EPRI MOV Performance Prediction Program

Addendum 6 to TR-103237-R2: PPM Version 3.2 Software Changes-NP

1009032NP

Final Report, May 2004

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PRODUCT DESCRIPTION

This addendum to EPRI report TR-103237-R2 (EPRI MOV Performance Prediction Program topical report) documents changes made to the EPRI Motor-Operated Valve (MOV) Performance Prediction Methodology (PPM) computer code between Version 3.1 and Version 3.2. Two changes were made to the user interface module addressing butterfly valve module predictions. 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.

Results & Findings

This report documents the changes made in going from EPRI PPM Version 3.1 to Version 3.2 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. An error in the handling of upstream piping disturbances was corrected, and the best-estimate "torque signature" predictions were replaced with a "design basis" torque predictions as a function of disk opening angle.

Challenges, Objectives

- To describe the changes made between Version 3.1 and Version 3.2 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

Applications, Values & Use

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 flow and differential pressure conditions.

EPRI Perspective

Addendum 6 to the EPRI MOV Performance Prediction Program topical report adequately demonstrates that PPM code modifications made between Versions 3.1 and 3.2 do not affect the code's predictive capability. This Addendum can be used as a basis for Nuclear Regulatory Commission (NRC) review and issuance of a Safety Evaluation approving use of Version 3.2 for design basis MOV thrust and torque predictions.

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). Two changes were made in the handling of butterfly module predictions. An error in the handling of upstream piping disturbances was corrected, and the best-estimate "torque signature" predictions were replaced with a "design basis" torque prediction as a function of disk opening angle.

Keywords

Valves
Performance
Motor-operated valves
Software tools

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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 included 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]) describes the changes in Version 2.0 and documents the results of re-assessment of the PPM using Version 2.0, to demonstrate that Version 2.0 provided 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. EPRI 1006930 (Reference [3]) describes the changes from Version 2.0 to Version 3.1.

Version 3.2 of the PPM has now been developed. This version corrects minor errors found in the software and incorporates a design change related to butterfly valve torque predictions. A new user manual/implementation guide has also been prepared (Reference [4]).

Purpose

The purpose of this report is to describe the changes made in going from Version 3.1 to Version 3.2 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.

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SUMMARY OF CHANGES IN VERSION 3.2

PPM Error Notice 2003-1 – Effect of Upstream Disturbances

Error Notice 2003-1, which is included in Appendix A, alerted users to an error in the PPM's calculation of the effect of upstream disturbances on the calculated hydrodynamic torque for butterfly valves. Specifically, in Versions 3.0 (Build 3.0.50) and 3.1 (Build 3.1.8) of the PPM, if the user checks the box next to *Upstream disturbance within 8 pipe diameters of valve* (indicating that there is an upstream disturbance within eight pipe diameters) and inputs a value of zero for the *Proximity in pipe diameters*, the following occurs when a prediction is run:

- The prediction is run based on *no* upstream disturbance within eight pipe diameters.
- The "Valve Inputs" section of the prediction report indicates that the user specified that there is no upstream disturbance within 8 pipe diameters (that is, the results in the prediction report are consistent with the inputs listed in the prediction report).
- In the PPM input form, the check box next to *Upstream disturbance with 8 pipe diameters of valve* is unchecked (indicating that there is *not* an upstream disturbance within eight pipe diameters).

The effect of this error is that the predicted torque requirement may be non-conservative for the inputs specified by the user. (However, as discussed above, the predicted torque requirement is consistent with the user inputs shown in the prediction report.) This error was corrected in Version 3.2 of the PPM.

PPM Information Notice 2002-1 – Butterfly Valve Output

Information Notice 2002-1, which is included in Appendix B, was issued to clarify the meaning of the various butterfly valve torque predictions made by the PPM and to provide procedures for obtaining design basis required torque predictions as a function of disk angle. Version 3.1 and earlier versions output only the maximum design basis required torque, which bounded the entire stroke. A "best estimate" torque was also output as a function of disk angle (for information only). The user could view the best estimate torque either as a table in the prediction report or as a plot.

In Version 3.2 of the PPM, the best estimate torque predictions are eliminated, and design basis torque predictions are made as a function of disk angle. Design basis torque predictions are now displayed in the prediction report torque tables and in the torque plots.

