under NAS 8-28518, Long Life Valve Design Concepts for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration.

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ABSTRACT

This report documents the results of testing a long life cryogenic shutoff valve. These demonstration tests were part of the Phase III of a long life valve design concepts study. For these tests the pneumatically actuated 10-inch hybrid poppet butterfly valve was subjected to approximately 1000 room temperature cycles, 9000 cryogenic (-200°F) cycles, and 10,000 high temperature (+200°F) cycles; sinusoidal and random vibration testing; flow capacity testing; non-destructive burst testing; and post test wear analysis. During the cycling tests the valve inlet pressure was 35 psig, and the actuation pressure was 750 psig. At the beginning of the valve cycling at 696 total valve cycles, the actuator configuration was changed from a bellows type to a piston type because of excessive leakage.

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SECTION 1

INTRODUCTION

This report documents the results of the Phase III demonstration tests of the Long Life Valve Design Concept Study. These tests were conducted under Contract NAS 8-28518 for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. The purpose of these tests was to demonstrate that the 10-inch pneumatically actuated hybrid poppet butterfly valve designed and manufactured during Phase II and Phase III, respectively, would meet the requirements and design goals established during the study program. These requirements and goals were as follows:

Media	RP-1 Propane, LH_2, LO_2, He, N_2
Temperature Range	-423° to +200°F
Ambient Pressure (Internal)	
Operating	35 psia (+3.5, -0)
Proof	70 psia (+7, -0)
Burst	140 psia (+14, -0)
Actuator Pressure (He or N_2)	
Operating	750 ± 50 psia
Proof	1500 ± 100 psia
Burst	3000 ± 200 psia
Valve Pressure Drop	2 psi maximum with 43 lb/sec air or N_2 at room ambient temperature and pressure and 35 psia at valve inlet.
Valve Leakage Goal	3×10^{-5} sccs at 100 psia internal valve pressure.

A summary of the testing is presented in Section 2 herein. The test specimen change and rework history are presented in Section 3. The test procedures and results are presented in Section 4. The discussion and conclusions are presented in Section 5. Included as Appendices A, B and C are the valve assembly drawing 966001, the bellows failure analysis, and the AETL vibration test report.

SECTION 2

TEST SUMMARY

The long life valve demonstration tests and inspections were conducted at the Fairchild Stratos Division, Manhattan Beach, California, during the period from 10-23-73 to 7-16-74 except for the vibration tests which were conducted at the Approved Engineering Test Laboratories, Los Angeles, California.

Test Summary Sheets 1 through 4 present the test program in its entirety. Each sheet presents in chronological order the test, test specimen configuration, date, test conditions, location of test results, test specimen rework and remarks briefly describing anomalies, rework and results.

TEST SUMMARY
LONG LIFE VALVE DEMONSTRATION TESTS

SHEET 1

Item	Test	Test Specimen Configuration	Date	Test Conditions	Test Results and Rework: Tables, Figures & Appendices	Remarks
1	Examination of Product	Actuator with Bellows	10-23-73	Prior to assembly, diameters and surface finishes of all bearings and associated shafts, dynamic seals and mating surfaces were measured and recorded. Details were inspected for workmanship, general quality and cleanliness. Test specimen was weighed.	Paragraph 4.1 Table 4-1	Weight: 54 pounds
2	Initial Testing	Actuator with Bellows	10-25-73	Valve and actuator internal leakages were measured with inlet pressure increments of 5 psi with nitrogen, and actuator pressure increments of 100 psi.	Paragraph 4.2 Figure 4-1 Paragraph 3.2	Poppet seal engaged at inlet pressures above 20 psig.
3	Low Temperature Life Cycle Cycling continued until 15 RT cycles 681 Cryogenic cycles 696 total valve cycles	Actuator with Bellows	12-12-73 to 12-20-73	10,025 cycles at -200°F. and room temperature with 35 psig valve inlet pressure and 750 psig actuation pressure, 3 sec open and 7 sec closed. Leakages and response tests at cryogenic and room temperatures conducted before, during and after cycling. Leakage Tests: With 750 psig actuator pressure, "cover" and "close" port leakage measured with valve open and inlet pressure, varied from 0 to 35 psig. With 750 psig actuator pressure "cover" and "outlet" port leakage measured with valve closed and inlet pressure varied from 0 to 35 psig. With 750 psig "close" port pressure and 35 psig valve inlet pressure measured "cover" and "outlet" port leakage after "close" port pressure reduced to zero. Response Tests: With 750 psig actuator pressure and 35 psig valve inlet pressure measured open-to-close and close-to-open response time.	Paragraph 4.3 Tables 4-2 & 4-5 Figures 4-2 thru 4-11 Paragraph 3.3.1 Table 3-2 Figure 3-3	Valve would not cycle due to excessive leakage thru actuator open port, actuator close port and solenoid vent ports. Configuration change to piston type actuator assembly.
	Cycling continued until 48 RT cycles 722 cryogenic cycles 770 total valve cycles	Actuator with Piston	3-7-74 to 3-11-74		Paragraph 3.3.3 Figure 3-4	Excessive cover port leakage; upper piston seal replaced and Kel-F stop disk added to piston; 10 micron filters added at actuator ports.
	Cycling continued until 167 RT cycles 772 cryogenic cycles 939 total valve cycles	Actuator with Piston	3-14-74 to 3-15-74		Paragraph 3.3.4	Occasional high actuator leakage indicating erratic actuator seal performance. Reworked actuator assembly to provide additional vent holes in bearing and annular vent path to piston.
	Cycling continued until 223 RT cycles 2255 cryogenic cycles 2478 total valve cycles	Actuator with Piston	3-19-74 to 3-28-74		Paragraph 3.3.5 Figure 3-5	Excessive valve and actuator leakage. Valve seal and two actuator piston seals replaced. Filler incorporated into actuator sleeve.
	Cycling continued until 331 RT cycles 5895 cryogenic cycles 6226 total valve cycles	Actuator with Piston	4-2-74 to 4-8-74		Paragraph 3.3.6	Valve would not fully open or close. Actuation link failed. Installed new redesigned actuation link.
	Cycling continued until 1016 RT cycles 5895 cryogenic cycles 6911 total valve cycles	Actuator with Piston	4-17-74 to 4-18-74		Paragraph 3.3.7	Excessive main seal leakage. Main seal refinished.

TEST SUMMARY
LONG LIFE VALVE DEMONSTRATION TESTS

SHEET 2

Item	Test	Test Specimen Configuration	Date	Test Conditions	Test Results and Rework: Tables, Figures & Appendices	Remarks
3 (cont.)	Cycling continued until 1044 RT cycles 5897 cryogenic cycles 6941 total valve cycles	Actuator with Piston	4-22-74 to 4-23-74			Excessive piston leakage. Piston seals replaced.
	Cycling continued until 1082 RT cycles 8943 cryogenic cycles 10,025 total valve cycles	Actuator with Piston	4-25-74 to 4-29-74			Low temperature life cycle test concluded.
4	High Temperature Life Cycle Cycling continued until 0 High temp cycles 10,039 total cycles (14 room temp cycles)	Actuator with Piston	5-8-74	10,004 cycles at 200^{o}F. with 35 psig valve inlet pressure and 750 psig actuation pressure, 3 sec open and 7 sec closed. Leakage and response tests at 200^{o}F. and room temperature conducted before, during and after cycling. Leakage Tests: With 750 psig actuator pressure "cover" and "close" port leakage measured with valve open for inlet pressure of 0 and 35 psig. With valve open and zero psig actuator pressure "cover", "close" and "open" port leakage measured with 15 psig and 35 psig inlet pressure. With 750 psig actuator pressure "cover" and "open" port leakage measured with valve closed and inlet pressure zero psig and 35 psig. With 750 psig actuator pressure "cover" and "outlet" leakage measured with valve closed and 15 psig and 35 psig inlet pressure. Response Tests: With 750 psig actuator pressure and 35 psig valve inlet pressure measured open-to-close and close-to-open response.	Paragraph 4.4 Tables 4-6 & 4-7 Figures 4-12 thru 4-16 Paragraph 3.3.9	Excessive cover port leakage. Shaft seal replaced.
	Cycling continued until 50 high temp cycles 10,089 total valve cycles	Actuator with Piston	5-10-74		Paragraph 3.3.10	Actuator close time too long. "Open" and "close" port orifices reduced to shorten close time.
	Cycling continued until 6541 high temp cycles 16,580 total valve cycles	Actuator with Piston	5-10-74 to 5-16-74		Paragraph 3.3.11	Excessive "cover" port leakage. Two large seals and one small piston seal replaced.
	Cycling concluded at 10,004 high temp cycles 20,043 total valve cycles	Actuator with Piston	5-20-74 to 5-22-74			High temperature Life Cycle Test concluded.

TEST SUMMARY
LONG LIFE VALVE DEMONSTRATION TESTS

Item	Test	Test Specimen Configuration	Date	Test Conditions	Test Results and Rework: Tables, Figures & Appendices	Remarks
5	Vibration Test Lateral No. 1 Axis Sinusoidal Sweep Closed Valve	Actuator w/Piston	5-28-74 to 6-5-74	"Cover" port and "outlet" port leakage measured before, during and after vibration run; 750 psig actuator pressure, zero psig and 35 psig inlet pressure. Sinusoidal sweep from 5 to 2000 Hz at one octave per minute at the following intensities: Frequency, Hz — Intensity 5 to 20 — 0.4 in. da 20 to 90 — 8.5g peak 90 to 131 — 0.02 in. da 131 to 2000 — 18.2g peak Random vibration over 20 to 2000 Hz for 5 minutes at the following intensities: Frequency, Hz — Intensity 20 to 100 — 9 db/Oct rise 100 to 400 — 1.0g^2/Hz 400 to 630 — 12 db/Oct rolloff 630 to 2000 — 0.15g^2/Hz Overall Acceleration: 25.0 grams	Paragraph 4.5 Table 4-8 thru 4-10 Figure 4-17 to 4-20 Appendix B	Successful run. Resonant points: 95G at 77 Hz, 100 + G at 1800 Hz, 240G at 1400 Hz, 100 + G at 25 Hz, 57G at 390 Hz.
	Sinusoidal Sweep Open Valve	Actuator with Piston				Successful run. Resonant points: 100+G at 1450 Hz, 100+ at 1700 Hz, 200G at 1500 Hz, 89G at 210 Hz, 85G at 285 Hz, 78G at 520 Hz, 73G at 1110 Hz and 62G at 275 Hz.
	Random Vibration Closed Valve	Actuator with Piston			Paragraph 3.3.12	Run stopped after 2 minutes. Mounting bolts sheared and loosened. Mounting flange reworked.
	Sinusoidal Sweep Open Valve (Retest)	Actuator with Piston				Successful run, resonant points: 57G at 1580 Hz, 90G at 1830 Hz, 80G at 1140 Hz, 55G at 950 Hz and 54G at 750 Hz.
	Random Vibration Closed Valve (Retest)	Actuator w/Piston				Successful run.
	Longitudinal No. 1 Axis Sinusoidal Sweep Closed Valve	Actuator with Piston				Sweep stopped at 130 Hz; fixture lifting off slip plate. Test setup revised. Two-inch thick plate added.
	Sinusoidal Sweep Closed Valve (Retest)	Actuator w/Piston				Successful run. Resonant Points: 65G at 180 Hz, 50G at 240 Hz and 59G at 1250 Hz.
	Sinusoidal Sweep Open Valve	Actuator with Piston			Paragraph 3.3.13	Sweep stopped at 350 Hz, excessive leakage through indicator rod hole. Indicator had vibrated loose and blew out. Plug installed.
	Sinusoidal Sweep Open Valve (Retest)	Actuator with Piston				Successful run. Resonant Points: 63G at 215 Hz, 53G at 1420 Hz, 53G at 233 Hz, 100 + G at 134, 41, 33, 29, 23 and 18 Hz, 90G at 1800 Hz, 80G at 1450 Hz and 75G at 1300 Hz.
	Random Vibration Close Valve	Actuator with Piston				Successful run

TEST SUMMARY
LONG LIFE VALVE DEMONSTRATION TESTS

Item	Test	Test Specimen Configuration	Date	Test Conditions	Test Results and Rework: Tables, Figures & Appendices	Remarks
5 (cont.)	Longitudinal No. 2 Axis Sinusoidal Sweep Closed Valve	Actuator with Piston				Successful run. Resonant Points: 100+G at 750 Hz, 67G at 410 Hz, 70G at 1002 Hz, 56G at 920 Hz, 100+G at 1350 Hz, 95G at 730 Hz, 75G at 470 Hz and 68G at 920 Hz.
	Sinusoidal Sweep Open Valve	Actuator with Piston				Successful run. Resonant Points: 70G at 1050 Hz, 100+ G at 1300, 1100, 730 and 490 Hz, 92G at 340 Hz, 96G at 320 Hz, 97G at 240 Hz, 66G at 165 Hz, and 75G at 122 Hz.
	Random Vibration Closed Valve	Actuator w/Piston				Successful run.
6	Flow Capacity	Actuator with Piston	6-12-74	With 750 psig to close actuator port and ullage pressurized to 35 psig, the close port was vented and the open port pressurized to 750 psig. Inlet, outlet and nozzle pressures were recorded during blow down. Flow and valve ΔP were computed at 10 valve inlet pressures.	Paragraph 4.9 Table 4-11 Figures 4-21, 4-22 and 4-23	See table below
7	Nondestructive Burst 750 psig to close port	Actuator w/Piston	6-28-74	750 psig to close port, then 87.5 psig slowly applied to valve inlet and held for 5 minutes.	Paragraph 4.9 Figure 4-24	No sign of distortion.
	750 psig to open port	Actuator w/Piston		750 psig to open port, then 87.5 psig slowly applied to valve inlet and held for 5 minutes.		No sign of distortion.
	1875 psig to open port	Actuator w/Piston		With water compressed into actuator ports, 1875 psig to open port and held for 5 mins.		No sign of distortion.
	1875 psig to close port	Actuator w/Piston		With water compressed into actuator ports, 1875 psig to close port and held for 5 mins.		No sign of distortion.
8	Final Disassembly and Inspection	Actuator with Piston	6-28-74 to 7-16-74	Disassembly of valve and actuator assemblies and inspection for signs of distortion or excessive wear. Re-measure component dimensions and finishes recorded during Examination of Product (Item 1).	Paragraph 4.10 Table 4-1 Figures 4-25 thru 4-33	Normal wear and contamination. Weight: 53 pounds.

Item 6 Remarks:

Total Inlet Press. PSIG	Flow SCFM Air	Press. Drop PSIG	Outlet Mach No.	Resistance Coefficient K
31.37	24,040	15.5	0.460	4.65
30.04	23,500	14.1	0.460	4.31
28.38	22,384	13.0	0.445	4.45
26.74	21,000	12.2	0.423	4.77
26.06	20,510	11.2	0.435	4.24
24.85	19,580	10.1	0.425	4.12
24.23	18,984	9.2	0.428	3.72
23.23	17,980	8.0	0.400	3.79
22.58	17,512	7.6	0.405	3.58
22.42	17,312	7.2	0.400	3.46

SECTION 3

TEST SPECIMEN

This section presents a description of the test specimen and follows the changes and rework of the unit throughout the test program. A summary of the component cycle life and rework is presented in Table 3-1.

3.1 TEST SPECIMEN DESCRIPTION

The test specimen at the start of the test program was a 10-inch hybrid poppet butterfly valve, P/N 99600, conforming to Assembly Drawing 996001, Revision B. Valve actuation was provided by a bellows type pneumatic actuator. Drawing 996001 is included in Appendix A of this report. A photograph of the test specimen is presented in Figure 3-1. The valve poppet and actuation linkage are shown in Figure 3-2. This reference illustrates the initial poppet translation which eliminates the seal scrubbing and the final rotation which reduces the pressure drop.

3.2 BELLOWS REPLACEMENT AFTER INITIAL TESTING

Bellows leakage occurred during the initial testing prior to the demonstration test. The test specimen was disassembled and the outer bellows, P/N 966057-1, was removed and checked for leakage. No leakage across the bellows was found; however, after being pressurized and submerged in alcohol,bubbles were seen at the end fitting indicating a leak in one or two of the plys. The test specimen was reassembled with a spare bellows and sent to the laboratory for the start of demonstration testing.

3.3 HARDWARE CHANGES DURING DEMONSTRATION TESTING

3.3.1 Change to Piston Type Actuator Assembly

After 696 combined room temperature and cryogenic cycles, the leakage of the outer actuator bellows, P/N 966057-1, was excessive. The bellows was sent to the vendor for failure analysis. The failure analysis indicated that the present unit was incorrectly designed to meet the 20,000 cycle objective. A newly designed bellows would require new actuator components as well as the revision of the actuator link and support. The decision was made to use a piston type actuator. A further discussion is presented in Section 5 of this report. A copy of the failure analysis report is included in Appendix B herein.

Table 3-1. Component Cycle Life and Rework Summary

Components	Part Number	Accumulated Cycles			
		Room Temp	Cryo Temp	High Temp	Total
Main Seal	966072				
Original Seal		223	2255	0	2,478
Replacement Seal		793	3640	0	4,433
Refinished Seal		80	3048	10,004	13,132
Total (Refinished Replacement Seal)		873	6688	10,004	17,565
Shaft Seal	966076				
Original		1096	8943	0	10,039
Replacement		0	0	10,004	10,004
Actuator Piston Seals					
Original - Upper	AR10105-234 A/H	33	41	0	74
- Lower	AR10105-234 P/H	208	1575	0	1,783
- Small	AR10105-222 P/Q	208	1575	0	1,783
1st Replacement - Upper	AR10105-234 A/H	996	5175	0	6,171
- Lower	AR10105-234 P/H	821	3641	0	4,462
- Small	AR10105-222 P/Q	821	3641	0	4,462
2nd Replacement - Upper	AR10105-234 A/H	52	3046	6,541	9,639
- Lower	AR10105-234 P/H	52	3046	6,541	9,639
- Small	AR10105-222 P/Q	52	3046	6,541	9,639
3rd Replacement - Upper	AR10105-234 A/H	0	0	3,463	3,463
- Lower	AR10105-234 P/H	0	0	3,463	3,463
- Small	AR10105-222 A/Q	0	0	3,463	3,463
Link, Act. Pivot	966046				
Original		231	5895	0	6,126
Replacement		770	3048	10,004	13,917
Kel-F Stop (Added)	–	1048	8221	10,004	19,273
Filler (Added)	–	873	6687	10,004	17,564
Piston Venting (Additional)	–	929	8171	10,004	19,104

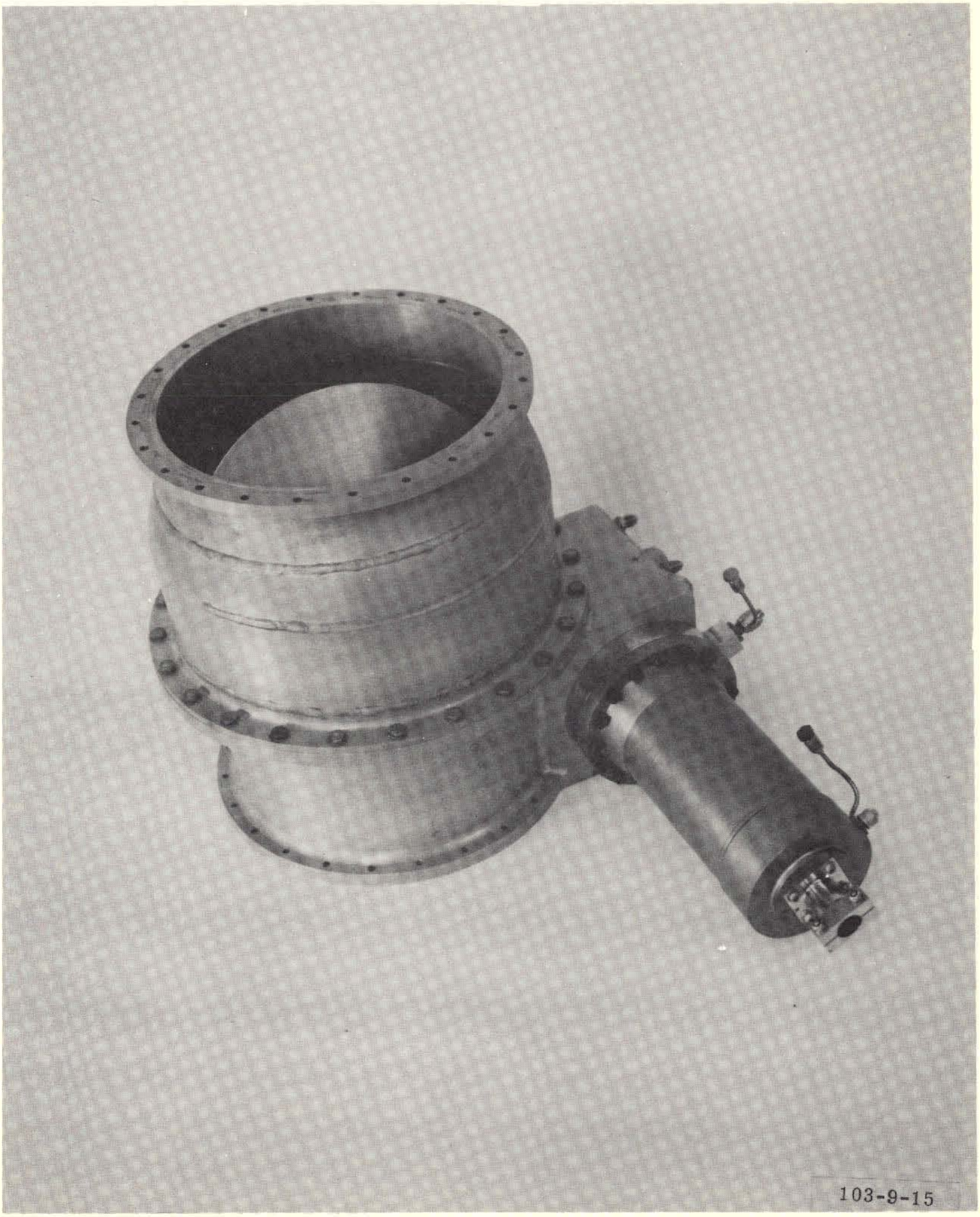

Figure 3-1. Test Specimen, 10-Inch Long Life Valve

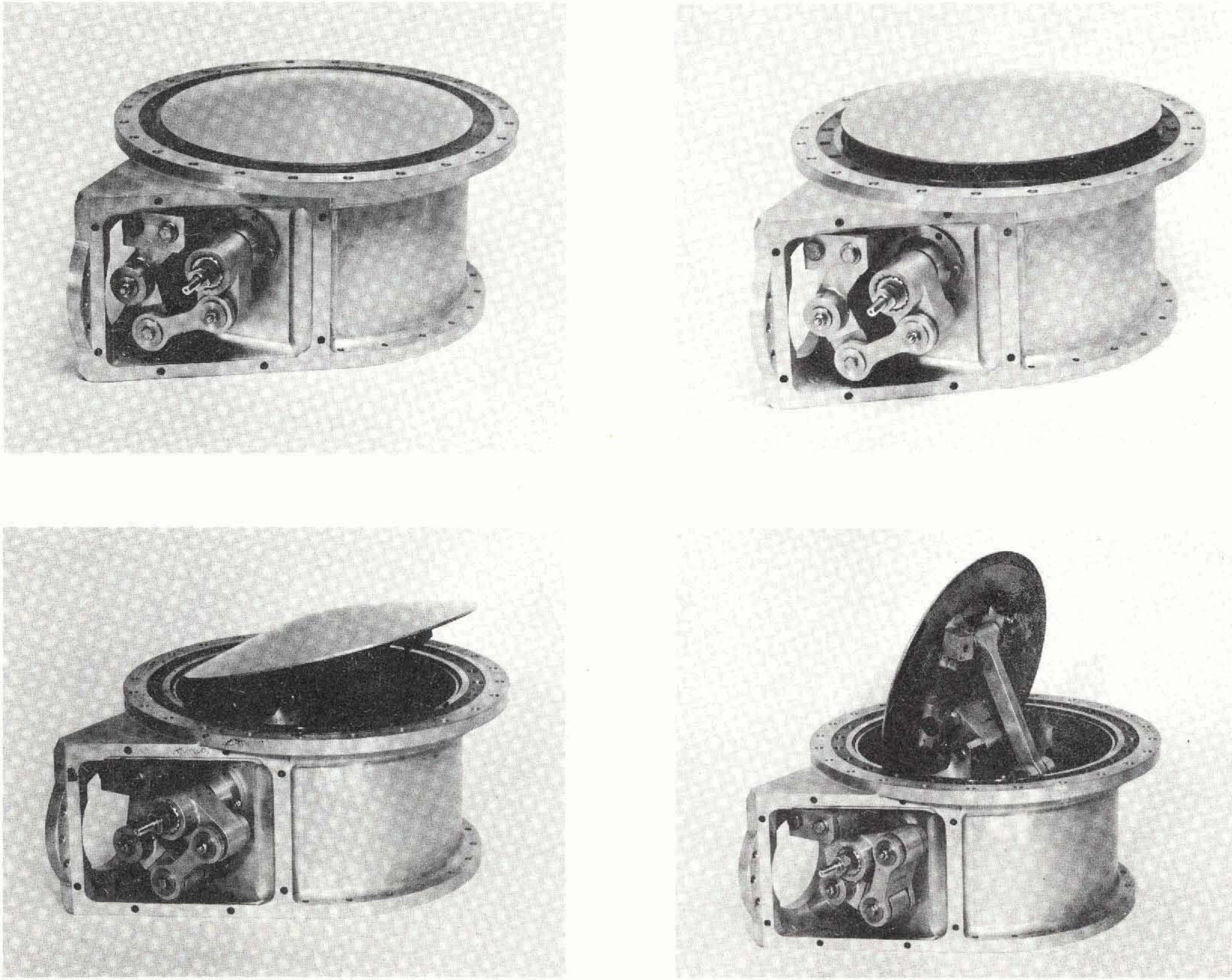

Figure 3-2. Valve Poppet and Actuator Linkage Positions

3.3.2 Description of Piston Type Actuator Assembly

A cross sectional view of the new piston type actuator assembly, P/N 966096, is shown in Figure 3-3. The various components are identified in the view. A material summary is presented in Table 3-2 which includes the part number, nomenclature, material and specification.

3.3.3 Seal Replacement and Stop Addition After 770 Cycles

The actuator was disassembled after 770 combined room temperature and cryogenic valve cycles during the low temperature life cycle test. The test specimen had exhibited excessive actuator leakage under cryogenic conditions. Inspection of the actuator revealed heavy deposits of contamination around the piston seals, Omniseal P/N AR10105-234. The contamination prevented the normally uniform contact between the cylinder and the seal. The contamination originated from the test system regenerator packing and would be eliminated by installing a 10-micron filter at each of the actuator ports. The upper actuator seal, Omniseal P/N AR10105-234, was replaced.

Inspection of the actuation linkage showed a heavy contact marking on both the actuator pivot link, P/N 966046, and the driver link, P/N 966047. These links provided the "open" actuator stop for the valve. To remedy this situation a Kel-F stop disk was added to the piston. The "open" stop was now on the actuator sleeve assembly, P/N 966085. The stop disk installation is shown in Figure 3-4.

3.3.4 Additional Piston Venting After 939 Cycles

The actuator was disassembled after 939 combined cycles. Occasionally high actuator leakage was indicative of erratic seal performance. The actuator piston assembly was designed with vent ports in the piston bearing, P/N 966093, to vent the large diameter piston seals, Omniseal P/N AR10105-234, to the actuator linkage cavity. This provided a means for measuring seal leakage. If sufficient seal leakage existed the small clearances between the bearing and the sleeve prevented adequate venting, resulting in pressure buildup downstream of the active seal. This in turn would reduce the pressure energization of the seal.

Additional vent holes were provided in the bearing, P/N 966093, and an annular vent path was added to the piston, P/N 966090. Subsequent tests demonstrated that these modifications eliminated the erratic seal operation.

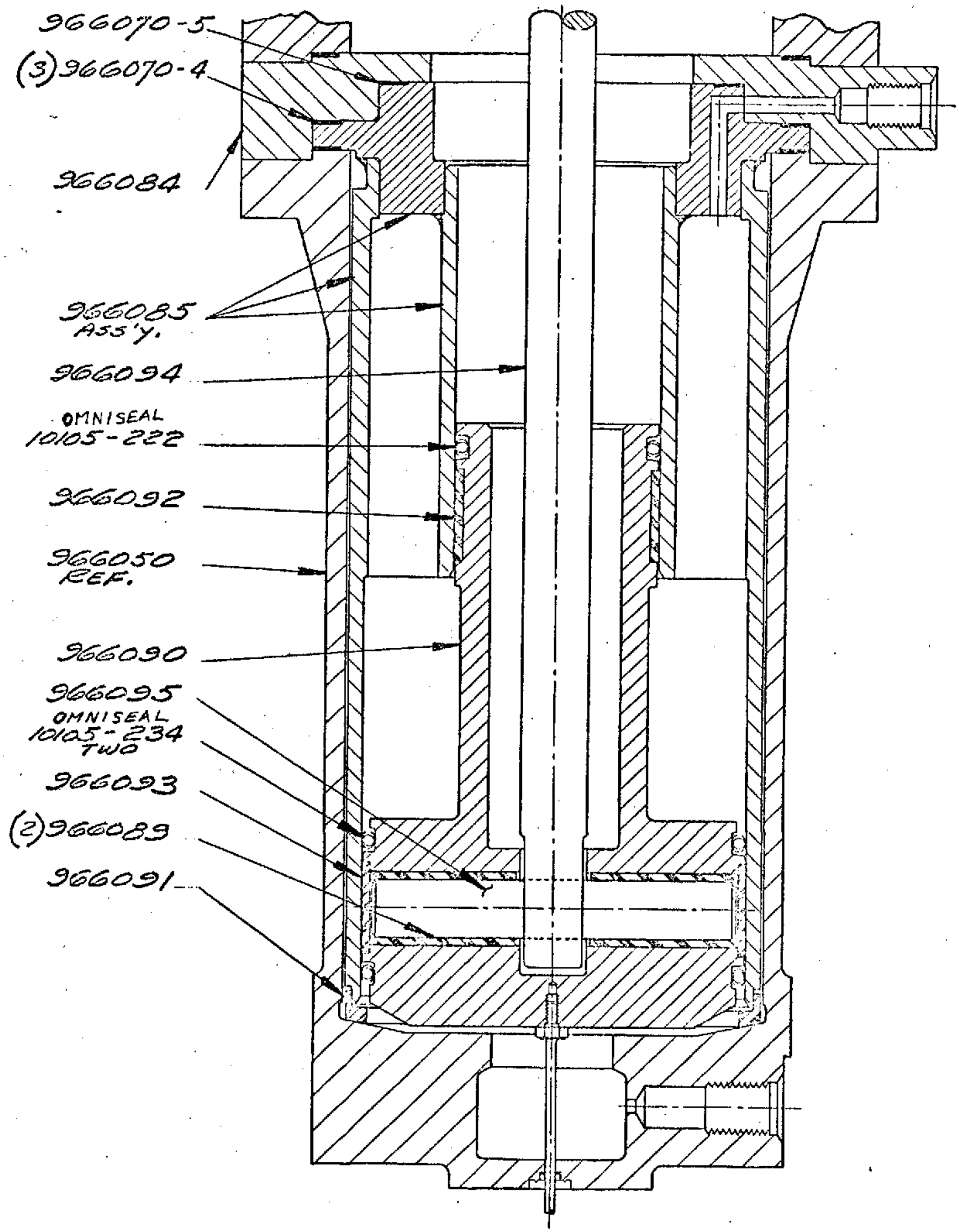

Figure 3-3. Cross Sectional View
Piston Actuator Assembly 966096

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STRATOS DIVISION
1800 ROSECRANS AVENUE
MANHATTAN BEACH, CALIF. 90266

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Table 3-2. New and Reworked Components and Assemblies for Test Specimen with Piston Type Actuator Assembly

Part Number	Nomenclature	Material	Specification
966084	Manifold (Rework 996061)	304L CRES	QQ-S-763
966086	Mount - Sleeve	321 CRES	QQ-S-763
966087	Sleeve - Outer	321 CRES	AMS 5645
966088	Sleeve - Inner	321 CRES	AMS 5645
966070-4	Seal - Face	TFE Teflon	AMS 3651
966070-5	Seal - Face	TFE Teflon	AMS 3651
966085	Sleeve Assembly	-	-
966089	Braking	SP211 Polyimide	-
966090	Piston	6061-T6 Al Aly	QQ-A-22518
966091	Snubber	TFE Teflon	AMS 3651
966092	Guide, Inner	SP211 Polyimide	-
966093	Guide, Outer	SP211 Polyimide	-
966094	Rod	A-286 CRES	AMS 5736
966095	Shaft	A-286 CRES	-
966096	Assembly - Actuator	-	-
AR10105-222 P/Q	Omniseal	Spring: 304 CRES	AMS 5528
		Cover: 80% Virgin TFE	-
		15% Glass	-
		5% Moly Disulphide	-
AR10105-234 A/H	Omniseal	Spring: 17-7PH CRES	AMS 5528
		Cover: TFE (Molded)	ASTM D1457 Type IV
AR10105-234 P/Q	Omniseal	Spring: 17-7PH CRES	AMS 5528
		Cover: 80% Virgin TFE	-
		15% Glass	-
		5% Moly Disulphide	

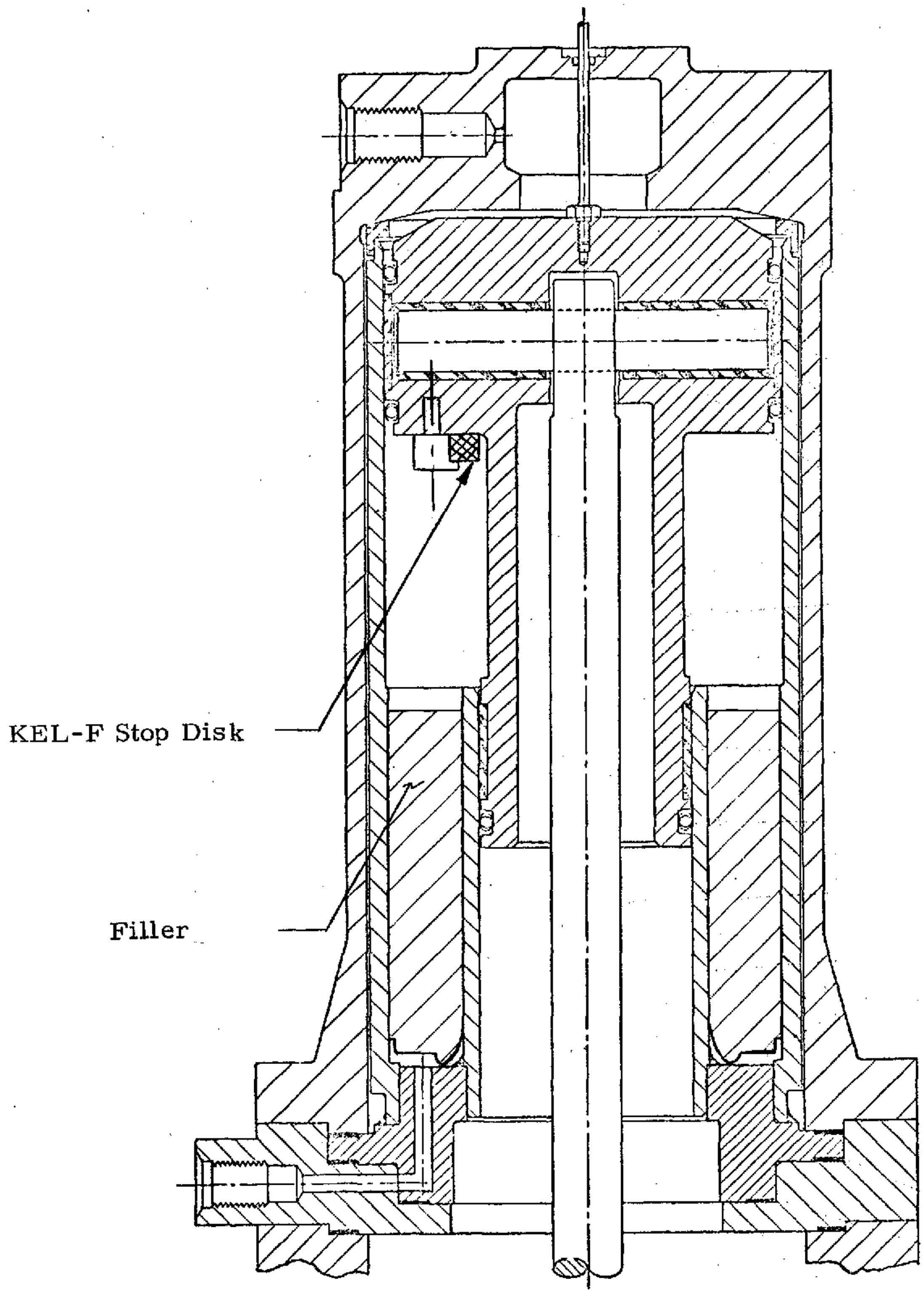


Figure 3-4. Cross Sectional View of Rework Piston Actuator Assembly 966096

3.3.5 Seal Replacement and Filler Addition After 2478 Cycles

Excessive valve and actuator leakage occurred after 2478 combined cycles. Inspection of the main seal seat, P/N 966072, showed that two areas of the sealing surface had broken away. A third area probably representative of the failure mechanism showed a curving crack across the sealing surface which, if it continued, would result in the spall-out of a small section of the seal.

To prevent this from occuring again a cylindrical filler was incorporated in the actuator sleeve assembly, P/N 966085, to minimize the "close" cylinder clearance volume. This permitted better control of the closing transient and reduced the poppet-seat impact. The filler is shown in Figure 3-4.

Testing was resumed after replacement of the valve seal seat, P/N 966072, and two actuator piston seals, Omniseal P/N AR10105-222 and AR10105-234.

3.3.6 Link Redesign After 6126 Cycles

The actuation link, P/N 96046, failed after a total of 6126 combined cycles. Inspection of the link revealed the break to be a typical fatigue frature at the most highly stressed area of the link. This area had received damage during earlier cycling due to the "open" stop action prior to installation of the Kel-F stop disk mentioned earlier. A photograph of the fractured link is presented in Figure 3-5.

The link was redesigned with increased sections in the critical area. The test specimen was reassembled and the cycling was continued.

3.3.7 Main Seal Refinished After 6911 Cycles

The test specimen was removed from the test setup for main seal inspection after 6911 combined cycles. The new main seal, P/N 966072, did not meet the low leakage levels of the original seal installation. Since the seal leakage was not reduced by increased cycling, the valve was removed for inspection. A bruised area of the seal face, approximately 0.002 deep and 0.040 long was identified. The cause of the damage was unknown. The main seal, P/N 966072 was refinished by removing 0.003 from the surface and was reassembled with the test specimen.

3.3.8 Actuator Seal Replacement After 6941 Cycles

The three actuator seals were replaced after 6941 combined room temperature and cryogenic valve cycles during the low temperature life cycle test.

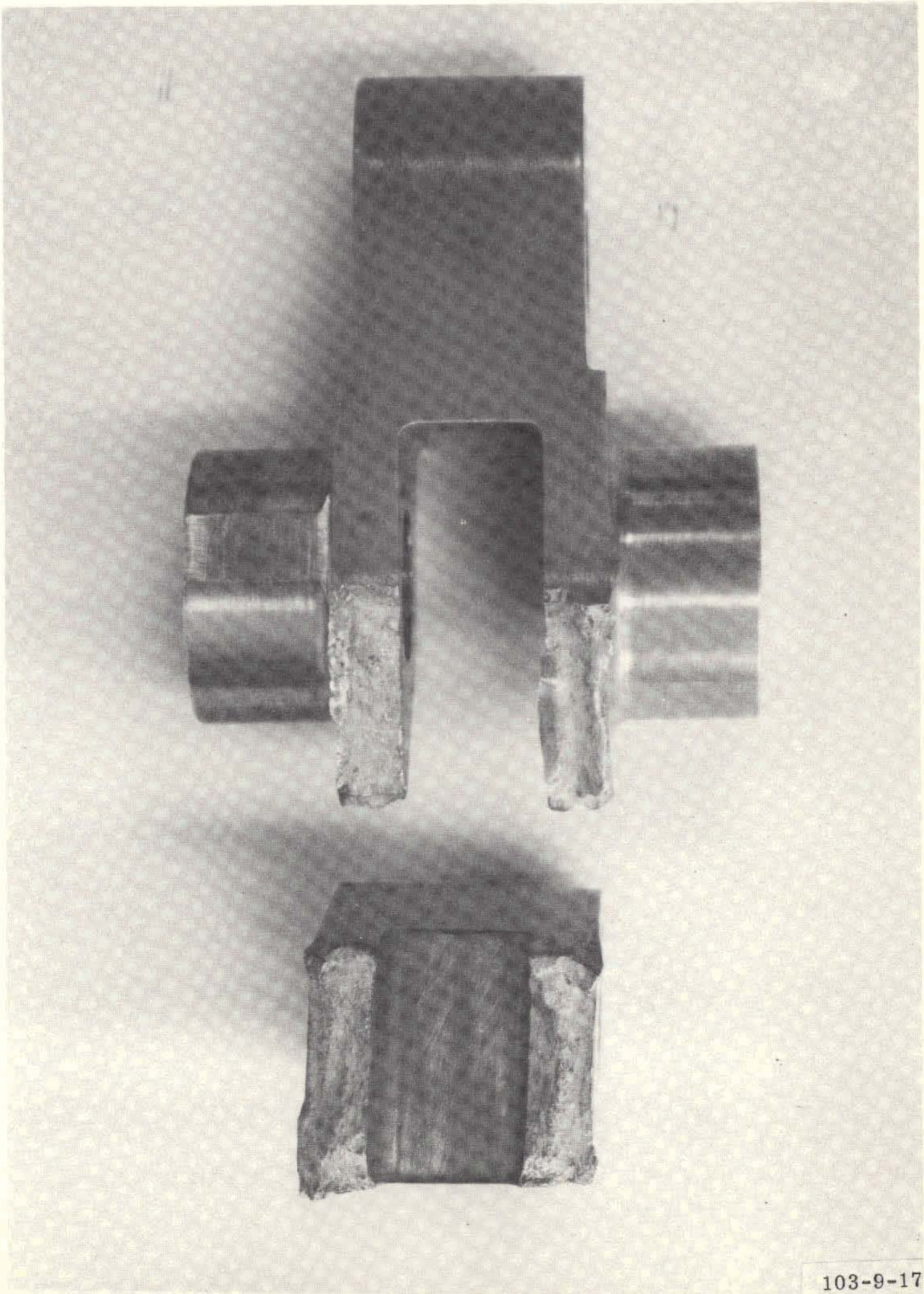


Figure 3-5. Failed Link, P/N 96046
During Low Temperature Life Test

3.3.9 Shaft Seal Replacement After 10,025 Cycles

During the high temperature life cycle test, after 10,025 total valve cycles, excessive cover port leakage was measured. This was attributed to a leaking shaft seal. The lip seal, P/N 966076, was replaced.

3.3.10 Orifice Resizing After 10,089 Cycles

After 10,089 total cycles the orifices, P/N 966073, in the "open" and "close" actuator ports were modified. The inside diameters of the "open" port and "close" port orifices were changed to 0.062 inch and 0.070 inch respectively. The modification was necessary to reduce the valve closing time.

3.3.11 Actuator Seals Replaced After 16,580 Cycles

After 16,580 total cycles the cover port leakage was excessive. The actuator was disassembled, and the two large diameter piston seals, P/N 10105-234 and the small diameter piston seal, P/N 10105-222 were replaced. The test specimen was then subjected to further high temperature cycling.

3.3.12 Mounting Flange Reworked During Lateral No. 1 Axis Vibration Test

During the random vibration in the Lateral No. 1 Axis, four mounting screws were sheared and nine additional screws were loosened. There was no damage to the valve or the actuator components.

An investigation showed that the locking capabilities of a number of the locking inserts as measured by the running torque with new screws had deteriorated. This may be due to the many times the screws had been removed and reinstalled during previous testing. The worn inserts were replaced, and all of the mounting screws were replaced.

The vibration levels at the end of the actuator were inspected. These output levels were found to be excessive. This was particularly due to the crosstalk caused by the unbalance in the valve and fixture about the axis of the shaker. A support clamp added between the actuator and the fixture reduced the actuator response to 60 "g" peak.

3.3.13 Potentiometer Removal During Longitudinal No. 1 Axis Vibration Test

During the sinusoidal vibration sweep in the Longitudinal No. 1 Axis with the valve in the open position, the stroke indicator rod from the potentiometer vibrated loose (unscrewed) and blew out. The potentiometer holding flange was removed. The transducer was damaged, and the indicator rod was bent. A plug was made to fit the rod hole in the actuator, and the plug was installed in place of the rod. The plug was held in place by the flange which held the potentiometer. The damaged stroke indicator is shown photographically in Figure 3-6.

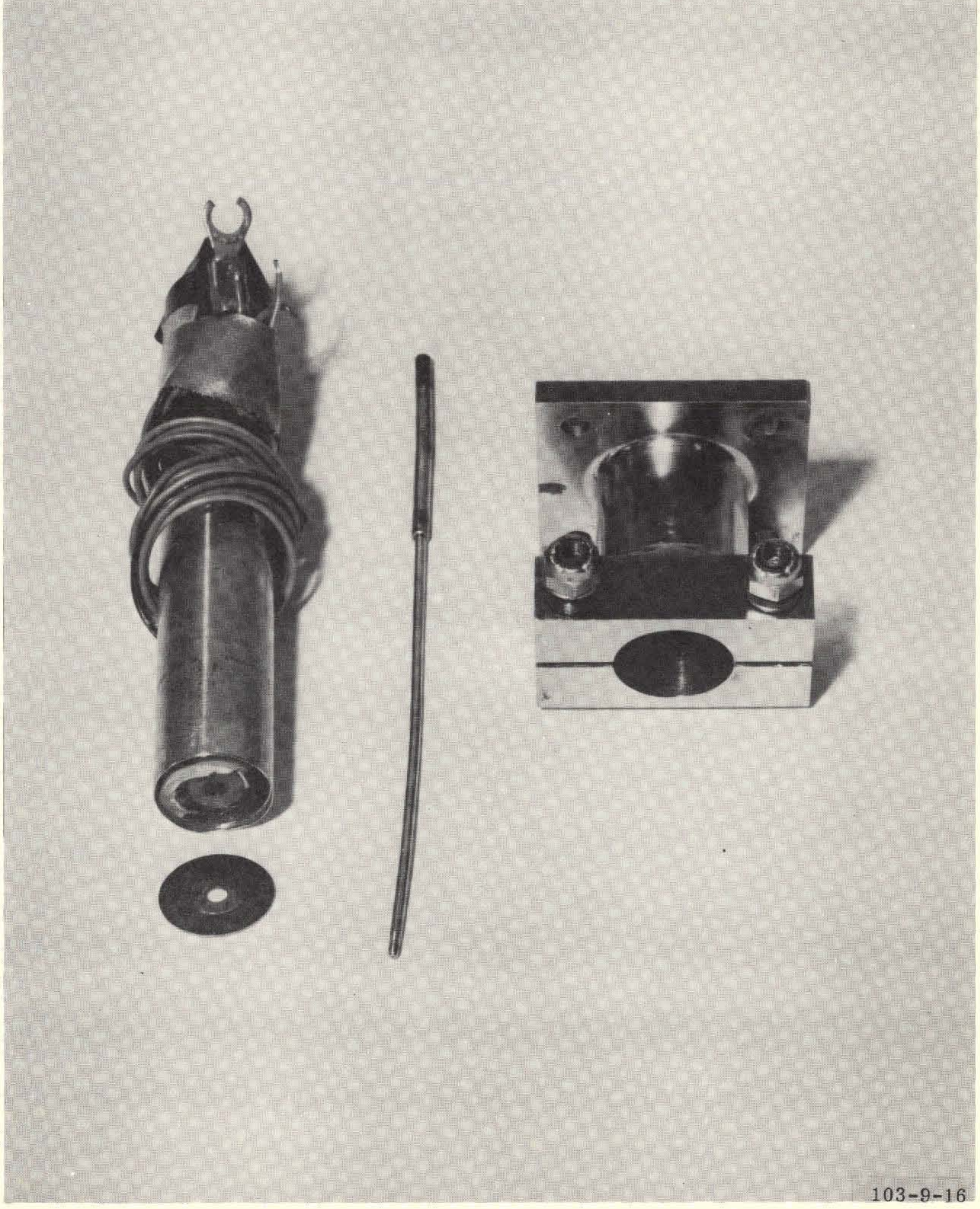


Figure 3-6. Damaged Stroke Indicator Removed from Test Specimen During Sinusoidal Sweep in Longitudinal No. 1 Axis

SECTION 4

TEST SETUPS, PROCEDURES AND RESULTS

4.1 EXAMINATION OF PRODUCT

Prior to the assembly of the test specimen all detail parts were inspected for workmanship, general quality, and cleanliness. The diameters and surfaces of all bearings and associated shafts, dynamic seals and mating surfaces were measured and recorded. All details were found to be satisfactory for their intended use. The results of these measurements, and those taken during final teardown, are presented in Table 4-1. The weight of the test specimen was 54.0 pounds.

4.2 INITIAL TESTING

The initial testing of the test specimen prior to demonstration testing included the measurement of valve and actuator internal leakage. The valve leakage was measured with the inlet pressure varied from zero to 35 psig in 5 psig increments, and the actuation pressure varied from zero to 750 psig in 100 psig increments. The pressurizing fluid was gaseous nitrogen. The results are shown in Figure 4-1. The pre-seal leakage was equivalent to an orifice of 0.0007 square inches. Poppet differential pressure above 20 psi was sufficient to engage the poppet seal. The leakage at this point appeared as a fixed orifice of 10^{-6} square inches. Application of the "close" actuation pressure had insignificant affect on the leakage rate.

The main seal was checked to determine if the leakage was caused by a local seal defect. The valve was inverted and partially filled with alcohol. Leakage was observed around the periphery of the poppet which indicated a surface finish or surface porosity phenomena and not a localized defect.

During the actuation cycling, there was prolonged leakage from the "close" actuator port. This was an indication of bellows leakage. Testing was stopped, and the test specimen was disassembled and inspected. See Section 5 for a further discussion.

