EPRI MOV Performance Prediction Program

Addendum 5 to EPRI TR-103237-R2: PPM Version 3.1 Software Changes-NP

1006930NP

Final Report, May 2004

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The work described in this report was developed under MPR Associates' Quality Assurance Program, which is in compliance with the requirements of Title 10 of the Code of Federal Regulations, Part 50 Appendix B.

CITATIONS

This report was prepared by

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This report describes research sponsored by EPRI.

The report is a corporate document that should be cited in the literature in the following manner:

EPRI MOV Performance Prediction Program: Addendum 5 to EPRI TR-103237-R2: PPM Version 3.1 Software Changes-NP, EPRI, Palo Alto, CA: 2002. EPRI 1006930NP.

REPORT SUMMARY

This addendum to EPRI report TR-103237-R2 (*EPRI MOV Performance Prediction Program Topical Report*) documents changes made to the EPRI MOV Performance Prediction Methodology (PPM) computer code between Version 2.0 and Version 3.1. The most significant change was the conversion from a DOS- to a Windows-based methodology. This addendum also demonstrates that the changes do not affect the code's ability to appropriately bound thrust and torque requirements for gate, globe, and butterfly valves.

Background
The EPRI MOV PPM is a validated computer code for determining the required thrust or torque to stroke gate, globe, and butterfly valves under design basis conditions. Version 1.0 of the code was a DOS-based program and was issued in 1995. EPRI report TR-103237-R1 (*EPRI MOV Performance Prediction Program Topical Report Revision 1*) documents a technical description of Version 1.0, including model data comparisons justifying the method. The Nuclear Regulatory Commission (NRC) issued a Safety Evaluation on Version 1.0 in March 1996. The NRC issued a supplemental Safety Evaluation covering specific hand calculation methods in February 1997. Revision 2 of TR-103237 was issued in April 1997 and includes the hand calculation methods, as well as the NRC Safety and supplemental Safety Evaluations.

Version 2.0 of the PPM was issued in August 1998 to correct minor software errors and incorporate features to facilitate implementation. EPRI AD-110778 described changes between Version 1.0 and 2.0 and demonstrated that the changes did not affect the code's ability to make bounding predictions of required thrust and torque. The NRC issued a Safety Evaluation covering Version 2.0 of the PPM in May 2000.

Version 3.0 was issued in August 2001. It incorporates a Windows-based user interface and automates many of the hand calculations that had previously been required. Version 3.0 was recalled shortly thereafter due to the discovery of a coding error. Version 3.1 corrected the error and was issued in November 2001.

Objectives
- To describe the changes made between Version 2.0 and Version 3.1 of the PPM code.
- To demonstrate that such changes do not affect the code's ability to appropriately bound expected thrust and torque requirements for gate, globe, and butterfly valves.

Approach
The programming team modified only the user interface module of the code (no changes were made to the gate, globe, butterfly, or system predictive modules). The primary change was the conversion of the user interface module from DOS to Windows. The team made additional

changes to 1) improve prediction report documentation, 2) expand program automation, and 3) simplify several implementation criteria. These changes do not affect the PPM code's ability to appropriately bound thrust and torque requirements for gate, globe, and butterfly valves.

Results

This report documents the changes made in going from EPRI PPM Version 2.0 to Version 3.1 and demonstrates that such changes did not affect the capability of the PPM code to appropriately bound thrust and torque requirements for gate, globe, and butterfly valves.

EPRI Perspective

Addendum 5 to the *EPRI MOV Performance Prediction Program Topical Report* adequately demonstrates that PPM code modifications made between Versions 2.0 and 3.1 do not affect the code's predictive capability. This Addendum can be used as a basis for NRC review and issuance of a Safety Evaluation approving use of Version 3.1 for design basis MOV thrust and torque predictions.

