EPRI Responses to NRC Request for Additional Information on Addenda 3, 4, 5, 6 and 7 to EPRI TR-103237-R2, *EPRI MOV Performance Prediction Program – Topical Report*

NRC Comment 1

The unwedging thrust model discussed in Addendum 3, "An Improved and Validated Gate Valve Unwedging Methodology" (TR-113564, December 1999), to the Electric Power Research Institute (EPRI) TR-103237-R2, "EPRI MOV Performance Prediction Program," uses a minimum static unwedging thrust observed from plant testing. Accordingly, a plant could perform multiple static unwedging tests and then use the lowest measured static unwedging thrust as input to the model to estimate a dynamic unwedging thrust. Provide additional justification for using a single potentially nonconservative static unwedging thrust in the unwedging thrust model.

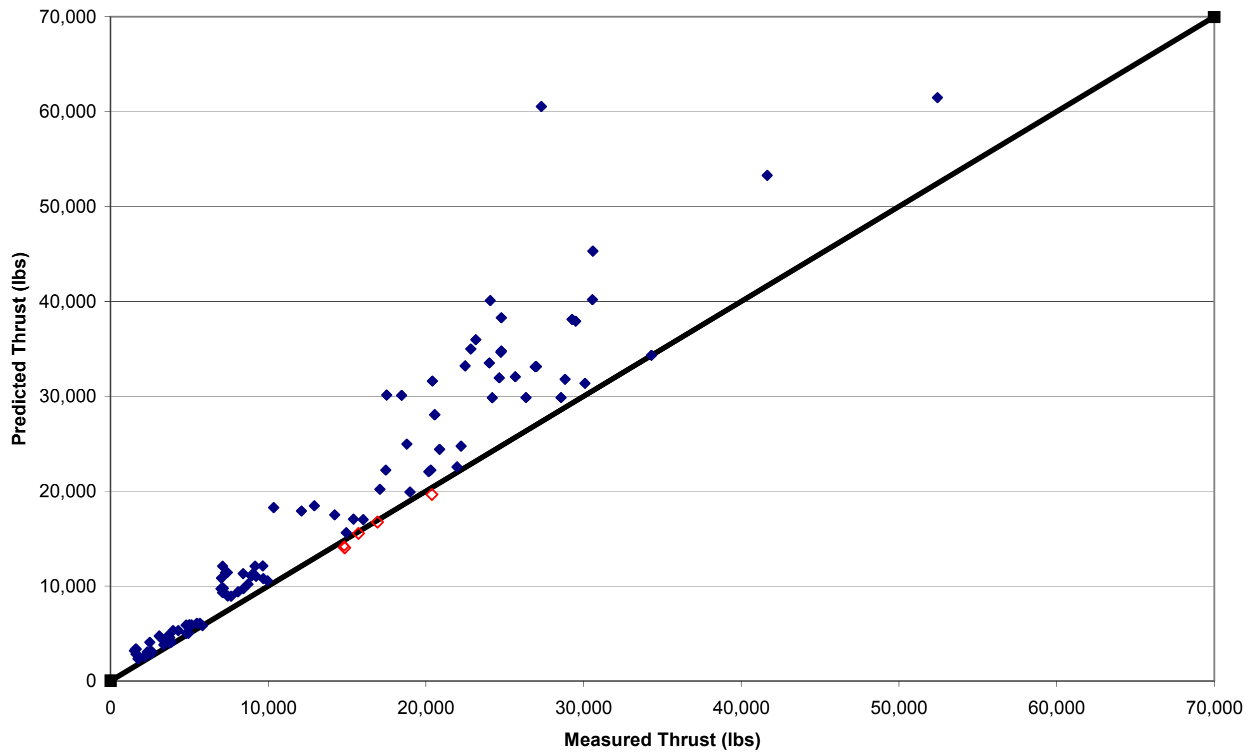
EPRI Response to Comment 1:

For validation of the improved unwedging methodology (Appendix A of Addendum 3), the minimum static unwedging thrust for each valve was used. This approach was used to be conservative; in other words, if predictions based on the minimum unwedging thrust are bounding, then the method itself is certain to be bounding.

Figure 1 shows a comparison of predicted unwedging thrust versus measured unwedging thrust for the 107 strokes included in *Method Validation* in Addendum 3. As shown in the figure, the refined unwedging methodology predicted bounding values of dynamic unwedging thrust for 102 of 107 strokes. Further, the underpredictions (shown as open points in the figure) are small.

These favorable results were achieved using the minimum measured static unwedging thrust for each valve. When plants apply the method, their approach is to use the "test stroke" for each valve, which is a stroke pre-designated for data collection. If there is a range of unwedging thrusts that can occur for the valve, then the "test stroke" value, on a probabilistic basis, will be in the range between the minimum and maximum values. As the method validation was performed using the minimum value, use of the "test stroke" value will yield a result that tends to be more conservative than that predicted in the Addendum 3 validation.

