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NAVAJO VALVE OPERATOR STUDY

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Memorandum

Memorandum
Denver, Colorado

TO : Chief, Mechanical Branch

DATE: November 16, 1988

THROUGH: Chief, Research and laboratory Services Division Graham 11/22
Chief, Electrical and Mechanical Engineering Division WRA 11/25

FROM : ACTING Chief, Hydraulics Branch

SUBJECT : Failure of Limitorque Valve Operators - Navajo Indian Irrigation Project - Laboratory Test Results (Your Memorandum Dated July 11, 1988) (Hydraulic Research)

The report on the findings of laboratory tests conducted on two Navajo Indian Irrigation Project Limitorque valve operators is enclosed. The study was conducted at the request of the Mechanical Branch, Electrical and Mechanical Engineering Division.

In summary, one valve was inoperative due to a corroded gear assembly and a burned out motor. The gear assembly would prevent the motor from turning; however the torque limit switch should provide protection for the motor when wired properly. Apparently the motor was wired incorrectly at one time. The second (operational) valve operated properly under all laboratory conditions and was sized properly for the application.

Clifford A. Pugh

Enclosure

cc: D-3420, D-3421 (Robinson), D-3423, D-3120, D-3423 (Finnefrock), D-3120 (Kinney), D-3751 (PAP file), D-3700, D-3750, D-3751, D-3752, D-3752 (Ehler), D-3752 (Fitzwater), D-3752 (Frizell)
(w/encl to each)

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(3752 Misc. corresp. 024)

NAVAJO VALVE OPERATOR STUDY

by
Dave Ehler
and
Jerry Fitzwater

The Hydraulics Branch has completed an investigation of two Limitorque valve operators. This study was conducted at the request of the Mechanical Branch, Electrical and Mechanical Engineering Division. The study was initiated to investigate problems encountered with Limitorque valve assemblies used on the Navajo Indian Irrigation Project near Farmington, New Mexico. Two valves were provided and are identified on Attachment 1. The valve study consisted of two parts: (1) Disassembly of a damaged valve operator, and (2) dynamic testing of a functional valve under operating flow and head conditions.

PART I Disassembly of Damaged Valve

Disassembly of the damaged valve began the week of July 25, 1988. Detailed information on this valve is provided in Attachment 1. Figures 1 and 2 provide details of the valve operator and a key to the various components. The end caps (parts number 6 and 7) and motor shell (18) were removed. There was no apparent damage in the geared limit switch (36) housing. The torque limit switch (37) and wiring housing did show evidence of moisture and corrosion. There was a loose wire with a terminal contact on it. The local control switches were then removed revealing a broken switch and the aforementioned switch contact missing. The motor showed evidence of overheating and coil damage. One winding was noticeably darker in color than the others, this winding tested open, see Photograph 1. The results of the test are noted in Attachment 2. The reason for the damaged winding could not be determined. The windings were series wye connected and in that connection it is difficult to reason why only one branch of the wye was damaged, unless the windings were previously connected incorrectly. A winding resistance chart and component wiring diagrams are provided in Attachment 2.

The motor rotor shaft turned freely 3 1/2 turns and then could not be turned. An attempt was made to turn the handwheel shaft (50) with a lever placed between the bolts. The mechanism still could not be turned either way. The handwheel had been broken and only the bolt ring remained. However, subsequent attempts did free the entire mechanism and allow the output shaft to turn. A second attempt with the lever on the handwheel shaft also turned the output shaft. In both cases it was still difficult to turn and much too tight to be turned by the motor. The mechanism did tend to turn more freely the more it was operated by hand.

When the output gear housing cover was removed, the cavity was filled with grease and the gears appeared to be in good condition. The condition of the grease was questionable since it was semi-crystallized and seemed rather heavy in consistency. There was no evidence of binding problems as the gears were turned thru approximately 1/3 of their full rotation although the entire assembly was still difficult to turn. The motor turns 100 revolutions for one revolution of the output shaft. The gear housing provides another turn reduction of 18 to 1/4. This agrees with the specifications.

The hand wheel side access cover (45) was removed. Again the parts appeared to be well lubricated. There was evidence of moisture and rust on the inside of the shaft but not on the moving parts.

