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FAIRCHILD STRATOS DIVISION'S TYPE II PROTOTYPE LOCKHOPPER VALVE: METC PROTOTYPE TEST VALVE NO. F-1, PROTOTYPE LOCKHOPPER VALVE-TESTING AND DEVELOPMENT PROJECT

Static Test Report

By
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D. A. Maxfield
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October 1981

Work Performed Under Contract No. AM21-81MC16050

TRW Energy Engineering Division
McLean, Virginia

TECHNICAL INFORMATION CENTER
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ABSTRACT

METC Prototype Test Valve No. F-1 is a hybrid design, based on a segmented ball termed a "visor valve," developed and manufactured by Fairchild Stratos Division under contract to the Department of Energy. The valve uses a visor arm that rotates into position and then translates to seal. This valve conditionally completed static testing at METC with clean gas to pressures of 1,600 psig and internal valve temperatures to 600°F. External leakage was excessive due to leakage through the stuffing box, purge fittings, external bolts, and other assemblies. The stuffing box was repacked several times and redesigned midway through the testing, but external leakage was still excessive. Internal leakage through the seats, except for a few anomalies, was very low throughout the 2,409 cycles of testing.

As shown by the low internal leakage, the visor valve concept appears to have potential for lockhopper valve applications. The problems that are present with METC Prototype Test Valve No. F-1 are in the seals, which are equivalent to the shaft and bonnet seals in standard valve designs. The operating conditions at these seals are well within the capabilities of available seal designs and materials. Further engineering and minor modifications should be able to resolve the problems identified during static testing.

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INTRODUCTION

Coal will most certainly play a key role in meeting our country's long-term energy needs. Most processes, such as pressurized fluidized-bed combustion and advanced coal gasification, operate at high temperatures and pressures. The lack of reliable lockhopper valves for handling solids at pressures to 1,600 psig and temperatures to 2000°F is a critical problem. Valve failures encountered in most pilot-plant operations are typically caused by abrasion, erosion, jamming, or other solids-related problems.

The Prototype Lockhopper Valve-Testing and Development project was initiated to design, develop, test, and evaluate new lockhopper valves that would be compatible with the harsh operating conditions encountered in the various coal-gasification plants. Four types of valves are being developed:

- Type I—Valves for feed systems
- Type II—Valves between injection hopper and gasifier
- Type III—Valves for char- and ash-removal systems
- Type IV—Valves for slurry-discharge systems

Typical lockhopper valve applications are shown in Figure 1.

Two companies were awarded contracts to develop prototype lockhopper valves: Fairchild Stratos Division (FSD) and Consolidated Controls Corporation (CCC). The initial phase of the three-phase program consisted of conceptual design and functional analysis. During this phase, each contractor conducted a design analysis and the individual component testing necessary to verify its design approach. This analysis and testing verified design assumptions, proved operability of unique mechanisms, obtained materials-wear data and materials-hardness data, and in general, made available all of the necessary data required to proceed with final design and fabrication of the prototype lockhopper valves.

The current phase (Phase II) of prototype lockhopper valve development consists of the detailed design, fabrication, and testing of 8-inch prototype valves. Testing consists of acceptance testing by the contractor prior to shipment of the valve to METC and verification testing at the METC Valve-Test Center. This report presents the results of static testing of the first FSD Type II prototype valve.

The ultimate objective of the Prototype Lockhopper Valve Testing and Development project is to perform successful verification testing on the prototype lockhopper valves. Successful testing would verify the valves' capability of fulfilling the following service criteria:

- System and differential pressures of 1,600 psig
- Media temperatures to 350°F for the Type I valve, 850°F for the Type II valve, 2000°F for the Type III valve, and 600°F for the Type IV valve
- Operating life of 30,000 cycles without internal refurbishment
- Internal leakage at end of operating life less than 10.0 scfm per inch of nominal bore size (80 scfm)
- External leakage at end of operating life less than 0.1 scfm
- Valve-actuation time of less than 30 seconds
- Valve operating force/torque repeatable and within the rated limits of the supplied actuator

To perform the required developmental testing, four lockhopper valve-test units, a computer-controlled data-acquisition and control system, and a metrology laboratory have been constructed at METC. Additional information on these facilities is provided in the Appendix.

TEST VALVE DESCRIPTION

METC Prototype Test Valve No. F-1, designed and built by Fairchild Stratos Division, under Contract No. DE-AC21-76ET-10666, is an 8-inch-diameter bore, rotary, segmented, ball-valve design which FSD calls a "visor valve." The valve incorporates a unique yoke-and-visor design to avoid rubbing contact between the sealing surfaces when opening or closing the valve. Figure 2 shows a schematic of the valve opening; Figure 3 is a photograph of the actual internals. The closure elements are moved linearly away from the seats and are then rotated 90° out of the flow stream. The closing cycle reverses this procedure. The valve has the advantage of poppet valve seating and the clear flow path of a ball valve.

Figure 4 shows the visor design incorporated in an FSD prototype lockhopper valve. An electric, motor-driven, gear actuator is used to rotate the valve's drive shaft. An arm attached to the drive shaft, in turn, drives two additional arms; one arm is attached to the rotation shaft and the other arm is attached to the translation shaft. The relationship between these two shafts allows the visors to completely lift off the seats prior to rotating. A pneumatic purge system is used to prevent solids buildup on critical sealing surfaces during the valve's closing cycle. The static testing reported in this document uses only clean gas (no solids), so the purge system was not used. The valve also includes a control system designed to back the visors off and repurge the seats if interference is encountered during the closing process. After three such cycles the valve is de-energized.

METC Prototype Test Valve No. F-1 is a Type II valve and so it must seal with pressure differentials of up to 1,600 psi from inlet to outlet and from outlet to inlet; consequently, the valve incorporates two visors and two seats (one at the inlet and one at the outlet). Both visors utilize the forces produced by the differential pressure across the visor to aid in sealing against the seat.

Piping connections on the inlet and outlet are Grayloc[1] flanges. These were selected for their ease of maintenance. Only four bolts are needed on each joint instead of the 12 required for an ANSI Class 1500 flange. Also, the valve weight is reduced about 700 pounds by using the Grayloc flanges instead of the ANSI Class 1500 flanges.

As part of the design process, FSD conducted a material-testing program to determine viable material combinations for their valve design. Table 1 gives the materials selected for the Type II valve for the major components. The maximum valve temperature for Type II valves is 850°F. The base material in the visor, Inconel 718, was chosen for its high yield strength. A hard coating, Stellite 1016, was then applied to obtain the necessary erosion resistance. The material selection for the valve body, Chrommoly steel, was based on resistance to corrosion and hydrogen-induced failures.

Figure 5 shows a photograph of the FSD valve. The actuator is on the left and the purge system is on the right.

OVERVIEW OF TESTING

This report presents the results for acceptance testing and static testing of the METC Prototype Test Valve No. F-1. These are the first steps in the prototype valve-test sequence shown in Figure 6. The results of acceptance testing conducted by FSD are presented in Table 2. During acceptance testing of the FSD Type II valve (Serial No. 001) by Fairchild, it was recognized that the valve would not open with an internal pressure 100 psi greater than the inlet and outlet lines. Also, the stuffing box was leaking excessively. This was caused by cracked gold-plating on an "O" ring and was corrected by adding an aluminum gasket to the "O"-ring seal. After acceptance testing, the valve was shipped to METC. It was received at METC on November 7, 1980, and prepared for static testing.

The test-plan sequence for static testing of Test Valve No. F-1 is shown in Table 3. The static testing was performed in the Valve Static Test Unit (VSTU) at METC. Table 4 summarizes the chronology of the test. The purpose of static testing is to establish baseline data for the test valve. Leakage rates, operating forces, and actuation times are measured.

The valve is tested in a clean, inert gas over a range of pressures and valve-body temperatures. Due to the relatively low number of valve cycles (approximately 2,000 compared with a design life of 30,000) and the absence of solids, no significant degradation of the test valve's performance is expected during static testing. Internal-leakage rates remained low throughout static testing, well within the acceptable range, but external-leakage rates exceeded the acceptable range for most of the static testing.

Minor leakage was observed at a number of joints and bolt holes. Temporary fixes, such as use of sealing compounds and retightening, were effective. The largest source of external leakage was the stuffing box. There were three primary problems: the packing nuts, the "O"-ring retainer, and the body joint.

The initial design of the test valve did not allow the packing nuts to be tightened once the test valve was assembled. Normal wear and compression of the packing resulted in the packing losing its preload, causing leakage. After several packing failures, FSD modified the packing nuts and supplied special tools so that the packing nuts could be tightened during testing.

Early in the testing at METC, problems were encountered with the packing around the outer stem blowing out. To correct this problem, FSD redesigned the stuffing box and added a retainer ring with inner and outer "O" rings. However, during higher temperature testing, the "O" rings also blew out repeatedly. A review of the design revealed that the shaft had been machined during assembly at FSD to clean up some galling marks. The first "O"-ring retainer was machined using print dimensions, which resulted in excess clearance between the retainer and the shaft. A new retainer ring was manufactured using the as-built dimensions of the shaft and stuffing box. After installation of this modified retainer ring no further packing blowouts occurred.

FSD encountered problems with the flange joint on the stuffing box during the acceptance testing. These problems were the result of the coating on the gold-plated "O" ring cracking. To correct the problem, an aluminum gasket was added to the joint.

[1]Manufacturers' names on products described herein are given only for technical completeness and do not constitute endorsement by the U.S. Government, its agencies, employees, or contractors.

The body joint performed satisfactorily until near the end of the high-temperature testing. At that point, it began leaking excessively. Testing was continued without corrective measures other than tightening of the bolts on the stuffing box.

The problems observed with external leakage are not in the areas of the valve that are novel or developmental. Solutions should be well within the capability of standard sealing materials and designs. The fact that the internal-leakage rate stayed extremely low (less than 0.1 scfm) over most of the static testing is very encouraging. Even the highest leakages recorded (1.3 scfm) are well below the maximum allowable of 80 scfm.

TEST DESCRIPTION AND RESULTS

The static testing consisted of a series of valve cycles with test data taken before and after. The test data series includes measurement of internal leakage, external leakage, operating force, and actuation time[1]. Testing was performed at three temperatures: 70°F (± 10°); 300°F (± 25°); and 600°F (± 25°). The valve was heated by resistance heaters (shown in Figure 7) mounted in the inlet and outlet bore of the test valve.

Internal leakage (i.e., seat leakage) is measured at eight test pressures (20, 50, 100, 200, 400, 800, 1,200, and 1,600 psig). The test valve is cycled between each measurement to establish a new contact between the visors and seats for each leakage test. The internal-leakage data, reported in Table 5, is obtained from a flow-measurement system installed on the outlet of the unpressurized side of the test valve. Tests were performed with pressure differentials across the valve in both directions. With Side 1 (the valve top or inlet) pressurized, the test determines leakage through the outlet seat of the valve. Similarly, pressurizing Side 2 (the valve bottom or outlet) tests the seal between the upper visor and seat. The side pressurized, the measured valve temperature (average of the standoff port thermocouples in the annulus between the heater and the valve inner diameter), and the actual test pressure are recorded for each test.

External leakage (e.g., body-joint leakage) is measured using a pressure-decay technique. The test valve is pressurized to 1,600 psig in the open position, and the double isolation valves on the VSTU are closed. The initial pressure, initial gas temperature, final gas temperature, and pressure drop are recorded. The external-leakage rate is calculated from the test time (usually 5 minutes), pressure loss, and temperature change, using the Ideal Gas Law. The volume of the pressurized region used for the calculations is the valve volume (3.48 cu. ft.) minus the heater volume (0.06 cu. ft.) plus the volume of the test connections (0.10 cu. ft.), which equals 3.52 cu. ft. Table 6 gives the results of the external-leakage tests.

Valve-actuation time is recorded by an automatic timer that uses limit switches on the actuator to sense the full-open and full-closed positions. The operating force is indicated by two strain gauges on the actuator drive shaft, one on the right side and one on the left side. As the valve was opened and closed, beginning (break), average (run), and peak readings were taken. Figure 8 shows the strain-gauge readings for a sample cycle. The torque varies greatly as the valve undergoes the rotations, translations, and seating involved with closing and opening. The torque patterns vary significantly from cycle to cycle. The actuation force during opening is best indicated by the peak torques encountered. The peak total torque was taken as the sum of the magnitudes of the peak torques on each side. For valve closing, the peak torque was often the torque limit set for the actuator, so the sum of the magnitudes of the larger of the break and average torques on each side were taken to indicate the closing torque. These values, along with the actuation time, are presented in Table 7.

Cycling of the valve between test series involved: first opening and closing the valve; pressurizing Side 1 to 1,600 psig; then pressurizing Side 2 to 1,600 psig; opening, closing, and reopening the valve; venting both sides to the atmosphere; and closing the test valve. This sequence simulates the conditions of position and pressure that would be encountered in lockhopper operation. Between test series, the test valve was cycled 150 to 300 times as shown in Table 3.

The valve temperatures recorded on the tables are averages of three standoff thermocouples, two located in the outlet port of the valve and one in the inlet port. A second thermocouple in the inlet port failed to operate properly; consequently, it was not averaged in the valve-temperature calculation. The internal temperature fluctuated widely during pressurization. This was due to the relatively cool pressurizing gas flowing through the annulus between the heater and valve inner diameter, where the stand-off thermocouples were located. The thermocouples were quickly cooled during pressurization, then reheated by the surrounding mass of valve and heater. The test valve has considerable thermal mass and, no doubt, maintained a relatively constant temperature. The variation in the temperature recorded by one of the thermocouples in the bottom valve port over a 4-hour testing period at 600°F is shown in

[1]These parameters were not measured in all of the test series.

Figure 9. This graph shows the temperature changes that occurred as cooler air was introduced into the valve as well as the effect of heater cycling. Table 8 shows the corresponding valve-body temperatures during this same period of time.

