How Ex-Situ Tests Can Help Address Class D Motor Operated Valve (MOV) Periodic Verification (PV)

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This white paper culminates in a case study showing how laboratory testing was used to address challenging differential pressure (DP) test requirements for a Class D Motor Operated Valve (MOV) from a nuclear power plant. The Introduction and JOG PV Program Summary below provide background information on the classification of MOV's and the need for DP testing.

1.0 INTRODUCTION

In response to performance concerns with MOV's in nuclear power plants, the U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance," in June 1989. This NRC GL recommended that nuclear power plant licensees verify the design-basis capability of their safety-related MOVs through dynamic testing where practicable. In September 1996, the NRC issued GL 96-05, recommending that nuclear power plant licensees assure the long-term design basis capability of safety-related MOVs. Specifically, this NRC GL requested that licensees establish a program, or ensure the effectiveness of their current program, to verify periodically that safety-related MOVs continue to be capable of performing their safety functions within the current licensing basis of the facility. In response, the four US nuclear power plant owners' groups[1] developed a Joint Owner's Group (JOG) to share information between licensees on MOV performance and to define/develop an industry-wide MOV Periodic Verification (PV) Approach. The JOG PV Program Description Report, MPR-1807 "Motor-Operated Valve Periodic Verification," was submitted to the NRC for review and approval in

[1] In 1996, the four US nuclear power plant owners' groups included the Boiling Water Reactor Owners' Group (BWROG), B&W Owners' Group (B&WOG), Westinghouse Owners' Group (WOG), and Combustion Engineering Owners' Group (CEOG).

1997. The NRC issued a Safety Evaluation later that year, approving the JOG PV Program with several conditions.

2.0 JOG PV Program Summary

The JOG Dynamic Test Program was developed to evaluate potential degradation in required thrust or torque for safety-related gate, butterfly, and globe valves.[2] The Program included repeated in-situ testing (static and dynamic) of 176 MOVs over a five year period. All testing was performed in accordance with the JOG Differential Pressure Test Specification to ensure consistency of testing and analysis. The specification included protocol for the following:

- Valve maintenance and material condition
- System conditions
- Instrumentation
- Sequence
- Data evaluation
- Documentation

Most importantly, the test protocol required recording of time-history data for stem thrust/torque, upstream pressure, and differential pressure in a prescribed manner.

JOG Long-Term MOV Periodic Verification Recommendations were developed based on the results of this JOG Test Program, with consideration of other industry data, such as test data from the Electric Power Research Institute (EPRI) MOV Performance Prediction Program. The JOG PV Methodology provides guidance for each valve type (gate, butterfly, and globe). In accordance with the JOG PV Methodology, licensees classify each safety-related MOV as JOG Class A, B, C or D according to (1) specific MOV design characteristics (features, materials, etc.), (2) particular system characteristics (fluid type, temperature, etc.), and (3) the current basis for the valve's required thrust/torque. Based on this classification, the JOG PV Methodology establishes static diagnostic testing intervals, considering risk and margin. Brief descriptions of each of the JOG Classes are as follows:

- Class A: valves determined to not be susceptible to degradation under their operating conditions, based directly on testing performed in the JOG program or by other acceptable programs, such as the EPRI MOV Performance Prediction Methodology (PPM). Only periodic static testing is required.
- Class B: valves determined to not be susceptible to degradation under their operating conditions, based on testing performed in the JOG program extended by analysis and engineering judgment to configurations and conditions beyond those tested. Only periodic static testing is required.

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[2] The JOG PV Program does not address actuator degradation. Degradation in actuator output thrust or torque is addressed separately by the individual licensees.

- Class C: valves determined to be susceptible to changes in the required thrust or torque, based on test results from the JOG program. Periodic differential pressure (DP) testing, design modification, and/or modification to the valve setup may be required.
- Class D: valves determined to be beyond the scope of the JOG program. Individual licensees are responsible for justifying the periodic verification approach for these MOV's.

