MOV OPERABILITY DETERMINATION

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ABSTRACT

This paper presents a technical approach for meeting the operability requirements of NRC GL 89-10. This technical approach will determine the design-basis requirements, verify equipment, determine the required forces to operate the MOV, evaluate the capability of the MOV, establish a target window that the MOV can operate, and justify operability. Alternatives are provide for justifying operability, and a sample operability review is provided for review. This paper is applicable for gate and globe valves with Limitorque operators.

BACKGROUND

The NRC issued GL 89-10 to ensure operability of MOVs and position-changeable MOVs in all safety-related fluid systems. NRC's staff evaluation of the data obtained from IEB 85-03 indicated that, unless additional measures are taken, failure of safety-related MOVs and position-changeable MOVs to operate under design-basis conditions will occur much more often than had previously been estimated.

PURPOSE

The purpose of this paper is to describe a methodology for meeting the operability requirements of GL 89-10.

METHODOLOGY

MOV operability can be determined by performing the following tasks:

- Design Basis Evaluation
- Hardware Verification
- MOV Capability Analysis
- Establish Target Windows
- MOV Diagnostic Testing
- Justification of MOV Operability

DESIGN BASIS EVALUATION

The first step in determining operability is establishing the design basis for the operation of each MOV. The design basis review shall consider all facets of operation which include:

- Function
- System
- Power Distribution System
- Electrical Controls

The basis for the reviews will be the plant configuration as defined in the current design basis documentation. Though not limiting, the following list contains those documents expected to define the current design:

- FSAR
- Tech Specs
- System Descriptions
- Operating Procedures (Normal, Abnormal, Emergency, Accident)
- P&IDs
- Piping Isometrics

Function Review

MOVs may have multiple functions. This review shall determine the safety function and normal operating function for each MOV.

System Review

The system review will determine the design-basis conditions for which the MOV has to perform its function. The safety-related operation of the MOV does not necessarily indicate the design-basis condition. Therefore all operational functions must be reviewed. The following conditions are evaluated:

- Differential Pressure
- Line Pressure
- Temperature
- Flow

In addition, the NRC has requested that evaluations on mispositioning and recovery from mispositioning be included. Mispositioning is considered for any MOV in a safety-related system that is not blocked from inadvertent operation from either the control room, the motor control center, or the valve itself.

Power System Distribution Review

This review will determine the minimum voltage requirements at the MOV terminals. This degraded voltage is normally based on the diesel generator load carrying capability during sequencing. Sometimes it is based on degraded grid conditions. Though not limiting, the following evaluations should be included:

- Length of cable
- Losses thru TOLs
- Motor losses due to ambient temperature

Electrical Controls Review

This review will determine the functional controls (interlocks, annunciators, indicators, etc) required for the MOV to perform its function.

HARDWARE VERIFICATION

The purpose of this task is to verify the existing hardware configuration for each MOV. This task would be accomplished by reviewing vendor drawings, original equipment specifications, existing databases, and walkdown data sheets. The information gathered during the hardware verification would also be used in performing the MOV capability analysis.

Additional verifications required are as follows:

- Control Logic
  This will ensure that the logic for the torque switch and position limit switch, and the circuitry for the interlock, annunciator, and indication switches are appropriate for the application.
- Thermal Overloads
  This will ensure that the overloads are properly sized or configured.
- Cable Sizing
  This will ensure that the power supply and cable sizes are adequate to provide the high starting currents needed for MOV operation.

MOV CAPABILITY ANALYSIS

Determining the capability of the MOV requires the following actions:

- Perform Required Thrust Calculation
- Determine Valve Limits
- Evaluate Operator Limits

Required Thrust Calculation

Required thrust calculations for gate and globe valves are performed using the classical industry equation:

$$ST = DPL + PL + PE$$

ST = total stem thrust

DPL = differential pressure load.

$DPL = VF \times A_o \times DP$

VF = valve factor
= 0.3 Gate Valve
= 1.1 Globe Valve

These valve factors represent the classical values typically used by the valve manufacturers. Actual valve factors may vary due to wear, aging, and maintenance.