The mechanical limit switch assembly (36) and torque switch assembly (48) were removed. There was no significant change in the effort required to turn the main sleeve shaft (Parts 62 thru 65 and 78 thru 89). The worm drive (Parts 66 thru 77) and handwheel shift mechanisms (Parts 40 thru 45) were removed, again no significant change in the effort required to turn the main sleeve shaft. The torque limit switches were set at minimum or very low values. Due to the difficulty in operating the valve, the mechanical limits were not verified.

Inspection of the lower gear assembly revealed more crystallized grease and voids that could contain water. The interior surfaces had the appearance of water or moisture contamination (rust or corrosion).

Torque measurements were made on the main valve shaft of 25 foot pounds and 16.67 foot pounds. The operator and gear assembly was soaked in solvent for 16 hours and torque readings again taken. Two foot pounds was required to move the worm shaft in either direction and 10 +/- 2 foot pounds to turn the worm shaft when the worm gear was engaged.

The gear assembly was then removed from the motor operator. The sleeve and shaft between the motor operator and output gear were corroded and the void was filled with a gritty black substance that appeared to be carbon. The gear assembly was still difficult to turn while the motor operator components turned with little friction and were well lubricated.

The output gear assembly was further disassembled so that the worm , shaft and worm gear could be inspected. The worm shaft showed wear and scouring on both ends on the outboard side of the "O" rings. The worm gear also showed wear and scouring on the inboard side of the valve. In both cases there are "O" rings to prevent water or moisture leakage into the gear assembly, but there is no positive way to lubricate the shafts.

CONCLUSIONS:

The general consensus is that the output gear assembly (moisture and turning friction) was the cause of the problems and eventual failure. The damaged control switch could have contributed to the problem, but without knowing when the damage occurred, shipping, supply yard or while installed, this cannot be evaluated.

The unit did not have heaters installed. Heaters would provide protection from moisture and condensation and subsequent rust and corrosion. There was evidence of this damage, but the motor, mechanical and electrical components were in good condition in this respect and would not impact on the operation of the valve operator.

Disassembly of the gear drive proved most interesting. The worm and worm gear appeared to be in fine condition with only a small amount of moisture in evidence. However, when the worm shaft and worm gear were removed there was corrosion on the bearing surfaces. This corrosion appears to be the cause of the high friction and difficulty in turning the motor shaft, see Photograph 2.

Another area of concern was the burned motor. The torque and mechanical limit switches normally protect the motor from damage unless these switches either malfunctioned, were bypassed, or the electrical phasing of the motors was reversed (installed incorrectly) or otherwise wired improperly. Reversing the phase rotation causes the motor to turn the opposite direction, in effect bypassing both the mechanical and torque limit switches. The excessive damage to just one winding could be explained by incorrect wiring of the 3-phase power to the motor.

Part II Dynamic Testing of the Second Valve

The second (operable) valve was equipped with a heater in the wiring and torque limit switch housing. A motor controller was added in the laboratory to place the valve in operation. The identification of this valve is provided in Attachment 1. The valve was installed on the high head test facility in the Hydraulics laboratory, see Photograph 3. The high head test facility is capable of providing pressure heads from 60 to 600 feet of water.

The valve was to be tested for pressure heads of 60 to 265 feet of water to simulate the actual field installation. Two pressure taps, one 5 diameters upstream and one 10 diameters downstream, were installed on the 4 inch pipe to record the necessary pressure data for the test. Two pressure transducers, one for upstream and one for differential, were calibrated and installed on the pressure taps. Data from the transducers were recorded on a strip chart recorder along with valve position and times. In order to determine the torque requirements to open and close the 4 inch Dresser valve while under a prescribed differential head, the motor operator was removed and a torque wrench was used to open and close the valve at each prescribed head. Maximum readings were recorded. The valve was then installed with flow in the opposite direction and all tests repeated. Upon completion of these tests the motor operator was installed and the test sequence was repeated with motor current recorded in lieu of the torque measurement. The results of the tests are provided in Table 1.