Figure 1 - Predicted versus Measured Unwedging Thrust



NRC Comment 2

Page 2-3 of Addendum 3 states that the differential pressure load sharing factor (X_0) in the gate valve unwedging equation was adjusted to bound the test data. However, some of the data are not bounded. Provide justification for X_0 not bounding all of the test data.

> ***EPRI Response to Comment 2:***
>
> As detailed on page 2-3 of Addendum 3, the Differential Pressure Load Sharing Factor (X_0) was set to 0.4 in the original PPM unwedging equation. However, use of this value in the refined unwedging equation does not result in predicted unwedging thrusts which adequately bound the test data. Accordingly, X_0 is adjusted in Addendum 3 such that results from the refined unwedging equation bound most of the test data. As discussed in the *Model Validation* (Section 3) the refined unwedging equation bounds the measured data for 102 of 107 strokes. For one valve, valve #4, the predictions bound the measured data on 6 of 7 opening strokes. For valve #17, the method is bounding on 3 of 7 opening strokes. Justification for not bounding data for Valves #14 and #17 is detailed on page 3-2 of Addendum 3.

Specifically, for valve #4, use of measured unwedging thrust from the preceding static stroke, as opposed to conservatively using the minimum measured unwedging thrust, results in the model being bounding for all strokes. For valve #17, a similar consideration reduces the underpredictions to values consistent with those observed in validation of the original unwedging model in TR-103229. See also the discussion in EPRI Response to Comment 1, which describes how typical implementation of the method will be more conservative than the validation approach.

NRC Comment 3

On page A-21 in Attachment A, "MPR Calculation 140-189-JEM-1, 'Validation of Refined Gate Valve Unwedging Methodology,'" to Addendum 3, the value of C for valve #9 is shown is shown as 0.226. Identify the manufacturer and pressure rating of valve #9. Discuss the consistency of the C value on page A-21 with the values specified in Table 2-1 of Addendum 3.

> ***EPRI Response to Comment 3:***
> Valve #9 is a 6 inch, Class 1500, Borg-Warner Gate Valve with a half-wedge angle of 5 degrees. For this valve manufacturer and pressure class, use of 0.226 for "C" in the refined unwedging equation is consistent with the values specified in Table 2-1 of Addendum 3.

NRC Comment 4

Addendum 3 states that the test data used to support the unwedging thrust model were for new or recently refurbished valves. Addendum 3 does not appear to address validation of the model for valves that have been in service for a number of years and where changes to critical valve surfaces could affect the conclusions presented. Discuss the justification for the applicability of the model to valves that have been in service.

> ***EPRI Response to Comment 4:***
> As discussed in Addendum 3 *Model Validation* (Section 3), the refined unwedging thrust model is validated against the same EPRI flow loop test data used for validation of the original unwedging equation. In the EPRI Flow Loop Test Program, the gate valves were preconditioned prior to testing to establish stable friction characteristics at the disk/seat interface. Appendix E of EPRI TR-103237-R2, *EPRI MOV Performance Prediction Program – Topical Report*, provides a summary of the EPRI Flow Loop Test Program. As described in this Appendix, the disk and seat surfaces of the gate valves were preconditioned by numerous short strokes under DP conditions until the friction coefficient increased to a plateau level and stabilized. Accordingly, this preconditioning resulted in valve performance that might be expected after extensive service.

NRC Comment 5

Addendum 3 states that the unwedging thrust model excludes valves that are susceptible to pressure locking or thermal bounding. However, the gate valve unwedging thrust model appears to have been validated using the results of static wedging data at ambient conditions only (i.e., closed and reopened at cold conditions). The applicability of the model for valves that are closed and reopened at other temperature combinations (i.e. closed hot and reopened cold, etc) does not appear to have been addressed. Provide justification for the applicability of the unwedging thrust model to valves that have been statically closed at elevated temperature or indicate a limitation in the applicability of the model.

EPRI Response to Comment 5:

The unwedging methodology presented in Addendum 3 is a refined, alternative approach to the original method included in the current EPRI PPM. This refined methodology is subject to the similar limitations of applicability as the original unwedging method. Specifically, neither of the methodologies can be applied to cases where pressure locking or thermal binding occur.

The coefficient of friction for self-mated Stellite disk-to-seat materials decreases with increasing temperature. As such, a static test at elevated temperature would have a lower seat friction coefficient (and potentially a lower required unwedging thrust) than tests performed at room temperature. The effect of temperature would be a concern only when the static testing conducted to determine the unwedging thrust was performed at a temperature significantly higher than the design basis temperature. Static testing is typically performed during outages, when the valve and the fluid in the valve are at room temperature. Accordingly, use of the methodology to determine unwedging thrust requirements at similar or higher temperatures is appropriate.