Keywords

Motor-operated valves
Air-operated valves
Gate, globe, and butterfly valves

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1
INTRODUCTION

Background

The Electric Power Research Institute (EPRI) Motor Operated Valve (MOV) Performance Prediction Methodology (PPM) is a validated method for determining the required thrust or torque to stroke gate, globe and butterfly valves under design basis conditions. Version 1.0 of the PPM computer code was issued in 1995. The PPM methodology and comparisons of PPM predictions to test data were presented in EPRI TR-103237-R1, *EPRI MOV Performance Prediction Program Topical Report Revision 1*. The Nuclear Regulatory Commission (NRC) issued a Safety Evaluation on this version of the PPM in March 1996. The NRC issued a supplemental Safety Evaluation covering specific hand calculation methods in February 1997. Revision 2 of EPRI TR-103237 was issued in April 1997 and includes these additional hand calculation methods, as well as the NRC Safety Evaluations.

Version 2.0 of the PPM computer code was issued in August 1998 to correct minor errors in the software and to incorporate features to facilitate user implementation. EPRI AD-110778 (Reference 1) described the changes in Version 2.0 and documented the results of re-assessment of the PPM using Version 2.0, to demonstrate that Version 2.0 provides bounding predictions of required thrust and torque. The NRC issued a Safety Evaluation covering Version 2.0 in May 2000.

Version 3.0 was issued in August 2001. Version 3.0 incorporated a Windows-based user interface and automated many of the hand calculations performed by the user in Versions 1 and 2. At the same time, a combined User Manual and Implementation Guide for Version 3.0 was issued (Reference 2). In November 2001, an error was identified in Version 3.0 and it was recalled and removed from distribution. No user had completed calculations using Version 3.0. The error was corrected and Version 3.1 of the PPM computer code was issued in late November 2001. The error did not necessitate a revision of the User Manual/Implementation Guide.

Purpose

The purpose of this report is to describe the changes made in going from Version 2.0 to Version 3.1 of the PPM and justify that these changes do not affect the code's ability to appropriately bound expected thrust/torque requirements for gate, globe and butterfly valves.

2

SUMMARY OF CHANGES IN VERSION 3.1

The most significant change in Version 3.1 is that a Windows-based user interface replaces the DOS-based user interface in Versions 1.0 and 2.0. This change has no effect on PPM thrust and torque predictions. The "technical modules" within the PPM -- the System Flow Module, Gate Valve Module, Globe Valve Module and Butterfly Valve Module -- were not modified in Version 3.1. Other changes made in Version 3.1 are discussed in the sections below.

Changes to Improve Prediction Report Documentation

With Versions 1.0 and 2.0 of the PPM, users had to prepare documentation outside the PPM software to fully implement the PPM methodology. For example, users had to document verification of the applicability of the PPM to the valve being evaluated. EPRI developed "workbooks" to simplify this process and allow users to combine this documentation with PPM prediction reports to obtain a complete documentation package for a PPM evaluation.

Version 3.1 of the PPM allows users to produce a prediction report that includes much of the documentation that previously had to be prepared outside the PPM software. Users can now input the additional information listed below into Version 3.1 of the PPM. The PPM includes this information in the PPM prediction report, producing a complete documentation package. *The additional inputs below do not affect the PPM prediction of required thrust/torque.*

1. General information about the MOV
   - Plant name and unit
   - Valve ID number
   - Valve description
   - Design basis scenario(s)
   - Valve vendor
   - Vendor drawing number
   - Vendor serial number
2. A list of numbered references and the ability to associate reference numbers with each input
3. Applicability criteria and the evaluation of the MOV application against these criteria
4. Comments and recommendations resulting from the evaluation

Version 3.1 also provides the following calculated values (as applicable) that are not provided by Versions 1.0 and 2.0:

- Upstream and downstream pipe inertia
- Critical pipe inertia
- ΔDP and ΔP_{UP} for globe valves (due to water inertia effects)
- Equivalent length
- Positive guide rail offset
- Negative guide rail offset
- Minimum guide rail clearance
- Stem factor
- Stroke time
- Disk weight
- Minimum flow resistance coefficient
- Equivalent valve factor
- Valve inlet diameter

These new outputs do not affect the PPM prediction of required thrust/torque.