CONCLUSIONS:

The valve operated satisfactorily for all the tests. The direction of flow in the valve can be in either direction. The torque required varied from 50 to 150 in-lb for flow toward the flat face of the valve and from 40 to 410 in-lb for flow toward the curved face (flow reversed). The motor operator was removed in order to make the torque tests. Through the gearing in the operator, the .13 horsepower motor is capable of providing 51,480 in-lb of torque at the valve. This would result in about 25,740 in-lb at the valve shaft, assuming 50% loss for friction and other losses. Therefore, the motor can deliver about 60 times more torque than the maximum torque measured to directly operate the valve under full head.

Attachment 1.

Identification of limitorque units tested:

1. The following unit was dissassembled

Type	SMC-04	Order	3F4272 A
Serial	M003497		
Duriron C	15988		

Motor:

Type	PA-3	FR	42
HP	.20	Time	15 min
AMB	40 C	Ins	13
RPM	1700	Freq	60 Hz
PH	3	V	230/460
FLA	2.2/1.1	Code	M

Gear assembly: Limitorque
L30136A-HJ
VGC8-2355-1-01

Valve: The valve was removed

2. The following unit was dynamically tested:

Type	SMC-04	Order	3E2250 J
Serial	M005025	valve	3 in BF
Dresser	18664		

Motor:

Type	PA-3	FR	42
HP	.13	Time	15 min
AMB	40 C	Ins	13
RPM	1130	Freq	60 Hz
PH	3	V	230/460
FLA	2.2/1.1	Code	P

Gear assembly: Dresser

Valve: Dresser 3" with flanges for 4" pipe

Attachment 2.

MOTOR WINDING RESISTANCE MEASUREMENTS (in Ohms)
The measurements were made between the indicated terminals.

	1	2	3	4-7	5-8	6-9
1	X	81	*			
2	81	X	*			
3	*	*	X			
47	25	63	*	X	41	41
58	61	27	*	41	X	41
69	61	63	*	41	41	X

* INDICATES OPEN
X INDICATES SAME POINT NO READING

Wiring diagrams

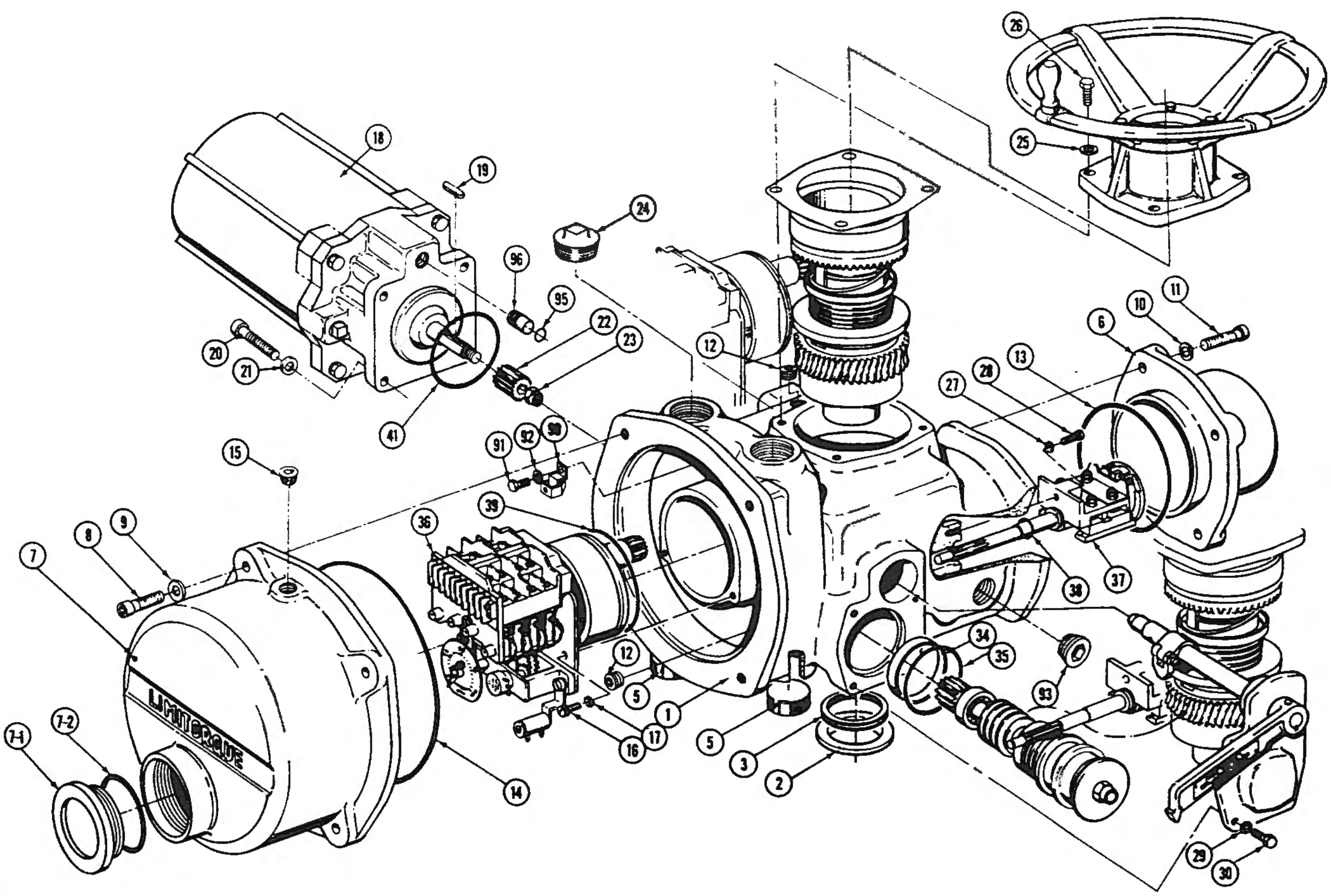
Torque Limit Switch

```
****************
*  O   **   O  *
* (19) **  (18)*
*      **      *
*  O---**---O  *
* (20) ** (20) *
****************
```