If the valve is later closed at elevated temperature, the following two scenarios could occur.

Closed Hot, Reopened Hot

Closure of a valve at elevated temperature and subsequent reopening at elevated temperature would not typically be expected to subject a valve to thermal binding. In addition, the refined unwedging method accounts for temperature dependence of the seat friction coefficient by using the maximum typical Stellite friction coefficient (0.6) determined during the EPRI Program, which is associated with low temperature and is bounding for high temperature. Accordingly, use of the refined unwedging method in this scenario would be appropriate.

Closed Hot, Reopened Cold

Closure of a valve at elevated temperature and subsequent reopening at lower temperature could potentially subject the valve to thermal binding. As discussed in Addendum 3, the refined unwedging method is not applicable to cases where thermal binding phenomena are present. As such, use of the method in this scenario would require a plant to clarify and justify whether or not thermal binding is present, in accordance with the processes set forth in their GL 95-07 program. If a plant verifies that thermal binding is not present, then the refined unwedging method can be used. Use of the refined unwedging method in this case is appropriate as it uses the maximum Stellite friction coefficient (0.6), which is associated with low temperature.

NRC Comment 6

Addendum 3 uses data from the EPRI flow loop test program in validating the refined gate valve unwedging equation. On page 3-1, Addendum 3 states that all of the differential pressure opening strokes in the EPRI flow loop test program were preceded by a differential pressure closure stroke (except for one test valve). In light of this specific testing sequence in the EPRI flow loop test program, discuss available MOV operating experience (such as that obtained during performance of the Joint Owners' Group program on MOV periodic verification) that would confirm the validation of the refined gate valve unwedging equation.

EPRI Response to Comment 6:

The NRC comment misstates the makeup of test data used in validation of the unwedging method. The *Model Validation* (section 3) states that all DP opening strokes for all valves were preceded by a DP closing stroke, except for stroke #18 **for each valve.** Therefore, results from each valve included unwedging data following both static closure and DP closure. (Note that the model validation includes test data from 18 MOVs.)

EPRI recognizes that for the opening strokes preceded by a DP closing stroke, the final closure thrusts could be less than the final closure thrusts prior to static opening strokes used to determine the static unwedging load. As discussed on page 3-1 of Addendum 3, EPRI judges this effect to be small, particularly since the torque switches for the EPRI testing were set very high. This conclusion is supported by the validation results which show that the results for the 18 DP opening strokes preceded by a static closing stroke were generally consistent with the results for the other strokes (DP opening strokes preceded by DP closing strokes).

The NRC comment also discusses consideration of available MOV operating experience, such as that obtained during performance of the Joint Owners' Group (JOG) Periodic Verification (PV) Program. It should be noted that the JOG PV program did not examine gate valve unwedging thrust. Analysis of opening stroke test data in the JOG PV Program included the points of interest "Just after Cracking" and "Flow Initiation".

NRC Comment 7

Table 2-1 in Addendum 3 provides the assumed values of the parameter C in the refined gate valve unwedging equation. Discuss the available test data used to establish the value of C for each of the half wedge angles listed in the table, and the uncertainty associated with the C value for each half wedge angle based on the amount of available test data.

EPRI Response to Comment 7:

Addendum 3 determines appropriately bounding values for the parameter C based on available test data from the EPRI flow loop test program. It should be noted that this test data is the same data used to validate the original unwedging method in the PPM. Although this data does not cover all half-wedge angles listed in Table 2-1, the effect of wedge angle is covered by the mathematically derived definition of C, which is discussed further below.

In Addendum 3, the constant C is defined as:

$$C = \frac{\mu}{\cos\theta + \mu\sin\theta} - 2X_o \frac{\cos\theta(\mu\cos\theta - \sin\theta)}{\cos\theta + \mu\sin\theta}$$

where,

☐: Coefficient of friction for Stellite-on-Stellite, dimensionless
☐: Half-wedge angle, degrees
X_0: Differential pressure load sharing factor, dimensionless

The above expression is derived from a force balance on a gate valve disk in the fully closed position, with a differential pressure load across the disk. Because the definition of the constant C covers the effect of disk geometry, justification of the C values listed in Addendum 3, Table 2-1 is based on justifying appropriate values for ☐ and X_0. For ☐, a value of 0.6, consistent with the maximum disk-to-seat friction coefficient, is conservatively used.

