DESIGN BASIS VERIFICATION AND PRESERVICE TESTING CONSIDERATIONS FOR OM CODE MANDATORY APPENDIX III

Neal E. Estep, PE
Kalsi Engineering, Inc.
745 Park Two Drive
Sugar Land, TX, USA 77478

ABSTRACT

ASME OM Code Mandatory Appendix III (Appendix III) [1] for inservice testing of motor-operated valves (MOVs) contains prerequisites for a design basis verification test (DBVT) and preservice test prior to initiating inservice testing. The DBVT has specific requirements that depend on valve type and operational experience and the preservice test must adequately bridge the DBVT and inservice test. In addition, certain replacement, repair, or maintenance activities require an evaluation to determine what aspects (if any) of the DBVT or preservice test require repeat testing and/or engineering analysis to either confirm existing reference values or establish new reference values. Finally, existing testing performed under legacy NRC Generic Letter (GL) 89-10/96-05 MOV Programs or ASME QME-1 functional qualification standard may be credited to satisfy all or a portion of the DBVT and preservice test.

The purpose of this paper is to describe, by valve type:

- the specific requirements for the DBVT and preservice test,
- the use of previous qualification testing (e.g. GL 89-10/96-05 and ASME QME-1) to satisfy the DBVT and preservice test requirements,
- what activities may require analysis and/or repeating portions of the DBVT and preservice testing, and
- applicability to legacy MOV programs.

INTRODUCTION

Appendix III specifies the requirements for DBVT, preservice testing, inservice testing, and exercise testing for MOVs. Under paragraph III-3100, it states that the requirements for a DBVT are specified in applicable regulatory documents. A review of MOV testing history shows that the following regulatory documents have identified various aspects of the DBVT:

1. Generic Letter 89-10 [2], and supplements for safety-related MOV testing and surveillance
2. Generic Letter 95-07 [3] for pressure locking and thermal binding
5. NRC Information Notice 2012-14 [6] for acceptable design basis verification test methods

Fundamental elements of the regulatory guidance are:

1. Comprehensively review and document the design basis requirements that have an effect on actuator output capability or the valve required thrust or torque. These include system, environmental, and operational/age-related items
that affect the valve required thrust or torque and actuator output capability.

2. Perform flow and differential pressure (DP) testing or use test-based methods to validate the valve required thrust or torque under the most limiting design basis conditions.

3. Perform flow and DP testing or use test-based methods to determine the dynamic stem thread coefficient of friction for rising stem valves.

4. Use industry accepted methods to determine the actuator output capability and stroke time under the most limiting design basis conditions for actuators with AC and DC motors.

5. Develop open and close stroke direction switch setting methods and test acceptance criteria for each MOV to provide functional margin and adequately account for degradation over the diagnostic test interval.

6. Use diagnostic testing to implement and verify the switch settings and satisfaction of test acceptance criteria. Test parameters must be sufficient to verify functional margin and functional margin degradation.

7. Perform evaluation of the test data to verify set-up criteria assumptions, establish trends, determine functional margin, identify performance related degradation, and perform a qualitative review of the data.

8. Configuration management and change controls to ensure the correct switch settings are determined and maintained throughout the life of the plant.

9. Assessment of MOV failures and maintenance activities.

The following sections in this paper describe the relationship of the DBVT, preservice test, and inservice test from a system perspective. Use of a system perspective helps define the interactions between the various tests, impact of repair/replacement/maintenance, test data analysis, and test data evaluation.

**NOMENCLATURE**

None

**TEST INPUTS AND OUTPUTS**

The following sections defines the significant inputs and outputs for the DBVT, preservice, and inservice tests. An understanding of the inputs and outputs identifies the relationship between tests and the specific changes that can affect each of these tests.

**DESIGN BASIS VERIFICATION TEST (DBVT)**

Inputs to the DBVT include the following items:

1. System, Environmental, and Operational (i.e. design basis) requirements and conditions: Operating scenarios, open/close safety function requirements, limiting stroke time, seat leakage, seismic loading, available voltage, environmental temperature, equipment qualification requirements, line pressure, DP, flow rate, fluid conditions, upstream and downstream flow resistances (including requirements for line-break isolation), in-service operating conditions, upstream flow disturbances within 8 pipe diameters for quarter-turn valves.

2. Actuator characteristics: Manufacturer, model, motor data (speed start torque, voltage, current draw, heat-up rate, temperature effects on torque/speed), gear ratio, torque switch spring pack, hand-wheel ratio, gear efficiencies, lubricant, available limit switches, environmental qualification conditions and requirements.

3. Valve characteristics: Manufacturer, type, sealing and sliding contact surface materials, trim characteristics, critical dimensions for calculation inputs, disk and stem orientation effects, upstream flow disturbance effects.