Manual Control Switch

```
   CL2 /  \   CL2 /  \
      |IND |     |IND |
       \  /12C    \  /16C
+------------+   +-----------+
|            |   |           |
|   =\ /=    |   | 4 =   = 3 |
|     X      |   |    |      |
|   =/ \=    |   | 4 =   = 5 |
|            |   |           |
+------------+   +-----------+
```

MAIN ACTUATOR ASSEMBLY

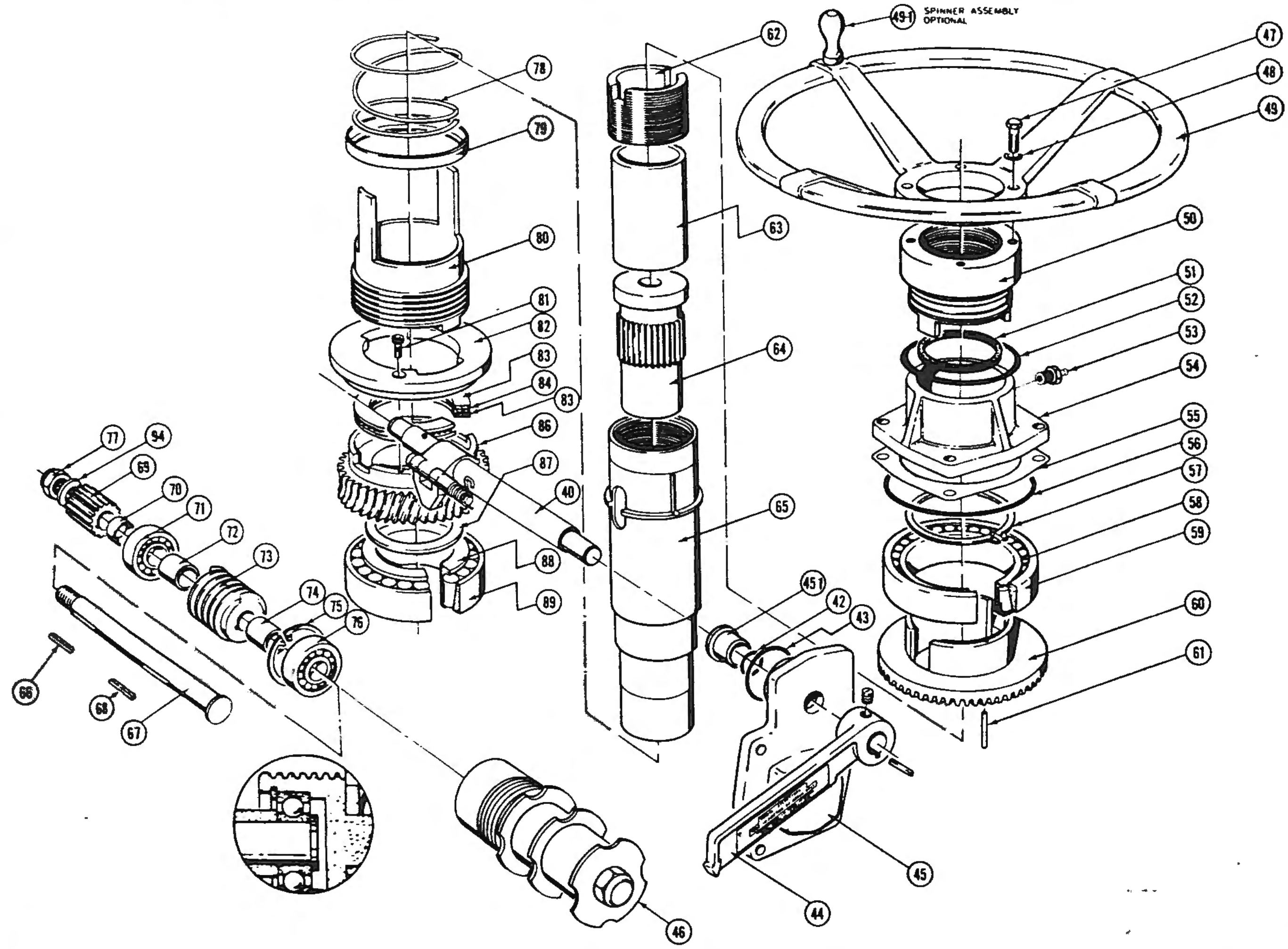


PARTS LIST		
PC.#	QTY.	DESCRIPTION
[illegible]	[illegible]	HOUSING
2	1	SEAL RETAINER
3	[illegible]	QUAD RING
5	2	PIPE PLUG
6	[illegible]	TORQUE SWITCH COMPARTMENT COVER
7	1	GEARED LIMIT SWITCH COMPARTMENT COVER
7-1	1	DIAL WINDOW
7-2	1	O-RING
8	4	SOC. HD. CAP SCREW
9	4	LOCKWASHER
10	4	LOCKWASHER
11	4	SOC. HD. CAP SCREW
12	2	PIPE PLUG (SMC-04 [illegible])
13	1	O-RING
