RECLAMATION

Managing Water in the West

TR-2011-07

Travel to Durango Pumping Plant, Durango, CO to measure opening torque on pump discharge and guard butterfly valves

Dates of travel: November 7-9, 2011

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

November 2011

BUREAU OF RECLAMATION
Technical Service Center
Denver, Colorado

TRAVEL REPORT

Code: 86-68460 Date: November 21, 2011

To: Manager, Hydraulic Investigations and Laboratory Services Group

From: K. Warren Frizell and Josh Mortensen

Subject: Travel to Durango Pumping Plant, Durango, CO to measure opening torque on pump discharge and guard butterfly valves

Travel period: 07 Nov 2011 – 09 Nov 2011

2. Places or offices visited: FCCD, Durango Pumping Plant

3. Purpose of trip: To measure opening torques on 3 different sized (36-, 24-, and 18-inch) butterfly valves within the Durango pumping plant. Both pump-discharge valves and guard valves are sized similarly based on pump size, with the guard valves being manually operated and the pump-discharge valves being motor-operated. Operational problems during the past summer have resulted in numerous occasions where motor-operators reach their torque limits prior to the valve opening. In addition, several of the manually operated guard valves could not be opened under typical full unbalanced head conditions.

4. Synopsis of trip:

Installation and Test Procedure: The afternoon of Monday, November 7, 2001 test instrumentation (strain gages) were installed on discharge and guard valves of Units 1, 3, and 6. On Wednesday morning (November 9, 2011) a strain gage rosette was installed on the discharge valve of Unit 5 to acquire test data from an additional unit. Unit 1 had 18-inch butterfly valves with shaft diameters of 2.559 in, Unit 3 had 24-inch butterfly valves with shaft diameters of 3.150 in, and Units 5 and 6 had 36-inch butterfly valves with shaft diameters of 5.510 in. Strain gages were used to measure the torque required to open (unseat) the downstream guard and pump-discharge valves of their respective units following standard operating procedures.

The gages were bonded to the exposed shaft (martensitic precipitation-hardening Stainless Steel 17-4 PH) between the valve and operator (Figure 1). General purpose strain gages manufactured by Vishay Measurements Group, Inc. (CEA-06-187UV-350/P2) were used for testing. This strain gage configuration actually contains two gages set at 45 degrees from center line as illustrated in Figure 2.

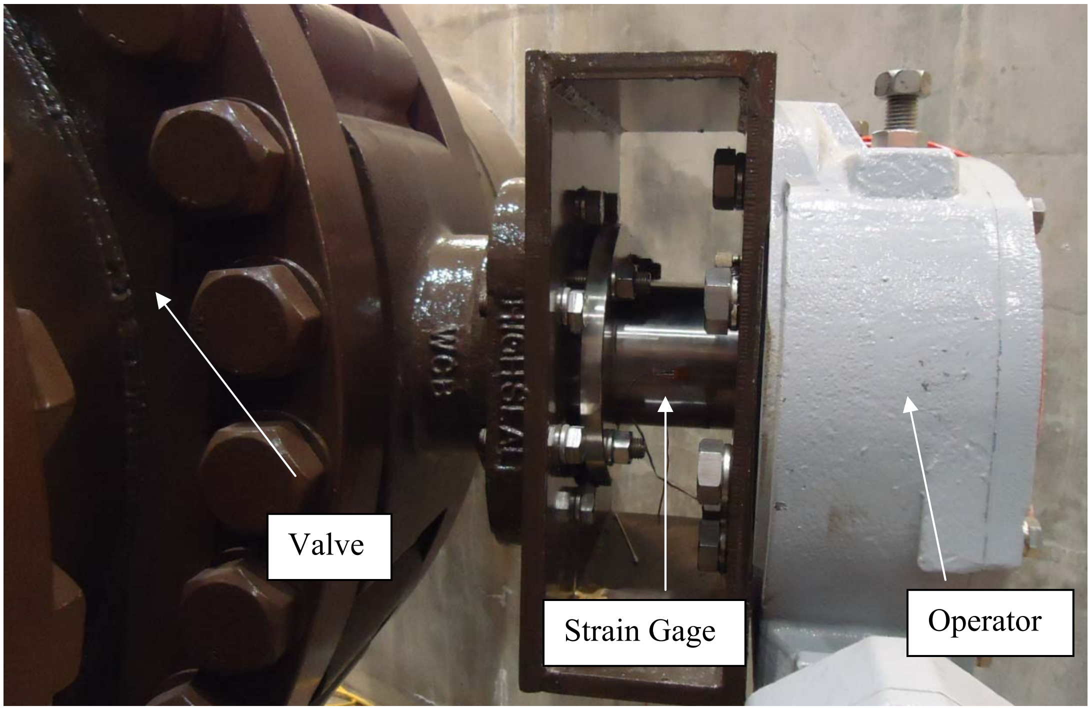

Figure 1 Location of strain gage installation on exposed shaft between valve and operator on Unit 6.