Improvements in Program Automation

With Versions 1.0 and 2.0 of the PPM, users were required to perform many tasks manually, outside the PPM software. For example, users were required to:

- Perform hand calculations to determine PPM input values (e.g., guide rail offsets for the positive and negative offset runs)
- Adjust input values (e.g., for the Equivalent Resistance Method, the supply tank pressure was set to the design basis upstream pressure)
- Perform calculations to obtain required thrust/torque predictions (e.g., unwedging load for gate valves and required torque for globe valves)

Version 3.1 of the PPM performs these tasks automatically using the equations and methods in Reference (3). For determining inputs, the user has the option of inputting a value or allowing the PPM to calculate a value. The tasks listed below are performed automatically by Version 3.1 of the PPM. *This automation does not make any changes in the PPM methodology.*

1. Implementation of the "blowdown unpredictability screen" (page 5-1 of Reference 3). New inputs for this screen are flow type (pumped flow or blowdown), maximum body guide width and minimum disk slot width.

2. Implementation of the PPM unwedging equation (Equation 5-3 of Reference 3).

3. Execution of the gate valve module for both the positive and negative offset runs, using the appropriate fluid temperatures (page 3-29 of Reference 3). The user is prompted for the minimum and maximum design basis temperatures. The results from both runs are incorporated into a single prediction report.

4. Execution of the appropriate technical modules for both the opening and closing strokes, if applicable. The results are incorporated into a single prediction report.

5. Substitution of guide materials for gate valves. If the disk and body guide materials are both stainless steel, carbon steel is automatically specified for the prediction (page 3-10 of Reference 3). If the maximum **–Content deleted, EPRI Proprietary Material--,** a message is printed in the prediction report indicating the results are "best available information."

   Note that PPM Error Notice 2001-1(Reference 4) and associated report (Reference 5), address evaluation of gate valves with stainless steel guides using the PPM. The software specification for Version 3.0/3.1 of the PPM was developed prior to issuance of this error notice and no coding changes have been made to address it. Accordingly, users of Version 3.1 will need to address this error notice when evaluating gate valves with stainless steel guides. This error notice has been issued by EPRI to all users of the PPM and is currently included with all Version 3.1 distributions.

6. Implementation of the equivalent resistance method (ERM). The user is prompted for the system evaluation method to be used. If the user selects the ERM, Version 3.1 implements the ERM as described on pages 5-3 through 5-5 of Reference (3). For example, the supply tank pressure is set to the design basis upstream pressure, and the system equivalent length is calculated using Equation 5-2 of Reference (3).

7. Implementation of the Single Point Method (SPM) for globe valves. The user is prompted for the system evaluation method to be used. If the user selects the SPM, Version 3.1 implements the SPM as described on page 5-13 of Reference (3). In addition, for subcooled water applications, the user is prompted for the upstream and downstream pipe inertias, and the effect of water inertia on the design basis DP and upstream pressure is calculated and applied per Equation 5-4 of Reference (3).

8. Calculation of required torque for self-actuating globe valve strokes. If a globe valve stroke is determined to be self-actuating, Version 3.1 implements Equation 5-5 of Reference (3) to calculate the required torque.

9. Implementation of the BFM Steam Method for butterfly valves. The user is prompted for the system evaluation method to be used. If the user selects the BFM Steam method, Version 3.1 implements the BFM Steam method as described on pages 5-16 and 5-17 of Reference (3).

10. Determination of "Stem orientation" for gate valves. The user is prompted for the "Stem orientation from vertical," and Version 3.1 determines whether the "Stem orientation" should be set to vertical or horizontal, per the guidance on page 3-13 of Reference (3).

11. Determination of the bearing coefficient of friction (COF) for butterfly valves. The user is prompted for the bearing material and fluid condition (clean water or raw water), and Version 3.1 determines the appropriate default bearing COF, per the guidance on page 3-22 of Reference (3).

12. Determination of the seat torque coefficient for butterfly valves. If the user chooses to use the default PPM seat torque prediction, the seat torque coefficient is determined automatically in Version 3.1, based on the guidance on pages 3-23 and 3-24 of Reference (3).