Table 4-1. Component Wear Data

Part Number	Component Nomenclature	Dimension Measured	Measured Valve Examination of Product	 Disassembly and Inspection	Wear (Dimensional Change)
966034	Link No. 2	Bushing No. 1	.5043 .5078	.5050 .5060 to .5080	+0.0007 -0.0018 to +0.0002
		Bushing No. 2	.5058 .5062	.5058 .5062	0.0000 0.0000
		Bushing No. 3	- -	.7503 .7502	- -
966035-1	Sleeve Bearing	Outside Diameter	.5002	.5002	0.0000
966035-2	Sleeve Bearing	Outside Diameter	.7498 .7497	.7495 .7498	-0.0003 +0.0001
966035-3	Sleeve Bearing	Outside Diameter	.5001 .5002	- -	- -
966035-4	Sleeve Bearing	Outside Diameter	.5003 .5002	.5000 .5001	-0.0003 -0.0001
966035-5	Sleeve Bearing	Outside Diameter	.4993	.4993	0.0000
966037	Link No. 1	Inside Diameter	.509 ± .001	.5010 .5030	- -
966040	Lip Seal Retainer	Bushing I.D.	1.1134	1.1090 1.1087	-0.0044 -
		Shaft	- -	1.1055 1.1058	- -
966044	Poppet Link Pivot	Bushing No. 1	.5047 .5050	.5050 .5053	+0.0003 +0.0003

Table 4-1. Component Wear Data (Continued)

Part Number	Component Nomenclature	Dimension Measured	Measured Valve		Wear (Dimensional Change)
			Examination of Product	Disassembly and Inspection	
966044 (Cont)	Poppet Link Pivot (Cont)	Bushing No. 2	.5047	.5047	0.0000
			.5056	.5056	0.0000
		Bushing No. 3	.5057	.5060	+0.0003
				.5057	0.0000
		Bushing No. 4	.5045	.5046	+0.0001
			.5056	.5056	0.0000
		Shaft	-	.5000	-
966045	Link No. 3	Bushing I.D.	-	.7520	-
			-	.7532	-
966046	Link Actuator Pivot	Bushing No. 1	.5043	.5060	+0.0017
			.5046	.5057	+0.0011
		Bushing No. 2	.5046	.5057	+0.0011
			.5051	.5060	+0.0009
		Bushing No. 3	.5055	.5060	+0.0005
			.5095	.5062	0.0000
		Bushing No. 4	.5052	.5060	+0.0008
			.5082	.5062	-0.0020
		Bushing No. 5	.7549	.7550	+0.0001
			.7558	.7568	+0.0010
		Bushing No. 6	.7546	.7550	+0.0004
			.7558	.7568	+0.0010
966047	Drive Actuator	Bushing No. 1	.7547	.7550	+0.0003
			.7551	.7555	+0.0004
		Bushing No. 2	.7557	.7557	0.0000
			.7562	.7580-.7575	+0.0018- +0.0013

Table 4-1. Component Wear Data (Continued)

Part Number	Component Nomenclature	Dimension Measured	Measured Valve Examination of Product	Measured Valve Disassembly and Inspection	Wear (Dimensional Change)
966048	Drive Poppet	Bushing No. 1	.5043 .5056	.5043 .5056	0.0000 0.0000
		Bushing No. 2	.5045 .5050	.5050 .5058	+0.0005 +0.0008
		Bushing No. 3	.7556 .7558	.7556 .7559	0.0000 +0.0001
		Bushing No. 4	.7551 .7554	.7551 .7556	0.0000 +0.0002
966062	Adjustable Poppet Shaft	Outside Diameter	.4998	.4997	-0.0001
966076	Lip Seal	Inside Diameter	1.240	.1245	+0.0005
966067	Torsion Shaft	$750^{+.000}_{-.001}$ OD	.7485 .7481 16	.7480 .7479 8	-0.0005 -0.0002 8
		$1.0460^{+.000}_{-.001}$ OD	1.0439 16	1.0439 4	12
		1.156 ± .010 OD	1.1536	1.1535 1.1537	-0.0001 +0.0002
		$1.250^{+.000}_{-.001}$ OD	1.2478 1.2480 4	1.2478 1.2480 3	+0.0001 +0.0001 1
		.210 ± .005 OD	.210		
		$1.108^{+.008}_{-.001}$ OD	1.1055 1.1058 16	1.1055 1.1058 8	0.0000 0.0000 8
966001	Valve Assembly	Weight	–	53 lb 11 oz	–

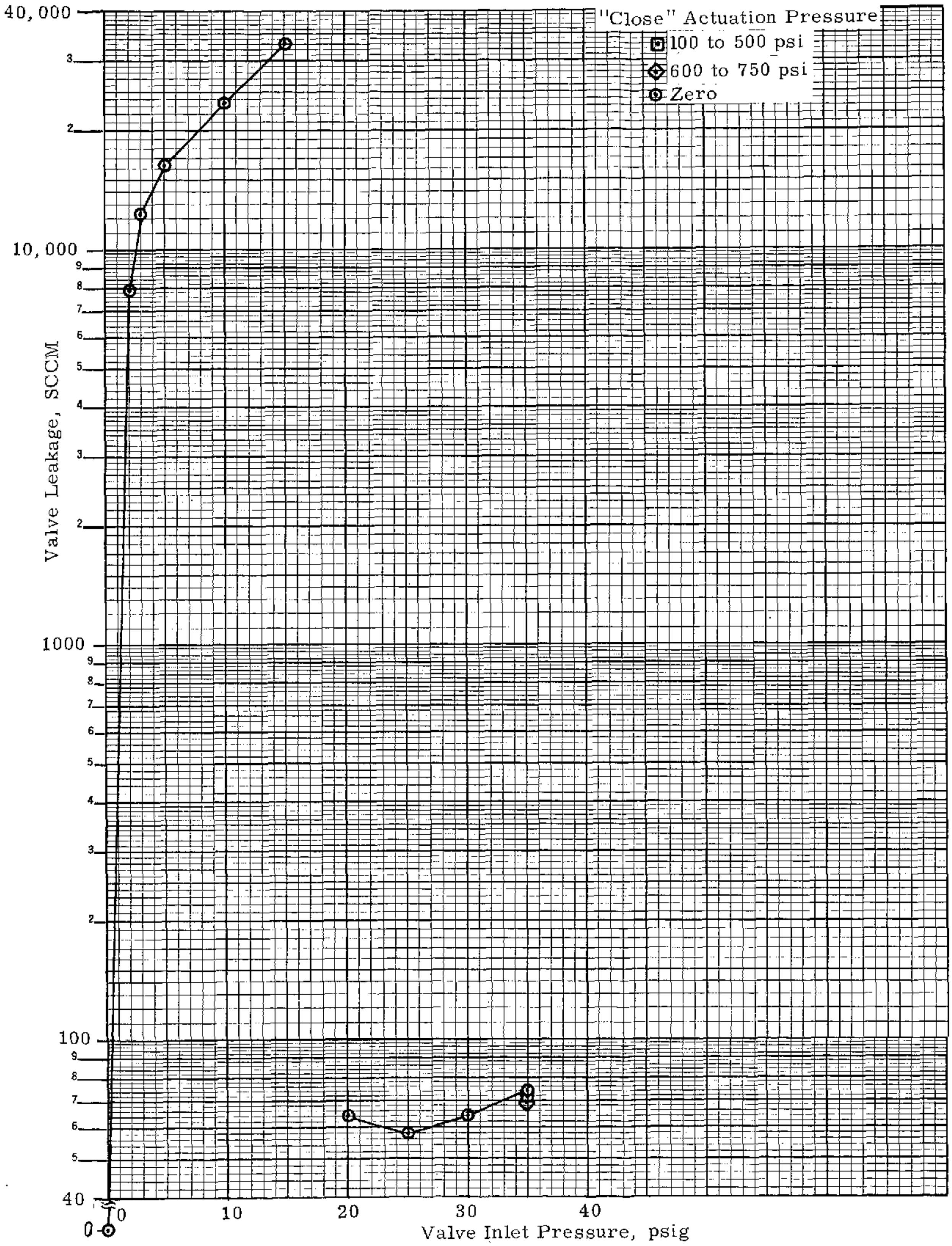


Figure 4-1. Valve Leakage During Initial Testing Bellows Type Actuator Assembly

4.3 LOW TEMPERATURE LIFE CYCLE TEST

The low temperature life cycle test consisted of 10,025 valve cycles at room and cryogenic (approximately -200°F) temperatures. The test setup for the low temperature life cycling including the leakage and response testing is shown schematically in Figure 4-2 and photographically in Figures 4-3, 4-4, and 4-5. The test specimen was changed from a bellows type actuator to a piston type actuator after 696 valve cycles.

4.3.1 Leakage and Response Testing

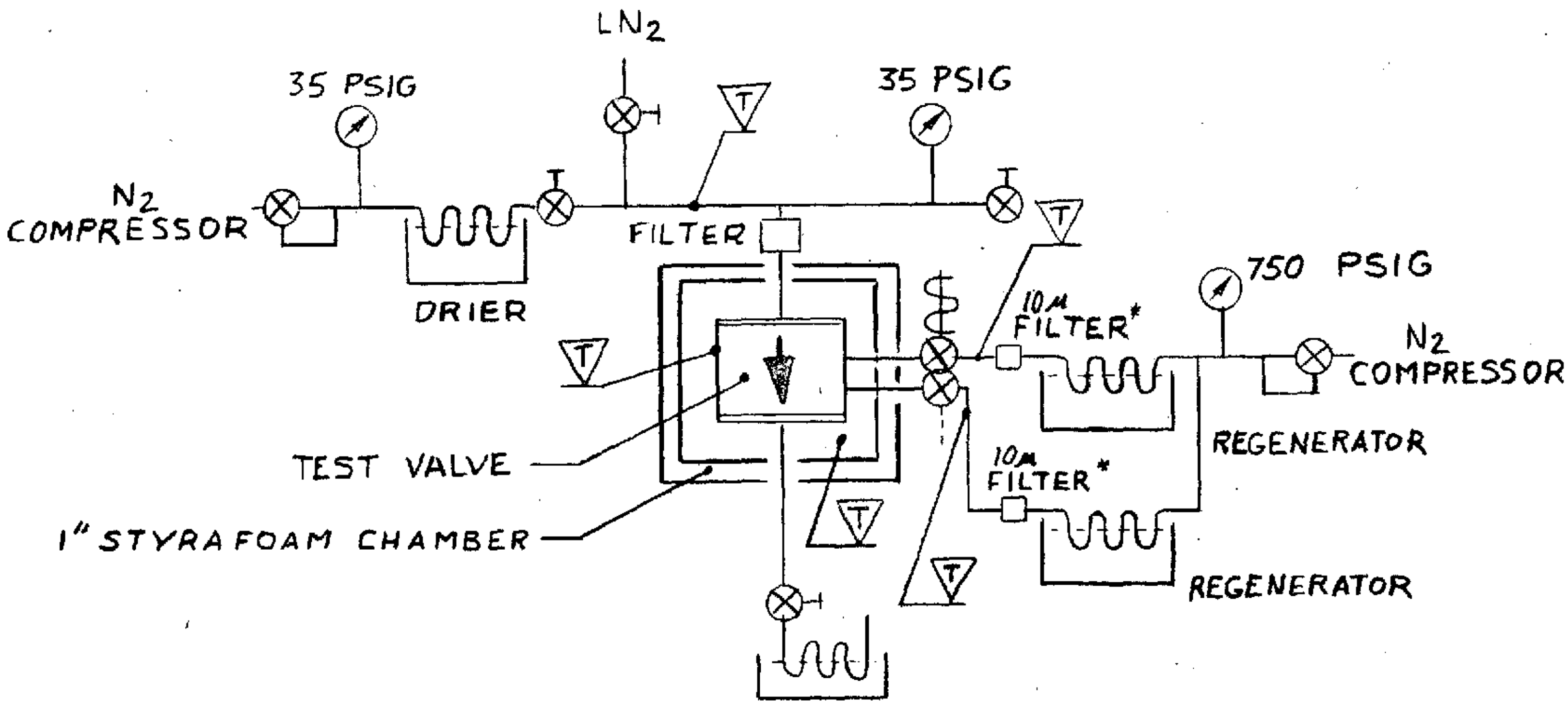
Before, during and after the life cycling the test specimen was subjected to leakage and response tests at room temperature, minus 200°F, and minus 300°F to check the performance of the unit and individual components. The component leakages (main seal, shaft seal, "open" actuator port, and "closed" actuator port) are presented in Table 4-2 and Table 4-3. The main seal and shaft seal leakages are presented graphically in Figures 4-6 and 4-7, respectively. Also included on these graphs are the main seal and shaft seal leakages for the high temperature tests which are described in paragraph 4.4. The response times are presented in Tables 4-4 and 4-5. The component leakages were determined from the data recorded during the leakage and response testing. The component leakages are identified by date, cycle history and temperature. In general the room temperature leakage and response tests were conducted at the start of each day's testing and the cryogenic leakage and response tests were conducted at the end of the day's testing. The response tests were conducted at more frequent intervals as is indicated by the cycle history. The methods of determining the component leakages from the test data are discussed in paragraph 4.3.2. The procedures used for conducting the leakage and response tests are discussed in paragraphs 4.3.1.1 and 4.3.1.2, respectively.

4.3.1.1 Leakage Tests

The leakage tests were conducted with the test specimen installed in the low temperature life cycle test setup shown in Figures 4-2 through 4-5. Gaseous nitrogen was used to pressurize the actuator and the poppet valve inlet. The leakage test procedures for the test specimen with the bellows type actuator were modified for the majority of testing for the test specimen with the piston type actuator assembly.

The procedure for testing the test specimen with the piston type actuator assembly is as follows:

a. The "open" actuator port was pressurized to 750 psig with zero psig applied to the valve inlet. The cover port and the "closed" actuator leakages were measured. The inlet pressure was increased to 35 psig and the cover and "close" port leakages were measured.



* 10µ filters added after 770 accumulated valve cycles.

Figure 4-2. Schematic Diagram, Low Temperature Life Cycle Test Setup

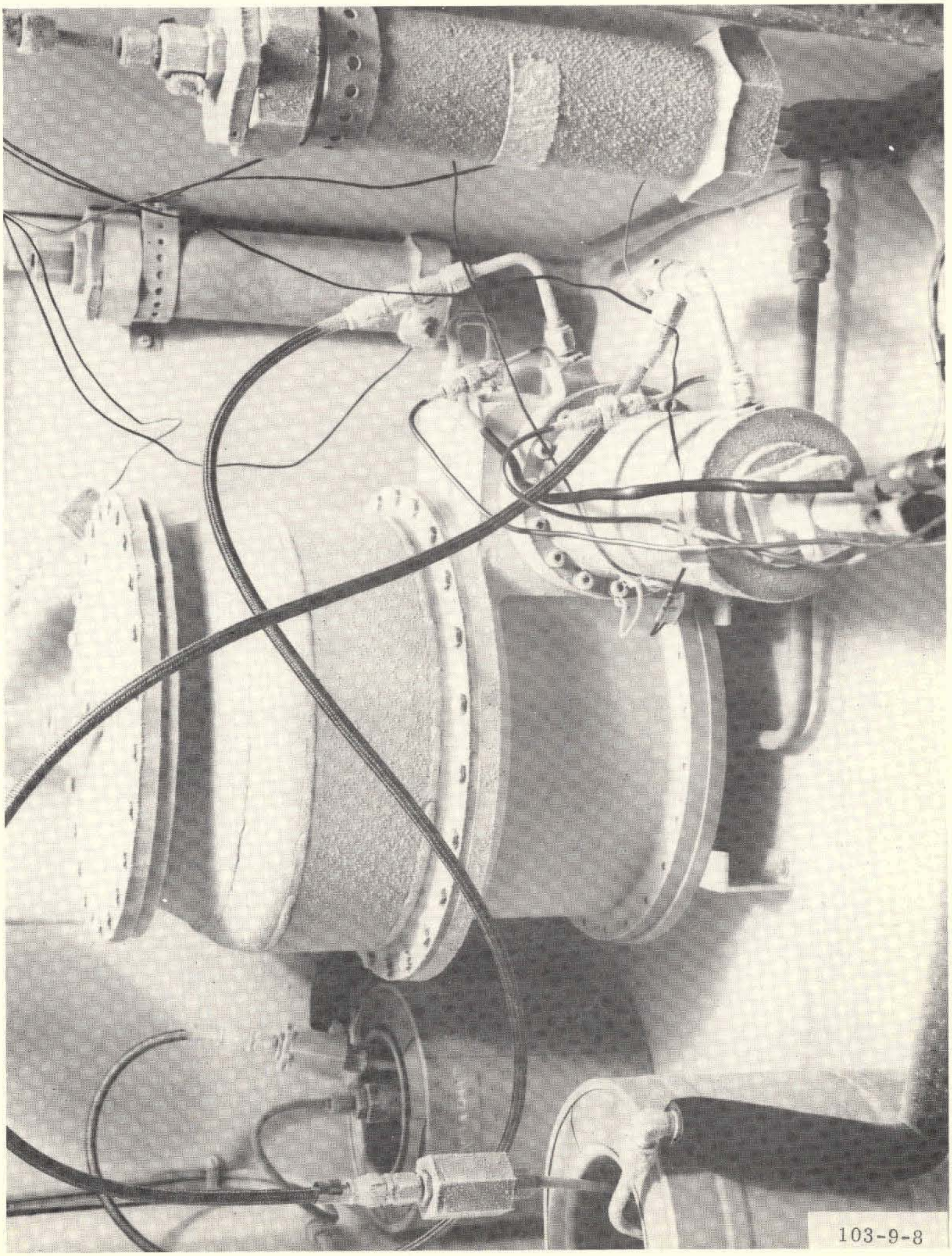


Figure 4-3. Test Setup, Low Temperature Life Cycle (Chamber Cover Removed), Test Specimen at Cryogenic Temperature

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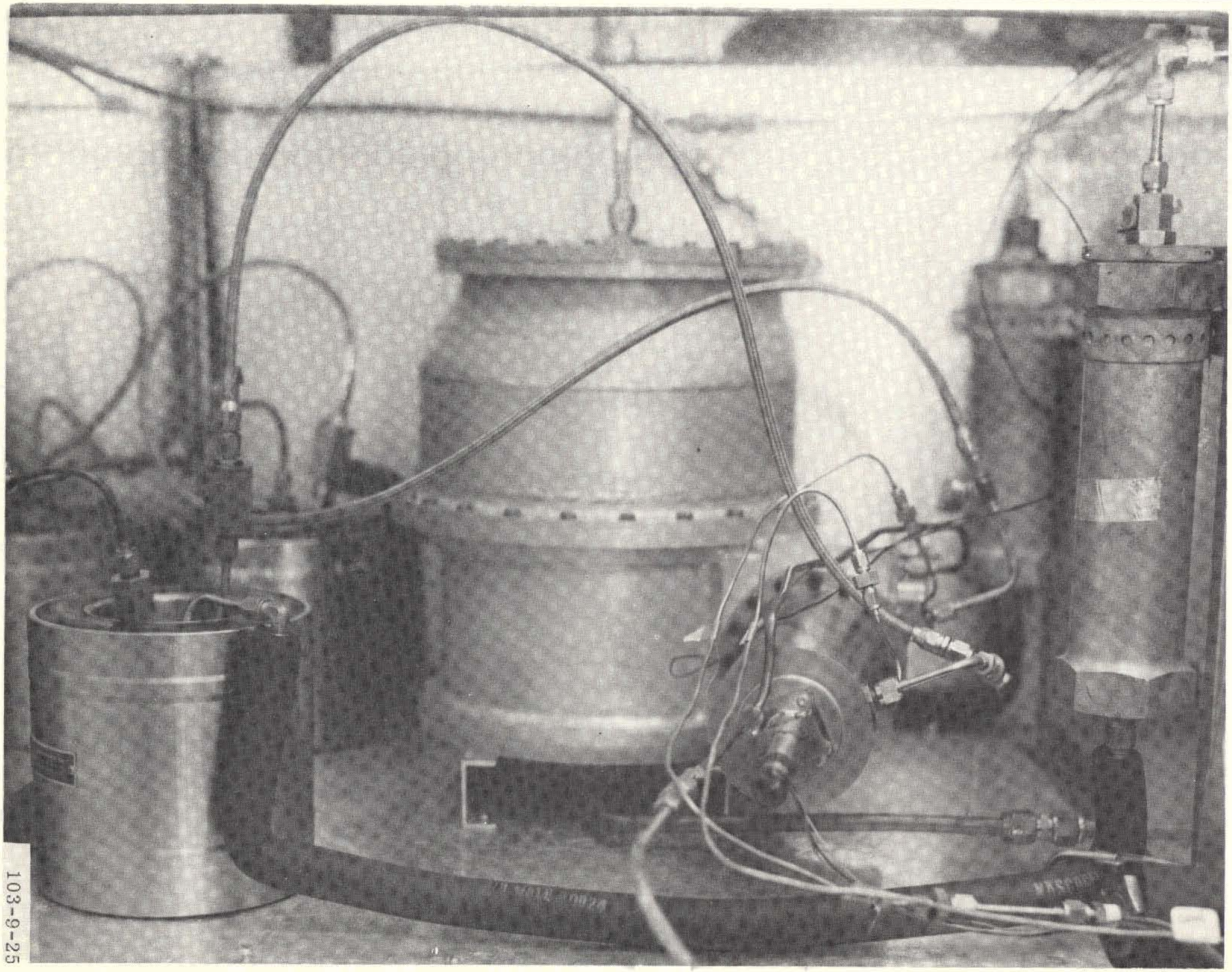

Figure 4-4. Test Setup, Low Temperature Life Cycle (Chamber Cover Removed), Test Specimen at Room Temperature

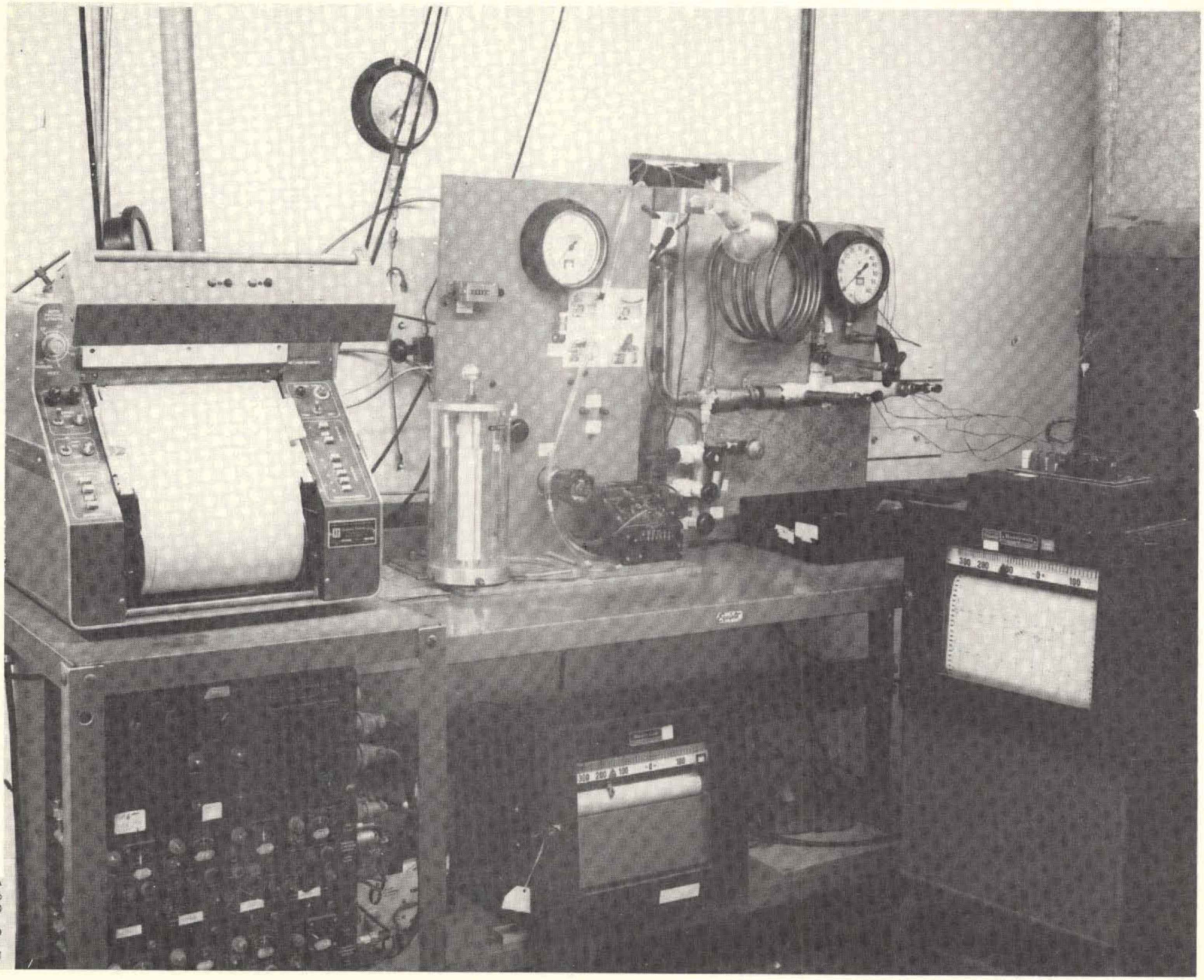

Figure 4-5. Test Setup, Low Temperature Life Cycle Test, Operator's Station

Table 4-2
Component Leakage, SCCM
Low Temperature Life Cycle Test
Room Temperature

Date	Temp. of Test, °F.	Total RT Cycles	Total -200°F. Cycles	Total Valve Cycles	Main Seal	Shaft Seal	Open Act.	Close Act.
12-13-73	RT	8	0	8	50	-	-	-
12-13-73	RT	9	0	9	-	∅[2]	146	-
12-17-73	RT	10	0	10	37.4	-	-	-
12-19-73	RT	11	96	107	29	-	-	-
12-20-73	RT	15	501	516	22.4	-	-	-
CONFIGURATION CHANGE: PISTON TYPE ACTUATOR ASSEMBLY								
3-7-74	RT	19	681	700	12.4	-	0	0
3-7-74	RT	33	681	714	46	-	0	0
3-11-74	RT	48	722	770	64	27	0	0
REWORK: PISTON SEAL REPLACED AND KEL-F STOP DISK ADDED								
3-14-74	RT	52	722	774	56	0.2	3.6	0
3-14-74	RT	57	722	799	138	24	0	0
3-14-74	RT	107	722	829	130	32	9.6	4
3-15-74	RT	167	722	889	139	32	32	5
REWORK: ADDITIONAL VENT HOLES IN BEARING AND ANNULAR VENT PATH								
3-19-74	RT	167	722	889	135	33	5.8	2.6
3-20-74	RT	167	722	889	130	-	4.2	3.2
3-20-74	RT	192	722	889	131	45	5.8	4.2
3-21-74	RT	195	759	954	173	0	0	0
3-22-74	RT	195	1224	1419	265	0	0	3.2
REPAIR TEST SETUP: "OPEN" ACTUATOR AND COVER PORT LEAKAGE								
3-25-74	RT	195	1626	1821	265	3.8	0	5.8
3-27-74	RT	195	2000	2195	340	8	7	7
3-28-74	RT	223	2255	2478	270	0	47	8
REWORK: VALVE SEAL AND TWO ACTUATOR PISTON SEALS REPLACED								
4-2-74	RT	223	2255	2478	15.6	47	20	.10
4-2-74	RT	231	2255	2486	14	20	12	1.1
4-3-74	RT	231	2630	2861	23	0	21	1
4-4-74	RT	231	3334	3565	21	0	5	10.2
4-8-74	RT	231	4805	4836	42	4490	19	650
REWORK: ACTUATOR LINK REDESIGNED								
4-17-74	RT	231	5895	6126	32	8764	10	55
4-17-74	RT	281	5895	6176	1394	295	195	12.6[1]
4-18-74	RT	506	5895	6401	1230	312	98	24
4-18-74	RT	966	5895	6861	1394	3105	175	21

Notes: (1) Main Seal Nicked
(2) ∅ = approximately zero

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Table 4-2 (continued)
Component Leakage, SCCM
Low Temperature Life Cycle Test
Room Temperature

Date	Temp. of Test, °F.	Total RT Cycles	Total -200°F. Cycles	Total Valve Cycles	Main Seal	Shaft Seal	Open Act.	Close Act.
4-18-74	RT	1016	5895	6911	1312	5494	1640	15
REWORK:	MAIN SEAL REFINISHED							
4-22-74	RT	1016	5895	6911	30	5577	163	7
4-22-74	RT	1042	5895	6939	39	-	820	5.2
4-23-74	RT	1044	5897	6941	36	740	190	14
REWORK:	THREE PISTON SEALS REPLACED							
4-25-74	RT	1044	5897	6941	30	-	820	0
4-25-74	RT	1078	5897	6975	30	0	1066	0
4-26-74	RT	1078	6567	7745	39	0	11	0
4-27-74	RT	1078	8437	9515	34	6972	1722	5.4
4-29-74	RT	1082	8943	10,025	32	12,054	0	0

Table 4-3

Component Leakage, SCCM
Low Temperature Life Cycle Test
Cryogenic Temperature

Date	Temp. of Test, °F.	Total RT Cycles	Total -200°F. Cycles	Total Valve Cycles	Main Seal	Shaft Seal	Open Act.	Close Act.
12-13-73	-300	9	0	9	90	-	-	37
12-17-73	-200	10	1	11	158	-	Ø	-
12-17-73	-200	10	96	106	Ø (5)	88	Ø	70
12-19-73	-200	11	490	501	Ø	-	13	-
12-20-73	-200	15	681	696	60 (1)	-	63	-
REWORK: NEW PISTON TYPE ACTUATOR ASSEMBLY								
3-8-74	-200	33	685	718	295	5	160	340
3-8-74	-300	-	-	-	6888 (2)	0	0	126
3-8-74	-200	-	-	-	-	-	9840	-
3-8-74	-200	-	-	-	-	-	6888	160
3-8-74	-200	33	722	755	2.7	-	14,104	3608
3-8-74	-270	44	722	766	-	-	12,464	-
REWORK: PISTON SEAL REPLACED AND KEL-F STOP DISK ADDED								
3-15-74	-200	167	772	889	-	4	340	340
REWORK: ADDITIONAL VENT HOLES IN BEARING & ANNULAR VENT PATH								
3-20-74	-200	192	726	918	820	20	475	24,600 (3)
3-20-74	-200	192	747	939	1066	0	0	0
3-20-74	-200	192	759	951	1066	0	0	0
3-20-74	-300	192	759	951	13,122	-	2640	0
3-21-74	-200	195	759	954	1066	0	0	0 (4)
3-21-74	-200	195	859	1054	1066	0	0	0
3-21-74	-200	195	1011	1206	1312	0	0	0
3-21-74	-200	195	1224	1419	1230	0	0	0
REPAIR TEST SETUP, "OPEN" ACTUATOR AND COVER PORT LEAKAGE								
3-22-74	-200	195	1224	1419	1476	45	245	490
3-22-74	-200	195	1278	1473	1066	0	3936	574
3-22-74	-200	195	1432	1627	1230	0	3116	1066
3-22-74	-200	195	1626	1821	1230	0	3444	1230

NOTES:

(1) Effective actuator close pressure < 100 psi

(2) High reading attributed to boil-off of LN_2 residual

(3) Erratic

(4) Test Setup leakage

(5) Ø = approximately zero

Table 4-3 (continued)

Component Leakage, SCCM
Low Temperature Life Cycle Test
Cryogenic Temperature

Date	Temp. of Test, °F.	Total RT Cycles	Total -200°F. Cycles	Total Valve Cycles	Main Seal	Shaft Seal	Open Act.	Close Act.
3-25-74	-200	195	1628	1826	1230	210	440	800
3-25-74	-200	195	1728	1926	4838	0	3444	495
3-25-74	-200	195	1890	2085	1230	60	930	440
3-26-74	-200	195	1893	2088	1066	246	410	1230
3-26-74	-200	195	2000	2195	1066	0	2624	1230
3-27-74	-200	223	2000	2223	1230	410	820	1772
3-27-74	-200	223	2181	2407	130	0	13,120	1968
3-27-74	-200	223	2255	2478	820	-	7626	1804
REWORK:	VALVE SEAL AND TWO ACTUATOR PISTON SEALS REPLACED							
4-2-74	-200	231	2255	2486	135	545	440	1066
4-2-74	-200	231	2630	2861	175	Ø	6068	1066
4-3-74	-200	231	3334	3565	230	Ø	1558	2870
4-4-74	-200	231	3488	3719	1066	Ø	2788	1886
4-4-74	-200	231	3488	3719	290	Ø	1738	2460
4-5-74	-200	231	3999	4230	290	Ø	160	720
4-5-74	-200	231	4210	4441	200	-	146	1886
4-5-74	-200	231	4805	4836	245	Ø	1230	8200
4-8-74	-200	231	4805	4838	490	Ø	160	4100
REWORK:	ACTUATOR LINK REDESIGNED							
REWORK:	MAIN SEAL REFINISHED							
4-23-74	-200	1042	5895	6939	290	542	770	5412
4-23-74	-200	1042	5897	6939	-	-	33,620	27,552
REWORK:	THREE PISTON SEALS REPLACED							
4-25-74	-200	1078	5897	6975	235	492	82	574
4-25-74	-200	1078	6567	7545	180	-	5740	200
4-26-74	-200	1078	7200	8278	188	20	595	158
4-26-74	-200	1078	7724	8802	290	45	345	150
4-26-74	-200	1078	7867	8945	220	0	290	127
4-27-74	-200	1078	8441	9519	550	65	85	1066
4-27-74	-200	1078	8943	10,021	390	0	3526	240

Table 4-4

Response Time, Sec.
Low Temperature Life Cycle Test
Room Temperature

Date	Temp. of Test, °F.	Accumulated Cycles RT	-200°F.	Total	Open to Close	Close to Open
12-12-73	RT	7	0	7	1.2	1.8
12-12-73	RT	7	0	7	1.6	2.05
12-20-73	RT	15	501	516	1.1	1.1
REWORK:	CONFIGURATION CHANGE TO PISTON TYPE ACTUATOR					
3-7-74	RT	19	681	700	1.7	1.5
3-7-74	RT	33	681	714	1.7	1.5
3-11-74	RT	48	722	770	1.8	1.1
REWORK:	1 PISTON SEAL REPLACED AND KEL-F STOP DISK ADDED					
3-14-74	RT	48	722	770	1.7 (1)	1.1 (1)
3-14-74	RT	52	722	774	-	1.5
REWORK:	ADDED VENT HOLES IN BEARING AND ANNULAR VENT PATH					
3-19-74	RT	167	722	889	1.65	1.1
3-19-74	RT	167	722	889	1.5	1.3
3-21-74	RT	195	759	954	0.7 (2)	0.4 (2)
3-22-74	RT	195	1224	1419	0.8	0.7
3-26-74	RT	195	2000	2195	-	0.4
3-27-74	RT	195	2000	2195	0.7	0.5
3-28-74	RT	223	2255	2478	0.7	0.5
REWORK:	VALVE SEAL AND TWO ACTUATOR PISTON SEALS REPLACED					
4-2-74	RT	231	2255	2486	0.8	0.4
4-2-74	RT	231	2305	2536	0.7	0.2
4-3-74	RT	231	2630	2861	0.8	0.2
4-4-74	RT	231	3334	3565	0.7	0.6
4-8-74	RT	231	4805	4836	0.7	0.5
REWORK:	ACTUATOR LINK REDESIGN					
4-17-74	RT	231	5895	6126	0.8 (1)	1.2 (1)
4-17-74	RT	235	5895	6131	0.7	0.2
4-17-74	RT	281	5895	6176	0.8	0.2
REWORK:	MAIN SEAL REFINISHED					
4-22-74	RT	1042	5895	6939	0.7	0.2
REWORK:	3 PISTON SEALS REPLACED					
4-25-74	RT	1044	5897	6941	0.7	0.5
4-25-74	RT	1078	5897	6975	0.6	0.2
4-26-74	RT	1078	6567	7545	0.7	0.6
4-27-74	RT	1078	8437	9515	0.7	0.6
4-29-74	RT	1082	8943	10,025	0.7	0.2

(1) 0 psig at inlet.
(2) New method of measuring response time.

Table 4-5

Response Time, Sec.
Low Temperature Life Cycle Test
Cryogenic Temperature

Date	Temp. of Test, °F.	Accumulated Cycles RT	-200°F.	Total	Open to Close	Close to Open
12-17-73	-200	10	1	11	4.3	2.9
12-17-73	-200	10	30	40	4.7	3.1
12-17-73	-200	10	40	50	3.4	3.9
12-17-73	-200	10	60	70	3.3	4.5
12-17-73	-200	10	80	90	3.0	6.1
12-19-73	-200	11	490	501	4.0	1.2
12-20-73	-200	15	515	530	2.9	6.5
REWORK:	CONFIGURATION CHANGE TO PISTON TYPE ACTUATOR					
3-8-74	-200	33	685	718	9.1	-
REWORK:	1 PISTON SEAL REPLACED AND KEL-F STOP DISK ADDED					
REWORK:	ADDED VENT HOLES IN BEARING AND ANNULAR VENT PATH					
3-20-74	-200	192	747	939	1.5 (2)	0.2 (2)
3-20-74	-200	192	759	951	1.5	0.2
3-21-74	-200	195	759	954	1.4	0.8
3-21-74	-200	195	759	954	1.3	0.2
3-21-74	-200	195	759	954	1.6	0.2
3-21-74	-200	195	859	1054	1.6	2.9
3-21-74	-200	195	1220	1415	1.4	0.2
3-21-74	-200	195	1220	1415	1.4	2.2
3-22-74	-200	195	1278	1473	1.6	1.1
3-22-74	-200	195	1432	1627	2.6	3.7
3-22-74	-200	195	1432	1627	2.6	0.3
3-27-74	-200	223	2000	2223	1.4	0.2
3-27-74	-200	223	2005	2228	1.3	0.2
3-27-74	-200	223	2087	2310	1.5	0.1
3-27-74	-200	223	2181	2407	1.6	0.25
3-27-74	-200	223	2255	2478	1.6	0.2
REWORK:	VALVE SEAL AND TWO ACTUATOR PISTON SEALS REPLACED					
4-2-74	-200	231	2255	2586	2.2 (1)	1.0 (1)
4-2-74	-200	231	2605	2836	1.6	0.25
4-2-74	-200	231	2630	2831	1.4	0.2
4-3-74	-200	231	2634	2865	1.6 (1)	1.4 (1)
4-3-74	-200	231	3010	3241	1.3	0.2
4-3-74	-200	231	3334	3565	1.5	0.2
4-4-74	-200	231	3488	3719	1.7	0.2
4-4-74	-200	231	3488	3719	1.7	0.3

(continued).....

Table 4-5 (continued)

Response Time, Sec.
Los Temperature Life Cycle Test
Cryogenic Temperature

Date	Temp. of Test, °F.	Accumulated Cycles RT	-200°F.	Total	Open to Close	Close to Open
4-4-74	-200	231	3757	3988	1.5	0.2
4-5-74	-200	231	4585	4816	1.6	0.3
4-5-74	-200	231	4605	4836	1.6	0.2
4-8-74	-200	231	4605	4836	1.3	0.3
REWORK:	ACTUATOR LINK REDESIGN					
REWORK:	MAIN SEAL REFINISHED					
REWORK:	3 PISTON SEALS REPLACED					
4-25-74	-200	1078	5897	7025	1.1	0.2
4-26-74	-200	1078	6567	7545	1.3	0.2
4-26-74	-200	1078	7197	8485	1.4	0.2
4-26-74	-200	1078	7724	8802	1.8	0.3
4-26-74	-200	1078	7867	8945	1.5	0.4
4-26-74	-200	1078	8057	9135	1.7	0.2
4-26-74	-200	1078	8413	9491	1.6	0.2
4-27-74	-200	1078	8441	9519	1.3	0.3
4-27-74	-200	1078	8467	9545	1.3	0.3
4-27-74	-200	1078	8943	10,021	1.7	0.4

(1) 0 psig at inlet.

(2) New method of measuring response time.

Figure 4-6. Main Seal Leakage Life Cycle Test

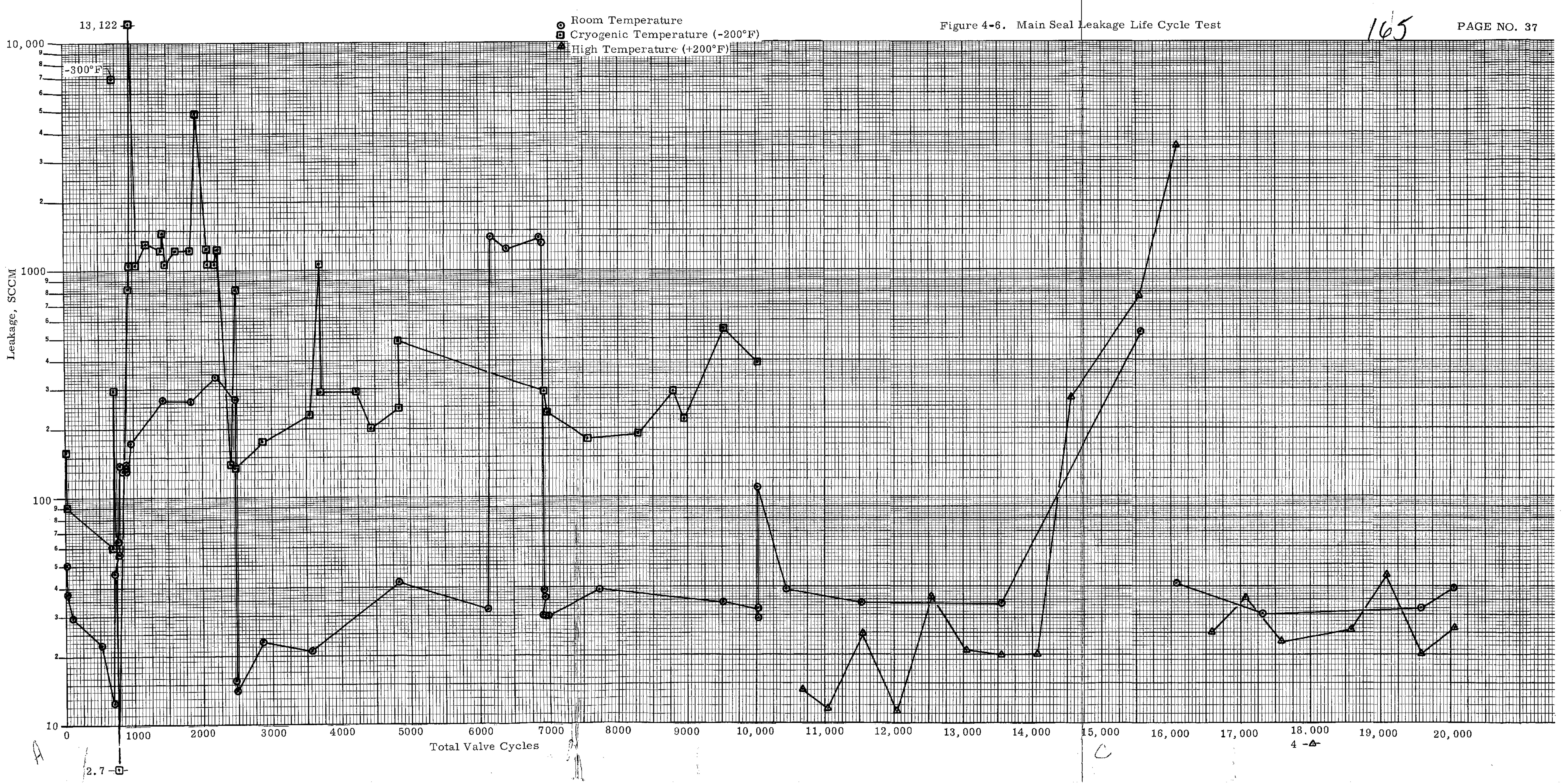
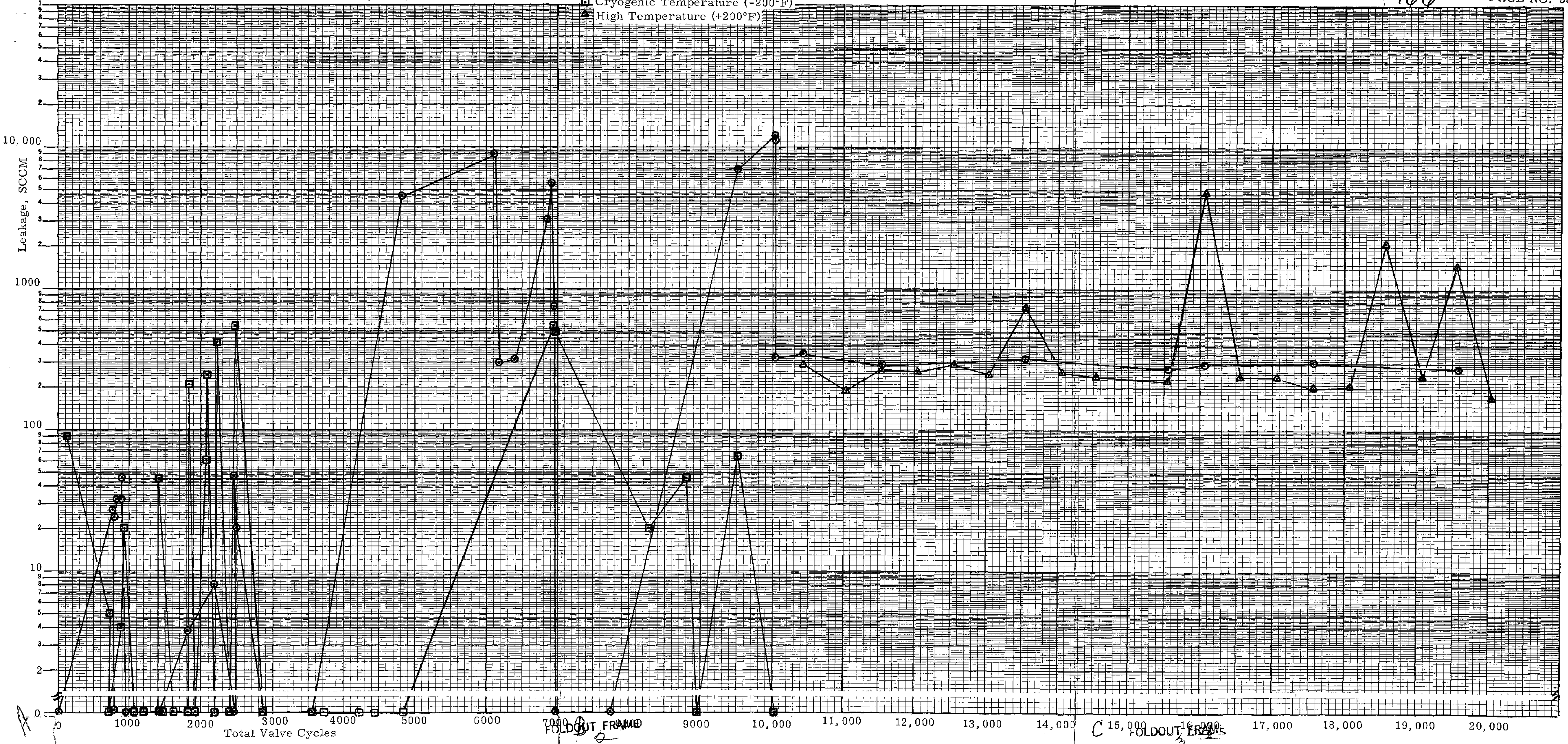


Figure 4-7. Shaft Seal Leakage Life Cycle Test



b. The "close" actuator port was pressurized to 750 psig with zero psig applied to the valve inlet. The cover port and outlet port leakages were measured. The inlet pressure was increased to 35 psig,and the cover and outlet port leakages were measured.

c. With the "close" port and inlet pressurized as described above, the "close" port pressure was released to zero psig. The cover port and outlet port leakages were measured.

4.3.1.2 Response Time Test

The response time tests were conducted with the test specimen installed in the low temperature life cycle test setup. Gaseous nitrogen was used to pressurize the actuator and valve inlet. The tests were conducted as described below.

The "close" actuator port was pressurized to 750 psig and the valve inlet was pressurized to 35 psig. Simultaneously, the "close" port was vented,and the "open" port was pressurized to 750 psig. The actuation pressure, valve position, inlet and outlet valve pressures were recorded on an oscillograph. Typical close-to-open and open-to-close response time transients are shown in Figures 4-8 and 4-9, respectively, at room and cryogenic temperatures.

4.3.2 Component Leakage Evaluation

The component leakages were evaluated from the leakage test data recorded during the low temperature life cycle. The data for the bellows type actuator assembly and the piston type were evaluated in the manner described below. Schematic diagrams of the valve with the bellows type actuator assembly and of the valve with the piston type actuator assembly are shown in Figures 4-10 and 4-11 respectively. The "open ","close",cover,and outlet ports, as well as the valve inlet, are identified. The main seal and shaft seal are also identified.

The "open" actuator leakage is equal to the "close" actuator port leakage plus the cover port leakage with the conditions of 750 psig at the "open" port and 35 psig at the valve inlet.

The "close" actuator leakage is equal to the "cover" port leakage with the conditions of 750 psig at the "open" port and 35 psig at the valve inlet.

The main seal leakage is equal to the outlet port leakage with the conditions of 750 psig at the "close" port and 35 psig at the valve inlet.