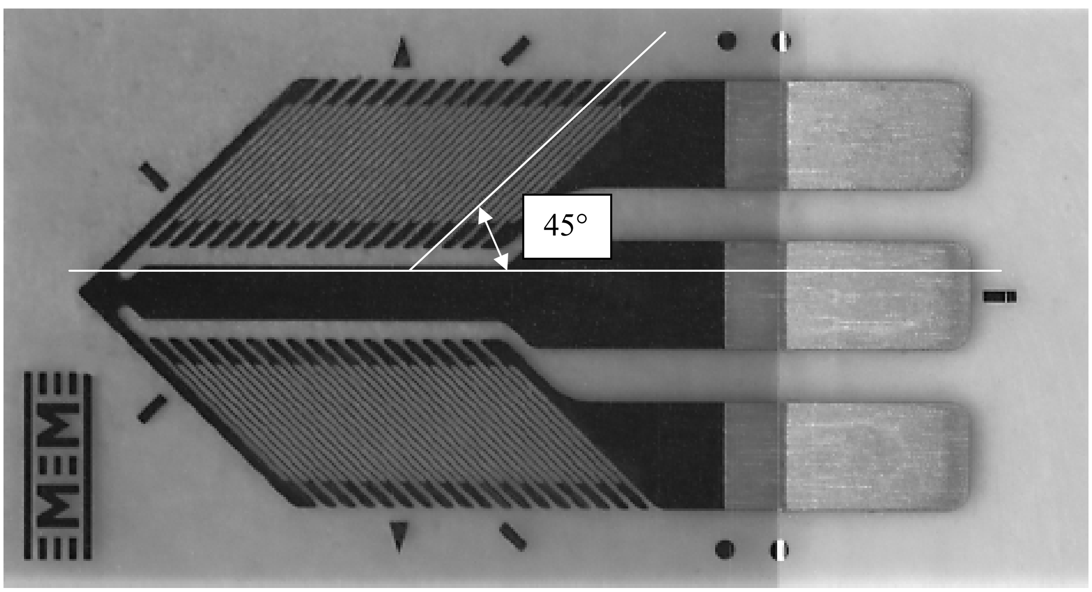

Figure 2 Shear/torque grid configuration of strain gages that were used for testing, set at 45 degrees from the longitudinal shaft axis.

Prior to installation, the shaft surface was prepared using metal degreaser, wet-abrading with conditioner, and cleaning with neutralizer per the manufacturer's instructions. The gages were bonded to the shaft using M-Bond 200 adhesive and were given sufficient time to dry before testing. Gages were carefully aligned along the longitudinal axis of the shaft as shown in Figure 3 to assure an accurate strain reading. These strain gages had preattached lead wires.

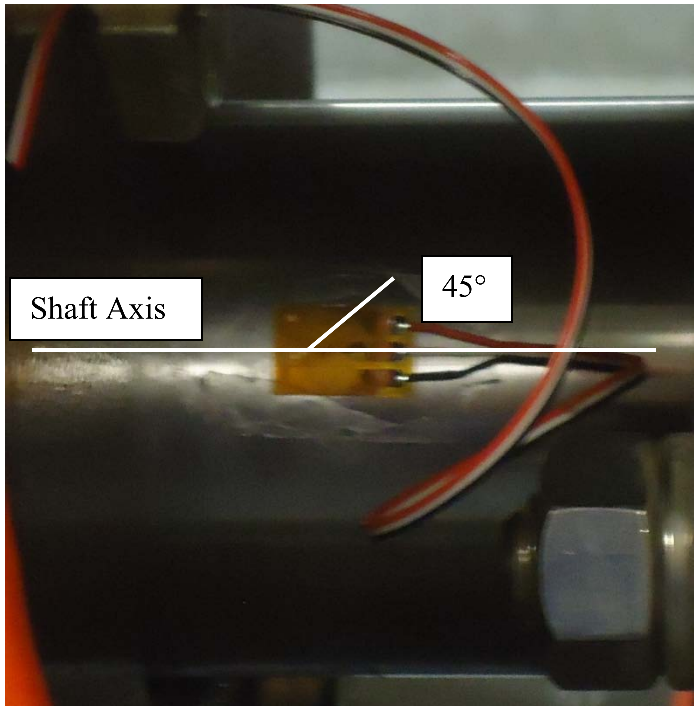

Figure 3 Alignment of strain gage installation on shaft for each unit.

