TIMOTHY RITI
Senior Project Manager, Regulatory Affairs

1201 F Street, NW, Suite 1100
Washington, DC 20004
P: 202.739.8137
txr@nei.org
nei.org

NUCLEAR ENERGY INSTITUTE

November 8, 2018

NRC Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Joseph Holonich Jr.

Subject: Follow up on Request for Additional Information on "EPRI MOV Performance Prediction Program: Addendum 10 to EPRI 103237-R2: PPM Version 4.0 Software Changes"

Project Number: 689

Dear Mr. Holonich:

Attached are the responses of the Electric Power Research Institute (EPRI) to the Request for Additional Information (RAI) on "EPRI MOV Performance Prediction Program: Addendum 10 to EPRI 103237-R2: PPM Version 4.0 Software Changes."

This letter, including the attachments, does not contain any EPRI proprietary information.

If there are any questions on this matter, please contact me at (202) 739-8037 or txr@nei.org, or John Hosler at (704) 252-0780 or jholser@epri.com.

Sincerely,

Timothy Riti

Attachment

c: Mr. Joseph Holonich Jr., NRR/DPR/PLPB, NRC
Mr. John Hosler, EPRI
Mr. James Heishman, EPRI
Mr. Thomas Walker, EPRI

EPRI Responses to
NRC Request for Additional Information Regarding
Addendum 10 to EPRI 103237-R2: PPM Version 4.0 Software Changes

NRC Question #1:

The submitted topical report details the changes made to the EPRI MOV Performance Prediction Program from software version 3.5 to 4.0. The major change was updating the software from a 32-bit platform to the latest Microsoft 64-bit environment and correcting noted software errors. The four DOS based technical modules (system flow model, glove valve module, butterfly valve module, gate valve module) were recoded from Microsoft QuickBasic to ANSI C. A complete line by line code review was completed and independently verified. Individual unit testing of each new ANSI C module using validation test cases designed to exercise all potential input options was completed comparing the results from each test case to results from the same test case performed with the original QuickBasic module. Please provide a few examples of the test cases performed that verify each module matched or exceeded those performed with the original PPM methodology.

EPRI Response:

The PPM modules were tested individually to compare the results from Version 4.0 to the results from Version 3.5. The results were documented in plots that show Version 4.0 predictions overlaid with Version 3.5 predictions. In all, there were 21 test cases for the system flow module (SFM), 33 test cases for the globe valve module (GLBM), 69 test cases for the butterfly valve module (BFM), and 50 test cases for the gate valve module (GATM). The test cases were selected to exercise all features/configurations within each of the four modules. Attachments 2-5 contain examples of typical comparison plots for the SFM, GLBM, BFM, and GATM test cases.

In all but three test cases, the results were consistent between the two versions. For the three cases with differences in the Version 3.5 and Version 4.0 results (GLBM #26, SFM #04, and SFM #08), two are attributable to code revisions in Version 4.0 that were made to correct errors. These errors were found in the legacy software while recoding the PPM for v4.0, and were evaluated in accordance with EPRI's Nuclear QA Program for potential effects on calculations previously performed with the software, and information and/or error notices regarding the legacy errors were distributed by EPRI to PPM users. The plots for these two cases are included in Attachment 6.

The third case showed slight differences in the plots that were assessed to be negligible. Based on the software verification and validation activities (including 100% line-by-line code review and unit testing), the small variations were attributed to the differences in the math processors used by the Microsoft Quick Basic and ANSI C compilers (for Versions 3.5 and 4.0, respectively). The differences do not significantly affect the overall thrust or torque predictions. The plots for this case are included as the last example in Attachment 6.

NRC Question #2:

Version 4.0 was revised to include an option to use the EPRI Refined Gate Valve Unwedging Methodology as defined in Addendum 3 to EPRI TR-103237-R2. Addendum 3 noted that this was an improved method to estimate the unwedging thrust required to open a gate valve from the wedged closed position. Please explain why in Version 4.0 that this is an option.

EPRI Response:

The original EPRI unwedging methodology, which was documented in EPRI TR-103237-R2 Dated April 1997, predicted the required unwedging thrust for a gate valve based on the maximum stem thrust achieved on the previous closing stroke, the stem thrust required to overcome packing friction, the maximum differential pressure (DP) for opening and key valve dimensions. The equation used in this methodology combines a term to predict the static unwedging thrust (required unwedging thrust with no DP applied) with a term to account for the effect of the opening DP. The original unwedging equation was validated against data from gate valve testing performed as part of the EPRI MOV Performance Prediction Program, and the predictions were bounding for 18 of the 19 test cases. The under-prediction for the one non-bounding case was 1%. Note that many PPM users have implemented this methodology by solving the equation for the maximum stem thrust achieved on the previous closing stroke, setting the required unwedging thrust to the actuator capability for the valve assembly and calculating a maximum allowable closing thrust. This value was then incorporated into the acceptance criteria for static diagnostic testing to ensure the valve would not be closed with a final closing thrust that would prevent the actuator from unwedging the valve.

The refined unwedging equation eliminates the term that predicts the static unwedging thrust and replaces it with the measured static unwedging thrust, which is a user input. Because there was conservatism in the prediction of the static unwedging thrust in the original unwedging methodology, the conservatism in the overall unwedging thrust prediction is reduced in the refined methodology. As stated in Addendum 3 to EPRI 103237-R2, the conservatism is reduced from an average of 41% with the original equation to 21% with the refined equation. Accordingly, both methods provide acceptable predictions of required unwedging thrust for gate valves that meet the applicability requirements.

Because both methods provide acceptable predictions and both have been accepted by the NRC, the PPM software allows either method to be used. Some PPM users may continue to use the original method because the results have already been incorporated into their MOV programs to determine the maximum allowable closing thrust, as discussed above.

Example Validation Plots for System Flow Module (SFM)

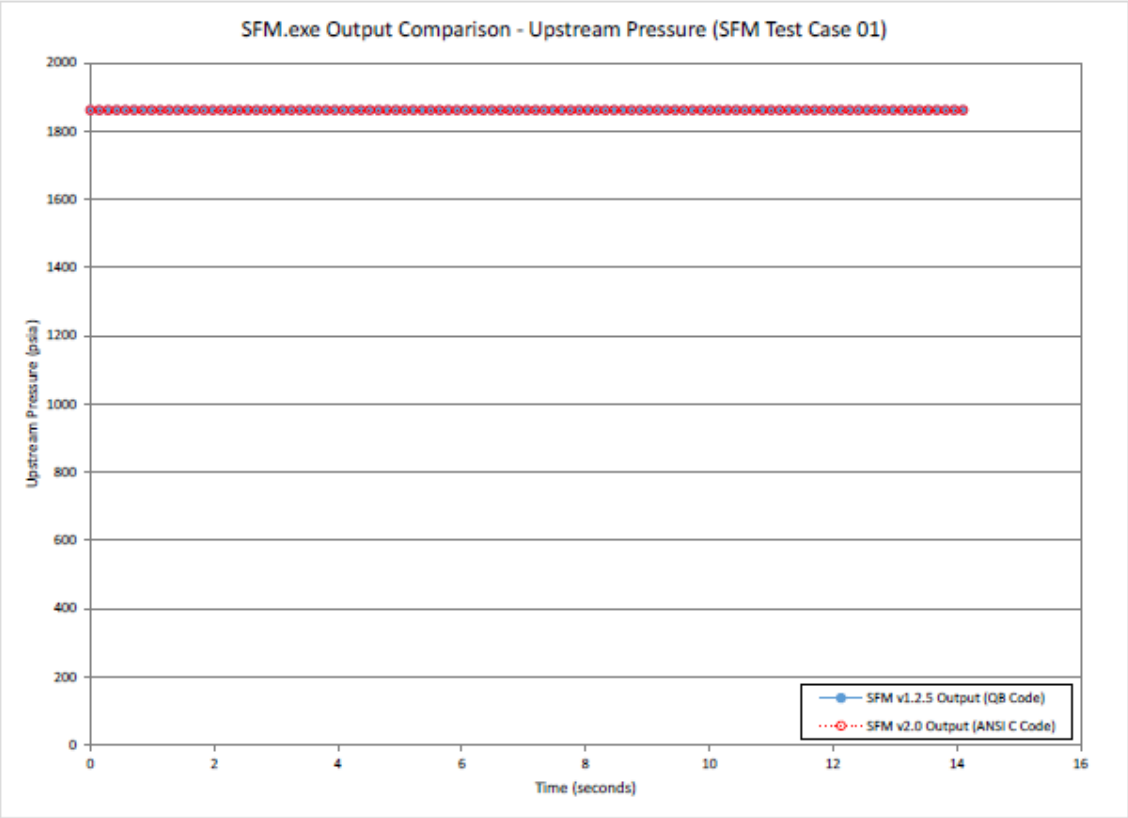
The following test cases are included:

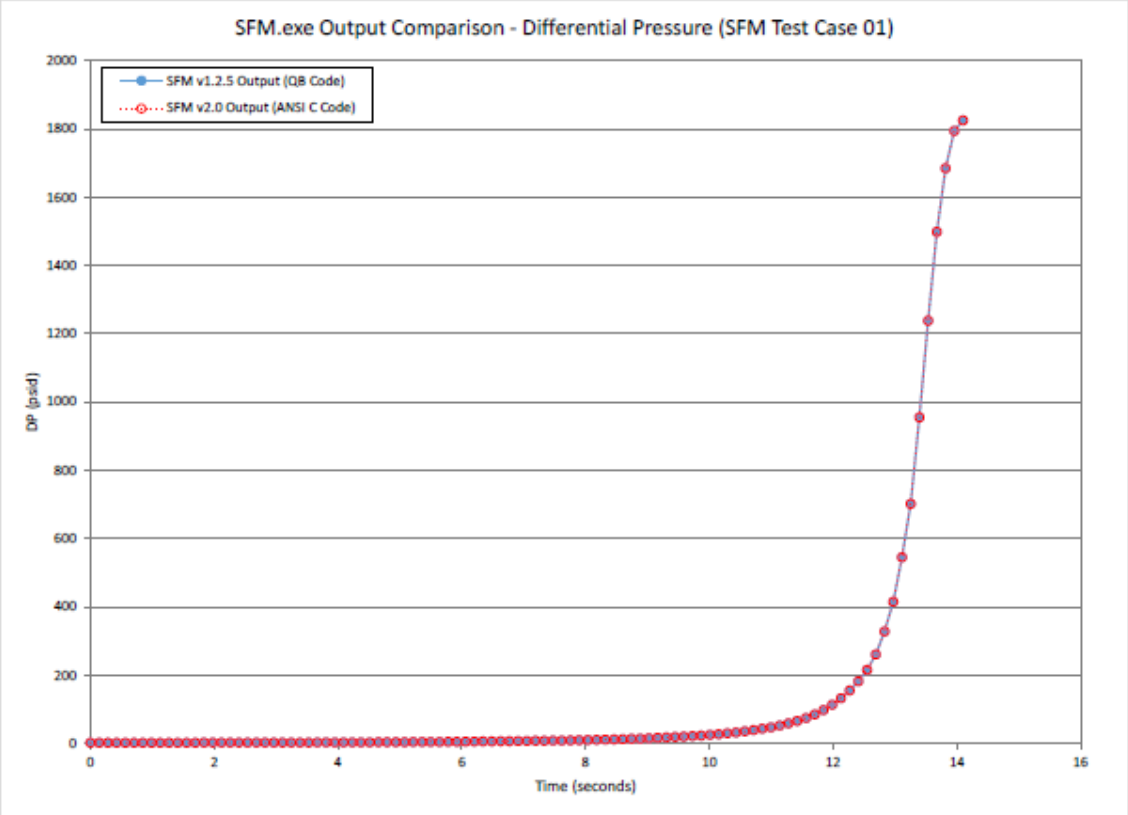
- Test Case 1: Equivalent Resistance Method analyzing a gate valve stroke with subcooled water with moderate flow rate
- Test Case 7: Full System Flow Model analyzing a gate valve stroke with two-phase fluid under blowdown conditions

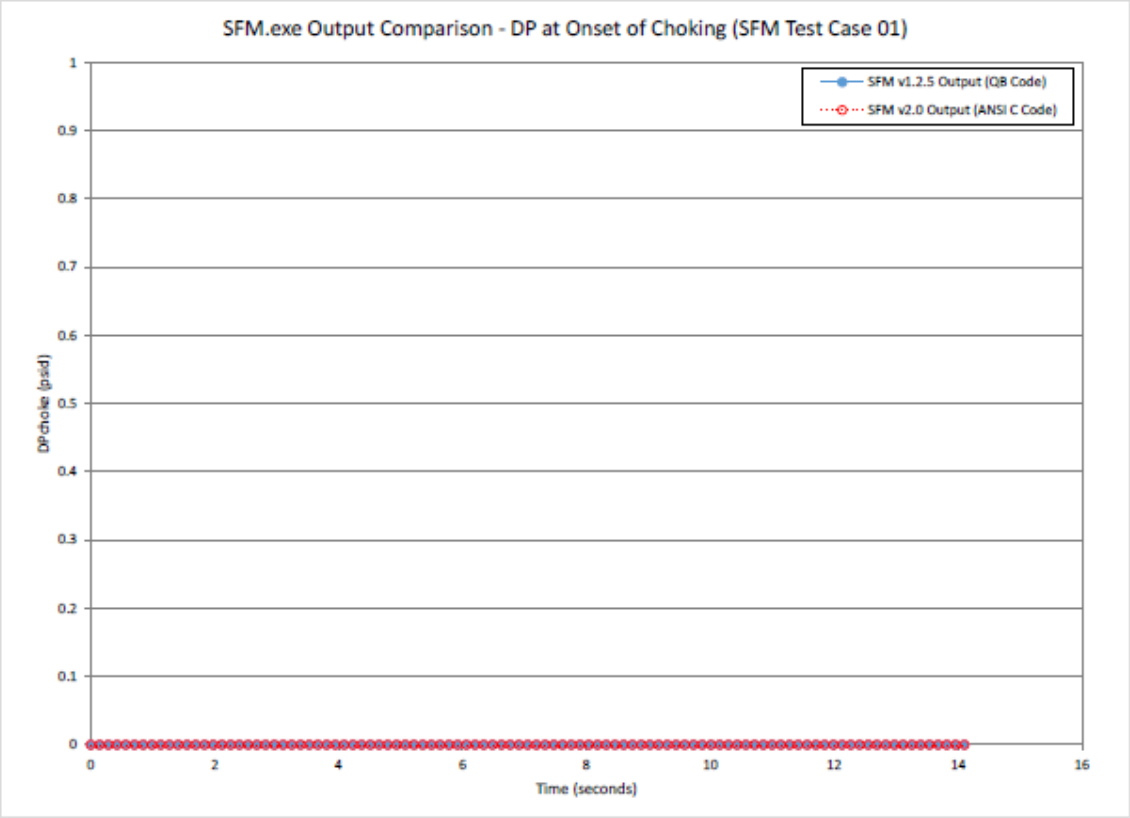
Note, as identified in the following plots,