4.3.3 Cycling with Bellows Type Actuator Assembly

The test specimen with the bellows type actuator assembly was installed in the test setup shown in Figures 4-2 through 4-5. A schematic diagram of the test

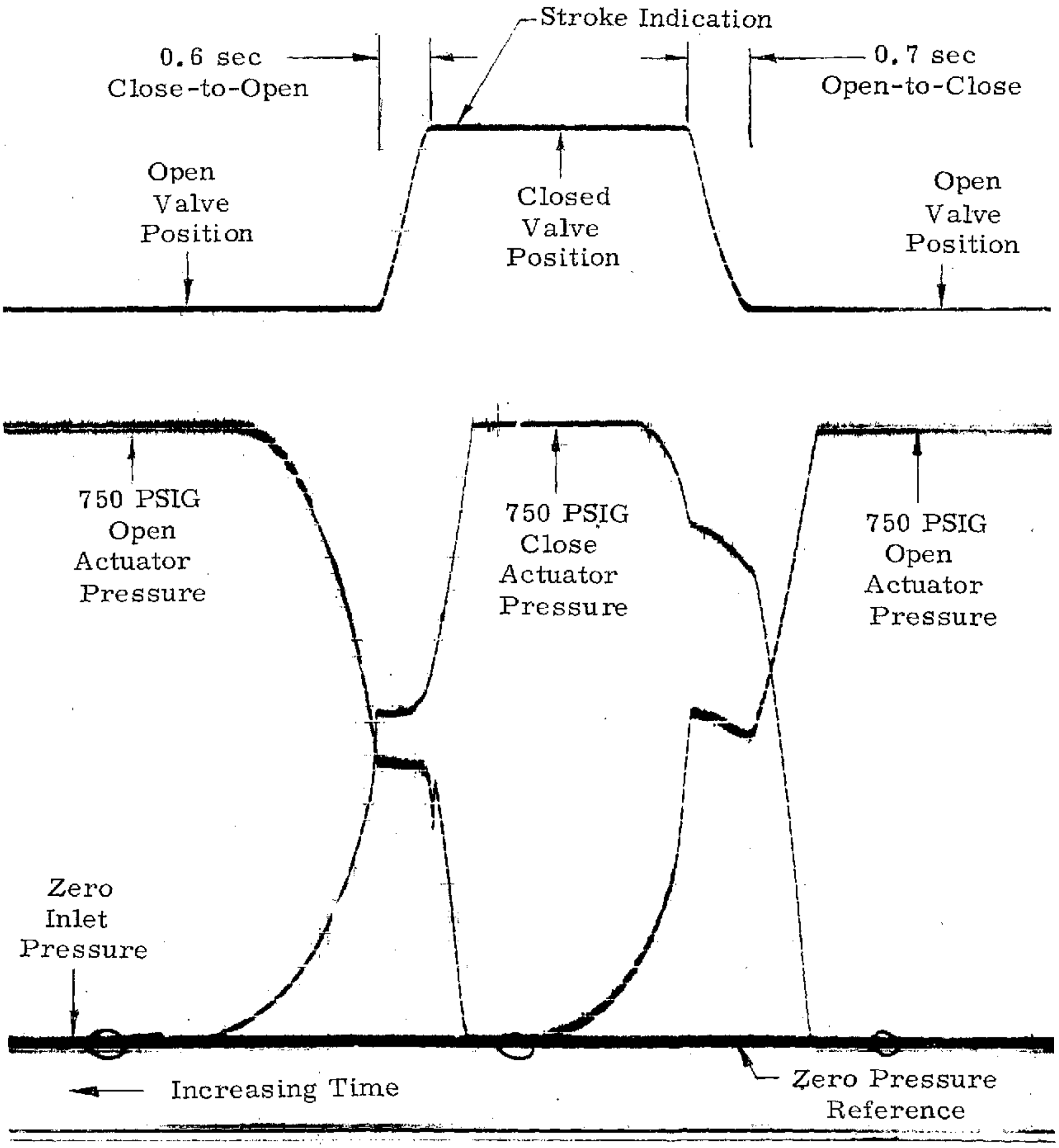


Figure 4-8. Typical Room Temperature Response Time Transients, Low Temperature Life Cycle Test

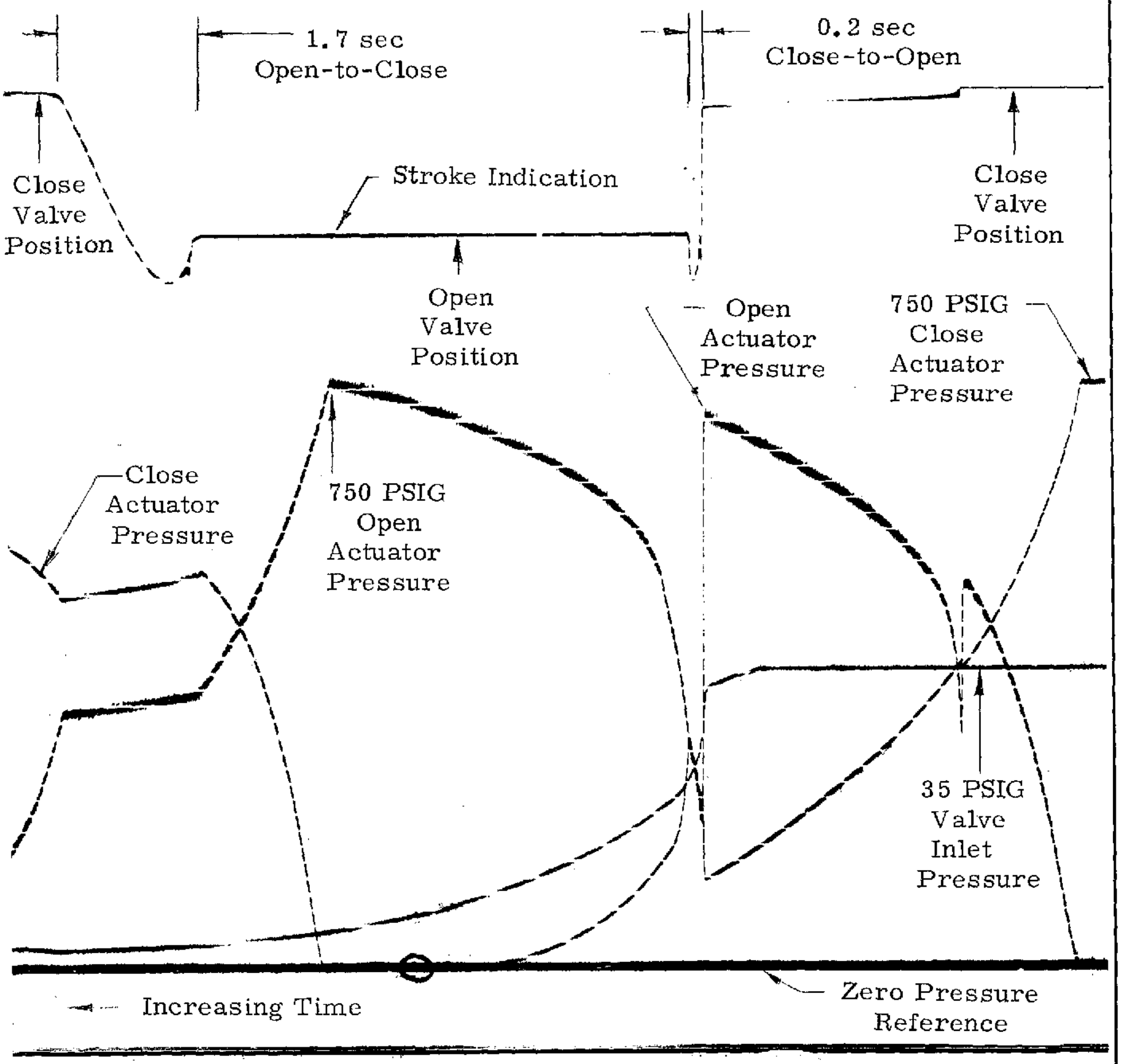


Figure 4-9. Typical Cryogenic Temperature Response Time Transients, Low Temperature Life Cycle Test

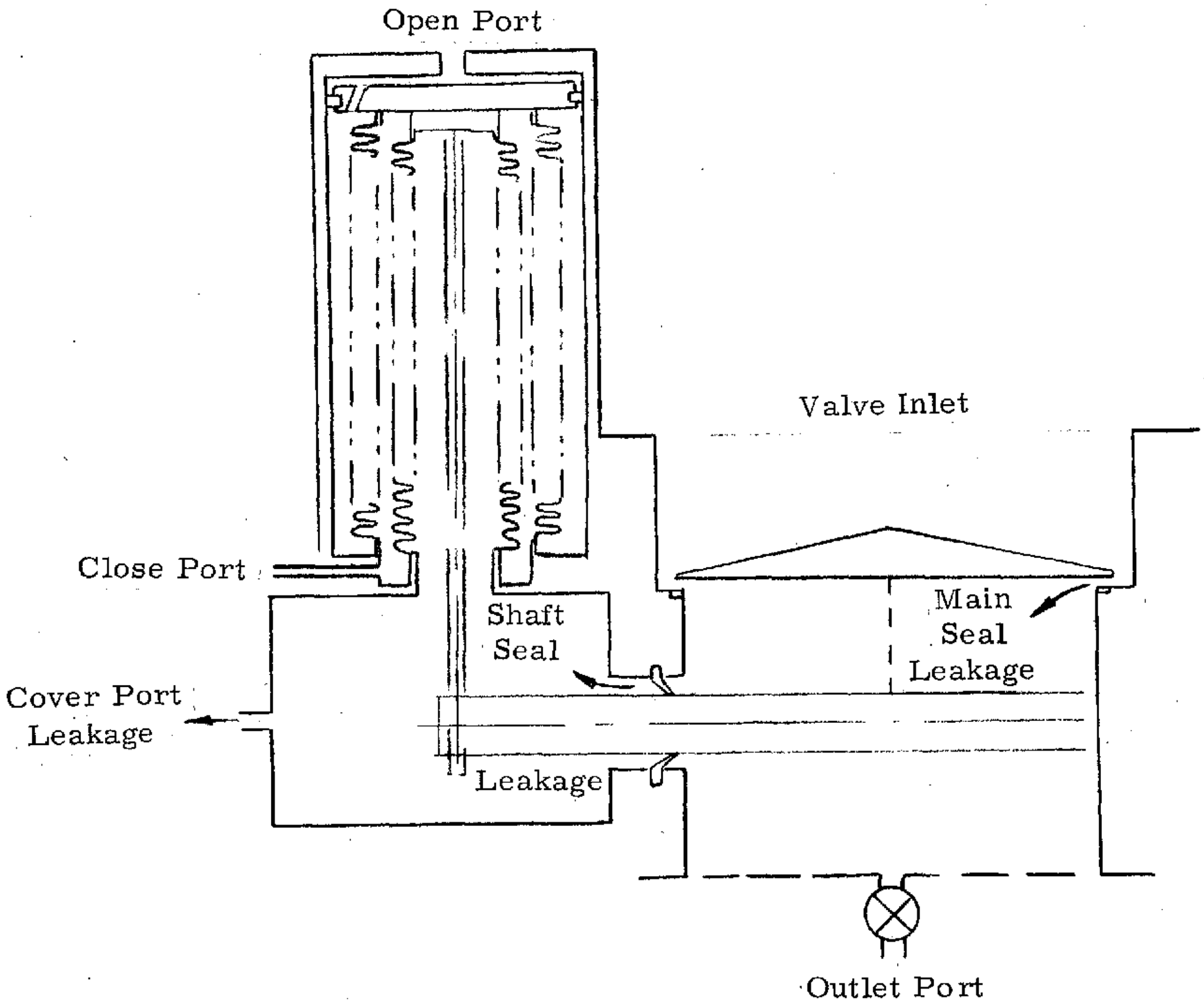


Figure 4-10. Schematic Diagram Bellows Type Actuator and Valve Assembly

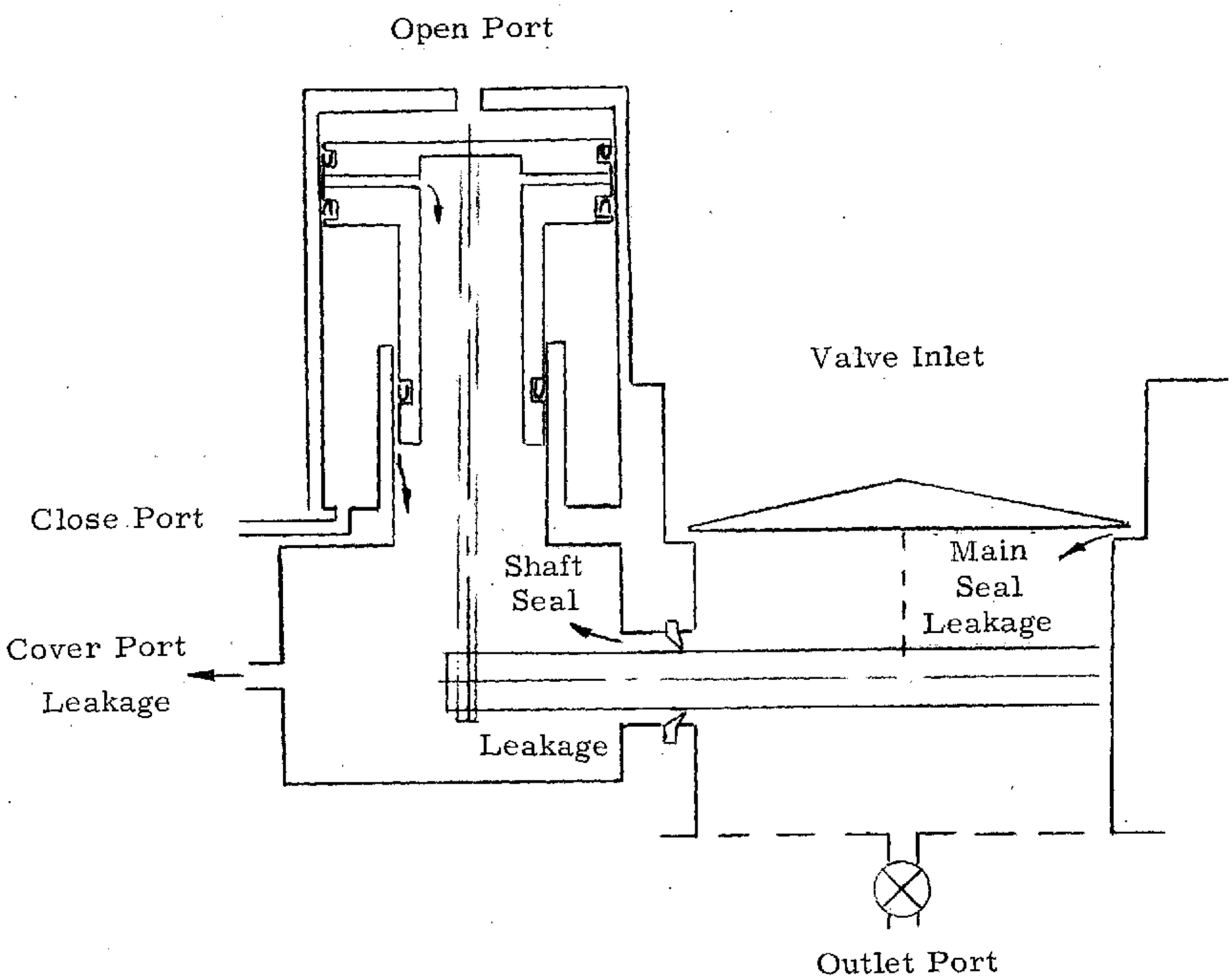


Figure 4-11. Schematic Diagram, Piston Type Actuator Assembly

setup is presented in Figure 4-2. Views of the setup, with the cover removed, are presented in Figures 4-3 and 4-4. A photograph of the operator's station is presented in Figure 4-5.

The test specimen and the test fluids were at approximately minus 200°F. In each cycle, the valve inlet was pressurized to 35 psig with nitrogen in the "closed" position. The actuation pressure was 750 psig nitrogen. The cycling schedule was open for 3 seconds and closed for 7 seconds.

After 10 room temperature cycles and 96 cryogenic cycles, the cycling was stopped to correct a malfunctioning stroke indicator. The indicator was disassembled. The stem was found to be unscrewed. This condition was corrected,and the cycling was continued.

After an accumulation of 15 room temperature and 681 cryogenic cycles (696 total cycles), the valve ceased to cycle due to excessive leakage through the "open" and "close" actuator ports and the solenoid vent port. The outer bellows was the cause of the leakage and a decision was made to change the test specimen configuration from a bellows type actuator assembly to a piston type actuator assembly. See paragraph 3.3.1 for further discussion of the configuration change.

4.3.4 Cycling With Piston Type Actuator Assembly

The redesigned test specimen was re-installed in the test setup,and cycling was continued. After an accumulated 48 RT and 772 cryogenic valve cycles, there was excessive cover port leakage and cycling was stopped. The unit was disassembled and inspected. See paragraph 3.3.3 for the results of the disassembly and inspection and a description of the test specimen rework.

Following the rework of the test specimen (Kel-F disk added and two outer piston seals replaced) and the rework of the test setup (addition of 10 micron filters at the actuator ports) cycling was continued. After an accumulated 167 RT cycles and 772 cryogenic valve cycles, the test was stopped due to occasionally high actuator leakage, indicating erratic actuator seal performance. The actuator was disassembled and inspected. The results of the disassembly and inspection and the rework are presented in paragraph 3.3.4.

After a total of 195 RT cycles and 1419 cryogenic cycles, there was test system leakage. The heat generator for the "open" actuator port was leaking around the O-ring groove and the Tygon tube to the cover port was split and leaking. The generator was repaired,and a copper line was installed between the cover port to outside the chamber. A Tygon tube ran from the copper tube to the leakmeter. These test setup leakages accounted for the zero actuator port leakages. (See Table 4-3, Total Accumulated Cycles: 939 through 1419).

After a total of 223 RT cycles and 2255 cryogenic cycles, the test was stopped due to excessive valve and actuator leakage. The test specimen was disassembled and inspected. The results of the inspection and the rework of the unit are presented in paragraph 3. 3. 5.

Following the rework of the test specimen, cycling was continued. After 331 RT cycles and 5895 cryogenic valve cycles, the valve would not fully open or close. Testing was stopped, and the unit was sent for disassembly and inspection. The results of the inspection and a description of the rework are presented in paragraph 3. 3. 6.

Cycling was continued following the rework of the test specimen. After 1016 RT and 5897 cryogenic cycles, there was excessive main seal leakage, and the cycling was stopped. The unit was sent for inspection. The results of the inspection and the results of the rework are presented in paragraph 3. 2. 6.

Following the refinishing of the main seal, cycling was continued. Excessive "open" and "close" actuator leakages caused the cycling to be stopped after 1044 room temperature cycles and 5897 cryogenic cycles. The unit was sent for rework. The results of the inspection are presented in paragraph 3. 2. 7.

Following the replacement of the three piston seals, cycling was continued until the low temperature life cycle test was concluded at 1082 RT cycles and 8943 cryogenic cycles, for a total of 10, 025 combined valve cycles.

4.4 HIGH TEMPERATURE LIFE CYCLE TEST

The high temperature life cycle test consisted of 10,004 valve cycles at 200°F. The test setup for the high temperature life cycling, including the leakage and response testing, is shown schematically in Figure 4-12 and photographically in Figures 4-13 and 4-14.

4.4.1 Leakage and Response Testing

Before, during and after the life cycling, the test specimen was subjected to room temperature and 200°F. leakage and response tests to check performance of the unit. The procedures used for conducting these tests are described in paragraphs 4.4.1.1 and 4.4.1.2.

Component leakages are presented in Table 4-6. The main seal and shaft seal leakages are presented graphically in Figures 4-6 and 4-7 respectively. The response times are presented in Table 4-7. The component leakages were determined from the data recorded during the leakage and response testing. The component leakage and the test results are identified by date, cycle history and temperature.

In general, room temperature tests were conducted at the start of each day's testing. During the day's cycling, the response tests were conducted at intervals indicated by Table 4-6. At the end of each day's cycling, the tests were conducted at the high temperature (200°F.). The method of determining the component leakage is discussed in paragraph 4.4.2.

4.4.1.1 Leakage Tests

The leakage tests were conducted with the test specimen installed in the high temperature life cycle test setup shown in Figures 4-12, 4-13 and 4-14. Gaseous nitrogen was used to pressurize the actuator. Air was used to pressurize the poppet valve inlet. The tests were conducted as follows:

a. The "open" actuator port was pressurized to 750 psig with zero psig applied to the valve inlet. The cover port and the "close" actuator port leakages were measured. The inlet pressure was increased to 35 psig,and the cover and "close" port leakages were measured.

b. With the valve in the open position, the actuator pressure was vented to zero. The valve inlet was pressurized to 15 psig,and the "cover" port, the "close" actuator port,and the "open" actuator port leakages were measured. The valve inlet pressure was then increased to 35 psig,and the leakages were measured.

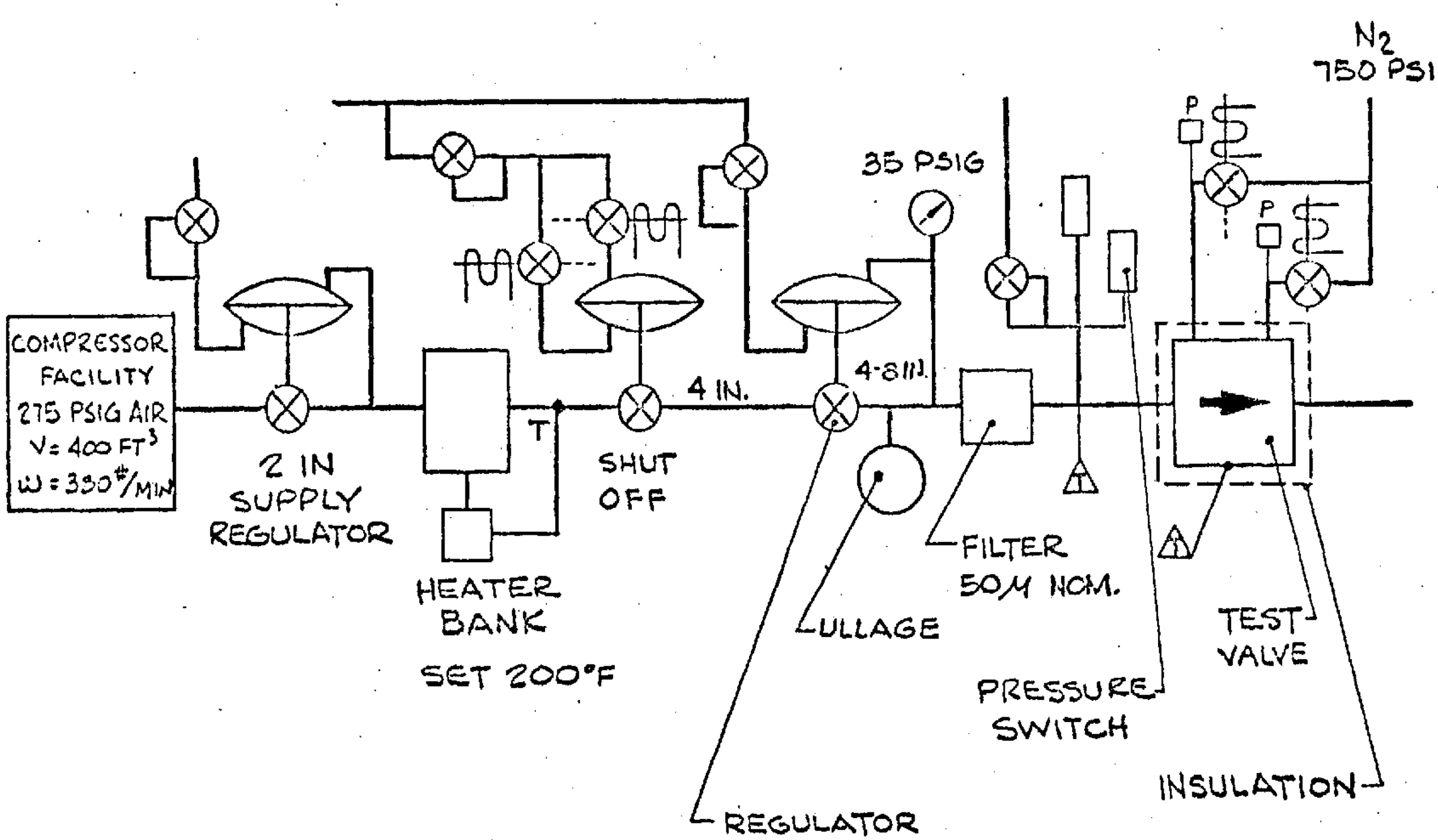


Figure 4-12. Schematic Diagram, High Temperature Life Cycle Test Setup

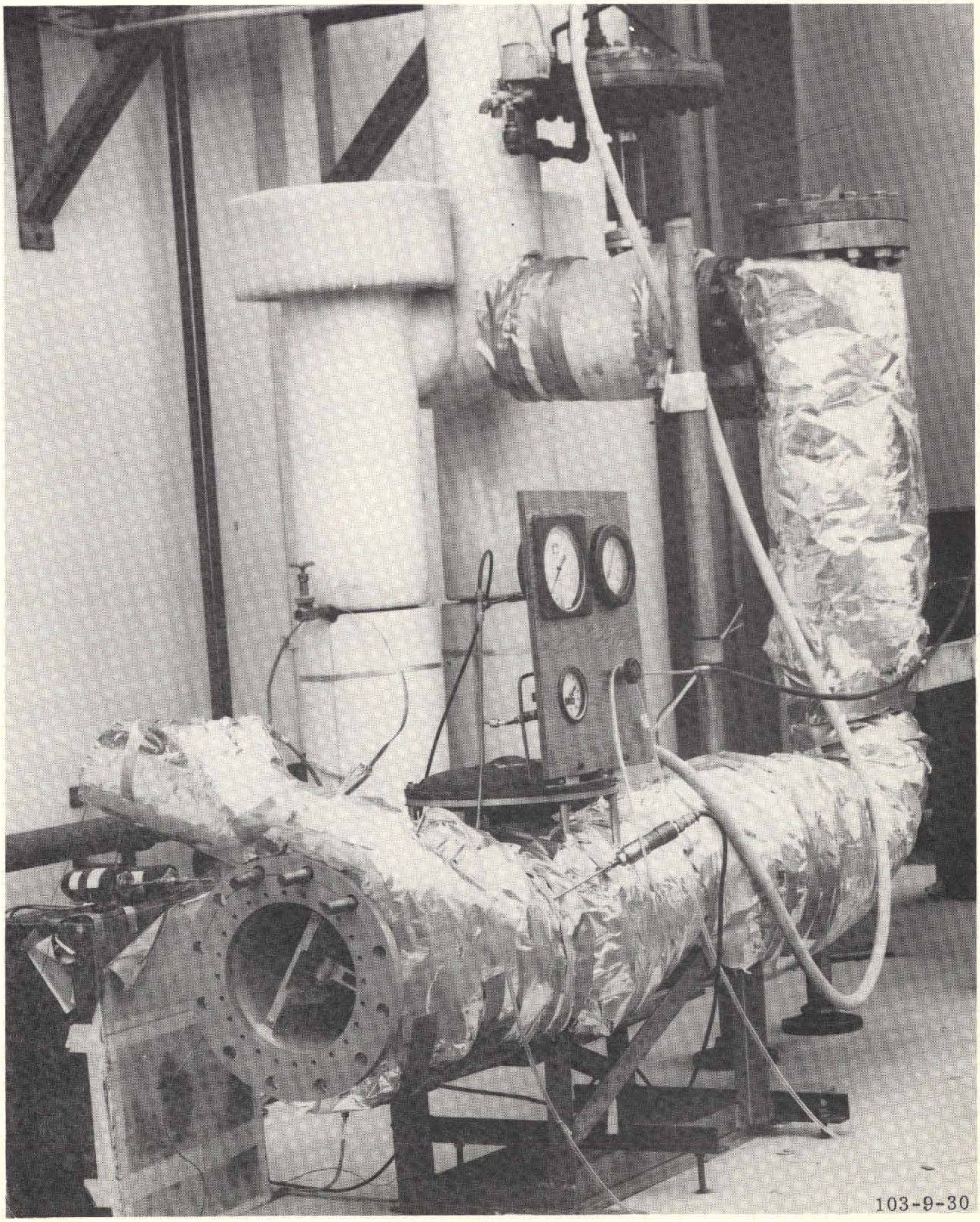


Figure 4-13. Test Setup, High Temperature Life Cycle (Cover Plate Removed)

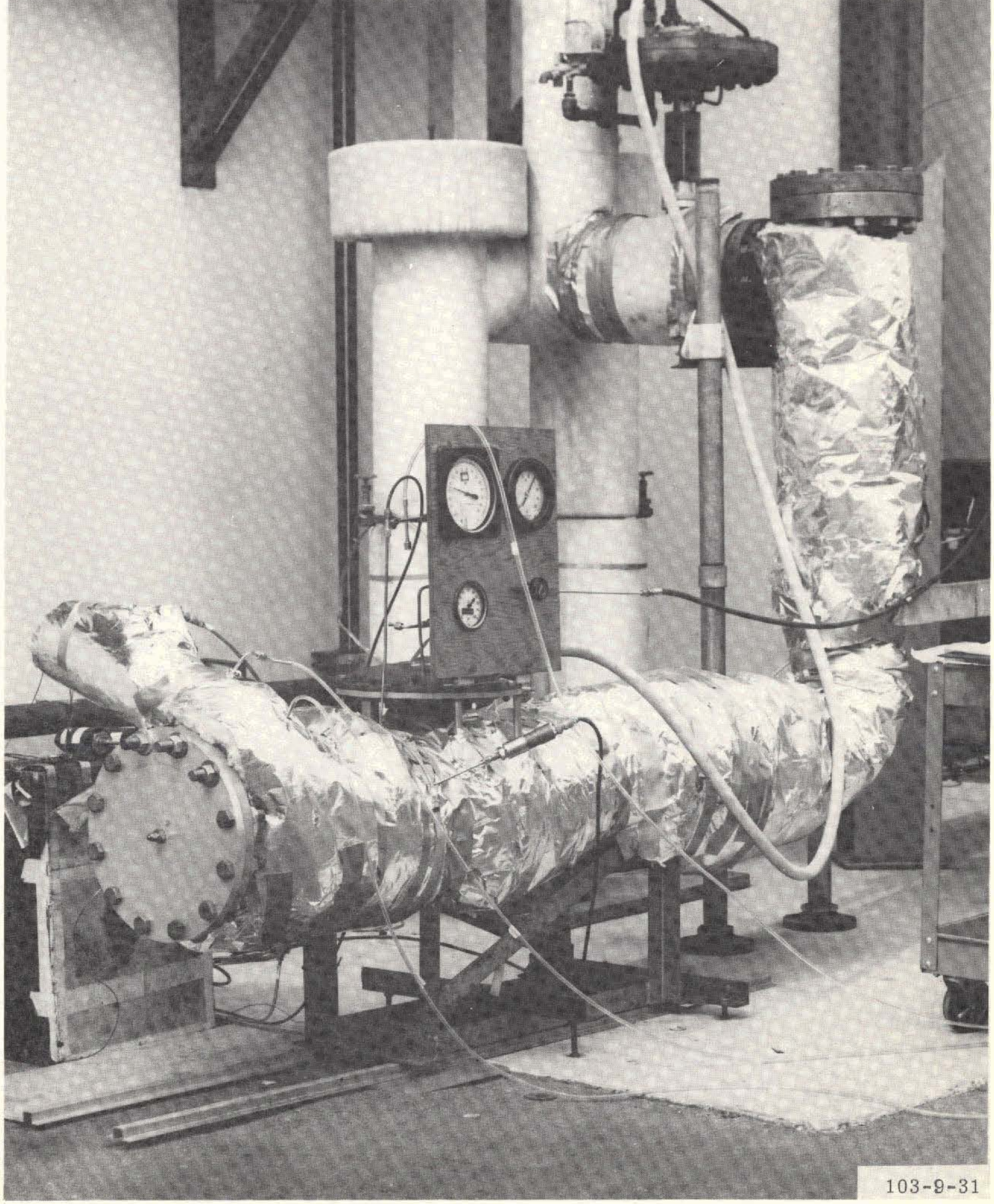


Figure 4-14. Test Setup, High Temperature Life Cycle

Table 4-6

Component Leakage, SCCM
High Temperature Life Cycle Test

Date	Temp. of Test, °F.	Accum. 200°F.	Cycles Total	Main Seal	Shaft Seal	Open Act.	Close Act.
5-8-74	RT	0	10,025	29	11,152	0	0
REWORK:	SHAFT SEAL REPLACED						
5-10-74	RT	0	10,039	110	325	30	0
5-13-74	RT	400	10,439	39	345	22	0
5-13-74	RT	1503	11,542	34	285	125	8
5-15-74	RT	3518	13,557	33.6 (1)	325	2223	1722 (2)/ 1640
5-16-74	RT	5533	15,572	529	270	1828	4838
REWORK:	THREE PISTON SEALS REPLACED						
5-20-74	RT	6038	16,077	41	290	0	0
5-21-74	RT	7547	17,586	30.6	300	120	8.4
5-21-74	RT	9548	19,587	34 (1)	275	700	3116 (2)/ 1804
5-22-74	RT (3)	10,004	20,043	39	-	-	1968
	RT	AFT. VIB		140	740	345	1722
5-10-74	200	400	10,439	14	290	37.2	0
5-13-74	200	1008	11,047	11.6	190	21	10.4
5-14-74	200	1503	11,542	24.8	270	65	10.2
5-14-74	200	2003	12,042	11.2	260	240	16
5-14-74	200	2510	12,549	36.2	290	790	225
5-15-74	200	3010	13,049	21	250	1230	875
5-15-74	200	3513	13,552	20	745	1974	1476
5-15-74	200	4020	14,059	20	260	2223	1066
5-15-74	200	4523	14,562	269	240	2644	2952
5-16-74	200	5533	15,572	762	225	3355	6396
5-16-74	200	5716	16,077	3471	4843	3939	12,795

NOTES
(1) Calculated using close actuator leakage at 35 psig valve inlet.
(2) Questionable irratic data; second no. at 35 psig valve inlet.
(3) Before vibration.

Table 4-6 (continued)

Component Leakage, SCCM
High Temperature Life Cycle Test

Date	Temp. of Test, °F.	Accum. 200°F.	Cycles Total	Main Seal	Shaft Seal	Open Act.	Close Act.
REWORK: THREE PISTON SEALS REPLACED							
5-20-74	200	6541	16,580	25	240	85	0
5-20-74	200	7044	17,083	35.8	240	187	0
5-21-74	200	7547	17,586	22.8	200	395	22
5-21-74	200	8047	18,086	4	205	975	450
5-21-74	200	8547	18,586	26	2132	2214	1476
5-21-74	200	9047	19,086	45	240	2624	390
5-21-74	200	9548	19,587	20 (1)	1476	2870	2706 (2)/ 2624
5-22-74	200	10,004	20,043	26 (1)	170	2460	1968 (2)/ 1886

NOTES

(1) Calculated using close actuator leakage at 35 psig valve inlet.
(2) Questionable irratic data; second no. at 35 psig valve inlet.
(3) Before vibration.

Table 4-7

Response Time, Sec
High Temperature Life Cycle Test

Date	Temp. of Test, °F.	Accumulated Cycles 200°F.	Accumulated Cycles Total	Open to Close	Close to Open
5-8-74	RT	0	10,034	0.5	0.5
5-10-74	RT	0	10,037	0.5	0.5
5-10-74	RT	0	10,039	0.5	0.5
5-13-74	RT	400	10,439	0.65	0.2
5-13-74	RT	404	10,443	0.6	0.2
5-13-74	RT	408	10,447	0.6	0.2
5-15-74	RT	3516	13,555	0.6	0.2
5-15-74	RT	3517	13,556	0.7	0.2
5-15-74	RT	3518	13,557	0.7	0.2
VALVE REWORK					
6-7-74	RT	10,004	20,043 after vib.	0.85	0.25
5-10-74	200	0	10,039	0.7	0.2
5-10-74	200	200	10,239	0.7	0.2
5-10-74	200	400	10,439	0.7	0.2
5-13-74	200	570	10,609	0.7	0.2
5-13-74	200	730	10,769	0.7	0.2
5-13-74	200	1008	11,047	0.6	0.2
5-13-74	200	1169	11,208	0.7	0.2
5-13-74	200	1353	11,392	0.6	0.2
5-13-74	200	1503	11,542	0.7	0.2
5-13-74	200	1669	11,708	0.7	0.2
5-13-74	200	1815	11,854	0.7	0.2
5-14-74	200	2003	12,042	0.7	0.2
5-14-74	200	2194	12,233	0.6	0.2
5-14-74	200	2352	12,391	0.7	0.2
5-14-74	200	2510	12,549	0.7	0.2
5-14-74	200	2678	12,717	0.7	0.2
5-14-74	200	2844	12,883	0.7	0.2
5-15-74	200	3010	13,049	0.7	0.2
5-15-74	200	3178	13,217	0.7	0.2
5-15-74	200	3342	13,381	0.7	0.2
5-15-74	200	3513	13,552	0.7	0.2
5-15-74	200	3698	13,737	0.7	0.2
5-15-74	200	3848	13,887	0.7	0.2
5-15-74	200	4020	14,059	0.7	0.2

Table 4-7 (continued)

Response Time, Sec
High Temperature Life Cycle Test

Date	Temp. of Test, °F.	Accumulated Cycles 200°F.	Accumulated Cycles Total	Open to Close	Close to Open
5-15-74	200	4188	14,227	0.6	0.2
5-15-74	200	4348	14,387	0.7	0.2
5-15-74	200	4523	14,562	0.7	0.2
5-15-74	200	4693	14,732	0.7	0.2
5-15-74	200	4853	14,892	0.7	0.2
5-15-74	200	5028	15,067	0.7	0.2
5-16-74	200	5206	15,245	0.7	0.2
5-16-74	200	5361	15,400	0.7	0.2
5-16-74	200	5533	15,572	0.7	0.15
5-16-74	200	5716	15,755	0.7	0.2
5-16-74	200	5868	15,907	0.6	0.2
5-16-74	200	6038	16,077	0.6	0.2
VALVE REWORK					
5-20-74	200	6204	16,243	0.7	0.2
5-20-74	200	6384	16,413	0.6	0.2
5-20-74	200	6541	16,580	0.6	0.2
5-20-74	200	6710	16,749	0.65	0.2
5-20-74	200	6876	16,915	0.6	0.2
5-20-74	200	7044	17,083	0.6	0.2
5-21-74	200	7202	17,241	0.65	0.2
5-21-74	200	7372	17,411	0.65	0.2
5-21-74	200	7547	17,586	0.7	0.2
5-21-74	200	7710	17,749	0.7	0.2
5-21-74	200	7879	17,918	0.65	0.2
5-21-74	200	8047	18,086	0.65	0.25
5-21-74	200	8213	18,252	0.7	0.2
5-21-74	200	8382	18,421	0.65	0.2
5-21-74	200	8547	18,586	0.7	0.2
5-21-74	200	8712	18,751	0.65	0.2
5-21-74	200	8882	18,921	0.65	0.2
5-21-74	200	9047	19,086	0.65	0.2
5-21-74	200	9212	19,251	0.65	0.2
5-21-74	200	9379	19,418	0.7	0.2
5-21-74	200	9548	19,587	0.65	0.2

c. The "close" actuator port was pressurized to 750 psig with zero psig applied to the valve inlet. The cover port and outlet port leakages were measured. The inlet pressure was increased to 35 psig, and the cover and open port leakages were measured.

d. The "close" actuator port was pressurized to 750 psig with 15 psig applied to the valve inlet. The cover port and outlet port leakages were measured. The inlet pressure was increased to 35 psig and the cover port and outlet port leakages were measured.

4.4.1.2 Response Time Test

The response time tests were conducted with the test specimen installed in the high temperature life cycle test setup. Gaseous nitrogen was used to pressurize the actuator, and air was used to pressurize the valve inlet. The tests were conducted as described below.

The "close" actuator port was pressurized to 750 psig, and the valve inlet was pressurized to 35 psig. Simultaneously, the "close" port was vented, and the "open" port was pressurized to 750 psig. The actuation pressure, valve position, inlet and outlet valve pressures were recorded on an oscillograph. Typical close-to-open and open-to-close response time transients, at room and high temperatures, are shown in Figures 4-15 and 4-16, respectively.

4.4.2 Component Leakage Evaluation

The component leakages were evaluated from the leakage test data recorded during the high temperature life cycle test. A schematic diagram of the piston type actuator assembly and the valve is shown in Figure 4-11. The valve inlet and the various ports are identified as well as the main seal and shaft seal.

The "open" actuator leakage is equal to the cover port leakage plus the "close" port leakage with conditions of 750 psig at the "open" actuator port and zero psig at the valve inlet.

The "close" actuator leakage is equal to the cover port leakage plus the "open" port leakage with the conditions of 750 psig at the "close" actuator port and 35 psig at the valve inlet.

The shaft seal leakage is equal to the cover port leakage plus the "close" port leakage with the valve in open position, zero psig at the open actuator port, and 35 psig at the valve inlet.

The main seal leakage is equal to outlet port leakage plus the cover port leakage with conditions of 750 psig at the "close" actuator port and 35 psig at the valve inlet minus the "close" port leakage.

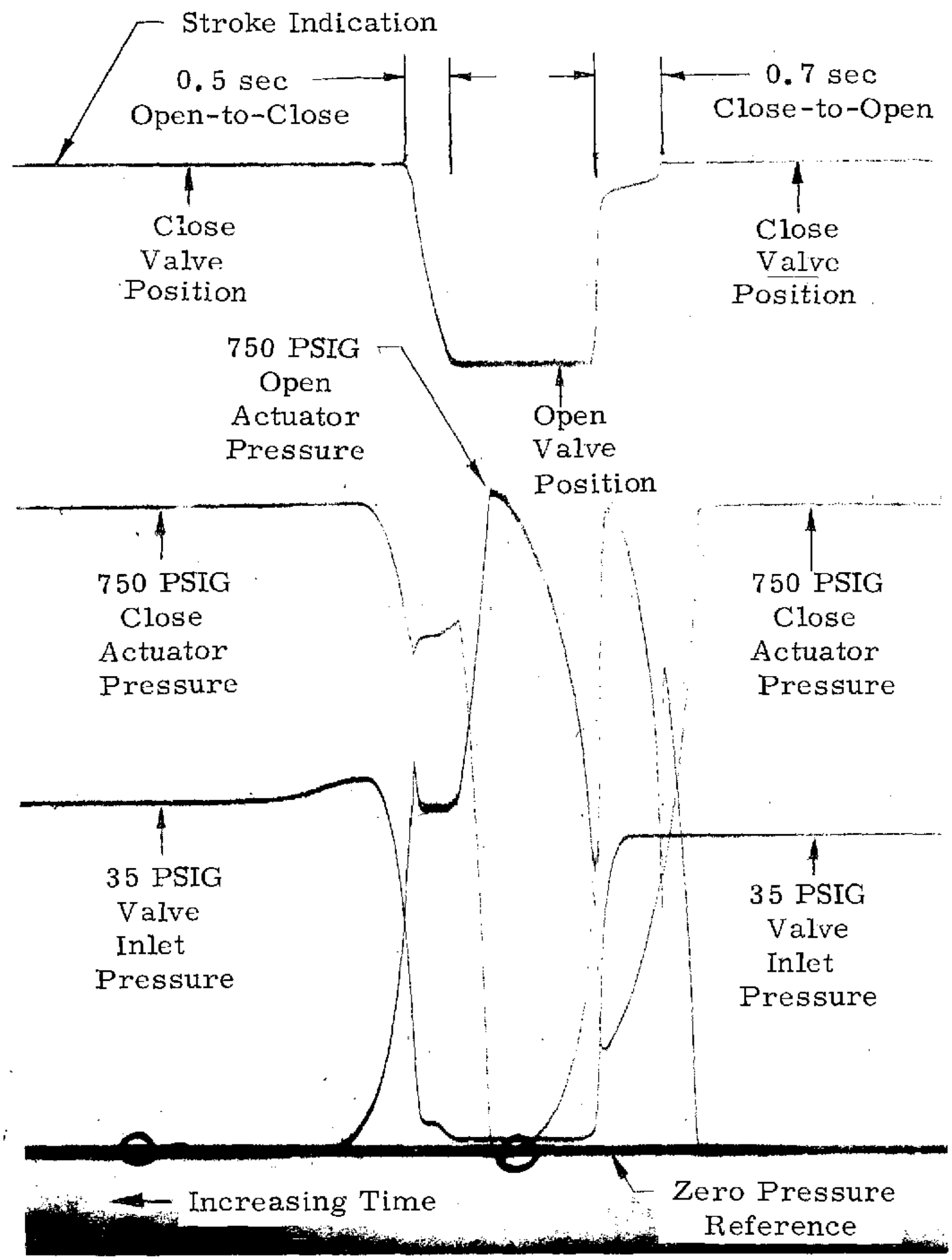


Figure 4-15. Typical Room Temperature Response Time Transients, High Temperature Life Cycle Test

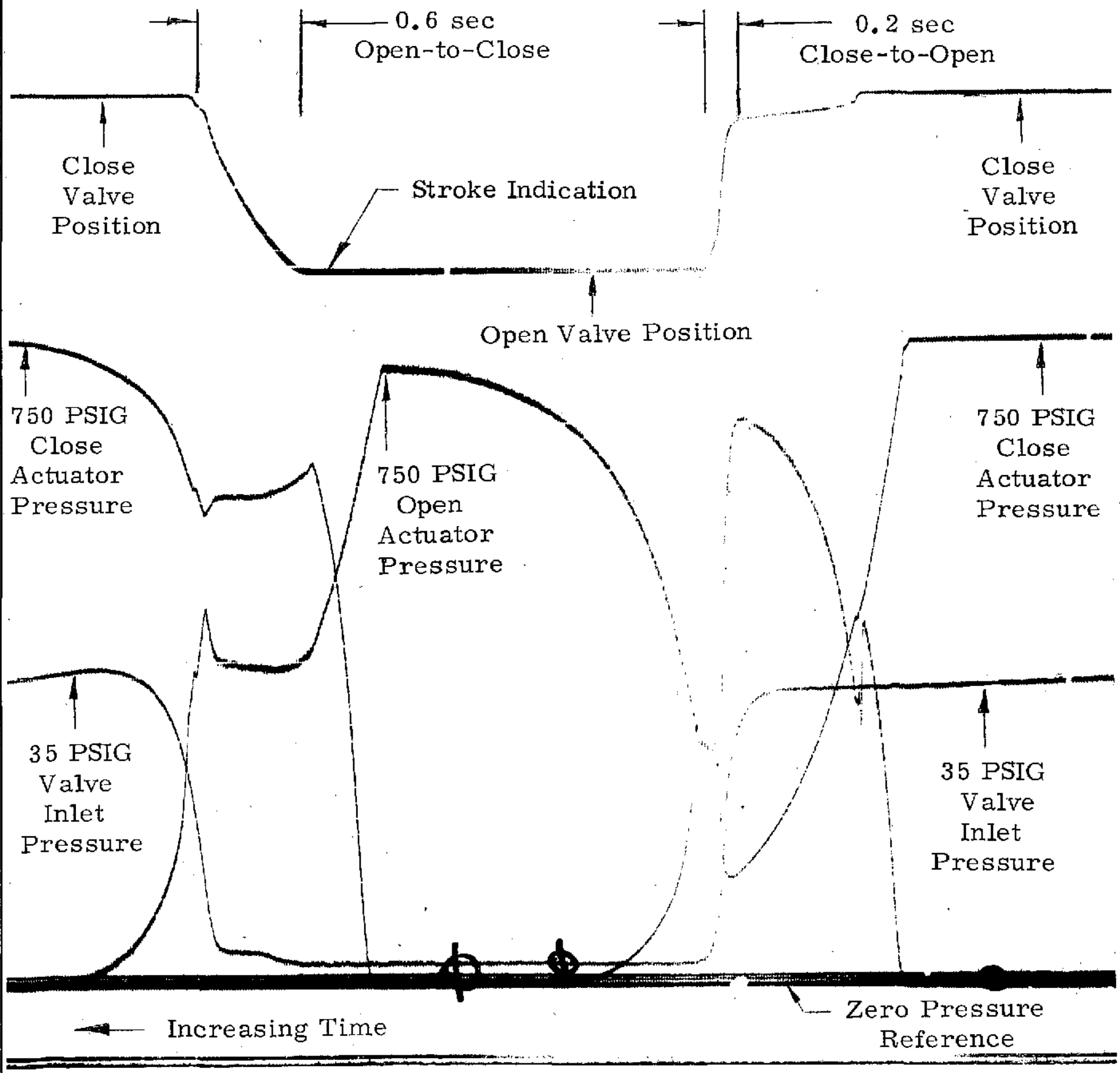


Figure 4-16. Typical High Temperature Response Time Transients, High Temperature Life Cycle Test

4.4.3 High Temperature Cycling

The test specimen was installed in the high temperature test setup shown in Figures 4-12, 4-13 and 4-14. With the supply and outlet regulators adjusted for optimal cycling performance and the heater controller adjusted for 200°F gas at the valve, the test specimen was cycled open for 3 seconds and closed for 7 seconds. In each cycle the valve inlet was pressurized with nitrogen at 35 psig in the closed position. The actuation pressure was 750 psig nitrogen.

After 10,039 accumulated cycles, the test was stopped due to excessive cover port leakage. The disassembly, inspection, and rework of the unit are described in paragraph 3.2.7.

The test specimen with the new shaft seal was reinstalled in the test setup, and cycling was continued. After an accumulated 10,089 total valve cycles, the cycling was stopped. The open port and close port orifices were sent for rework. See paragraph 3.2.8 for rework details.

Cycling was continued with the reworked orifices installed until 16,580 cycles were complete, at which time the cycling was stopped. The unit was sent for rework. See paragraph 3.2.9 for details of rework.

Cycling was continued after the rework until a total of 20,043 accumulated valve cycles were completed. Then the test was concluded.

4.5 VIBRATION TEST

The vibration test was conducted at the Approved Engineering Test Laboratories (AETL), Los Angeles, California. The test procedures used and the test results obtained during the vibration testing are presented in AETL Report No. 5330-1203 dated 8 July 1974, entitled "Vibration Test Report on Ten-Inch Long Life Valve, Part Number 966000, Serial Number 0001." A copy of this report is included as Appendix C of this report. Supplementary test description and test data are presented in the following paragraphs.

The vibration testing consisted of sinusoidal sweeps with the poppet valve in the open and the closed positions and random vibration with the poppet valve in the closed position along each of the three major valve axes, namely the valve axis, the actuator axis, and normal to the actuator axis.

4.5.1 Resonances

Resonant frequencies and intensities were evaluated from the x-y plots recorded during the sinusoidal sweeps. The x-y plots are presented in the AETL test report included in Appendix C herein. Resonant frequencies and intensities for the vibration sweeps are presented in Table 4-8. The data is identified by sweep, valve position, and output accelerometer location.

4.5.2 Monitored Leakage Data

Leakage was monitored before, during, and after each vibration run. Cover port and outlet port leakages were monitored with zero and 35 psig nitrogen gas applied to the valve inlet with the poppet valve in the closed position. Cover port leakage was monitored with zero and 35 psig applied to the valve inlet with the valve in the open position. The actuation pressure was 750 psig nitrogen gas. A schematic of the leakage test setup is presented in Figure 4-17. The component leakages (main seal, shaft seal, "open" actuator port, and "closed" actuator port) are presented in Table 4-9. These leakages were determined from the measured leakage test data presented in Table 4-13.

4.5.3 Leakage Test Prior to Vibration

A leakage test was conducted prior to the start of vibration testing. The test was conducted with the test specimen installed in the Lateral No. 1 axis. The setup is shown in Figure 4-17. Cover port leakage was measured with the valve in the closed position and with zero and 35 psig applied to the valve inlet. Outlet port and cover port leakages were measured with the valve in the closed position and with 15 and 35 psig nitrogen gas applied to the valve inlet. The actuation pressure was 750 psig nitrogen. The component leakages, which are presented in Table 4-9, were determined from the measured test data.

Table 4-8
Resonant Frequency Summary
Vibration Test

Axis of Vibration and Valve Position	RESONANT FREQUENCY AND AMPLITUDE — OUTPUT ACCELEROMETER LOCATIONS *							
	No. 2 Poppet		No. 3 Body		No. 4 (in direction of vibration on actuator cover)		No. 5 Actuator End	
	Hz	G's	Hz	G's	Hz	G's	Hz	G's
Lateral No. 1 Closed	770 1150 1780	95 43 20	1800 1320 1160	100+ 44 40	1400 1050 237 287 620	240 45 32 31 26	250 390 570 1500	100+ 57 46 46
Lateral No. 1 Open	1500 1380 1800 180 230	40 33 27 28 28	1450 1700 1100 220 515	100+ 100+ 50 32 29	1500 210 285 520 1100	200 89 85 78 73	275 400 590 1800 1460	62 45 32 24 25
Lateral No. 1 Closed (Retest)	Loose Cable		1580 310 1008 930	57 48 38 34	1830 1140 780 340 265	90 80 45 37 36	950 750 305 480 1650	55 54 41 31 28
Longitudinal No. 1 Closed (Retest)	180	26	180 240 940	65 50 40	179 940	38 33	1250 1800 175 220	59 46 41 34
Longitudinal No. 1 Open (Retest)	215 1420 1820 34	63 53 44 25	233 1470 960	53 39 32	134 41 33 29 23 18 14.5 1800 960 215	100+ 100+ 100+ 100+ 100+ 100+ 90 40 39 33	1450 1300 1680 220	80 75 51 45

* Control Accelerometer (No. 1) located on fixture in the direction of vibration.

Table 4-8 (continued)
Resonant Frequency Summary
Vibration Test

Axis of Vibration and Valve Position	RESONANT FREQUENCY AND AMPLITUDE — OUTPUT ACCELEROMETER LOCATIONS *							
	No. 2 Poppet		No. 3 Body		No. 4 (in direction of vibration on actuator cover)		No. 5 Actuator End	
	Hz	G's	Hz	G's	Hz	G's	Hz	G's
Longitudinal No. 2 Closed	750	100+	920	56	650	44	1350	100+
	410	67	1400	46	900	37	730	95
	1002	70	1000	43	320	36	470	75
	340	39	400	31	205	35	920	68
			215	28	1600	28	224	56
			122	29			118	54
Longitudinal No. 2 Open	128	34	1050	70	880	46	1300	100+
	1880	32	900	38	1080	45	1100	100+
	455	30	1550	37	1640	38	730	100+
	930	26	420	26	680	43	490	100+
			220	26	335	36	340	92
			120	25			320	96
							240	97
							165	66
							122	75

* Control Accelerometer (No. 1) located on fixture in the direction of vibration.

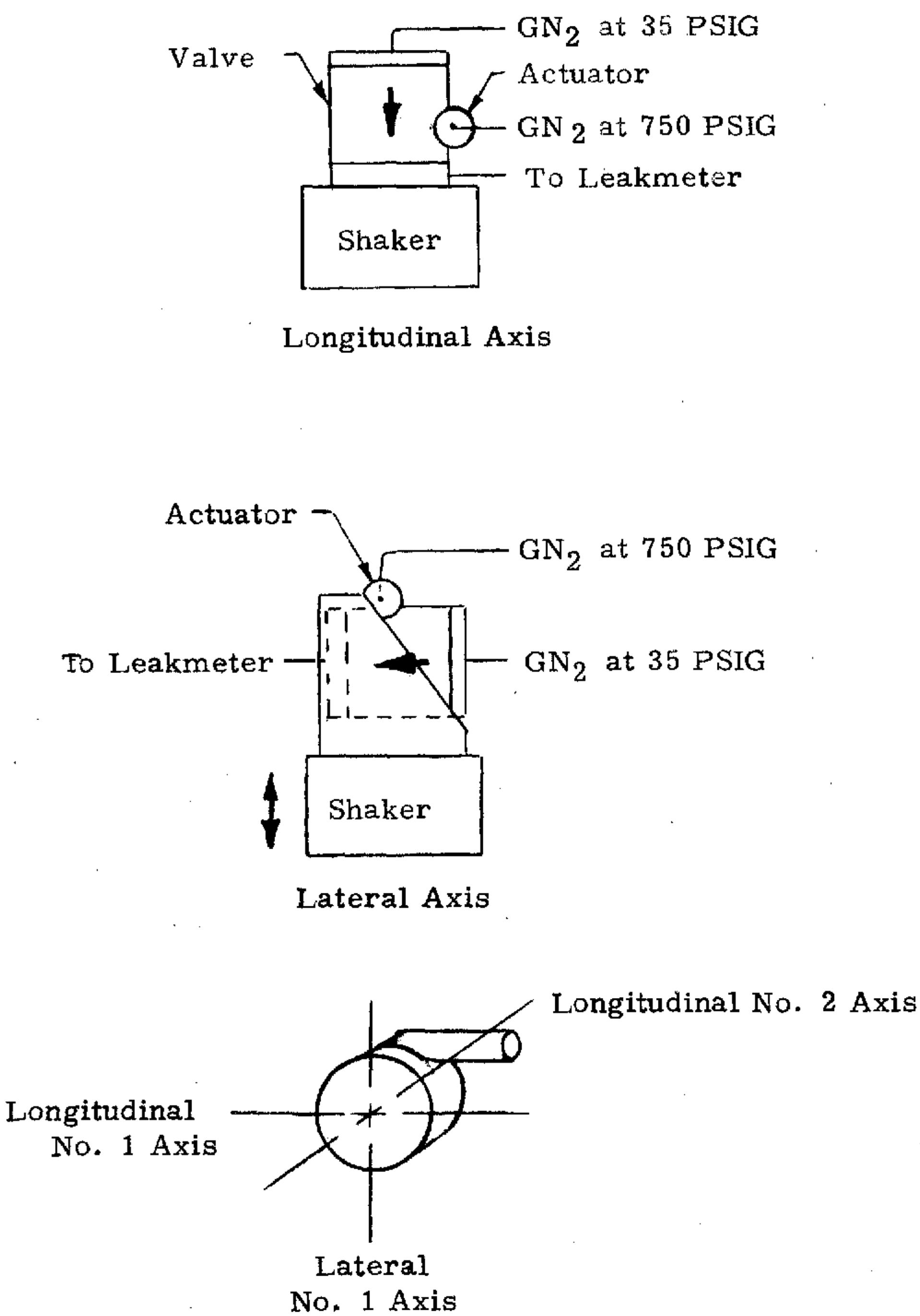


Figure 4-17. Schematic Diagram, Vibration Test Setup and Axis Identification

Table 4-9

Component Leakage, SCCM
Vibration Test

Description		Main Seal	Shaft Seal	Open Actuator	Close Actuator
Leakage Test Prior to Vibration Tests		39			1968
Lateral No. 1 Axis Sinusoidal Sweep Closed Valve	Before During After	56 - 34			1886 - 1640
Lateral No. 1 Axis Sinusoidal Sweep Open Valve	Before During After		230 - -	260 - -	
Lateral No. 1 Axis (1) Random Vibration Closed Valve	Before During After	39 39 100			2050/1640 1840 1476
Lateral No. 1 Axis Sinusoidal Sweep Closed Valve (Retest)	Before During After	10 38 38			1501/1722 1558 1558
Lateral No. 1 Axis Random Vibration Closed Valve	Before During After	38 49 38			1312 1394 1476
Longitudinal No. 1 Axis Sinusoidal Sweep (2) Closed Valve	Before During After	39 39 -			1968/1886 1886 -
Longitudinal No. 1 Axis Sinusoidal Sweep Closed Valve (Retest)	Before During After	39 39 9.2			1968/1804 1640 1394
Longitudinal No. 1 Axis Sinusoidal Sweep (3) Open Valve	Before During After		235 - -	5 - -	

NOTES:

(1) Mounting bolts sheared
(2) Fixture lifting off slip plate; test stopped at 430 Hz
(3) Lost stroke indicator rod; test stopped at 350 Hz; plug installed

Table 4-9 (continued)
Component Leakage, SCCM
Vibration Test

Description		Main Seal	Shaft Seal	Open Actuator	Close Actuator
Longitudinal No. 1 Axis Sinusoidal Sweep Open Valve (Retest)	Before During After		115 - -	155 - -	
Longitudinal No. 1 Axis Random Vibration Closed Valve	Before During After	41 51/75 41			1640/1640 1394 1391
Longitudinal No. 2 Axis Sinusoidal Sweep Closed Valve	Before During After	39.2 30 49			1886/1722 1476 1476
Longitudinal No. 2 Axis Sinusoidal Sweep Open Valve	Before During After		400 - -	240 - -	
Longitudinal No. 2 Axis Random Vibration Closed Valve	Before During After	41 56 36			1804/1640 1394 1394

4.5.4 Vibration in Lateral No. 1 Axis

Following the leakage test, the test specimen successfully completed the sinusoidal vibration sweeps in the Lateral No. 1 axis with the valve poppet in the open and closed positions. After two minutes of the required five minutes of random vibration, the run was stopped due to sheared and loosened mounting screws. The location of damaged and loosened screws is shown in Figure 4-18. A description of the required rework is presented in paragraph 3.2.10.

