LABORATORY TEST ON AMERICAN DARLING AND IOWA 6-INCH WEDGE-GATE VALVES

COMPLETED BY

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PURPOSE

The Hydraulics Branch received an American Darling, No. 42, 250-lb O.W.G., 6-in (152 mm) NRS HW gate valve from the Navajo Indian Irrigation Project, New Mexico. The valve is a nonrising stem, wedge disk arrangement with bronze disks and seating rings. Laboratory tests were requested to determine the torque required for valve operation under high differential pressures.

Because of the high torque values required to operate the American Darling valve, similar tests were made on an Iowa valve for comparison.

INSTRUMENTATION

The American Darling valve was taken apart, and two strain gages (M&M EA-06-500BH-120) attached at 45° to the centerline and 90° from each other on the shaft, just below the handwheel. The two strain gages placed at such locations made it possible to detect torsional changes in the shaft, independent of temperature fluctuation. The strain gages were then calibrated with a 500-ft-lb (680-N•m) torque wrench. Torque data were recorded on a strip chart recorder, calibrated to 1-mm = 10-ft-lbs (13.6 N•m) of torque.

Two 500 lb/in² (3450 kPa) transducers were installed on the 6 inch (152 mm) pipe, one upstream (4 pipe diameters) and one downstream (11 pipe diameters) from the valve. Pressure readings from these transducers were also recorded on the strip chart. Pressure readings were calibrated using 1 mm = 5 lb/in² (34.5 kPa).

A method to detect the percentage of the valve stem travel was needed. As the valve was a nonrising stem type, a device was fabricated which converted the rotational movement of the handwheel to an electrical signal through the use of a LVDT (linear variable differential transformer). A number of turns on the handwheel produced a linear movement of the core of the LVDT, which was outputted to the recorder. (See figure 1) The calibration was such that 5-mm movement on the recorder represented 12.5 percent of the total shaft travel.
A seven-stage vertical turbine pump was used to supply the large differential pressures needed for the valve tests. The pump was driven by a 250-hp, (186 kW) variable speed, d-c motor. Flow rate was determined by an 8.0-by 4.5-in (203-by 114-mm) venturi meter installed 10 ft (3m) downstream from the pump outlet.

The American Darling valve was disassembled, inspected for damage, and photographed. The reassembled valve was then placed in the testing facility. The valve test procedure was divided into three stages.

The first series of tests provided data on the valve for full cycle operation (fully open to fully closed to fully open). Test procedure consisted of: (1) starting with the valve in the fully open position, (2) regulating flow to achieve the desired upstream pressure, (3) closing the valve to the fully closed position, and (4) reopening it. The above operating procedure was repeated for initial upstream pressure head settings of 50 to 577.5 ft (15 to 176 m) of head in 50-ft (15 m) increments. During the series, the torque, differential pressure across the valve and valve opening were recorded.

The second series of tests was conducted to identify a torque-pressure relationship for the initiation of valve wedge movement using different percentage openings of the valve. Valve settings ranged from 12.5 to 87.5 percent of travel in 12.5 percent increments. At each valve opening, recordings of torque, line pressures, and position were made as the pressure head was incremented in 50-ft (15 m) intervals over the 50- to 577.5-ft (15-to 176-m) range. To account for slack in the valve stem movement, the valve wheel was turned two full turns each side of the set opening to assure wedge motion. Again, torque, line pressure across the valve, and valve opening were recorded on the strip chart.

The third series of tests centered on defining the torque required to unseat the valve disks under different pressures. Prior to each test, the valve wedge was seated with 100 ft-lb (136 N-m) of torque. Data were recorded as torque was applied to the valve wheel to break the disk loose from the valve seat. The test was repeated for upstream pressure heads of 50 to 577.5 ft (15 to 176 m) of water in 50-ft (15-m) increments.

Upon completion of the above tests, the Mechanical Branch requested that we determine if there would be any benefit from cleaning the valve disks and seats. The valve was disassembled, cleaned, and reassembled and the three series of tests repeated (see test results).
To get a better feel of what the torque values are for other 6-in (152-mm) 250-lb valves as compared to the American Darling valve, it was decided to test a valve from a different manufacturer. We were able to locate and borrow a new Iowa valve from the Denver Water Board. The wedge design was slightly different than the American Darling. The American Darling has one large wedge, whereas, the Iowa has two smaller wedges. The Iowa valve was taken apart, photographed, and calibrated the same as the American Darling. It was installed, instrumented, and tested in the same manner as before. However, the Iowa valve testing program was abbreviated to save time. The valve was tested at the 12.5, 25, and 37.5 percent of travel along with the breaking of seat and seating torques, the same as for the American Darling. Data were taken and plotted for comparison with the American Darling valve data.