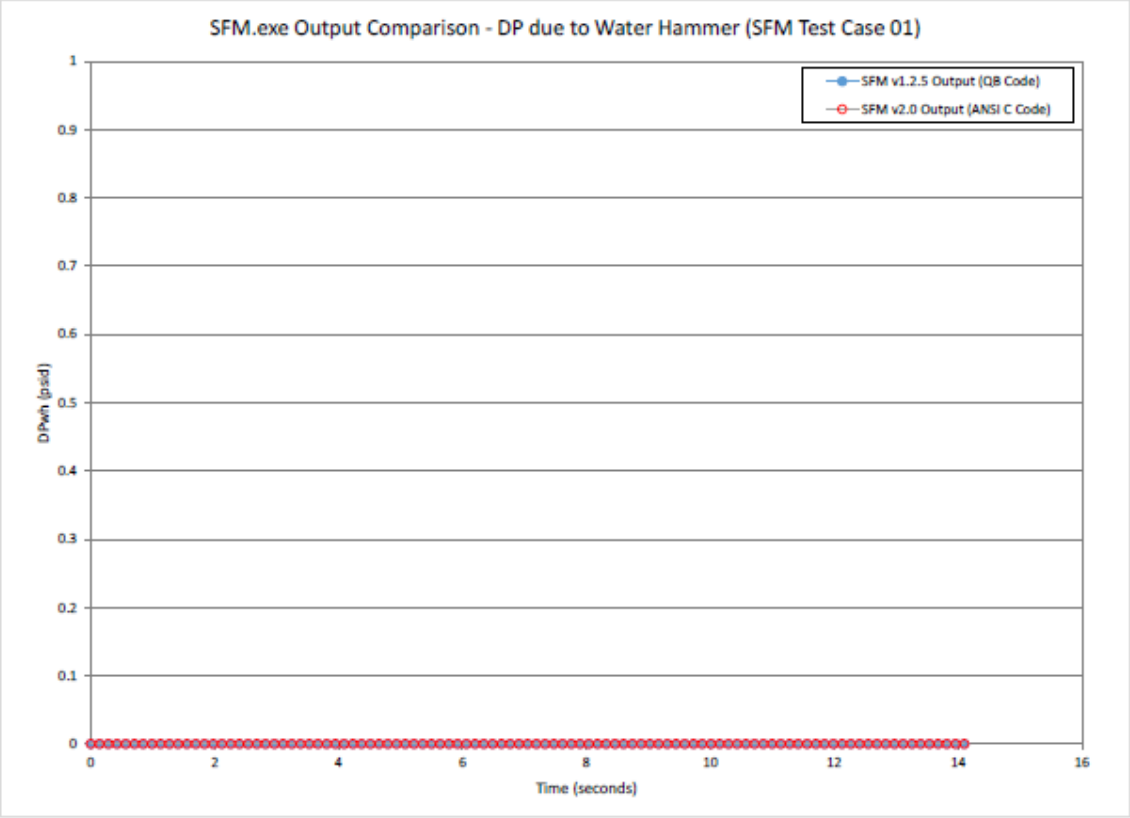
- SFM.exe v1.2.5 is the version of the SFM module that is included in overall PPM software v3.5 (i.e., QuickBasic version of the SFM module).
- SFM.exe v2.0 is the version of the SFM module that is included in the overall PPM software v4.0 (i.e., ANSI C version of the SFM module).

SFM Test Case 1

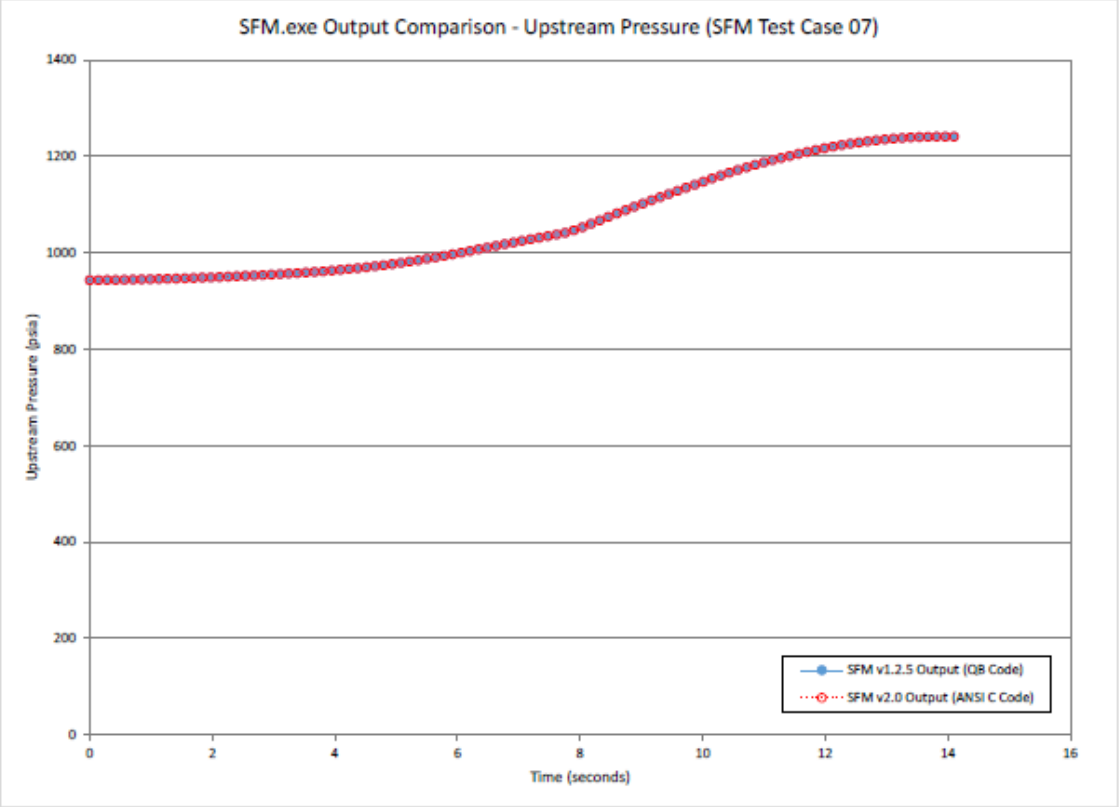


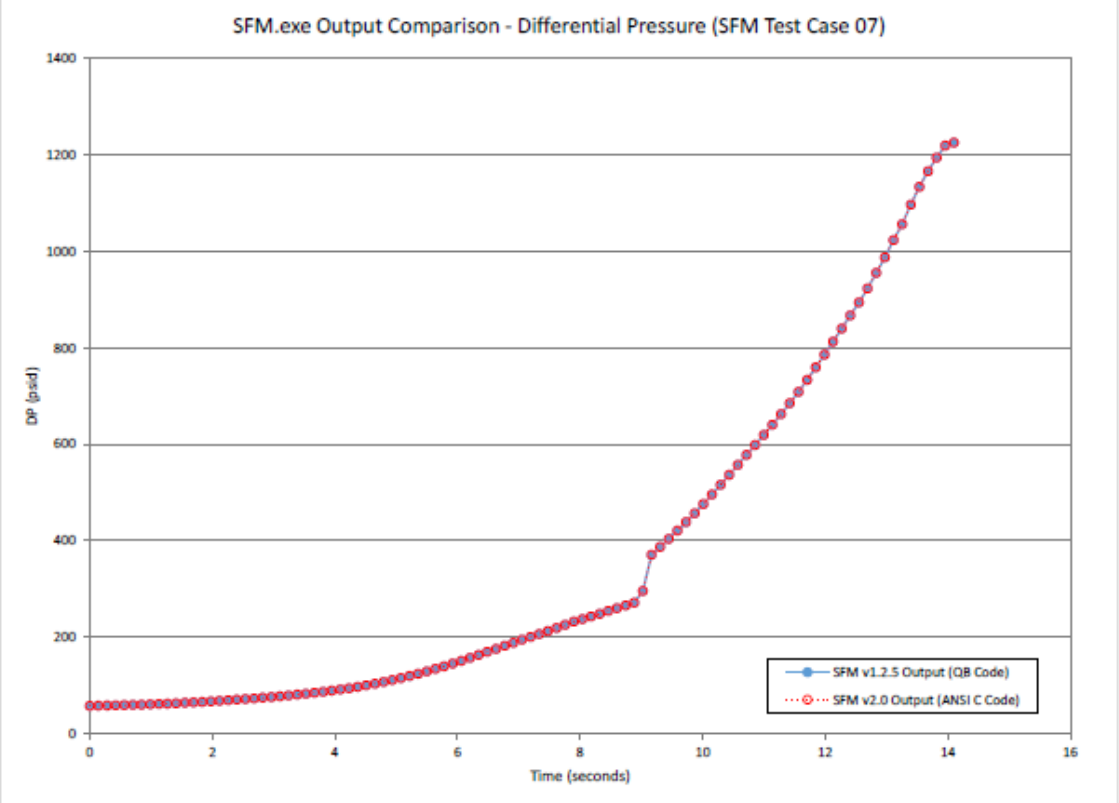


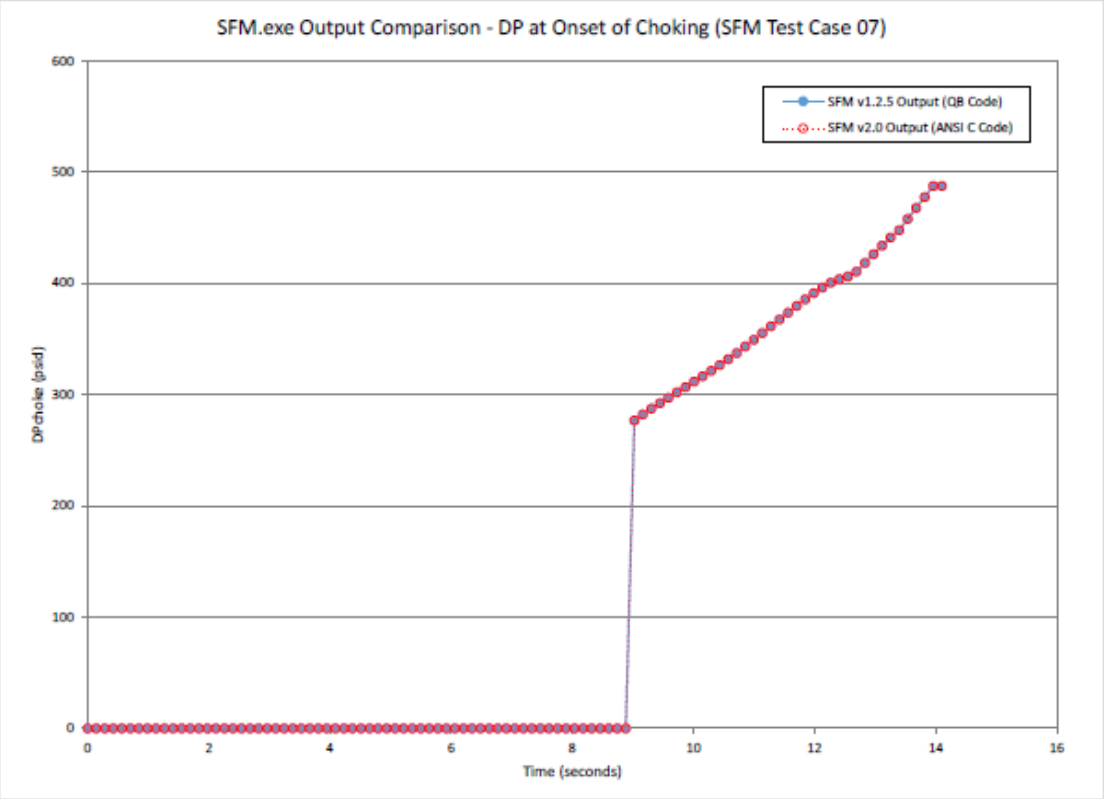

SFM.exe Output Comparison - DP at Onset of Choking (SFM Test Case 01)
SFM v1.2.5 Output (QB Code)
SFM v2.0 Output (ANSI C Code)
DPchoke (psid)
Time (seconds)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14
16

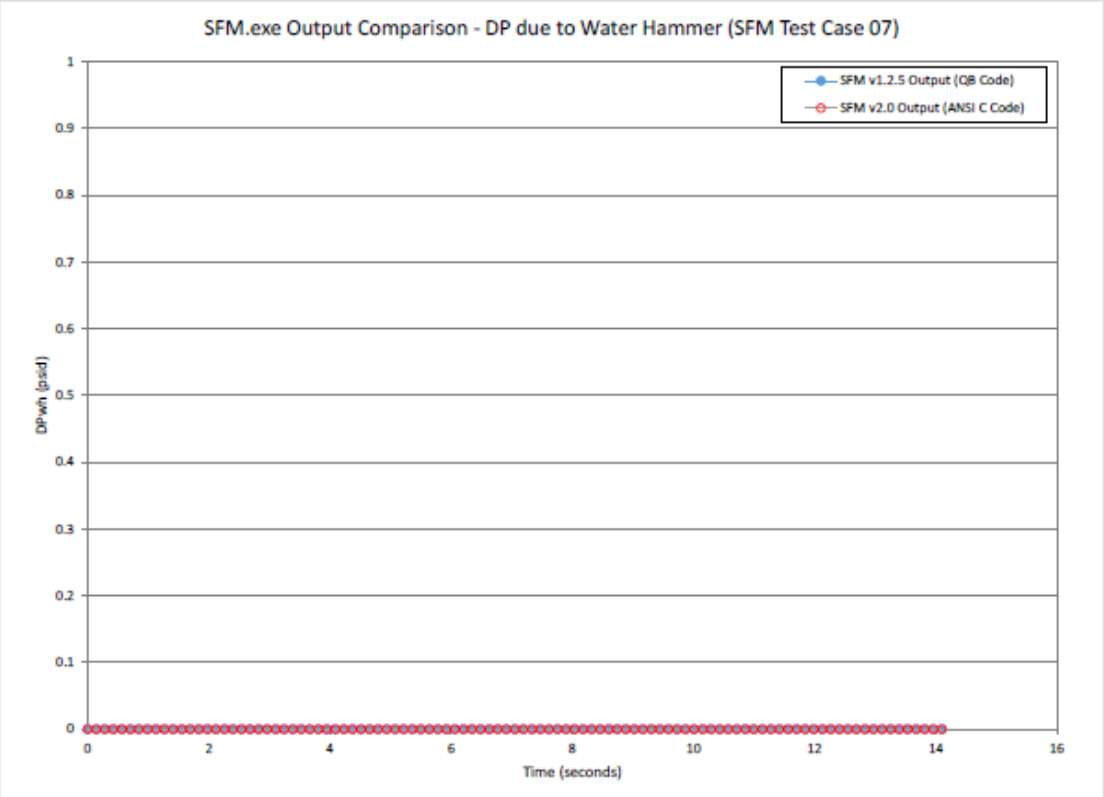

SFM.exe Output Comparison - DP due to Water Hammer (SFM Test Case 01)
SFM v1.2.5 Output (QB Code)
SFM v2.0 Output (ANSI C Code)
DPwh (psid)
Time (seconds)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14
16

SFM Test Case 7






SFM.exe Output Comparison - DP at Onset of Choking (SFM Test Case 07)
SFM v1.2.5 Output (QB Code)
SFM v2.0 Output (ANSI C Code)
DPchoke (psid)
Time (seconds)
0
100
200
300
400
500
600
0
2
4
6
8
10
12
14
16


SFM.exe Output Comparison - DP due to Water Hammer (SFM Test Case 07)
SFM v1.2.5 Output (QB Code)
SFM v2.0 Output (ANSI C Code)
DPwh (psid)
Time (seconds)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14
16

Example Validation Plots for Globe Valve Module (GLBM)

The following test cases are included:

- Test Case 1: Unbalanced disk, rising-rotating stem globe valve with flow over-seat
- Test Case 25: Balanced disk, rising-only stem globe valve with flow over-seat

Note, as identified in the following plots,

- GLBM.exe v1.1 is the version of the GLBM module that is included in overall PPM software v3.5 (i.e., QuickBasic version of the GLBM module).
- GLBM.exe v2.0 is the version of the GLBM module that is included in the overall PPM software v4.0 (i.e., ANSI C version of the GLBM module).