Following the rework of the test specimen at Fairchild, the unit was returned to AETL and successfully re-subjected to sinusoidal and random vibration with the valve poppet in the closed position. During the sinusoidal sweep, the cable to the No. 2 accelerometer was loose. This was corrected for the random vibration run.

4.5.5 Vibration in Longitudinal No. 1 Axis

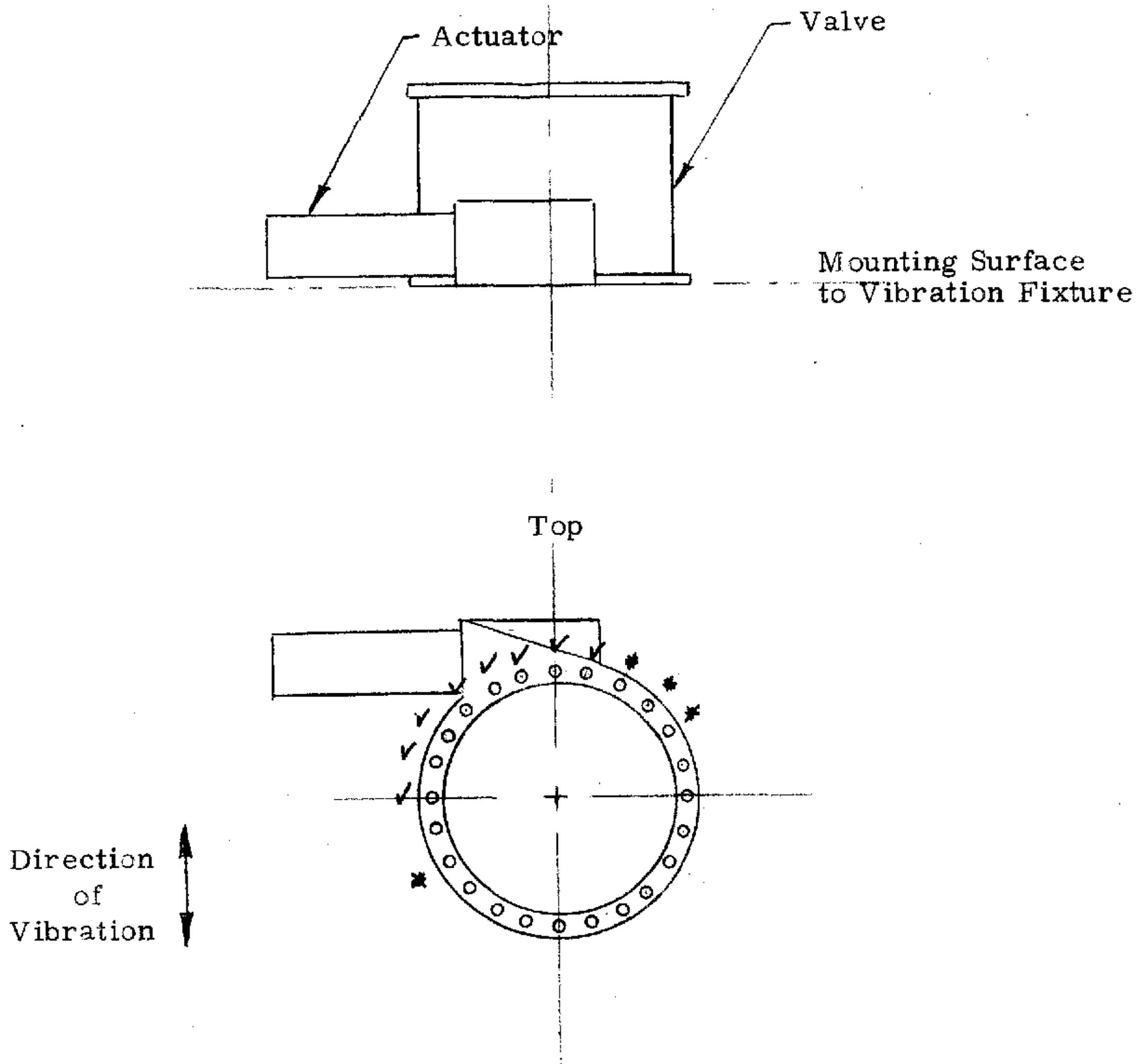
With the test specimen installed in the Longitudinal No. 1 axis test setup shown in Figure 4-19, the unit was subjected to a sinusoidal vibration sweep. The run was discontinued at 130 Hz due to the fixture lifting off the slip plate of the vibration machine. The problem was attributed to the high center of gravity of the test specimen. The test setup was reworked by installing the present test fixture on a four foot square by two inch thick slide plate. This had the effect of lowering the center of gravity of the test unit and fixture. There was no apparent damage to the test specimen.

The sinusoidal sweep with the valve in the closed position was successfully completed. The sweep with the valve in the open position was discontinued at 350 Hz due to excessive leakage through the stroke indicator rod hole in the actuator housing. During the run, the indicator rod from the potentrometer had vibrated loose (unscrewed) and blew out. The damaged components were reworked at Fairchild. See paragraph 3.2.11 for a description of the rework.

Following the rework, the unit successfully completed the sinusoidal sweep with the valve in the open position and the random vibration with the valve in the closed position.

4.5.6 Vibration in Longitudinal No. 2 Axis

The test specimen was installed in the longitudinal No. 2 axis, shown in Figure 4-20, and successfully completed the sinusoidal sweep with the valve poppet in the open and in the closed positions, and the random vibration with the valve in the closed position.



* - Broken Screws (4 pieces)

✓ - Loose Screws (9 pieces)

24 Total Screws

Figure 4-18. Mounting Failure During Random Vibration in Lateral No. 1 Axis

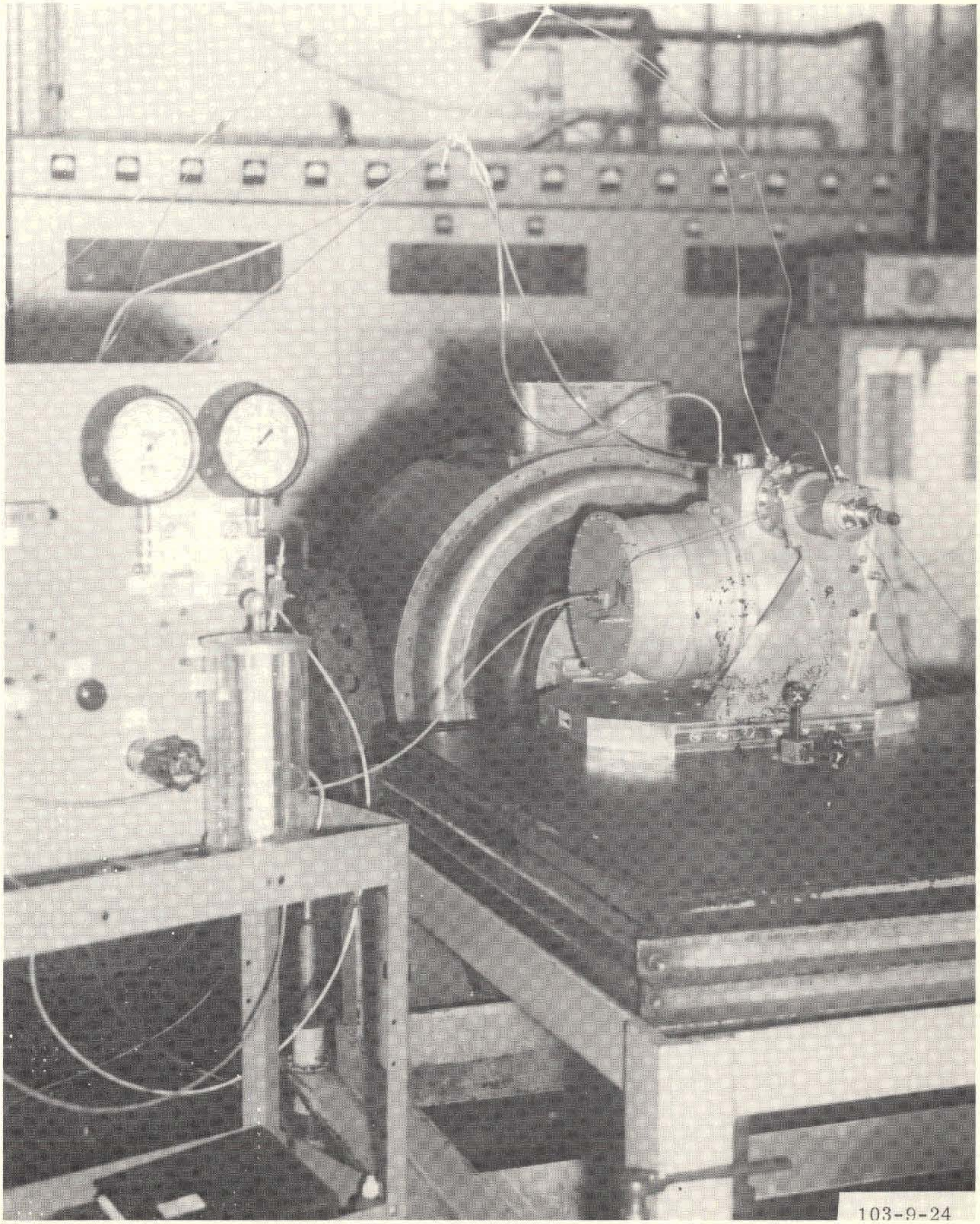


Figure 4-19. Test Setup, Vibration in Longitudinal No. 1 Axis

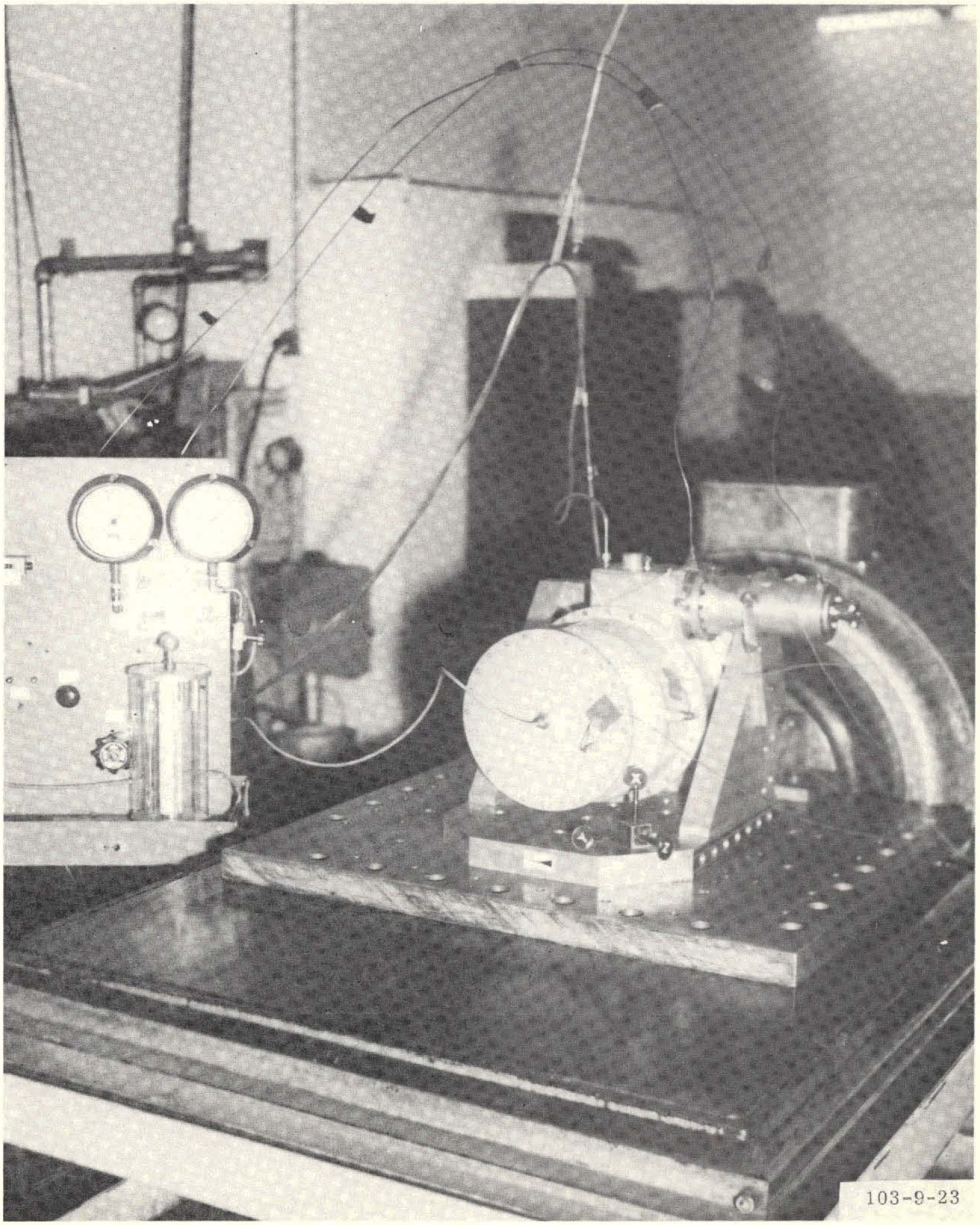


Figure 4-20. Modified Test Setup, Vibration in Longitudinal No. 2 Axis

4.5.7 Leakage and Response After Vibration Testing

Following the vibration testing, the test specimen was subjected to the leakage and response tests described in paragraphs 4.4.2.1 and 4.4.2.2. Component leakages are presented in Table 4-6. The time responses are presented in Table 4-7.

4.6 FLOW CAPACITY TEST

The test specimen was installed in the flow capacity test setup shown in Figures 4-21, 4-22 and 4-23. With 750 psig nitrogen applied to the "close" actuator port, the ullage was pressurized to 35 psig with the supply compressors. Simultaneously, the "close" port was vented,and the "open" port was pressurized with 750 psig nitrogen. The inlet, outlet and nozzle pressures were recorded during the blowdown. Flow and valve pressure drop at ten valve inlet pressures are presented in Table 4-10, as well as valve outlet Mach Number. The maximum valve discharge Mach Number was established by the flow orifice area in relation to the flow area of the 10-inch discharge pipe.

The pressure drop conditions are normalized by the use of the pressure drop coefficient K where

$$K = \frac{\Delta P}{\rho V^2 / 2 g_c}$$

Where: ΔP = Pressure drop across valve
ρ = Outlet fluid density
V = Outlet fluid velocity
g_c = Gravitational constant

This data is also presented in Table 4-10.

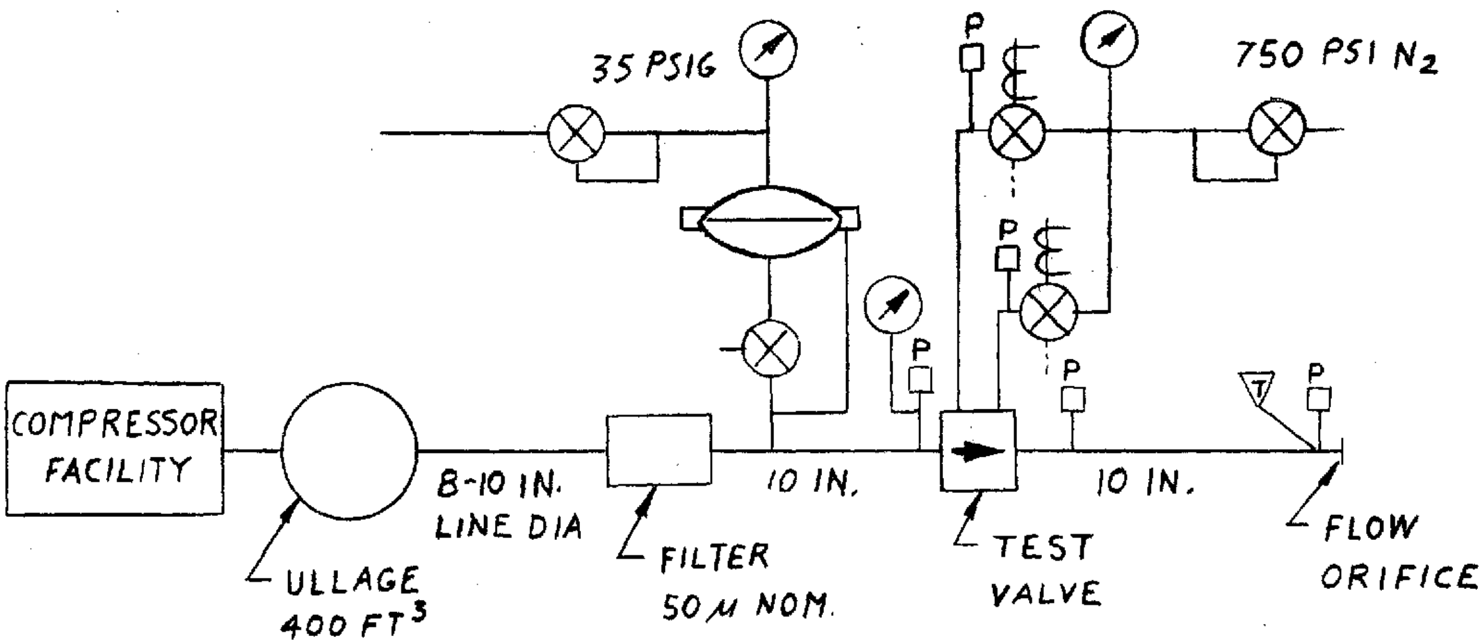


Figure 4-21. Schematic Diagram, Flow Capacity Test Setup

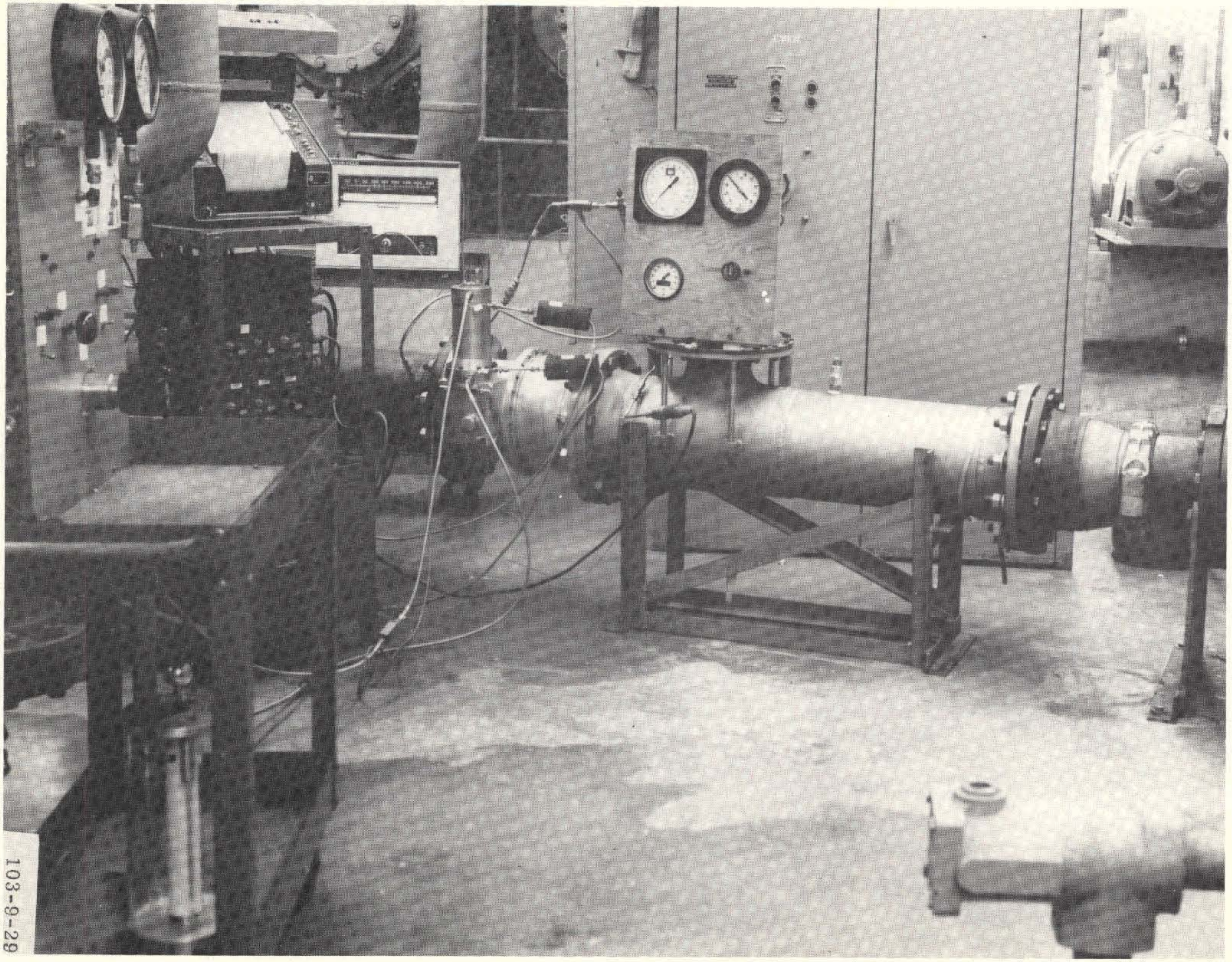


Figure 4-22. Test Setup, Flow Capacity Test, View of Test Specimen and Test Instrumentation

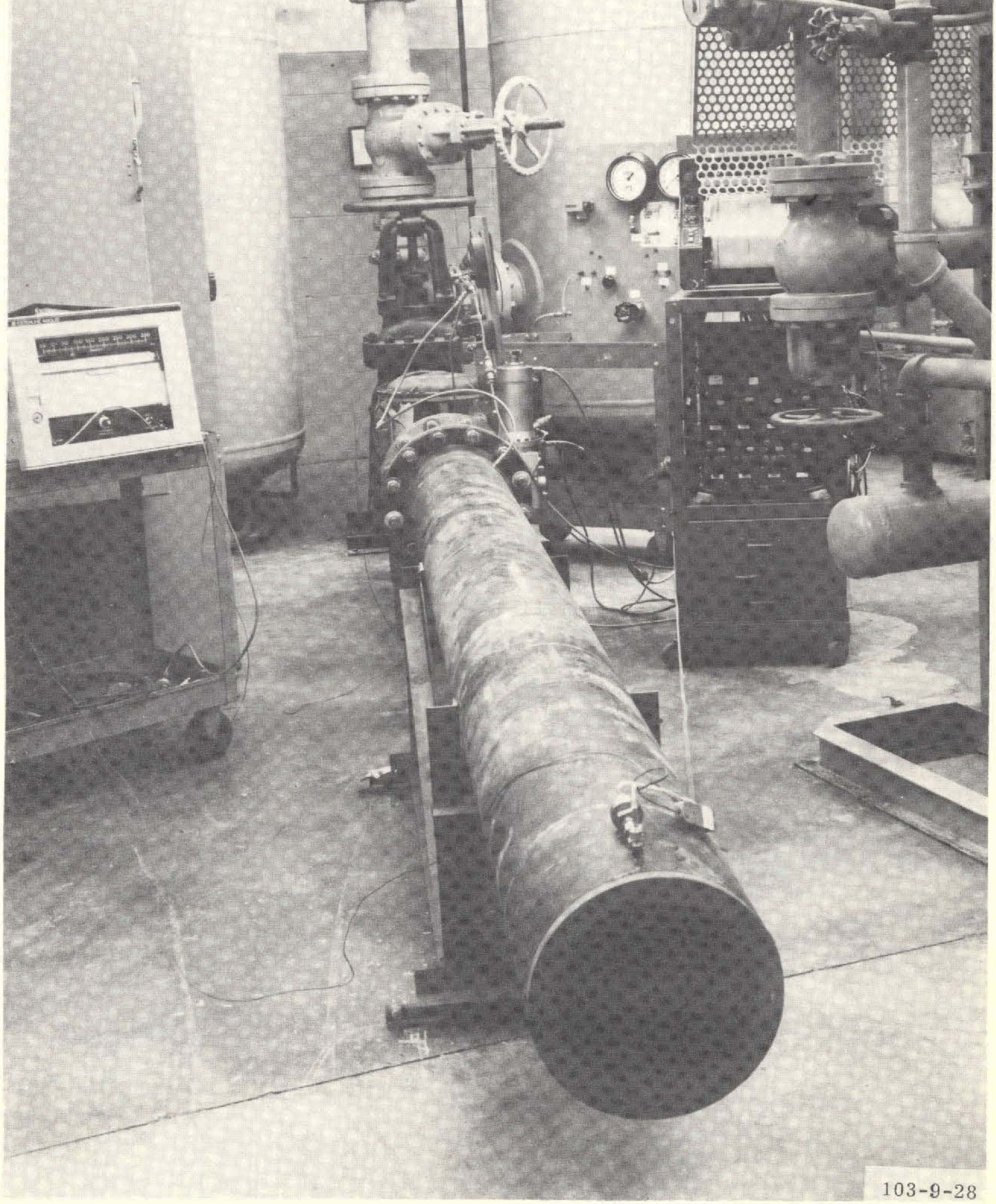


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Figure 4-23. Test Setup, Flow Capacity Test
View of Diffuser Section

Table 4-10

Flow Capacity Test Data

Item No.	Total Inlet Pressure PSIG	Flow SCFM Air	Pressure Drop PSIG	Outlet Mach No.	Resistance Coefficient K
1	31.37	24,040	15.5	0.460	4.65
2	30.04	23,500	14.1	0.460	4.31
3	28.38	22,384	13.0	0.445	4.45
4	26.74	21,000	12.2	0.423	4.77
5	26.06	20,510	11.2	0.435	4.24
6	24.85	19,580	10.1	0.425	4.12
7	24.23	18,984	9.2	0.428	3.72
8	23.23	17,980	8.0	0.400	3.79
9	22.58	17,512	7.6	0.405	3.58
10	22.42	17,312	7.2	0.400	3.46

4.7 NONDESTRUCTIVE BURST TEST

The test specimen was successfully subjected to the following nondestructive burst test. The test specimen, with the leakage flange plates installed on both ends, was placed in the proof chamber. Figure 4-24 presents a view of the unit in the test setup.

The "close" actuator port was pressurized to 750 psig with nitrogen gas. The valve inlet was slowly pressurized to 87.5 psig with nitrogen and held at this pressure for 5 minutes. The pressures were relieved, and the test specimen was visually examined for permanent distortion. None was visible.

The "open" actuator port was pressurized to 750 psig. The valve inlet was slowly pressurized to 87.5 psig and held for 5 minutes. The pressures were relieved, and the test specimen was visually examined for permanent distortion. None was visible.

The "close" actuator port was pressurized to 1875 psig with water and held for 5 minutes. The pressure was relieved, and the test specimen was visually examined for permanent distortion. None was found.

The "open" actuator port was pressurized to 1875 psig with water and held for 5 minutes. The pressure was relieved, and the test specimen was visually examined for permanent distortion. None was found.

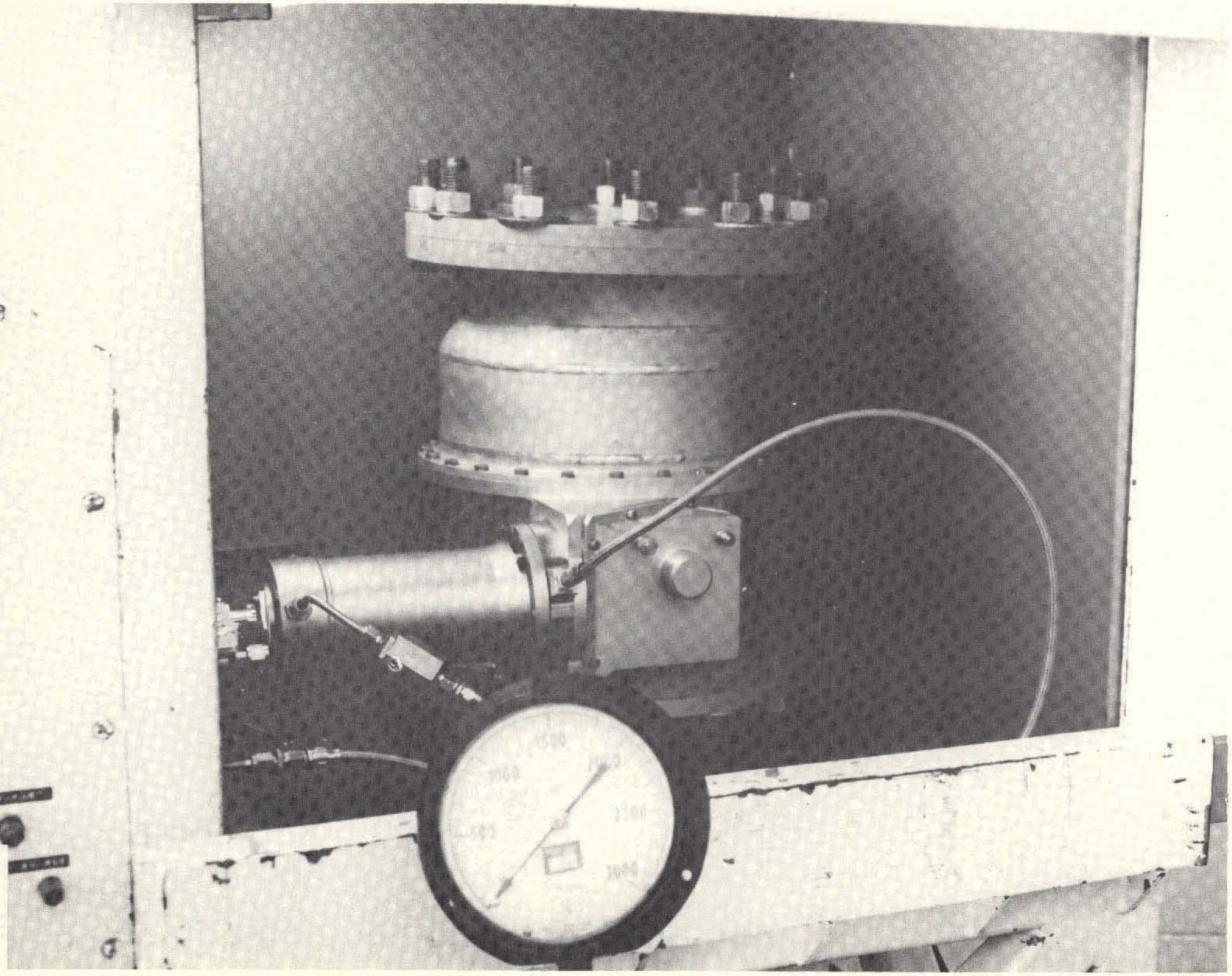

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Figure 4-24. Test Setup, Nondestructive Burst Test

4.8 FINAL DISASSEMBLY AND INSPECTION

The test specimen was disassembled and inspected for signs of distortion and excessive wear. The component dimensions and finishes that were recorded in Paragraph 4.1 were remeasured. The results, along with the change in dimensions due to wear, are presented in Table 4-1. Photographs of components to show their condition after the completion of the test program are presented in Figures 4-25 through 4-33.

Figure 4-25 presents a view of the piston assembly with an all-over view of the surfaces and contamination.

Figure 4-26 shows a view of the small piston seal surface and contamination.

Figure 4-27 shows a view of the rod end large diameter piston seal surface and contamination.

Figures 4-28 and 4-29 present views of the large diameter Omniseal at the head end of the piston. The surface condition and contamination are clearly shown.

The surface condition and contamination of the Sleeve Assembly, 966085, are shown in Figures 4-30 and 4-31.

Figure 4-32 presents a view of the poppet main sealing surface condition.

Particle contamination of the main seal is shown in Figure 4-33.

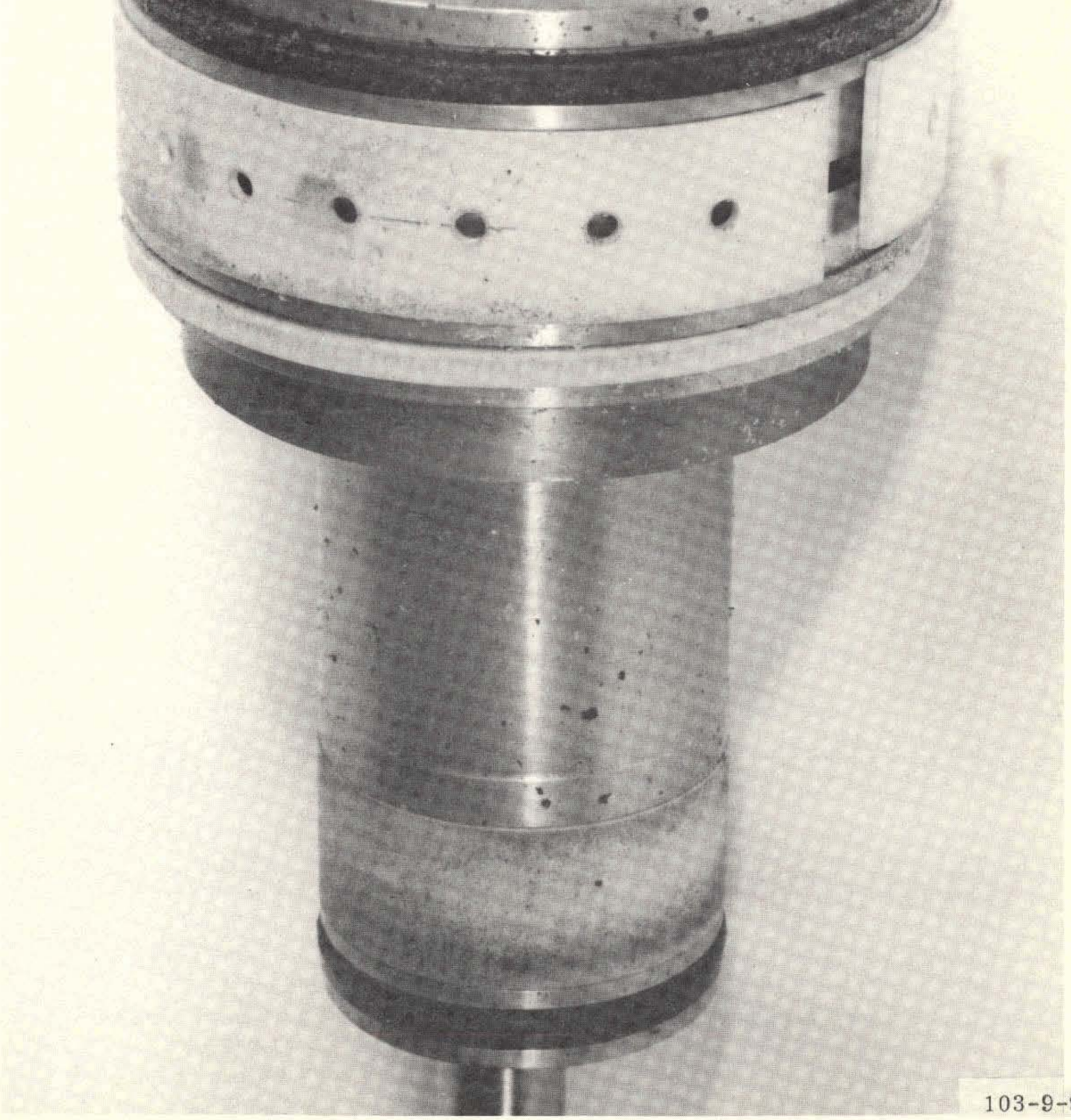

Figure 4-25. Piston Assembly Contamination
Final Disassembly and Inspection

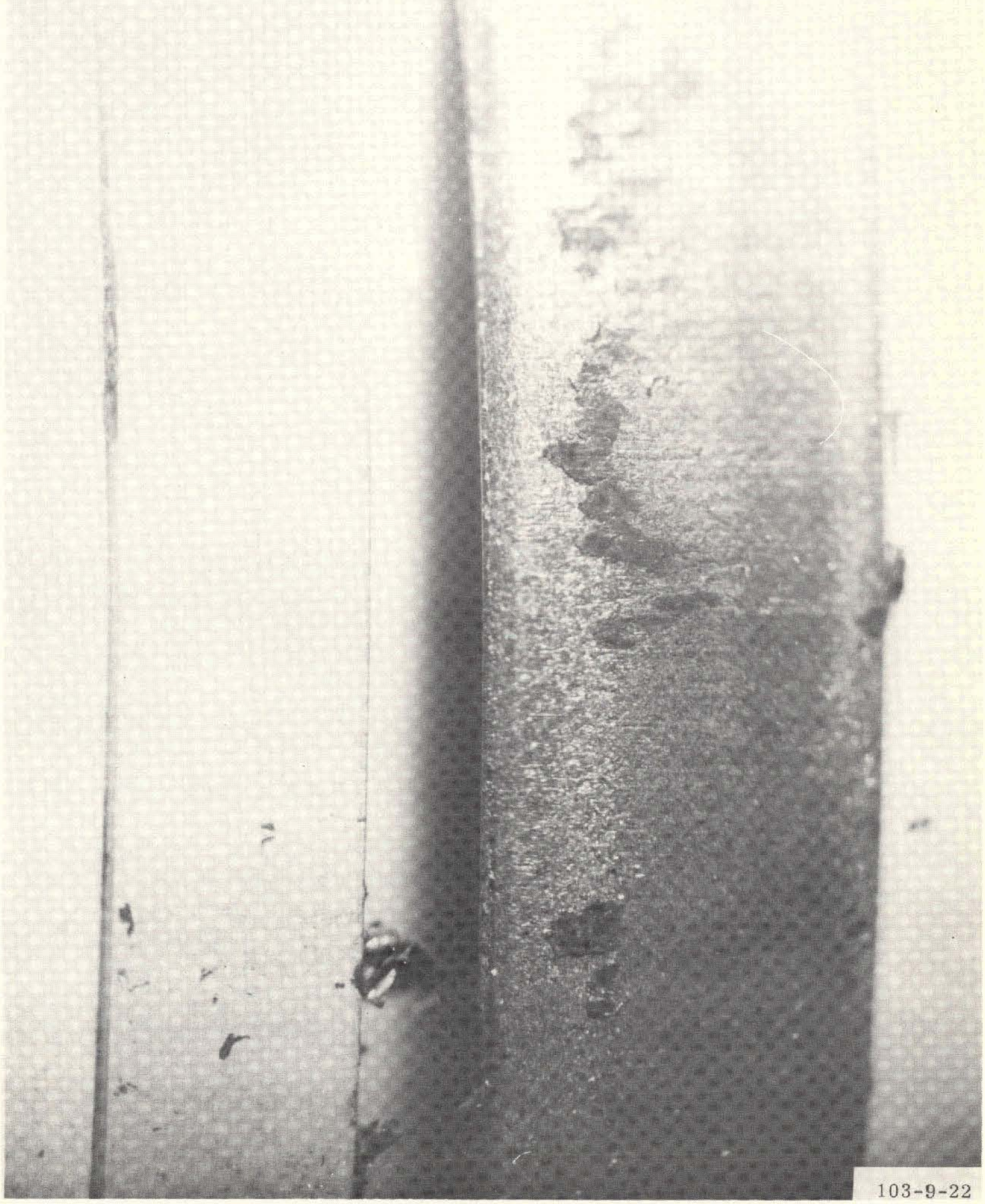

Figure 4-26. Small Piston Seal Surface Condition and Contamination
Final Disassembly and Inspection

Figure 4-27. Rod End Piston Seal Surface Condition and Contamination Final Disassembly and Inspection

Figure 4-28. Piston Head End Seal Surface Condition and Contamination Final Disassembly and Inspection

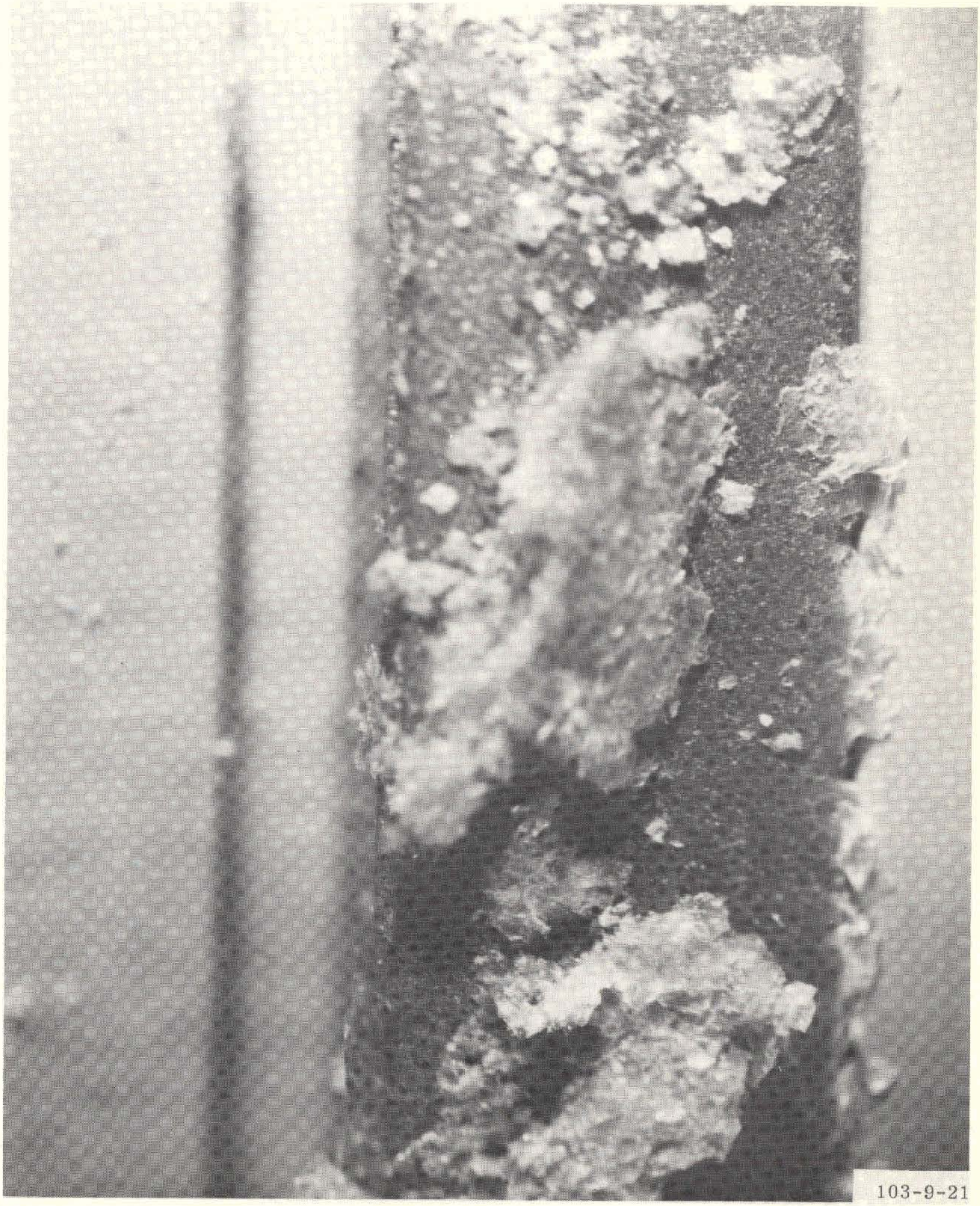

Figure 4-29. Enlarged View of Piston Head End Seal Surface Condition and Contamination. Final Disassembly and Inspection

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STRATOS DIVISION
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103-9-10

Figure 4-30. Sleeve Assembly 966085
Surface Condition and Contamination
Final Disassembly and Inspection

103-9-19

Figure 4-31. Sleeve Assembly 966085
Outer Sleeve Surface Condition
Final Disassembly and Inspection

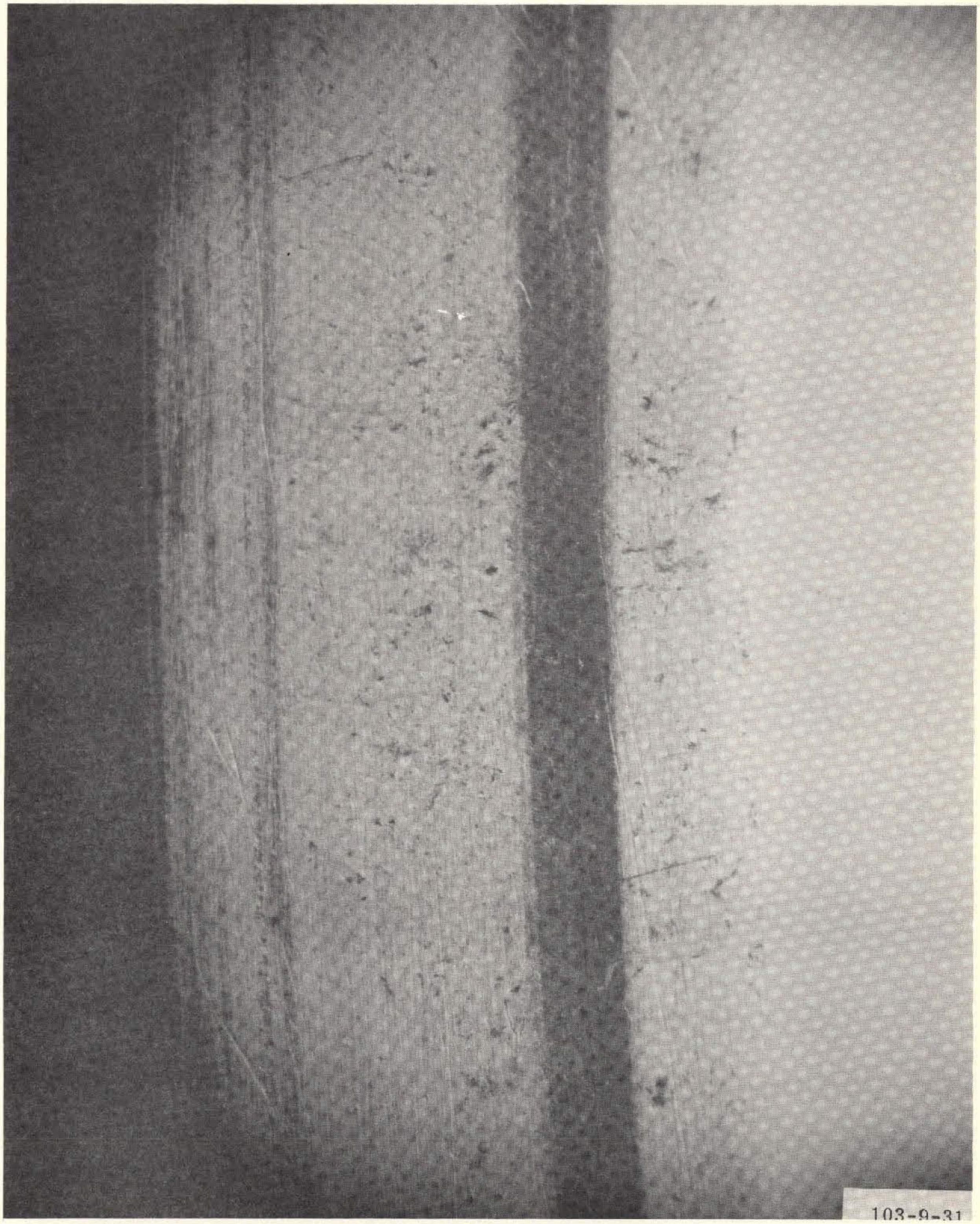


Figure 4-32. Poppet Main Sealing Surface Condition
Final Disassembly and Inspection

Figure 4-33. Main Seal Particle Contamination
Final Disassembly and Inspection

SECTION 5

DISCUSSION

5.1 CONFIGURATION CHANGE

The actuator configuration was changed from a bellows type to a piston type after 696 cycles of low temperature life cycling. Bellows leakage had occurred during the low temperature cycling. The failure analysis of the outer bellows assembly, PN 966057, indicated that the unit was incorrectly designed to meet the 20,000 cycle objective. The unit, as originally designed, was subjected to a 2-inch compression cycle from the neutral position with 750 psig external pressure and then extended back to the neutral position with 750 psig internal pressure. A review of the bellows design revealed that the motion stress of the bellows alone was commensurate with the 20,000 cycle design goal,but when this motion stress was combined with the pressure stress due to the 750 psig pressure, the cycle life indicated was less than 600 cycles.

An attempt was made to redesign the bellows for the pressure stress, as well as the motion stress within the original specified envelope. The original design was as good as could be attained. Increasing the number of convolutions to reduce the motion stress also makes the squirm (lateral misalignment and deformation) problem of internal pressurization more severe.

A practical solution would be to reduce the bellows stroke to the order of one inch, with a proportional increase of the bellows effective area to equalize the pressure and motion stresses. This charge would require new actuator components as well as revision of the actuator link and link support for the higher loading.

Because the program objective was to develop long life valve concepts, the decision was made to minimize further delays by changing the actuator to a piston type configuration.

5.2 COMPONENT REPLACEMENT AND REWORK

The main seal, PN 966072, was replaced once and refinished once during the demonstration testing. The original seal had accumulated a total of 2479 cycles, and the replacement seal had accumulated 4462 cycles prior to being refinished. By the end of testing, the replacement seal which had been refinished had accumulated 13,102 cycles for a total of 17,564 cycles.

The shaft seal, PN 966076, was replaced once during the testing. The original seal had accumulated 10,039 cycles. The replacement seal had accumulated 10,004 cycles.

The actuator piston link, PN 996046, failed during the demonstration testing. The original link had accumulated 6226 cycles, and the redesigned link had completed a total of 13,803 cycles. The redesign of the link consisted of increasing the cross section at the high stress areas. During a piston seal replacement at 770 total valve cycles, heavy impact markings had been noticed on the actuator linkage. At this time a separate "open" stop was added to the piston cylinder to alleviate this problem.