The term X_0 in the above expression represents the distribution of the DP load between the upstream and downstream seating surfaces. When a disk is seated, or wedged, contact loads are developed at both the upstream and downstream disk-to-seat interfaces. In this condition, a differential pressure load on the disk is reacted by some combination of increased load at the downstream seat and decreased load at the upstream seat. Specifically, X_0 is the percentage of the DP load which is reacted by a decreased load at the upstream seat.

Addendum 3 determines an appropriately bounding value for the factor X_0, and consequently appropriately bounding values for the parameter C, based on test data from 18 MOVs from the EPRI flow loop test program. Specifically, a value of X_0 of 0.357 is found to produce reliable results that, with minor exceptions, bound the data (Note: see also Response to Comment 2). For Borg-Warner low pressure class valves (150 lb and 300 lb class), a lower value of X_0 (0.189) was found to produce suitable results, based on testing of 2 such valves. Based on this approach, an uncertainty allowance for the value of C is not needed.

NRC Comment 8

Addendum 3 indicates that the refined gate valve unwedging equation bounds the measured test data for 16 of the 18 valves within the EPRI flow loop test program used to validate the refined equation. Discuss the level of confidence in the use of the refined gate valve unwedging equation and the uncertainty factor that might need to be included in the evaluation of individual MOV design-basis capability.

EPRI Response to Comment 8:

Using the conservative validation approach presented in Addendum 3, the refined method bound data for 102 of 107 opening strokes (over 95%). 2 of the 18 MOVs in the validation (valves #4 and #17) had 1 or more strokes that were not bounded. However, as discussed in the *Model Validation* (Section 3), re-evaluating the validation (to remove excess conservatism from the approach) results in the model bounding all strokes for valve #4 and in predictions for valve #17 similar to those observed with the original unwedging methodology. These results show a high level of confidence that unwedging predictions using the refined methodology will be suitable for use. The refined EPRI unwedging methodology provides bounding (not best estimate) predictions of unwedging thrust. Accordingly, it is not necessary to include an uncertainty factor in the unwedging method for evaluation of individual MOV design-basis capability.

NRC Comment 9

The test data used to evaluate the proposed unwedging stem nut coefficient of friction model proposed in Addendum 4, "Use of Static Closure Data for Determining the Stem-to-Stem Nut Coefficient of Friction at Unwedging" (TR-113989, December 1999), to EPRI TR-103237-R2 was performed at ambient conditions. Past research has shown that lubricating characteristics can change at elevated temperature, resulting in changes in the stem coefficient of friction. Provide justification for applying the model to stems and stem nuts that are at elevated temperatures, or clarify the applicability of the model to stems and stem nuts at ambient temperature.

EPRI Response to Comment 9:

The analysis in Addendum 4 accounts for the effect of elevated temperature on stem-to-stem nut COF due to heat conduction through the valve yoke and stem from hot fluid in the valve. Typically, ambient temperature strokes were considered for the COF values at TST, since this data was intended to represent valve static setup tests. The analysis of COF at unwedging included data from test sequences with low and high temperature fluid in the valve. Specifically, flow loop valves 3, 9, 13, 14, 24, 30, and 43 and in situ valve 4 (8 of 34 valves) included tests with elevated temperature fluid in the valve (450ºF to 660ºF).

With regard to the Population Analysis described in Addendum 4, Figure 9A (adapted from Figure 2-1 of Addendum 4) shows the distribution of stem-to-stem nut COF data at unwedging from the hot test sequences along with the other results at low temperature. As shown in the plot, no trend or particular effect is evident for the unwedging COF data from hot test sequences in comparison to the COF data from ambient test sequences.

For the Valve-Unique Analysis described in Addendum 4, the histogram in Figure 9B shows the difference between the COF at unwedging (from a hot DP test sequence) and a valve's average static COF at TST (from ambient tests) for the 8 valves tested with elevated temperature fluid.[1] As shown in the figure, the average COF difference is -0.0101, which is more favorable than the average COF difference considering both ambient and hot temperature test sequences (-0.0052). In other words, the elevated temperature data indicate a slightly lower unwedging COF. In addition, a COF difference of 0.042, which bounds 98.4% of data in Addendum 4, bounds 100% of the COF data for the hot test sequences.

Accordingly, the effect of elevated fluid temperature on the stem-to-stem nut COF is negligible. However, it should be noted that these results and evaluations do not cover conditions where the ambient (room environment) temperature around the MOV is elevated. Such conditions could increase the stem nut (and stem lubricant) temperature further (above the conditions covered by Addendum 4). If additional adjustments are needed to account for elevated room environment temperature, the Licensee is responsible to account for this effect. EPRI Report 1009609, *Motor-Operated Valve Lubricant Performance and Condition Assessment*, provides information regarding the effect of changes in stem nut (lubricant) temperature on stem-to-stem nut friction.