A_o = seating contact area

DP = differential pressure

PL = packing load

The packing load force is the drag on the stem created by friction as the stem moves through the packing material.

PE = piston effect

The piston effect is the line pressure force acting on the stem. This effect may be positive, negative, or non-existence dependent on the operation (open or close) of the MOV.

Piston effect for globe valves:

$PE = A_s \times (LP - DP)$

A_s = stem area

LP = line pressure

Piston effect for gate valves:

$PE = A_s \times LP$

Valve Limits

The valve limit is evaluated under two conditions:

- Seismic
- Weak Link

The seismic limit represents the maximum amount of stem load that can be applied to the valve during the design basis seismic event.

The weak link limit represents the maximum amount of stem load that the weakest component of the valve can withstand before damage can occur, in both the open and close direction.

Operator Limits

The limiting component for the operator is identified by evaluating the following operator parameters:

- Operator Thrust Rating
- Operator Torque Rating
- Spring Pack Capability
- Motor Capability

The operator thrust/torque rating are obtained from the operator vendor.

The spring pack capability is evaluated by calculating the corresponding stem thrust value from the minimum and maximum spring pack torque values. The spring pack torque values can be obtained from the operator vendor or by performing an actual spring pack test.

The motor capability is evaluated at the following conditions:

- 100% Voltage
- Undervoltage
- Stall

ESTABLISH THRUST WINDOW

A thrust window is established which represents an operating range for the MOV based on the above evaluations. The window is comprised of three values:

- Min CST
- Max CST
- Max TT

The Min CST (control switch trip) is equal to the required stem thrust (ST).

The Max CST is the thrust level at which the motor must be de-energized. The Max CST is the lessor of the following limits:

- Valve Seismic Limit
- Valve Weak Link Limit
- Operator Ratings
- Maximum Spring Pack Capability
- Motor Capability @ Undervoltage

The Max TT (Total Thrust) is the maximum thrust that can be experienced with inertia. The Max TT is the lessor of the following limits:

- Valve Seismic Limit
- Valve Weak Link Limit
- Operator Ratings

Establishing the target window will also require that both torque switch repeatability (TSR) and diagnostic accuracies (DA) be taken into account. The TSR is defined as the variance in actual output torque from test run to test run for a given torque switch setting. The DA is defined as the variance in data output attributed to error inherent to the diagnostic hardware. Since these two events are not dependent on each other, they are combined by the square root of the sum of the squares method.

MOV DIAGNOSTIC TESTING

After the thrust window is established, setpoint selection and adjustments can be verified based on setup and operability testing. The purpose of the tests is to reduce uncertainties which affect the selection of the setpoints (friction coefficients, spring pack characteristics, rate of loading, stem factor) and to demonstrate that the setpoints selected will ensure proper MOV performance over the anticipated range of operating conditions. There are two basic types of setup and operability tests:

- Static
  Static tests obtain MOV information such as the functional characteristics of the specific valve and motor operator under static conditions. It's main purpose is to allow switch settings to be established delivering the desired thrust output, as well as to identify operator and valve anomalies.

- Dynamic
  Dynamic tests provide information related to the performance of the MOV under actual system operating conditions.

JUSTIFICATION OF MOV OPERABILITY

GL 89-10 requires that each MOV should be demonstrated to be operable by testing it at the design basis conditions. In cases where such testing in situ is not practicable, alternative methods can be developed. In addition, each MOV should be stroke tested, to verify that the MOV is operable at no-pressure or no-flow conditions even if testing at design-basis conditions cannot be performed.

As stated in GL 89-10, "Alternatives to testing a particular MOV in situ at design-basis pressure or flow, where such testing cannot practicably be performed, could include a comparison with appropriate design-basis tests results on other MOVs, either in situ or prototype. If such information is not available, analytical methods and extrapolations to design-basis conditions, based on best data available, may be used until test data at design basis conditions become available to verify operability". The NRC has identified this as the two-step approach.

