Design Basis Testing and Alternative Methodologies

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Abstract

U. S. NRC Generic Letter (GL) 89-10, ***Safety-Related Motor-Operated Valve Testing and Surveillance,*** recommends that licensees perform a series of actions necessary to ensure the operational readiness of certain motor-operated valves installed in nuclear plant safety-related systems. Action Item b of GL 89-10 recommends that licensees develop a program to establish the correct MOV switch settings to ensure high reliability of safety-related MOVs and Action Item c recommends that the correct switch settings be implemented through field testing. Action Item c also recommends that the MOV be tested at or near design basis differential pressure in order to demonstrate the adequacy of existing or revised switch settings.

In the discussion following action Item c, the U.S. NRC also recognizes that testing at or near design basis differential pressure may not be practical for some valves. The difficulties associated with testing MOVs installed in nuclear plant safety-related systems was debated extensively during the U. S. NRC public workshops on GL 89-10. As a consequence, individual licensees and industry groups have developed a number of alternative approaches that may be used to demonstrate MOV capability consistent with Action Item c without actually performing insitu dynamic testing.

Acceptable alternatives to insitu full flow dynamic testing include the following:

1. Reduced flow testing,
2. grouping of valves and testing a representative sample of the group,
3. use of prototype data on specific valves obtained in a flow loop,
4. use of the EPRI PPM,
5. use of vendor supplied methods that have been validated and
6. full-flow design qualification testing (new valves only)

Licensees have used each of the alternatives listed above to demonstrate the design basis capability of MOVs consistent with Action Item c of GL 89-10. This presentation will review the conditions, limitations and issues associated with each approach listed above and describe how these methods may be used for MOVs in KEPCO plants.

Background

During the public workshops on GL 89-10, NRC management and staff reviewed the MOV issue and discussed a wide range of activities being performed by the NRC, various nuclear industry groups (such as NUMARC now NEI, INPO, EPRI and others) and standards committees (such as ASME and IEEE) to facilitate MOV performance improvement. In addition to known weaknesses in the methods used by the industry to implement correct limit and bypass switch settings, the NRC highlighted research results that indicated a larger generic issue with methods used to establish thrust requirements for rising stem gate valves. As part of the resolution of Generic Issue 87, ***Failure of HPCI Steam Line Without Isolation***, researchers at the Idaho National Engineering and Environmental Laboratory (INEEL) performed full flow isolation tests to evaluate the ability of certain motor-operated gate valves to close under blowdown conditions. The results of these tests supported the contention that the generic model for calculating valve thrust requirements for gate valves may not always be conservative.

In addition to the findings relating to thrust calculations, the INEEL researchers and participating test equipment suppliers discovered that MOV output capability changed between static and dynamic test conditions. The phenomena termed "load sensitive behavior" or "rate-of-loading" is the difference in the output thrust of an MOV between static and dynamic conditions (usually lower under dynamic conditions).

Based on the INEEL research and other individual plant events the NRC suggested in GL 89-10 that MOVs be tested at or near design basis differential pressure for the purpose of demonstrating operability. The NRC suggested this approach because a validated method of calculating thrust requirements was not available, and it was not clear how all of the various phenomena affecting MOV performance could be addressed through a static testing program.

A complete picture of the NRC staff position on dynamic testing in the early 90's is captured in the responses to questions 22-32 of GL 89-10 Supplement 1. Here the NRC recognizes that it may not be practical to test all MOVs at or near design basis conditions because of operational limitations or safety issues. The NRC also points out that with the proper justification test results from other valves in the plant could be used as a basis for establishing the correct switch settings for certain MOVs. The NRC also recognized that reduced flow/DP testing could be used with the proper justification, that prototype data from off-site facilities could also be used and suggested a larger industry-wide collaborative effort to develop and validate thrust calculational methods.

Establishing the Correct Switch Settings (GL 89-10 action item b)

MOV limit and bypass switches are set based on stem travel, light indications and desired bypass coverage. Limit switches are geared to the motor and change position after a certain number of motor revolutions. These switches control valve position only and should not be used for torque-controlled seating.

MOV output is typically controlled by a torque switch in the close direction. The torque switch lever arm is geared to the worm shaft or springpack assembly within the actuator. Torque switches are set to open at a predetermined springpack displacement. The proper torque switch setting is determined by a thrust or torque calculation or both and torque switches are typically set under static test conditions. The test objective is to establish the torque switch setting that produces adequate thrust to overcome the expected loads due to differential pressure and flow.