[1] It should be noted that both the COF at Unwedging and the static COF at TST for in situ valve 4 are from test sequences with elevated temperature fluid.

Figure 9A - Stem COF at Unwedging versus Thread Pressure

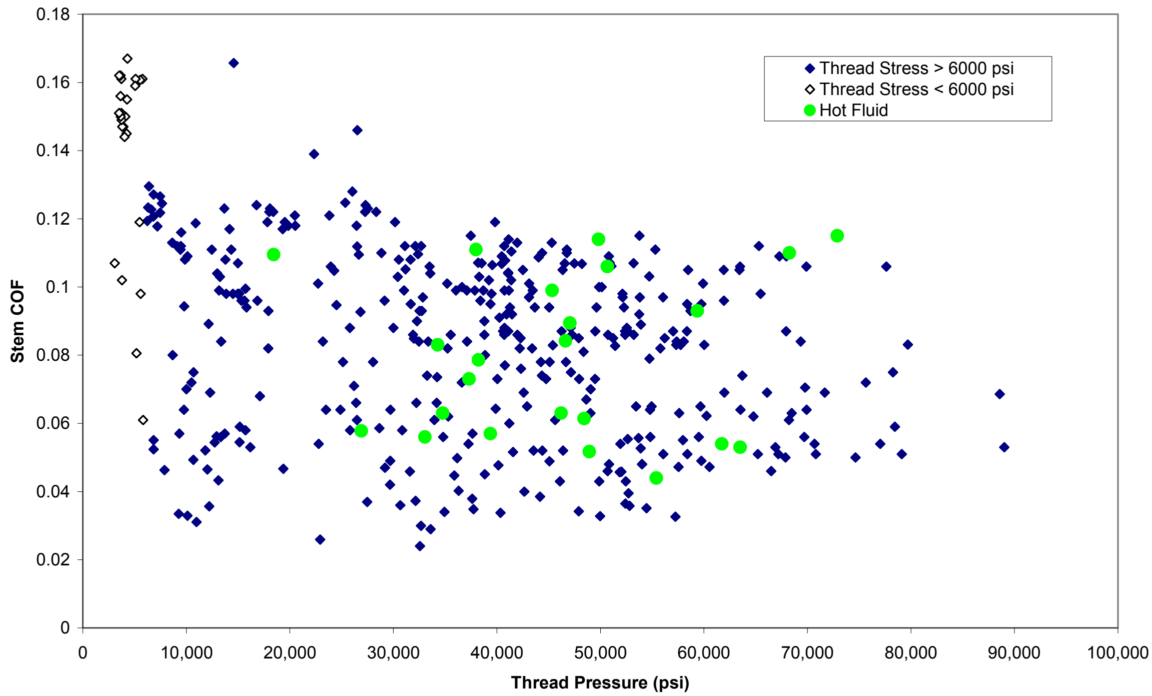
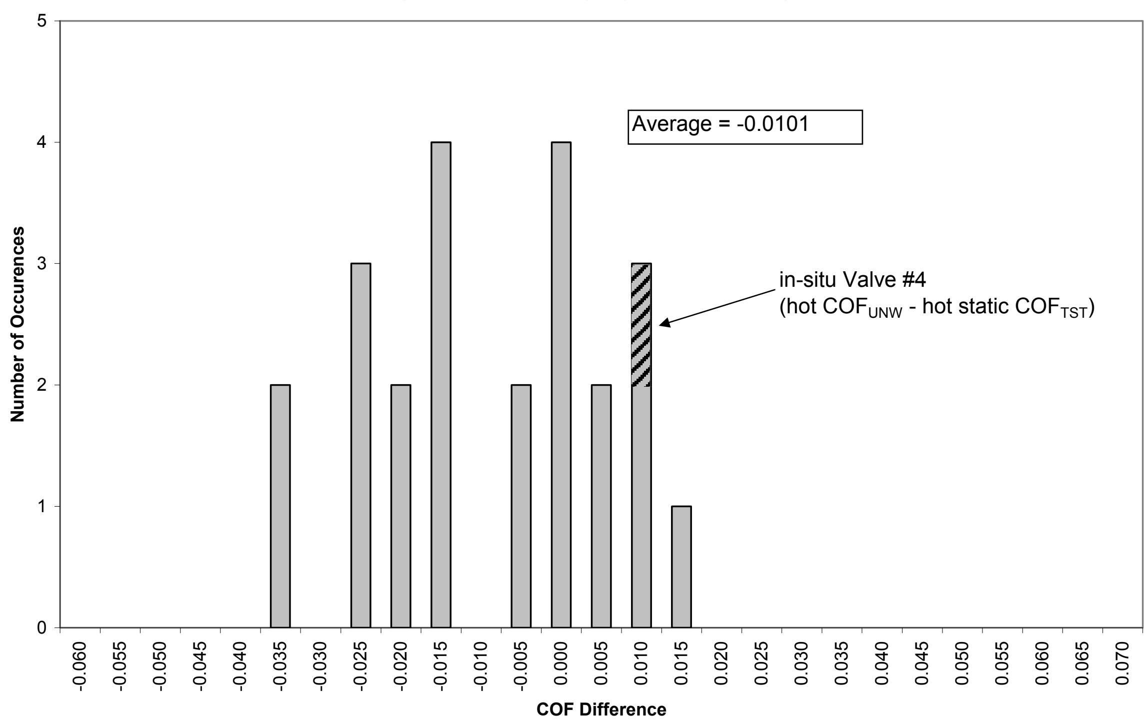