In determining whether testing of a MOV in situ under design-basis conditions is practicable, an evaluation of the safety implications should be performed. This would include evaluation of the potential for damage to the MOV or other plant equipment. If the test of the MOV would require violation of plant technical specifications or procedures, alternatives to testing the MOV in situ under design-basis conditions may be necessary.

If testing at design-basis conditions is not practicable, the following alternatives are available as the best data available until test data at design-basis conditions become available to verify operability:

- Identify Adequate or Sufficient Margin
- Extrapolation of Partial Design-Basis Tests
- INEL Test Data
- Prototype testing

Identify Adequate or Sufficient Margin

When the results of a MOV capability analysis indicate a large thrust window between the Min CST and Max CST, it would indicate that the MOV has excessive capability for its application. Two methods could be utilized in justifying operability.

- Set-up switches near the upper limit (Max CST).
- Recalculate required thrust using a worst case valve factor.

Extrapolation of Partial Design-Basis Tests

The design-basis test would be performed as close as possible to the design-basis conditions. In addition, two interim data points would be chosen to establish any relationships with a change in the design-basis conditions. The following information would be gathered from each partial design-basis test:

- Differential Pressure
- Line Pressure
- Thrust at Flow Cut-Off
- Thrust at Unseating
- Packing Load
- Stem Torque

Using the above information and the required stem thrust equation from the MOV capability analysis, the actual valve factor could be calculated. Then recalculate the required stem thrust using the calculated valve factor from the test results and the design-basis conditions.

A disadvantage is that INEL test data shows thrust can be non-linear with increasing DP. This would identify certain valves as being "unpredictable", and very hard to justify and set limits on extrapolation.

Prototype Testing

Prototype is defined, by the NRC, as an MOV that will perform in such a manner that its test results are applicable to the MOV being demonstrated to be operable under design-basis conditions. The prototype MOV may be identical to the MOV in question or similar in nature of the MOVs, and may be located in the same plant, in another nuclear power plant, at a test facility, or at any location where the MOV could be adequately tested. The prototype test data may be obtained from several MOVs in order to increase the reliability of the data.

A disadvantage is that prototypes cannot accurately represent any given valve. In addition, the valve would have to be tested at the design basis conditions and orientation of the valve as a minimum.

INEL Test Data

The Idaho National Engineering Laboratory (INEL) provided research for the NRC in their efforts to address Generic Letter 87, "Failure of HPCI Steam Line Without Isolation". INEL's research examined the methods used by the industry to predict the required stem force of a valve, and provide guidelines for the extrapolation of in-situ test results to design basis conditions. Conclusions of their testing indicated that regardless of fluid conditions, the valves tested required more thrust for opening and closing under various differential pressure and flow conditions than would have been predicted from standard industry calculations and typical friction factors. As a result of the testing, INEL developed an equation to predict the forces required to close the valve at design-basis conditions.

A disadvantage is that the equation is only valid for flexwedge gate valves in the closing direction that have been shown to be predictable.

SUMMARY

This paper addresses one approach to determining operability. Other approaches are available and it is up to the utilities to determine which approach best fits their needs. Design-basis testing is the only method approved for determining operability, however alternatives are available to evaluate operability with the best data available until design-basis testing becomes available. Which ever method the utilities use, data must be provided to justify their operability determination.

REFERENCES

NRC Generic Letter 89-10, *Safety-Related Motor-Operated Valve Testing and Surveillance*, issued June 28, 1989

Supplement 1 to Generic Letter 89-10, *Results of the Public Workshops*, issued June 13, 1990

NMAC/EPRI NP-6660-D, *Application Guide for Motor-Operated Valves in Nuclear Power Plants*.

NUMARC 91-01, *Industry Guidance in Responding to NRC Generic Letter 89-10*.

Limitorque Corporation, 1988, *Limitorque Selection Guide*.

NRC Generic Issue 87, *Failure of HPIC Steam Line Without Isolation*.