Figure 4-1. GLBM Test Case 1

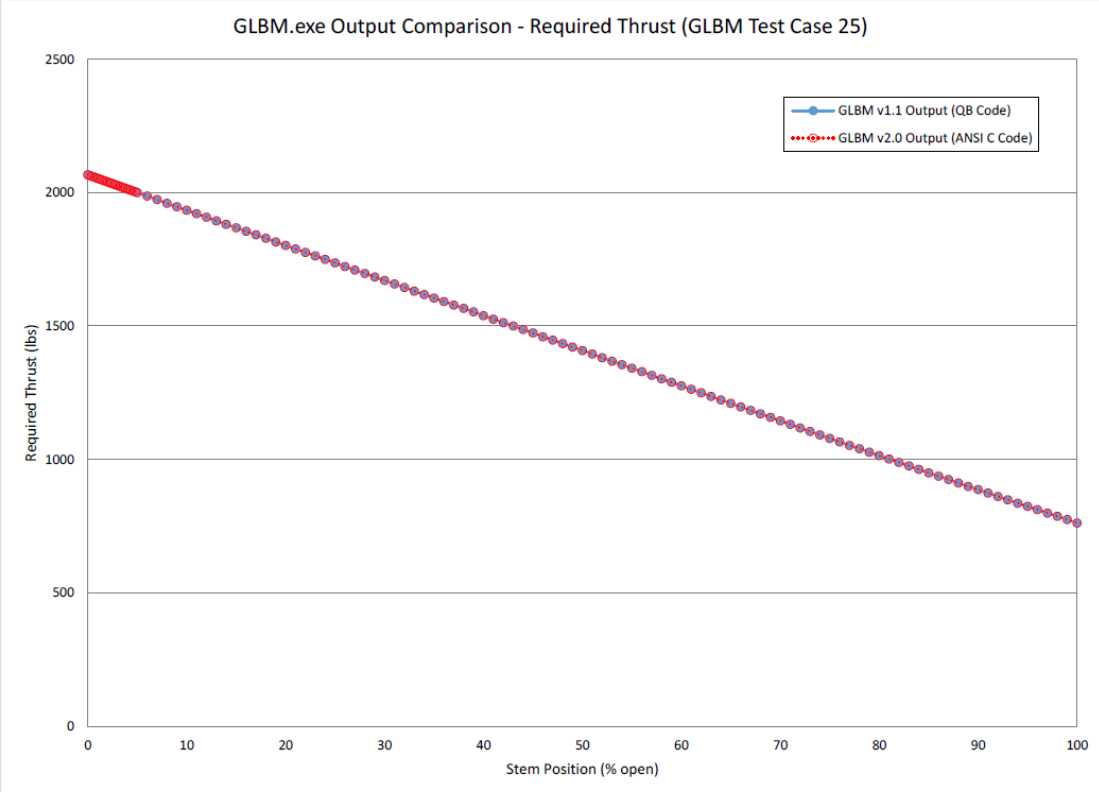


Figure 4-25. GLBM Test Case 25

Example Validation Plots for Butterfly Valve Module (BFM)

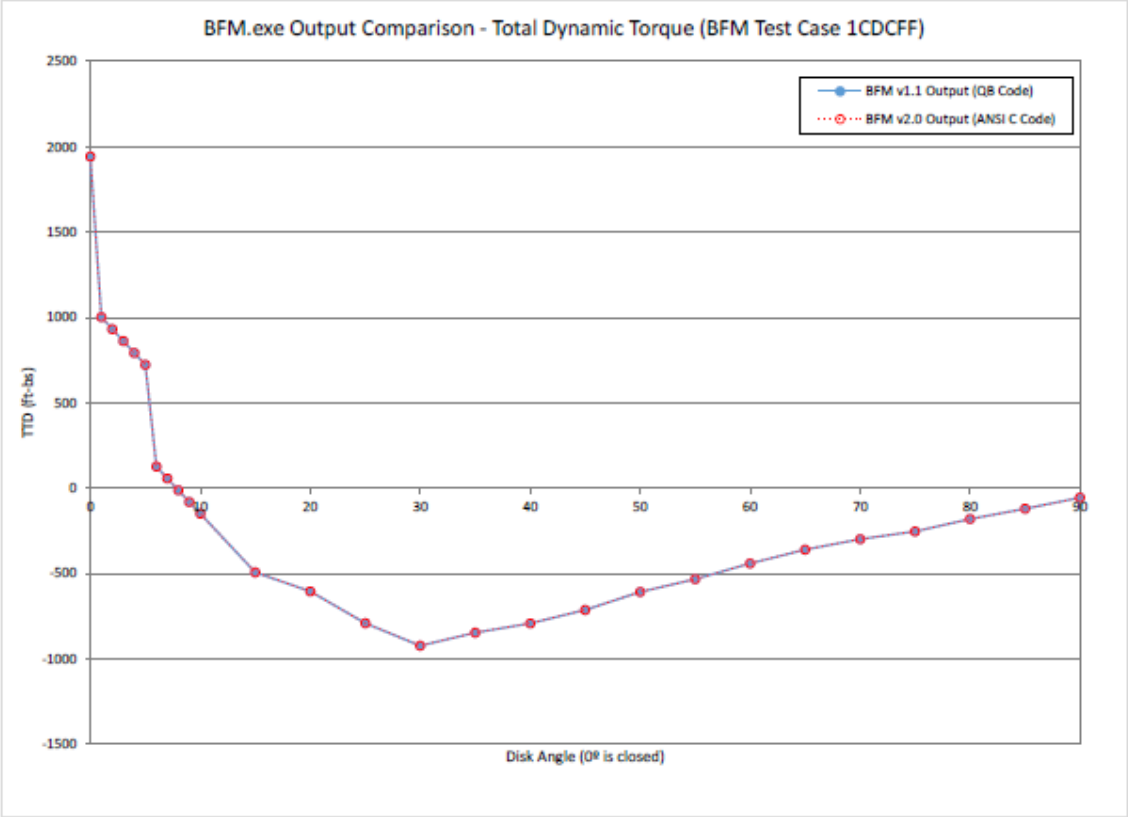
The following test cases are included:

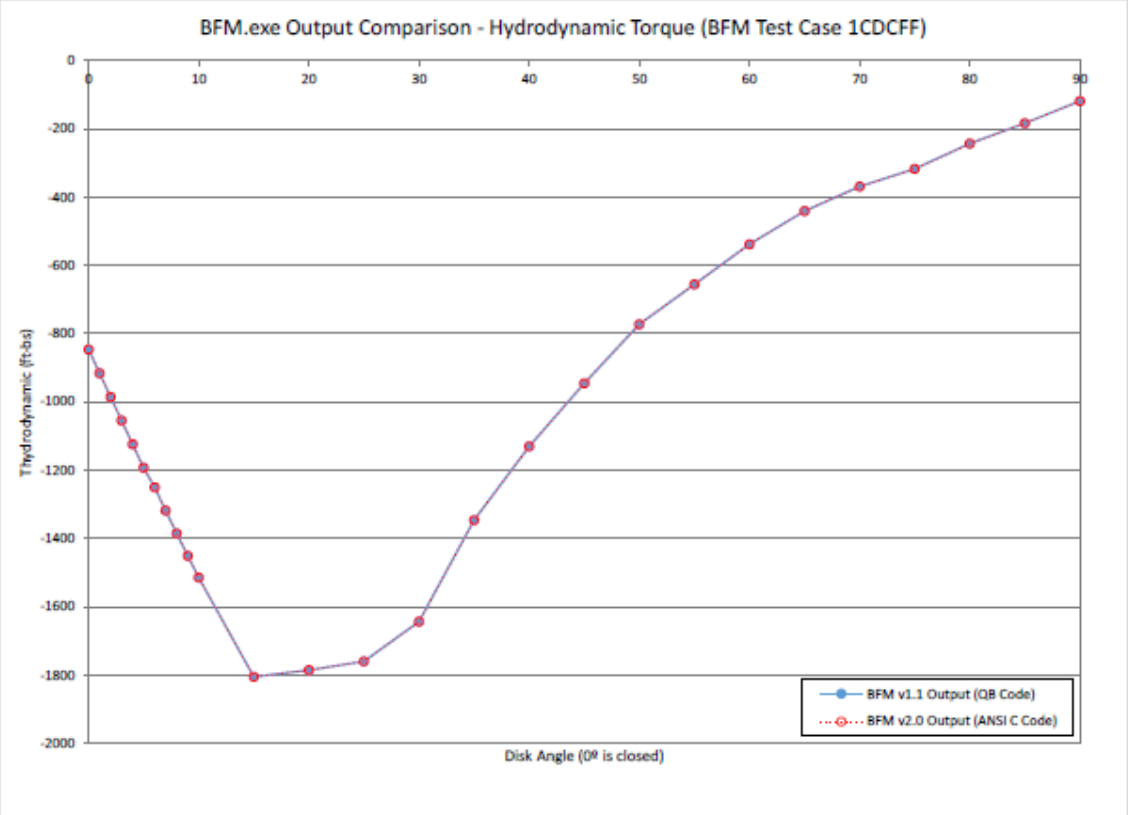
- Test Case 1CDCFF: Double-offset butterfly valve, shaft upstream, with compressible flow
- Test Case 1IDFFF: Single-offset butterfly valve, shaft downstream, with incompressible flow

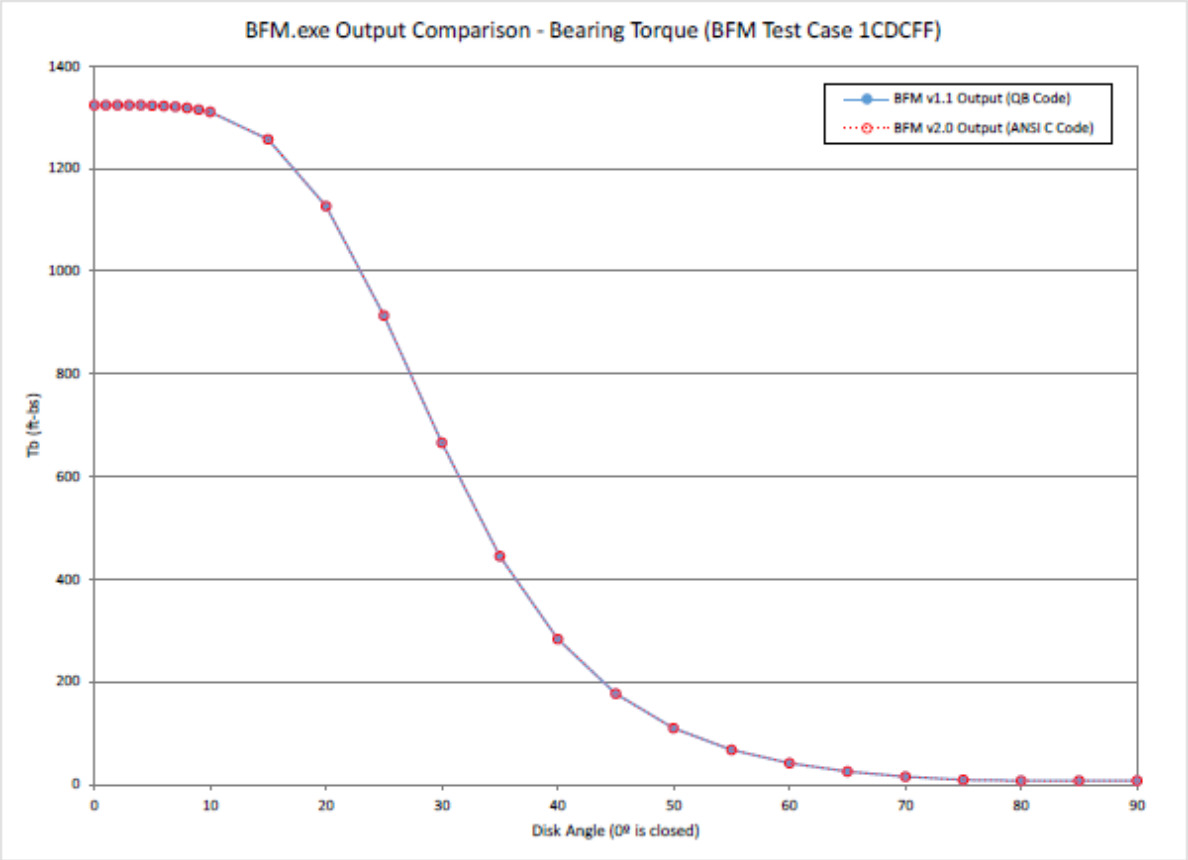
Note, as identified in the following plots,