Calculations are generally used to determine the desired torque switch setting. The typical calculational process combines forces from the packing load around the stem, forces from the line pressure, which tends to expel the stem from the valve body and forces from the differential pressure acting on the valve disk. The force from the differential pressure acting on the valve disk tends to be the most difficult to predict and is the parameter of interest during full flow testing.

The differential pressure force is the product of upstream pressure minus downstream pressure (differential pressure) multiplied by seat area and a representative valve factor. Valve factor is typically used as a disk friction term but may be comprised of components other than pure sliding friction.

Once the desired thrust or torque is calculated, a process must be used to account for actuator repeatability, rate-of-loading, test equipment uncertainty, expected degradation over time and other factors. These adjustments usually require the thrust calculation result to be adjusted upward. The field test engineer uses the adjusted thrust to set torque switches.

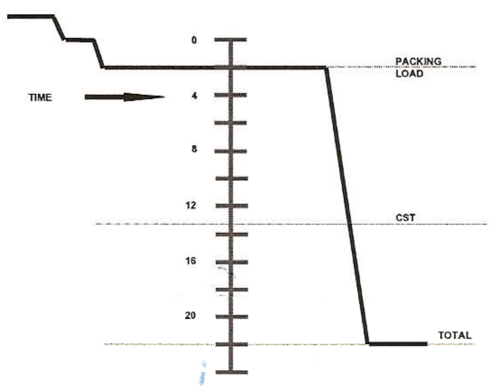

Figure 1

During field testing, the test engineer measures the thrust available at torque switch trip as depicted in Figure 1 above. The thrust at torque switch trip must meet or exceed the adjusted required thrust value. The motor torque at torque switch trip must be less than the reduced voltage capability of the actuator motor and the total thrust and torque must be less than structural weak links.

Under dynamic conditions the load profile will change to reflect the gradual thrust buildup that results from the increasing differential pressure force on the valve disk. Figure 2 identifies the normally expected change in the load profile due to differential pressure. The MOV torque switch is set correctly when the torque switch setting is higher than the region of the dynamic thrust signature that indicates hard seat contact. It is important to note that in many cases the thrust at torque switch trip maybe lower under dynamic conditions due to the rate-of-loading effect.

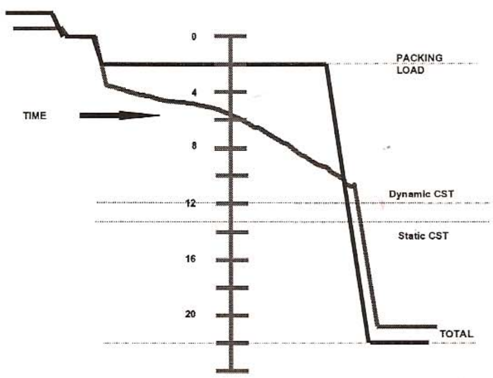

Figure 2

The example above is for an MOV that can be tested under maximum expected flow and pressure. The margin in the example above would be the difference between the maximum DP effect and dynamic CST value. However, this margin must be adjusted to allow for test equipment uncertainty, actuator repeatability, expected degradation and other factors.

Because of operational or safety issues, it may not be possible to test certain MOVs under full flow conditions. During development and implementation of GL 89-10 programs nuclear plants in the U.S. used all of the NRC suggestions contained in Supplement 1 and discussed above. Various methods used to demonstrate the adequacy of thrust calculational methods are discussed in the following paragraphs:

Reduced Flow Testing

For those valves that cannot be tested at design basis conditions, consideration is often given to performing a reduced flow test. Because the flow rate and resulting load rate can cause changes in the load profile, reduced flow testing should be performed as close to the maximum expected flow as possible.

In the Motor-Operated Valve Users Group (MUG) document titled, *GUIDANCE ON THE DEVELOPMENT OF STATIC AND DYNAMIC TEST ACCEPTANCE CRITERIA FOR MOVs,* reduced flow and pressure testing is recommended provided certain conditions are met. The licensee should first attempt to achieve at least 80% of maximum expected flow and pressure. If 80% or greater is achieved then the results can be extrapolated to 100% by solving for valve factor using the standard equation and recalculating thrust using the new valve factor and maximum expected pressures. The analysis method should also evaluate expected piston load and packing load and make corrections as applicable.