Other Minor Changes

Several other minor changes were made to correct typographical or other minor errors in the software. For example:

- In the prediction report and input forms printout, the title for the user-input friction coefficient section for gate valves was corrected from "Upstream Disturbance Information" to "Friction Coefficients."
- Flows, DPs, and thrusts/torques in the prediction report tables were rounded to the nearest whole number.
- Calculated stroke times were rounded to the nearest tenth of a second.
- "EPR" was corrected to "EPRI" in the Applicability table in the user-defined report.
- "7000°F" was corrected to "700°F" in the Applicability table in the user-defined report.
- For butterfly valves, the prediction report column labeled "Required Torque" was labeled "Total Torque," consistent with previous versions of the software.

None of these changes affects the PPM methodology.

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CONCLUSIONS

The following changes are made in Version 3.2 of the PPM:

- The error documented in PPM Error Notice 2003-1 was corrected.
- "Best estimate" butterfly valve torque predictions, which users were not allowed to use for setting up valves, were eliminated, and design basis torque predictions as a function of disk angle were added.
- Changes to address minor interface errors, which did not affect thrust or torque predictions, were made.

Version 3.2 was developed in accordance with a Quality Assurance Program that satisfies 10 CFR 50, Appendix B. All software changes from Version 3.1 to Version 3.2 were documented and independently verified. The modified software was independently validated in accordance with a written test plan to verify that the software performed its required functions. A verification and validation report summarizes the requirements, design, and testing of Version 3.2 of the PPM and documents the results of validation testing.

Because the changes in Version 3.2 do not reflect any changes in the PPM methodology or its implementation approach, it is concluded that the validation and assessment of Version 2.0 of the PPM is applicable to Version 3.2.

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REFERENCES

1. *EPRI MOV Performance Prediction Program Addendum 1 to EPRI TR-103237-R2*, EPRI, Palo Alto, CA: 1998. AD-110778.

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

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

4. *EPRI MOV Performance Prediction Program: Performance Prediction Methodology (PPM) Version 3.2 User Manual and Implementation Guide*, EPRI, Palo Alto, CA: 2003. 1009031.

A
PPM ERROR NOTICE 2003-1

MPR ASSOCIATES INC. ENGINEERS

Enclosure (1) to
MPR Letter Dated
April 9, 2003

PPM Software Error Notice 2003-1

Error Classification: Class 1[1]

Affected Versions of PPM: Version 3.0 (Build 3.0.50) and Version 3.1 (Build 3.1.8)

Background

The EPRI MOV Performance Prediction Methodology (PPM) evaluates common gate, globe and butterfly valves for required thrust or torque under design basis conditions. For butterfly valves, the hydrodynamic torque is one of the components that make up the total required torque. The hydrodynamic torque is the stem torque required to overcome loads imposed by the fluid on the valve disk. The required hydrodynamic torque can be affected by disturbances upstream of the valve. These disturbances can lead to velocity skews that increase the torque to rotate the disk. If there is a disturbance within eight pipe diameters of the valve, the user is required to input the *Proximity in pipe diameters* of the disturbance. The closer the disturbance is to the valve inlet, the more pronounced the effect of the velocity skew on the required hydrodynamic torque.

Description of Error

In Versions 3.0 (Build 3.0.50) and 3.1 (Build 3.1.8) of the PPM, if the user inputs a value of zero for the *Proximity in pipe diameters*, the effect of the upstream disturbance on the required torque is not properly incorporated, potentially resulting in non-conservative predictions of required torque. Note that the "Valve Inputs" section of the PPM prediction report indicates that there is no upstream disturbance with 8 pipe diameters, even though the user specified an upstream disturbance at 0 pipe diameters. This error may affect the maximum predicted torque if the hydrodynamic torque opposes disk motion (all opening strokes and closing strokes of offset disk valves with shaft downstream). For cases where the maximum predicted torque occurs at or near the fully closed position, the effect is expected to be very small (or zero).

Corrective Action

To avoid this error, users should input 0.0001 pipe diameters for cases where the actual proximity is 0 pipe diameters. This difference (performing the calculation with 0.0001 rather than 0) is judged to have a negligible effect on the accuracy of the PPM results.

QUALITY ASSURANCE DOCUMENT This document has been prepared, reviewed and approved in accordance with the Quality Assurance requirements of 10CFR50, Appendix B, as specified in the MPR Quality Assurance Manual.	Prepared by Thomas Walker Reviewed by Paul S. Damerell Approved by Paul S. Damerell

[1] A Class 1 error is an error that allows the program to execute to completion and, under certain circumstances, report incorrect results that are not easily identifiable as incorrect.