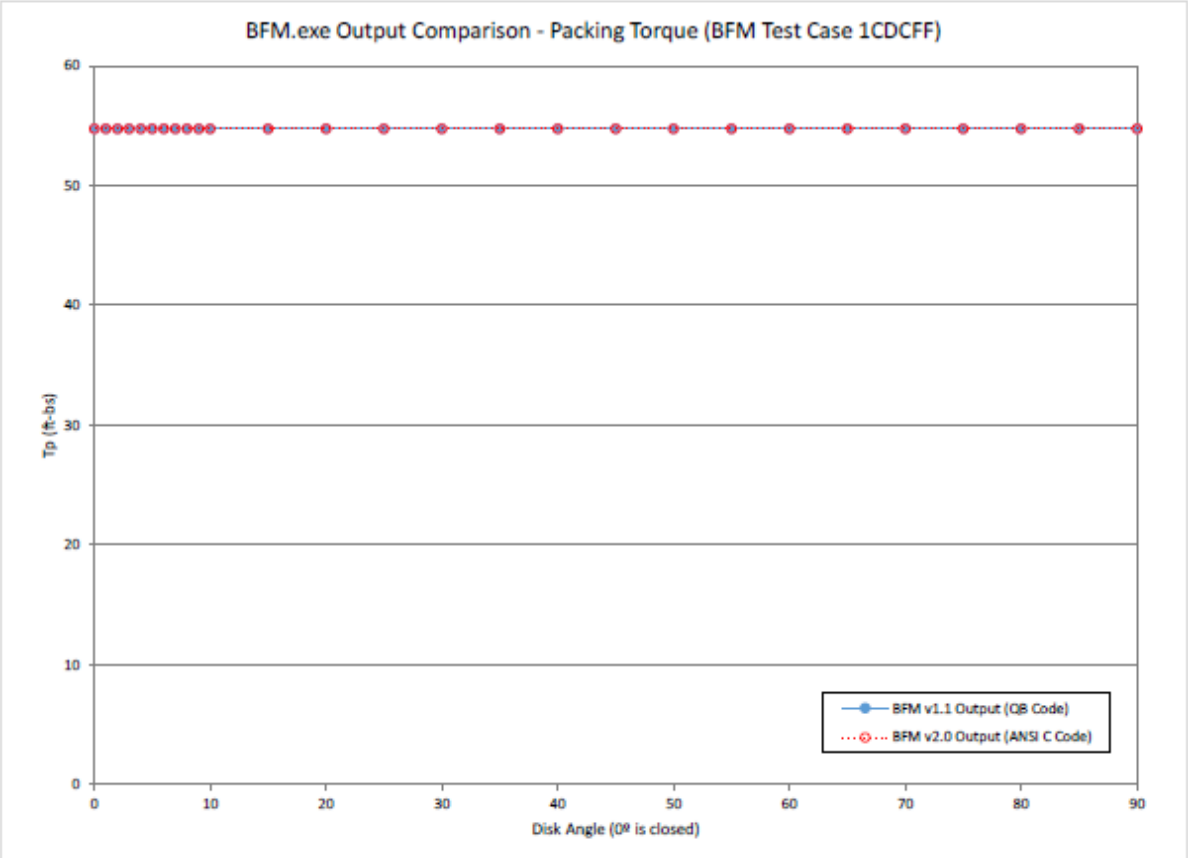
- BFM.exe v1.1 is the version of the BFM module that is included in overall PPM software v3.5 (i.e., QuickBasic version of the BFM module).
- BFM.exe v2.0 is the version of the BFM module that is included in the overall PPM software v4.0 (i.e., ANSI C version of the BFM module).

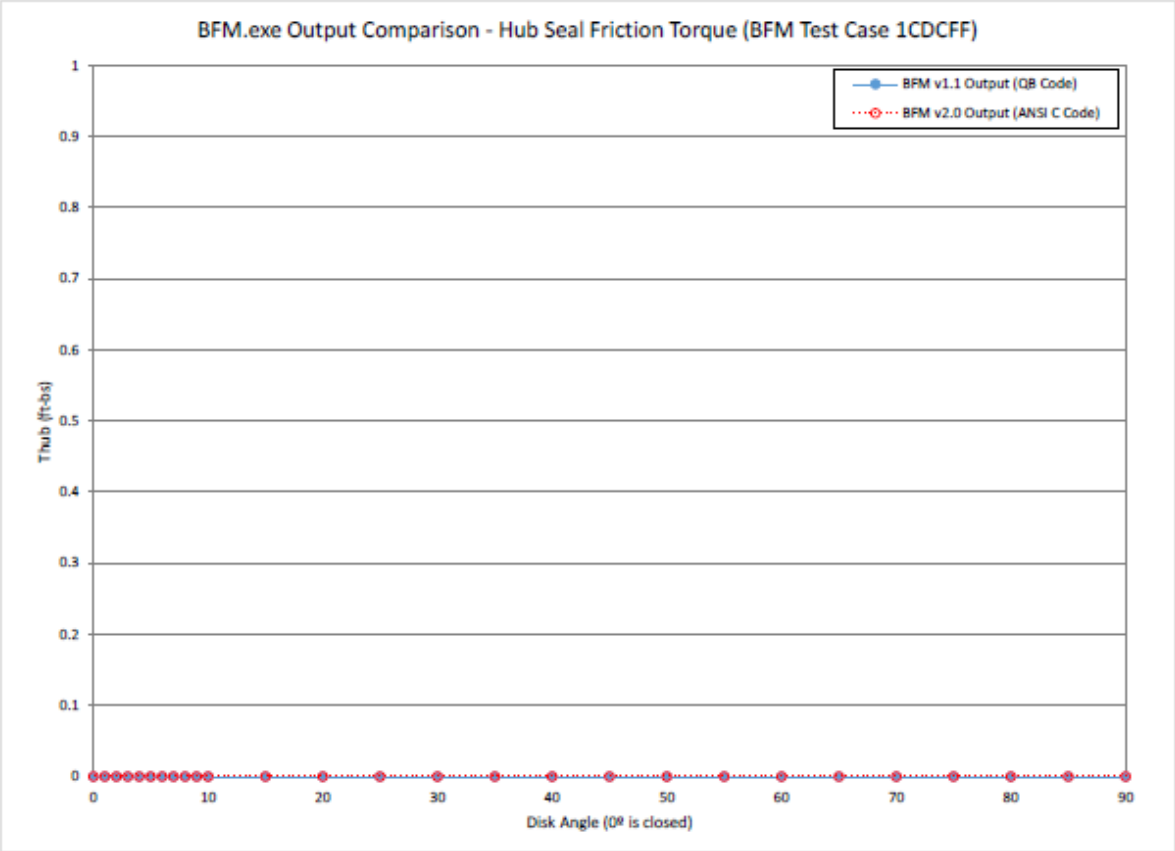
BFM Test Case 1CDCFF

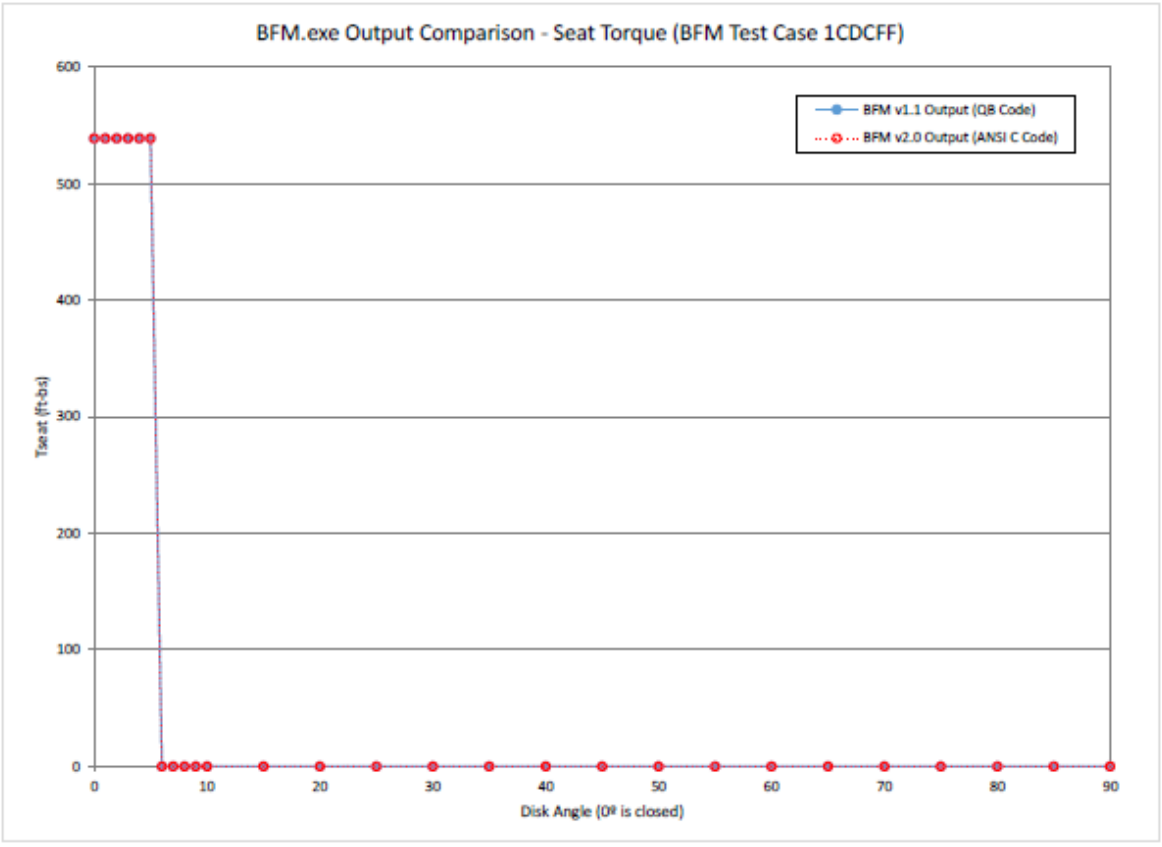


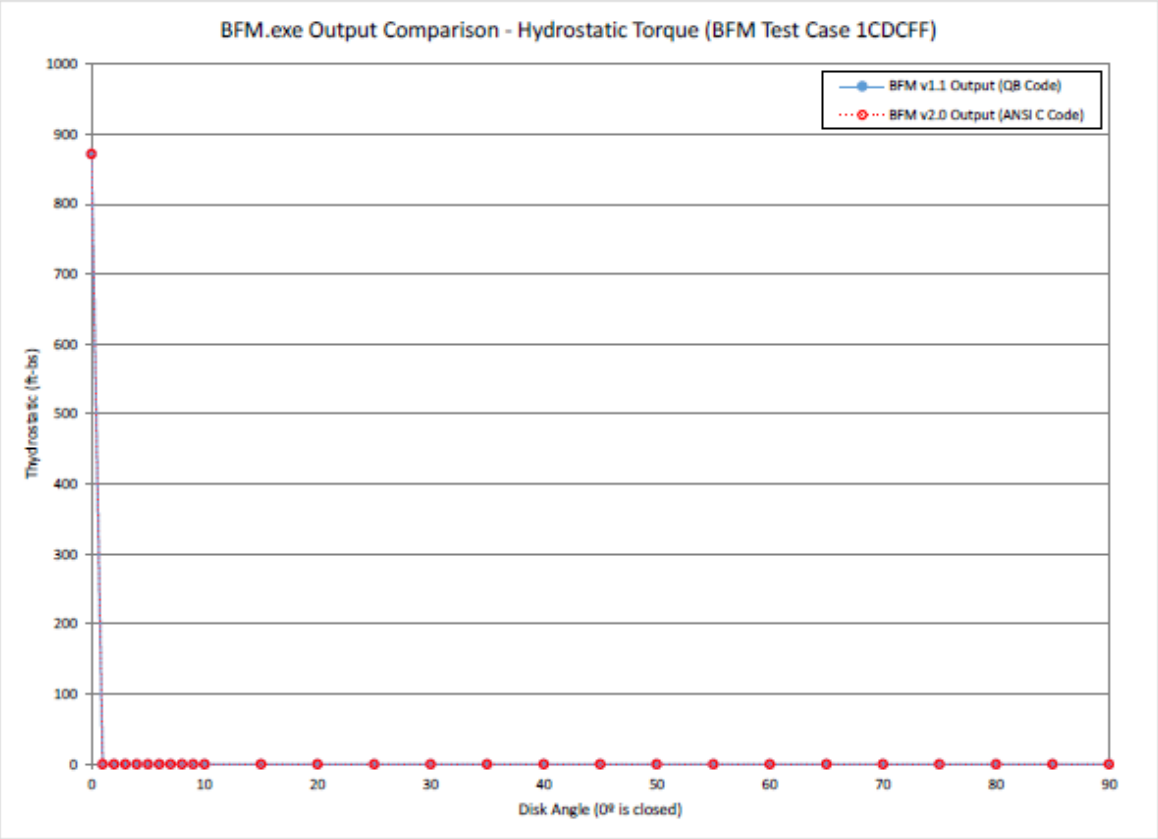



BFM.exe Output Comparison - Bearing Torque (BFM Test Case 1CDCFF)
BFM v1.1 Output (QB Code)
BFM v2.0 Output (ANSI C Code)
Tb (ft-bs)
Disk Angle (0º is closed)
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50
60
70
80
90