Classified valves in service maintain their classification provided that there are no disallowing modifications and/or adverse change in the valve service condition. Disallowing modifications and/or adverse change in valve service conditions would require the valve to re-enter the JOG classification process, which would include re-establishing the design basis for the valve's required thrust and torque.

For Class D valves, the JOG states that individual licensees are responsible for justifying the periodic verification approach for MOV's within the scope of GL 96-05. Nonetheless, the JOG provides some recommendation for addressing Class D valves. In particular, the following recommendations are provided:

1) Perform in situ DP tests and evaluate the results for degradation
2) Perform laboratory-type testing of the valves or sub-components to specifically address the degradation mechanism that was not covered by the JOG program (e.g., potential galling of self-mated 300 series stainless steel surfaces at temperatures above 120 ^{o}F)
3) Obtain information from other industry sources that provide insight on the conditions that were not covered by the JOG program

Any information learned during these efforts is to be incorporated into the plant-specific MOV Periodic Verification Program. Individual plants have already developed or are in the process of developing plans to address their Class D valves. Plans may include:

1) Replacing a Class D valve with a Class A valve
2) Modifying the Class D valve such that it can be re-categorized to Class A
3) Performing plant specific DP testing

Options 1 and 2 can be quite expensive. Option 3 will be less expensive, but does not necessarily eliminate the need for modifications.

Further details on the background of the JOG program, NRC responses, Safety Evaluations, and Technical Reports can be found in the JOG MOV Periodic Verification Summary[i]

3.0 DP Testing of Class D MOVs

As discussed above, one of the recommendations provided by JOG for addressing Class D valves is DP testing. As in the JOG PV Program, the purpose of this DP testing is to develop a basis for addressing the potential degradations (increases) in required thrust or torque under differential pressure (DP) conditions. The JOG PV Program developed a protocol[ii] for DP testing MOVs to ensure the conducted tests fulfilled this purpose. The protocol defines minimum requirements for the DP testing with regard to system lineup, test measurements, and the DP load across a valve during testing.

While it is certainly preferable to perform this DP testing in-situ, a plant may find it difficult or impractical to align a specific system in such a way to meet these minimum DP test requirements for certain MOVs (even during an outage). In that case, careful planning must be undertaken to remove the valve during an outage and have it taken to a facility that can supply the flows and system characteristics required for testing. An alternative is to test a spare valve if available as a rotational spare. Advantages of lab testing may include the use of customized and/or additional monitoring ports and higher accuracy instrumentation. The laboratory environment can also provide improved control of ambient conditions and arbitrary cycle timing and testing configuration, which can be limited in a plant environment. If necessary, replication of accident conditions is also possible, as well as the inclusion of plant-specific fluid contaminants (such as sediment) that may be relevant to long-time valve performance.

3.0 Case Study: Salem's Service Water Valve

Salem/Hope Creek nuclear power stations have several safety-related butterfly valves that are classified as "D" because their bearing/shaft material combination was not covered by the JOG PV Program. These MOVs are Weir tricentric valves with a Nitronic 60 bearing and Inconel stem. This material combination is uniquely suited to this application of brackish water in a high torque (high bearing stress) application. Other materials have proven not to last due to MIC attack or erosion from the silt. To develop a basis for a periodic verification program for these valves, Salem initially performed in-situ DP testing. However, due to limitations regarding the system alignment and test measurements, the results of this testing were inconclusive. Operations procedures prevented Salem from obtaining an open stroke under full differential pressure due to the concern for water hammer impacts to the system. Accordingly, Salem determined that ex-situ DP testing of this valve design was required.