The three lead wires from the strain gages were soldered to the Ethernet cable wires that connected to the data acquisition conditioning box. Gages on all units were wired in a ½ bridge configuration which allowed the tandem gage configuration to output a single shear strain reading. Units 1 and 3 had only one set of strain gages installed on each shaft. Two sets of gages were installed on Unit 6 on opposite sides of the shaft. This was done to compare and confirm consistency of reading outputs in a ½ bridge configuration, and to test a full bridge wiring configuration to determine if it would be useful. After initial testing, the full bridge did not appear to be producing correct outputs so only data from the ½ bridge configurations will be reported.

The gages operate by sensing a small change in gage resistance due to stretching or compressing the encapsulated wire grid in conjunction with deflection of the shaft. The maximum and minimum strains for a pure torque condition are aligned at 45-degrees to the shaft axis, hence the gage design noted above. Signals were transferred through an Ethernet cable from the gage into a D4 data acquisition conditioning box with a USB interface to a laptop computer. The data conditioning box acquired data at 8 Hz and output shear strain readings directly for the ½ bridge configuration selected. The shear strain measurements were recorded in a text file and then used to calculate torque based on the diameter and material properties of the shaft.

Testing: The tests that were performed are detailed in table 1. As was mentioned previously, only data recorded from gages wired in a ½ bridge configuration will be presented. The test condition is a description of the general conditions for the test. Variables included balanced heads across the valves or unbalanced heads; hard seated versus soft seated versus out of the seat; check valve between the discharge valve and the guard valve fully seated versus open; and the use of motor operator or hand wheel.

Table 1: Test runs to measure opening torque on 3 different sized butterfly valves.

Test No.	Date	Time	Unit No.	Valve	Test condition	Bridge config.
1	11/8/2011	8:18	6	Discharge	Balanced/drained/seated/motor-operator	Full
2	11/8/2011	8:33	6	Guard	Unbalanced/seated/hand wheel	Full
3	11/8/2011	9:37	6	Discharge	Unbalanced/pump/seated/motor-operator	Full
4	11/8/2011	10:11	6	Discharge	Unbalanced/pump/off seat/motor operator	Full
5	11/8/2011	11:15	6	Discharge	Unbalanced/pump/check closed/motor operator	Full
6	11/8/2011	14:01	3	Guard	Unbalanced/seated/check open/hand wheel	Half
7	11/8/2011	14:15	3	Guard	Balanced/seated/check closed/hand wheel	Half
8	11/8/2011	14:29	3	Discharge	Balanced/seated/motor operator	Half
9	11/8/2011	14:33	3	Discharge	Unbalanced/pump/seated/motor operator	Half
10	11/8/2011	14:44	1	Guard	Balanced/seated/motor-operator	Half
11	11/8/2011	14:54	1	Discharge	Balanced/seated/motor operator	Half
12	11/8/2011	14:57	1	Discharge	Unbalanced/pump/seated/motor operator	Half
13	11/8/2011	16:18	6	Discharge	Unbalanced/pump/seated/motor operator/hand wheel	Half
14	11/8/2011	16:23	6	Discharge	Balanced/seated/motor operator	Half
15	11/8/2011	16:28	6	Discharge	Balanced/seated/motor operator	Half
16	11/8/2011	16:30	6	Guard	Unbalanced/seated/hank wheel	Half
17	11/8/2011	16:37	6	Discharge	Unbalanced/pump/seated/motor operator	Half
18	11/8/2011	16:45	6	Discharge	Unbalanced/seated/motor operator	Half
19	11/9/2011	8:20	5	Discharge	Unbalanced/pump/seated/motor operator	Half
20	11/9/2011	8:57	6	Discharge	Balanced/pump/seated/motor operator	Half
21	11/9/2011	9:05	6	Discharge	Unbalanced/pump/seated/motor operator	Half

The general test procedure began with zeroing the strain gage bridge output, initiating recording, moving (or attempting to move) the valve under test, stopping recording. For the unbalanced discharge valve tests this included starting the pump with the valve initially closed. The balanced head tests were controlled at the valve with motor operators placed in local control. Table 2 shows the maximum torque values obtained during testing.