13. Implementing PPM Error Notice 97-01 (Reference 7). This error notice indicates that for self-actuating globe valve strokes, the required thrust should not be set below the packing load for opening strokes or below the packing plus stem rejection load for closing strokes. Version 3.1 addresses this error notice by setting the maximum required thrust in the prediction report equal to the greater of the PPM prediction and the packing load for opening strokes and the greater of the PPM prediction and the packing plus stem rejection load for closing strokes.

14. Calculation of selected inputs. The following inputs are calculated or determined automatically based on existing (in Version 2.0) and new (in Version 3.1) inputs.
    - Water inertia. The user is prompted for the piping lengths and diameters.
    - Disk weight (gate valves). No new inputs are required.
    - Body rail misalignments for positive/negative offset runs (gate valves). No new inputs are needed.
    - Full stroke length (gate valves). The seat ring inside diameter is used as the default value.
    - Stem factor (gate valves). The user is prompted for the stem pitch, lead and thread type.
    - Inlet diameter. The user is prompted for the valve size and pressure class.
    - Stroke time. The user is prompted for the overall ratio, the motor speed and (for butterfly valves) the HBC ratio.
    - Minimum flow resistance coefficient. No new inputs are needed.
    - Stem added length. No new inputs are needed.

Minor Changes to Methodology

Five minor changes were made to the methodology in Version 3.1. These five changes are discussed below, along with the reasons they were implemented and the effect of each change on PPM predictions of required thrust and torque.

Implementation of System Flow Module

The System Flow Module has many features that are not needed for typical PPM predictions. For example, the System Flow Module evaluates two valves in parallel stroking simultaneously and allows the user to model the head versus flow characteristic of a pump. Since nuclear plants typically define design basis conditions for their valves using conservative assumptions, such as pumps being at shutoff head and all parallel lines being closed, these features are not typically used. In Version 3.1, System Flow Module features that are not typically used are "disabled." To reflect this change, the wording of the applicability limitations for use of the System Flow Module is changed. Table 2-1 shows the wording changes. These changes do not affect PPM thrust and torque predictions.

Design Basis Temperatures Used for Gate Valves

In Versions 1.0 and 2.0, the user is prompted for a single design basis temperature. This temperature is used for both the System Flow Module and the various valve modules. For gate valves with a range of design basis temperatures, Reference (3) provides guidance to the user for selecting the temperatures to be used for the positive and negative offset runs (page 3-29 of Reference 3). This guidance is based on maximizing the coefficients of friction (COFs) used in the Gate Valve Module. The positive offset run maximizes the seat COF, and the negative offset run maximizes the guide COF.

Because the same temperature is used for both the System Flow Module and the Gate Valve Module, the positive and negative offset runs may require different system flow modeling methods. For example, if a gate valve has carbon steel disk and body guides and a range of design basis temperatures from 70°F to 500°F, the positive offset run will use the Equivalent Resistance Method, and the negative offset run will require the Full System Flow Model. This added complication in implementing the PPM for gate valves is unnecessary since the effect of the temperature on gate valve friction is the major effect, and the effect on the System Flow Module is a minor effect.

To facilitate implementation of the PPM for gate valves, Version 3.1 prompts the user for the minimum and maximum design basis temperatures and uses the appropriate value in the Gate Valve Module for the positive and negative offset runs (per Reference 3). However, Version 3.1 always uses the minimum temperature in the System Flow Module. To evaluate the effect of this approach on the predicted DP profile, several PPM System Flow Model predictions were run. All inputs were the same in each run except the temperature and the fluid medium. Runs were made with subcooled water as the fluid medium and temperatures of 70°F, 100°F, 130°F and 160°F, and with flashing water as the fluid medium and temperatures of 220°F, 250°F and 280°F. **Figure 2-1** is a plot of the DP profiles for these seven predictions. As shown, the temperature has a negligible effect on the predicted DP profile except near the fully closed position (0% open). Near fully closed, multiple choking occurs for the three flashing water predictions, resulting in a lower DP across the valve, as compared to the predictions at lower temperatures. This result suggests that use of a lower temperature is conservative (i.e., result in a higher predicted DP) under some conditions.