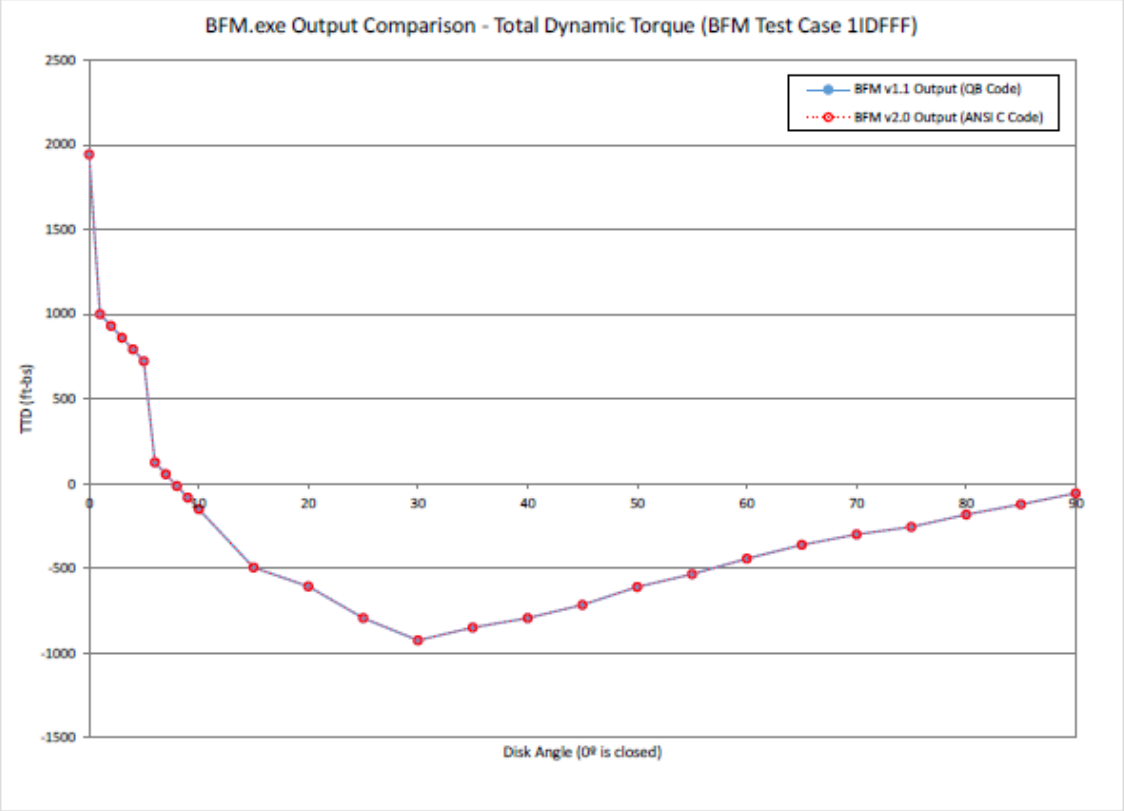

BFM.exe Output Comparison - Packing Torque (BFM Test Case 1CDCFF)
BFM v1.1 Output (QB Code)
BFM v2.0 Output (ANSI C Code)
Tp (ft-bs)
Disk Angle (0º is closed)
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80
90

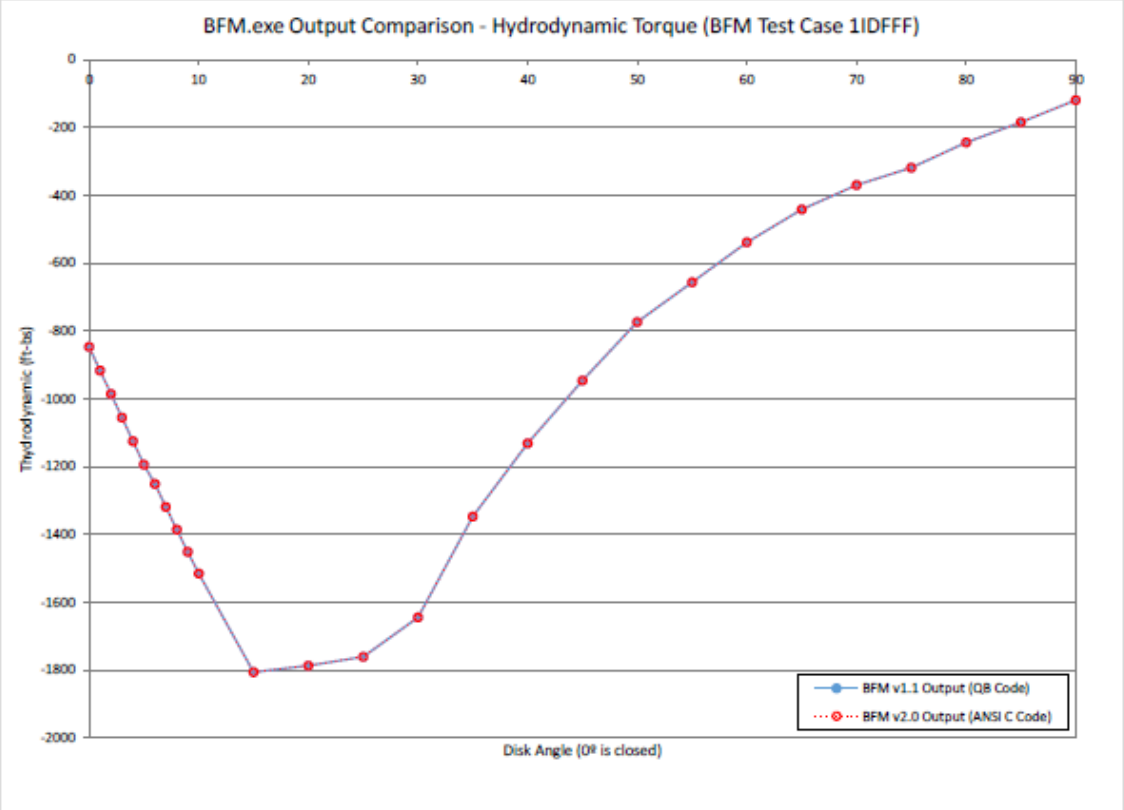

BFM.exe Output Comparison - Hub Seal Friction Torque (BFM Test Case 1CDCFF)
BFM v1.1 Output (QB Code)
BFM v2.0 Output (ANSI C Code)
Thub (ft-bs)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
Disk Angle (0º is closed)

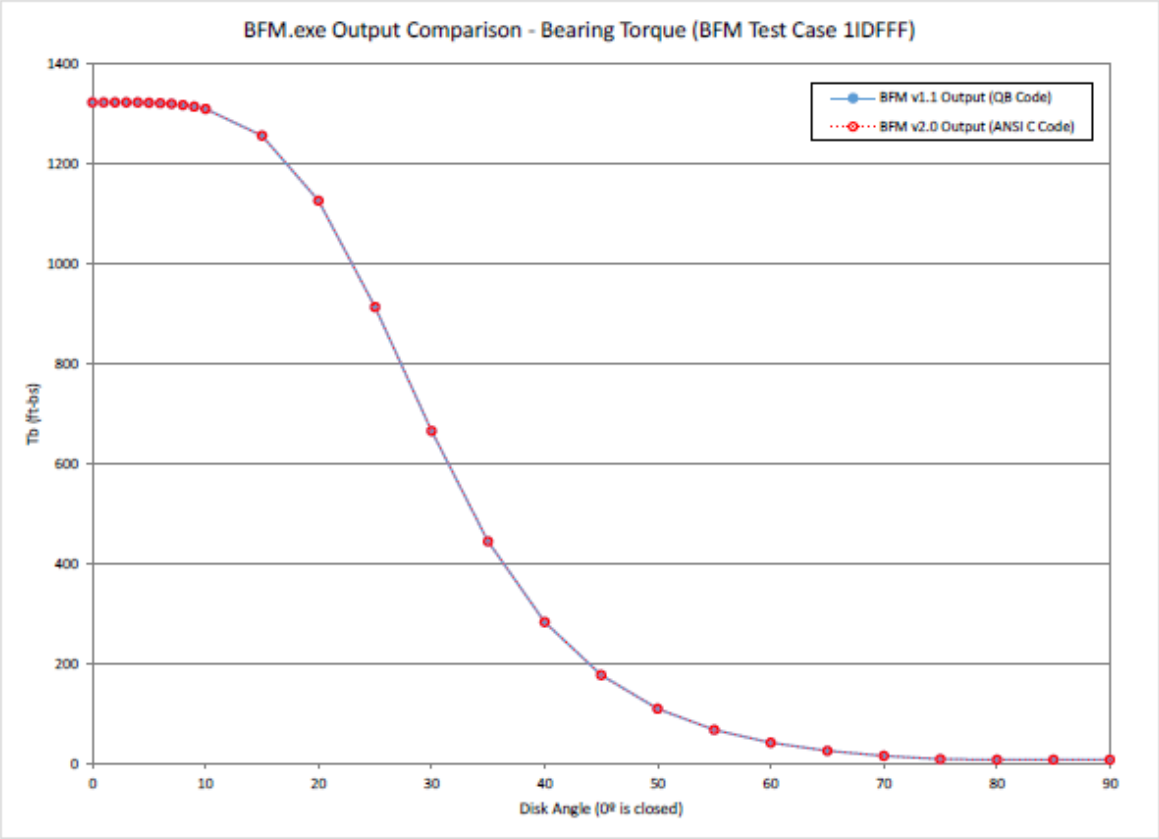

BFM.exe Output Comparison - Seat Torque (BFM Test Case 1CDCFF)
BFM v1.1 Output (QB Code)
BFM v2.0 Output (ANSI C Code)
Tseat (ft-bs)
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Disk Angle (0º is closed)

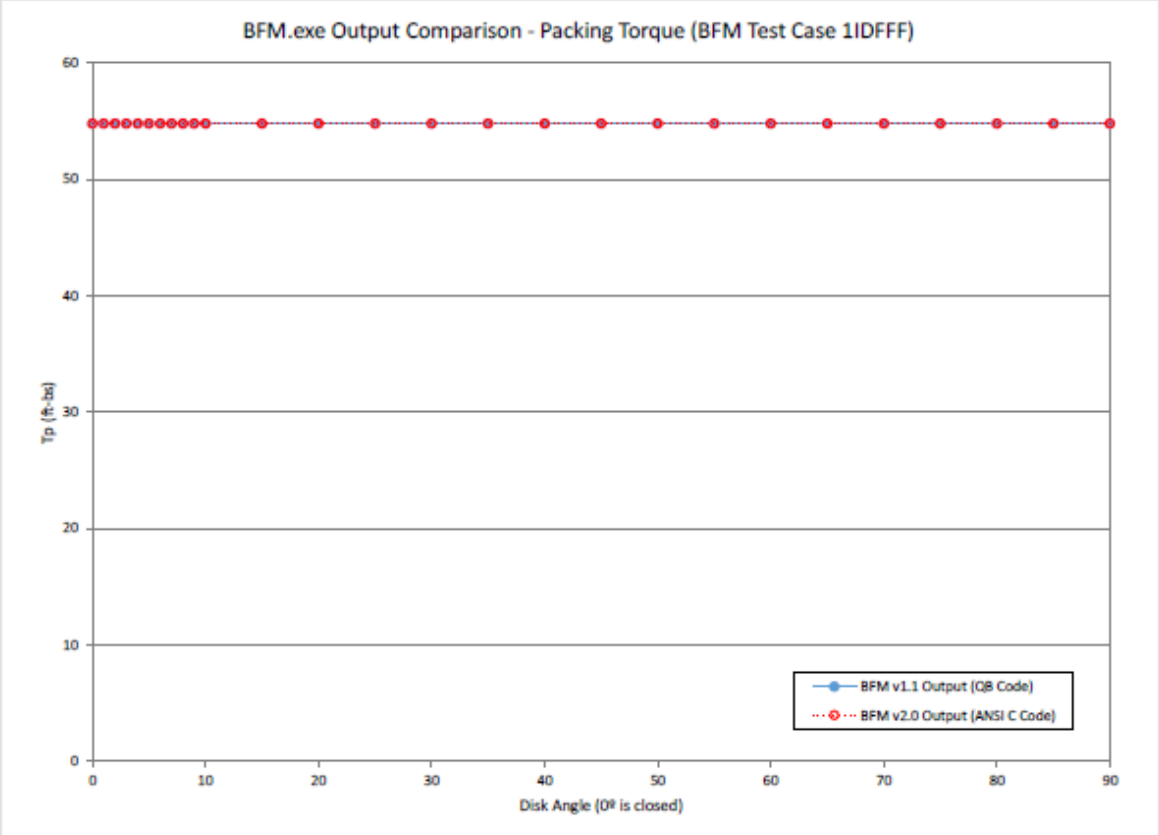

BFM.exe Output Comparison - Hydrostatic Torque (BFM Test Case 1CDCFF)
BFM v1.1 Output (QB Code)
BFM v2.0 Output (ANSI C Code)
Hydrostatic (ft-lbs)
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Disk Angle (0º is closed)