14	1	O-RING
15	1	PIPE PLUG
16	2	FIL. HD. MACH. SCREW
17	2	LOCKWASHER
18	1	MOTOR
19	1	KEY
20	4	SOC. HD. CAP SCREW
21	4	LOCKWASHER

PARTS LIST		
Pc#	QTY.	DESCRIPTION
[illegible]	[illegible]	MOTOR PINION
23	1	FLEXLOC NUT
[illegible]	2	PIPE PLUG (SMC-[illegible])
25	4	LOCKWASHER
[illegible]	[illegible]	HEX. HD. CAP SCREW
27	1	LOCKWASHER
[illegible]	[illegible]	FIL. HD. MACH. SCREW
29	4	LOCKWASHER
[illegible]	[illegible]	HEX. HD. CAP SCREW
34	1	QUAD RING SPACER
[illegible]	1	QUAD RING
36	1	GEARED LIMIT SWTICH ASSY
[illegible]	[illegible]	TORQUE SWITCH ASSY
38	1	O-RING
[illegible]	[illegible]	O-RING
41	1	O-RING
90	[illegible]	GROUND LUG
91	2	HEX. HD. CAP SCREW
92	2	LOCKWASHER
93	1	PIPE PLUG
[illegible]	[illegible]	O-RING
96	1	CONDUIT NIPPLE