The low cycle life of the original seals is attributed to test system contamination which was corrected by installation of 10 micron filters in the test system.

5.3 LEAKAGE

Representative main seal leakages for the life cycling are listed:

Cycles	Cryo Temp Cycling (SCCM)	High Temp Cycling (SCCM)
Room Temperature	33	28
Extreme Temperature	249	270

The above leakage values are what could be expected at room temperature and at -200°F and +200°F. Differential expansion at the temperature extremes appears to be the problem.

5.4 RESPONSE TIME

Response times were measured during the low temperature and the high temperature life cycling. Typical values are listed below:

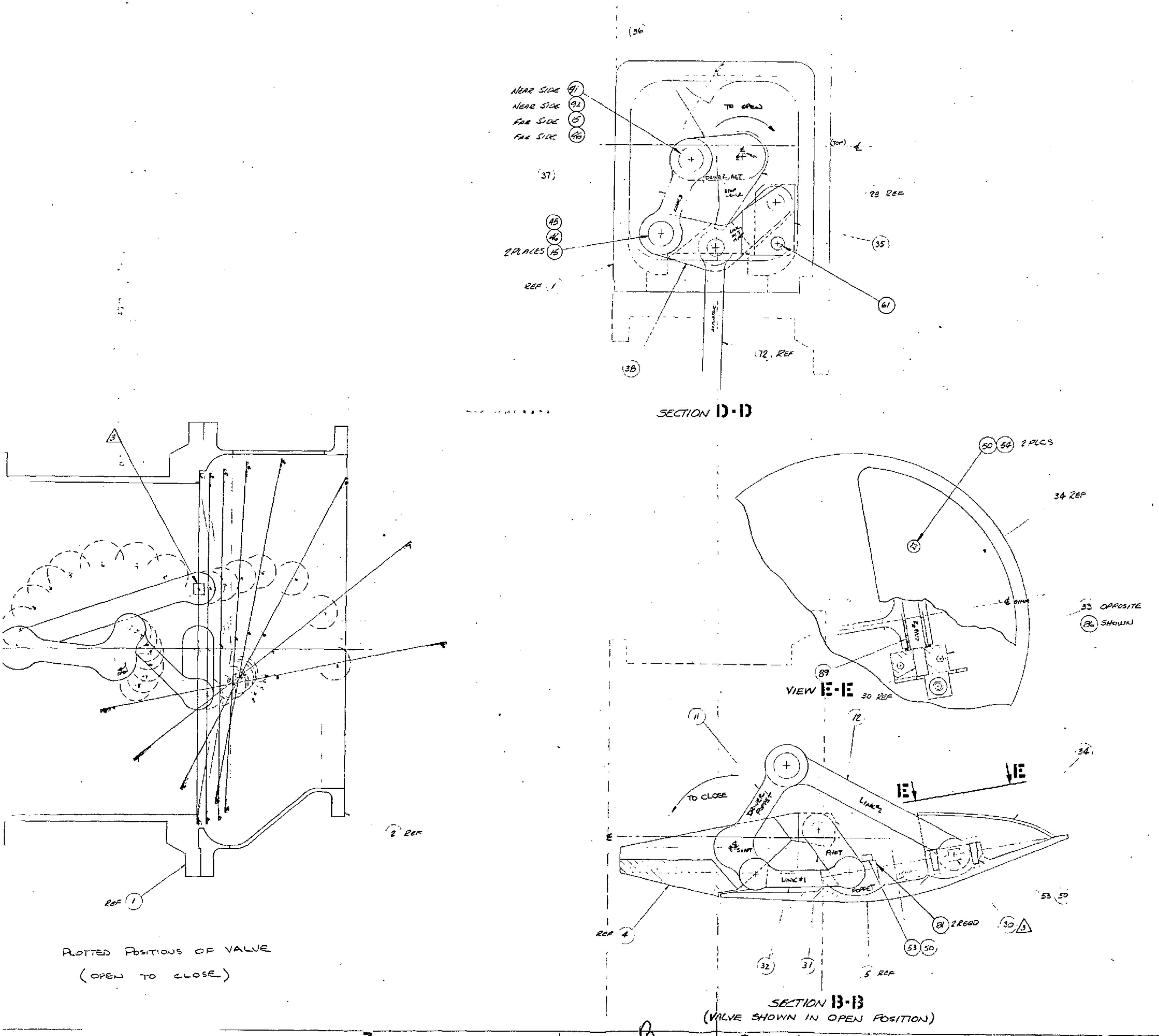
Test Condition	Open-to-Close(Sec)	Close-to-Open (Sec)
Room Temp. (during cryo testing)	0.8	0.4
-200°F.	1.3	0.2
+200°F.	0.7	0.2
Room Temp. (during high temp. testing)	0.7	0.2

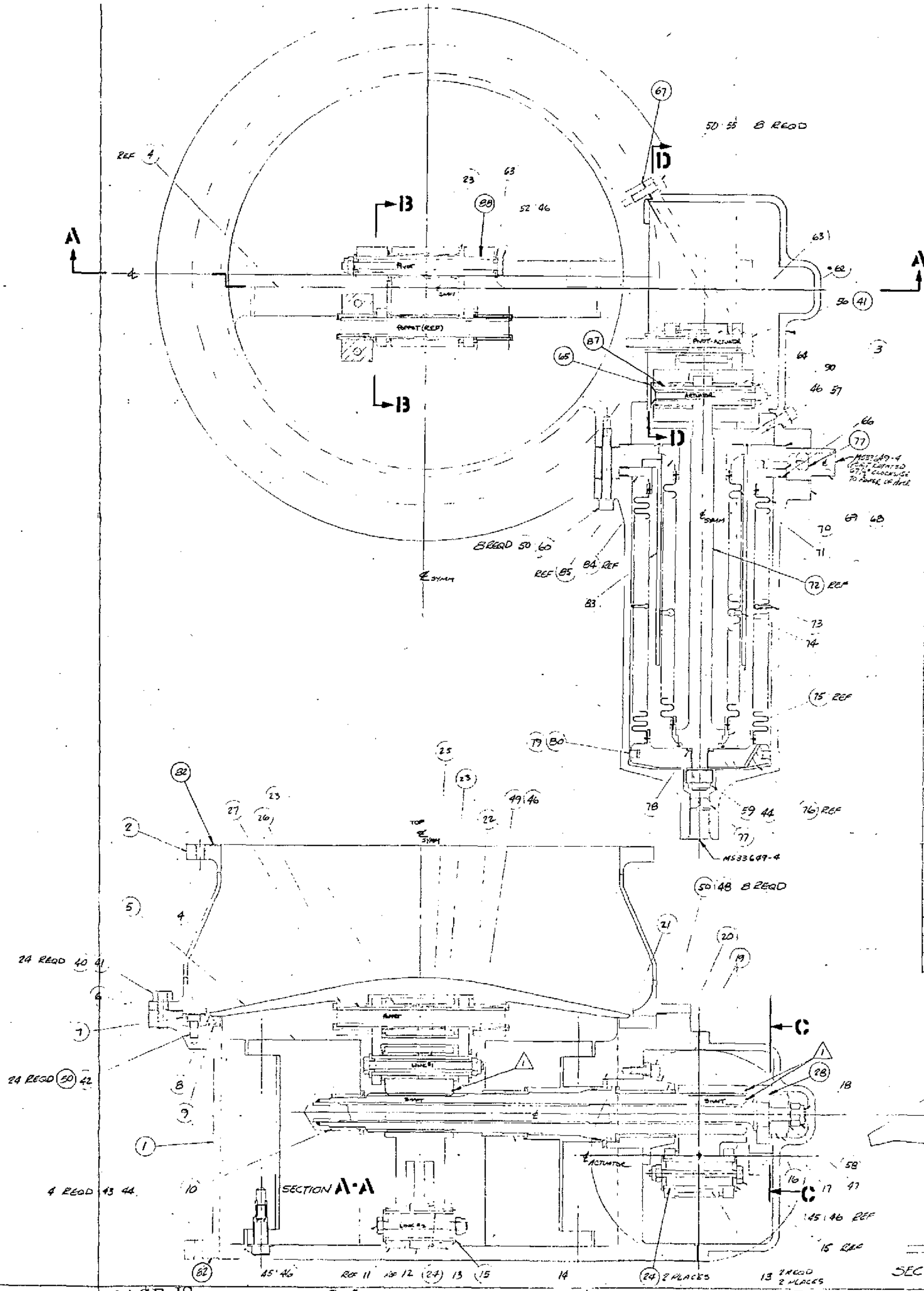
APPENDIX A

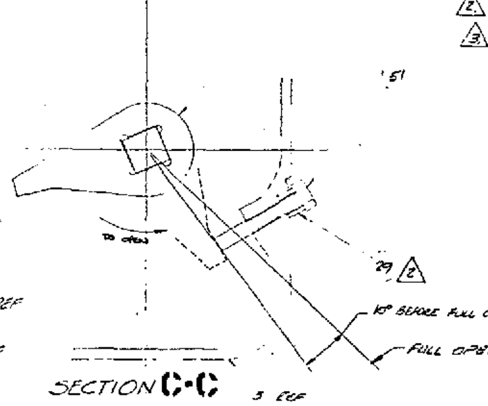
Drawing 966001, Rev. B

(1 Sheet)

LTR	DESCRIPTION	DATE	APPD
A	ITEM 19: 966031-7 WAS 966033-7		
B	ITEM 43: #4441 WAS MS51975-9 ADDED ITEM 91 & 92 SECTION DD: REVISED LINKAGE HARDWARE		







1		SCREW, 100° FLAT	MS24693-76				92
1		KEEPER	966032-6				91
1		KEEPER	966032-1				90
2		BEARING	966031-3				89
1		SLEEVE	966035-3				88
1		SLEEVE	966035-4				87
1		SUPPORT, DEFLECTOR R.H.	966065				86
REF		FIXED END BELLOWS OUTER BELLOWS	966060	PART OF 70			85
REF		FIXED END FITTING INNER BELLOWS	966059	PART OF 71			84
1		SUPPORT GUIDE	966042				83
2		SEAL, FACE INLET & OUTLET	966070-3	SHIPPED AS LOOSE ITEMS			82
2		BLOCK, ALLOW	966069				81
1		RING	966079				80
1		EXPANDER	966078				79
1		SEAL, FACE (BELLOWS)	966070-1				78
2		ORIFICE	966073				77
REF		FREE END FITTING OUTER BELLOWS	966043	PART OF 70			76
REF		FREE END FITTING INNER BELLOWS	966058	PART OF 71			75
1		GUIDE, INNER	966055				74
1		GUIDE, OUTER	966054				73
REF		SHAFT, ACTUATOR	966049	PART OF 71			72
1		BELLOWS ASSY - INNER	966056				71
1		BELLOWS ASSY - OUTER	966057				70
1		HOUSING	966050				69
1		MANIFOLD	966061				68
1		GASKET, COVER	966066				67
3		SEAL, FACE, ACT.	966070-4				66
1		KEEPER, MODIFIED	966032-5				65
2		BEARING	966033-2				64
2		KEEPER	966032-5				63
2		BEARING	966031-4				62

NOTES:

1. ALIGN INDEX MARKS AS NOTED WHEN ASSEMBLING.
2. SHORTEN ITEM 29 AS REQD TO OBTAIN 10° DIMENSION.
3. POSITION OF SQUARE IN RETAINERS ACTS AS ADJUSTMENT ℄ OF SQUARE IS OFF CENTER REFER TO DETAIL DWG TO ASSEMBLE.

QTY REQD	CODE IDENT	DESCRIPTION	PART NO.	SPECIFICATION	MATERIAL	ZONE	ITEM NO.
1		BOLT, HEX 3/8-24 × 2.88	AN3C27A				61
8		SCREW, CAP 10-32 × 2.00	NAS1351C3-32				60
1		NUT SELF LOCK 3/8-24	MS21083-C6				59
1		NUT, SELF LOCK 5/16-24	MS21083-C5				58
1		SCREW, 100° FLAT 10-32 × 3.00	MS24693-298				57
1		BOLT, HEX 1/4-28 × 3.03	AN C30A				56
8		SCREW, CAP 10-32 × .62	NAS1351C310				55
2		SCREW, PAN 10-32 × .50	MS51958-63				54
8		SCREW, CAP 10-32 × .62	NAS1351C3-10				53
1		BOLT, HEX 10-32 × 3.90	AN3C37A				52
1		BOLT, HEX 1/4-28 × 1.53	AN4C14A				51
55		WASHER #10	NAS620C10L				50
1		BOLT, HEX 10-32 × 2.90	AN3C27A				49
9		SCREW, CAP 10-32 × .50	NAS1351C3-8				48
1		WASHER 5/16	AN960C516L				47
6		NUT, SELF LOCK 10-32	MS21083-C3				46
3		BOLT, HEX 10-32 × 2.15	AN3C21A				45
5		WASHER 3/8	AN960C616L				44
4		BOLT - SHOULDER 1/4-20	P/N 4441	AC DESIGN CORP VAN NUYS CA			43
24		SCREW, CAP 10-32 × .38	NAS1351C3-6				42
25		WASHER 1/4	AN960C416L				41
24		BOLT, HEX 1/4-28 × .78	AN4C6A				40
1		LINK, ACT. PIVOT	966046				38
1		LINK #3	966045				37
1		DRIVER, ACTUATOR	966047				36
1		PIVOT BLOCK	966077				35
1		DEFLECTOR	966063				34
1		SUPPORT, DEFLECTOR L.H.	966064				33
1		LINK #1	966037				32
1		LINK, POPPET PIVOT	966044				31
1		SHAFT, ADJUSTABLE (POPPET)	966062				30
1		SPACER, STOP	966071				29
1		STOP LEVER	966036				28
2		BEARING	966052				27
2		SLEEVE	966035-5				26
2		SLEEVE	966035-1				25
4		SLEEVE	966035-2				24
6		BEARING	966031-5				23
2		KEEPER	966032-4				22
1		LIP SEAL	966076				21
1		RETAINER, LIP SEAL	966040				20
1		BEARING	966031-7				19
1		TORSION SHAFT ASSY	966067				18
1		BEARING	966033-1				17
1		BUSHING, COVER	966074				16
6		KEEPER	966032-2				15
1		BEARING	966031-6				14
6		BEARING	966031-2				13
1		LINK #2	966034				12
1		DRIVER, POPPET	966048				11
1		BEARING	966031-1				10
1		SEAT	966072				9
1		DISC SPRING	966075				8
1		RETAINER, SEAT	966039				7
1		FLANGE SEAL, MAIN	966070-2				6
1		POPPET ASSY	966053				5
1		SUPPORT	966038				4
1		COVER	966051				3
1		DUCT ASSY	966068				2
1		BODY ASSY	966041				1

LIST OF MATERIALS OR PARTS LIST

QTY	NEXT ASSY	USED ON
	FINAL	966000

APPLICATION

EXCEPT AS SPECIFIED
A. DIM. ARE IN INCHES
B. DIM. APPLY AFTER PLATING
C. BREAK EDGES .015R MAX
D. INTERNAL CORNERS .015R MAX
E. CONCENTRICITIES .010 TIR
F. PARALLELISMS .010 IN./IN.
G. SQUARENESS .010 IN./IN.
H. ANGLES ± 0° 30'
I. MACHINED SURFACES ASA B46.1 ✓
J. .XX = ± .03 .XXX = ± .010
K. DIMENSIONS PER USASI Y14.5
L. THREADS PER MIL-S-7742
M. REMOVE ALL BURRS

FINISH | HEAT TREAT

CONTRACT NO.
DR | APPD | APPD | APPD | APPD
APPROVAL
APPROVAL

FAIRCHILD

10" VALVE

SIZE: J | CODE IDENT NO.: 01359 | DWG NO.: 966001

SCALE | SHEET

APPENDIX B
Stainless Steel Products
Bellows
Failure Report

Report No. 2646
(2 pages)

219

FAILURE ANALYSIS REPORT

STAINLESS STEEL PRODUCTS, Burbank, CA.

Date of Report 1/25/74 Report No. 2648

SSP Part No. 2207636-101 Serial No. ______ Part Name Bellows Assy. Outer

Customer Part No. 966057 Ref: Failure Report No. -

HISTORY: The bellows assembly was installed in a valve and cycled to failure @ 696 cycles; per Fairchild Stratos AVO dated 20 December 1973. A cycle consists of bellows motion from neutral to 2" compression to neutral with 700 psig external pressure to 700 psig internal pressure cycling. The requirement is for 20,000 cycles.

INVESTIGATION AND ANALYSIS:

See attached sheets

CONCLUSIONS AND RECOMMENDATIONS:

It is concluded that the bellows design was not adequate for the total requirement and a bellows will not function for the required cycles of motion and pressure within the envelope specified.

SIGNATURES:

Name of Analyst H R Thompson Date 1/25/74

Approval ______

Customer Fairchild - Stratos

Address ______

INVESTIGATION AND ANALYSIS:

The bellows assembly was visually examined upon receipt of part at SSP Products. This examination revealed a large crack in the outer ply at the crest of one convolution and cracks in the inner ply at the crest of all convolutions. In addition, a crack was found in the outer ply of one convolution at the root.

The end fittings were removed from the bellows and the bellows sectioned and mounted for examination.

The material thickness of each ply was measured at the root, peak and sidewall using a microscope. The thicknesses measured were as follows:

Inner Ply			Middle Ply			Outer Ply		
Root	Side	Crest	Root	Side	Crest	Root	Side	Crest
.010	.010	.009	.010	.010	.009	.010	.010	.009
.010	.010	.009	.010	.010	.009	.010	.010	.009

This indicates approximately 10% thinning at the crest of the convolution which is normal for the height of convolution forming on this bellows.

The hardness of the material was measured using a microhardness testing machine. The following readings were obtained:

Crest	Side	Root
580 Knoop	440-457 Knoop	645 Knoop
53 Rc	42-43 Rc	56 Rc

The sidewall reading is normal for Inconel 718 heat treated material. The higher readings at the crest and root are an indication of strain hardening resulting from the high stresses during bellows cycling.

The mounted section was polished and etched to observe the material grain structure. The structure appears normal with a grain size of approximately #6.

In addition the forming radii at the crest and root of the convolutions were observed to be normal.

No problems were observed with respect to material forming or processing.

The bellows design was reviewed with respect to performance requirements and the resulting induced stresses. This review indicates that stresses due to the 2" compression cycle alone were comensurate with the 20,000 cycle requirement. However, when the stress due to pressure cycling is combined with the motion stress the cycle life indicated is less than 600 cycles. The design apparently did not consider the pressure cycling.

An attempt has been made to design a bellows for the pressure cycling as well as the motion within the envelope specified. The original design was as good as could be attained.

APPENDIX C

AETL
VIBRATION TEST REPORT
Report No. 5330-1203
(60 pages)

APPROVED ENGINEERING TEST LABORATORIES

Report No. 5330-1203
P. O. No. 8-23028 222
Date: 8 July 1974

57 Page Report

Test Report No. 5330-1203

Vibration Test Report

on

Ten-Inch Long Life Valve

Part Number 966000
Serial Number 0001

TESTED FOR: FAIRCHILD/STRATOS DIVISION
1800 Rosecrans Avenue
Manhattan Beach, California 90266

TESTED BY: APPROVED ENGINEERING TEST LABS
5320 W. 104th Street
Los Angeles, California 90045

OFFICIAL SEAL
KARL G. SCHMIDT
NOTARY PUBLIC-CALIFORNIA
LOS ANGELES COUNTY
My Commission Expires Sept. 22, 1977

STATE OF CALIFORNIA
COUNTY OF LOS ANGELES } ss.

DEANE HELLER, Project Manager being duly sworn, deposes and says: That the information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

Deane Heller

SUBSCRIBED and sworn to before me this 8 day of July 1974

Karl G. Schmidt

Notary Public in and for the County of Los Angeles, State of California.

SIGNATURES

Written By: Karl G. Schmidt Date: 7-8-74
PUBLICATIONS MANAGER, Karl G. Schmidt

Approved By: Deane Heller Date: 7/8/74
PROJECT MANAGER, Deane Heller

Approved By: William J. Ryan for Date: 7/8/74
QUALITY CONTROL MANAGER, Robert Roma

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this report is to present the test procedures used and the test results obtained during the performance of a test program. The test program was conducted to determine conformance of a Ten-Inch Long Life Valve, Part Number 966000, Serial Number 0001, to the Vibration Test requirements specified in Reference 2.1 in accordance with Reference 2.2.

2.0 REFERENCES

2.1 Fairchild/Stratos Division Document Number ER 966-15

2.2 Fairchild/Stratos Division Purchase Order Number 8-23028

3.0 SUMMARY

3.1 One Ten-Inch Long Life Valve, Part Number 966000, Serial Number 0001, has been subjected to the Vibration Testing described in this report. During the Vibration Test, as noted in Notice of Deviation Number 1, following two minutes of random vibration testing in the Lateral Number 1 Axis (normal to the actuator), the mounting bolts sheared. Testing was discontinued and the specimen was returned to the customer. Following return to AETL, the sinusoidal run in the "closed position" was repeated and the full five-minute random was run.

3.2 All results are presented for evaluation.

4.0 TEST CONDITIONS AND TEST EQUIPMENT

4.1 Test Conditions

Unless otherwise specified in this report all tests were performed at room ambient conditions consisting of a temperature of 70±20°F, a relative humidity of less than 95 percent and a barometric pressure of 29.92±2.0 inches of mercury absolute.

4.2 Test Equipment

AETL Number	D41L
Instrument	Accelerometer
Manufacturer	Endevco Corp.
Model Number	2213M5
Serial Number	FB05
Calibration Period	Three months (Cal. Due 8-29-74)
Range and Accuracy	0 to 10,000 g; ±3.0%

AETL Number	D43L
Instrument	Logarithmic Voltmeter/Converter
Manufacturer	Hewlett Packard
Model Number	4562A
Serial Number	1211A01301
Calibration Period	Six months (Cal. Due 7-26-74)
Range and Accuracy	0.5 to 5 KHz, 0 to 80 db; ±1.0 db

AETL Number	D84L
Instrument	Vibration Exciter
Manufacturer	M. B. Electronics
Model Number	C150
Serial Number	100
Calibration Period	N/A
Range and Accuracy	15,000 force pounds

AETL Number	D113L
Instrument	X-Y Recorder
Manufacturer	Moseley
Model Number	2D-2A
Serial Number	284
Calibration Period	Prior to use
Range and Accuracy	0 to 50 volts; ±2.0%

4.2 Test Equipment (Cont.)

AETL Number	D151L
Instrument	Amplifier
Manufacturer	Ling
Model Number	PP75/90
Serial Number	None
Calibration Period	N/A
Range and Accuracy	10 to 10 KHz; ±1.0 db

AETL Number	D162L
Instrument	Charge Amplifier
Manufacturer	M. B. Electronics
Model Number	N400
Serial Number	None
Calibration Period	Prior to use
Range and Accuracy	--

AETL Number	D163L
Instrument	Charge Amplifier
Manufacturer	M. B. Electronics
Model Number	N400
Serial Number	None
Calibration Period	Prior to use
Range and Accuracy	--

AETL Number	D164L
Instrument	Charge Amplifier
Manufacturer	M. B. Electronics
Model Number	N400
Serial Number	None
Calibration Period	Prior to use
Range and Accuracy	--

4.2 Test Equipment (Cont.)

AETL Number	D165L
Instrument	Charge Amplifier
Manufacturer	M. B. Electronics
Model Number	N400
Serial Number	None
Calibration Period	Prior to use
Range and Accuracy	--

AETL Number	D166L
Instrument	Charge Amplifier
Manufacturer	M. B. Electronics
Model Number	N400
Serial Number	None
Calibration Period	Prior to use
Range and Accuracy	--

AETL Number	D167L
Instrument	Ensemble Averager
Manufacturer	Spectral Dynamics
Model Number	SD302
Serial Number	51
Calibration Period	One year (Cal. Due 3-5-75)
Range and Accuracy	512° of freedom; ±1.0% average gain

AETL Number	D168L
Instrument	Real Time Analyzer
Manufacturer	Spectral Dynamics
Model Number	SD301A
Serial Number	64
Calibration Period	One year (Cal. Due 3-5-75)
Range and Accuracy	10 to 20 KHz, 0.03 to 60 Hz bandwidth; ±1.0 db

4.2 Test Equipment (Cont.)

AETL Number	D169L
Instrument	Sweep Oscillator Servo
Manufacturer	Spectral Dynamics
Model Number	SD114
Serial Number	92
Calibration Period	One year (Cal. Due 1-21-75)
Range and Accuracy	5 to 5 KHz, 1 to 1,000 g; ±2.0%

AETL Number	D170L
Instrument	Automatic Level Programmer
Manufacturer	Spectral Dynamics
Model Number	SD117
Serial Number	27
Calibration Period	Prior to use
Range and Accuracy	5 to 5 KHz, 1 to 1,000 g

AETL Number	D217L
Instrument	Accelerometer
Manufacturer	Bruel & Kjaer
Model Number	4335
Serial Number	354646
Calibration Period	Three months (Cal. Due 8-29-74)
Range and Accuracy	5 to 10 KHz; ±2.0%

AETL Number	D219L
Instrument	Accelerometer
Manufacturer	Bruel & Kjaer
Model Number	4335
Serial Number	354625
Calibration Period	Three months (Cal. Due 8-29-74)
Range and Accuracy	5 to 10 KHz; ±2.0%

4.2 Test Equipment (Cont.)

AETL Number	D220L
Instrument	Accelerometer
Manufacturer	Bruel & Kjaer
Model Number	4335
Serial Number	354628
Calibration Period	Three months (Cal. Due 8-29-74)
Range and Accuracy	5 to 10 KHz; ±2.0%

AETL Number	D240L
Instrument	Accelerometer
Manufacturer	M. B. Electronics
Model Number	303
Serial Number	162951
Calibration Period	Three months (Cal. Due 8-29-74)
Range and Accuracy	5 to 10 KHz; ±2.0%

AETL Number	D246L
Instrument	Control Console
Manufacturer	M. B. Electronics
Model Number	T388
Serial Number	210
Calibration Period	Daily
Range and Accuracy	10 to 6 KHz, ±1.0 db

AETL Number	E895V
Instrument	Tape Recorder
Manufacturer	Ampex
Model Number	FR1100/ES100
Serial Number	114M
Calibration Period	Prior to use
Range and Accuracy	DC to 20 KHz; ±1.0%

AETL Number	E1212S
Instrument	True RMS Voltmeter
Manufacturer	Ballantine Labs
Model Number	320U/21
Serial Number	40006
Calibration Period	Six months (Cal. Due 11-17-74)
Range and Accuracy	100 μvolts to 320 vrms; ±3.0%

5.0 TEST PROCEDURES AND TEST RESULTS

5.1 Vibration Test

Date Started: 28 May 1974
Date Completed: 5 June 1974

5.1.1 The specimen was installed in a test fixture and was mounted on the vibration exciter in the Lateral Number 1 (normal to actuator) axis. A pressure of 750 psig was applied to the close port. The specimen was subjected to sinusoidal sweep over the frequency range of 5 to 2000 Hz at a sweep rate of one octave per minute at the following intensities:

Frequency (Hz)	Intensity
5 - 20	0.4 inch da
20 - 90	8.5 g peak
90 - 131	0.02 inch da
131 - 2000	18.0 g peak

5.1.2 The specimen was then subjected to one sinusoidal sweep at the frequencies and intensities noted in Paragraph 5.1.1 with 750 psig applied to the open port.

5.1.3 With 750 psig applied to the close port and with the specimen in the Lateral Number 1 axis, the specimen was subjected to random vibration over the frequency range of 20 to 2000 Hz at the following intensities:

Frequency (Hz)	Intensity
20 - 100	9 db/octave rise
100 - 400	1.0 g^2/Hz
400 - 630	12 db/octave rolloff
630 - 2000	0.15 g^2/Hz
Overall Acceleration:	25.0 grms

5.1.4 As noted in Notice of Deviation Number 1, following two minutes of random vibration, the mounting bolts sheared. The specimen was returned to the customer.

5.1.5 Following return to AETL, the specimen was mounted on the vibration exciter in the Lateral Number 1 axis and was subjected to the testing described in Paragraph 5.1.1 with 750 psig pressure applied to the close port.

5.1.6 The specimen was then subjected to five minutes of random vibration in the Lateral Number 1 axis at the frequencies and intensities noted in Paragraph 5.1.3.

5.1.7 The specimen was then mounted on the vibration exciter in the longitudinal axis and with a pressure of 750 psig applied to the close port was subjected to sinusoidal sweep as noted in Paragraph 5.1.1. The sweep was discontinued at 130 Hz due to the fixture lifting off the slip plate. At a later date, testing in the longitudinal axis was repeated with 750 psig applied to the close port. A sinusoidal sweep from 5 to 2000 Hz at the intensities noted in Paragraph 5.1.1 was performed.

5.1.8 The specimen, mounted on the vibration exciter in the longitudinal axis and with 750 psig applied to the open port, was subjected to sinusoidal sweep at the frequencies and intensities noted in Paragraph 5.1.1. Testing was stopped at 350 Hz per customer request. At a later date, testing was repeated in the longitudinal axis with 750 psig applied to the open port over the frequency range of 5 to 2000 Hz at the intensities noted in Paragraph 5.1.1.

5.1.9 The specimen, mounted on the vibration exciter in the Longitudinal Number 1 axis, was then subjected to five minutes of random vibration at the frequencies and intensities noted in Paragraph 5.1.3 with 750 psig applied to the close port.

5.1.10 The specimen was then mounted on the vibration exciter in the Longitudinal Number 2 axis and with a pressure of 750 psig applied to the close port, the specimen was subjected to sinusoidal vibration over the frequency range of 5 to 2000 Hz at a sweep rate of one octave per minute at the intensities noted in Paragraph 5.1.1.

5.1.11 The specimen, mounted on the vibration exciter in the Longitudinal Number 2 axis, and with 750 psig applied to the open port, was then subjected to sinusoidal sweep over the frequency range of 5 to 2000 Hz at a sweep rate of one octave per minute at the intensities noted in Paragraph 5.1.1.

5.1.12 The specimen, mounted on the vibration exciter in the Longitudinal Number 2 axis, and with 750 psig applied

5.1.12 Continued:

to the close port, was subjected to five minutes of random vibration over the frequency range of 20 to 2000 Hz at the intensities noted in Paragraph 5.1.3.

5.1.13 During all sinusoidal and random vibration testing specified above, accelerometers were located as noted below. The outputs of the control and response accelerometers were recorded and X-Y plots were prepared. For random vibration testing, PSD plots were prepared. The locations are as follows:

Accelerometer Number	Location
1	Direction of Vibration on Fixture
2	Crosstalk on Poppet
3	Crosstalk on Body
4	Direction on Vibration Actuator Case
5	Actuator End

5.1.4 The sinusoidal vibration X-Y plots are presented in Appendix 1. The PSD plots are presented in Appendix 2. Visual examination at the completion of testing revealed no adverse effects.

AETL

NOTICE OF DEVIATION

APPROVED ENGINEERING TEST LABORATORIES

DATE: 5-28-74

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- [X] LOS ANGELES DIVISION / 5320 WEST 104TH STREET / LOS ANGELES, CALIFORNIA 90045 / (213) 776-3202
- [ ] VALLEY DIVISION / 9551 CANOGA AVENUE / CHATSWORTH, CALIFORNIA 91311 / (213) 341-0830
- [ ] SAUGUS DIVISION / 20744 SOLEDAD CANYON ROAD / SAUGUS, CALIFORNIA 91350 / (805) 259-8184
- [ ] CALIFORNIA TEST LABS DIV. / 619 E. WASHINGTON BLVD. / LOS ANGELES, CALIF. 90015 / (213) 747-4235

CUSTOMER: FAIRCHILD / STRATOS MJO NO.: 5330-1203

PART NO.: 966000 N.O.D. NO.: 1

SERIAL NO.: 0001 P.O. NO.: 8-23028

TEST PROCEDURE: ER 966-15 PARAGRAPH: 4.5.2

REQUIREMENT: NO DAMAGE SHALL RESULT

DEVIATION: AFTER TWO (2) MINUTES OF RANDOM IN THE LATERAL #1 AXIS (NORMAL TO ACTUATOR) THE MOUNTING BOLTS SHEARED.

DISPOSITION: TESTING DISCONTINUED - SPECIMEN RETURNED ON 5-31-74 AND SIDE RUN IN "CLOSED" POSITION REPEATED AND RUN FULL 5 MIN RANDOM RUN.

APPROVAL ______ (Customer Representative)

CUSTOMER NOTIFICATION:

Made to: FAIRCHILD REP. How: VERBAL

Date & Time: 5-28-74 @ 1605 HRS By: M. R. Mustard

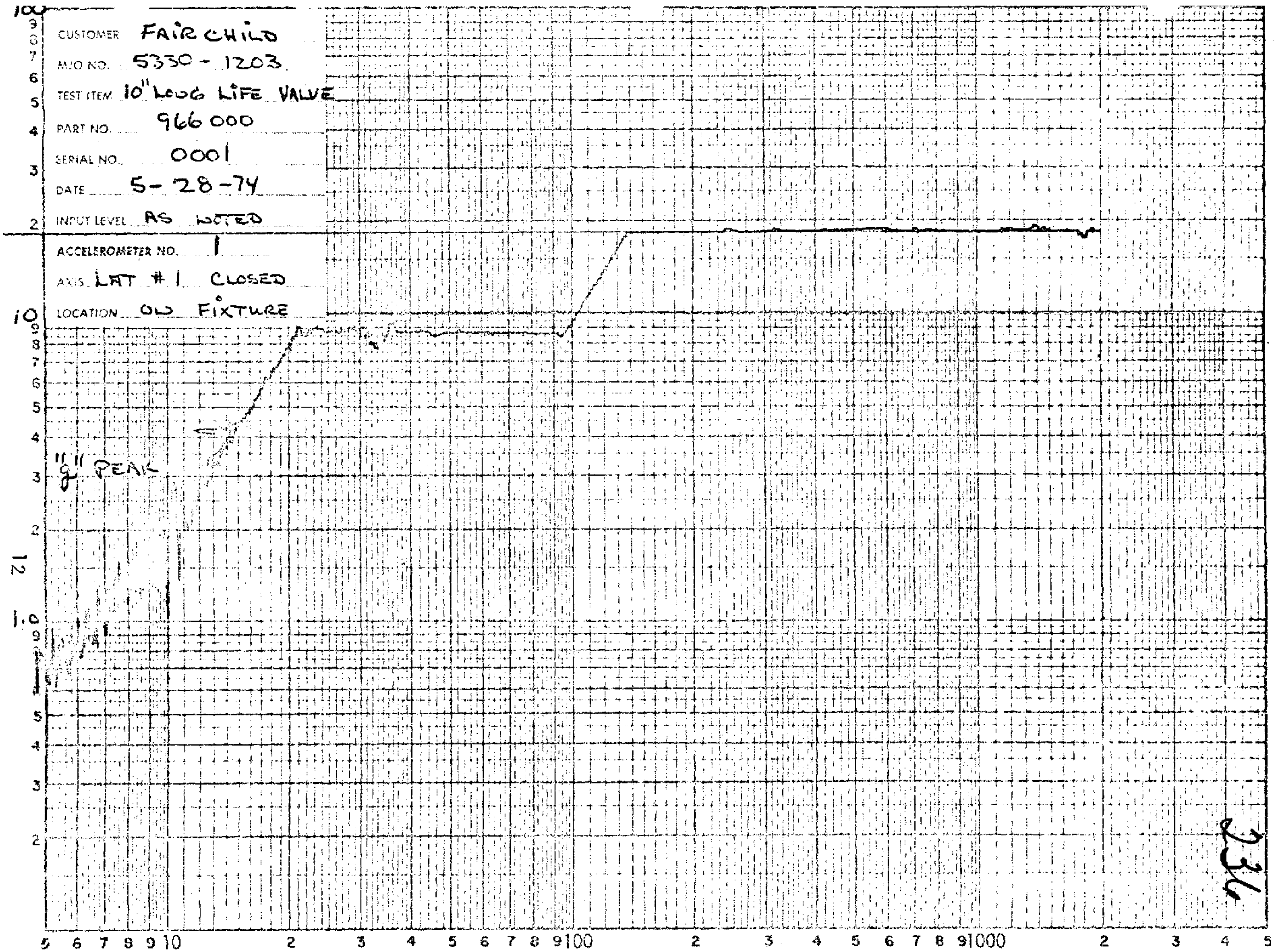
DCAS Notified: [ ] YES [ ] NO ______ DATE

Deane Heller
A.E.T.L. Dept. Supervisor

A&B PTG

APPENDIX I

X-Y Plots



FORM 1062-X-34 NEW 12-71

12

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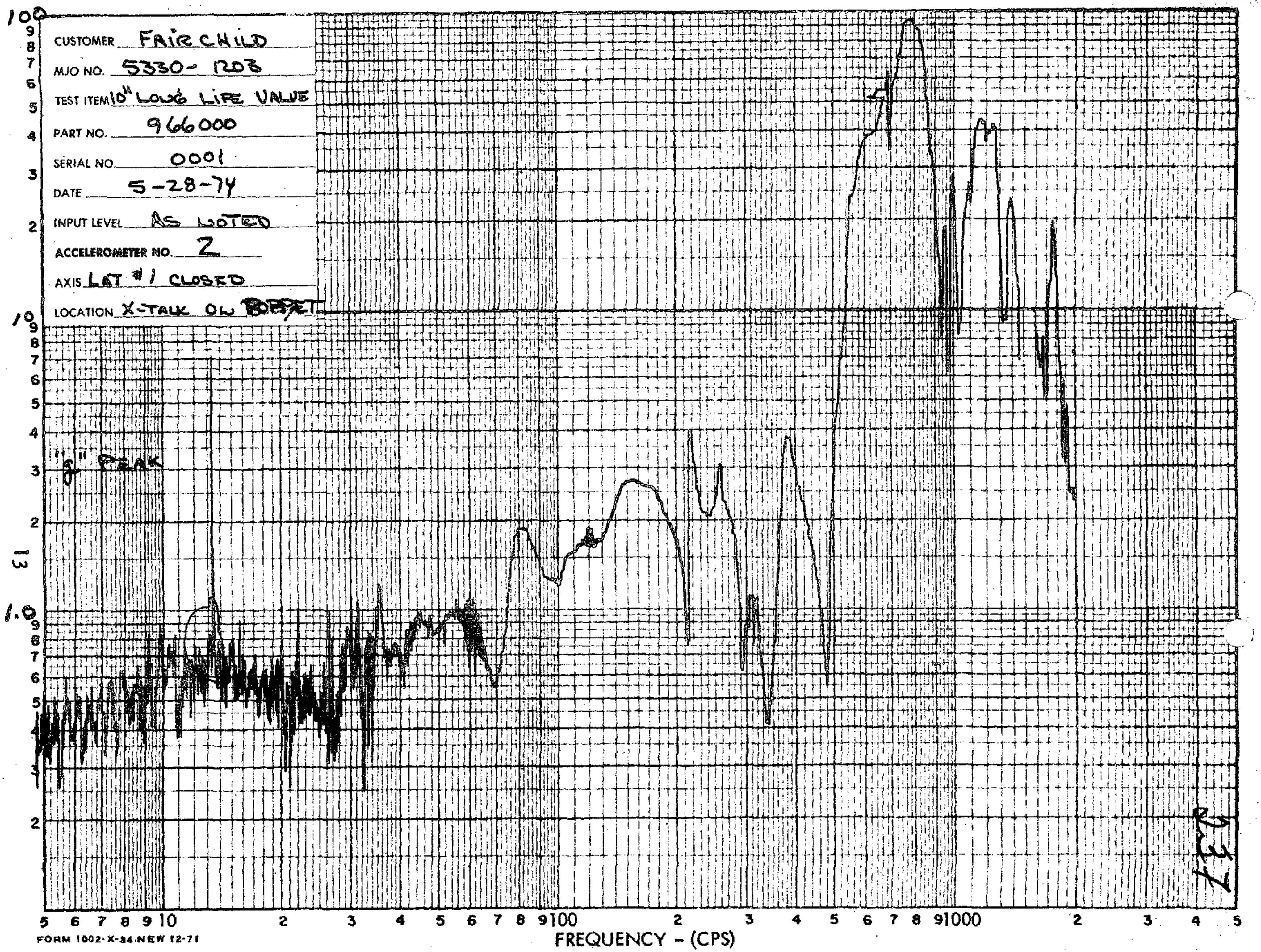
CUSTOMER FAIRCHILD
MJO NO. 5330- 1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 5-28-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 2
AXIS LAT #1 CLOSED
LOCATION X-TALK ON POPPET
"g" PEAK
FREQUENCY - (CPS)
FORM 1002-X-34-NEW 12-71

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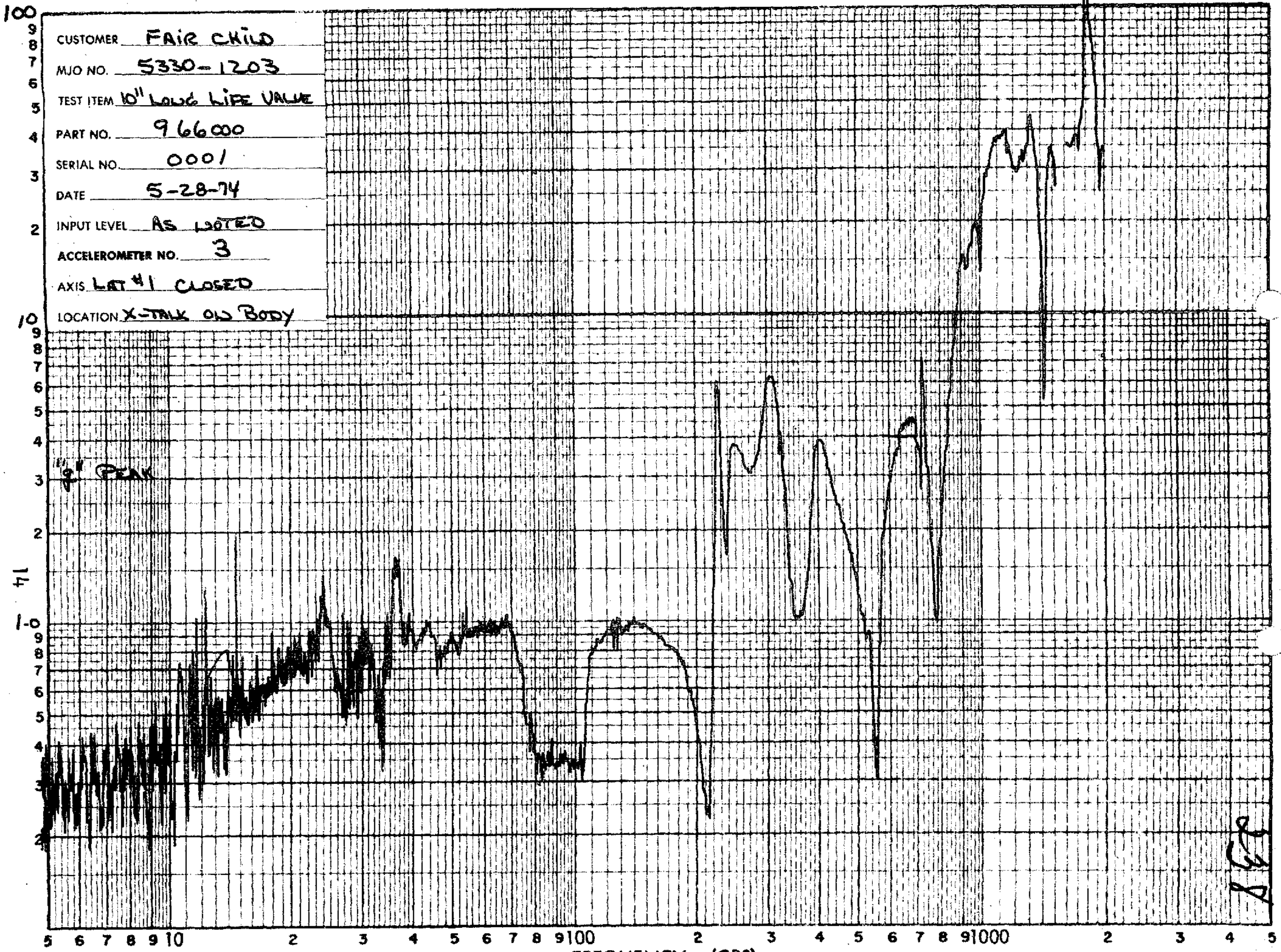

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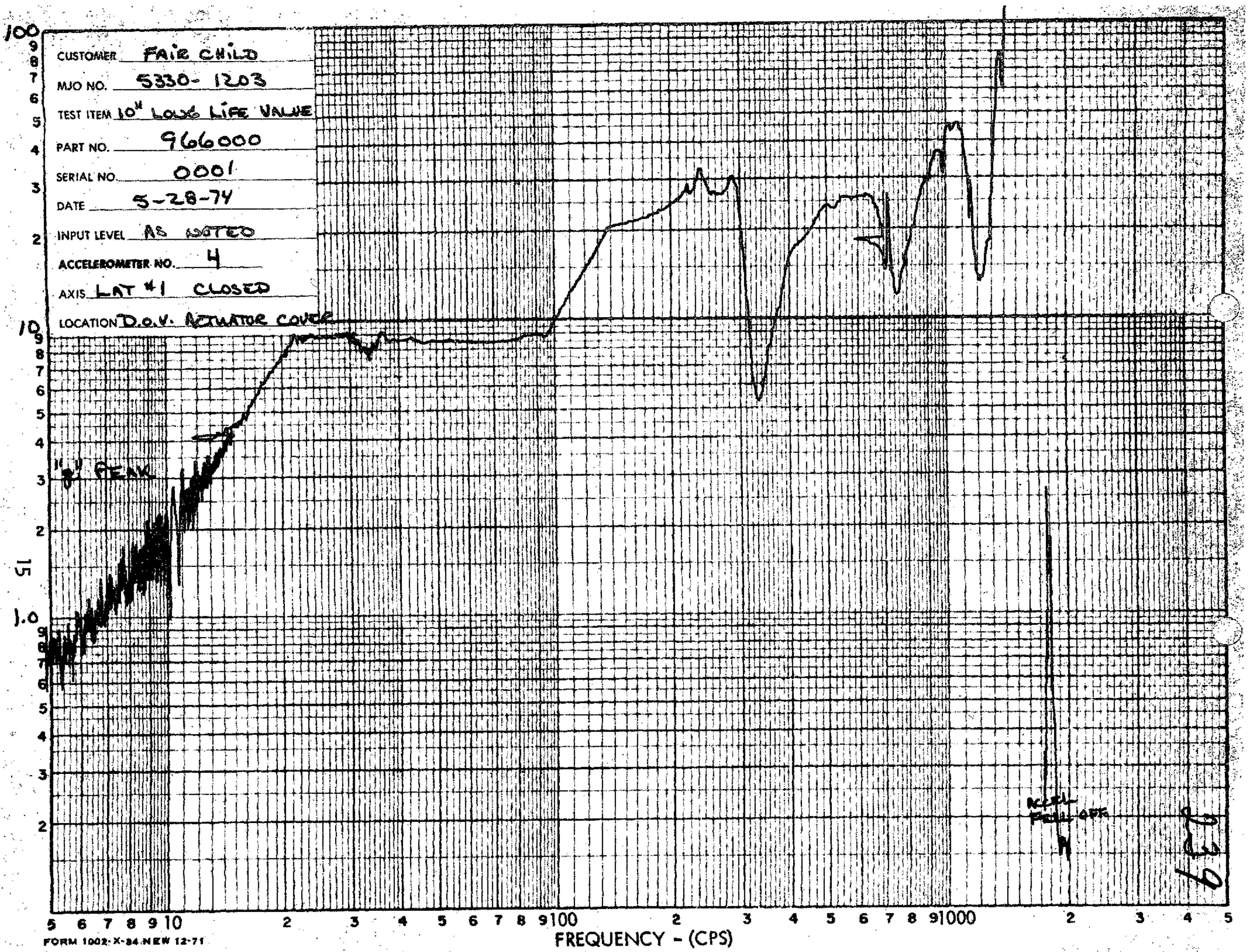
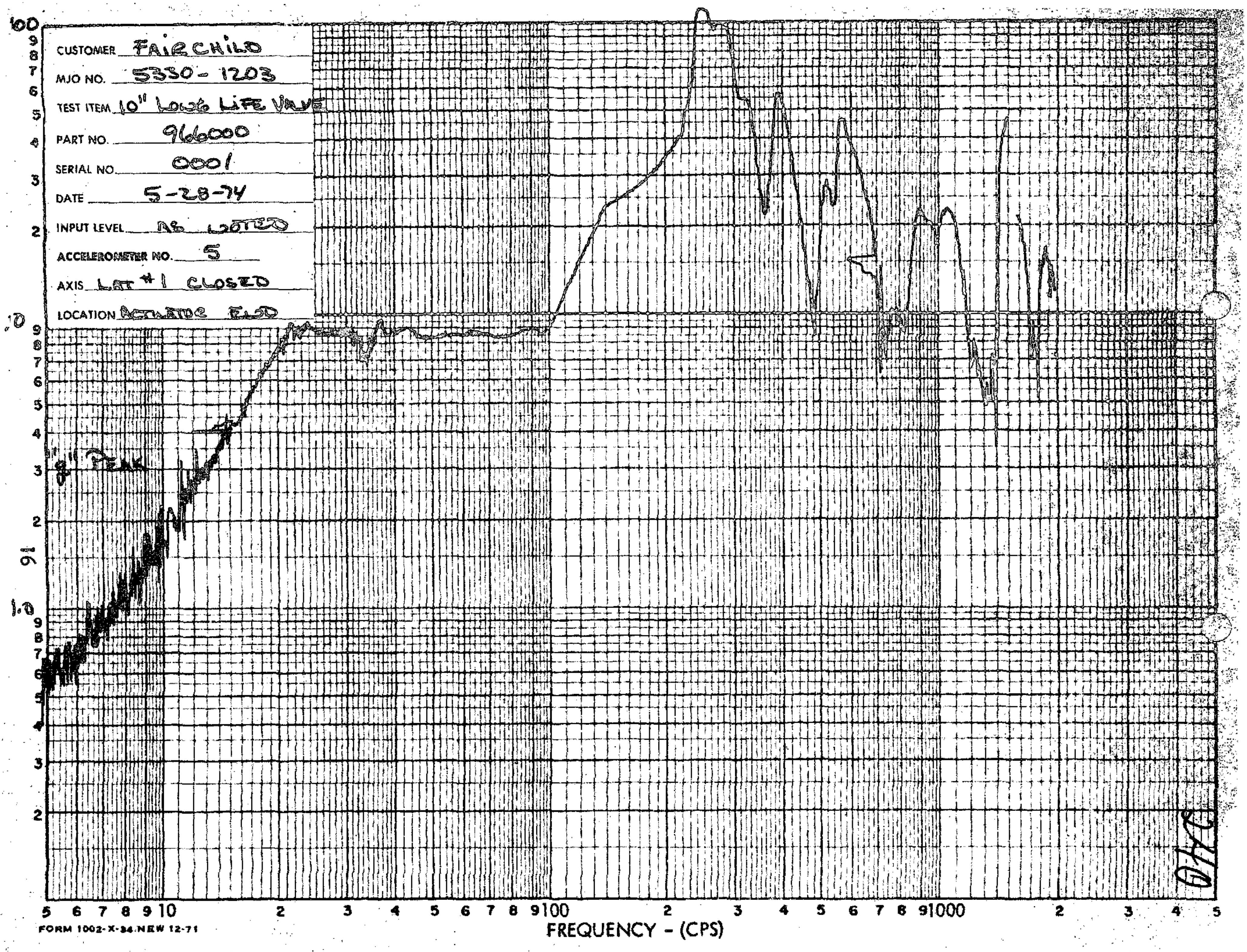
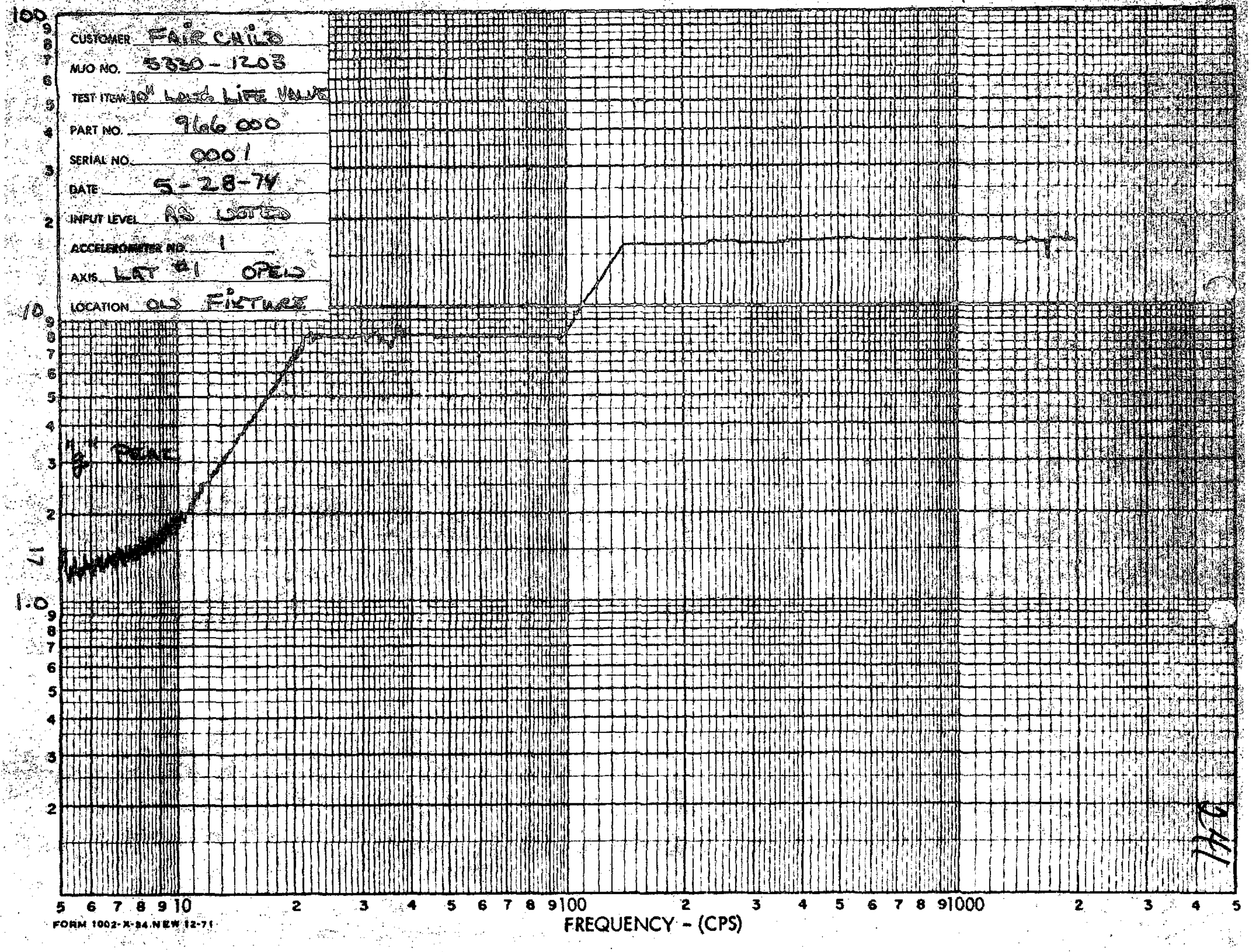