During testing at FSD, the valve originally cycled in 32 seconds. The actuator was adjusted prior to final acceptance testing to cycle in 28 to 29 seconds. Over the duration of the testing, the actuation times for opening and closing the valve decreased from about 27.8 seconds, to a consistent 26.2 seconds for opening or closing at either atmospheric or a high balanced pressure. This compares favorably to the maximum allowable actuation time of 30 seconds.

Figure 10 shows the variation in the peak torque required to open and close the valve versus cumulative test-valve cycles. The data displays considerable scatter; however, no general trend of operating force as a function of test-valve cycles is noted. Peak torque is displayed for valve opening, while the greater of break and running torque is displayed for valve closing.

Internal leakage in METC Prototype Test Valve No. F-1 remained well below the maximum acceptable leakage. In fact, leakage was often less than the limits of the flowmeter (0.02 scfm). Figure 11 shows the internal leakage when the inlet side (Side 1) was pressurized at pressures of 200 psig and 1,600 psig. The leakage rate during the high-pressure tests had begun to increase toward the end of testing. It is not known if this trend would have continued or leveled off at some threshold value. The leakage when Side 2 was pressurized, except for two anomalies, stayed extremely low, never exceeding 0.1 scfm. One anomaly occurred around 450 cumulative test-valve cycles. High leakage readings, over 84 scfm, were recorded for pressures of 20 to 400 psig. The leakage then dropped below the flowmeter limits. There are two possible explanations for these high readings. One possibility is that one of the rotating arms was catching on a bolt head. The bolts for the spring-ball retainer were inadvertently assembled with lock washers, which resulted in the bolt head projecting into the path of the rotating arms. Contact between the arm and the bolt head could have prevented the visors from seating solidly against the seats. Another possibility is that the spring ball that holds the visor from rotating until it is fully retracted was catching. This could have resulted in misalignment of the visors. It had been squealing and, at this point in the test, a lubricant was applied. With the cycle count at 1,486, excessive leakage again occurred (roughly 80 scfm). The torque limiter on the actuator was adjusted to allow greater seating torque, and the leakage immediately dropped.

Figure 12 shows how the external leakage varied throughout the test. The leakage rate was never below the acceptable maximum of 0.1 scfm. The initial external leakage was 1.0 scfm and increased to over 7.0 scfm during the ambient and 300°F tests. Just prior to 1,000 cumulative test-valve cycles, the stuffing box was rebuilt by an FSD representative. Some of the packing rings were replaced by two "O" rings in an aluminum retainer ring. The original and modified stuffing-box arrangements are shown in Figure 13. This lowered external leakage until 1,200 cycles when the packing blew again. METC personnel repacked the stuffing box.

Following the 1,399-cycle test series, the stuffing box was again repacked, but leakage continued. A review of the stuffing-box design by FSD personnel revealed that during assembly the outer shaft had been galled. To correct this, the shaft was machined to a slightly smaller diameter. The "O"-ring retainer had been designed from the original shop drawings, which resulted in improper clearances between the retainer and the shaft. FSD then supplied a stainless-steel "O"-ring retainer machined according to the as-built dimensions of the shaft and housing. At this time, FSD also modified the packing glands and supplied special wrenches that allowed the packing to be adjusted without removing the rotation and translation arms. As normal wear and compression of the packing occurred, the glands could be adjusted to maintain the proper preload on the packing. These two modifications eliminated the massive leakage through the shaft packings (i.e., packing blowout).

External leakage also was observed around some of the structural bolts in the stuffing box. Since these bolts were outside the seal between the stuffing box and the side cover, the leakage was an early indication of leakage through this seal. During acceptance testing at FSD, leakage was observed at this seal and a modification was made to the joint. This joint began leaking severely near the end of testing. No corrective action was attempted and testing was completed with the joint between the stuffing box and the side cover leaking.

Various other joints leaked during testing and were successfully corrected by tightening. When attempts were made to tighten the 1/8-inch NPT fitting on the end of the visor shaft, the fitting sheared off. A 3/8- or 1/2-inch fitting is more of a standard size for use in a plant environment and less subject to unintentional damage.

One of the more serious events to occur during static testing happened when the valve was being checked out after repacking. The valve was being cycled on manual override so the normal depressurization cycle did not occur. The sequence used to depressurize the valve resulted in 1,600 psig being trapped between the visors. This internal pressure applied a 40-ton force to each visor, which prevented them from moving. The cause of the difficulty was not immediately obvious. After discussion with FSD, METC personnel increased the torque limit on the actuator, but the valve still did not open. The decision was made to disassemble the test valve for inspection. Escaping gas from the purge fitting during disassembly was the first indication of the trapped pressure in the valve. Upon inspection, the visors had sheared two 3/8-inch bolts holding them to the shaft. The valve functioned normally after replacement of the bolts. Had the purge system been in operation this incident probably would not have occurred, since one of the steps in the purge sequence vents the valve body. However, a local indication of the pressure in the valve body would be desirable to prevent future occurrences.[1]

At various times, the testing was delayed or had to be modified due to malfunctions of the heaters or the compressor used to supply the 1,600-psig air. The most serious of these nearly resulted in some of the cycles between test series being performed with the test valve pressurized to 1,200 psig instead of 1,600 psig. None of these incidents are judged to have a detrimental effect on the test data obtained.

At the conclusion of static testing, the valve was removed from the test unit and positioned so that the sealing surfaces could be inspected. Figures 14 and 15 show the seats and visors. The sealing surfaces on Side 1 appear in good condition with the contact line clearly visible. On the Side 2 visor, a scuff mark can be seen. This may be responsible for the slight increase in internal leakage noted near the end of testing. It is assumed that this resulted from the valve closing on a piece of foreign material. Possibly this would not have occurred if the purge system had been operational.

The most outstanding observation from static testing was the extremely low internal leakage. This data indicates that the developmental portion of the valve (i.e., the visor/seat design and motion) was working properly.

CONCLUSIONS

1. METC Prototype Test Valve No. F-1 completed static testing with clean gas at the METC VSTU, but unacceptably high external leakage was encountered.

2. External leakage was above the acceptance level throughout the testing. High external leakage necessitated frequent repairs and adjustments to the valve. Leakage occurred through the stuffing box, through the 1/8-inch purge fittings, and through the spring-ball retainer bolts.

3. Internal leakage was very low for both the top and bottom (Side 1 and Side 2) seats. Leakage was above the acceptable level during only two leakage test series and was corrected by adjusting the seating torque. The seats and visors successfully sealed against pressure differentials up to 1,600 psig at internal temperatures ranging from ambient to 600°F.

4. Actuation time for the valve was acceptable during the testing, decreasing by about 1.5 seconds to a steady 26.2 seconds to open or close the valve. Operating-force measurements were somewhat erratic throughout the test, but remained well within the capability of the valve's actuator.

5. The 1/8-inch NPT purge fittings on the end of the shafts are sensitive to overtightening and other unintentional damage.

6. Trapped pressure in the valve caused the valve to lock up. The bolts holding the visors to the yokes were sheared when opening the valve was attempted. There was no easy way to detect the pressure trapped in the valve body.

7. Leakage occurred through the mounting-bolt holes on the spring-ball retainer. This flow was probably from leakage of the joint between the side cover and the stuffing box. This joint was leaking severely near the end of the testing.

8. The major problems with the FSD valve involved the stuffing box. Due to leakage problems, "O" rings and a retainer were added to the stuffing box during testing at METC. Additional leakage problems occurred because the clearances on the "O"-ring retainer were too large. Modifications that allowed tightening of the packing and a retainer designed from as-built dimensions corrected the packing leakage problems.

9. The FSD visor-valve design concept appears to work quite well in temperatures up to 600°F and pressures up to 1,600 psig. Design

[1]The manufacturer has indicated that future Type II valves will be supplied with a body-pressure indicator.

problems primarily concern external leakage, and solutions should be achievable with minor design changes.

RECOMMENDATIONS

1. The purge-port fittings should be larger than 1/8 inch, preferably 1/2 inch.

2. Trapped pressure in the valve body presents a serious safety problem for maintenance operations, as well as an operational problem when internal damage results. A local pressure indicator in the valve body is strongly recommended.[1] Also, the opening torque limit should be checked to be sure that the valve stalling torque is not sufficient to shear the internal bolts.

3. The stuffing box apparently still requires some redesign to correct the leakage through the joint with the side cover. The packing itself sealed quite well after the re-designed parts were installed. However, it has yet to be demonstrated that the external-leakage requirement can be met even with the re-designed internals. Also, since the packing nuts require frequent adjustment during valve operation, a more resilient preload would be desirable.

4. The visor-valve concept, METC Prototype Test Valve No. F-1, appears to be a good design for lockhopper service, although minor changes in the initial design are required. The external-leakage problems should be reviewed with Fairchild Stratos Division and design changes implemented. A brief static test should be performed on the modified design to verify the performance of the valve prior to dynamic testing.

[1]The manufacturer has indicated that future Type II valves will be supplied with a body-pressure indicator.

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METC PROTOTYPE
TEST VALVE NO. F-1
STATIC TEST REPORT

TABLES

Table 1. Materials of Construction for FSD Type II Valves

Component	Material
Body, Flanges,	5 Chrom-½ Moly Alloy Steel
Stuffing Boxes	SA-217 Gr C5
Flow Guide	SIC 6 Graphite
Visor	Inconel 718 with Stellite 1016 Plasma-Sprayed Coating
Aligning Ball	Silicon Nitride
Yoke	Armco 17-4PH
Shaft	
Translator	Inconel 718
Rotator	Armco 17-4PH
Seat	Inconel 718 with Stellite 1016 Plasma-Sprayed Coating
Seals	
Shaft	Grafoil[1]
Flange	Inconel X Gold-Plated "O" Ring with Aluminum Gasket

[1] Stainless-steel retainer and Viton "O" rings were added part way through testing.

Table 2. Data from Acceptance Testing Performed at Fairchild—METC Prototype Test Valve No. F-1

External Leakage (October 21-22, 1980)

12.4-psi pressure drop in 30 minutes for a leakage rate of 0.1 scfm at 1,600-psig internal pressure

Internal Leakage (October 22, 1980)

Seat	Pressure (psig)	Internal Leakage (scfm)
Upper	20	0.0004
"	200	0.0006
"	400	0.0008
"	800	0.0016
"	1,200	0.0027
"	1,600	0.0041
Lower	20	0.0060
"	200	0.0140
"	400	0.0100
"	800	0.0060
"	1,200	0.0030
"	1,600	0.0030

Actuation Time (October 22, 1980)

Ambient Pressure	1st Cycle	10th Cycle
Closing Time (sec)	28	28
Opening Time (sec)	29	28
1,600-psig Balanced Pressure		
Closing Time (sec)	29	20
Opening Time (sec)	29	29

Approximate number of test-valve cycles at the end of acceptance testing	150
Test media	Nitrogen

Table 3. Test-Plan Sequence—METC Prototype Test Valve No. F-1

Sequence Number	Sequence	Valve Temperature (°F)
1	Visual Inspection	Ambient
2	Test Data	Ambient
3	Static Test Run—150 Cycles	Ambient
4	Test Data	Ambient
5	Static Test Run—150 Cycles	Ambient
6	Test Data	Ambient
7	Test Data	300
8	Static Test Run—150 Cycles	300
9	Test Data	300
10	Static Test Run—150 Cycles	300
11	Test Data	300
12	Static Test Run—300 Cycles	300
13	Test Data	300
14	Test Data	600
15	Static Test Run—150 Cycles	600
16	Test Data	600
17	Static Test Run—150 Cycles	600
18	Test Data	600
19	Static Test Run—300 Cycles	600
20	Test Data	600
21	Test Data	Ambient
22	Static Test Run—30 Cycles	Ambient
23	Test Data	Ambient
24	Static Test Run—30 Cycles	Ambient
25	Test Data	Ambient
26	Valve Disassembly	Ambient
27	Metrology Inspection	Ambient
28	Valve Assembly	Ambient
29	Test Data	Ambient

Notes: 1. Test data includes actuation time, operating force, internal leakage, and external leakage.

2. Steps 26-29 not included in this report.

Table 4. Test Summary—METC Prototype Test Valve No. F-1

Date	Activity/Test	Cumulative Test-Valve Cycles[1]	Remarks/Results
6/9/81	Began preparation	0	
6/17/81	Checked out installation	9	
6/18/81	Ambient temperature tests	10	
6/19/81		106	1/8-inch purge fitting broke while being tightened; removed broken fitting, plugged hole, and continued tests.
6/20/81		262	Completed ambient tests.
6/21/81	Heated valve to 300°F	464	One thermocouple reading ambient; omitted it from recorded valve temperatures. Pressurizing gas drops temperature readings.
6/22/81		468	Increased temperature controller to 650°F, then 700°F. Added more insulation to Side 1 and 2 heaters.
6/23/81	Shut down unit to await repair of leak	870	Leakage from shaft packing on left side excessive. Stopped tests, took photos.
7/14/81	Valve accidentally depressurized from both sides when closed, trapping pressure; repacked stem and bearing (in stuffing box)	1,057	Valve would not open with pressure trapped outside, even with increased torque. Removed heater hubs, found bolts holding visors to the yokes had sheared off. FSD representative repaired and installed "O" rings and aluminum retainer in stuffing box.
7/16/81	Verified actuation time and checked leakage at ambient temperature	1,083	Valve successfully repaired.
7/21/81	Connected heaters and thermocouples	1,089	
7/27/81	Leak data at ambient temperature	1,089	Problems with compressor (lack of process water) caused delays. Leakage noted in spring-ball detent support studs and 1/8-inch purge port, left side.

[1] Approximately 150 cycles performed prior to arrival at METC are not included.