Figure 1

BASIC SUBASSEMBLIES



PARTS LIST		
PC.#	QTY.	DESCRIPTION
[illegible]	[illegible]	[illegible] SHAFT ASSY
42	1	QUAD RING
[illegible]	[illegible]	[illegible]
44	1	DECLUTCH LEVER ASSY
[illegible]	[illegible]	[illegible]
45-1	1	FLANGE BUSHING
[illegible]	[illegible]	[illegible] ASSY
47	4	HEX. HD. CAP SCREW
[illegible]	[illegible]	LOCKWASHER
49	1	HANDWHEEL
[illegible]	[illegible]	SPINNER ASSY (OPTIONAL)
50	1	HANDWHEEL ADAPTER
[illegible]	[illegible]	[illegible]
52	1	O-RING
[illegible]	[illegible]	[illegible]
54	1	HOUSING COVER
[illegible]	[illegible]	[illegible]
56	1	O-RING
[illegible]	[illegible]	RETAINING RING
58	1	BEARING CONE (UPPER)
[illegible]	[illegible]	[illegible]
60	1	BEVEL GEAR
[illegible]	[illegible]	[illegible]
62	1	LOCKNUT
[illegible]	[illegible]	[illegible]
64	1	STEM NUT

PARTS LIST		
Pc#	QTY.	DESCRIPTION
[illegible]	[illegible]	[illegible]
66	1	KEY
[illegible]	[illegible]	[illegible]
68	1	KEY
[illegible]	[illegible]	WORM SHAFT GEAR
70	1	GEAR SPACER
[illegible]	[illegible]	BALL BEARING
72	1	WORM SPACER
[illegible]	[illegible]	WORM
74	1	WORM SPACER
[illegible]	[illegible]	RETAINING RING
76	1	BALL BEARING
[illegible]	[illegible]	[illegible]
78	1	COMPRESSION SPRING
[illegible]	[illegible]	SPRING CUP
80	1	CLUTCH SLEEVE
[illegible]	[illegible]	SOC. HD. CAP SCREW
82	1	ECCENTRIC RING
[illegible]	[illegible]	THRUST RACE (SMC-031 Only)
84	1	THRUST BEARING
[illegible]	[illegible]	WORM GEAR
87	1	WORM GEAR SPACER (SMC-031 Only)
[illegible]	[illegible]	BEARING CONE (LOWER)
89	1	BEARING CUP (LOWER)
[illegible]	[illegible]	WASHER

Figure 2

TABLE 1.

DYNAMIC TEST RESULTS FOR NAVAJO VALVE 3 INCH

TEST NUMBER ONE FLOW TOWARD FLAT FACE OF BUTTERFLY

HEAD PSI	MAX. MOTOR CURRENT CLOSING IN AMPERES	OPENING	TIME IN SECONDS TO CLOSE	OPEN	DISCHARGE IN CFS	MAX TORQUE (in-lb) SEE NOTE
BALANCED	0.61	0.63	56.00	56.00	0.00	50.00
33.00	0.61	0.63	56.00	56.00	1.81	90.00
70.00	0.61	0.63	56.00	56.00	2.59	110.00
90.00	0.61	0.63	56.00	56.00	3.03	130.00
125.00	0.59	0.61	56.00	56.00	3.45	150.00