B
PPM INFORMATION NOTICE 2002-1

May 6, 2002

PPM Software Information Notice 2002-1 (Prediction of Butterfly Valve Design Basis Required Torque as a Function of Disk Position)

Background

The EPRI MOV Performance Prediction Methodology (PPM) is a validated tool for evaluating the required thrust or torque to stroke gate, globe, and butterfly valves. Version 1.0 of the PPM was issued in 1995. Version 2.0, which corrected minor errors in Version 1.0, was issued in 1998. Version 3.0, which included an upgraded user interface developed for the Windows operating system, was issued in 2001. Version 3.1 was issued in late 2001 and corrected a coding error found in Version 3.0.

The PPM Butterfly Valve Module within the PPM was originally developed to conservatively predict torque requirements for motor-operated valves (MOVs). For this purpose, only a single design basis maximum required torque, which bounds the entire stroke, was needed because MOV actuator capability is relatively constant with stroke position. In recent years, the PPM has been used to predict torque requirements for air-operated butterfly valves. Because air actuator capability is generally stroke position dependent, it is important to make required torque predictions throughout the entire stroke. This information notice is being issued to provide an approach for determining design basis required torque versus disk position when using the PPM software, based on guidance provided in the Butterfly Valve Model report (Reference [1]).

Purpose

The purpose of this information notice is to clarify the meaning of the various torque predictions included in PPM prediction report for butterfly valves and to provide procedures for making design basis required torque predictions as a function of disk angle.

Discussion

PPM Torque Predictions

The summary section of the PPM prediction report (page 1 in Version 3.0/3.1, and page 2 in Version 1.0/2.0) provides the following single value torque predictions:

1. Required Actuation Torque: This single value prediction is the motive torque that must be provided by the actuator to rotate the valve disk in the specified stroke direction. It is the larger of the Total Seating/Unseating Torque (Item 2 below) and the Total Dynamic Torque (Item 4 below). The Required Actuation Torque is the design basis maximum required torque for use in MOV actuator sizing and torque switch setting. *The PPM does not provide design basis required torque as a function of disk position. However, values can be obtained using the procedures detailed in this information notice.*

2. **Total Seating/Unseating Torque:** This single value prediction is the maximum required torque to seat (closing strokes) or unseat (opening strokes) the disk.

3. **Maximum Transmitted Torque (including the disk angle at which it occurs):** This single value prediction is the maximum stem torque (magnitude and disk angle) predicted by the model throughout the stroke. It is equal to the larger of the Required Actuation Torque (item 1 above) and the peak hydrodynamic torque throughout the stroke. This torque value is provided for weak-link evaluation of the valve and the actuator and is not required to be provided by the actuator.

4. **Total Dynamic Torque (including the disk angle at which it occurs):** This single value prediction is the maximum total dynamic torque (magnitude and disk angle) required to rotate the disk in the specified direction and covers disk angles greater than 0°. This torque value does not take credit for hydrodynamic torque when it assists disk motion.

In addition to the above torque predictions, the PPM report provides a Torque Signature (T_{SIG}) prediction as well as all individual torque components at 1° increments of disk angle from 0° to 90°. The T_{SIG} prediction is listed in the first torque column in the torque table and it is the algebraic sum of all the torque components at each disk angle. *In PPM Versions 1.0 and 2.0, the Torque Signature (T_{SIG}) prediction is labeled as Total Torque (ft-lb). In Versions 3.0 and 3.1, it is labeled as Required Torque.*

T_{SIG} is an estimate of total torque as a function of disk angle, and was provided to assist utility engineers in interpreting test data. **T_{SIG} takes credit for hydrodynamic torque when it assists disk motion. Consequently, it is non-conservative to use T_{SIG} as the design basis required torque when the hydrodynamic torque component assists disk motion.**

Obtaining Design Basis Required Torque Values versus Stroke Position

Incompressible Flow Conditions

To obtain predicted design basis required torque values as a function of disk angle for incompressible flow applications, the T_{SIG} values (Labeled "Total Torque" or "Required Torque") must be adjusted. The procedure for performing this adjustment is provided below.

1. Run the PPM using guidance in References (2), (3) and (4), and print out the prediction report, including the detailed torque table(s).