Application of the PPM to AOVs and HOVs

Version 3.1 provides required thrust/torque predictions for air-operated valves (AOVs) and hydraulically-operated valves (HOVs). This change was made to allow nuclear plants to apply the PPM to these valve types. The user is prompted for the actuator type (MOV, AOV or HOV), and for AOVs and HOVs, the following adjustments are made to the technical module input values.

Water Inertia

For AOVs and HOVs, water inertia is not a concern because water inertia is a transient effect, and actuator output is continuous for AOVs and HOVs. Accordingly, Version 3.1 sets pipe inertias to zero for AOVs and HOVs.

Torque Reaction Friction

Unlike an MOV, the actuator for an AOV or an HOV does not transmit any torque to the valve stem that needs to be reacted. Accordingly, Version 3.1 adjusts inputs related to the torque reaction effect to minimize the calculated torque reaction load. For gate valves, *External torque restraint*" is specified as "yes," the *Friction conditions at torque reaction surface* is set to "low friction," the *Torque arm length* is set to 99.99 and the *Stem factor* is set to 0.0001. This approach results in **–Content Deleted, EPRI Proprietary Material--** for every 100,000 pounds of required stem thrust.

For globe valves, the *Stem motion* is set to "rising/rotating." The only effect of this change is to set the torque reaction factor to 1 (which sets the torque reaction friction to zero), which provides an accurate prediction of required thrust. There is no torque reaction effect for butterfly valves.

For globe and butterfly valves, the changes described above for AOVs and HOVs have no effect on the PPM prediction of required thrust/torque. For gate valves, the torque reaction component of the PPM thrust prediction for AOVs and HOVs will be slightly conservative.

For air-operated butterfly valves, actuator output capability typically varies with disk angle; therefore, it is important to determine required torque as a function of disk angle. Since the PPM was originally developed for MOVs, for which only the maximum required torque is important, obtaining stem torque versus disk angle is not straight-forward. Information Notice 2002-1 (Reference 6) provides guidance to users in obtaining predicted design basis stem torque versus disk angle from a PPM prediction report for all versions of the PPM, including Version 3.1. Information Notice 2002-1 also provides guidance for use of the results. Specifically, the information notice indicates that results for incompressible flow applications should be considered “best available information,” and results for compressible flow applications (which set the required torque at all disk positions to the maximum predicted torque) are bounding, design basis predictions.

Calculation of Unwedging Thrust and Maximum Allowable Closing Thrust

Reference (3) provides an equation for predicting the required unwedging load for gate valves (Equation 5-3). An input to this equation is the maximum closure thrust; the required unwedging thrust increases with increased valve closure thrust. This equation can be implemented by using the actual maximum closure thrust from a static test and predicting the associated required unwedging thrust. However, most users of Versions 1.0 and 2.0 have found that this approach is not desirable because any change in the actual maximum closure thrust necessitates a change in the calculation.

The approach typically used is to input the maximum allowable closing thrust (which is an administrative limit) as the maximum closure thrust and compare the predicted unwedging thrust to the actuator capability for opening. If the required unwedging thrust is less than the actuator opening capability, then the actuator is verified to have sufficient capability to unwedge the valve disk as long as the maximum allowable closing thrust is not exceeded. If the required unwedging thrust is greater than the actuator opening capability, then a new maximum allowable closing thrust is calculated using the actuator opening capability as the required unwedging thrust. The administrative limit is then changed (i.e., decreased) to this calculated value to ensure margin for unwedging the valve disk.

In Version 3.1, the user is prompted for the maximum allowable closing thrust and the actuator opening capability, and the approach described above is implemented. This change does not affect unwedging thrust predictions but is a change in the implementation approach.