CUSTOMER FAIR CHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 5-28-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 4
AXIS LAT #1 CLOSED
LOCATION D.O.V. ACTUATOR COVER
"g" PEAK
ACCEL FELL OFF
15
FREQUENCY - (CPS)
FORM 1002-X-34 NEW 12-71



CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 5-28-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 5
AXIS LAT #1 CLOSED
LOCATION ACTUATOR END
.8" PEAK
9 G
FREQUENCY - (CPS)
FORM 1002-X-34 NEW 12-71


CUSTOMER FAIR CHILD
M/O NO. 5330 - 1203
TEST ITEM 10" Lord Life Valve
PART NO. 9166 000
SERIAL NO. 0001
DATE 5-28-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 1
AXIS LAT #1 OPEN
LOCATION OLD FIXTURE
½" PEAK
10
1.0
100
5 6 7 8 9 10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4 5
FREQUENCY - (CPS)
FORM 1002-X-34 NEW 12-71
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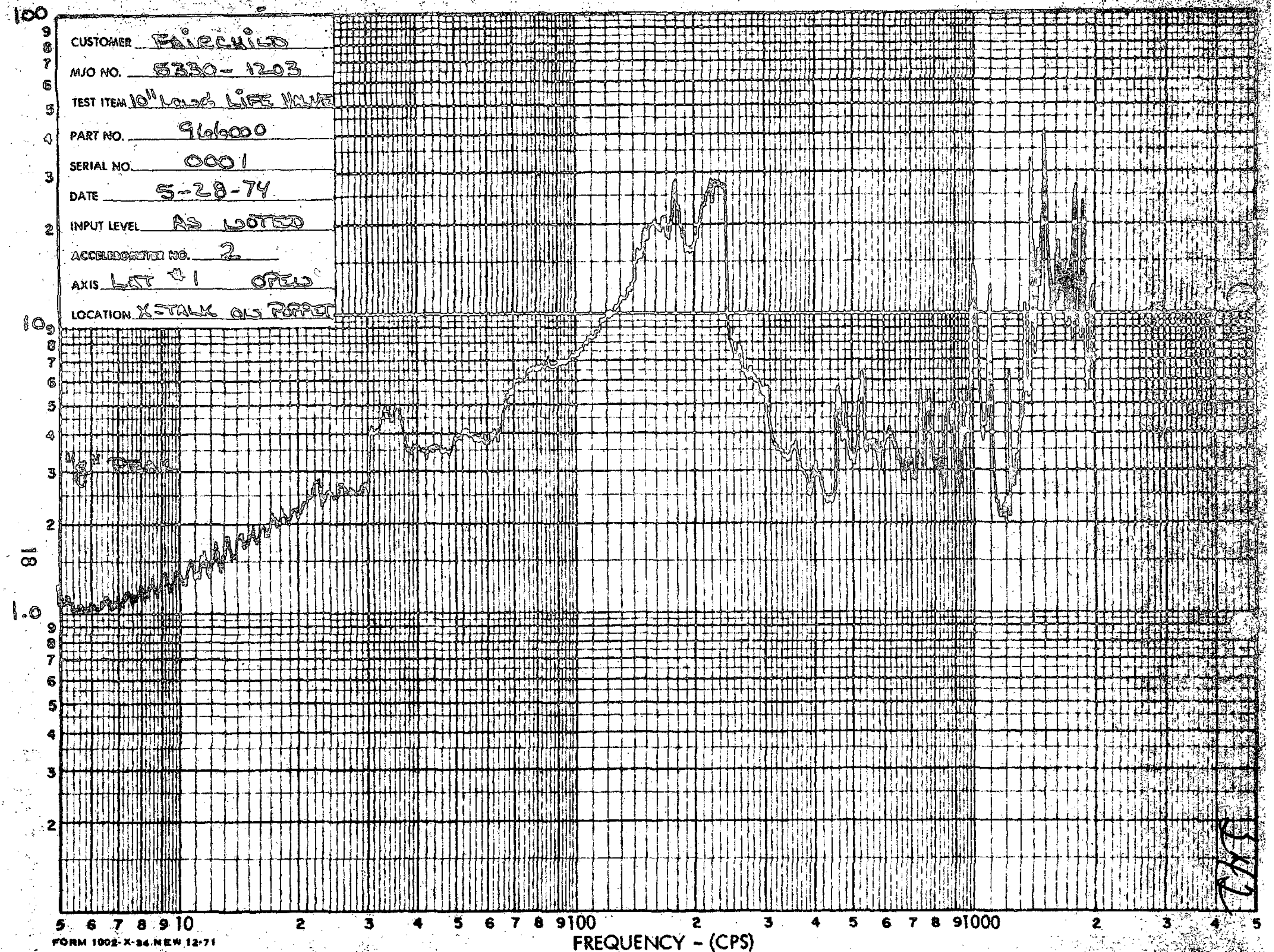
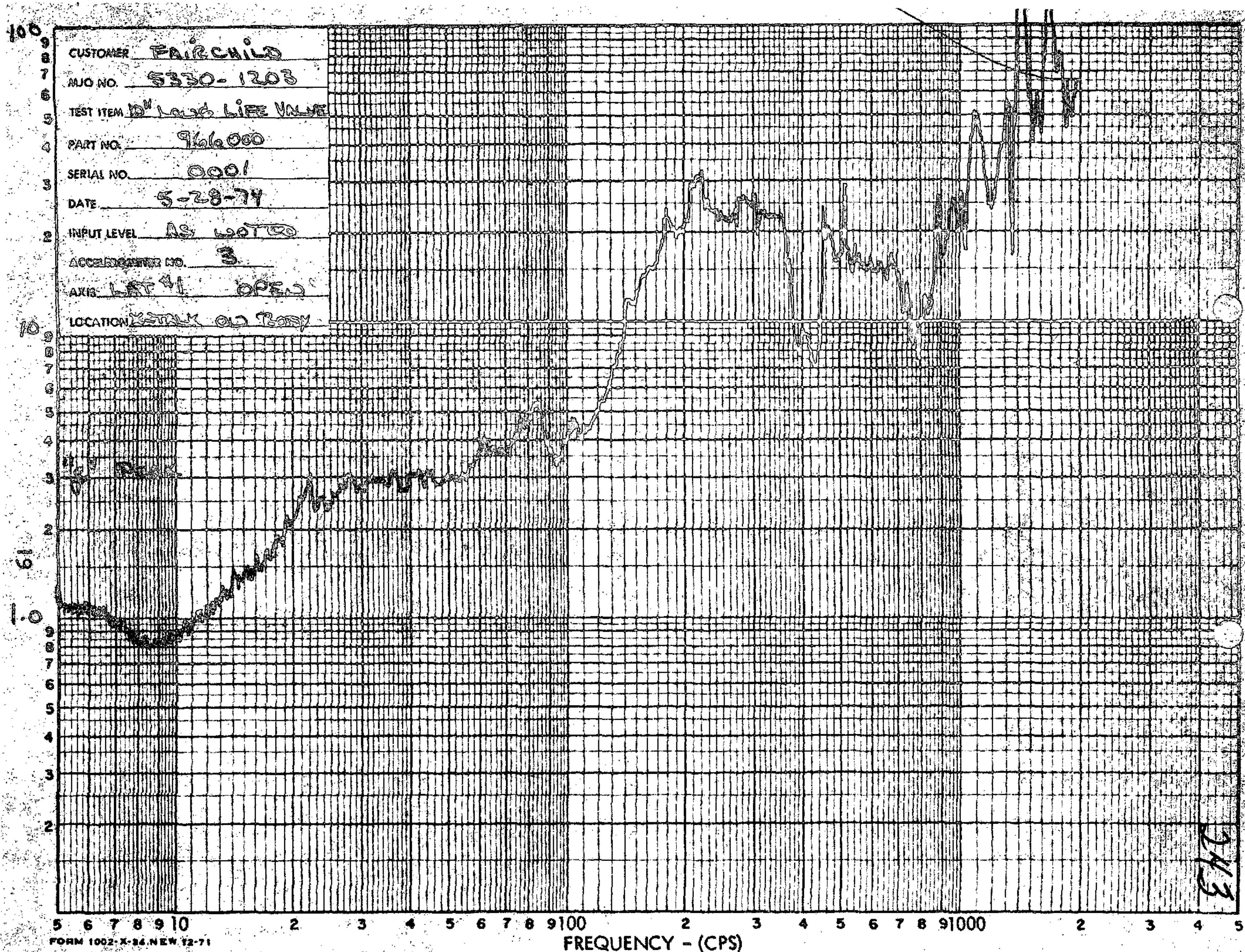

CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" Load Life Valve
PART NO. 966000
SERIAL NO. 0001
DATE 5-28-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 2
AXIS LAT #1 OPEN
LOCATION X-STALK ON POPPET
100
10
1.0
.1
1/8" PEAK
5 6 7 8 9 10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4 5
FREQUENCY ~ (CPS)
FORM 1002-X-34 NEW 12-71



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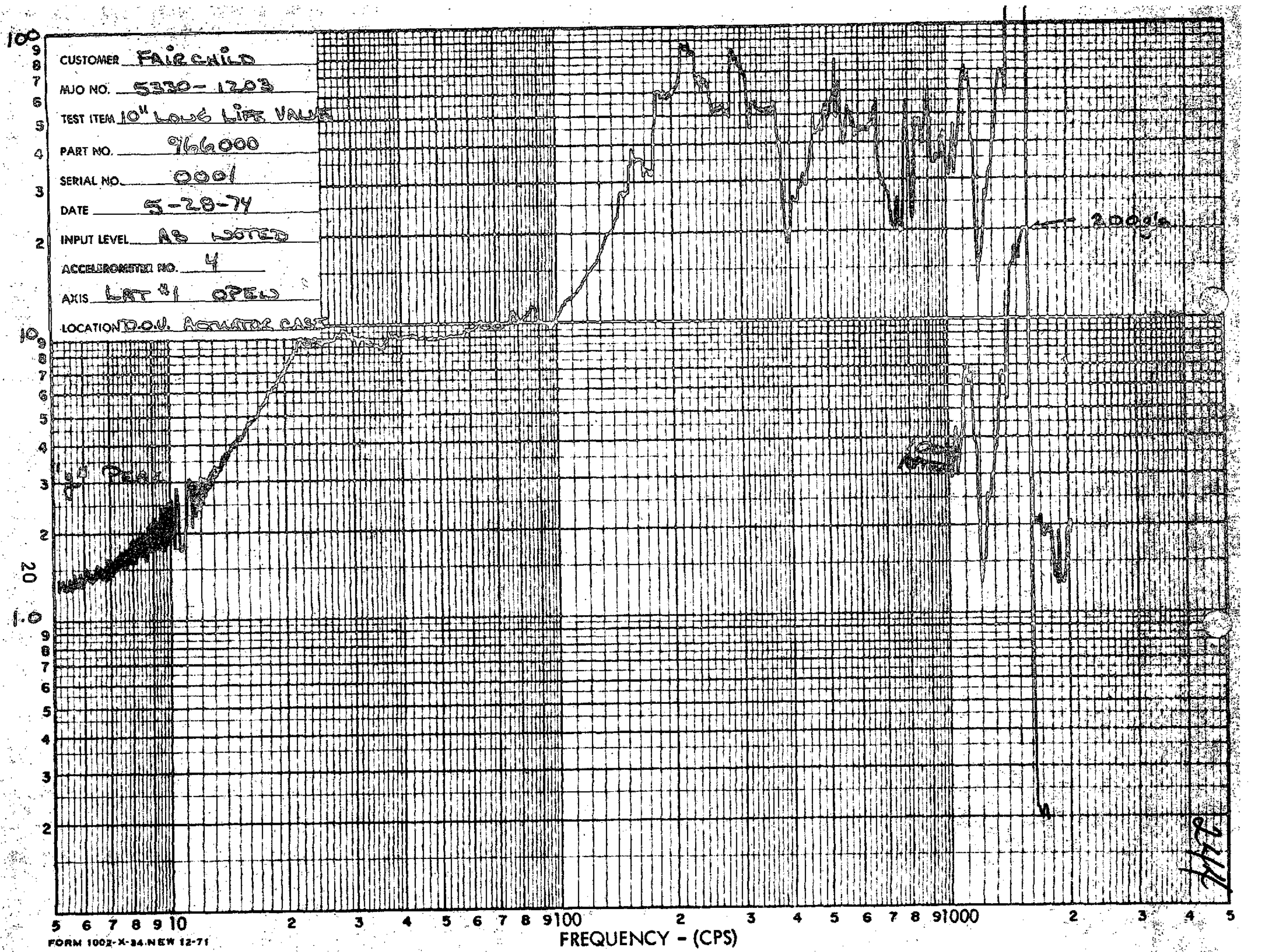
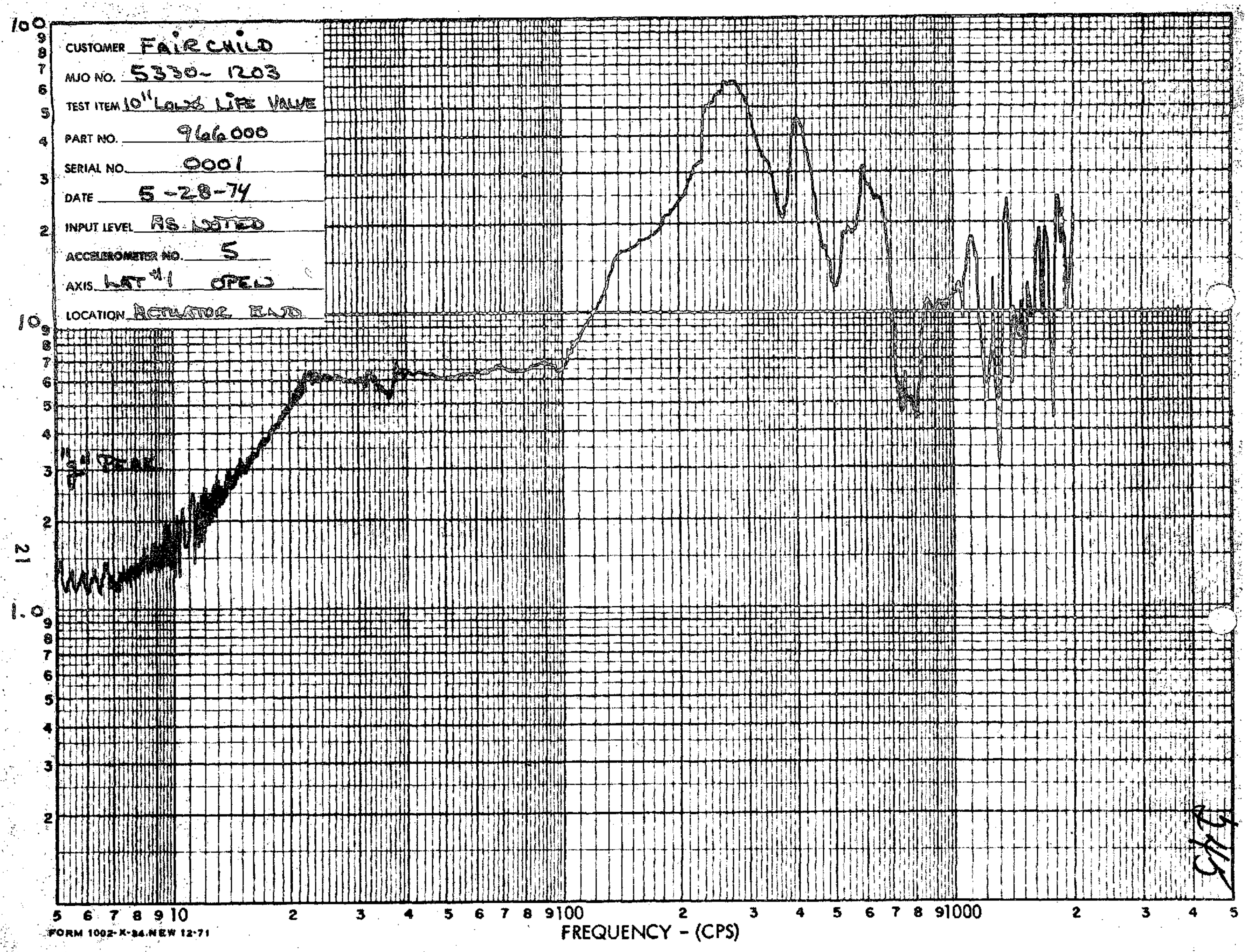


CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 5-28-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 4
AXIS LAT #1 OPEN
LOCATION D.O.U. ACTUATOR CASE
200g's
20
FREQUENCY - (CPS)
FORM 1002-X-34 NEW 12-71


CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LOX LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 5-28-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 5
AXIS LAT #1 OPEN
LOCATION ACTUATOR END
1/2" PEAK
FREQUENCY - (CPS)
FORM 1002-X-34 NEW 12-71

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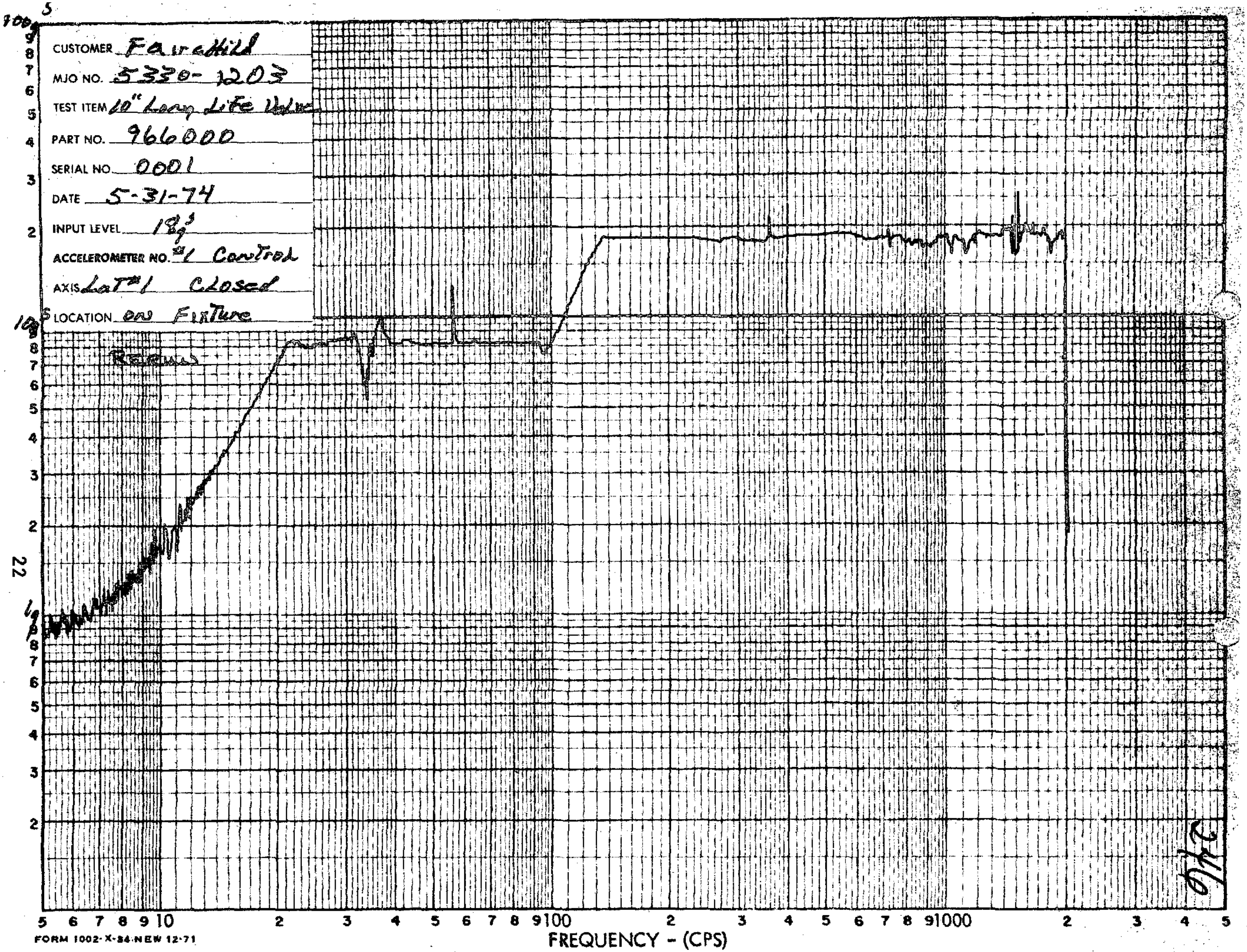

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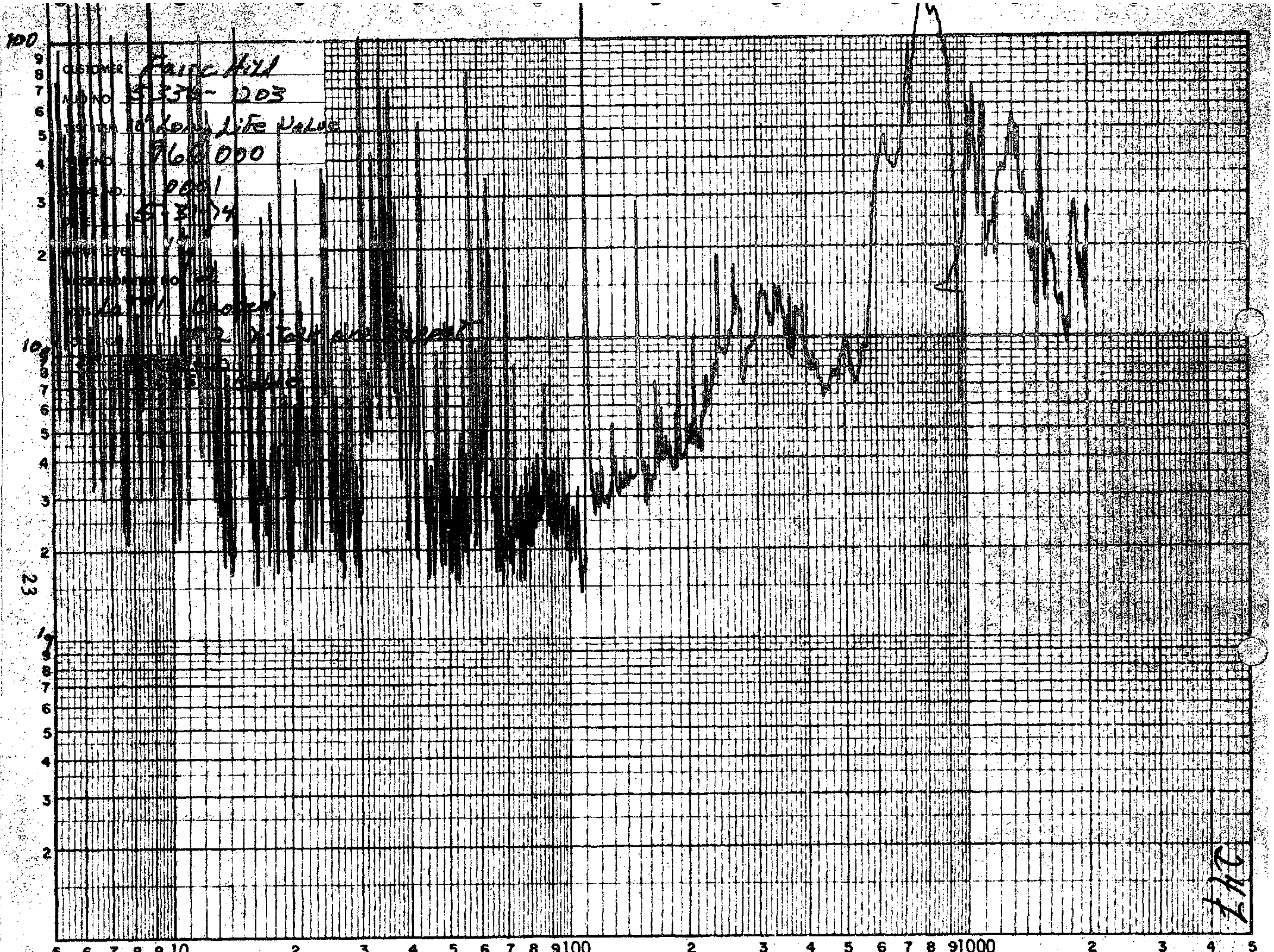
FORM 1002-X-34-NEW 12-71


CUSTOMER
5 6 7 8 9 10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4 5
FREQUENCY – (CPS)
FORM 1002-X-34-NEW 12-71

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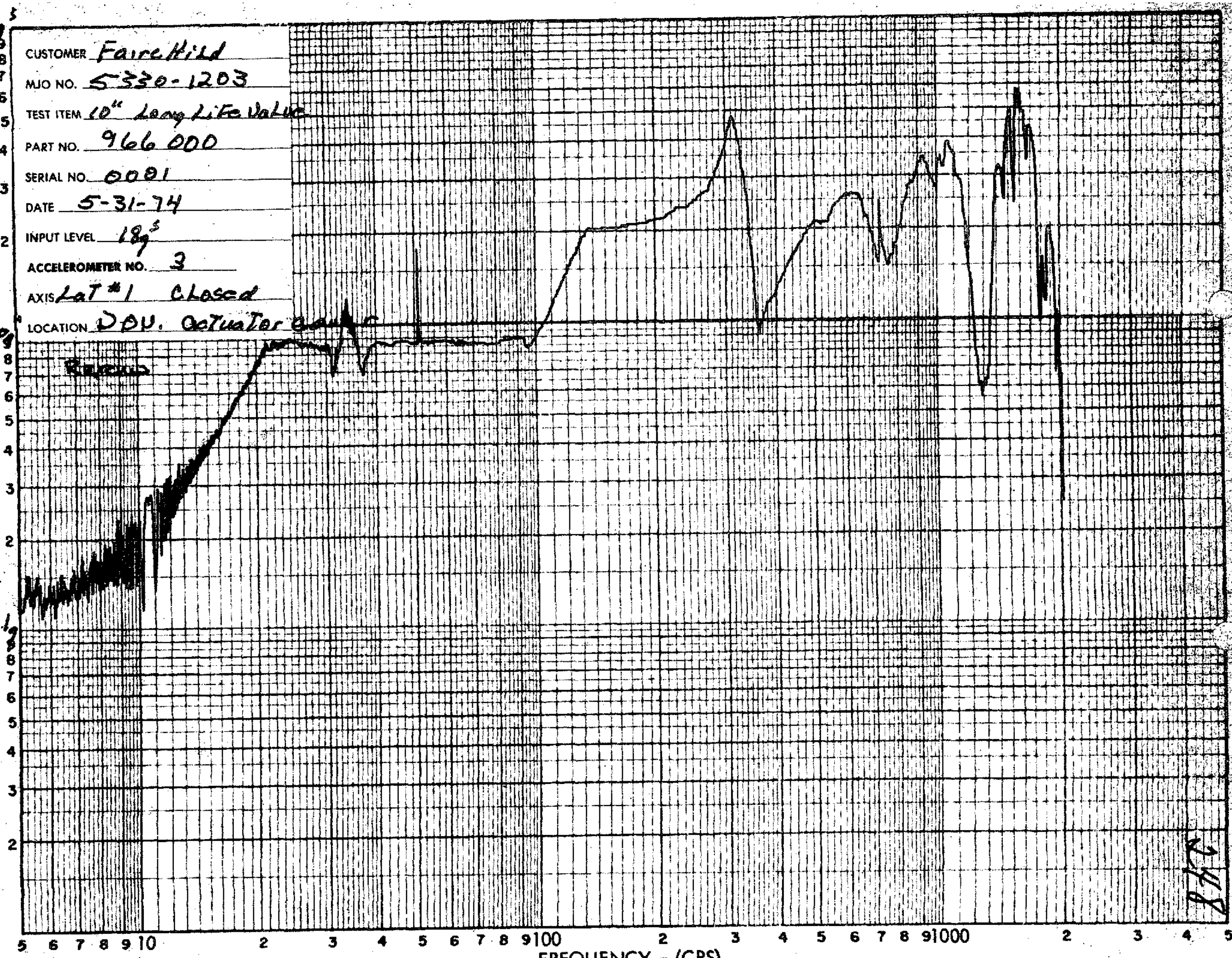

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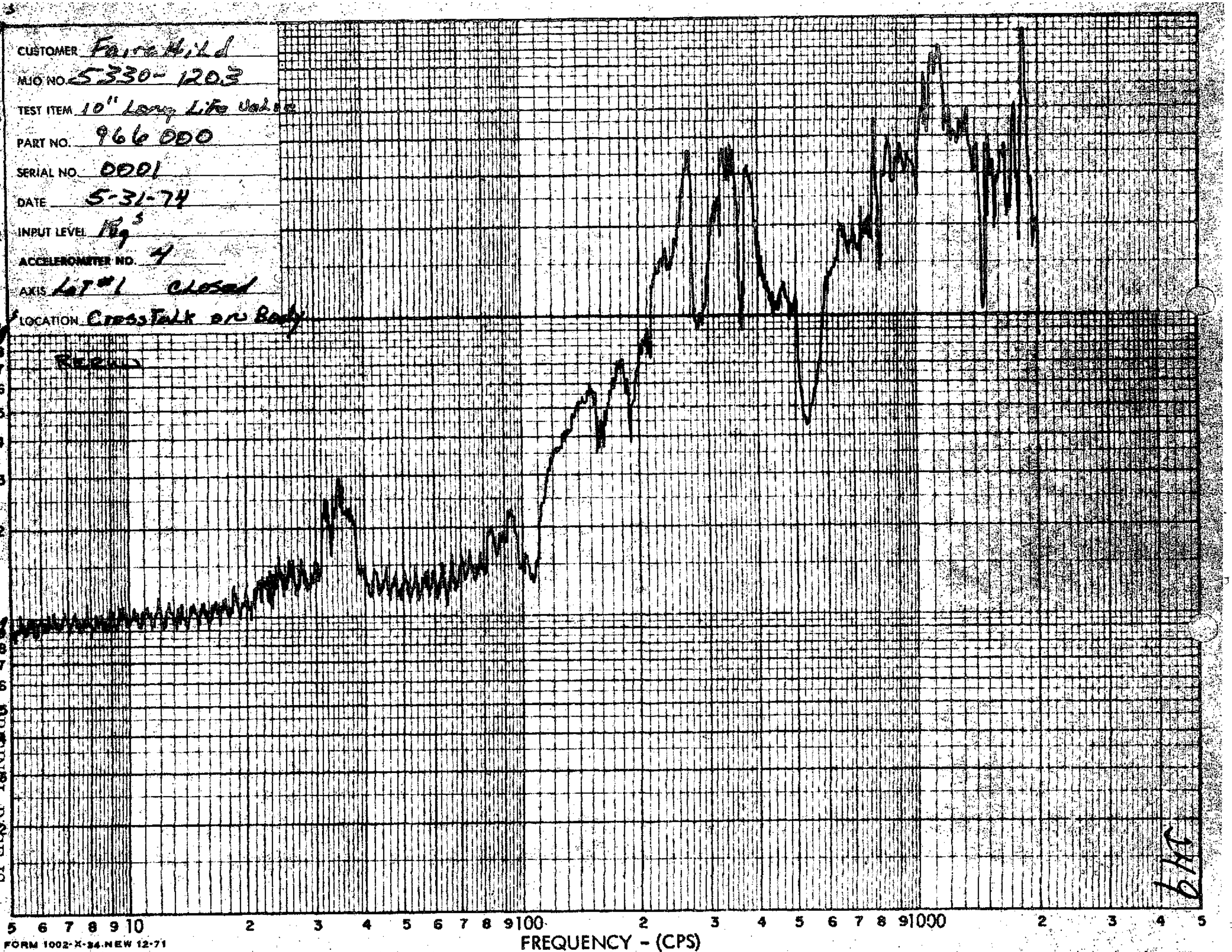

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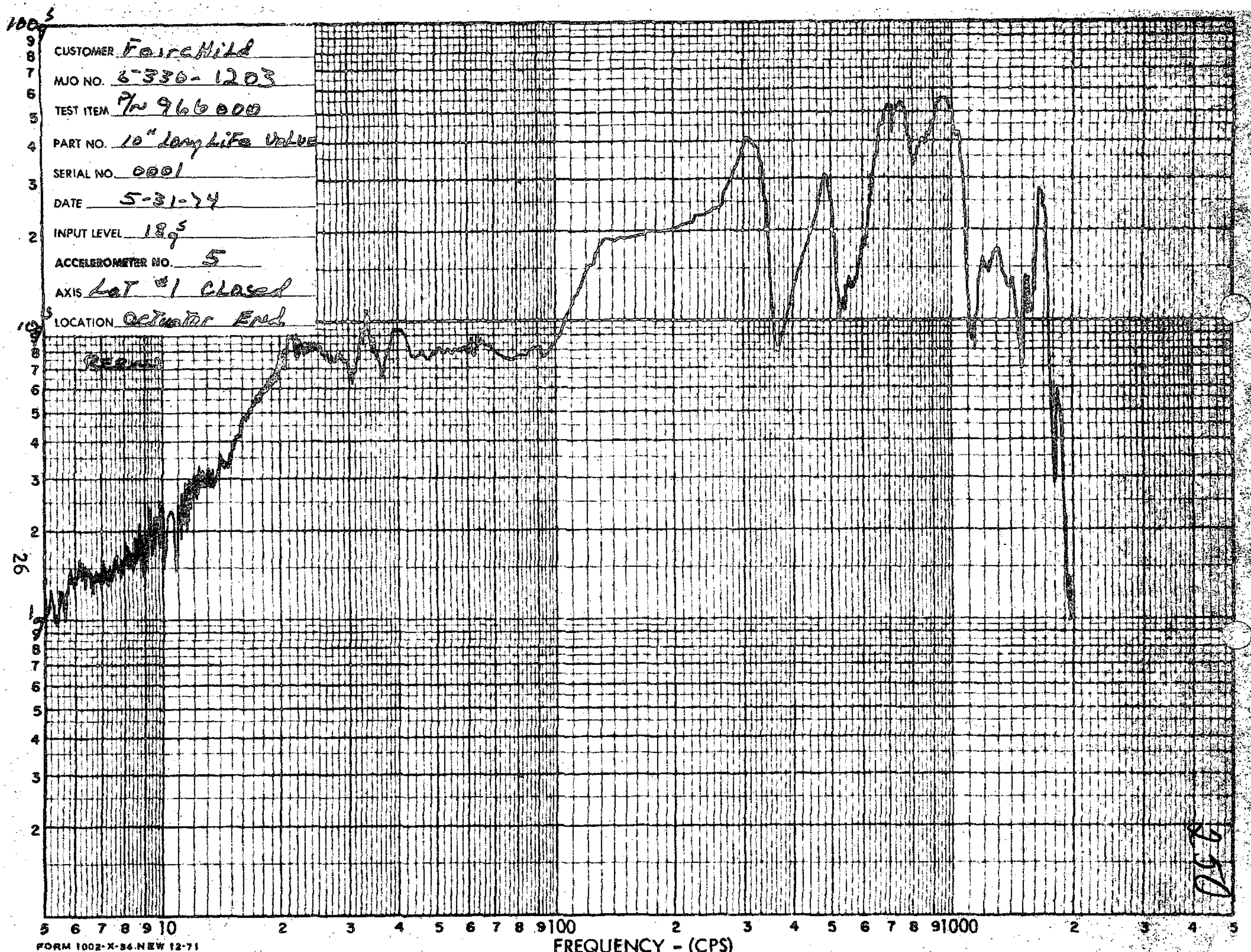
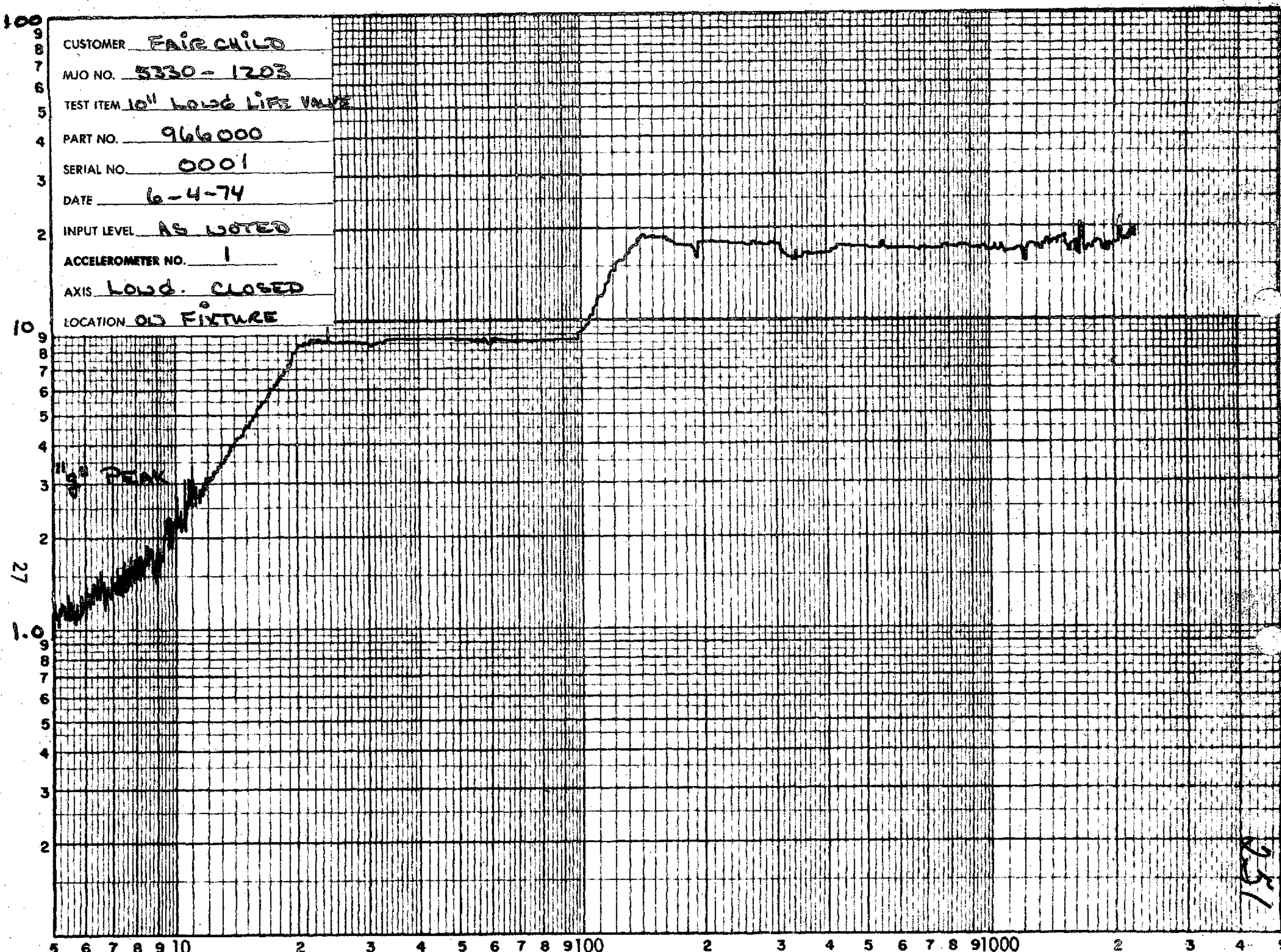
249