4. Actuator to valve interface (rising stem only) characteristics: Stem thread lubricant, thread geometry, thread friction, rate-of-loading, stem thread friction degradation.

**DBVT outputs include:**

1. Limiting system, environmental, and operational (i.e. design basis) conditions, such as maximum upstream pressure, maximum DP, maximum environmental temperature, minimum supply voltage, limiting stroke time, safety-related stroke directions, in-service operating conditions used to establish classification and degradation allowances under the Joint Owners’ Group (JOG) MOV Periodic Verification (PV) program [8].

2. Valve required thrust or torque for the most limiting open and close stroke operating scenarios, including mitigation or calculation methods to address thermal binding and pressure locking for certain gate valves. Allowance for age and service-related degradation that could increase the valve required thrust or torque. Limiting values for running load, unseating and/or seating loads, disk and stem orientation, and proximity of upstream flow disturbances.

3. Actuator output capability and switch setting configuration for the most limiting open and close stroke operating scenarios. Output capability is typically determined using industry-accepted practices such as the Limitorque or ComEd method for AC motors and the DC Motor Method (DCMM) for DC motors. Limiting values for control switch repeatability, spring pack degradation, motor terminal voltage, and structural strength.

4. For rising stem valves, the limiting static and dynamic thread friction coefficient and allowances for rate-of-
loading and thread friction degradation. Criteria may also be provided for the required stem lubricant and maximum allowed stem nut thread wear.

5. Preservice and in service test acceptance criteria based on the valve required thrust or torque and actuator output capability, including assumptions for uncertainties (measurement and other), and required system conditions during the test (static or DP test).

Determination of valve operating requirements is specified in III-3100 and III-6410. These paragraphs specify the following methods to determine or verify the valve required thrust and/or torque for DBVT purposes:

1. Measurements from dynamic (flow and DP) testing in situ or in a flow loop, along with justification for testing at conditions other than design basis conditions.
2. Justified (or validated) analytical techniques or methods using valve parameters that allow extrapolation to the design basis conditions.
3. Grouping with an engineering evaluation, alternative testing technique, or both, to justify the grouping approach.
4. Engineering evaluation of operating experience for valve types (i.e. ball, plug, and diaphragm valves) where the need for DBVT has not been previously identified.

With the exception of Item 4, these methods are consistent with those previously identified in applicable regulatory documents, such as GL 89-10 (and supplements), IN 2012-14 and RG 1.100 (which references ASME QME-1 qualification testing). IN 2012-14 states that the most preferred methods are in situ testing at or near design basis conditions and validated analytical techniques, such as the EPRI MOV Performance Prediction Method (PPM). The least preferred method is using grouping data from other plants or research programs since such data is typically obtained without 10 CFR 21 reporting requirements (i.e. obtained as non-QA).

Key inputs that define the thrust or torque requirements by valve type are:

1. Gate valve: pressure locking effect, thermal binding effect, unwedging thrust, packing load, stem rejection thrust, DP thrust, and torque reaction thrust. Degradation considerations are needed for the DP thrust and stem thread COF.
2. Globe valve: Unwedging thrust (for steep plug angles only), packing load, stem rejection thrust, DP thrust, seating load, side loading thrust, identification of the balanced or unbalanced area over which the DP acts, and torque reaction thrust. Degradation allowances are needed for the stem thread COF and side loading thrust, if applicable.

3. Quarter-turn valve: Seating/unseating torque, running torque, hydrodynamic torque, bearing torque, hydrostatic torque, effect of upstream disturbances on hydrodynamic torque, fluid type, and disk orientation effects. Degradation allowances are needed for the bearing torque and seating/unseating torque.
4. Diaphragm valve: Pressure force, running thrust, diaphragm flexure force. Degradation allowances may be needed for the diaphragm if maintenance does not preclude elastomer hardening.

MOVs in most legacy GL 89-10/96-05 programs have satisfied the DBVT requirements. Under Appendix III, it will be important to ensure the elements of the DBVT are available and defined for each MOV. In addition, there may be “new scope” Appendix III MOVs that were not in the legacy MOV programs that will require DBVT.

**PRESERVICE TEST**

Inputs to the preservice test include the following items:

1. Test acceptance criteria, including limiting assumptions that were used to establish the valve required thrust or torque and the actuator output capability.
2. Whether static or DP testing is required. DP testing may be required for certain MOVs where age and service-related degradation has not been quantified (see GL 96-05, Reference 4).