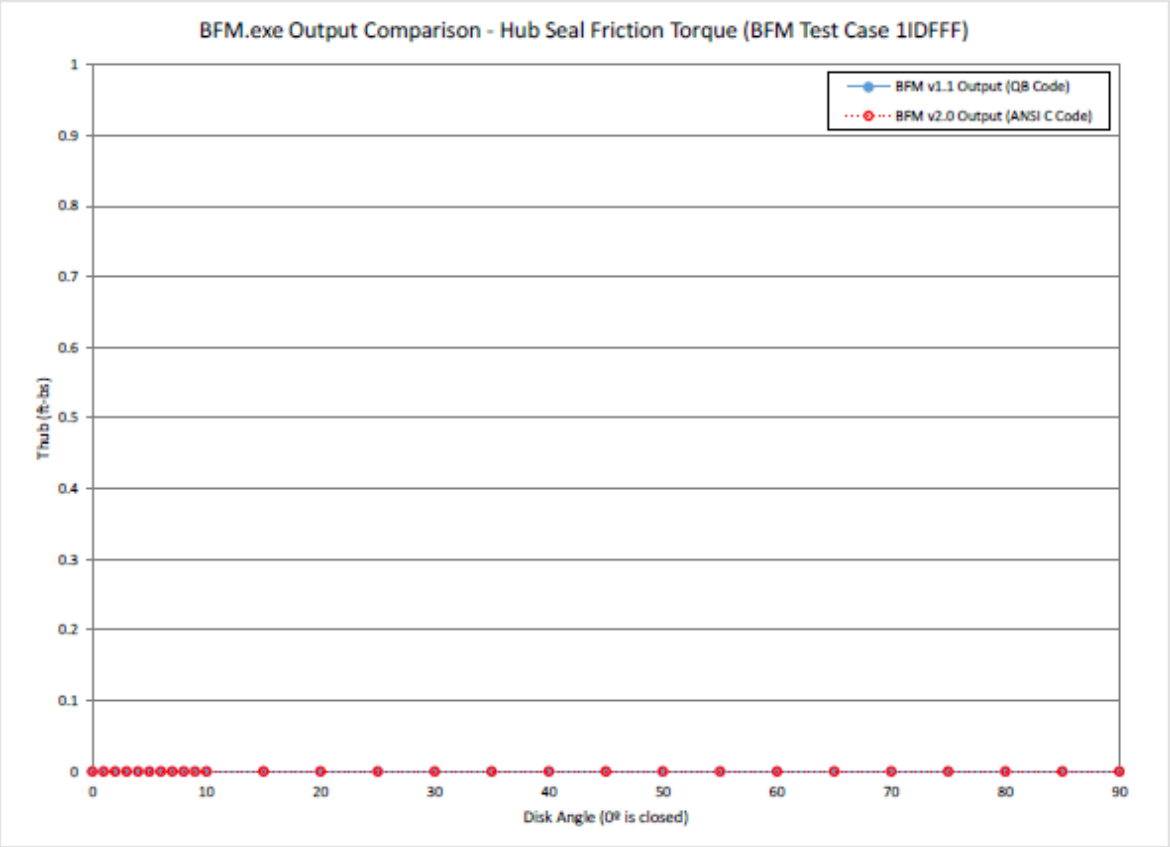
BFM Test Case 1IDFFF

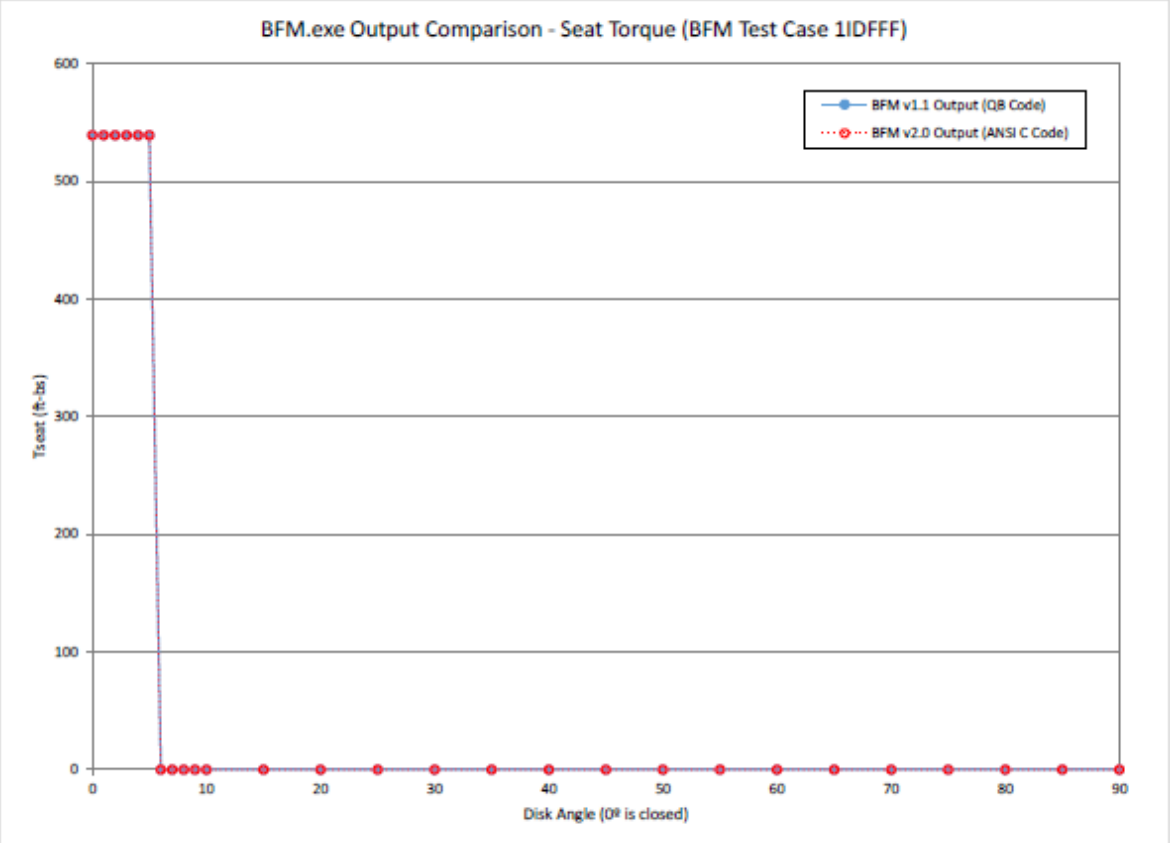


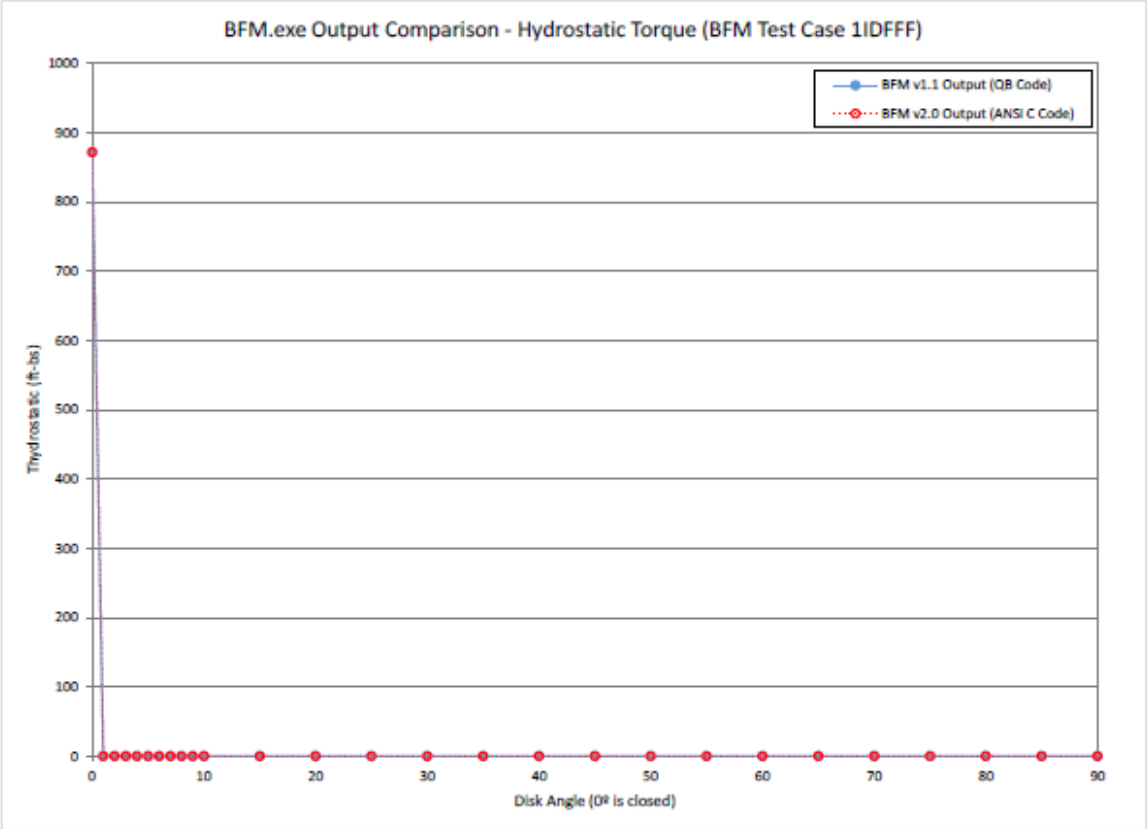



BFM.exe Output Comparison - Bearing Torque (BFM Test Case 1IDFFF)
BFM v1.1 Output (QB Code)
BFM v2.0 Output (ANSI C Code)
Tb (ft-lbs)
Disk Angle (0º is closed)
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50
60
70
80
90


BFM.exe Output Comparison - Packing Torque (BFM Test Case 1IDFFF)
BFM v1.1 Output (QB Code)
BFM v2.0 Output (ANSI C Code)
Tp (ft-lbs)
Disk Angle (0º is closed)
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80
90


BFM.exe Output Comparison - Hub Seal Friction Torque (BFM Test Case 1IDFFF)
BFM v1.1 Output (QB Code)
BFM v2.0 Output (ANSI C Code)
Thub (ft-lbs)
Disk Angle (0º is closed)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60
70
80
90


BFM.exe Output Comparison - Seat Torque (BFM Test Case 1IDFFF)
BFM v1.1 Output (QB Code)
BFM v2.0 Output (ANSI C Code)
Tseat (ft-lbs)
Disk Angle (0º is closed)
0
100
200
300
400
500
600
0
10
20
30
40
50
60
70
80
90


BFM.exe Output Comparison - Hydrostatic Torque (BFM Test Case 1IDFFF)
BFM v1.1 Output (QB Code)
BFM v2.0 Output (ANSI C Code)
Thydrostatic (ft-bs)
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Disk Angle (0º is closed)

Example Validation Plots for Gate Valve Module (GATM)

The following test cases are included:

- Test Case 1: 4” Flex-wedge gate valve with subcooled water (disk guide bottom edge: dull contact)
- Test Case 2: 4” Flex-wedge gate valve with subcooled water (disk guide bottom edge: sharp contact)
- Test Case 11: 4” Flex-wedge gate valve with subcooled water (disk guide bottom edge: chamfer with broken edge, dull contact)
- Test Case 12: 4” Flex-wedge gate valve with subcooled water (disk guide bottom edge: chamfer without broken edge, dull contact)
- Test Case 19: 6” Flex-wedge gate valve with high-temperature subcooled water (body seat ring edge: sharp)
- Test Case 20: 6” Flex-wedge gate valve with low-temperature subcooled water (body seat ring edge: dull)

Note, as identified in the following plots,

- GATM.exe v2.00 is the version of the GATM module that is included in overall PPM software v3.5 (i.e., QuickBasic version of the GATM module).
- GATM.exe v3.0 is the version of the GATM module that is included in the overall PPM software v4.0 (i.e., ANSI C version of the GATM module).