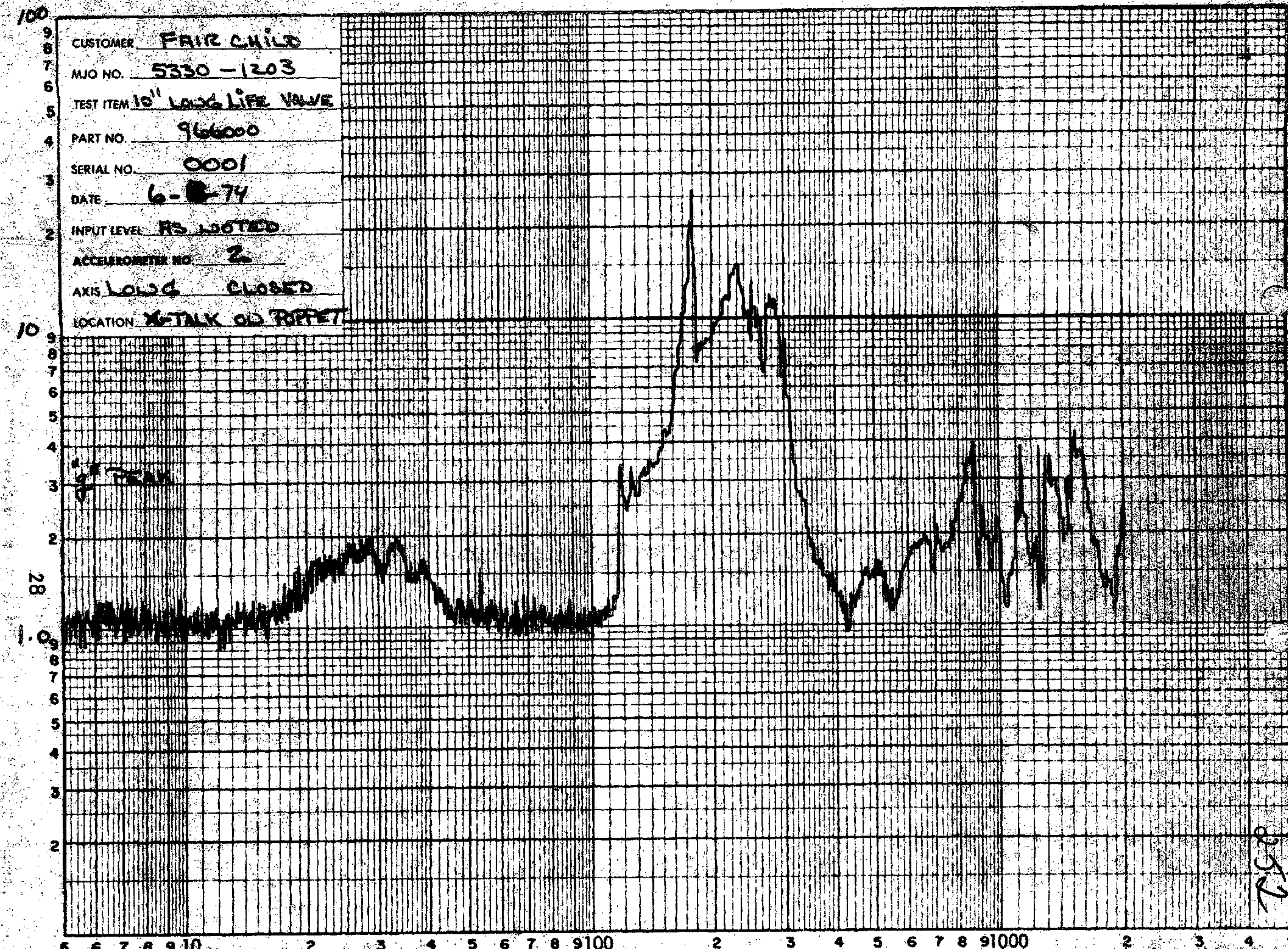
FORM 1002-X-34.NEW 12-71

257



27

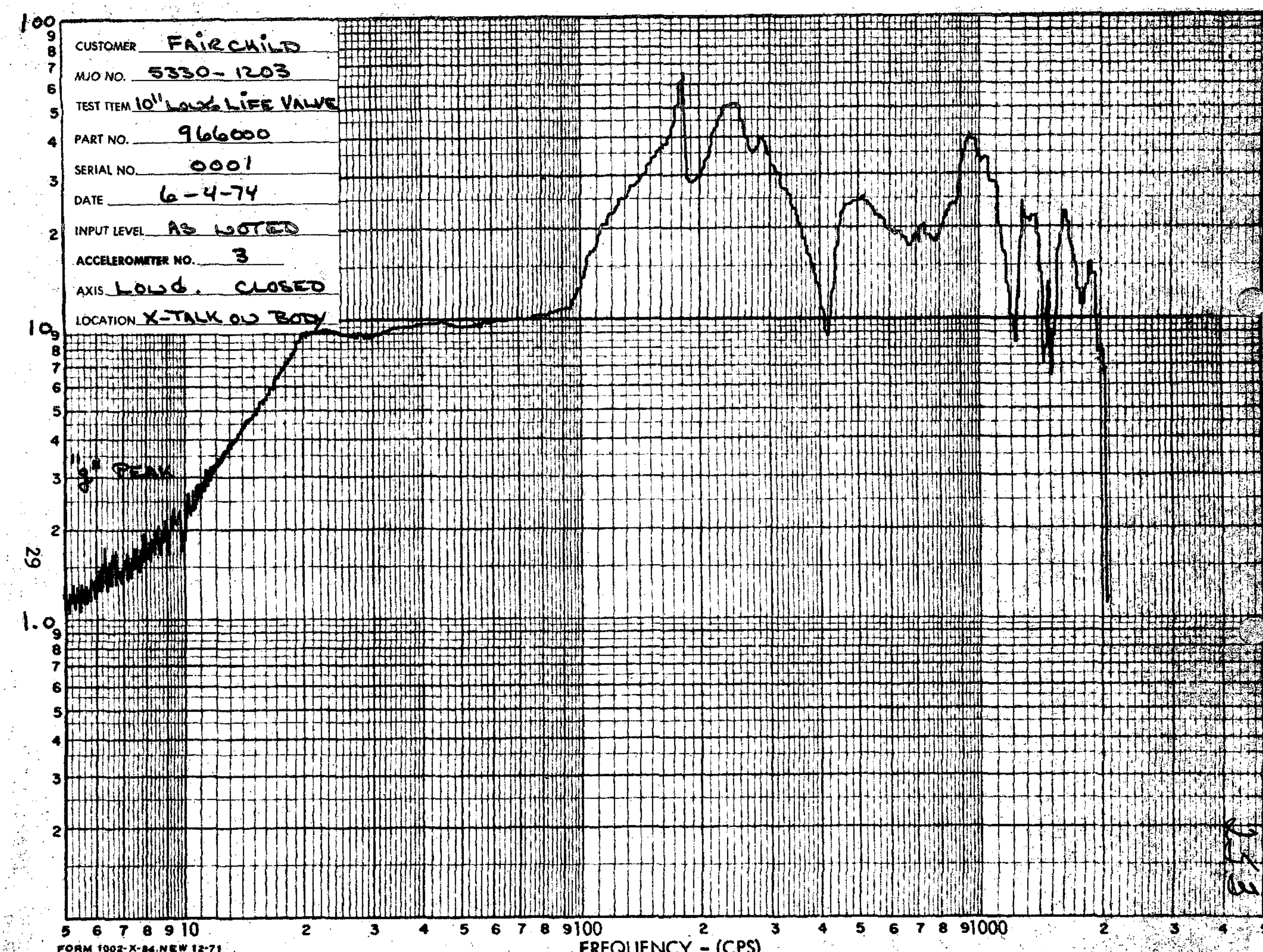
FORM 1002-X-84.NEW 12-71



FORM 1002-X-24-NEW 12-71

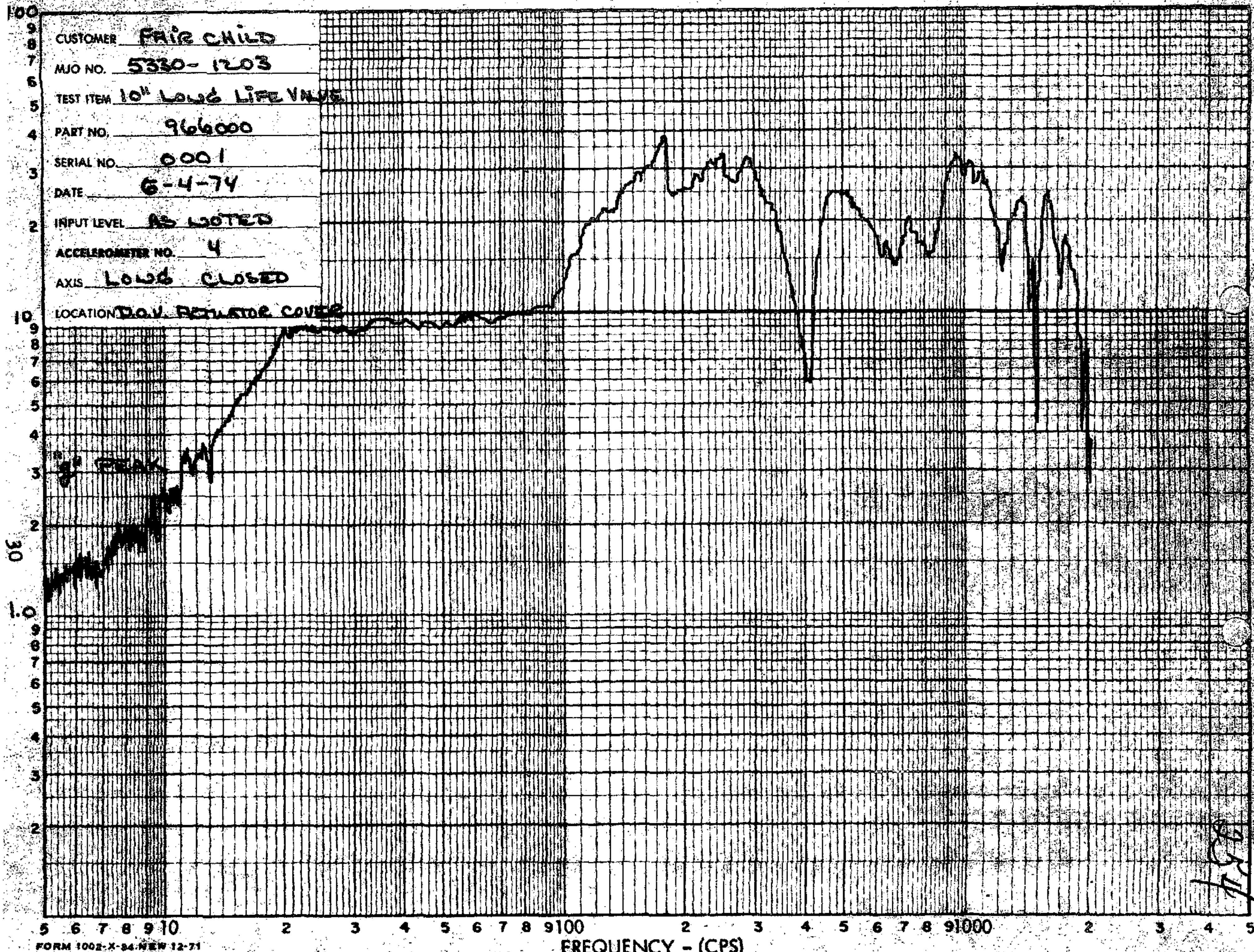
28

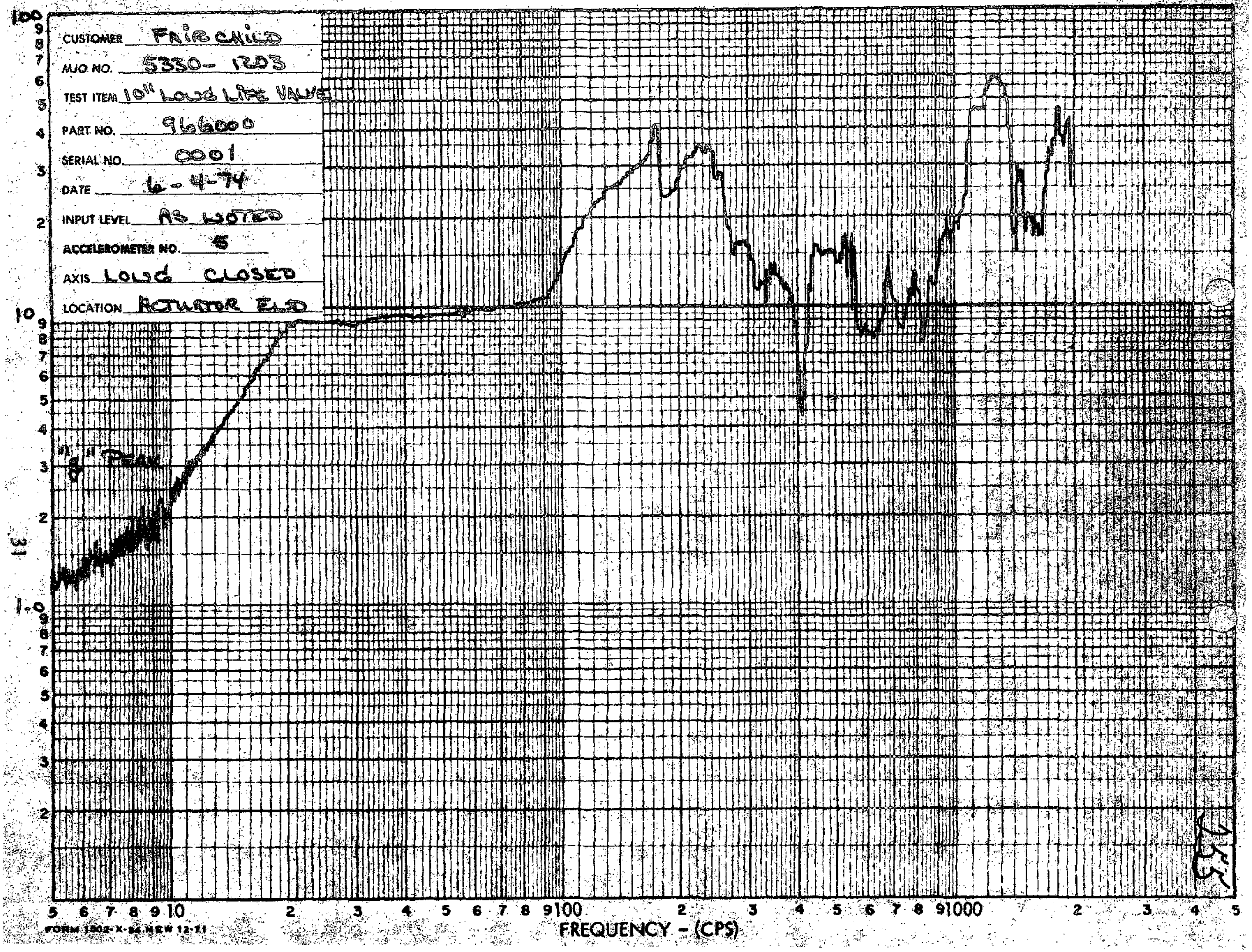
252

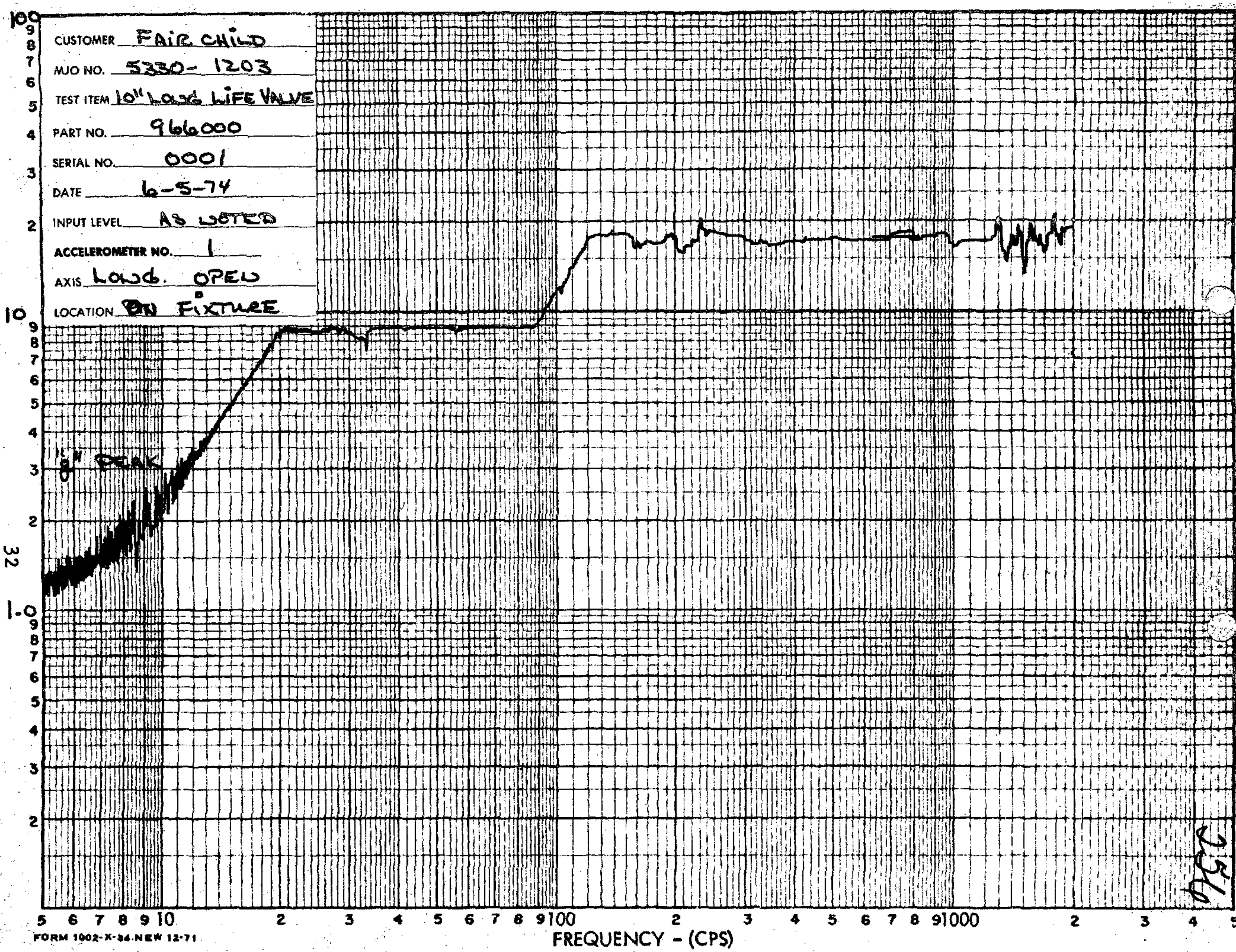


CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LOX LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-4-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 3
AXIS LONG. CLOSED
LOCATION X-TALK ON BODY
"g" PEAK
100
10
1.0
FREQUENCY - (CPS)
10
100
1000
FORM 1002-X-84.NEW 12-71

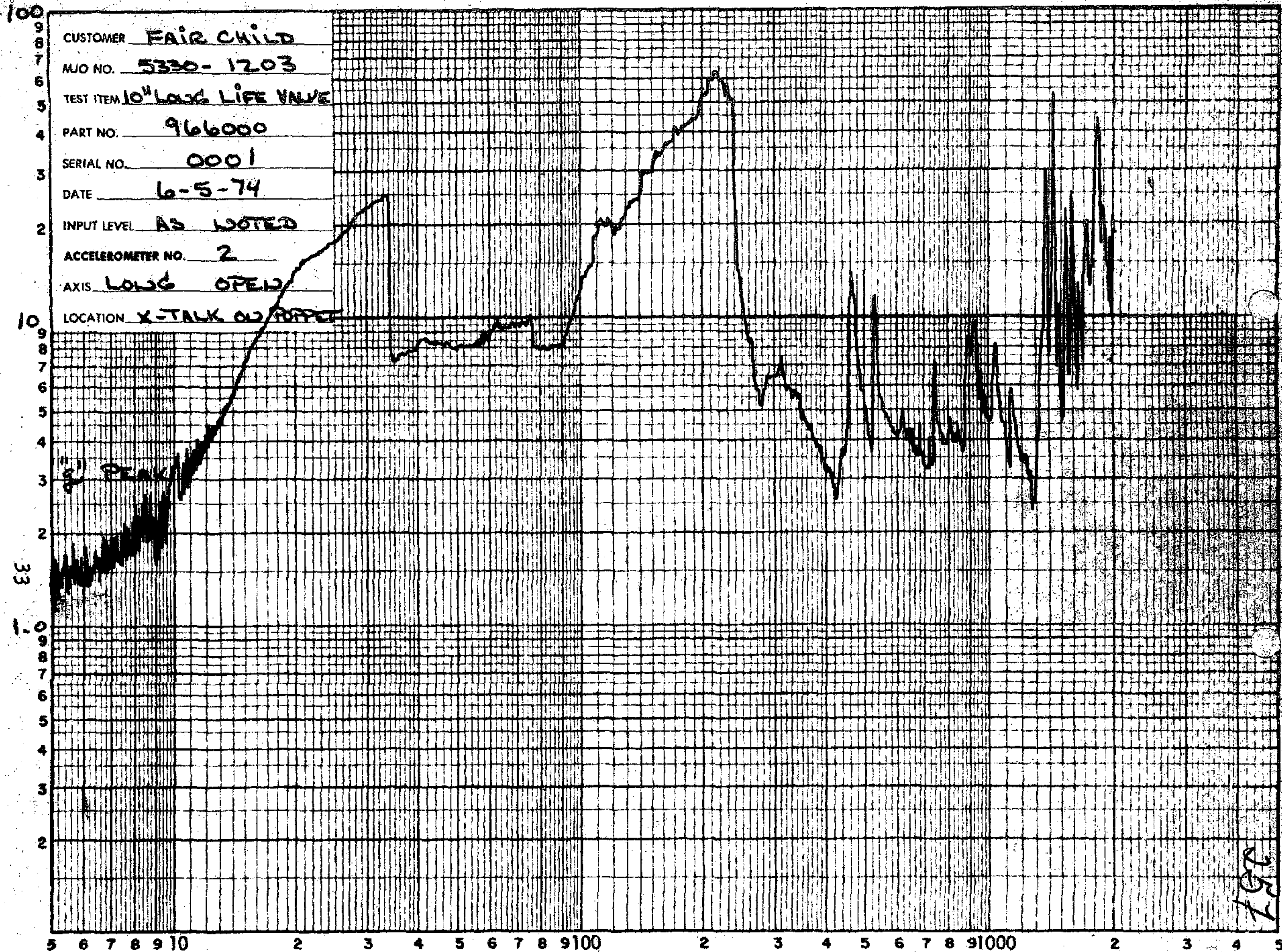
29


CUSTOMER FAIR CHILD
MJO NO. 5330- 1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-4-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 4
AXIS LONG CLOSED
LOCATION D.O.V. ACTUATOR COVER
g PEAK
30
FREQUENCY - (CPS)
FORM 1002-X-34-NEW 12-71
234


CUSTOMER FAIRCHILD
M/O NO. 5330-1203
TEST ITEM 10" LOW LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-4-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 5
AXIS LONG CLOSED
LOCATION ACTUATOR END
±.8" PEAK
FREQUENCY - (CPS)
FORM 1002-X-54 NEW 12-71
255

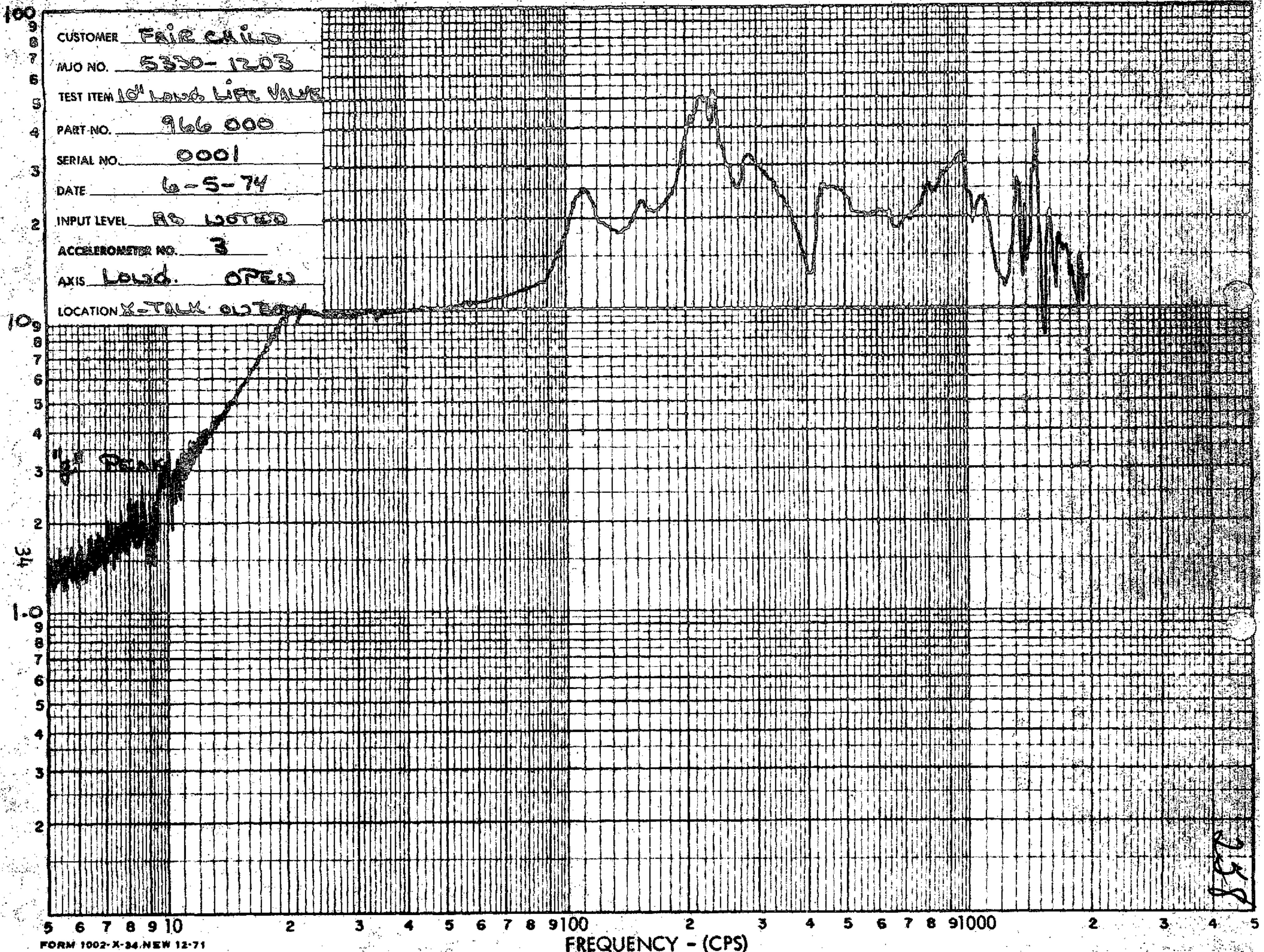

CUSTOMER FAIR CHILD
MJO NO. 5330- 1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 1
AXIS LONG. OPEN
LOCATION ON FIXTURE
1/8" PEAK
FREQUENCY - (CPS)
FORM 1002-X-34 NEW 12-71

32

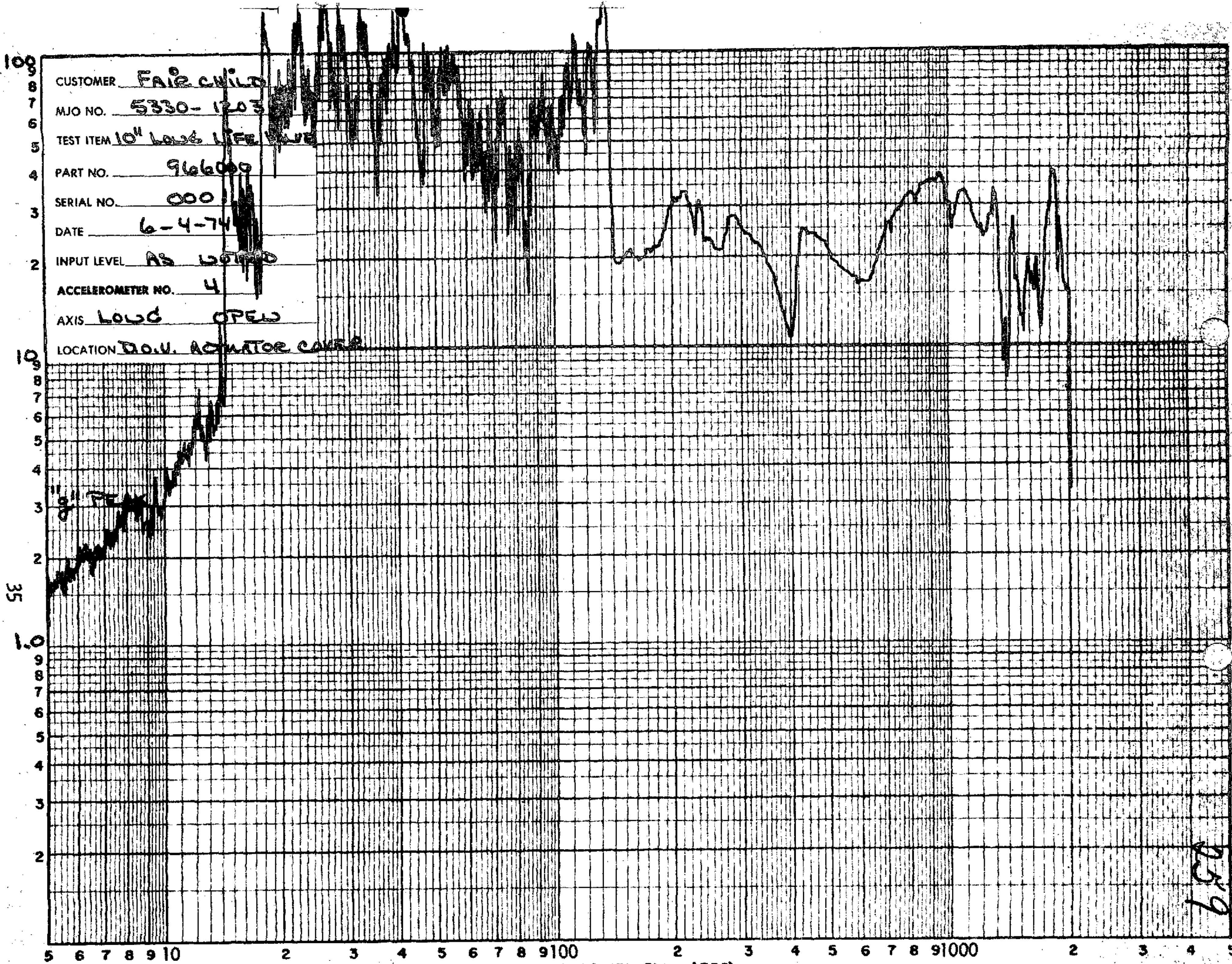


FORM 1002-X-34 NEW 12-71

33


CUSTOMER FAIR CHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966 000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 3
AXIS LONG. OPEN
LOCATION X-TALK OUTBOARD
"g" PEAK
100
10
1.0
5 6 7 8 9 10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4 5
FREQUENCY - (CPS)
FORM 1002-X-34 NEW 12-71
34

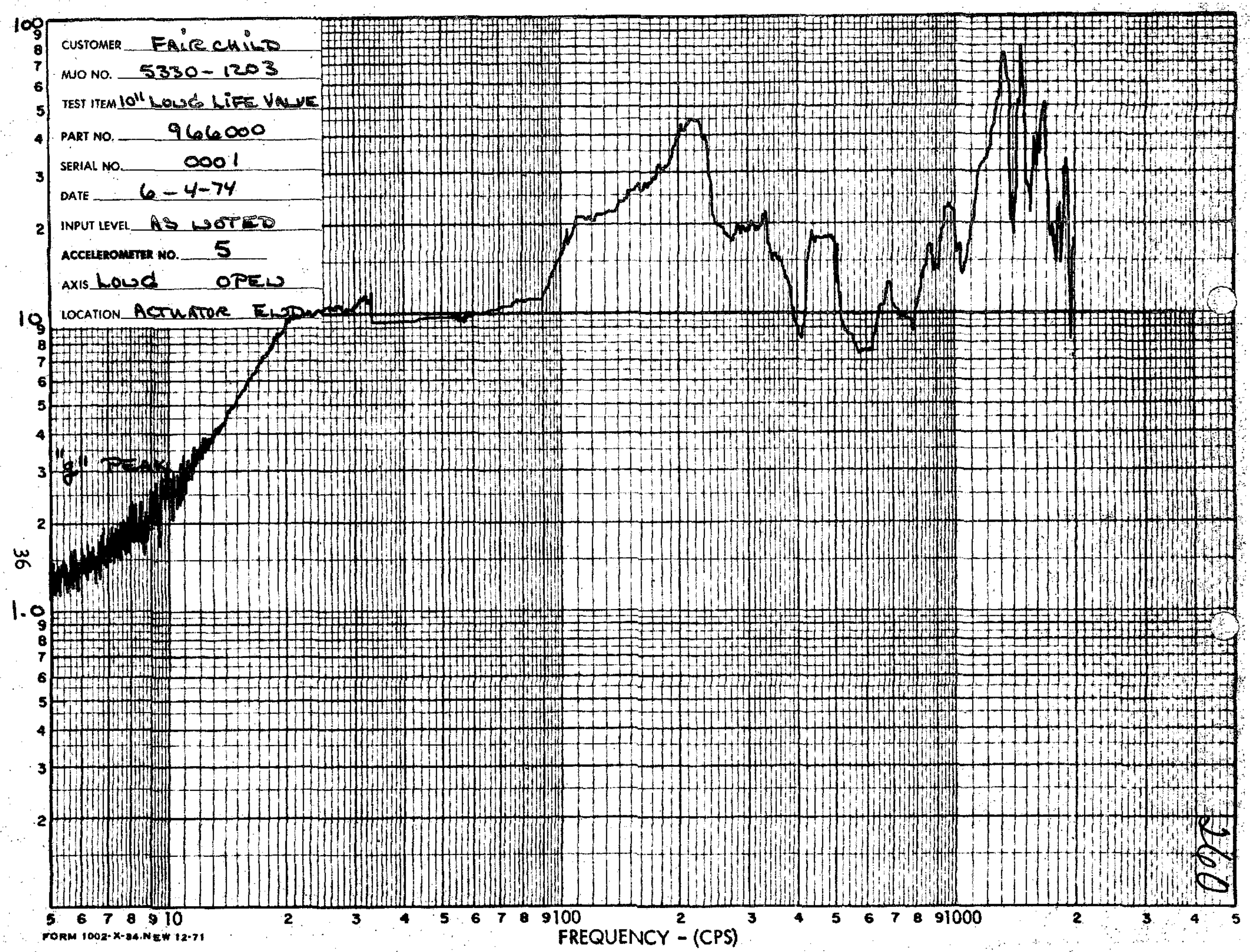
258

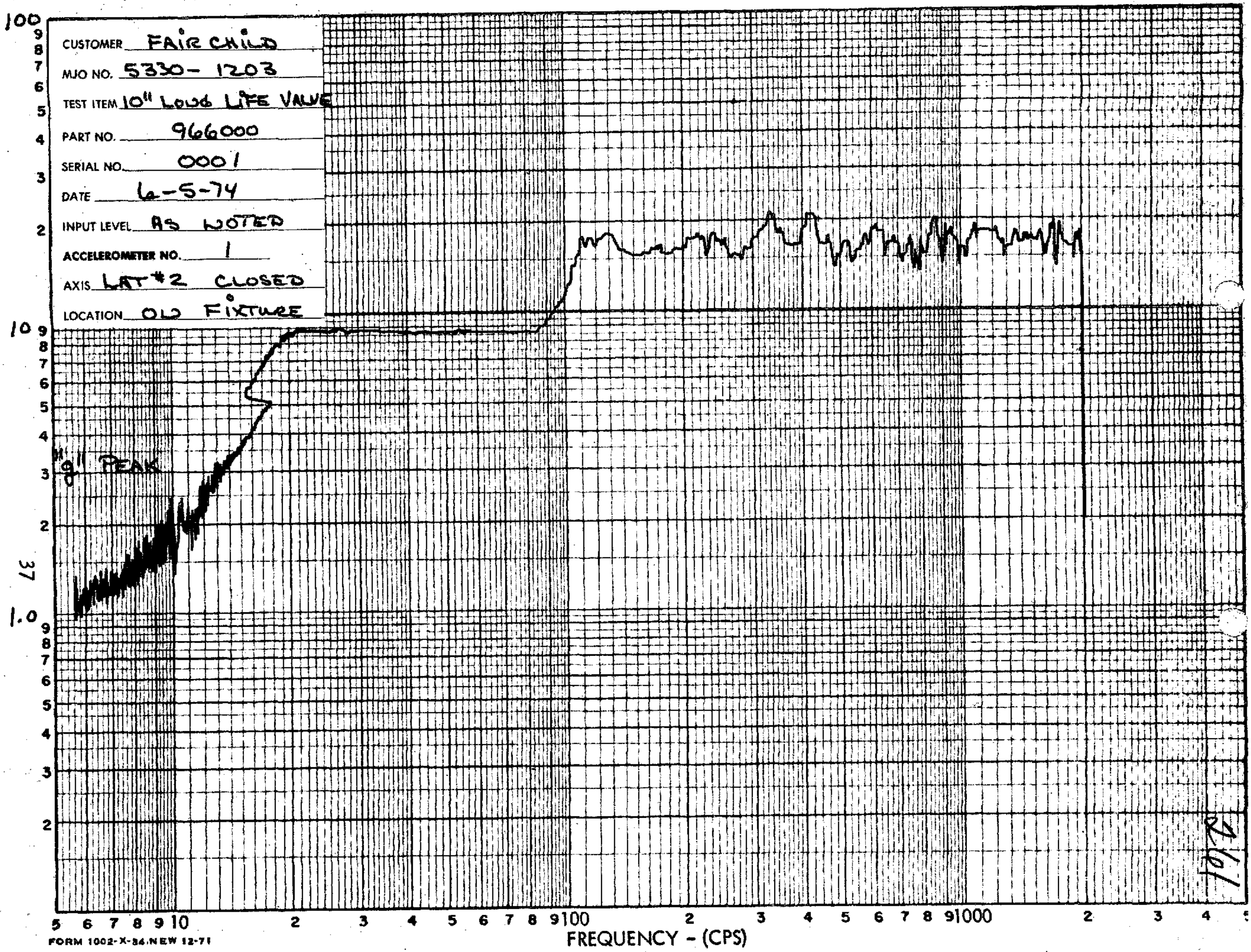


FORM 1002-X-94 NEW 12-71

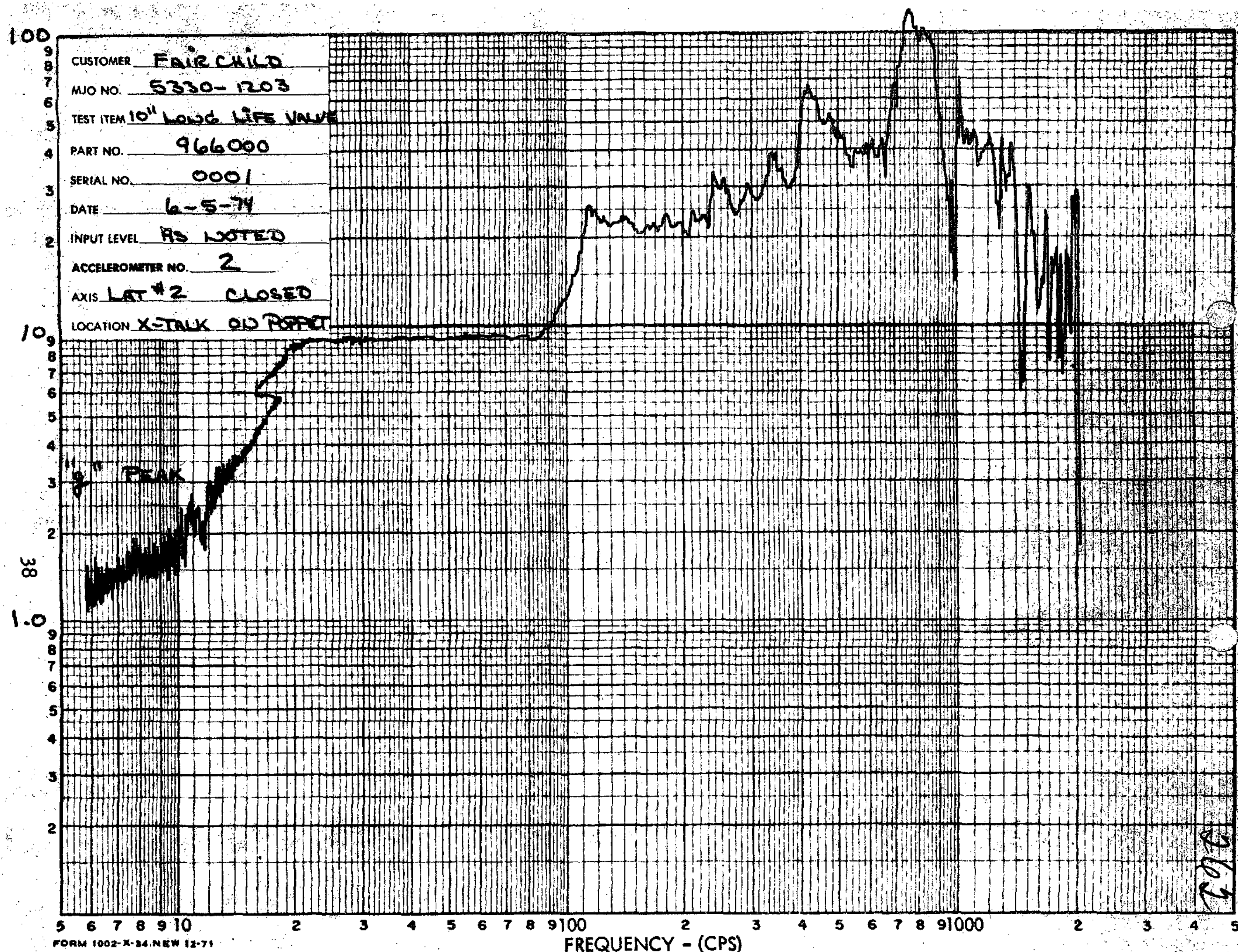
35

259

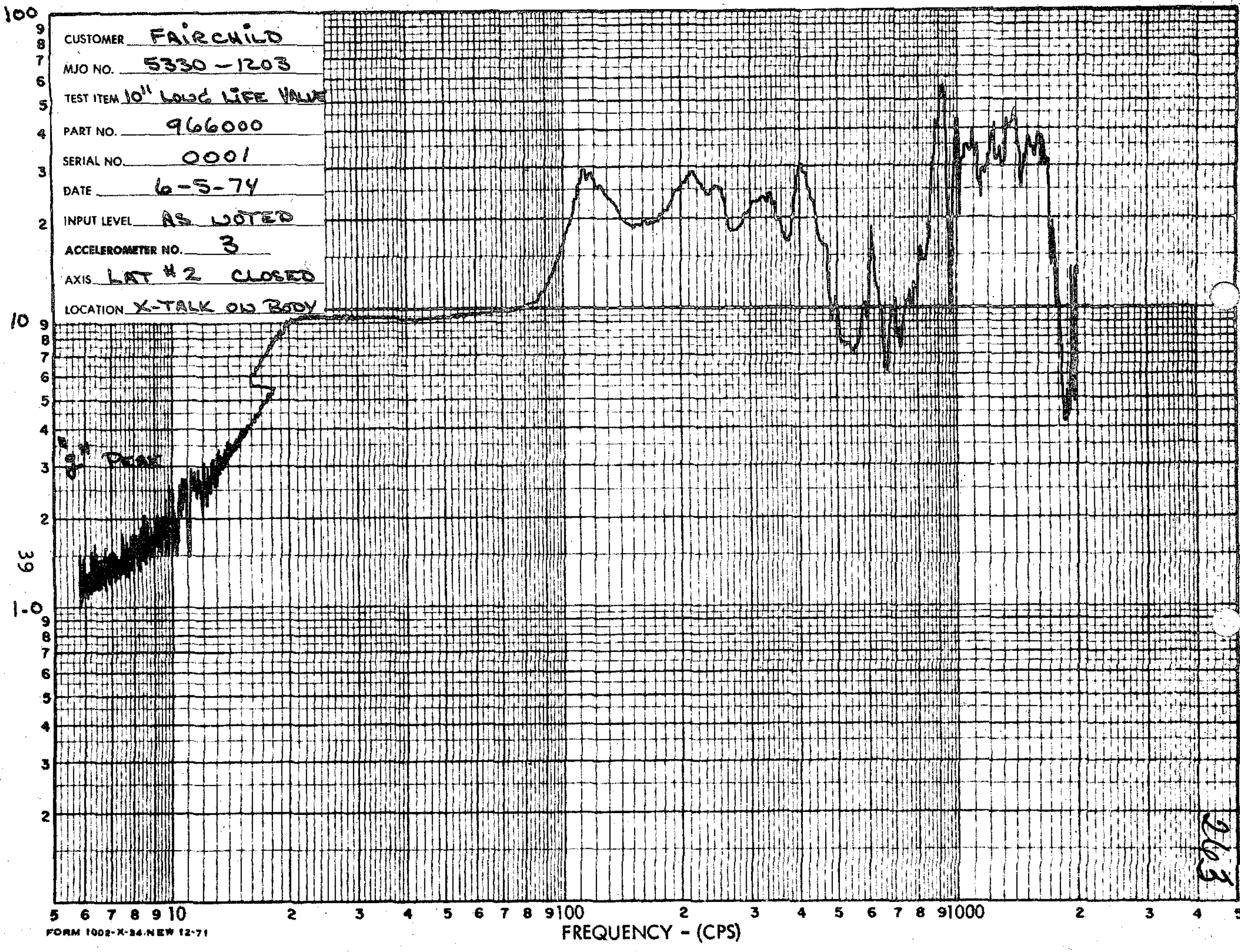

CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-4-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 5
AXIS LONG OPEN
LOCATION ACTUATOR
"g" PEAK
FREQUENCY - (CPS)
FORM 1002-X-34-NEW 12-71
36
260

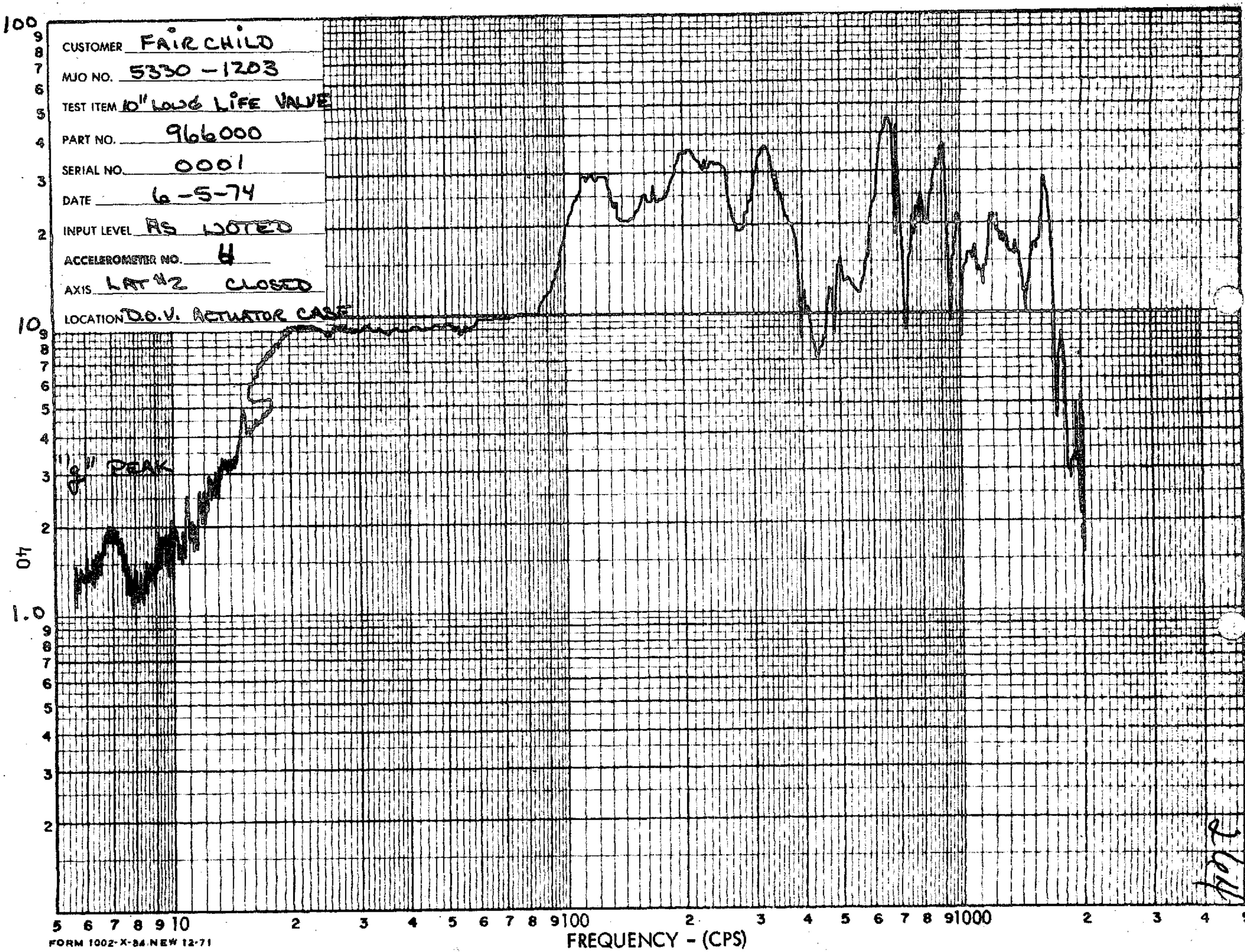


CUSTOMER FAIR CHILD
MJO NO. 5330- 1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 1
AXIS LAT #2 CLOSED
LOCATION OLD FIXTURE
"g" PEAK
FREQUENCY - (CPS)
FORM 1002-X-34.NEW 12-71
37
2107

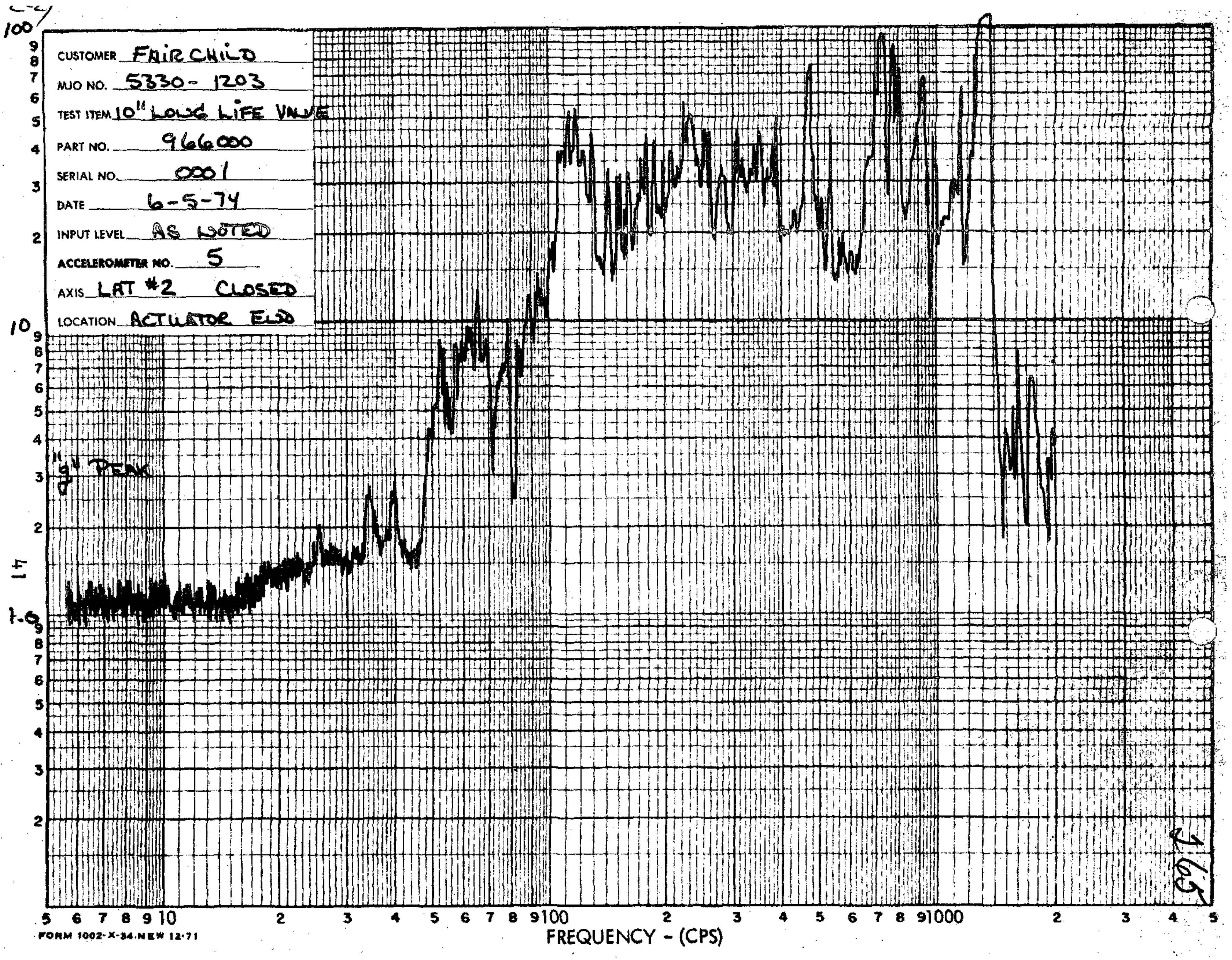

CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 2
AXIS LAT #2 CLOSED
LOCATION X-TALK ON POPPET
"g" PEAK
100
10
1.0
5 6 7 8 9 10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4 5
FREQUENCY - (CPS)
FORM 1002-X-34.NEW 12-71

38


CUSTOMER FAIRCHILD
MJO NO. 5330 – 1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 3
AXIS LAT #2 CLOSED
LOCATION X-TALK ON BODY
"g" PEAK
100
10
1-0
FREQUENCY – (CPS)
FORM 1002-X-24 NEW 12-71
39
263

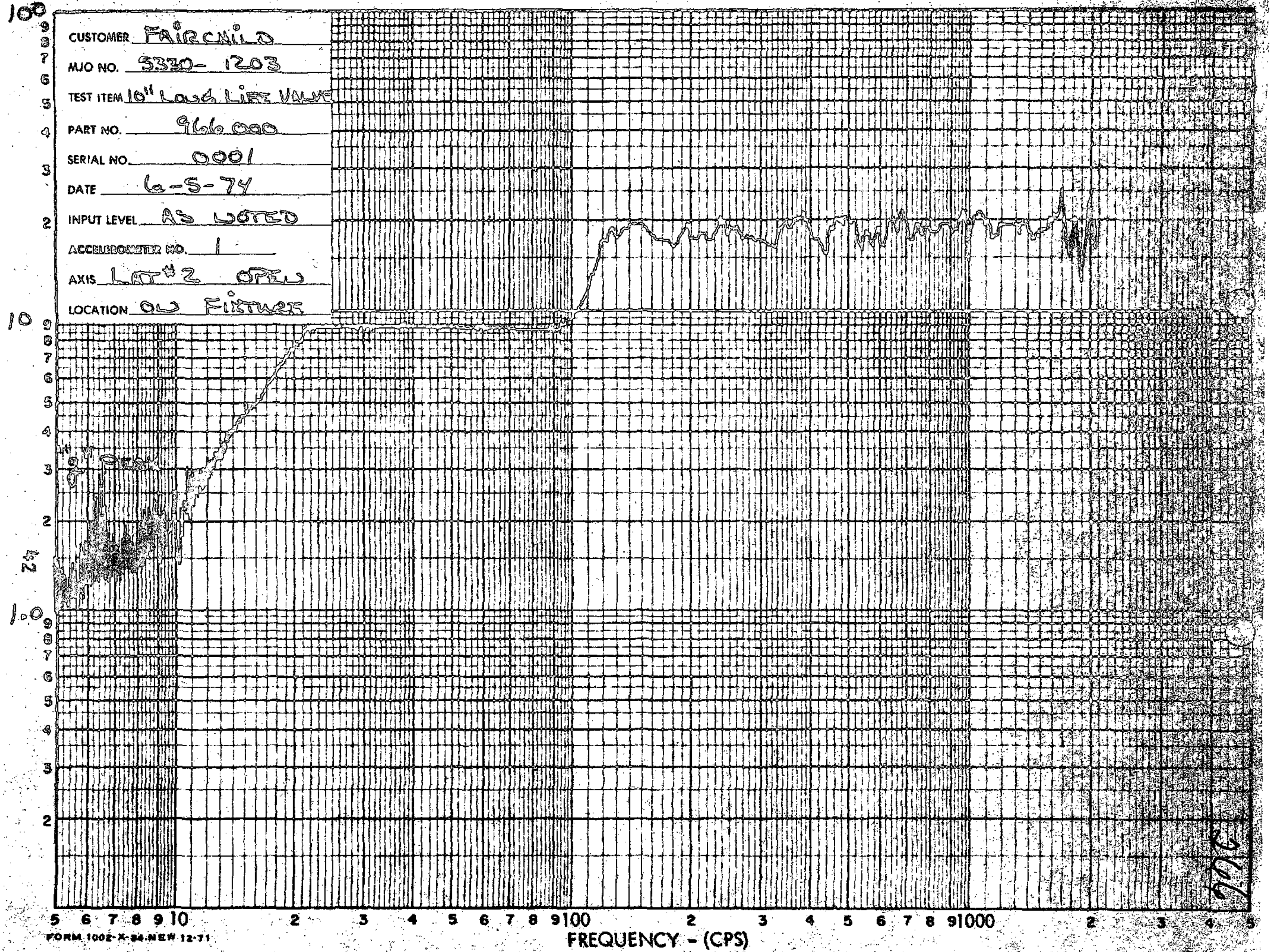


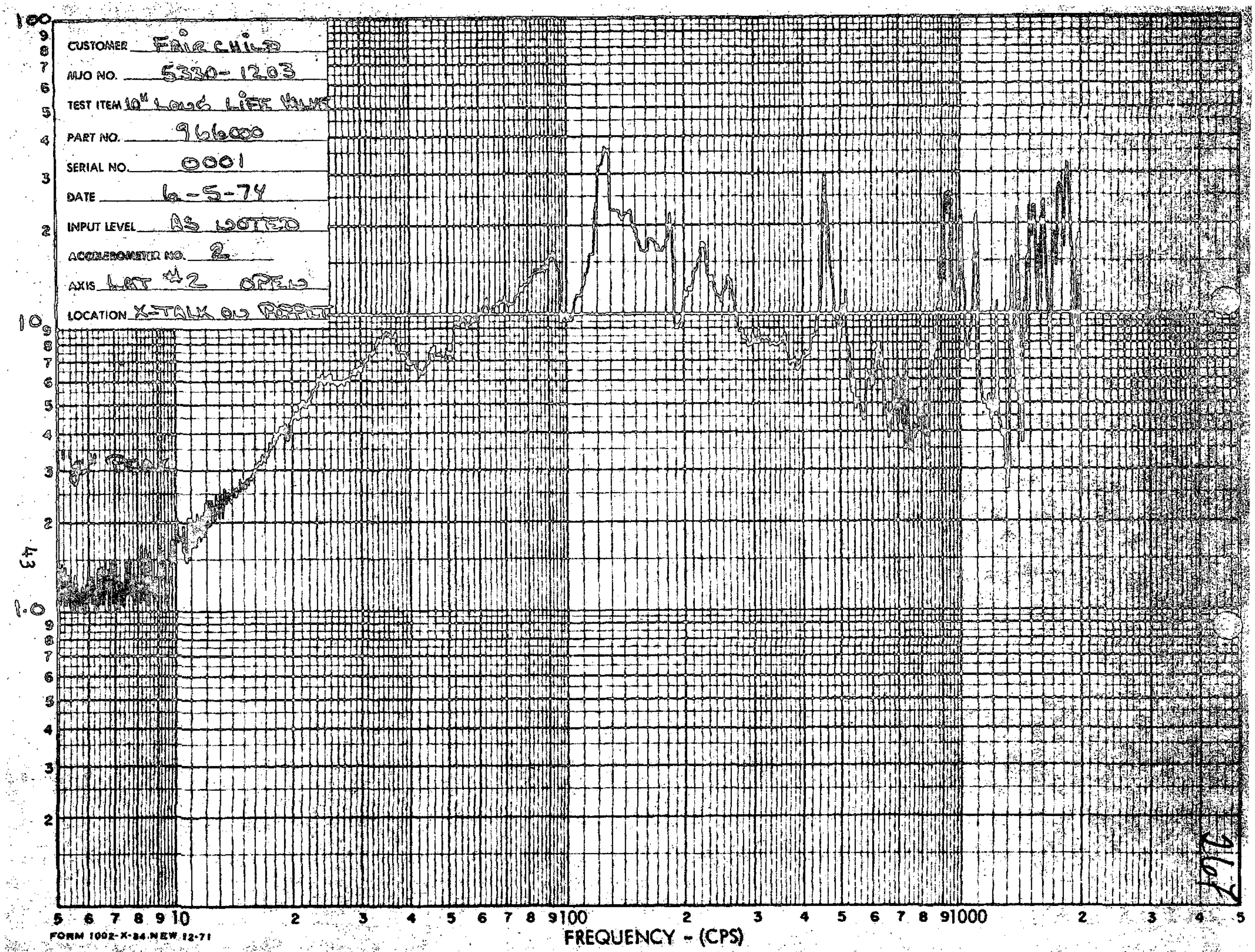
FORM 1002-X-34 NEW 12-71



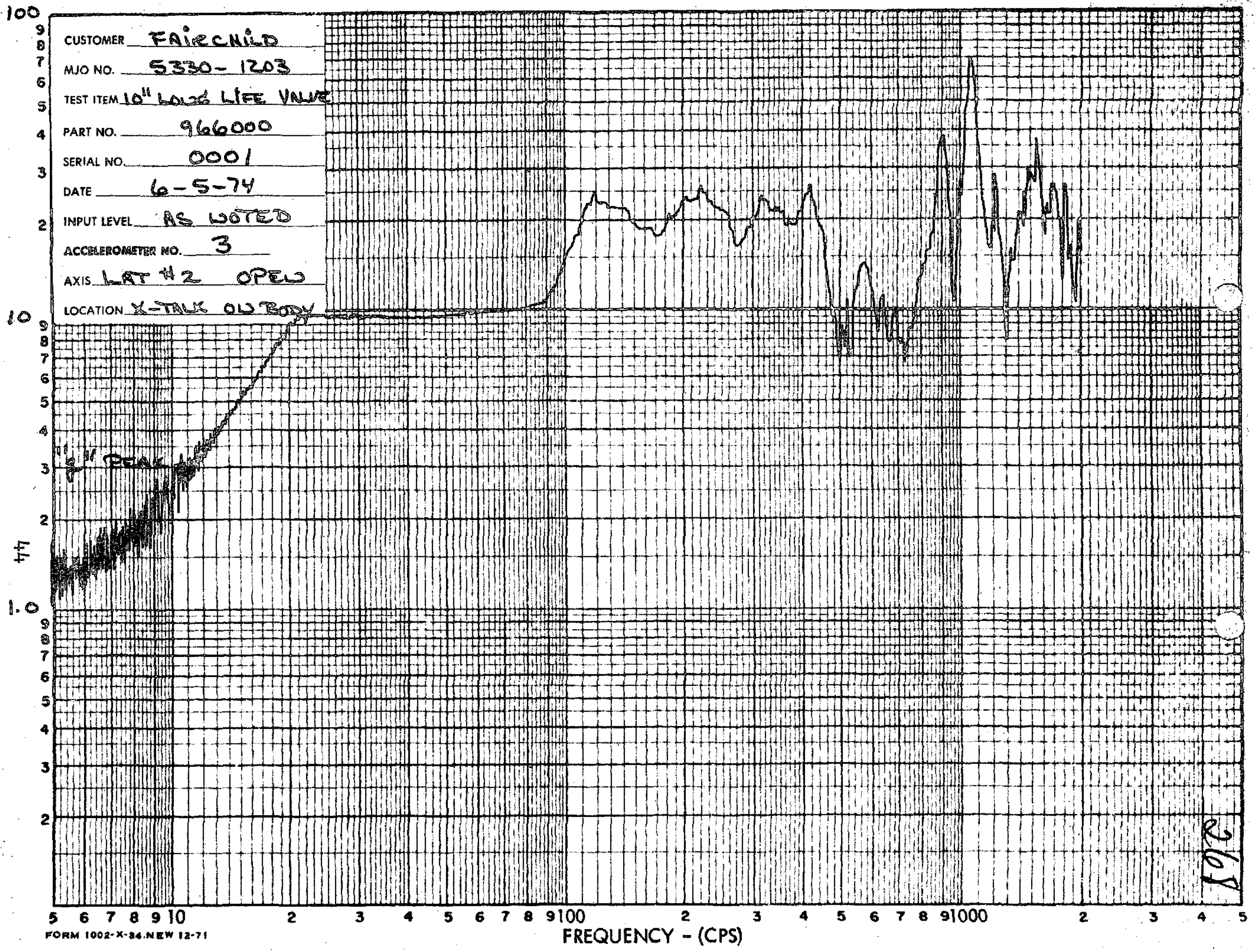
CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 5
AXIS LAT #2 CLOSED
LOCATION ACTUATOR END
"g" PEAK
100
10
1.0
5 6 7 8 9 10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4 5
FREQUENCY - (CPS)
FORM 1002-X-34-NEW 12-71