Table 4. Test Summary-METC Prototype Test Valve No. F-1 (Continued)

Date	Activity/Test	Cumulative Test-Valve Cycles	Remarks/Results
7/28/81	Heated valve; seal or packing on right shaft blown; heater Side 2 blown	1,119	Fuses blew. Shutdown valve and heaters. Discovered "O"-ring damage. Repacked stuffing box. Heater and valve repaired. Compressor problems required reduction in pressure to 1,200 psig. Spring-ball detents squealed, were lubed with Nev-R-Seez.
7/29/81	Completed 300°F testing; repaired heater; heated valve to 600°F	1,207	Broken connection on coil of top heater repaired.
7/30/81	High external leakage; heater ruptured; valve and heater repair required	1,445	Rebuilt left-side stuffing box, then right side leaked. Packing nuts would not stay tight. Heater connection appeared fragmented.
8/24/81	Valve repaired with new parts for stuffing boxes from FSD	1,457	Small-shaft and large-shaft stuffing boxes rebuilt with redesigned stainless-steel retainer ring. Heaters replaced.
8/28/81	Continued static testing at ambient temperature	1,457	Checked valve prior to testing and replaced "O" ring. Started test and found excessive leakage (internal). Adjusted visor seating torque limiter.
8/31/81	Started 600°F testing	1,505	Miscellaneous problems with electrical supply, compressor, and data-acquisition computer.
9/1/81		1,714	Heater problems. Top heater burned out. Continued with one heater. Tightened packing nuts. Compressor went down. Cycled valve (once/hour) until pressure available.
9/2/81	Completed 600°F testing	2,080	Excessive leakage around 10-inch stuffing-block flange on right side.
9/3/81	Ambient-temperature post-600°F testing	2,241	Continued tests despite stuffing-box leakage.
9/4/81	Completed testing	2,409	

Table 5. Internal-Leakage Test Data—METC Prototype Test Valve No. F-1

Cumulative Test-Valve Cycles[1]	Valve Internal Temperature (°F)	Valve Side Pressurized	Test Pressure (psig)	Internal Leakage (scfm)	Equivalent Leak Area $(mil^2)^2$
Internal Temperature: Ambient					
13	75	Top	14.9	0.00[3]	
16	75	Top	51.4	0.00	
19	75	Top	100.5	0.00	
22	75	Top	202.2	0.11	28
25	75	Top	404.8	0.16	21
28	75	Top	810.6	0.14	9.4
31	75	Top	1,213.0	0.06	3.0
34	75	Top	1,617.3	0.04	1.4
38	75	Bottom	16.5	0.00	
41	75	Bottom	51.5	0.00	
44	75	Bottom	100.2	0.00	
47	75	Bottom	203.4	0.04	10
50	75	Bottom	405.5	0.03	4.0
53	81	Bottom	813.5	0.00	
56	82	Bottom	1,216.5	0.00	
59	82	Bottom	1,622.0	0.00	
213	86	Bottom	17.8	0.00	
216	86	Bottom	52.2	0.00	
219	86	Bottom	101.3	0.00	
222	86	Bottom	203.7	0.00	
225	86	Bottom	408.8	0.00	
228	86	Bottom	815.5	0.00	
231	86	Bottom	1,219.4	0.00	
234	86	Bottom	1,626.1	0.00	
238	86	Top	18.1	0.00	
241	86	Top	50.9	0.00	
244	86	Top	101.5	0.00	
247	86	Top	203.1	0.00	
250	86	Top	409.6	0.03	4.0
253	86	Top	814.2	0.03	2.0
256	86	Top	1,218.4	0.00	
259	86	Top	1,626.1	0.00	
413	80	Top	18.1	0.00	
416	80	Top	51.3	0.00	
419	80	Top	101.9	0.00	
422	80	Top	202.1	0.00	

[1] Approximately 150 cycles performed prior to arrival at METC are not included.

[2] Equivalent leak-area calculation:

$$A = 2{,}393 \frac{Q\sqrt{T_1}}{P_1}$$

A = equivalent leak area ($mil^2 = 10^{-6}$ in.^{2})

Q = leak flow (scfm)

P_1 = test pressure (psia)

T_1 = test valve temp (°R)

[3] A value of 0.00 indicates less than 0.02 scfm.

Table 5. Internal-Leakage Test Data—METC Prototype Test Valve No. F-1 (Continued)

Cumulative Test-Valve Cycles	Valve Internal Temperature (°F)	Valve Side Pressurized	Test Pressure (psig)	Internal Leakage (scfm)	Equivalent Leak Area (mil²)
425	80	Top	406.0	0.00	
428	80	Top	813.1	0.00	
431	80	Top	1,214.2	0.00	
434	80	Top	1,618.7	0.00	
438	80	Bottom	17.2	8.44	15,000
441	80	Bottom	51.0	18.63	16,000
444	80	Bottom	103.7	33.10	16,000
447	80	Bottom	202.4	59.25	15,000
450	80	Bottom	404.7	>84.00	
453	80	Bottom	812.0	0.00	
456	80	Bottom	1,214.3	0.00	
459	80	Bottom	1,622.4	0.00	
Internal Temperature: 300°F					
471	208	Bottom	16.0	0.00	
474	248	Bottom	52.1	0.00	
477	211	Bottom	103.5	0.00	
480	278	Bottom	204.1	0.00	
483	271	Bottom	408.3	0.00	
486	257	Bottom	813.1	0.00	
489	225	Bottom	1,214.4	0.00	
492	216	Bottom	1,622.4	0.00	
496	217	Top	19.4	0.00	
499	248	Top	53.0	0.00	
502	260	Top	102.3	0.00	
505	262	Top	205.4	0.00	
508	266	Top	409.5	0.00	
511	265	Top	813.0	0.00	
514	254	Top	1,218.2	0.00	
517	233	Top	1,620.2	0.00	
671	376	Top	18.2	0.00	
674	370	Top	55.4	0.00	
677	360	Top	101.3	0.00	
680	348	Top	205.7	0.00	
683	360	Top	408.7	0.00	
686	387	Top	815.9	0.00	
689	381	Top	1,219.9	0.00	
692	381	Top	1,626.7	0.00	
696	370	Bottom	20.7	0.00	
699	409	Bottom	51.0	0.00	
702	424	Bottom	99.7	0.00	
705	419	Bottom	204.9	0.00	
708	410	Bottom	407.3	0.00	
711	395	Bottom	812.8	0.00	
714	369	Bottom	1,218.6	0.00	
717	332	Bottom	1,622.0	0.00	
871	313	Bottom	19.9	0.00	

Table 5. Internal-Leakage Test Data—METC Prototype Test Valve No. F-1 (Continued)

Cumulative Test-Valve Cycles	Valve Internal Temperature (°F)	Valve Side Pressurized	Test Pressure (psig)	Internal Leakage (scfm)	Equivalent Leak Area (mil²)
874	372	Bottom	51.8	0.00	
877	395	Bottom	102.1	0.00	
880	400	Bottom	205.3	0.00	
883	385	Bottom	409.8	0.00	
886	390	Bottom	813.9	0.00	
889	368	Bottom	1,214.8	0.00	
892	342	Bottom	1,617.9	0.00	
896	367	Top	18.9	0.00	
899	353	Top	53.6	0.00	
902	389	Top	104.5	0.00	
905	381	Top	203.4	0.26	83
908	373	Top	409.5	0.03	4.9
911	363	Top	811.5	0.00	
914	348	Top	1,213.6	0.00	
917	359	Top	1,618.0	0.00	
Tests Following Re-Work of Valve by FSD					
1,065	75	Top	15.4	0.00	
1,068	75	Top	50.7	0.00	
1,071	75	Top	100.6	0.00	
1,074	75	Top	202.0	0.24	61
1,077	75	Top	403.6	0.22	29
1,080	75	Top	808.4	0.24	16
1,083	75	Top	1,210.4	0.16	7.2
1,086	75	Top	1,616.8	0.08	2.7
1,090	71	Bottom	18.5	0.00	
1,093	71	Bottom	53.2	0.00	
1,096	71	Bottom	101.8	0.00	
1,099	71	Bottom	204.7	0.05	13
1,102	71	Bottom	406.5	0.05	6.5
1,105	71	Bottom	811.3	0.09	6
1,110	71	Bottom	1,212.3	0.04	1.8
1,113	71	Bottom	1,619.7	0.04	1.4
Internal Temperature: 300°F					
1,295	433	Top	18.7	0.00	
1,298	466	Top	53.1	0.00	
1,301	408	Top	102.8	0.00	
1,304	359	Top	202.0	0.29	92
1,307	337	Top	405.8	0.03	4.8
1,310	327	Top	811.7	0.03	2.4
1,313	331	Top	1,214.7	0.03	1.6
1,316	295	Top	1,618.3	0.03	1.2
1,320	194	Bottom	19.7	0.00	
1,323	197	Bottom	50.6	0.00	
1,326	188	Bottom	105.6	0.00	

Table 5. Internal-Leakage Test Data—METC Prototype Test Valve No. F-1 (Continued)

Cumulative Test-Valve Cycles	Valve Internal Temperature (°F)	Valve Side Pressurized	Test Pressure (psig)	Internal Leakage (scfm)	Equivalent Leak Area (mil^2)
1,329	190	Bottom	204.7	0.05	14
1,332	168	Bottom	407.2	0.00	
1,335	174	Bottom	811.3	0.03	2.2
1,338	163	Bottom	1,213.4	0.03	1.5
1,341	155	Bottom	1,615.9	0.03	1.1
Internal Temperature: 600°F					
1,350	541	Top	20.9	0.00	
1,353	591	Top	54.3	0.00	
1,356	540	Top	104.8	0.00	
1,359	623	Top	205.8	0.03	11
1,362	592	Top	406.9	0.03	5.5
1,365	557	Top	811.1	0.03	2.8
1,368	528	Top	1,216.2	0.03	1.8
1,371	508	Top	1,619.7	0.03	1.4
1,375	631	Bottom	20.9	0.00	
1,378	685	Bottom	55.0	0.00	
1,381	690	Bottom	106.0	0.00	
1,384	695	Bottom	204.9	0.04	15
1,387	688	Bottom	406.1	0.00	
1,390	684	Bottom	811.5	0.00	
1,393	667	Bottom	1,214.9	0.00	
1,396	618	Bottom	1,618.6	0.00	
1,687	619	Top	21.8	0.00	
1,690	653	Top	55.1	0.00	
1,693	642	Top	102.8	0.00	
1,696	596	Top	204.1	0.00	
1,699	571	Top	406.3	0.00	
1,706	552	Top	803.2	0.00	
1,709	518	Top	1,206.0	0.00	
1,712	492	Top	1,611.1	0.00	
1,715	568	Bottom	21.2	0.00	
1,718	601	Bottom	54.2	0.00	
1,721	611	Bottom	101.3	0.00	
1,724	606	Bottom	203.8	0.00	
1,727	578	Bottom	406.1	0.00	
1,730	554	Bottom	806.1	0.00	
1,733	513	Bottom	1,210.6	0.00	
1,736	464	Bottom	1,615.8	0.00	
1,890	717	Bottom	23.0	0.00	
1,893	624	Bottom	55.9	0.00	
1,896	690	Bottom	106.1	0.00	
1,899	632	Bottom	206.0	0.00	
1,902	654	Bottom	406.9	0.00	
1,905	670	Bottom	811.4	0.00	
1,908	604	Bottom	1,210.4	0.00	
1,911	563	Bottom	1,611.6	0.00	

Table 5. Internal-Leakage Test Data—METC Prototype Test Valve No. F-1 (Continued)

Cumulative Test-Valve Cycles	Valve Internal Temperature (°F)	Valve Side Pressurized	Test Pressure (psig)	Internal Leakage (scfm)	Equivalent Leak Area (mil²)
1,915	765	Top	23.0	0.00	
1,918	660	Top	56.2	0.00	
1,921	615	Top	106.4	0.00	
1,924	655	Top	205.4	0.03	11
1,927	673	Top	408.2	0.08	15
1,930	701	Top	809.3	0.11	11
1,933	704	Top	1,213.2	0.10	6.7
1,936	733	Top	1,615.7	0.13	6.6
2,188	766	Bottom	23.2	0.00	
2,191	660	Bottom	55.9	0.00	
2,194	663	Bottom	105.0	0.00	
2,197	674	Bottom	203.1	0.00	
2,200	650	Bottom	404.2	0.00	
2,203	642	Bottom	805.4	0.00	
2,206	627	Bottom	1,206.8	0.00	
2,209	613	Bottom	1,610.8	0.00	
2,213	673	Top	22.4	0.00	
2,216	612	Top	54.7	0.00	
2,219	664	Top	104.6	0.00	
2,222	662	Top	204.8	0.08	29
2,225	675	Top	406.8	0.27	52
2,228	668	Top	807.2	0.44	43
2,231	668	Top	1,208.1	0.69	45
2,234	672	Top	1,607.2	0.92	46
Ambient Temperature Tests Following 600°F Operation					
2,246	85	Top	20.7	0.00	
2,249	85	Top	53.3	0.00	
2,252	85	Top	103.1	0.00	
2,255	85	Top	204.1	0.18	46
2,258	85	Top	405.0	0.56	75
2,261	85	Top	805.2	0.85	58
2,264	85	Top	1,206.3	1.30	60
2,267	85	Top	1,606.3	1.15	40
2,271	85	Bottom	21.6	0.00	
2,274	85	Bottom	54.6	0.00	
2,277	85	Bottom	104.2	0.00	
2,280	85	Bottom	202.7	0.00	
2,283	85	Bottom	401.9	0.00	
2,286	83	Bottom	802.4	0.00	
2,289	83	Bottom	1,205.8	0.00	
2,292	83	Bottom	1,609.8	0.00	
2,356	85	Bottom	21.5	0.00	
2,359	85	Bottom	55.2	0.00	
2,362	85	Bottom	104.9	0.00	
2,365	85	Bottom	204.4	0.00	
2,368	85	Bottom	406.3	0.00	

Table 5. Internal-Leakage Test Data—METC Prototype Test Valve No. F-1 (Continued)