Figure 9B - Histogram of Total COF Difference for Hot Test Sequences (COF at Unwedging - Static COF)



NRC Comment 10

Past NRC-sponsored research has shown that different stem lubricants can respond differently at elevated temperature. The lubricants used to validate the unwedging stem nut coefficient of friction model in Addendum 4 were not discussed. Provide additional information on the lubricants used during the testing, the condition of the lubricants, and the applicability of the resulting model to stem nuts at both ambient and elevated temperature conditions.

EPRI Response to Comment 10:

The analysis in Addendum 4 covers 34 wedge gate valves tested in the EPRI MOV Program. The test matrix includes full-scale testing of MOVs performed in flow loops at various valve test facilities as well as in situ test data obtained from nuclear power plants. The valves used in EPRI flow loop testing were disassembled, cleaned, reassembled, re-lubricated, and then stroked to precondition the valves prior to testing. The stem lubricant used for all of the EPRI flow loop test valves was Swepco-Moly 101, with the exception of EPRI MOV #61, which was lubricated with Mobilux EP-1. The in situ test data was obtained from valves tested within plant MOV programs. The condition of these lubricants would be typical of that yielded by the plant maintenance programs. These valves included the stem lubricants listed below.

- EP-0 (Exxon)
- EP-1 (Exxon)
- EP-2 (Texaco)
- Lubriplate
- Mobilux EP-0
- Mobil 28

Accordingly, the combination of flow loop and in situ testing covers a range of lubricants. EPRI recognizes the potential for lubricating characteristics, and consequently the stem-to-stem nut friction coefficient (COF), to change with temperature. In the EPRI Response to Comment 9, the effect of elevated temperature (due to conduction from a hot fluid medium) is shown to be of negligible influence based on data from 7 flow loop valves (with Swepco-Moly 101) and 1 in situ valve (with Lubriplate). If additional adjustments are needed to account for elevated stem lubricant temperature, due to elevated ambient temperature, the Licensee is responsible to account for this effect. EPRI Report 1009609, *Motor-Operated Valve Lubricant Performance and Condition Assessment*, provides additional information regarding the effect of temperature on stem-to-stem nut friction for various lubricants.

NRC Comment 11

The applicability of the unwedging stem nut coefficient of friction model in Addendum 4 to stem nuts that experience lubrication aging, drying, or excessive contaminants from the atmosphere has not been discussed. Provide justification for using the model for stem nuts that are susceptible to lubrication aging, drying, excessive dirt, and other contaminants.

EPRI Response to Comment 11:

EPRI recognizes the potential for the stem-to-stem nut coefficient of friction (COF) to change over time. Plant Preventative Maintenance (PM) Programs are intended to maintain a suitable condition of the stem lubricant and thereby limit this variation. If additional adjustments are needed to account for changes in the COF over time, the Licensee is responsible to account for this effect.

NRC Comment 12

Chapter 3, Addendum 4, concludes that on a population basis the unwedging stem friction coefficient is lower than or comparable to the static closing stem friction coefficient. However, on page 2-3, Addendum 4, states that the unwedging stem friction coefficient data population has a slightly wider range than the static closing stem friction coefficient. Also, Figure 2-2 indicates that a specific value bounds 99 percent of the unwedging stem friction coefficient data while a lower value bounds 99 percent of the static closing stem friction coefficient data. Discuss the basis for the conclusion that the unwedging stem friction coefficient is lower or comparable to the static closing stem friction coefficient on a population basis.