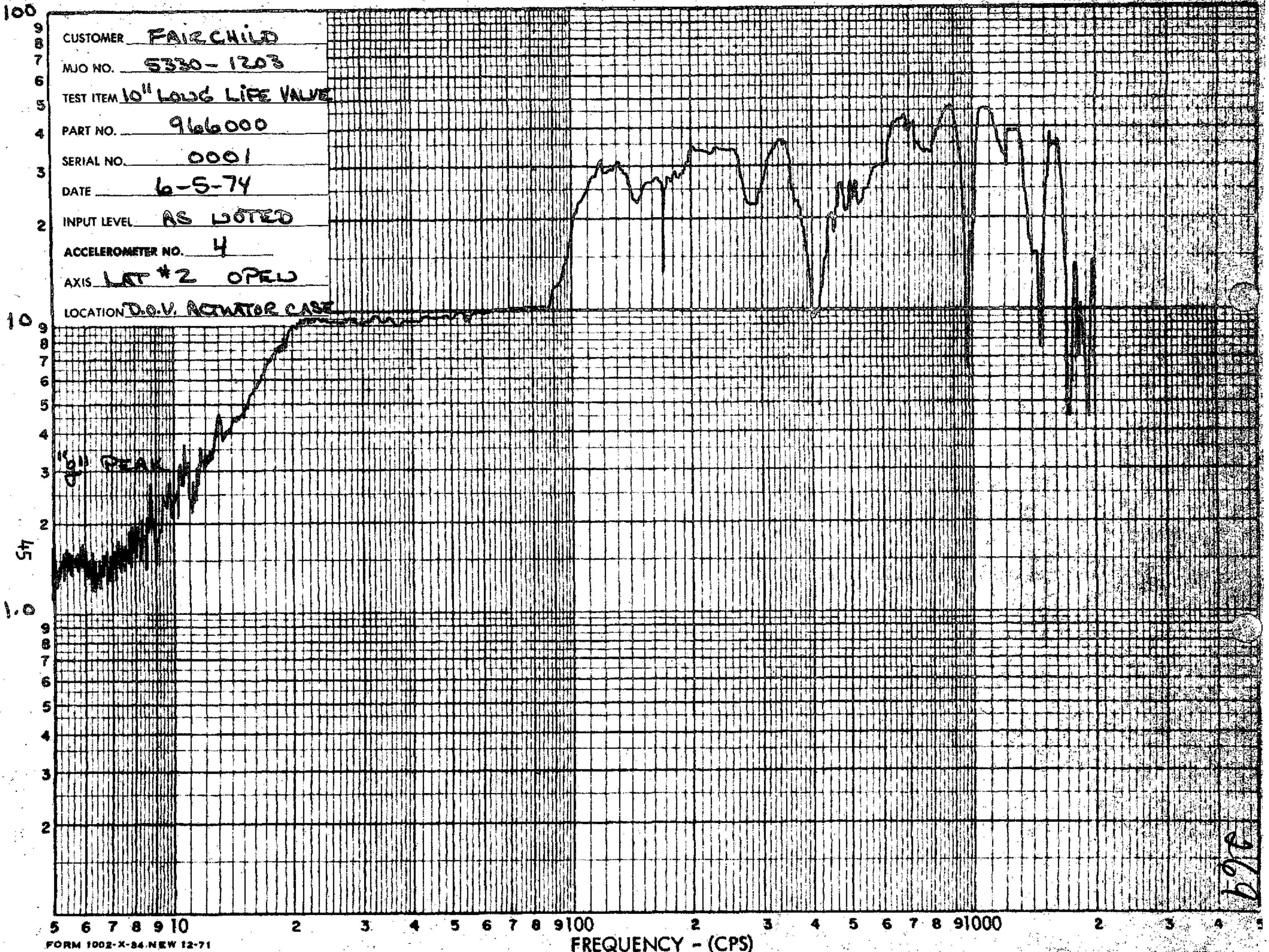
265

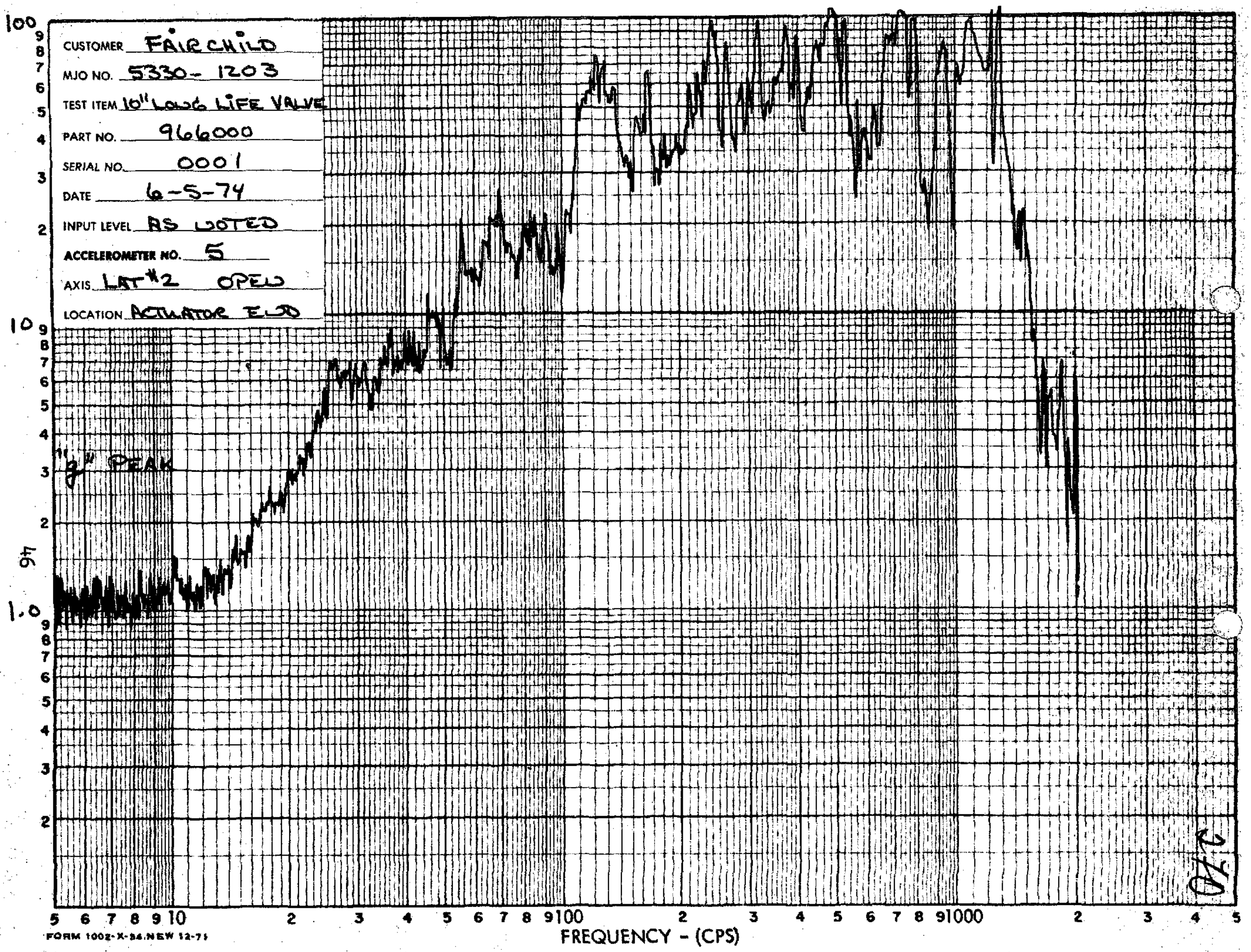

CUSTOMER FAIRCHILD
MJO NO. 5330- 1203
TEST ITEM 10" Load Lift Valve
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 1
AXIS LAT #2 OPEN
LOCATION ON FIXTURE
100
10
1.0
FREQUENCY - (CPS)
FORM 1002-X-84 NEW 12-71



CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LOAD LIFT VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 2
AXIS LAT #2 OPEN
LOCATION X-TALK ON POPPET
100
10
1.0
5 6 7 8 9 10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4 5
FREQUENCY - (CPS)
FORM 1002-X-34 NEW 12-71
43
267


CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LOAD LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 3
AXIS LAT #2 OPEN
LOCATION X-TALK ON BODY
.8" PEAK
FREQUENCY - (CPS)
FORM 1002-X-34.NEW 12-71


CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 4
AXIS LAT #2 OPEN
LOCATION D.O.V. ACTUATOR CASE
"g" PEAK
5g
100
10
1.0
5 6 7 8 9 10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4 5
FREQUENCY - (CPS)
FORM 1002-X-34 NEW 12-71



CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL AS NOTED
ACCELEROMETER NO. 5
AXIS LAT #2 OPEN
LOCATION ACTUATOR END
"g" PEAK
FREQUENCY - (CPS)
FORM 1002-X-34.NEW 12-71

APPENDIX 2

PSD Plots

CUSTOMER FAIRCHILD

MJO NO. 5330-1203

TEST ITEM 10" LONG LIFE VALVE

PART NO. 966000

SERIAL NO. 0001

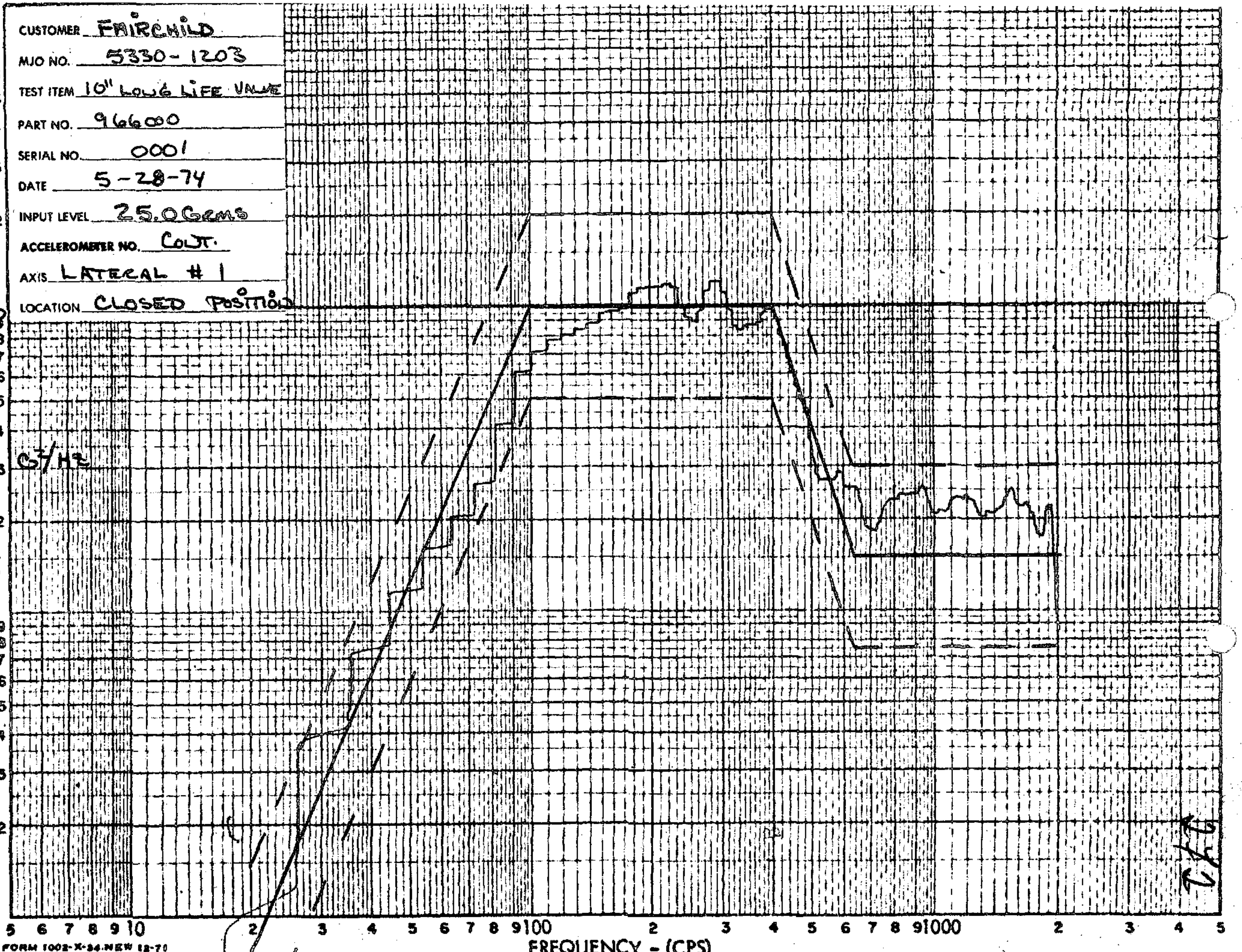
DATE 5-28-74

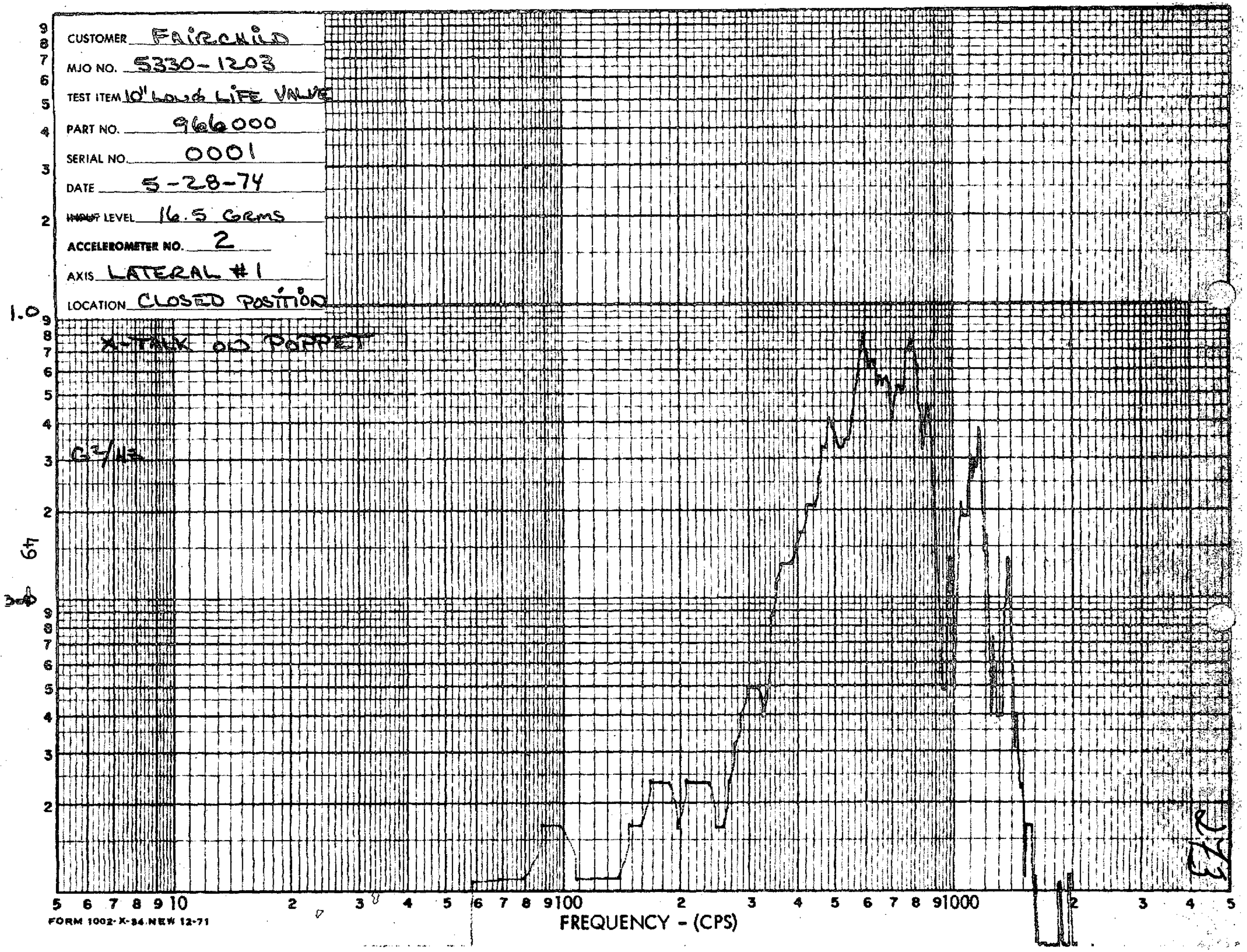
INPUT LEVEL 25.0 Grms

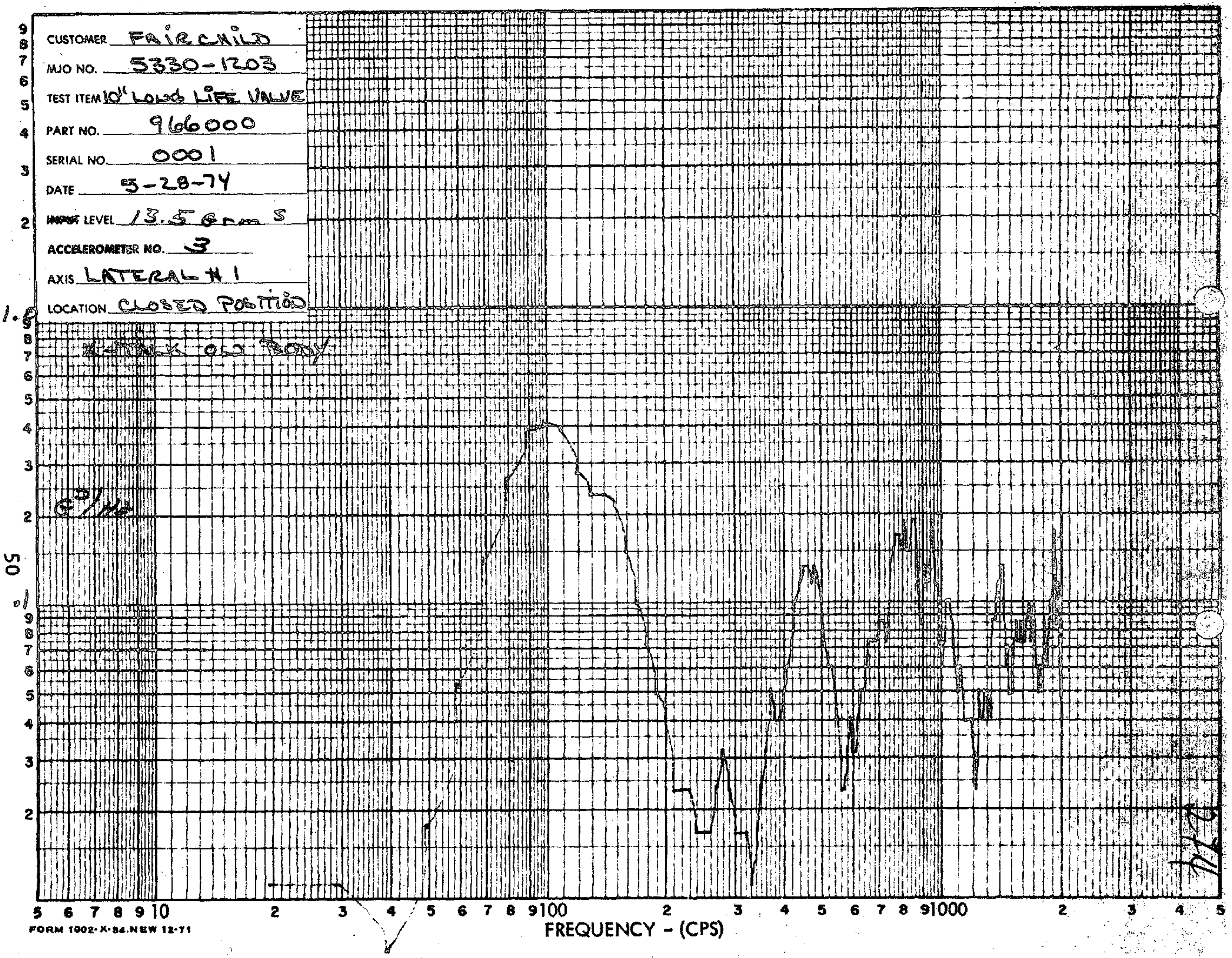
ACCELEROMETER NO. CONT.

AXIS LATERAL #1

LOCATION CLOSED POSITION




CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LOW & LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 5-28-74
INPUT LEVEL 16.5 GRMS
ACCELEROMETER NO. 2
AXIS LATERAL #1
LOCATION CLOSED POSITION
X-TALK ON POPPET
G²/HZ
1.0
FREQUENCY - (CPS)
FORM 1002-X-34 NEW 12-71


CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 5-28-74
INPUT LEVEL 13.5 Grms
ACCELEROMETER NO. 3
AXIS LATERAL #1
LOCATION CLOSED POSITION
X-TALK ON BODY
G²/Hz
1.0
.1
50
5 6 7 8 9 10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4 5
FREQUENCY - (CPS)
FORM 1002-X-84.NEW 12-71

CUSTOMER FAIRCHILD

MJO NO. 5330-1203

TEST ITEM 10" LONG LIFE VALVE

PART NO. 966000

SERIAL NO. 0001

DATE 5-28-74

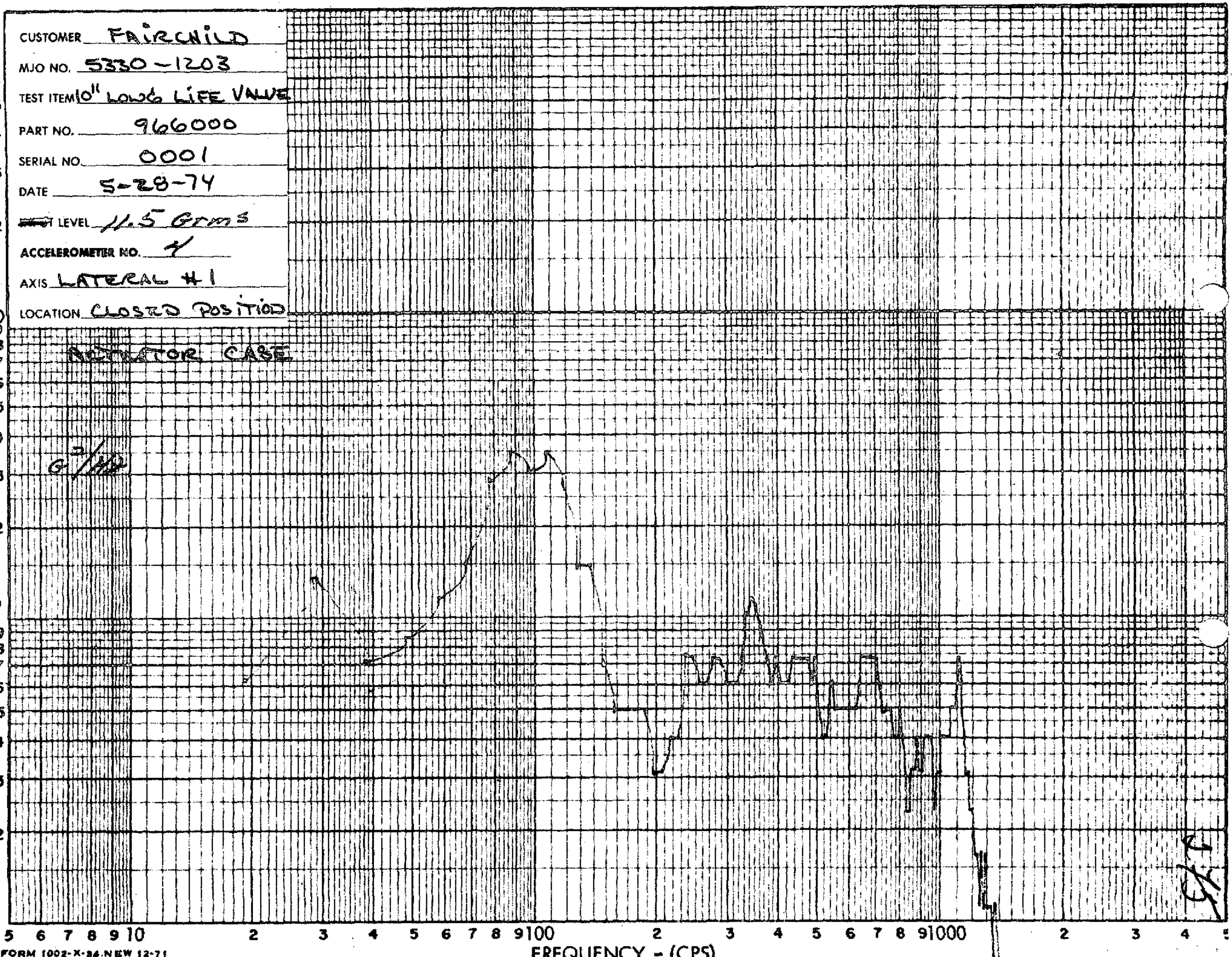
LEVEL 11.5 Grms

ACCELEROMETER NO. 4

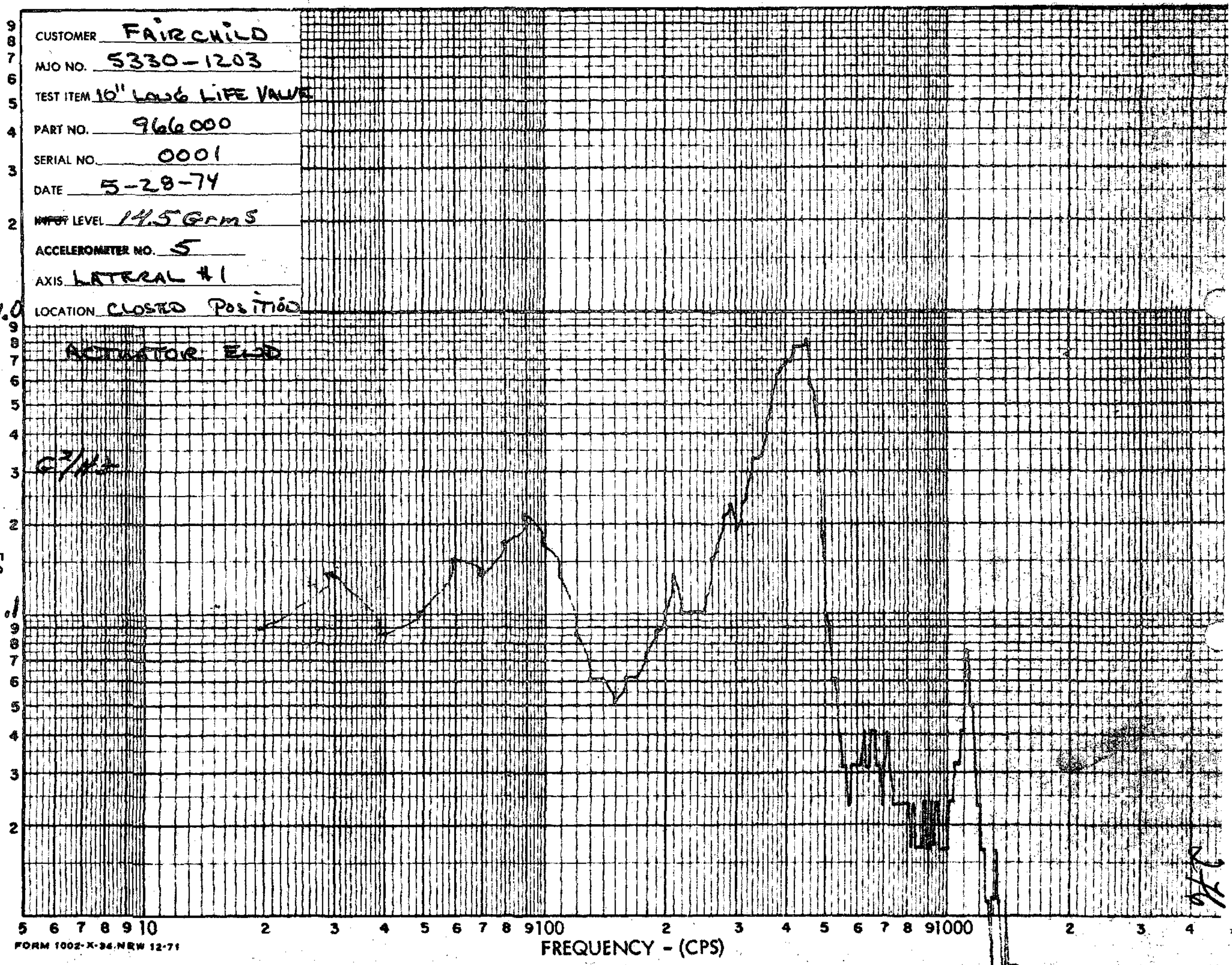
AXIS LATERAL #1

LOCATION CLOSED POSITION

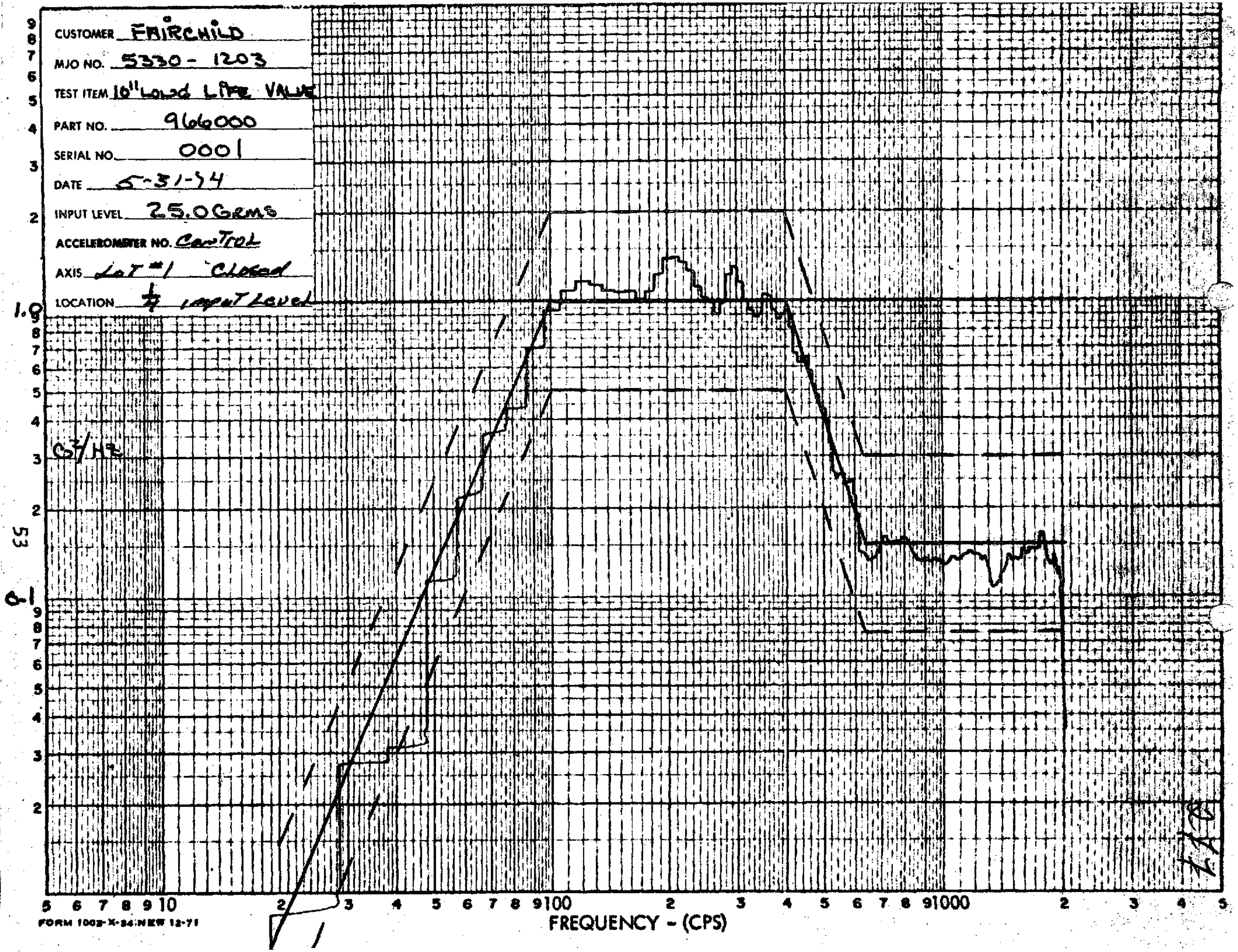
ACTUATOR CASE

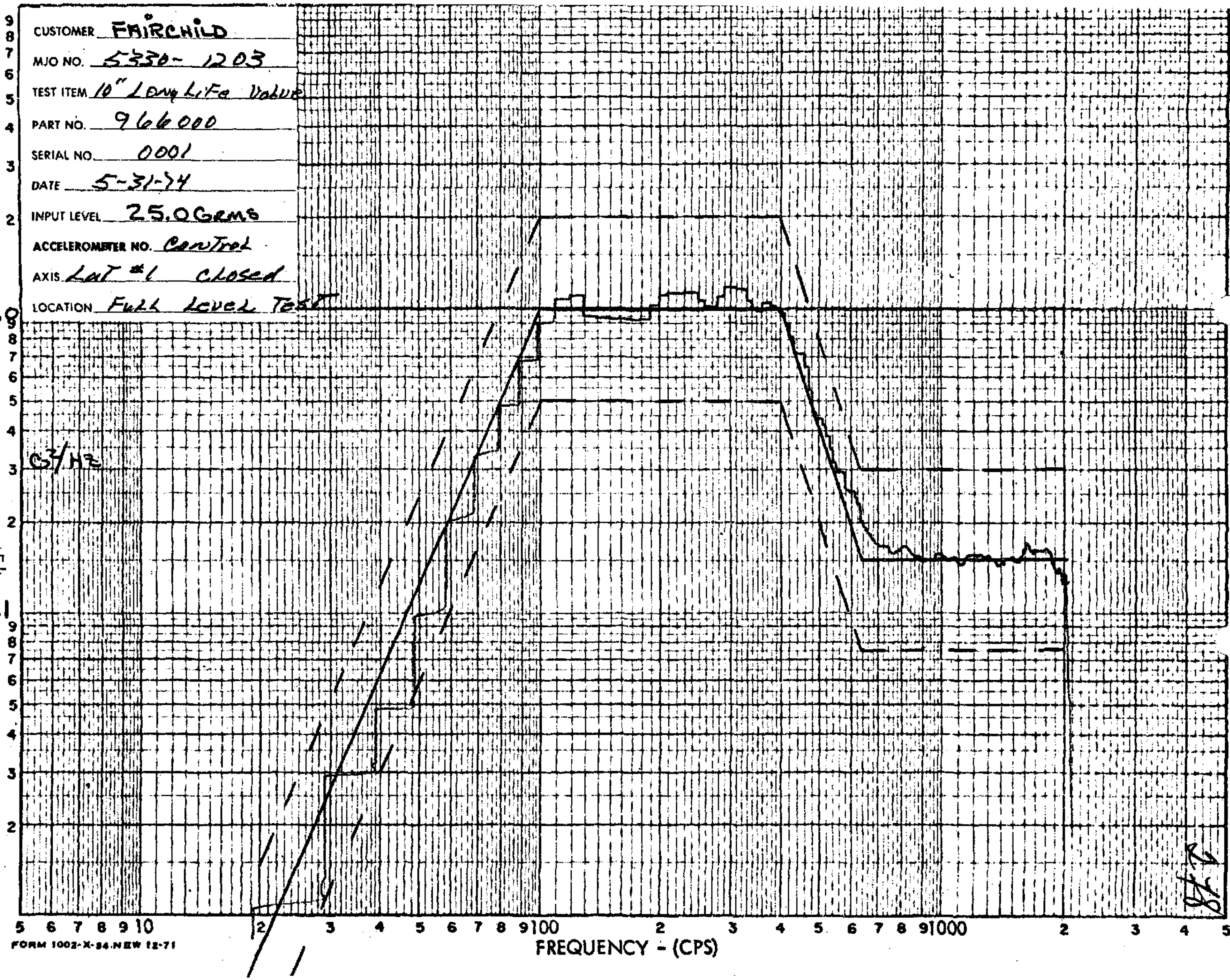


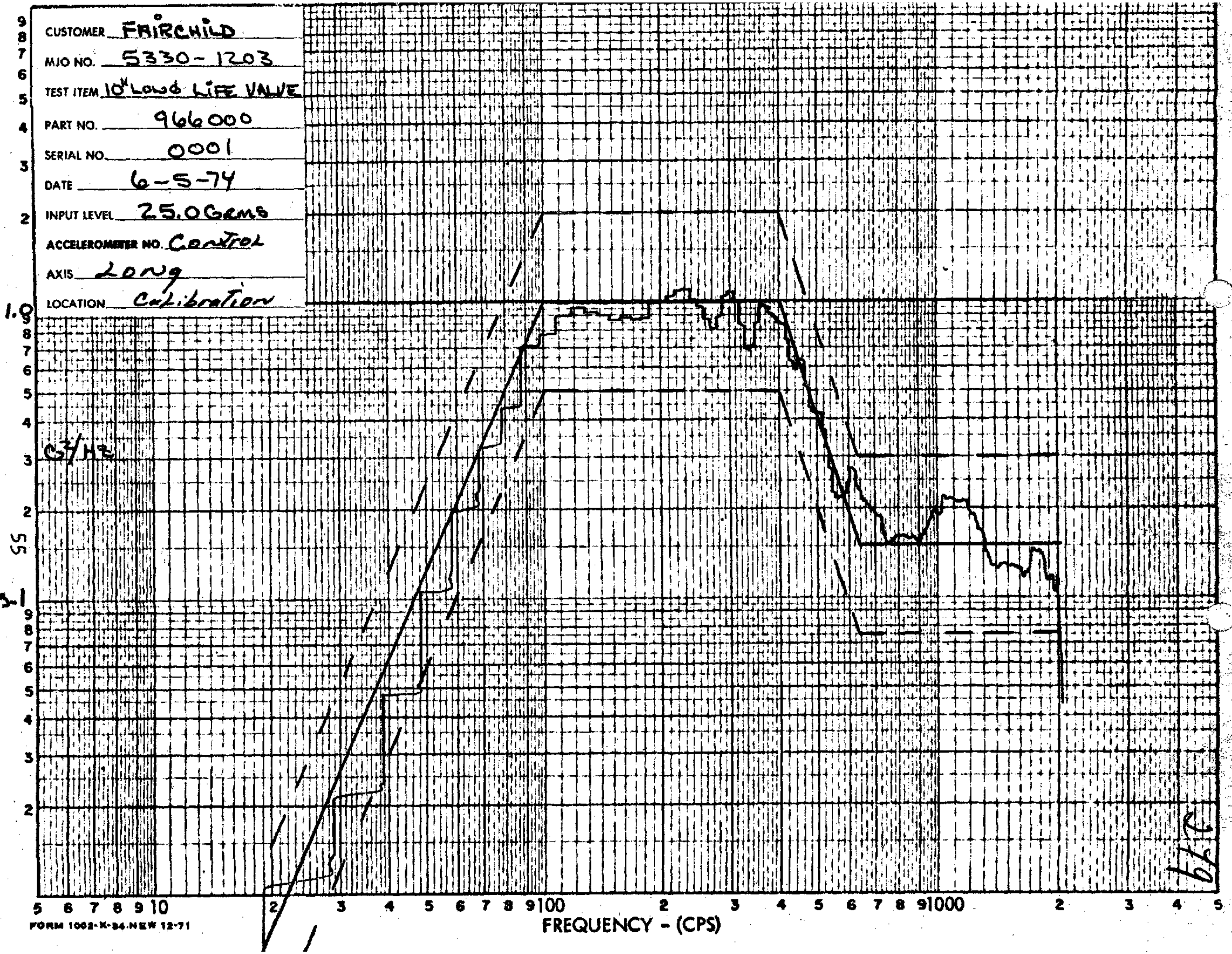
FORM 1002-X-34.NEW 12-71


CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 5-28-74
INPUT LEVEL 14.5 Grms
ACCELEROMETER NO. 5
AXIS LATERAL #1
LOCATION CLOSED POSITION
ACTUATOR END
G²/Hz
1.0
.1
5 6 7 8 9 10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4
FREQUENCY - (CPS)
FORM 1002-X-34.NEW 12-71

52


CUSTOMER FAIRCHILD
MJO NO. 5330- 1203
TEST ITEM 10" Load Life Valve
PART NO. 966000
SERIAL NO. 0001
DATE 5-31-74
INPUT LEVEL 25.0 Grms
ACCELEROMETER NO. Control
AXIS Lot #1 Closed
LOCATION ½ input Level
G^2/Hz
FREQUENCY - (CPS)
FORM 1002-X-34:NEW 12-71


CUSTOMER FAIRCHILD
MJO NO. 5330- 1203
TEST ITEM 10" Long Life Valve
PART NO. 966000
SERIAL NO. 0001
DATE 5-31-74
INPUT LEVEL 25.0 Grms
ACCELEROMETER NO. Control
AXIS LAT #1 closed
LOCATION Full Level Test
G²/Hz
1.0
0.1
FREQUENCY - (CPS)
FORM 1002-X-54.NEW 12-71


CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL 25.0 Grms
ACCELEROMETER NO. Control
AXIS Long
LOCATION Calibration
G²/Hz
1.0
.1
10
100
1000
FREQUENCY - (CPS)
FORM 1002-K-34-NEW 12-71
55
279

CUSTOMER FAIRCHILD

MJO NO. 5330-1203

TEST ITEM 10" LONG LIFE VALVE

PART NO. 966000

SERIAL NO. 0001

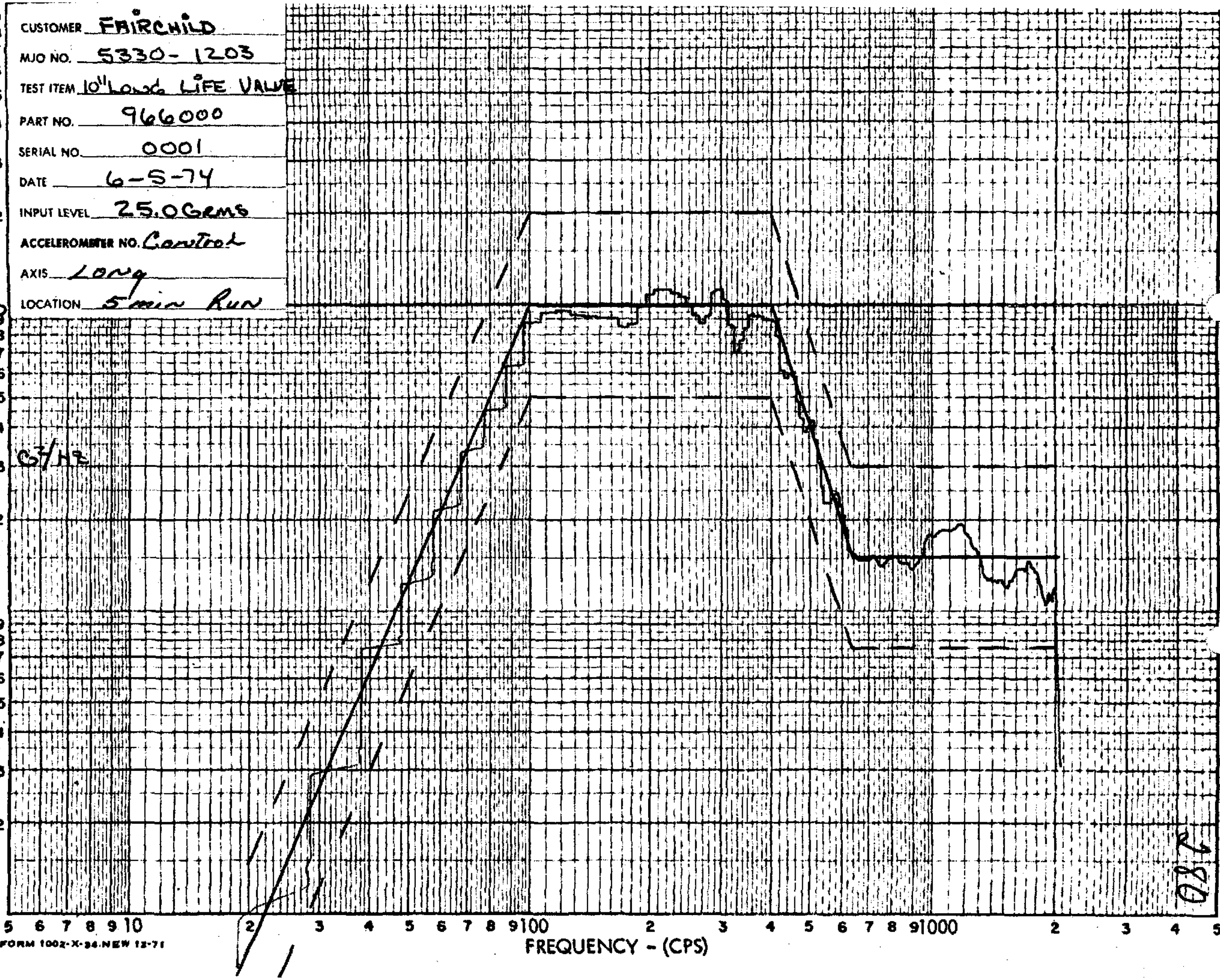
DATE 6-5-74

INPUT LEVEL 25.0 Grms

ACCELEROMETER NO. Control

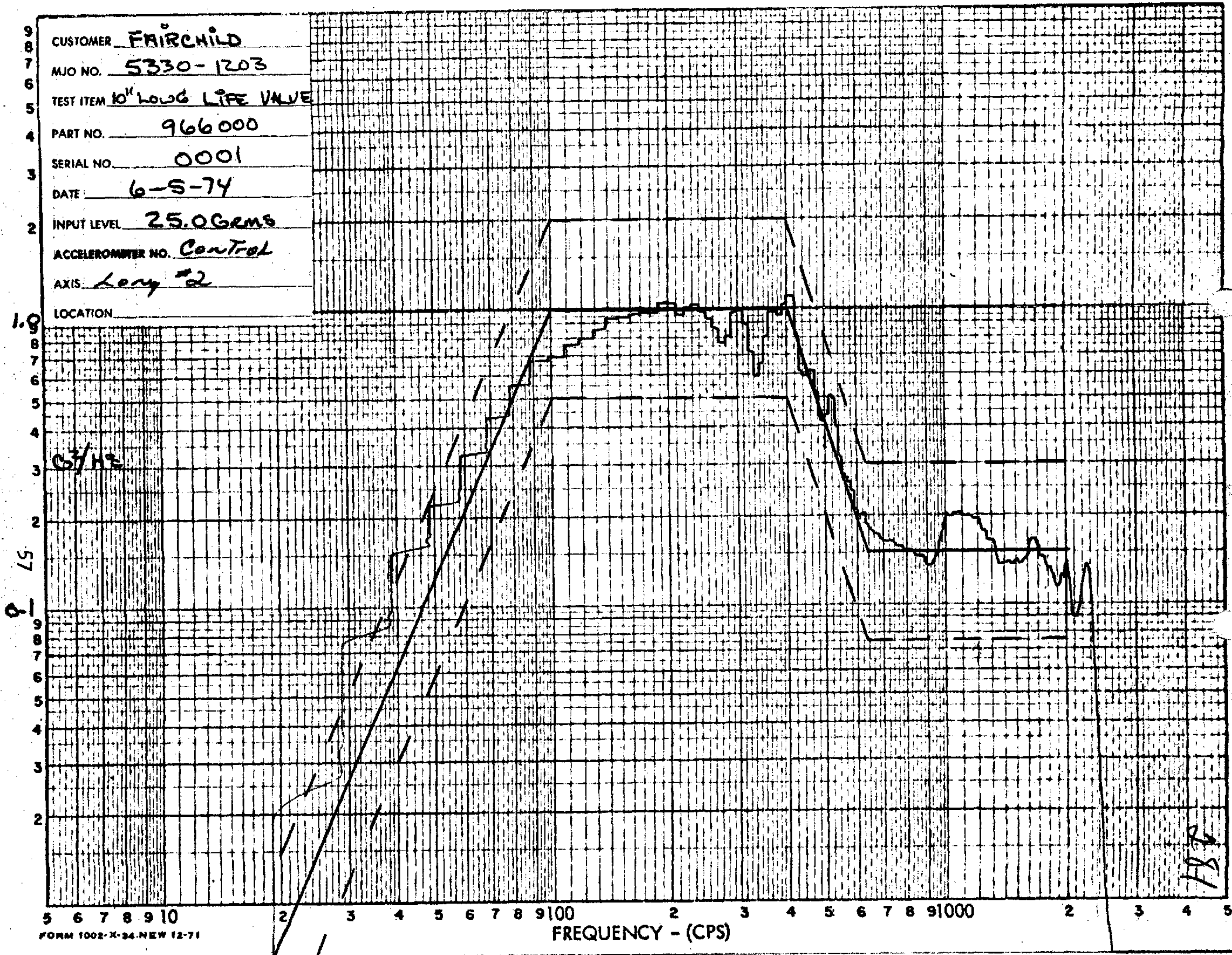
AXIS LONG

LOCATION 5 min RUN



FORM 1002-X-34-NEW 12-71

3-195


CUSTOMER FAIRCHILD
MJO NO. 5330-1203
TEST ITEM 10" LONG LIFE VALVE
PART NO. 966000
SERIAL NO. 0001
DATE 6-5-74
INPUT LEVEL 25.0 Grms
ACCELEROMETER NO. Control
AXIS Long #2
LOCATION
G²/Hz
1.0
0.1
FREQUENCY - (CPS)
FORM 1002-X-34-NEW 12-71