Pipe Roughness for System Calculations

In Version 3.1, the pipe roughness (page 3-5 of Reference 3) is automatically set to 0.00015 feet. This value is applicable for commercial steel piping per Reference (8). This change was made to facilitate implementation of the PPM. There should be no effect on the PPM required thrust/torque predictions, since a pipe roughness of 0.00015 feet is expected to be appropriate for valves that would be evaluated using the PPM.

Table 2-1.
Changes in System Model Applicability Wording[(1)]

Category	Feature	Range of Applicability
General	System type	Pump flow or blowdown
	System boundaries	System must have boundaries that can be modeled as constant pressure~~, or as a pre-determined time-dependent pressure for source tank~~.
Pump systems	Fluid medium	Subcooled water throughout system (up to 3000 psia, 700°F).
	Configuration	System must be modelable (reducible) as a single flow path ~~one of Configurations 1-3 shown in Figure 3-1~~.
	Piping System ~~for main flow path~~	Flow path from source tank to pump to MOV to discharge tank must be modelable as equivalent pipe segments.
	~~Pump characteristics~~	~~System must be modelable as a single pump between source tank and MOV.~~
	~~Pump recirculation line (optional)~~	~~Must be modelable as a single line from pump discharge back to source tank.~~
	~~Bypass line (optional)~~	~~Must be modelable as a single line to a separate discharge tank.~~
Blowdown systems	Fluid medium (at the valve)	Subcooled water, two-phase water and steam, or steam up to 3000 psia, 700°F.
	Configuration	System must be modelable as a single flow path ~~from source tank to MOV to discharge tank, as shown in Configuration 4 of Figure 3-1~~.
	Flow restrictors (optional)	Single flow restrictor in each of upstream and downstream piping.

Note (1): Text with gray background is added in Version 3.1. Text shown in "strikethrough" font is deleted in Version 3.1.

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Figure 2-1.
DP versus Stroke Position for Various Fluid Temperatures

3
CONCLUSIONS

The most significant change in Version 3.1 of the PPM is that a Windows-based user interface replaces the DOS-based user interface in Versions 1.0 and 2.0. This change has no effect on PPM thrust and torque predictions. The other changes in Version 3.1 of the PPM can be classified into the following three categories, as discussed in Section 2.

- Changes to improve prediction report documentation do not affect PPM thrust and torque predictions.
- Improvements in program automation do not affect PPM thrust and torque predictions.
- Minor changes to the methodology do not affect the bounding nature of PPM thrust and torque predictions. Specifically:
    - The disabling of some of the System Flow Module functionality and use of a pipe roughness of 0.00015 do not affect PPM thrust and torque predictions.
    - A revised method for implementing the PPM unwedging equation is a change in the implementation approach but not a change in the thrust predictions.
    - Application of the PPM to AOVs and HOVs is an extension of the applicability of the PPM that is justified based on the adjustments made to technical module inputs.
    - Use of the minimum design basis temperature for all System Flow Module runs has a negligible (conservative) effect on PPM thrust and torque predictions.

Based on these changes in Version 3.1 of the PPM, it is concluded that the validation and assessment of Version 2.0 of the PPM is applicable to Version 3.1.

4
REFERENCES

1. EPRI Report AD-110778, *EPRI MOV Performance Prediction Program Addendum 1 to EPRI TR-103237-R2*, October 1998.

2. EPRI Report 1006206, *EPRI MOV Performance Prediction Program: Performance Prediction Methodology (PPM) Version 3.0 User Manual and Implementation Guide*, July 2001.

3. EPRI Report TR-103244-R2, *EPRI MOV Performance Prediction Program Implementation Guide*, Revision 2.

4. EPRI PPM Software Error Notice 2001-1, May 2001

5. EPRI Report 1002847, *Updated Guidance for Use of PPM for Gate Valves with Stainless Steel Guides*, May 2001.

6. EPRI PPM Software Information Notice 2002-1, Prediction of Butterfly Valve Design Basis Required Torque as a Function of Disk Position, May 2002

7. EPRI PPM Software Error Notice 97-01, April 4, 1997

8. Crane Technical Paper #410

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