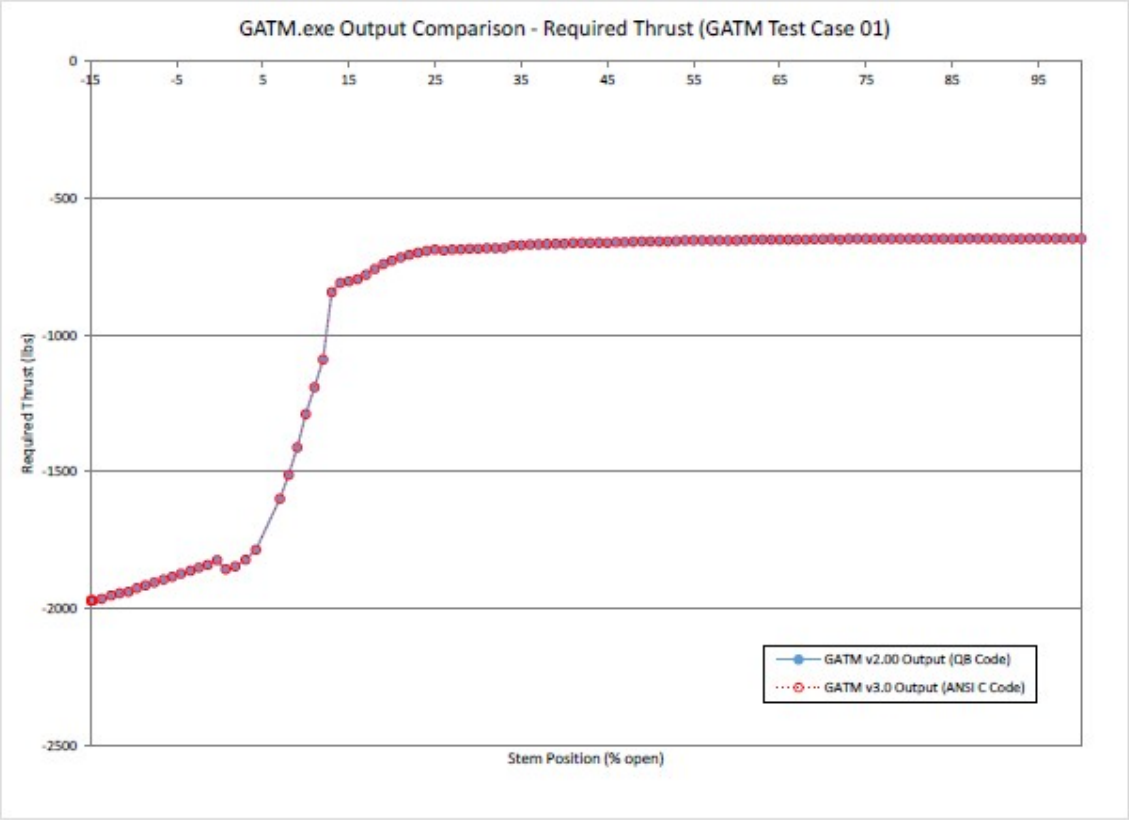


Figure 4-1. GATM Test Case 1

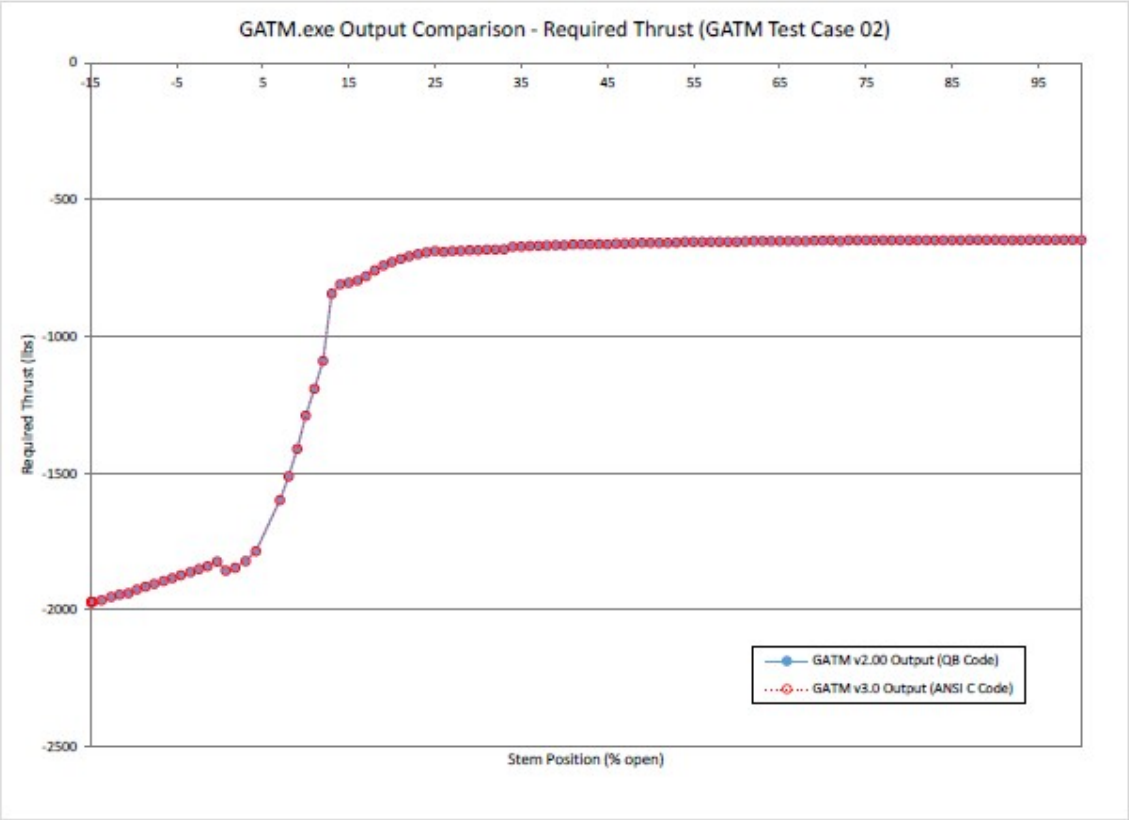


Figure 4-2. GATM Test Case 2

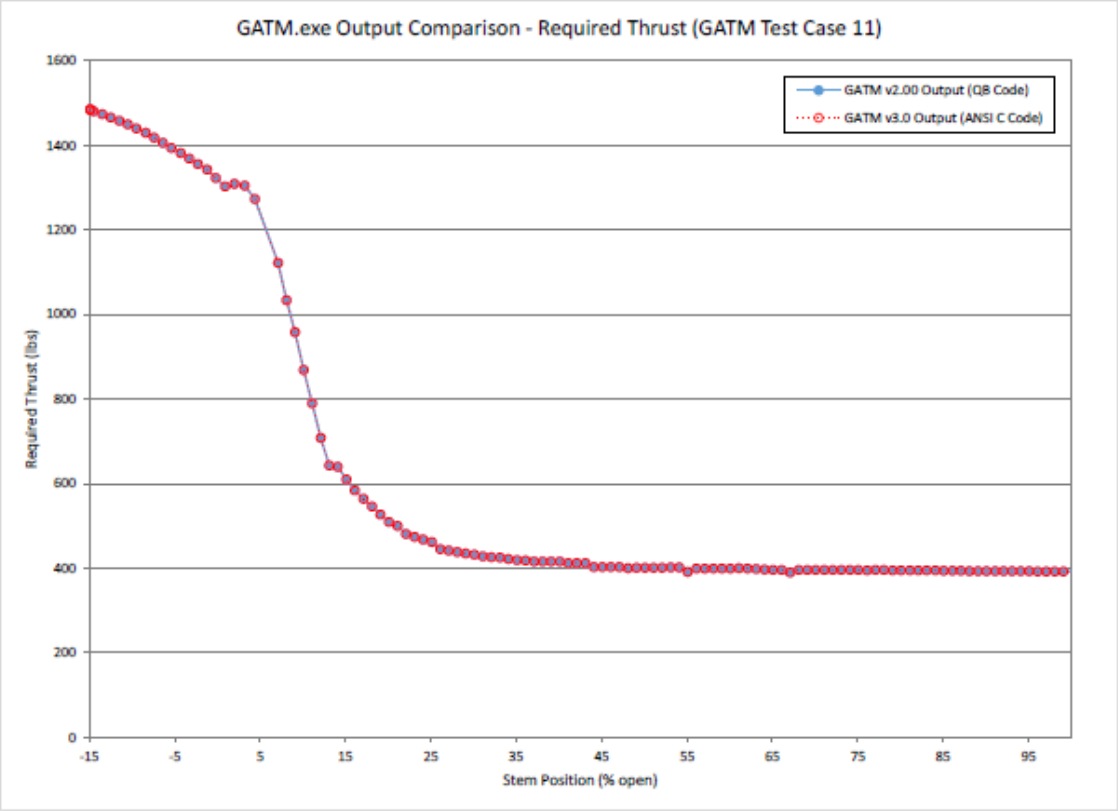


Figure 4-9. GATM Test Case 11

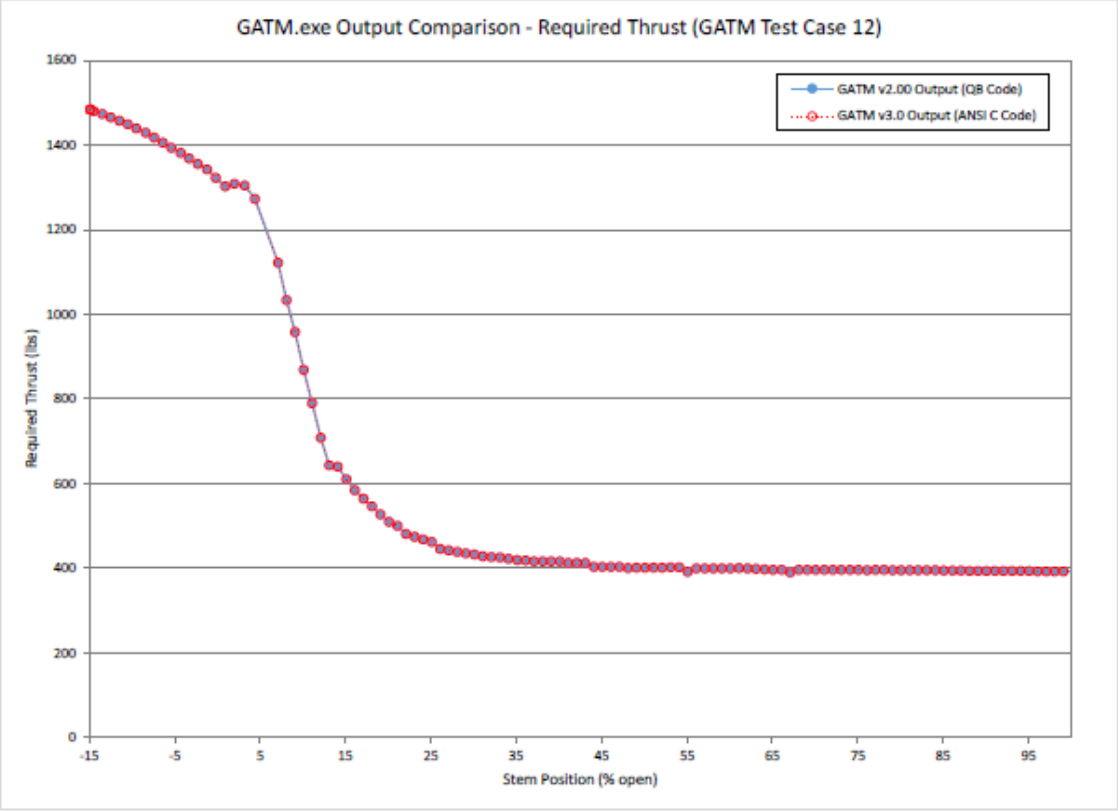


Figure 4-10. GATM Test Case 12

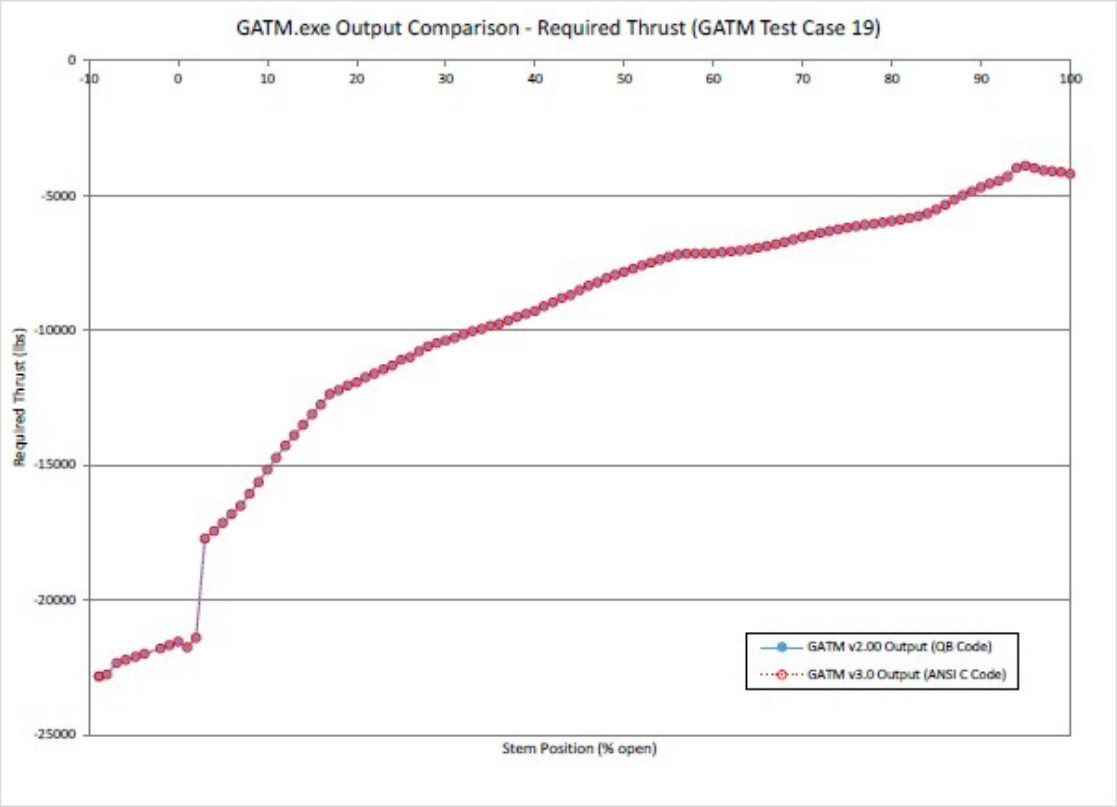


Figure 4-17. GATM Test Case 19

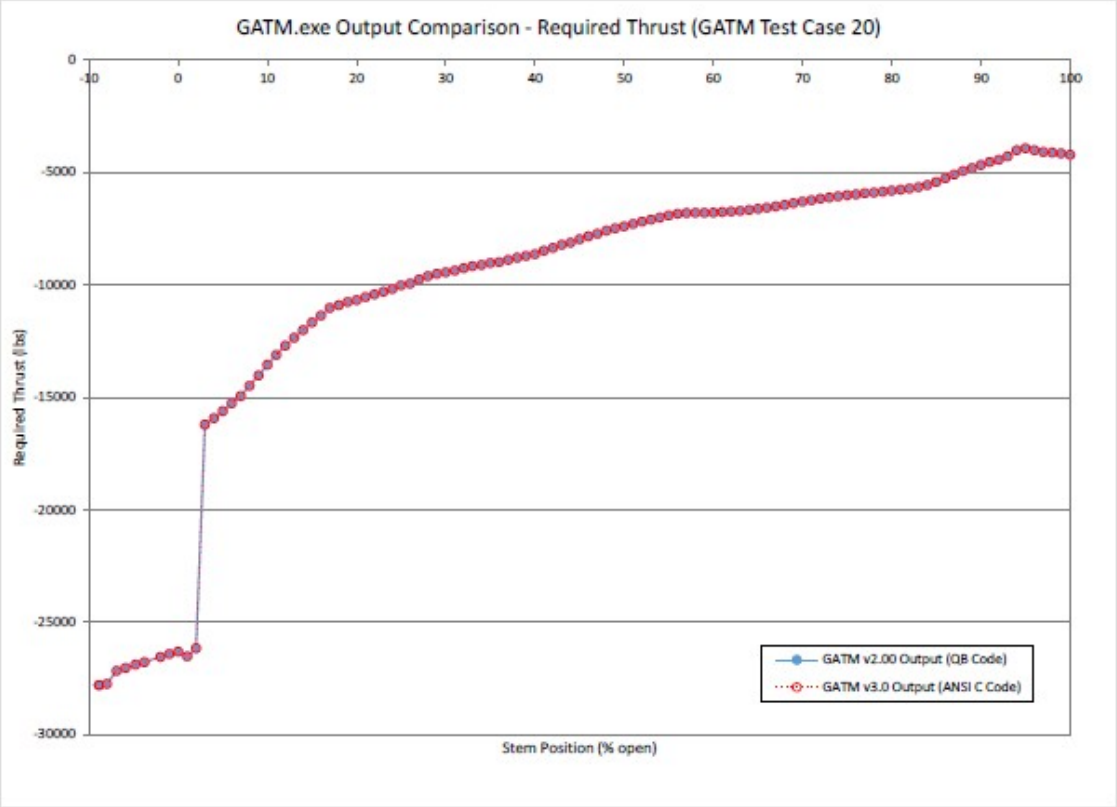


Figure 4-18. GATM Test Case 20

Test Cases with Differences Between Versions 3.5 and 4.0

The following test cases are included:

- GLBM Test Case 26: Balanced disk, rising-stem globe valve with flow over-seat (with the stem pitch and roll angles both at 90°)

  Note: For this test case, Version 3.5 (GLBM v1.1) generates the results shown, and Version 4.0 (GLBM v2.0) issues a "division by zero" error message (see attached) and does not perform a prediction. Because of a known issue in the legacy code, Version 3.5 generates results if both the stem pitch and roll angles are set to 90°, a configuration that is not physically possible. The cause of this issue was related to the conversion of 0° to radians, which resulted in very small, but non-zero, angles. This issue has been corrected in Version 4.0, and as a result an error message is generated so that the user can correct the inputs and re-run the prediction.