2. Review each row of the torque table(s).

3. If the hydrodynamic torque shown in the torque table is positive, then the T_{SIG} value shown (in the *Total Torque* or *Required Torque* column) is the design basis required torque value at that stroke position.

4. If the hydrodynamic torque shown in the torque table is negative, then the T_{SIG} value must be adjusted to obtain the design basis required torque. If the valve has a symmetric disk or a single offset disk installed with the shaft upstream, then the absolute value of the hydrodynamic torque should be added to the T_{SIG} value to obtain the design basis required torque at that disk angle. If the valve has a single offset disk installed with the shaft downstream, then *twice* the absolute value of the hydrodynamic torque should be added to the T_{SIG} value to obtain the design basis required torque at that disk angle.

5. By performing steps 3 and 4 for each disk angle in the torque table, a design basis required torque versus disk angle prediction is obtained. This procedure is summarized in the table below:

Disk Type	Shaft Orientation	Design Basis Required Torque	
		For Negative Hydrodynamic Torque	For Positive Hydrodynamic Torque
Symmetric	N/A	$=T_{SIG}$ + Absolute Value of T_{HYD}	$=T_{SIG}$
Single Offset	Shaft Upstream	$=T_{SIG}$ + Absolute Value of T_{HYD}	$=T_{SIG}$
	Shaft Downstream	$=T_{SIG}$ + 2 * Absolute Value of T_{HYD}	$=T_{SIG}$

Example

The butterfly valve benchmark problem in Appendix C of Reference (2) is used as an example. The torque table is shown on pages 9 -14 of that prediction report. As shown, the hydrodynamic torque is negative at all stroke position except 0° and 90°, where it is zero. As shown on page 4 of the prediction report, the valve has a symmetric disk. Therefore, the T_{SIG} values in the Torque Signature column must be increased by the absolute value of the hydrodynamic torque at every disk angle except 0° and 90°. The table below shows this adjustment for disk angles from 55° to 45°.

Values Printed in Prediction Report			Design Basis Required Torque (T_{SIG} + Absolute Value of Hydrodynamic Torque)
Disk Angle	T_{SIG} (Labeled Total or Required Torque)	Hydrodynamic Torque	
55°	1.7	-14.0	15.7
54°	1.9	-14.1	16.0
53°	2.0	-14.5	16.5
52°	2.1	-14.9	17.0
51°	2.2	-15.3	17.5
50°	2.5	-15.6	18.1
49°	2.6	-16.2	18.8
48°	2.9	-16.7	19.6
47°	3.3	-17.2	20.5
46°	3.7	-17.7	21.4
45°	3.8	-18.8	22.6

Compressible Flow Conditions

For compressible flow applications, References (3) and (4) require use of the PPM's BFM Steam system modeling approach. This method applies the maximum values of DP and inlet pressure throughout the entire stroke to ensure that a bounding value of maximum design basis required torque is obtained. For these strokes, the design basis required torque should be set equal to the Required Actuation Torque (from the prediction report summary) at all disk angles.

Use of Results

As discussed above, the PPM was developed for MOVs, and the emphasis of the butterfly valve model was to predict a single value of the maximum design basis required torque for the stroke. The PPM was validated and found to conservatively predict this maximum value.

For *incompressible flow* conditions, and when the adjustments described above were properly applied, the butterfly valve model was shown to provide bounding predictions of design basis required torque at all disk angles (except in isolated cases near the fully open position where required torque is low). However, there are variations in the flow coefficients at specific disk angles assumed by the PPM and those found within the butterfly valve population. Therefore, for incompressible flow conditions, users should consider the predicted design basis required torque values versus disk angle determined as described above as “best available information.”

For *compressible flow* conditions, use of the maximum required actuation torque (from the PPM Prediction Report Summary Table) at all disk positions will result in a bounding prediction of design basis required torque.

References

1. EPRI TR-103224, EPRI MOV Performance Prediction Program: Butterfly Valve Model Description Report, September 1994

2. EPRI TR-103243-R2, EPRI MOV Performance Prediction Program: Performance Prediction Methodology (PPM) Version 2.0 Software User Manual Revision 2, July 1998.

3. EPRI TR-103244-R2, EPRI MOV Performance Prediction Program: Performance Prediction Methodology Implementation Guide Revision 2, August 1998.

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