NRC Information Notice 90-40, *Results of NRC-Sponsored Testing of Motor-Operated Valves*, issued June 5, 1990.

J.C. Watkins, R. Steel, K.G. DeWall, *NRC Test Results and Operations Experience Provide Insights for a New Gate Valve Stem Force Correlation*, INEL

SAMPLE
OPERABILITY REVIEW AT PARTIAL DESIGN BASIS

This example will illustrate the operability review of a MOV using extrapolation of partial design-basis testing.

VALVE DATA

The valve used in this example is as follows:

Type:	Gate
Size:	4"
Seat Dia.:	3.5"
Stem Dia.:	1.375"
Operator:	Limitorque
Size:	SB-0-25
DP:	1750 psi
LP:	1750 psi
Undervoltage:	80%

MOV CAPABILITY ANALYSIS

Calculate the required thrust: (close direction)

$$ST = (VF \times A_o \times DP) + PL + (A_s \times LP)$$

where: $VF = 0.3$
$A_o = 9.62 \text{ in}^2$
$A_s = 1.48 \text{ in}^2$
$PL = 1500 \text{ lbs}$

$ST = 9150$ lbs

Determine the valve limit:

The valve vendor has provided the following valve limits:

Seismic:	25000 lbs
Weak Link:	45000 lbs

Determine the operator limits:

Operator Thrust Rating:	24000 lbs
Operator Torque Rating:	500 ft-lbs
Spring Pack Capability:	
Max:	39106 lbs
Min:	4860 lbs
Motor Capability:	
100% voltage:	32475 lbs
80% voltage:	20784 lbs
Stall:	44653 lbs

ESTABLISH THRUST WINDOW

Based on the above evaluations:

Min CST: 9150 lbs

Max CST: 20784 lbs (80% voltage)

MAx TT: 24000 lbs (operator thrust rating)

Accounting for Torque Switch Repeatability (TSR) and Diagnostic Accuracies (DA):

TSR: 5.0%
DI: 9.2%

Using the square root of the sum of the squares method:

Accuracy: 10.47%

Thrust window based on equipment accuracies:

Min CST: 10220 lbs

Max CST: 18814 lbs

Max TT: 21725 lbs

MOV TESTING

Testing was not practicable at design-basis conditions, therefore testing was performed at less-than severe design-basis conditions.

Test Conditions:

DP: 1580 psi
LP: 1580 psi

Figure 1 shows the force trace taken from a full cycle design-basis test using the VOTES diagnostic system.

Figure 2 is a zoom of the trace in the open direction to locate the force needed to open the valve.

Force @ Unseating: 7111 lbs

Figure 3 is a zoom of the trace in the close direction to locate the force needed for flow cut-off.

Force @ Flow Cut-off: 11242 lbs
Force @ CST: 16693 lbs
Force @ TT: 18250 lbs

OPERABILITY EVALUATION

Operability evaluation will be based on the worst-case condition (closing direction). Additional data taken from the trace is the packing load.

Packing Load: 1000 lbs

Using the required thrust equation the actual valve factor can be calculated:

$$VF = \frac{ST - PL - (A_s \times LP)}{A_o \times DP}$$

$VF = 0.52$

Using the revised VF, the required thrust at design-basis conditions can be calculated:

$$ST = (VF \times A_o \times DP) + PL + (A_s \times LP)$$

where: $VF = 0.52$
$A_o = 9.62\ in^2$
$A_s = 1.48\ in^2$
$PL = 1500$ lbs
$DP = 1750$ lbs
$LP = 1750$ lbs

$ST = 12884$ lbs

Static testing was also performed to evaluate rate of loading. The following data was recorded:

Force @ CST: 16518 lbs

Comparing the static test results with the dynamic test results indicates a difference of 1% which is less than the 5% error for TSR. Therefore, rate of loading is not a factor for this valve. If the difference between the static and dynamic tests resulted in a value greater than TSR, then rate of loading effects would need to be evaluated.

Based on the revised required stem thrust calculation and equipment accuracies:

Min CST: 14346 lbs