In addition to addressing potential degradation of the Coefficient of Friction (COF) for the specified shaft/bearing material combination due to repeated DP stroking, Salem personnel identified a second potential degradation mechanism to be evaluated during the ex-situ DP testing. Specifically, the subject valves (located in the service water system) operate in a water environment with a considerable amount of silt. Salem personnel were concerned that silt build-up in the bearings may affect the bearing/shaft COF over time (and thus, increase required torque). Per consultation with the valve manufacturer, installation of Bal-Seals at the bearings could stop silt intrusion into the bearing area. Accordingly, the ex-situ DP testing would need to evaluate the effects of repeated DP stroking, intrusion of silt into the bearing area, and the performance of the Bal-Seals. To facilitate this condition, 15,000 gallons of the river water from the plant was transported to the test facility and used as the test medium during the ex-situ DP testing.

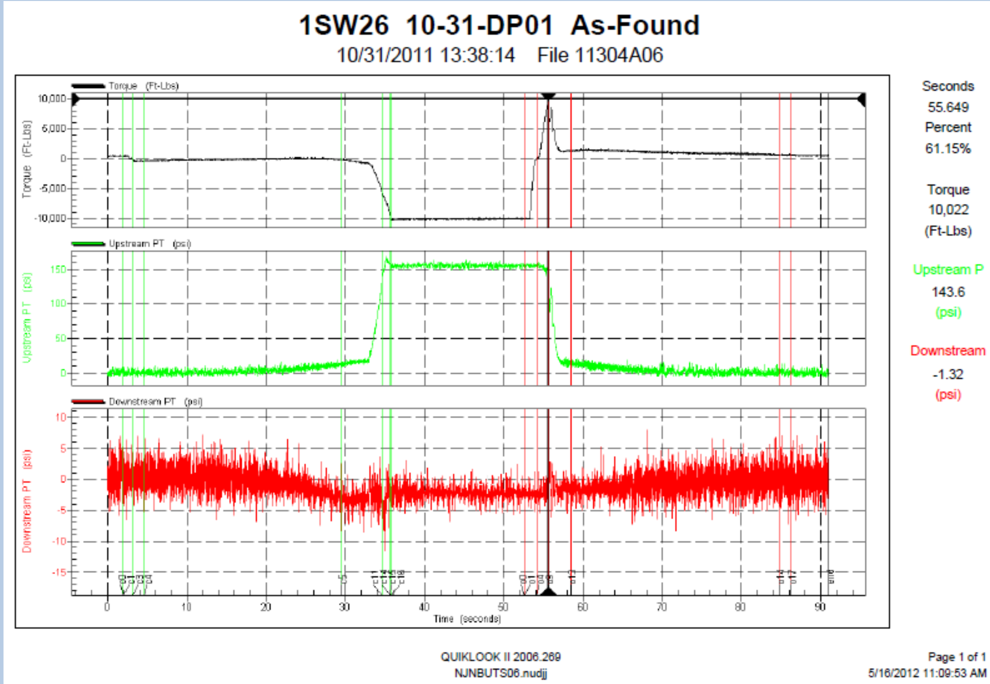
The ex-situ testing had to be performed rapidly during an outage when one valve could be taken out of the line. Ultimately, Salem had one week to ship the valve to a test facility, perform all DP testing, and ship the valve back to Salem to get the valve re-installed prior to plant start-up. Alden quickly constructed a flow loop to test the valve at maximum laboratory-achievable flow and shut-off head: 10,000 gpm and 160 psi, respectively, which satisfied the JOG Test Protocol DP loading requirements. In addition, the flow loop was instrumented in accordance with the JOG Test Protocol instrumentation requirements. More than 60 DP tests were performed over a 5 day period to provide a large set of data points. Overall, the testing included the following steps:

1) As-found test was performed on a valve installed for 6 years in a service water application - The torque coefficient was measured for opening and closing against pressure. Repeated DP testing was conducted over several days, at several DP loads on the disk and with varying dwell time in between tests. (Dwell time allowed the silt to settle out of the flow stream into the bearing areas.)
2) Disassembly of the valve with inspection of the bearings and shaft.
3) Installation of Bal-Seals and new bearings.
4) Re-mounting of the valve in the test loop and repeated DP testing, as described above to obtain a new bearing baseline COF.