Cumulative Test-Valve Cycles	Valve Internal Temperature (°F)	Valve Side Pressurized	Test Pressure (psig)	Internal Leakage (scfm)	Equivalent Leak Area (mil^2)
2,371	85	Bottom	806.8	0.00	
2,374	85	Bottom	1,206.7	0.00	
2,377	85	Bottom	1,609.5	0.00	
2,383	75	Top	20.9	0.00	
2,386	75	Top	51.1	0.00	
2,389	75	Top	103.3	0.00	
2,392	75	Top	202.2	0.19	49
2,395	75	Top	403.7	0.47	62
2,398	75	Top	806.3	0.62	42
2,401	75	Top	1,205.7	1.06	48
2,404	75	Top	1,612.0	1.23	42

Table 6. External-Leakage Data—METC Prototype Test Valve No. F-1

Cumulative Test-Valve Cycles[1]	Valve-Body Test Temperature (°F)	Gas Temperature Initial/Final (°F)	Initial Pressure (psig)	Net Pressure Decay (psi)	Test Time (min.)	External Leakage (scfm)[2]
12	Ambient	66/66	1,605	25	5	1.18
12	"	66/78	1,605	59	30	0.74
62	"	77/77	1,524.3	52.4	5	2.43
237	"	89/89	1,524.9	46.9	5	2.13
262	"	85/85	1,528.0	46.9	5	2.14
437	"	67/77	1,527.5	51.0	5	3.68
462	"	75/80	1,522.0	51.0	5	3.04
495	300°F	129/144	1,526.1	48.3	5	3.62
520	"	110/136	1,607.5	59.3	5	5.52
695	"	167/213	1,624.8	41.4	5	6.03
720	"	205/240	1,593.8	34.5	5	4.26
895	"	229/239	1,595.7	35.9	5	5.54
920	"	179/284	1,626.3	49.6	5	7.20
1,089	Ambient	65/72	1,553.2	44.0	5	3.02
1,116	"	76/83	1,549.6	46.8	5	2.99
1,319	300°F	170/232	1,564.9	61.9	5	7.79
1,374	600°F	288/412	1,563.5	63.5	5	8.44
1,399	"	351/436	1,587.0	56.4	5	6.23
1,714	"	94/93	1,597.6	48.2	5	2.00
1,739	"	94/92	1,591.1	34.4	5	1.33
1,914	"	98/99	1,624.6	22.0	5	1.05
1,939	"	94/97	1,630.6	23.3	5	1.41
2,212	"	90/89	1,618.1	173.6	5	7.73
2,237	"	90/92	1,615.3	169.4	5	7.93
2,270	Ambient	77/77	1,548.2	77.6	5	3.63
2,295	"	79/81	1,543.8	121.2	5	5.81
2,380	"	83/84	1,534.1	121.0	5	4.41
2,407	"	76/73	1,536.7	124.0	5	5.37

[1] Approximately 150 cycles performed prior to arrival at METC are not included.

[2] External leakage is calculated as follows:

$$\text{scfm} = \frac{\dfrac{T_O}{P_O} V_O \left(\dfrac{P_1}{T_1} - \dfrac{P_2}{T_2} \right)}{t}$$

T_O = 520°R (std. conditions)
P_O = 14.7 psia (std. conditions)
V_O = 3.52 ft^3 (valve volume)
t = 5 min. (test duration)
P_1 = initial pressure, psia
P_2 = final pressure, psia
T_1 = initial temperature, °R
T_2 = final temperature, °R

Table 7. Operating Force and Actuation Time—METC Prototype Test Valve No. F-1

Cumulative Test-Valve Cycles[1]	Atmospheric Pressure				Balanced 1,600-psig Pressure			
	Closing		Opening		Closing		Opening	
	Time (sec)	Torque[2] (ft.-lbs.)	Time (sec)	Peak Torque (ft.-lbs.)	Time (sec)	Torque[2] (ft.-lbs.)	Time (sec)	Peak Torque (ft.-lbs.)
10	27.7	825	27.8	899	27.7	975	27.8	1,087
462	27.6	900	27.7	1,688	27.5	563	27.6	338
468	27.5	450	27.6	525	27.5	638	26.2	563
1,347	26.1	375	26.2	1,575	26.2	1,650	26.2	1,425
2,241	26.2	825	26.2	300	26.2	938[3]	26.2	1,612[3]
2,407	26.2	1,125	26.2	975	26.2	900	26.2	788

[1] Approximately 150 cycles performed prior to arrival at METC are not included.

[2] The sum of the larger of the break and running torques for each side of the shaft.

[3] Data was recorded incorrectly. These results represent an engineering judgment as to the correct data.

Table 8. Valve-Body Temperatures During 600° F Testing—METC Prototype Test Valve No. F-1

Thermo-couple	Location	Time				
		0400	0500	0600	0700	0800
TC-1	External Entrance Area	245	260	245	250	255
TC-2	External Exit Area	220	225	220	215	225
TC-3	External Seat Area	230	235	230	235	250
TC-4	External Body	200	225	210	220	240
TC-5	External Cover	200	210	205	210	220
TC-6	External Cover Hub Area	195	205	200	205	215
TC-7	External Cover Hub Area	140	190	180	200	200
TC-8	Internal Entrance Area	290	285	295	295	300
TC-9	Internal Exit Area	245	235	245	235	235
TC-10	Internal Seat Area	250	250	250	250	265
TC-11	Internal Body	205	225	210	225	240
TC-12	Internal Cover	200	220	210	225	220
TC-13	Internal Cover Hub Area	200	215	210	215	225
TC-14	Internal Cover Hub Area	195	200	200	205	200
TC-15	Actuator Motor Housing	85	105	120	115	145