EPRI Response to Comment 12:

As shown in Figure 2-2, the static COF data exhibits a slightly tighter distribution than the unwedging COF data. The weighted average unwedging COF for all valves (0.0852) is slightly lower than the weighted average static COF (0.0904). In addition, Figure 2-2 graphically shows that the percentage of the population bounded by a specific value of COF is generally higher for the unwedging COF population than for the static COF population, except at the high end of the COF range where the COFs are comparable. Accordingly, it is concluded that on a population basis, the unwedging COF is lower than or comparable to the static COF. However, it is noted that due to the slightly wider distribution of the unwedging data compared to the static data, a specific COF value which bounds an extremely high percentage of the data (i.e., 99%) is higher for the unwedging COF data than for the static COF data.

NRC Comment 13

Addendum 4 allows a stem friction coefficient value that bounds 95 percent of the static closing stem friction coefficient data for the tested valves at a nuclear power plant to be applied as the unwedging stem friction coefficient for the total MOV population at the plant. Discuss the percentage of valves within the MOV population that need to be tested in applying this assumption. Also, discuss the level of confidence in this method of estimating unwedging stem friction coefficient, and the uncertainty that should be applied in the design-basis capability evaluation for individual MOVs to account for the assumption of unwedging stem friction coefficient.

EPRI Response to Comment 13:

The NRC comment pertains to the description of the Population Analysis method on page 3-1 of Addendum 4. Within this description, the discussion specifically mentions use of a COF which bounds 95% of applicable data as an example to the user. It is not EPRI's intent that this value be used as a criterion established in Addendum 4. A Licensee is responsible for defining and justifying a COF, applicable at torque switch trip for static testing, that appropriately covers the MOVs at the plant. Specification of a statistical criterion to be used in selecting an appropriate COF is beyond the scope of Addendum 4.

NRC Comment 14

Addendum 4 on page 3-2 allows the measured static closing stem friction coefficient at torque switch trip for a specific valve to be increased by a certain amount to obtain an applicable unwedging stem friction coefficient for that valve, provided the nominal thread pressure for unwedging at design-basis conditions is greater that 6000 pounds per square inch (psi). Discuss the level of confidence in this method of estimating unwedging stem friction coefficient, and the uncertainty that should be applied in the design-basis capability evaluation of the individual valve to account for the assumption of unwedging stem friction coefficient.

EPRI Response to Comment 14:

The Valve-Unique Analysis method states that for a specific valve, the measured COF at torque switch trip for a static test should be increased by 0.042 to obtain a COF that is applicable to unwedging, provided the nominal thread pressure for unwedging at design basis conditions is greater than 6000 psi. Justification for use of this value (0.042) is on page 2-3 of Addendum 4. Specifically, a COF difference (unwedging COF – static COF) of 0.042 bounds 98.4% of the data. This result is judged to be sufficiently bounding and no additional uncertainty needs to be applied.

NRC Comment 15

Addendum 5, "PPM [Performance Prediction Methodology] Version 3.1 Software Changes" (October 2002), to EPRI TR-103237-R2 on page 2-6 states that Version 3.1 of the EPRI PPM provides required thrust/torque predictions for air-operated valves and hydraulically operated valves. For air-operated butterfly valves, Addendum 5 states that the PPM results for incompressible flow applications should be considered best available information while the results for compressible flow applications are considered to be bounding for design-basis predictions. Discuss the uncertainties associated with the use of the EPRI PPM Version 3.1 for air-operated butterfly valve applications and limitations on those applications for PPM Version 3.1 users.

EPRI Response to Comment 15:

As discussed in Addendum 5, Information Notice 2002-1 provides a methodology for users to determine design basis required torque versus disk position for Versions 1.0, 2.0, and 3.1 of the PPM software. (Note that Versions 3.2 and 3.3 of the PPM software incorporate this methodology.) However, Information Notice 2002-1 cautioned that due to possible differences in the default PPM flow coefficients versus disk angle and those of industry butterfly valves, such predictions may not be bounding for portions of the stroke and should be considered "best available" information.

In 2003, EPRI assessed these variations in the flow coefficients versus disk angle and issued PPM Error Notice 2003-2. This Error Notice quantified the variations with respect to disk angle and developed a method for users to account for these variations. Use of the methods detailed in this Error Notice and Information Notice 2002-1 will provide bounding design basis required torque predictions as a function of disk angle. Note that Version 3.3 of the PPM software incorporates both the Error Notice and the Information Notice.

NRC Comment 16

Addendum 5 on page 2-7 describes the implementation of the PPM in determining margin for unwedging a gate valve disk. Discuss the approach described in Addendum 5 as it relates to the revisions to the PPM described in Addenda 3 and 4 on unwedging thrusts.

EPRI Response to Comment 16:

The description on page 2-7 of Addendum 5 pertains to use of an MOV's maximum allowable closing thrust in the original unwedging methodology (described in EPRI TR-103244). A predicted unwedging thrust calculated in this manner would be expected to be the maximum unwedging thrust for the MOV. This value could be compared to the MOV's actuator opening capability to ensure margin for unwedging the valve disk. This implementation approach has been incorporated into the PPM software (Versions 3.1 and later) as an optional calculation. This change does not affect the PPM unwedging thrust predictions.