Table 2: Maximum torque values from test runs with ½ bridge configuration.

Test No.	Unit No.	Valve	Maximum Torque (ft-lb) Gage 1	Gage 2	Successfully opened
6	3	Guard	8868		Yes
7	3	Guard	6292		Yes
8	3	Discharge	1942		Yes
9	3	Discharge	7716		Yes
10	1	Guard	4557 (torque limit) 5050 (hand wheel)		No Yes
11	1	Discharge	197		Yes
12	1	Discharge	2237		Yes
13	6	Discharge	19711 (torque limit) 20128 (hand wheel)	20276 (torque limit) 20723 (hand wheel)	No Yes
14	6	Discharge	6848	5866	Yes
15	6	Discharge	1906	1548	Yes
16	6	Guard	45287	44870	No – crack in casing
17	6	Discharge	18221	16596	Yes
18	6	Discharge	20223 (torque limit)	19149 (torque limit)	No
19	5	Discharge	26857		Yes – with some effort to not allow limit to be hit
20	6	Discharge	6499	6151	Yes
21	6	Discharge	5687	5716	Yes

5. Conclusions: During testing, we measured only the strain induced on the valve shaft by either the motor operator or the hand wheel. FCCD personnel monitored valve operators during most of the runs, noting the setting that the operator reached upon opening of the valve or the setting when the upper torque limit switch was activated. Reasonable agreement between these torque readings was found. No pressure differential measurements were collected as no gauges exist. The terms balanced versus unbalanced can therefore be a myriad of differing differential pressures across the valves depending on seating of the discharge valve, check valve and guard valves and possible leakage across any of these seats. This is evident by the results for a typical unbalanced test on Unit no. 6 with the upper torque limit switches engaging on some but not all similar runs. We were able to open all valves successfully under balanced conditions. In addition, all valves would open when partially or fully unbalanced with the exception of the bypass valve on Unit No. 6. Torque limits were reached on the Unit no. 1 guard valve (motor-operated) at a value of about 4600 ft-lb, but the valve was opened using the hand wheel at a little over 5000 ft-lb. The discharge valve on Unit no. 6 reached the torque limit on 2 tests (13 and 18), both considered to be unbalanced head tests. The valve was opened using the hand wheel during test 13 but was not used in test 18. Perhaps the most critical finding was the inability to manually open the guard valve on Unit no. 6 with unbalanced head conditions. Torques of more than 3.5 times in excess of the 12,188 ft-lb specified by the manufacturer were applied, resulting in a crack in the operator head cover (figure 4). It is evident from the scatter in data that there are many variables that affect the opening torque on these butterfly valves. The amount of differential pressure is probably the most significant; however, the seating pressure and time that has passed with the valve seated are also critical.

Uncertainties in the actual strain measurements are dependant both on the data acquisition conditioner as well as the gage installation. The D4 data acquisition conditioner box has a specified uncertainty of ±1 microstrain. When converted to torque, this is ±30 ft-lb for the 36-inch valves, ±6 ft-lb for the 24-inch valves, and ±3 ft-lb for the 18-inch valves. Slight misalignment of the gage with the shaft axis can result in errors of ±1.7-percent of the reading in microstrain per degree, resulting in torque variations of around 300 ft-lb for the 36-inch valves, to typically less than 100 ft-lb for the 24- and 18-inch valves for the range of shear strains measured. We estimated gage misalignment to be less than 1-degree for all gages installed.

Figure 4: Note crack in operator cover, 36-inch guard valve, manually operated, Unit no. 6.

6. Action correspondence initiated or required: Provide FCCD with a complete documentation of the testing for their files.

7. Client feedback received:

cc: FCCD-303 (Miller)
FCCF-402 (Manzanares)
86-68410 (Shisler)

SIGNATURES AND SURNAMES FOR:

Travel to: Durango Pumping Plant, Durango, Colorado

Dates of Travel: November 7-9, 2011

Names and Codes of Travelers: K. Warren Frizell and Josh Mortensen, 86-68460

Travelers:

K. Warren Frizell — 11/16/2011 Date
Hydraulic Investigations and Laboratory Services Group

Joshua D. Mortensen — 11/16/11 Date
Hydraulic Investigations and Laboratory Services Group

Peer Review by:

Tracy B. Vermeyen, P.E. — 11/16/11 Date
Hydraulic Investigations and Laboratory Services Group

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Hydraulic Investigations and Laboratory Services Group