METC PROTOTYPE TEST VALVE NO. F-1 STATIC TEST REPORT

FIGURES

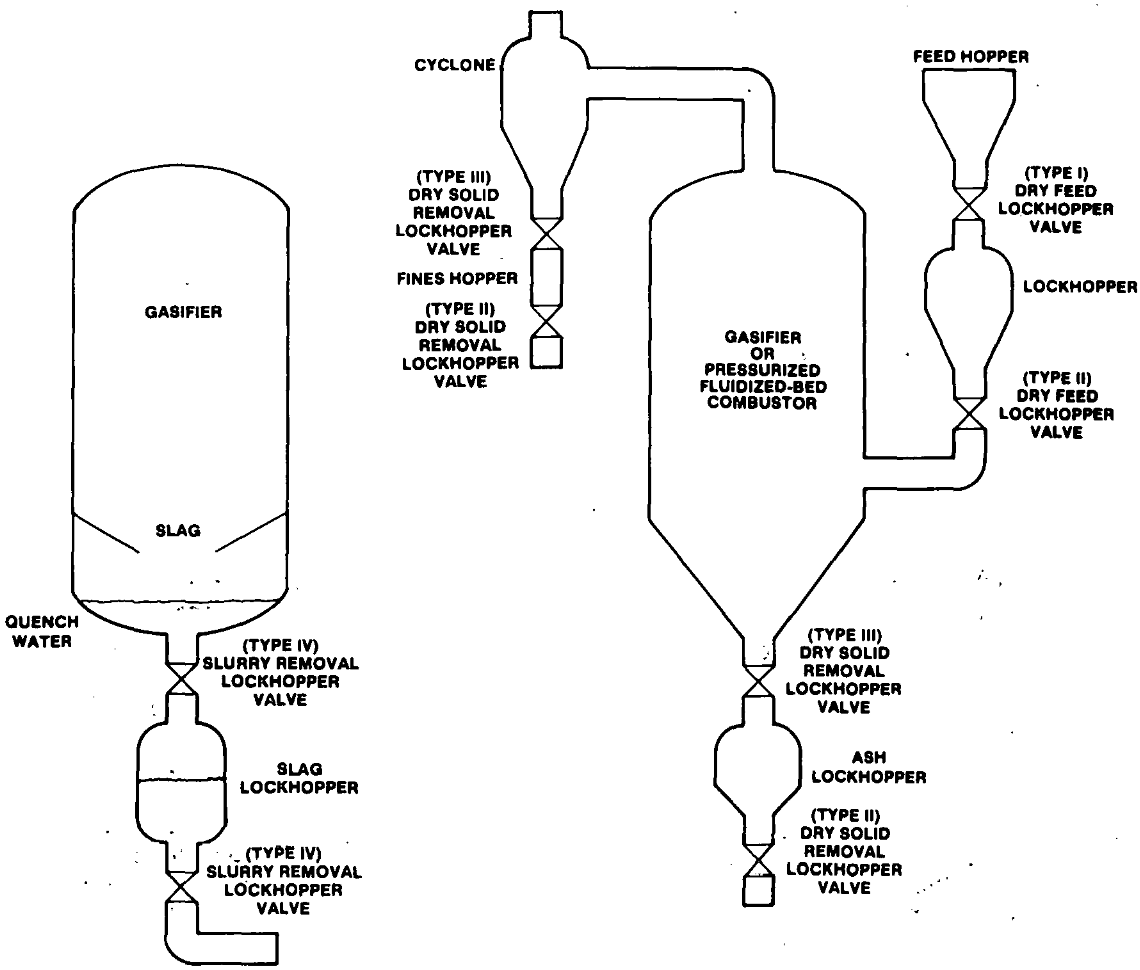


Figure 1. Typical Lockhopper Valve Applications

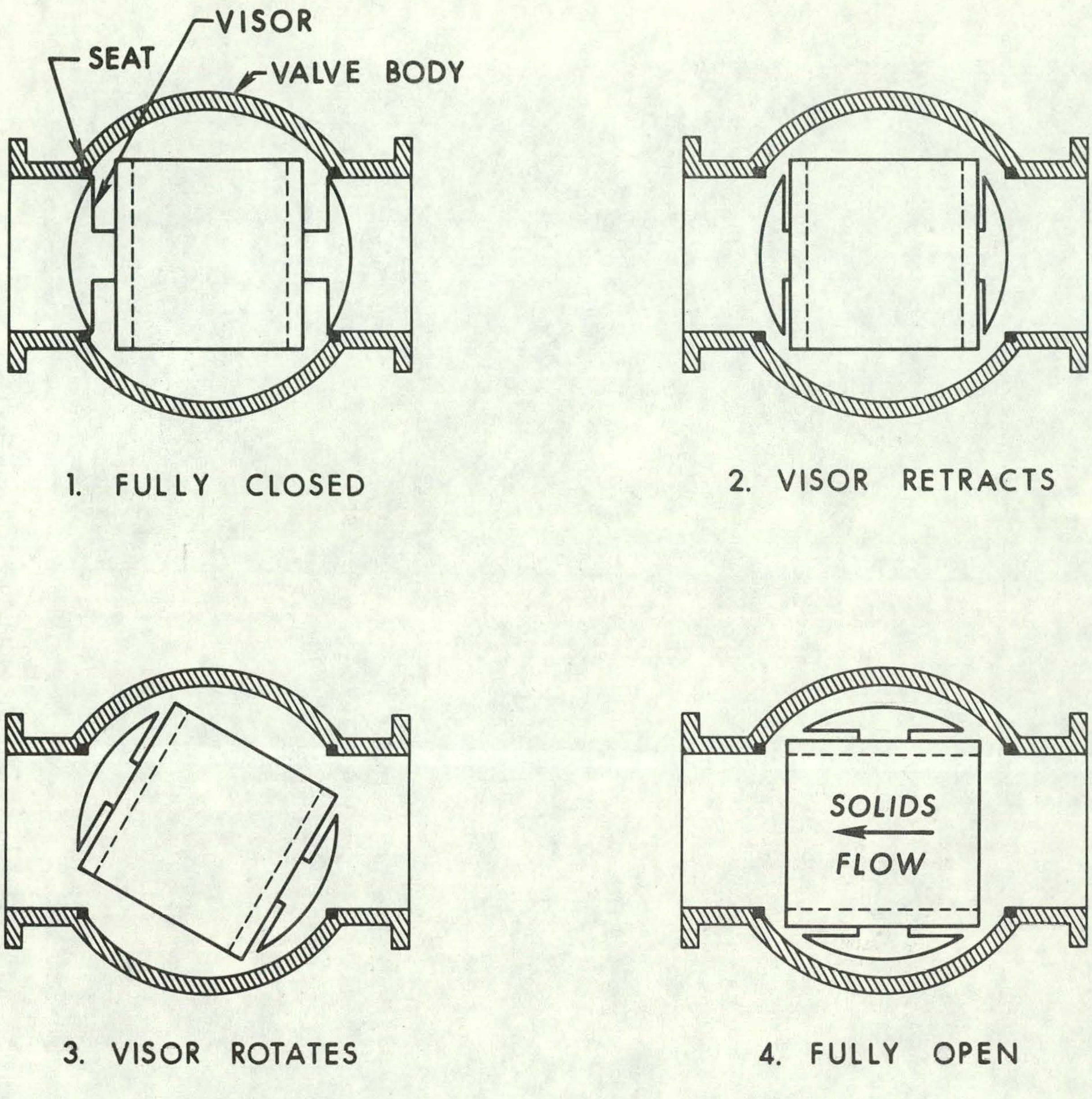


Figure 2. Operation Schematic of the Fairchild Retractable-Visor Valve

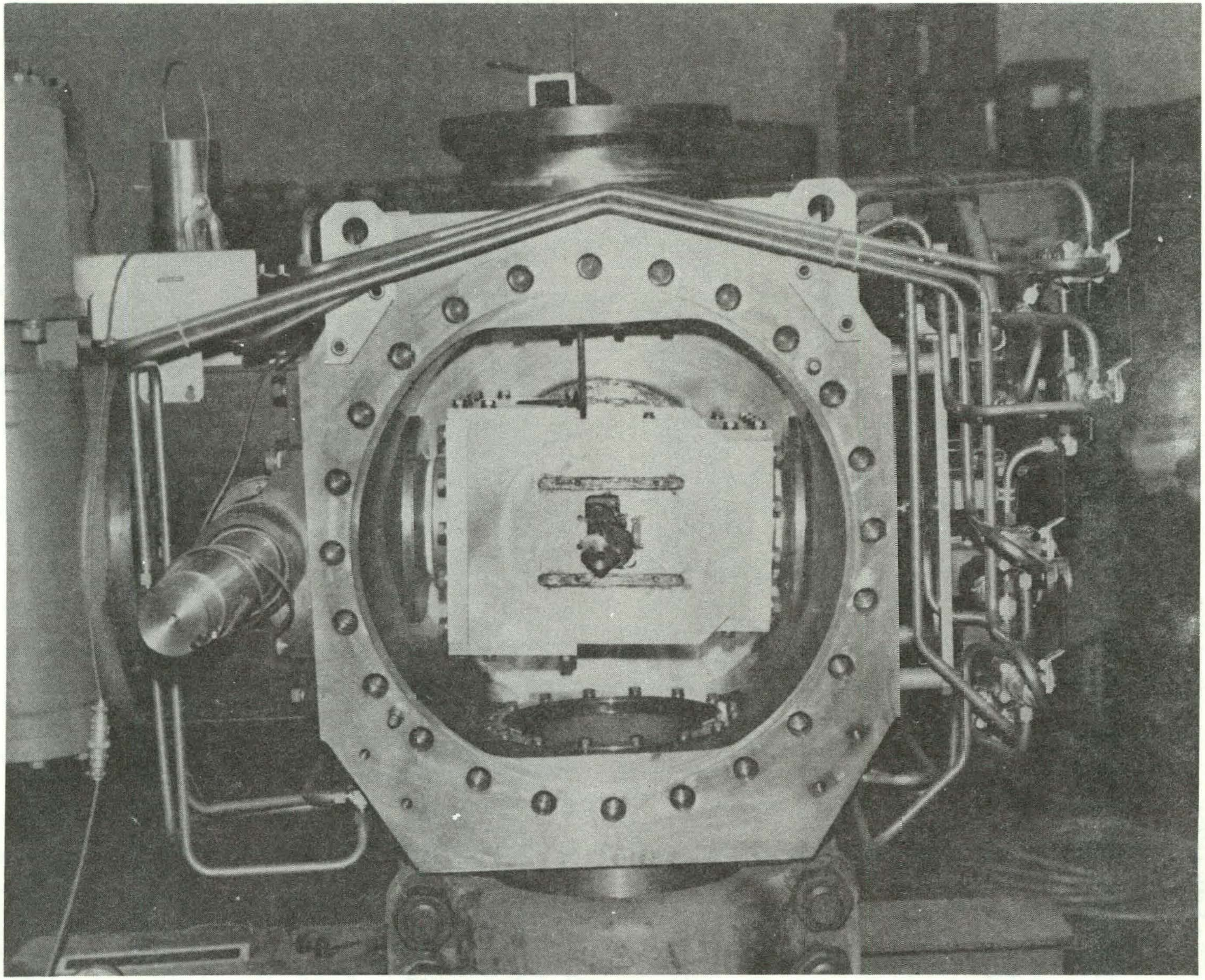


Figure 3. Internal Arrangement of Fairchild Type II Prototype Valve

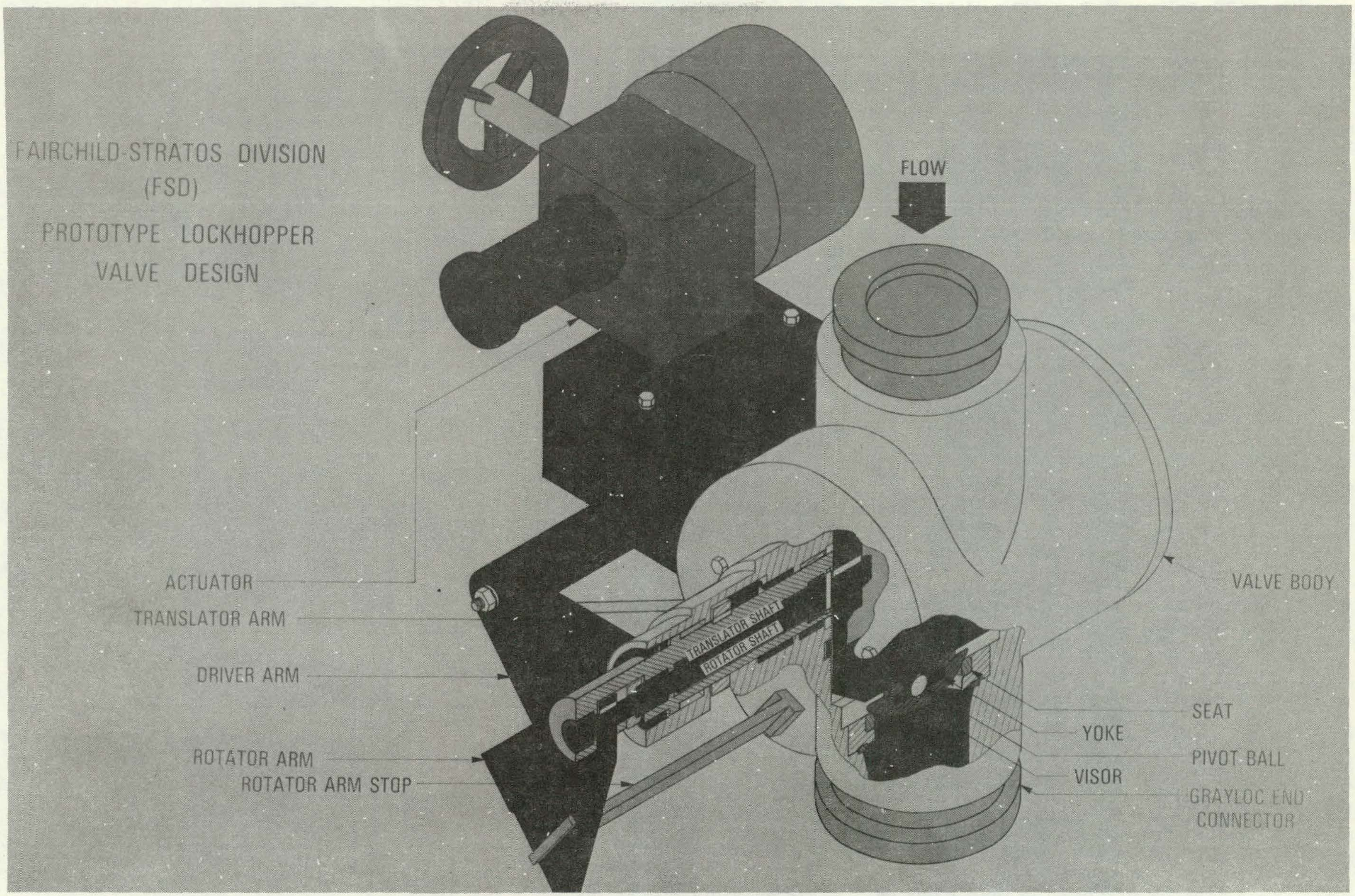


Figure 4. Drawing of FSD Lockhopper Visor Valve

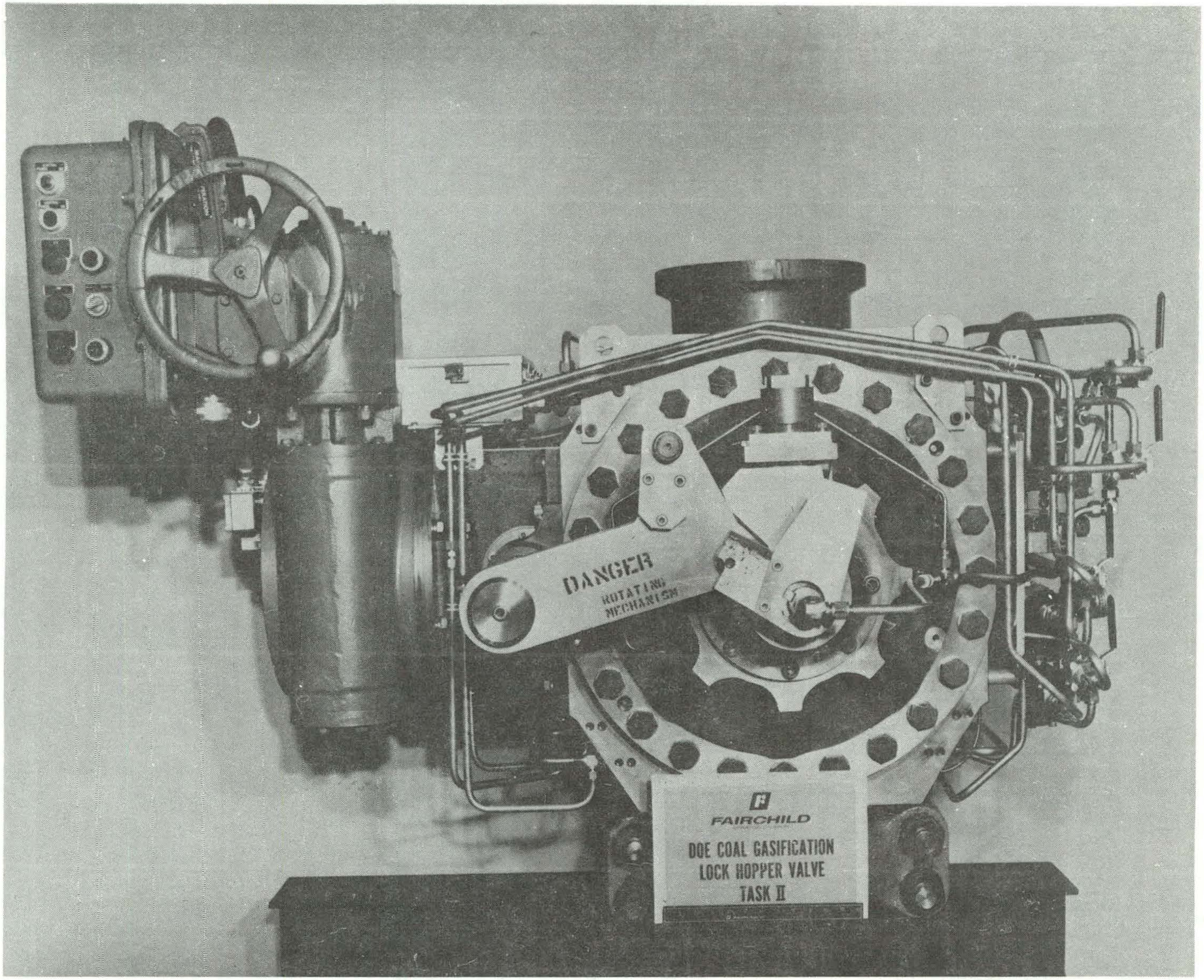


Figure 5. Fairchild Type II Prototype Lockhopper Valve—METC Prototype Test Valve No. F-1