Outputs from the preservice test include the following items:

1. Test conditions, including ambient temperature, system pressure, DP, fluid temperature, and flow rate. These items are needed to ensure that the inservice test is conducted under similar conditions.
2. Test data and test results, which are referred to in Appendix III as IST values or performance test data.
3. Recording or verification of MOV configuration, such as the items identified in III-9100.
4. Test analysis and evaluation results per III-6200, III-6300, and III-6400.
5. Independent review and final records.

MOVs in most legacy GL 89-10/96-05 programs have a “baseline” test that will satisfy most requirements of the Appendix III preservice test. Exceptions include “new scope” MOVs and certain items such as record of test conditions, recording or verification of MOV configuration, and certain aspects of the test analysis and evaluation requirements, which includes determination of functional margin and functional margin degradation.

**INSERVICE TEST**

Inputs to the inservice test include the following items:

1. Test acceptance criteria, including limiting assumptions used to establish the valve required...
thrust/torque and the actuator output capability, from the most recent preservice test.

2. Work activity sequencing to ensure no unacceptable preconditioning is performed since the inservice test is to be performed in the as-found condition.

3. Required test conditions from the preservice test.

Outputs from the preservice test include the following items:

1. Test conditions, including ambient temperature, system pressure, DP, fluid temperature, and flow rate. These items are needed to ensure that the inservice test is conducted under similar conditions.
2. Test data and test results, which are referred to in Appendix III as IST values or performance test data.
3. Recording or verification of MOV configuration, such as the items identified in III-9100.
4. Test analysis and evaluation results per III-6200, III-6300, and III-6400.
5. Independent review and final records.

Similar to the preservice test, MOVs in most legacy GL 89-10/96-05 programs have “periodic verification” tests that will satisfy most requirements of the Appendix III inservice test. Exceptions include “new scope” MOVs and certain items such as record of test conditions, recording or verification of MOV configuration, and certain aspects of the test analysis and evaluation requirements, which includes determination of functional margin and functional margin degradation.

**EFFECT OF REPLACEMENT, REPAIR, OR MAINTENANCE**

Changes to any of the inputs that are used to determine the valve required thrust or torque or actuator output capability need to be evaluated for impact on the DBVT or preservice test. Repair, replacement, and modification activities all have the potential to impact one or more of the critical inputs to varying degrees. For example, routine gate valve maintenance to correct excessive seat leakage can have little effect on the valve required thrust if minor lapping is performed. However, if the disk were replaced, or re-oriented for certain gate valves, then a more extensive evaluation is required to ensure that any critical inputs to the thrust calculation are identified and addressed. Depending on the new sealing or wear surface material, disk orientation and changes to critical dimensions and tolerances, follow-up actions can include documenting that there was no effect on the required thrust to revising an EPRI PPM calculation or performing an in-situ DP test. For additional guidance, the JOG MOV PV program identifies “disallowing modifications” that can invalidate a prior valve qualifying basis established based on in situ DP testing and due to changes to in-service operating conditions [8].

Examples of other, less obvious activities that may be of significance include: 1) revisions to an emergency operating procedure that change the sequence of operating valves in series which increase the DP requirements of an MOV; 2) Adding electrical loads or re-sequencing the emergency diesel generator loads can reduce the motor terminal voltage; and 3) power uprate conditions may result in an increase in the MOV ambient temperature used to determine the available motor torque.

Comprehensive guidance is required to address replacement, repair, or maintenance activities. Defining routine maintenance activities that have no or minor impact on the DBVT inputs is a significant first step. Other maintenance activities will need to be evaluated if they potentially impact one of the following DBVT inputs or outputs:

1. System, environmental, or operational requirements and conditions.
2. Actuator characteristics that are used to determine the actuator output capability.
3. Valve characteristics that are used to determine the valve required thrust/torque.
4. Actuator-to-valve interface characteristics that are used to determine the torque-to-thrust conversion efficiency for rising stem valves.

Under legacy MOV programs, most plants developed change-management controls and guidance to address revisions to operating procedures, system modifications, and MOV work activities to assess impact on the valve required thrust or torque and actuator output capability. The level of evaluation and/or post-activity testing is defined for most common MOV maintenance activities. However, under Appendix III, plants will be required to more exactly identify which performance parameter is expected to be affected by the activity to support observed deviations between new and previously established reference test values. Appendix III also specifies requirements to more formally document these evaluations.

**SUMMARY**

An understanding of the various DBVT, preservice test, and inservice test inputs and outputs provides a framework to identify the dependencies among these Appendix III testing activities and the impact of replacement, repair, or maintenance. In addition, gaps between legacy MOV programs and Appendix III requirements can also be more easily identified and addressed.

Figure 1 summarizes the various inputs and outputs presented in this paper.

**REFERENCES**

Figure 1: Appendix III Test Process Flows