The unwedging methods discussed in Addenda 3 and 4 are not incorporated in the PPM software and are unrelated to the unwedging implementation method discussed in Addendum 5. Specifically, Addendum 3 develops an alternative approach for predicting required unwedging thrust and Addendum 4 develops approaches that can be used to determine the stem COF applicable to gate valve unwedging.

NRC Comment 17

Addendum 6, "PPM Version 3.2 Software Changes" (November 2003), EPRI TR-103237-R2 on page 2-1 states that Version 3.2 of the EPRI PPM has eliminated the best estimate torque predictions for butterfly valves and that design-basis torque predictions are made as a function of disk angle. Discuss the resolution of the uncertainty associated with the application of the EPRI-PPM Version 3.2 to air-operated butterfly valves discussed previously in Addendum 5 for Version 3.1.

EPRI Response to Comment 17:

(Note: see also Response to Comment 15) The development of design-basis torque predictions as a function of disk angle for butterfly valves is detailed in Information Notice 2002-1 (included in Appendix B of Addendum 6). As detailed in the Information Notice, one of the outputs provided in a PPM report is a Torque Signature (T_{SIG}) prediction at 1º increments of disk angle from 0º to 90º. In versions of the PPM software previous to Version 3.2, the T_{SIG} prediction was the algebraic sum of all torque components at each disk angle. In other words, T_{SIG} took credit for hydrodynamic torque when it assisted disk motion. Accordingly, T_{SIG} was considered an estimate of total torque as a function of disk angle and it was potentially non-conservative to use T_{SIG} as the design basis required torque. Information Notice 2002-1 provided a methodology for users to convert these "best estimate" torque predictions to design basis torque predictions. As documented in Addendum 6, this methodology is incorporated into Version 3.2 of the PPM and the output reports from this version of the software provide users with design basis torque predictions as a function of disk angle.

NRC Comment 18

Addendum 7, "PPM Version 3.3 Software Changes" (October 2005), to EPRI TR-103237-R2 describes multiple errors that are present in previous versions of the EPRI PPM that are said to be corrected in Version 3.3 of the software. Discuss the quality assurance controls placed on previous PPM versions that failed to prevent the identified errors and the corrective actions that have been implemented to identify any additional errors in the previous PPM versions. Discuss the reliability of those previous PPM versions in light of the identified and other errors that might not have been identified to date. Also, discuss the quality assurance controls that have been implemented for PPM Version 3.3 to avoid significant errors in its application, implementation, and results.

EPRI Response to Comment 18:

During the development of WinPPM Version 3.3, several errors or bugs were discovered with Version 3.2. Each error was found to apply to specific, narrow conditions. Although for this reason the impact of the errors was likely to be small and limited, this finding showed that the testing of Versions 3.1 and 3.2 was not sufficiently thorough.

Development of Versions 3.1 and 3.2 was performed under a Quality Assurance program that satisfies the requirements of 10 CFR 50 Appendix B. This program included processes and procedures for controlled development of software, which included verification and validation as part of the process. For example, software requirements were documented in a software requirements specification, which was independently verified. Further, independent validation testing of the software was performed in accordance with a written validation plan, and the results of the testing were documented. The errors arose because the validation testing, although judged to be adequate at the time, did not test certain combinations of conditions that led to the problems.

As a result of this finding, corrective actions were undertaken. Specifically, thorough and painstaking re-validation testing of WinPPM was undertaken. Special attention was given to ensuring that all of the combinations of conditions that could exercise the logic and features of PPM in different ways were tested. As a result of this effort, there is a high level of confidence that errors in Versions 3.1 and 3.2 have been identified. Error Notices were prepared and distributed to all PPM Users so that calculations performed with these versions could be appropriately evaluated and, if needed, adjusted. With proper application of these Error Notices, predictions performed with Versions 3.1 and 3.2 have a high level of confidence and reliability.

Development of Version 3.3 was also performed under a Quality Assurance Program that satisfies 10 CFR 50 Appendix B. In light of the problems with prior versions and the lessons learned and corrective actions applied, testing of Version 3.3 was more carefully defined and was more rigorous and thorough. Finally, internal QA audits of the projects to develop Versions 3.1, 3.2 and 3.3 were carried out, to confirm that all of the procedure requirements for software development had been completed and documented.

Throughout this process, EPRI evaluated 10 CFR 21 reportability requirements. By documenting and distributing Error Notices so that users could suitably evaluate predictions performed with Versions 3.1 and 3.2, the appropriate actions were taken and no further reporting was required.