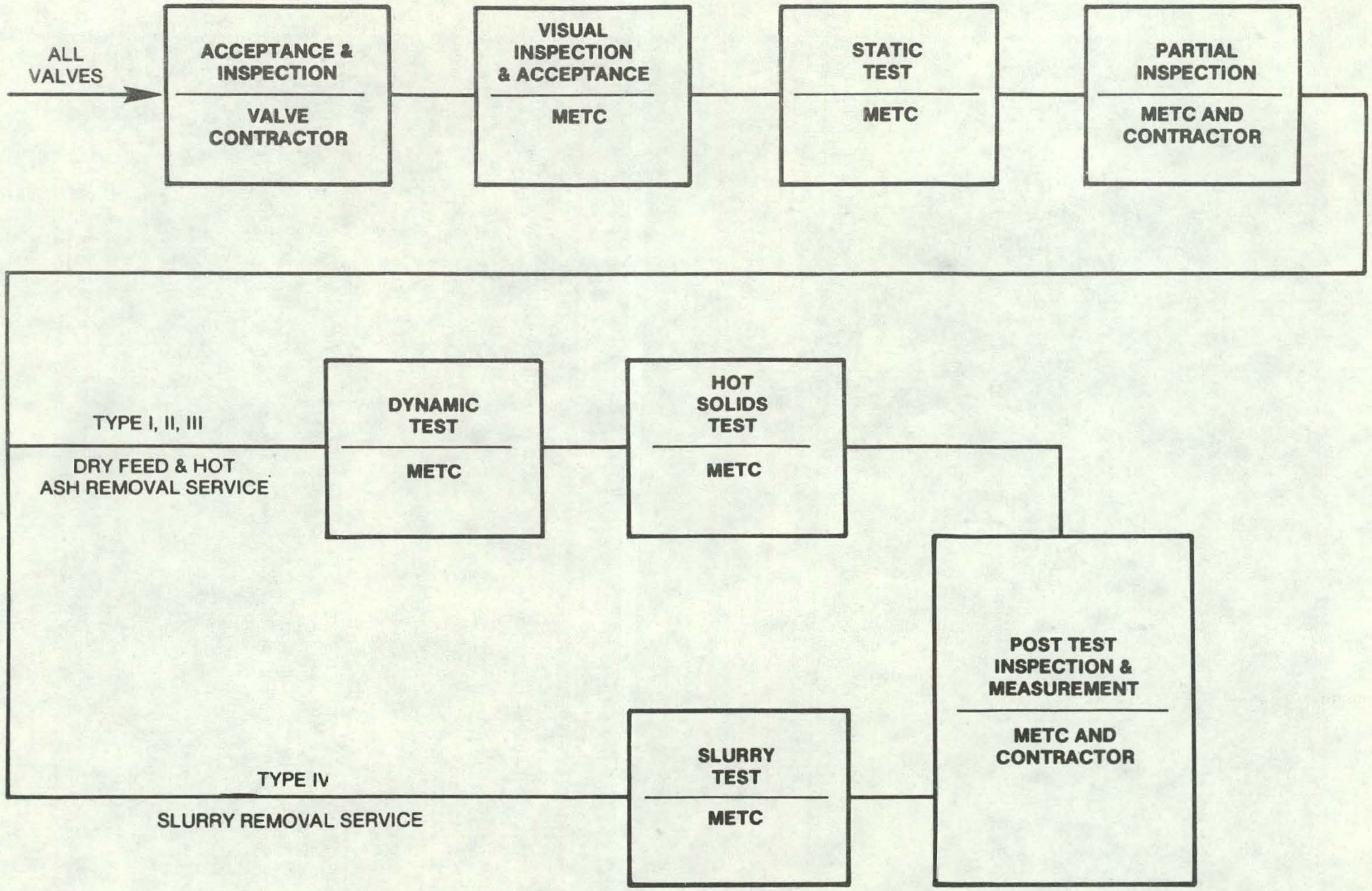


Figure 6. Prototype Valve Test Sequence

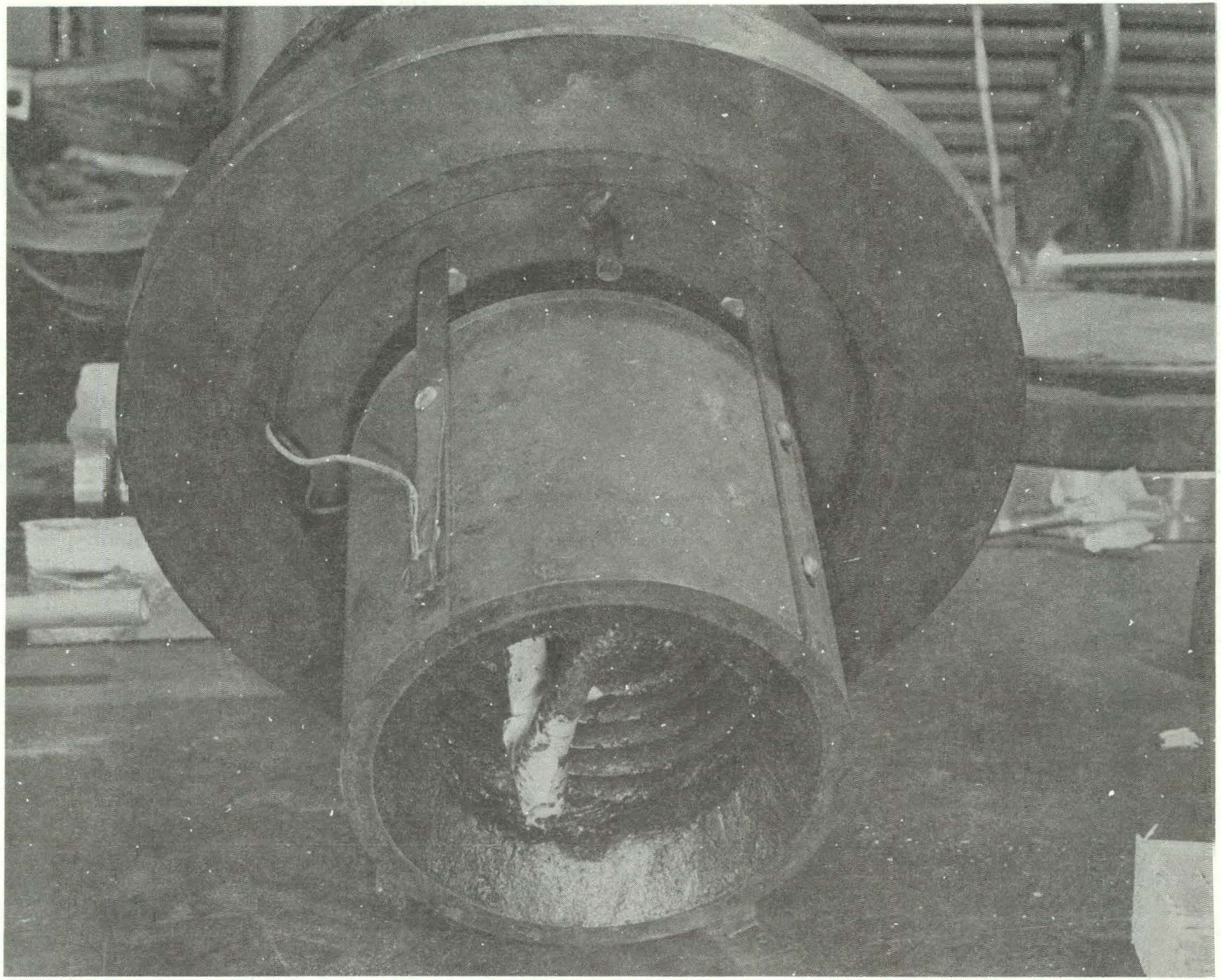


Figure 7. Internal Heater—METC Prototype Test Valve No. F-1

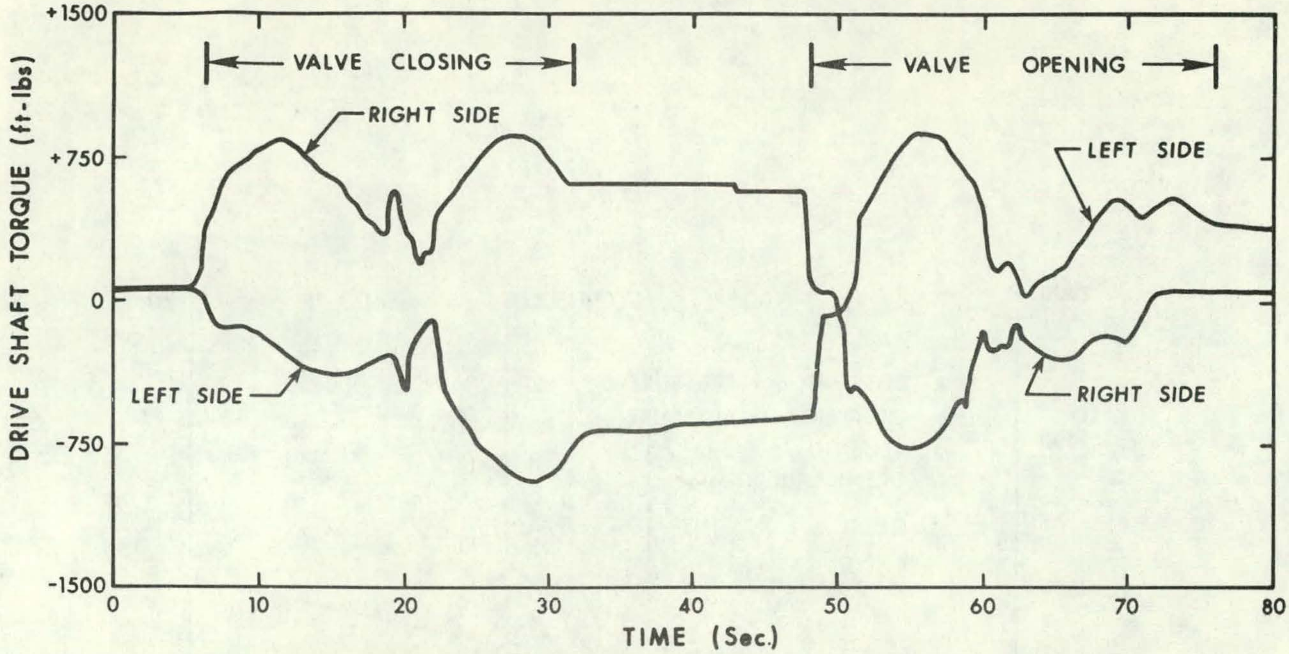


Figure 8. Sample Operating Torque Profile, 462 Cumulative Test-Valve Cycles—METC Prototype Test Valve No. F-1

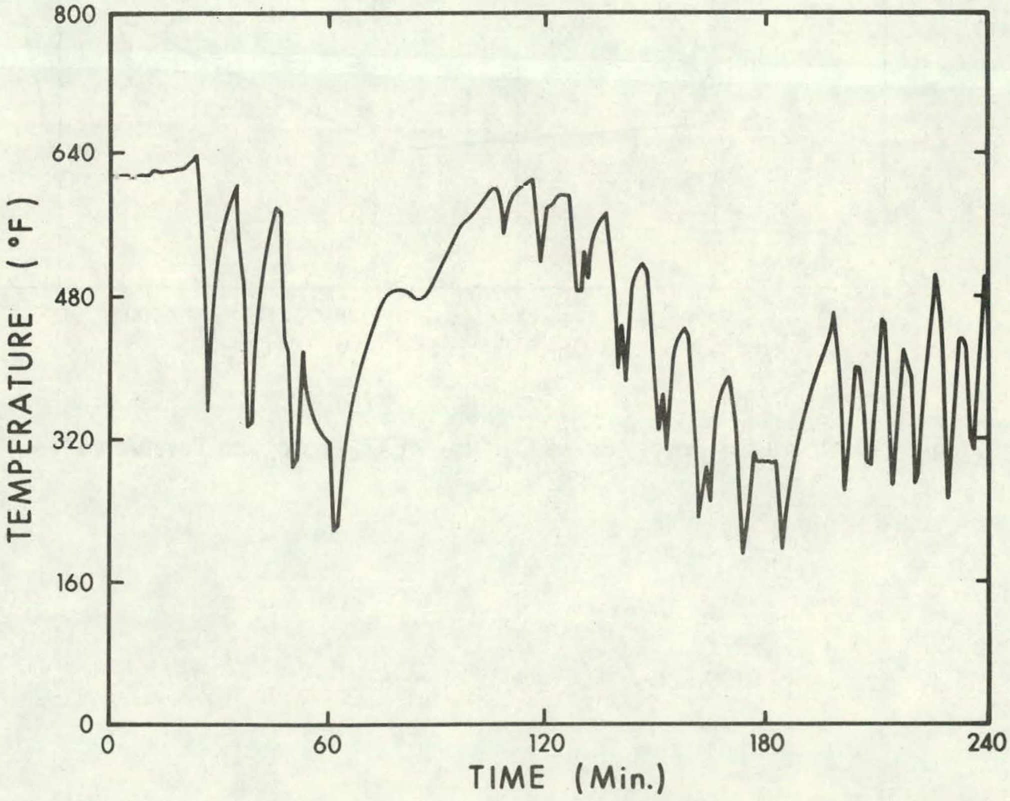


Figure 9. Variations in Side 2 Port Thermocouple Over 4 Hours of 600° F Testing—METC Prototype Test Valve No. F-1