For cases where 80% of the maximum expected flow and pressure cannot be achieved, the MUG guidance recommends that three test pressures be used that are at least 10% apart. The test data can be extrapolated to the maximum expected condition by solving for valve factor or plotting a straight line through the results.

Group Testing

Similar or identical valves may be grouped together and a representative sample tested under maximum expected conditions and the results applied to the remaining population of the group under certain conditions. There is no absolute criterion on how many samples are required for each group. The NRC recommended in GL 89-10 supplement 1 that 30% would be an acceptable population. Licensees in the U.S. were inconsistent in selection of minimum sample sizes. Since identical valves can behave differently, at least 3 samples from each group should be used as an absolute minimum.

The results from each test in the group should be analyzed for the purpose of extracting valve factor and any other load that varies with flow and pressure. The data should be analyzed using statistical processes and the results applied to the remaining population. A grouping strategy can be the most economical approach for large groups of identical MOVs.

Use of Prototype Flow Loop Data

Because of safety and economic consequences it is not possible to test certain MOVs under differential pressure and flow conditions in an operating nuclear power plant. Recognizing this issue, the NRC suggested in 89-10 Supplement 1, that prototype data obtained in off site facilities might be used to validate thrust calculations. Strategies of grouping identical valves so that the results of DP tests could be used to validate calculations for use on other identical valves were also suggested by the NRC. In response, the U. S. nuclear industry developed several alternative methodologies to adequately validate thrust calculations without DP testing all MOVs.

As a consequence, another alternative that has been used from time-to-time is flowloop testing of identical valves. Identical valves, either acquired from the OEM or from the plant's inventory of spare parts are suitable for prototype testing. Because the plant valves may have been subjected to conditions that effect valve factor, a series of tests are required in order to assess the effect of wear or age on valve factor performance. It is also desirable to test several prototype valves before establishing final design values to apply to a larger population.

EPRI PPM

The EPRI Performance Prediction Methodology (PPM) is one alternative method used to calculate MOV thrust requirements. The EPRI PPM is an advanced valve factor method that has been validated by a combination of prototype laboratory data and field data. The PPM requires detailed information on valve internal conditions. This detailed information can be obtained from the OEM or the valve can be disassembled and direct measurements used to obtain the required information. Internal dimensional measurements are not easily performed on valves 6 inches and less.

Some valves require modification in order to conform to PPM dimensional requirements. As a consequence PPM cannot be used on all valves. Maintenance records should be assessed prior to purchasing OEM dimensional information. Valve maintenance activities will change many dimensions and will void the calculated required thrust using this information.

Because PPM is supported by laboratory and field data it is not necessary to perform additional DP testing if PPM is used. PPM results are also expected to bound any valve factor degradation over time.

OEM Validated Methods

As part of their design and qualification process some valve manufacturers have developed and validated thrust or torque models for certain valves. These valve manufacturer and valve design specific models can be used to establish switch settings without additional full flow testing.

Because of changes in actuator performance due to dynamic conditions, licensees must develop additional methods to address factors not covered by the OEM calculations. For example the OEM may not have used a representative MOV during their validation testing and adjustments are needed to address stem factor performance, rate-of-loading, and other actuator specific uncertainties.

Full-flow design qualification testing (new valves only)

In plant dynamic testing, prototype testing, EPRI PPM and most other methods used to fully validate MOV set-up requirements add significant cost to the MOV program. As a consequence, new valve purchases often require the valve OEM to provide design qualification data for new valves prior to delivery.

Many valve OEMs now have full flow test facilities that are available for design qualification testing. A number of engineering companies in the U.S. also have flowloops that are often contracted by valve OEMs to facilitate this testing.

Conclusions

GL 89-10 requested that U. S. nuclear plants complete 89-10 programs by mid 1994. The EPRI PPM was not available until late 1994. As a consequence U. S. plants developed a range of methods necessary to validate MOV thrust calculations. Full flow testing, reduced flow testing, grouping and prototype testing were used extensively to satisfy 89-10 requirements.

Thrust calculations that are developed for individual valve types and implemented in the field by testing must be supported by validation data. The typical process required that a representative sample of the MOVs be setup using the results of a thrust calculation. The representative sample is then DP tested. The DP tests either confirmed that the calculation is conservative or the calculational method is adjusted and the MOVs retested. Though there are no strict guidelines on what percentage of a group should be DP tested, test results from 3 or more identical valves is generally sufficient to demonstrate a thrust calculation method produces conservative results.

These alternatives can significantly reduce the burden of full flow testing and at the same time increase confidence in MOV capability.