RESULTS

The American Darling test results show that the highest torque required to operate the valve occurs at the seating of the disks, or final closing. Torque required ranged from 185 to 193 ft-lb (252 to 263 N·m). Breaking loose from the seat required 133 to 144 ft-lb (181 to 196 N·m) of torque.

The results showed that the Iowa valve required less torque in seating and breaking of the seat than the American Darling. The general operation of the valve during normal opening and closing operation also proved to be easier.

The limited data in figure 2 indicate that a cleaned valve requires more torque at a differential pressure greater than 200 lb/in² (1379 kPa), and less for differential pressure less than 100 lb/in² (689 kPa). Essentially, the same torque is required for differential pressures between 100 lb/in² (689 kPa) and 200 lb/in² (1379 kPa).

Figure 3 is a comparison between the American Darling valve after cleaning and the Iowa valve of the torque required to seat the valve disks. The American Darling valve requires higher torque to seat the disks over the full range of differential pressures tested. The amount of torque required to seat the American Darling valve disks varied from about 2-1/2 times more at a 50-lb/in² (345 kPa) differential pressure to more than four times as much at a differential pressure of 240 lb/in² (1655 kPa).

Figure 4 shows that less torque was required to break the valve free of the seat after cleaning. The torque required was reduced from 25 to 15 ft-lb (34 to 20 N·m) at a differential pressure of 30 lb/in², and from 175 ft-lb to 160 ft-lb at a differential pressure of 250 lb/in².
Figure 5 shows the comparison between the American Darling valve after cleaning and the Iowa valve of the torque required to break the seat of the valve. For differential pressures less than 100 lb/in$^2$ (689 kPa), the Iowa valve required slightly greater torque to break the valve seat. For differential pressures greater than 110 lb/in$^2$ (758 kPa), the American Darling valve required greater torque. At a differential pressure of 240 lb/in$^2$ (1655 kPa), the American Darling valve required about 150 ft-lb (203 N·m) of torque to break the valve seat, while the Iowa valve required about 85 ft-lb (115 N·m) of torque.

Figure 6 shows the torque requirements for the American Darling valve before and after cleaning, with a valve setting of 12.5 percent, on the closing cycle. At 50 lb/in$^2$ (345 kPa) before cleaning, the torque required to move the disks is greater by 30 ft-lb (41 N·m). At 250 lb/in$^2$ (1724 kPa), the torque required is greater by 50 ft-lb (68 N·m).

Figure 7 shows the torque requirement for the American Darling valve before and after cleaning with a valve setting of 12.5 percent, on the opening cycle. Before cleaning, the torque required to move the disks at 60 lb/in$^2$ (414 kPa) is greater by 30 ft-lb (41 N·m), and at 240 lb/in$^2$ (1655 kPa), it is greater by 20 ft-lb (27 N·m).

Figure 8 compares the torque requirement between American Darling and Iowa valves, after cleaning, at a valve setting of 12.5 percent, on the closing cycle. The Iowa valve required about 10 ft-lb (13.6 N·m) less at 60 lb/in$^2$ (414 kPa) and about 35 ft-lb (47 N·m) less at 190 lb/in$^2$ (1310 kPa) to move the disks.

Figure 9 compares the torque requirement between American Darling and Iowa, after cleaning, at a valve setting of 12.5 percent, on the opening cycle. No conclusions could be made.

Figure 10 shows the torque requirement of America Darling valve before and after cleaning, with a valve setting of 25 percent, on the closing cycle. Before cleaning the torque required to move the disks at 20 lb/in$^2$ (138 kPa) is greater by about 20 ft-lb (27 N·m). At 115 lb/in$^2$ (793 kPa), the torque required is 35 ft-lb (47 N·m) greater.

Figure 11 shows the torque requirement of American Darling valve before and after cleaning, with a valve setting of 25 percent, on the opening cycle. No real conclusion could be made from these data.

Figure 12 compares the torque requirement between the American Darling and the Iowa valve, after cleaning, at a valve setting of 25 percent, on the closing cycle. No real comparison could be made.