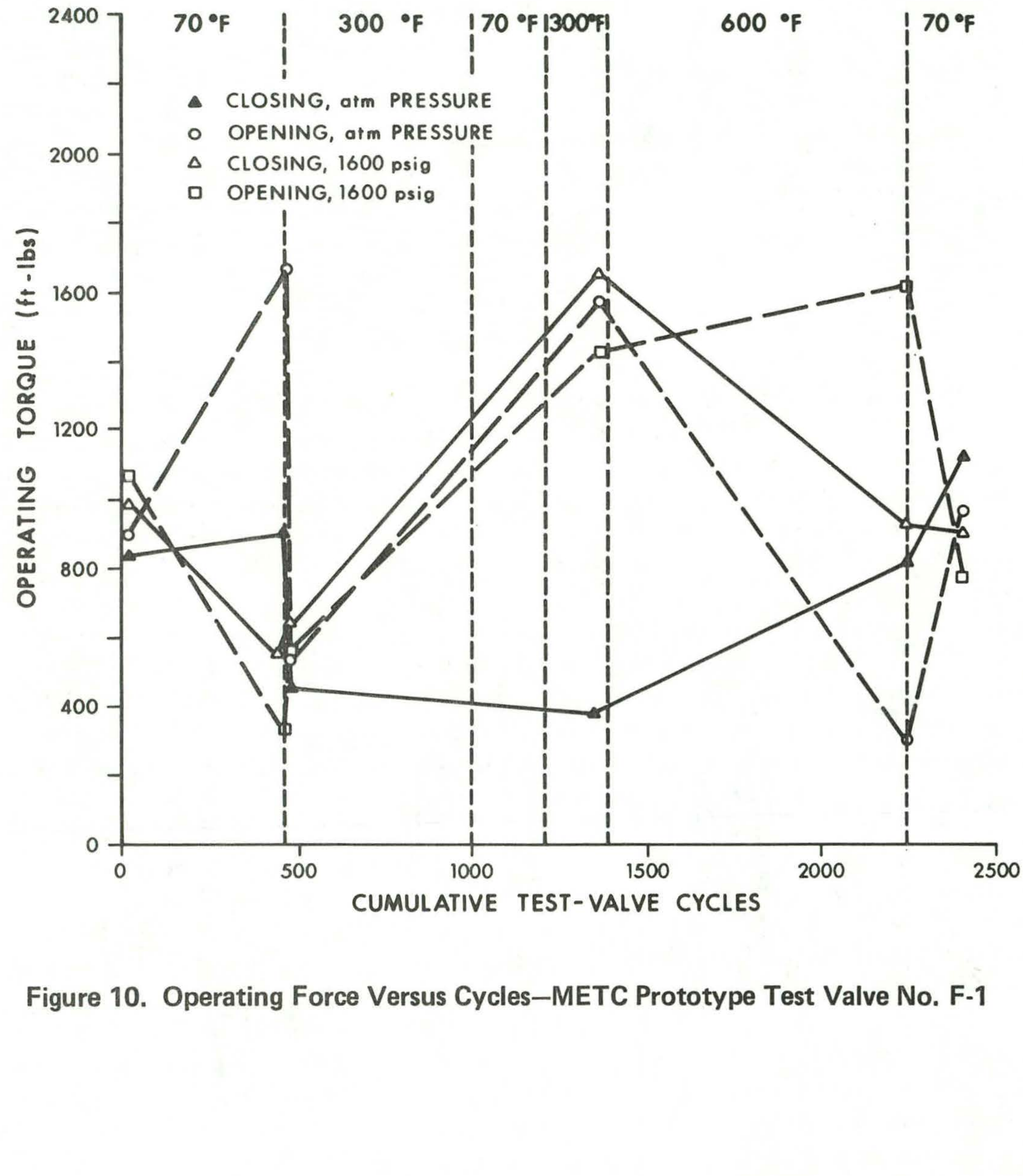


Figure 10. Operating Force Versus Cycles—METC Prototype Test Valve No. F-1

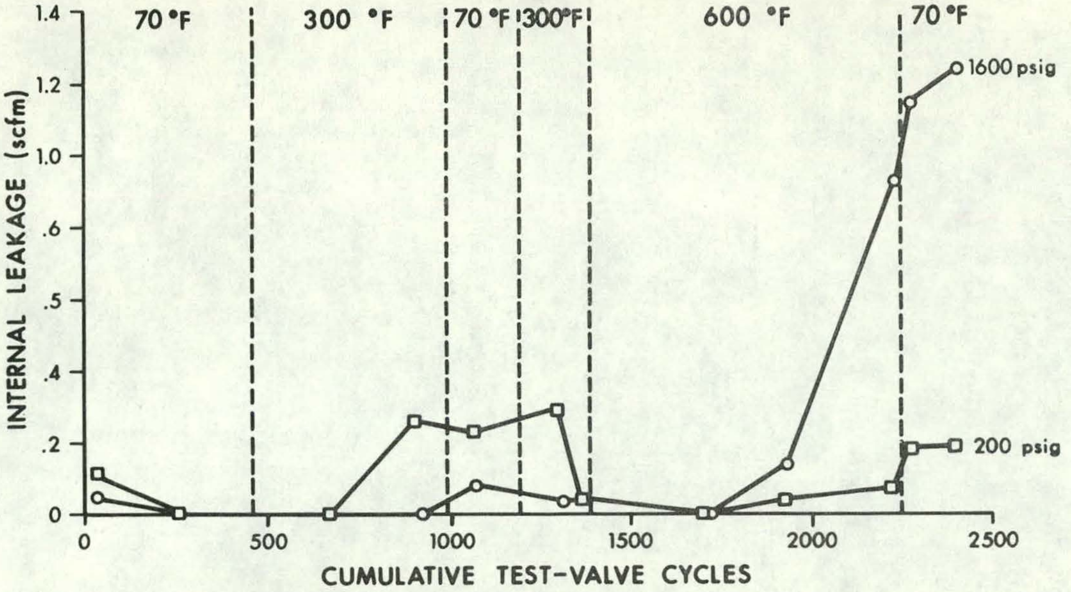


Figure 11. Internal Leakage Versus Cycles, Top Side Pressurized–
METC Prototype Test Valve No. F-1

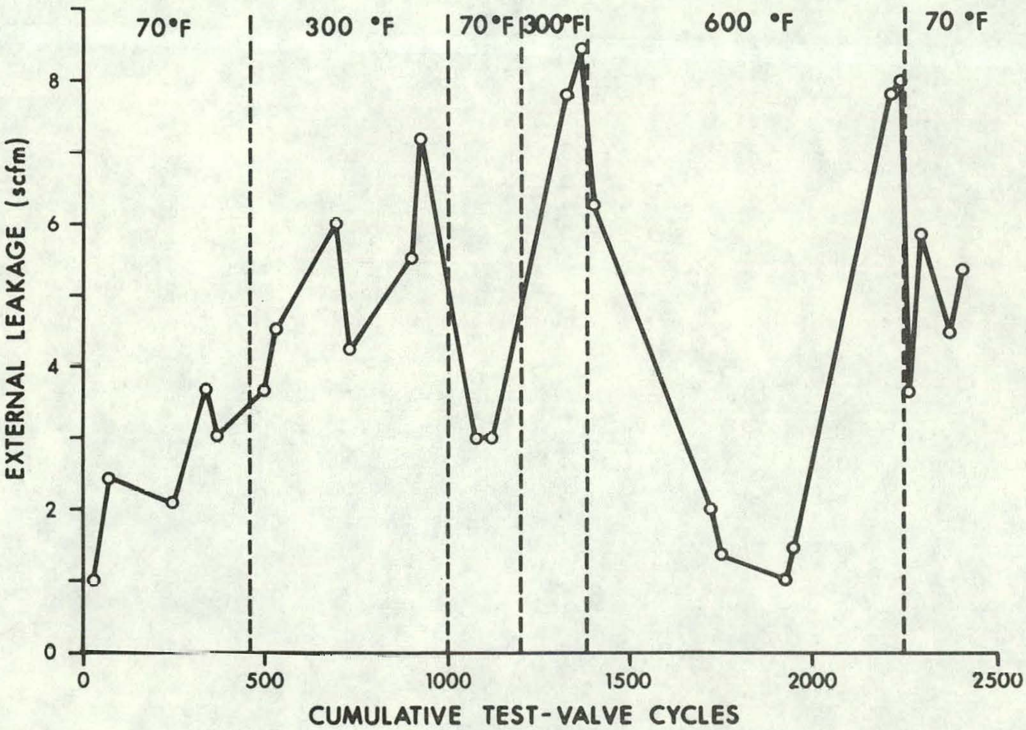
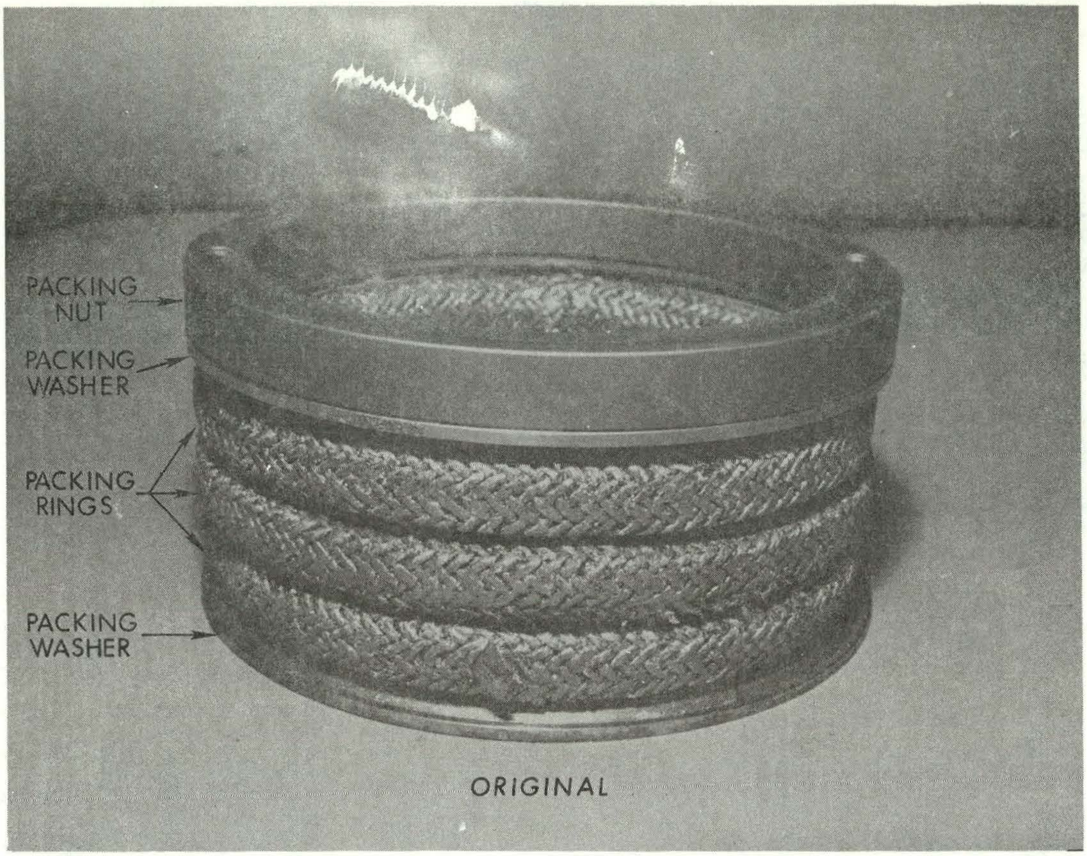


Figure 12. External Leakage Versus Cycles–METC Prototype Test Valve No. F-1



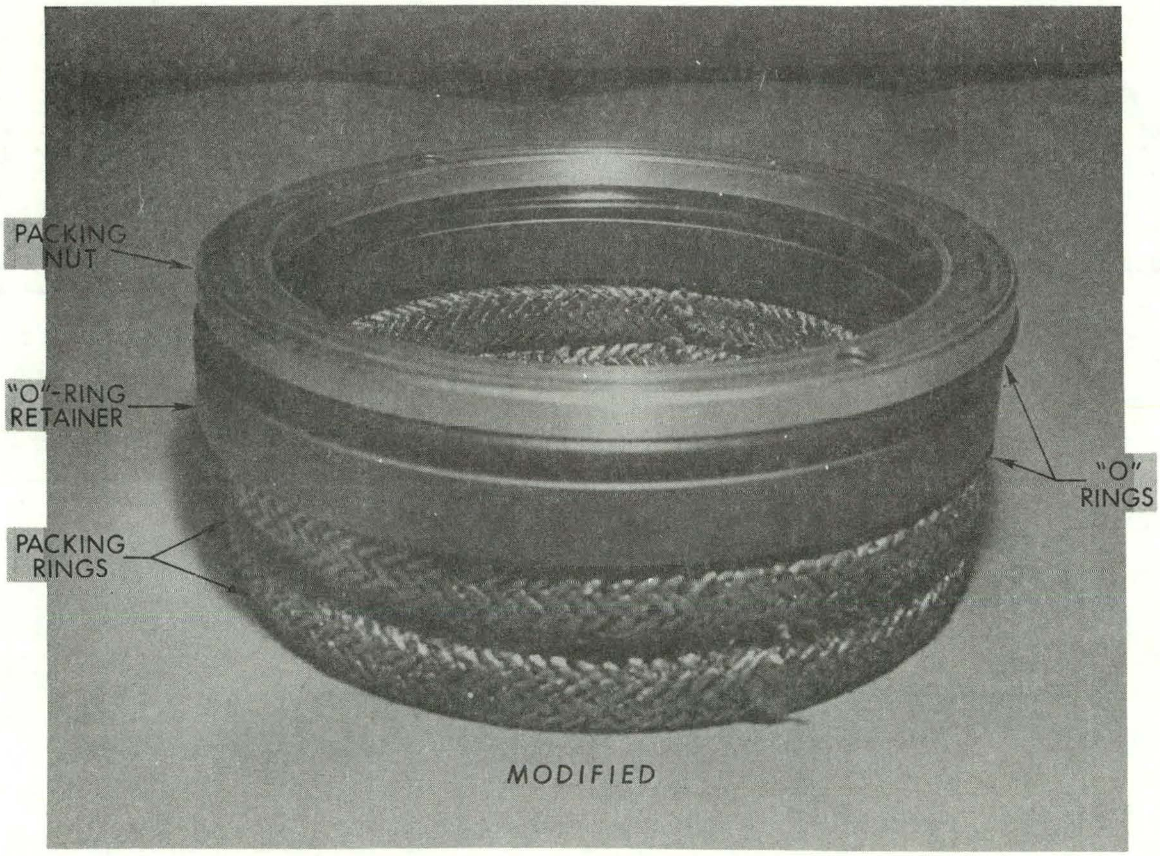
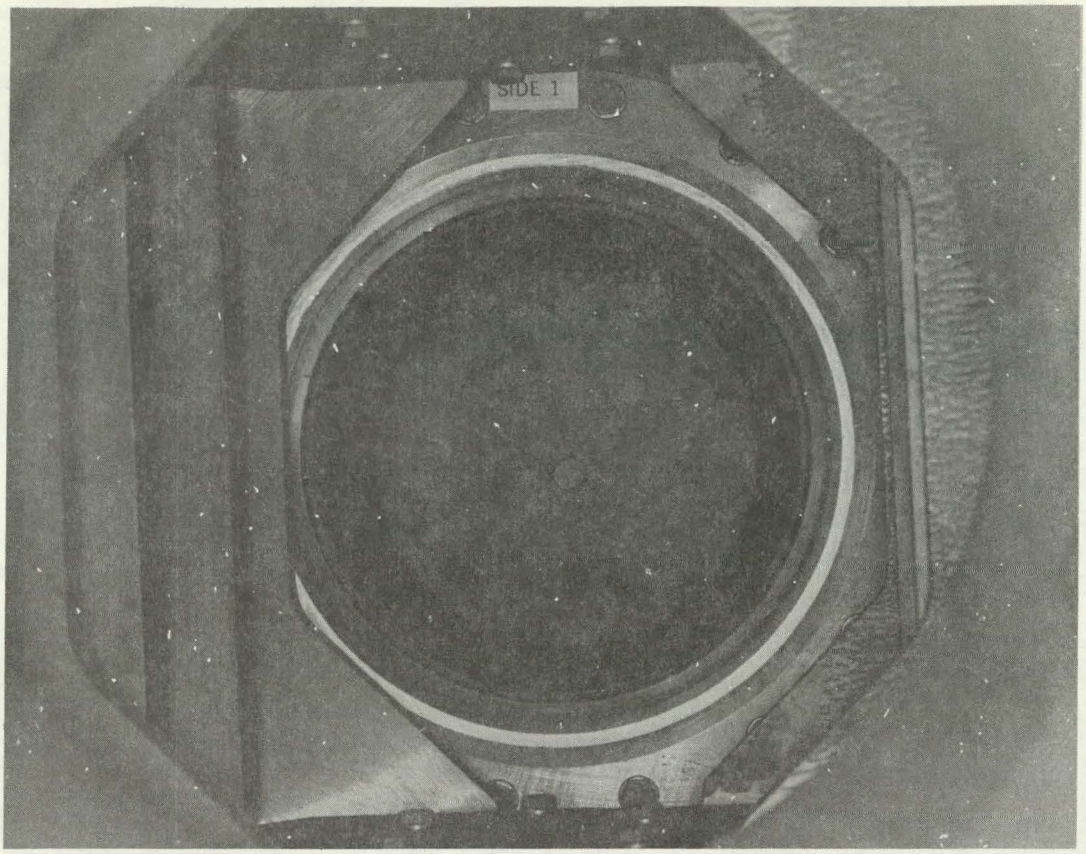