Results from repeated DP testing of the as-found valve showed that the bearing COF (a) varied within a small band between tests, (b) in general was greater than that specified by the vendor, but (c) did not show a trend of further degradation. Upon disassembly, the as-found valve showed significant build-up of silt in the bearing/shaft contact region. However, inspection of the cleaned shaft and bearings showed little to no damage to the contact surfaces due to this silt build-up. Upon reassembly with new bearings and the Bal-Seals, DP testing showed a much lower bearing COF than the as-found condition. In addition, the testing showed little variance in the COF between tests and no indication of degradation due to repeated DP testing. Furthermore, inspection of the lower bearing endcap after repeated DP tests showed little flow of sediment through the bearing area (i.e., initial inspections appeared to show that the Bal-Seal significantly reduced the amount of silt getting into the bearing region). Traces of upstream pressure, downstream pressure, and torque are shown in Figure 1 before (a) and after (b) the installation of the bal-seals. The opening (positive) torque was significantly lower (6,500 ft-lbs vs. 10,000 ft-lbs) after this installation.

As a result of this ex-situ DP testing, Salem personnel are developing preliminary bounding COF values for their Weir tricentric butterfly valves with and without Bal-Seals. To validate these COF values, Salem is scheduling an additional ex-situ verification DP test to be conducted at Alden in the Fall of 2012.

a)



b)

Figure 1: Traces of torque, upstream pressure and downstream pressure (a) before the installation of Bal-Seals and (b) after the installation of Bal-Seals.

4.0 Summary

DP testing provides a method to ensure the long-term capability of safety-related MOVs. Through the JOG PV Program, the US Nuclear Industry used DP testing to develop long-term periodic verification programs for most safety-related MOV designs and applications. A limited number of MOV designs/applications or new valve installations may be beyond the JOG PV guidance, however. For these MOVs, nuclear plants must develop their own periodic verification basis and validate a bounding bearing COF or valve factor. Although in-situ DP testing of these valves is the preferred approach, plant operations do not always allow for the required test conditions and/or the necessary testing time. In these cases, qualified testing laboratories can provide customized testing to be performed at any time including during a scheduled refueling outage.

Salem's tricentric butterfly valve in the Alden test loop

While the deadline for full implementation of the JOG PV Methodology (including addressing Class D valves) is rapidly approaching in September 2012, other valve testing requirements are on the horizon, such as those potentially imposed by adoption of ASME Mandatory Appendix III. Ex-situ testing provides nuclear plants an option that, with proper planning and execution, can be flexible, comprehensive, and less resource-intensive than in-situ testing.

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Ludwig Haber is a Principal Engineer at Alden specializing in fluid dynamics (experimental and computational), and turbomachinery performance. In particular, Dr. Haber has been involved in numerous studies and analyses supporting testing of safety related equipment, including experimental efforts supporting nuclear power plants in diagnosing and optimizing process flow systems such as: raw water debris management, component cavitation and flow capacity, as well as emergency equipment operability. Before coming to Alden, he worked at General Electric. He has B.S., M.S., and Ph.D. degrees from Virginia Tech.

Jeffrey Gratz has Bachelor of Science and Master in Engineering degrees from Rensselaer Polytechnic Institute. Since joining MPR in 1999, he has been involved in various projects for the fossil and nuclear power industries and the US Navy with emphasis in valve/actuator analyses and diagnostics, software design and development, process design, and emission controls. He serves as the Program Manager and Lead Engineer for maintenance of the EPRI MOV Performance Prediction Methodology (PPM), which defines analysis methods for evaluation of valve operability that the USNRC considers acceptable, in lieu of design basis testing. Mr. Gratz has performed evaluations of MOVs regarding valve operability, including the determination of required thrust/torque, weak-link analysis, motor/actuator capability, stroke time analysis, etc.

[i] *Joint Owner's Group (JOG) Motor Operated Valve Periodic Verification Program Summary,* MPR-2524-A, Rev. 1

[ii] *Specification for Joint Owner's Group Periodic Verification Dynamic Testing*, MPR Specification 197-002-1, Revision 1