Figure 13 compares the torque requirement between the American Darling and the Iowa valve, after cleaning, at a valve setting of 25 percent, on the opening cycle. No real comparison could be made.
The sizable amount of data scatter displayed on some of the figures cannot be precisely evaluated. The data do show trends and should be considered from that standpoint.

D. L. King

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Figure 1. Photograph of the American Darling valve installed and instrumented for testing.
Figures 2 thru 13
English to SI Conversion

P.S.I. x 6.894 = kPa
Ft. Lbs. x 1.36 = N\cdot m
AMERICAN DARLING
250 - Pound 6 inch Gate Valve
Torque Requirement to seat valve

\[ Y = 0.578 \times + 77.304 \quad \text{BEFORE CLEANING} \]
\[ Y = 1.100 \times + 2.303 \quad \text{AFTER CLEANING} \]
250 - Pound 6 inch Gate Valve
Torque Requirement to seat valve

\[ y = 1.137 \times -2.00 \quad \text{AMERICAN DALLAS} \]
\[ y = 0.252 \times +0.331 \quad \text{IOWA VALVE} \]

Differential Pressure Across Valve
PSI

Figure 3
AMERICAN DARLING
250 - Pound 6 inch Gate Valve
Torque Requirement to break seat of valve

\[ Y = 0.702 \times X + 2.873 \quad \text{BEFORE CLEANING} \quad \triangle \]

\[ Y = 0.651 \times X - 6.186 \quad \text{AFTER CLEANING} \quad \bigcirc \]

Figure 4
250 - Pound 6 inch Gate Valve
Torque Requirement to break seat of valve

\[ Y = 2.851 \times X + 0.128 \] AMERICAN DARLING
\[ Y = 0.168 \times X + 44.804 \] IOWA VALVE

Differential Pressure Across Valve
PSI

Figure 5
250 - Pound 6 inch Gate Valve
Torque Requirement - 12.500 % Open (Closing Cycle)
12.500

\[ Y = 0.593 \times 12.522 \text{ BEFORE CLEANING } \triangle \]

\[ Y = 0.494 \times -10.596 \text{ AFTER CLEANING } \circ \]

Differential Pressure Across Valve

**Figure 6**
AMERICAN DARLING
250 - Pound 6 inch Gate Valve
Torque Requirement - 12.500 % Open (Opening Cycle)

\[ Y = 0.326 \times X + 32.179 \quad \text{BEFORE CLEANING} \]
\[ Y = 0.376 \times X - 2.562 \quad \text{AFTER CLEANING} \]

Figure 7
250 - Pound 6 inch Gate Valve
Torque Requirement - 12.573 % Open (Closing Cycle)
12.500

\[ Y = 0.494 \, x + 12.536 \quad \text{AMERICAN DARLING} \quad \bigcirc \]
\[ Y = 0.270 \, x + 2.169 \quad \text{IOWA VALVE} \quad \triangle \]

Differential Pressure Across Valve
PSI

Figure 8
250 - Pound 6 inch Gate Valve
Torque Requirement - 92.17% Open (Opening Cycle)

\[ Y = 0.002 \times X - 6.589 \] AMERICAN DARLING \( \circ \)

\[ Y = 0.229 \times X + 16.826 \] IOWA VALVE \( \triangle \)

Figure 9
AMERICAN DARLING
250 - Pound 6 inch Gate Valve
Torque Requirement - 25.000 % Open (Closing Cycle)

Y = 0.466 X + 5.508 BEFORE CLEANING △
Y = 0.314 X + 1.229 AFTER CLEANING ○

Figure 10
AMERICAN DARLING
250 - Pound 6 inch Gate Valve
Torque Requirement - 25,000 % Open (Opening Cycle)
25,000

\[ Y = 0.459 \times X + 7.250 \] \text{BEFORE CLEANING} \triangle

\[ Y = 0.443 \times X + 0.247 \] \text{AFTER CLEANING} \bigcirc

Figure 11
250 - Pound 6 inch Gate Valve
Torque Requirement - 25.71% Open (Closing Cycle)

\[ Y = 0.314 \times -1.223 \quad \text{AMERICAN RISING} \bigcirc \]
\[ Y = 0.134 \times +5.627 \quad \text{IOWA VALVE} \bigtriangleup \]
250 = Pound 6 inch Gate Valve

Torque Requirement - 21.00% Open (Opening Cycle)

25,000

Y = 2.443 X + 2.247  AMERICAN DIALING

Y = 0.365 X + 4.038  IOWA VALVE

Figure 13