Figure 13. Original and Modified Stuffing-Box Arrangements— METC Prototype Test Valve No. F-1



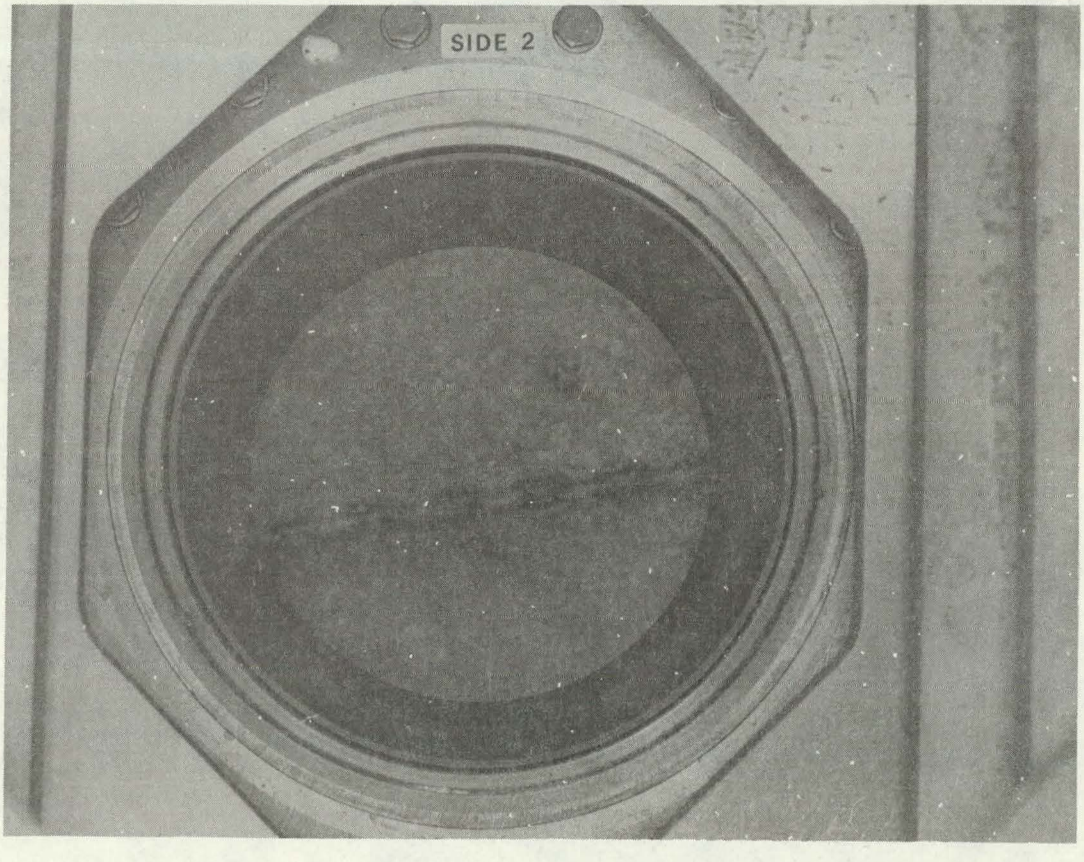


Figure 14. Side 1 and Side 2 Seats After Static Testing—METC Prototype Test Valve No. F-1

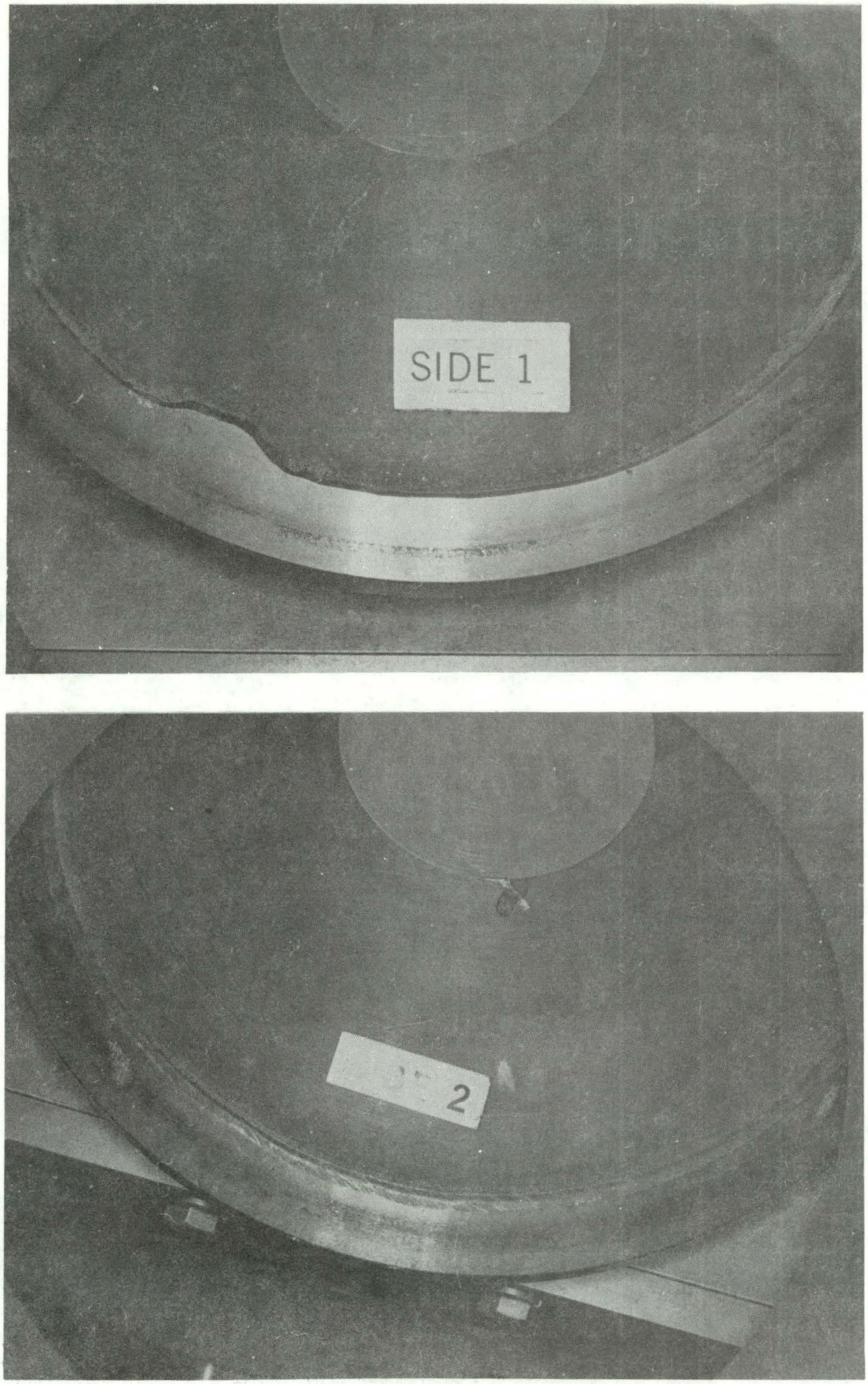


Figure 15. Side 1 and Side 2 Visors After Static Testing—METC Prototype Test Valve No. F-1

METC PROTOTYPE TEST VALVE NO. F-1 STATIC TEST REPORT

APPENDIX

The Morgantown Energy Technology Center has constructed four test units for the evaluation of valves for coal-conversion service. The capabilities of these test units are summarized on Figure I-1. These facilities are supplemented by a computerized Automatic Data-Acquisition and Control System (ADACS), an extensive metrology laboratory, and a staff of highly-trained operating technicians.

The Valve Static Test Unit (VSTU) evaluates the valve's performance (operating force, operating time, stem leakage, and seat leakage) with dry gas at ambient and elevated temperatures. The purpose is to provide baseline data for comparison with the results of testing with solids. A schematic is shown on Figure I-2.

Valves may be heated to 850°F using resistance or induction heaters. A typical operating sequence is shown in Figure I-3.

The Valve Dynamic Test Unit (VDTU) operates the valve in a simulated lockhopper mode. Ambient-temperature solids flow in batches through the vertical test train. Two or three valves are in series and the sections between them are alternately pressurized and vented.

The Valve Hot Solids Test Unit (VHSTU) operates much like the VDTU. The difference is that the solids being lockhoppered through the test train are at an elevated temperature. The fluidized-bed solids heater in the unit can provide solids at up to 2000°F.

The Valve Slurry Test Unit (VSLTU) is designed to test valves to be used for aqueous-slurry rather than dry-solids service.

The ADACS facility is dedicated solely to the valve-testing program. It provides automatic control of the test units, real-time monitoring of valve operation, data acquisition, and display of the test results.

The metrology laboratory has a wide range of equipment running from Weber Gauge Blocks to a Boice C-201 CMM 3-dimensional measuring machine to provide extensive capabilities for physical measurements. These capabilities are supplemented by equipment for surface finish characterization, hardness determination (both for metals and elastomers), and alloy verification. Cameras and lighting systems are available for documenting the disassembly of a valve and the condition of each part.

Parameter	Valve Static Test Unit (VSTU)	Valve Dynamic Test Unit (VDTU)	Valve Hot Solids Test Unit (VHSTU)	Valve Slurry Test Unit (VSLTU)
PRESSURE (PSIG):	← 0-1,600 →			
PRESSURIZING MEDIA:	← Air or Nitrogen →			
TEST MEDIA	Dry Gas	Non-flammable Solids up to 4 Mesh	Non-flammable Solids up to 4 Mesh	Water Slurry up to 50% Solids
MEDIA TEMPERATURE	Ambient	Ambient	100-2000°F	100-200°F
EXTERNAL HEATERS FOR VALVE BODY	100-850°F	100-850°F	None	None

Figure I-1. METC Valve-Testing Facilities

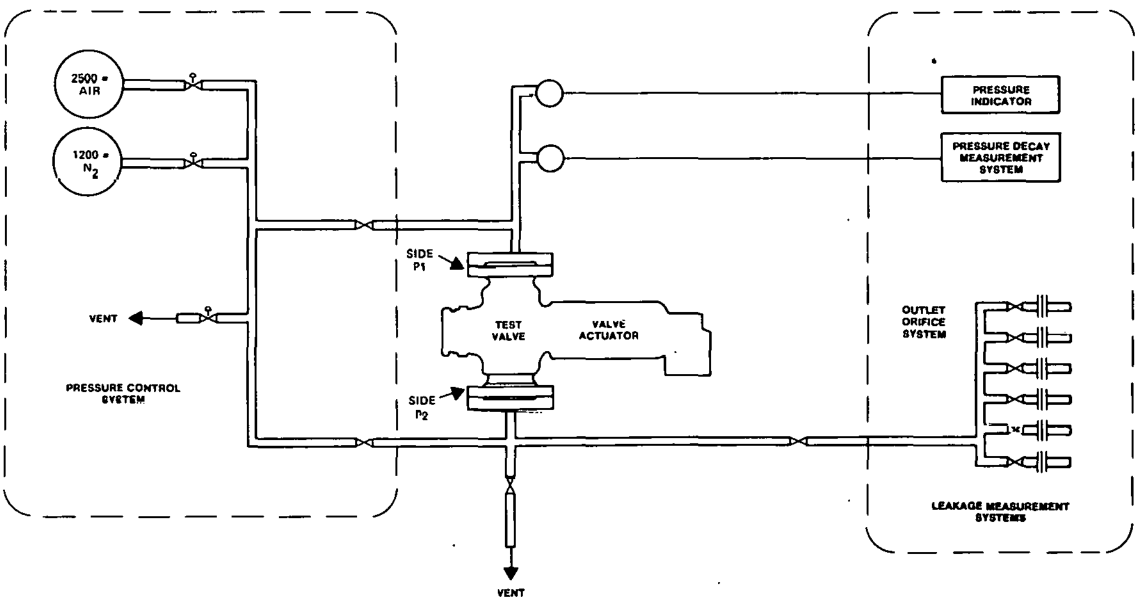


Figure I-2. Valve Static Test Unit (VSTU) Schematic

Event	Estimated Time (sec)	Remarks
1. Actuation Time (Atmospheric)	30	
2. Operating Force (Atmospheric)	N/A	Manual
3. Pressurize P_1 and P_2	200	
4. Operating Force (Rated Pressure)	N/A	Manual
5. Actuation Time (Rated Pressure)	30	
6. External-Leakage Test	300	
7. Depressurize P_1 and P_2	200	
8. Internal-Leakage Test	3,600	45 sec per Flow Meter Leg
9. Automatic Valve-Cycling Sequence		Assume 50 Auto Cycles
• Close Test Valve	30	
• Pressurize P_1	200	
• Perform Gross Leakage Test	20	
• Equalize Pressure Across Test Valve	20	
• Open Test Valve	30	
• Close Test Valve	30	
• Open Test Valve	30	
• Depressurize P_1 and P_2	200	
• Close Test Valve	30	
• Open Test Valve	30	
• Miscellaneous Pauses and Delays	20	
• Total 150 Valve Cycles (50 Auto Cycles)	32,000	
10. Internal-Leakage Test	3,600	
11. Auto Cycles (150 Valve Cycles)	32,000	
12. Internal-Leakage Test	3,600	
13. Depressurize P_1 and P_2	200	
14. Repeat Events 1 through 6	560	
15. Depressurize	200	
TOTAL	76,520 sec 21.3 hours	Plus Manual Steps

Notes:

1. Assumes 150 test-valve-cycle automatic sequences.
2. For elevated-temperature tests, preheat may be required at approximately 150°F per hour and cooling at 100°F per hour.
3. USON leakage test is available as option.
4. This table lists the time required for each test-valve temperature.

Figure I-3. Typical VSTU Test Sequence

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