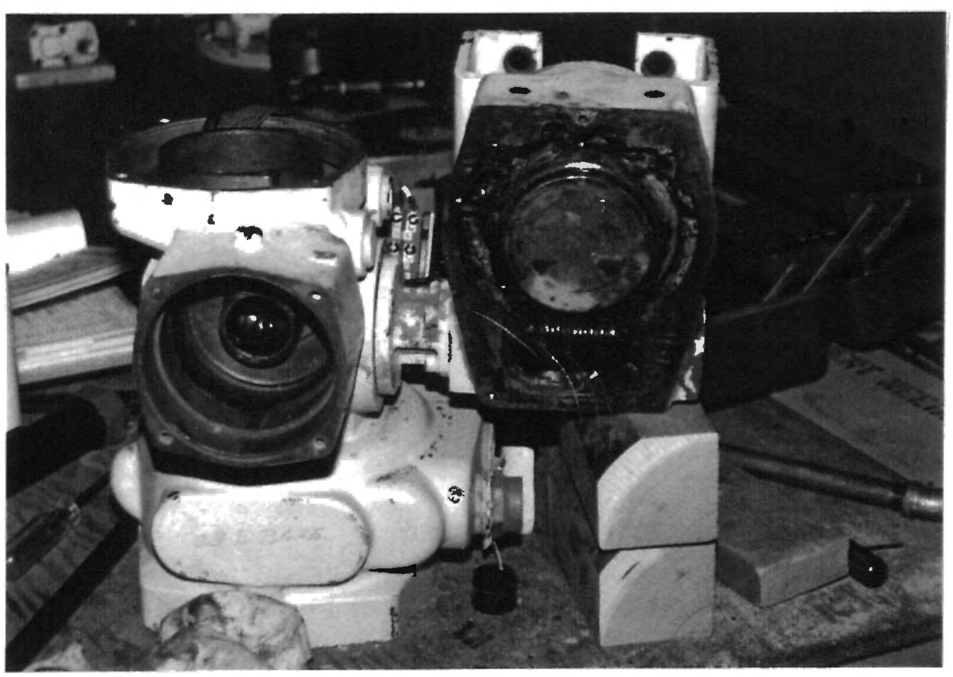
TEST NUMBER TWO FLOW TOWARD CURVED FACE OF BUTTERFLY

HEAD PSI	MAX. MOTOR CURRENT CLOSING IN AMPERES	OPENING	TIME IN SECONDS TO CLOSE	OPEN	DISCHARGE IN CFS	MAX TORQUE (in-lb) SEE NOTE
BALANCED	0.63	0.66	56.00	56.00	0.00	40.00
30.00	0.64	0.67	56.00	56.00	1.84	110.00
70.00	0.64	0.66	56.00	56.00	2.65	240.00
100.00	0.64	0.66	56.00	56.00	3.11	320.00
125.00	0.63	0.66	56.00	56.00	3.54	410.00

NOTE: TORQUE MEASURED WITH A TORQUE WRENCH THRU ENTIRE ROTATION WITH MOTOR OPERATOR REMOVED. READING IS THE MAXIMUM ENCOUNTERED THRU THE ROTATION.

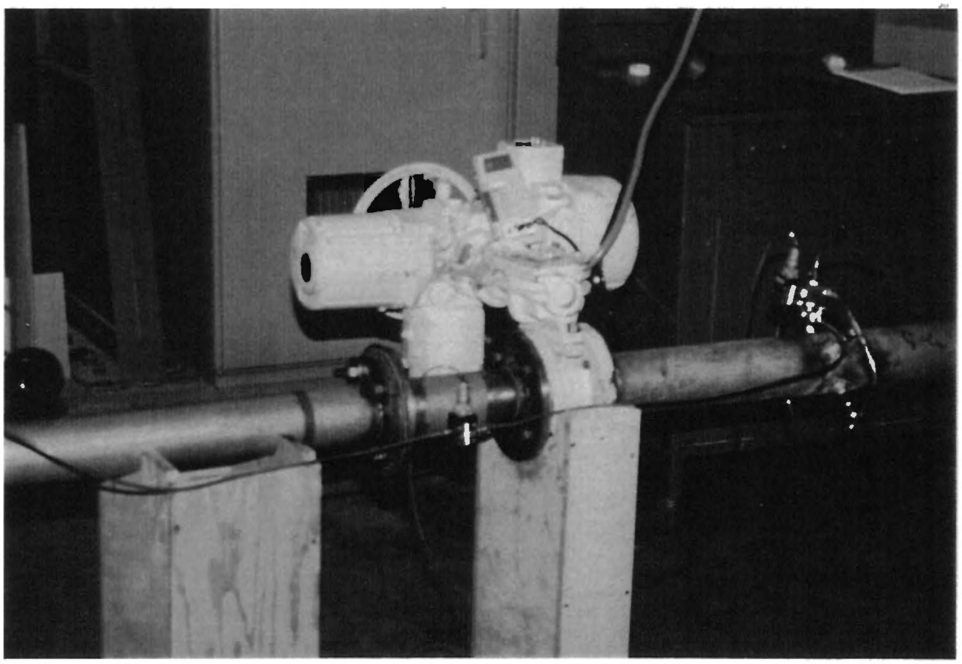
Motor Stator and Rotor
Burned windings are at upper and lower left

PHOTOGRAPH 1



Controller Housing and Output Gear with Cover Removed

PHOTOGRAPH 2



Valve and Operator Installed on Test Facility

PHOTOGRAPH 3