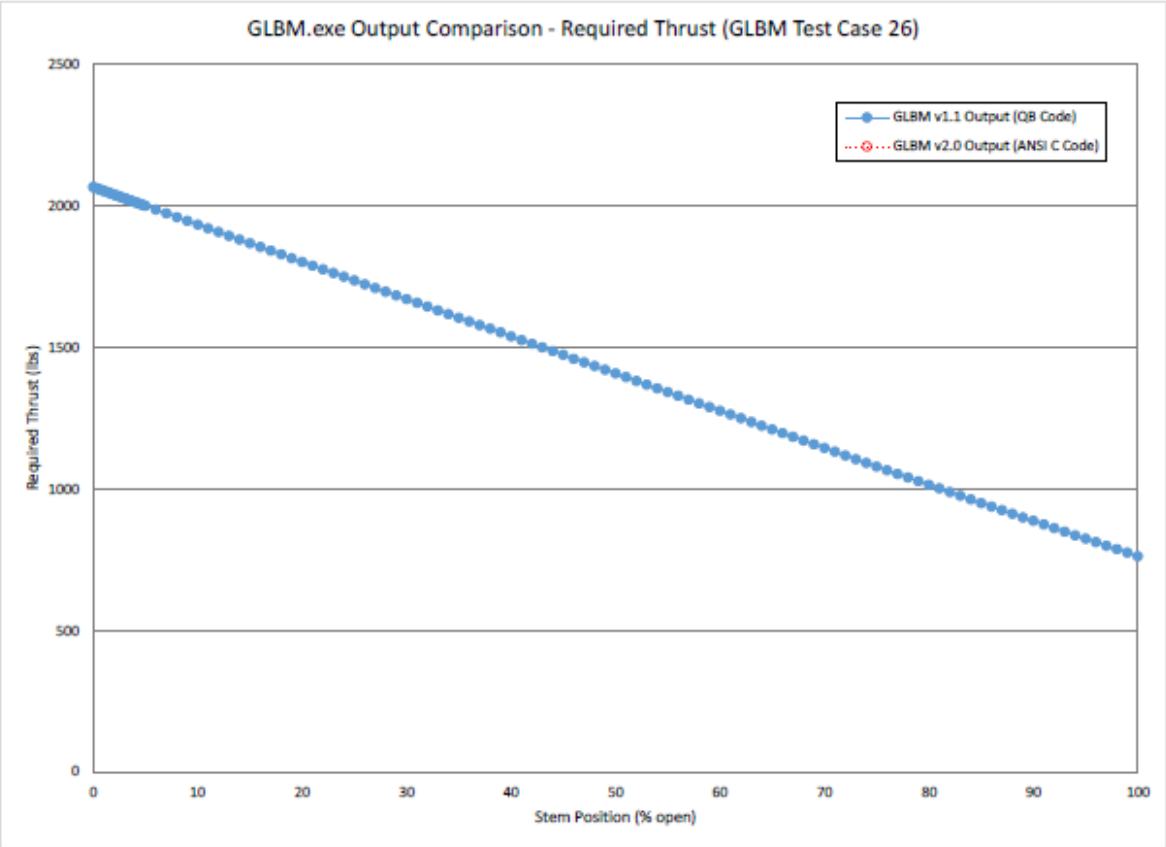
- SFM Test Case 08: Full System Flow Model analyzing a gate valve stroke with two-phase fluid under blowdown conditions

  Note: The differences between Version 3.5 (SFM v1.2.5) and Version 4.0 (SFM v2.0) are the result of correcting an error in the legacy code.

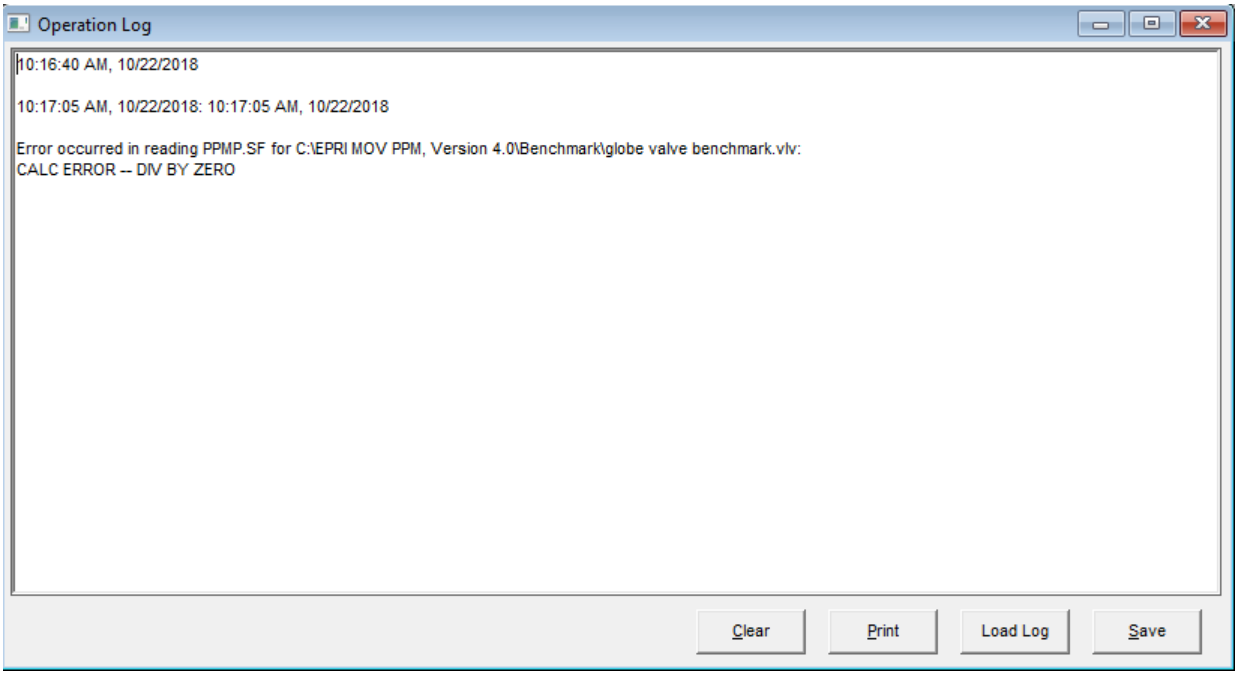
- SFM Test Case 04: Equivalent Resistance Method analyzing a gate valve stroke with cold, subcooled water under high flow conditions

  Note: The differences between Version 3.5 (SFM v1.2.5) and Version 4.0 (SFM v2.0) are assessed to be the result of differences in the math processors used by the Microsoft Quick Basic (Version 3.5) and ANSI C (Version 4.0) compilers. The differences are negligible and do not significantly affect the overall thrust or torque predictions.

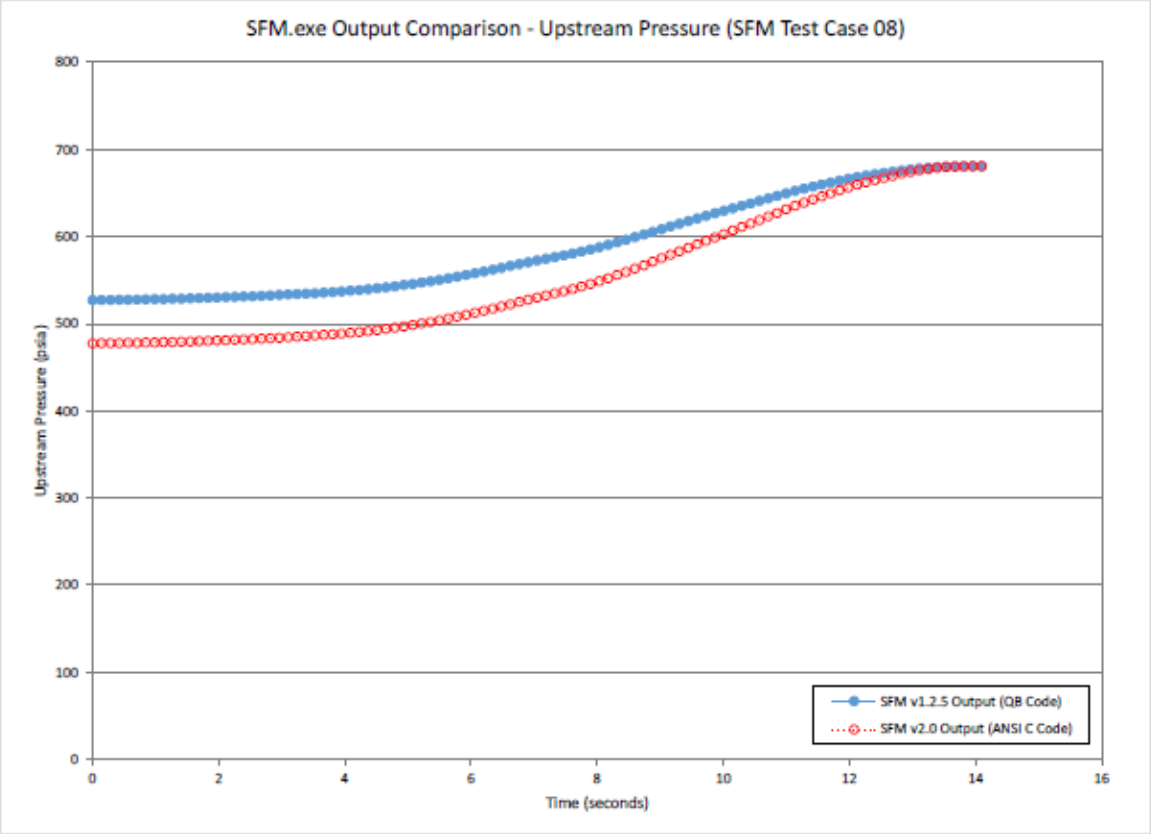
GLBM Test Case 26

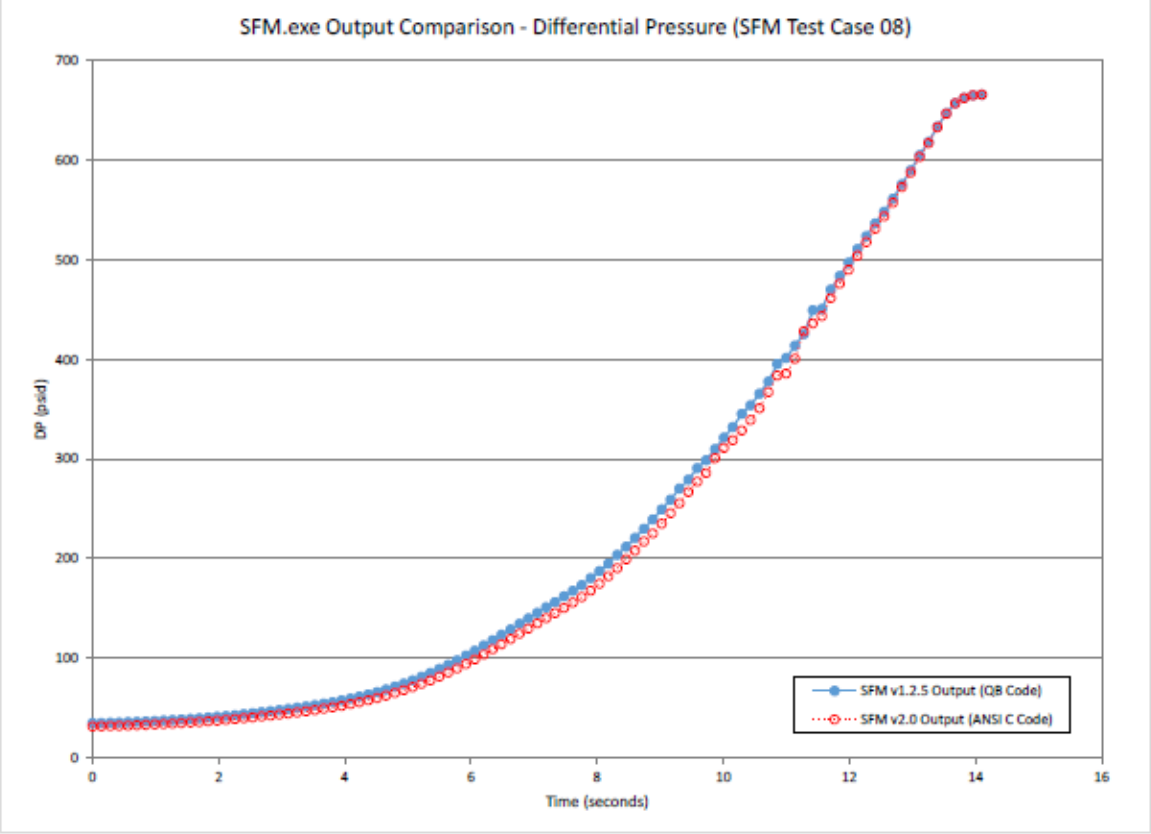


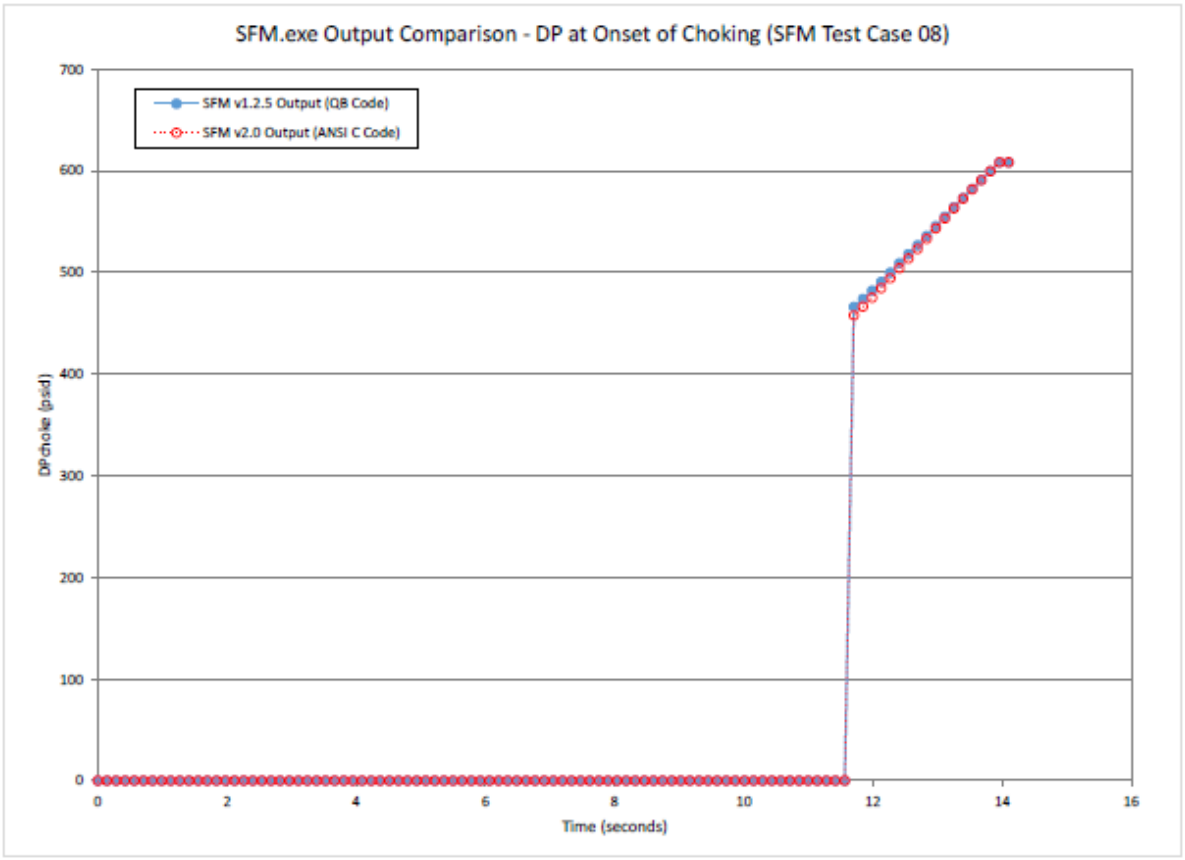
PPM Version 4.0 Error Message:

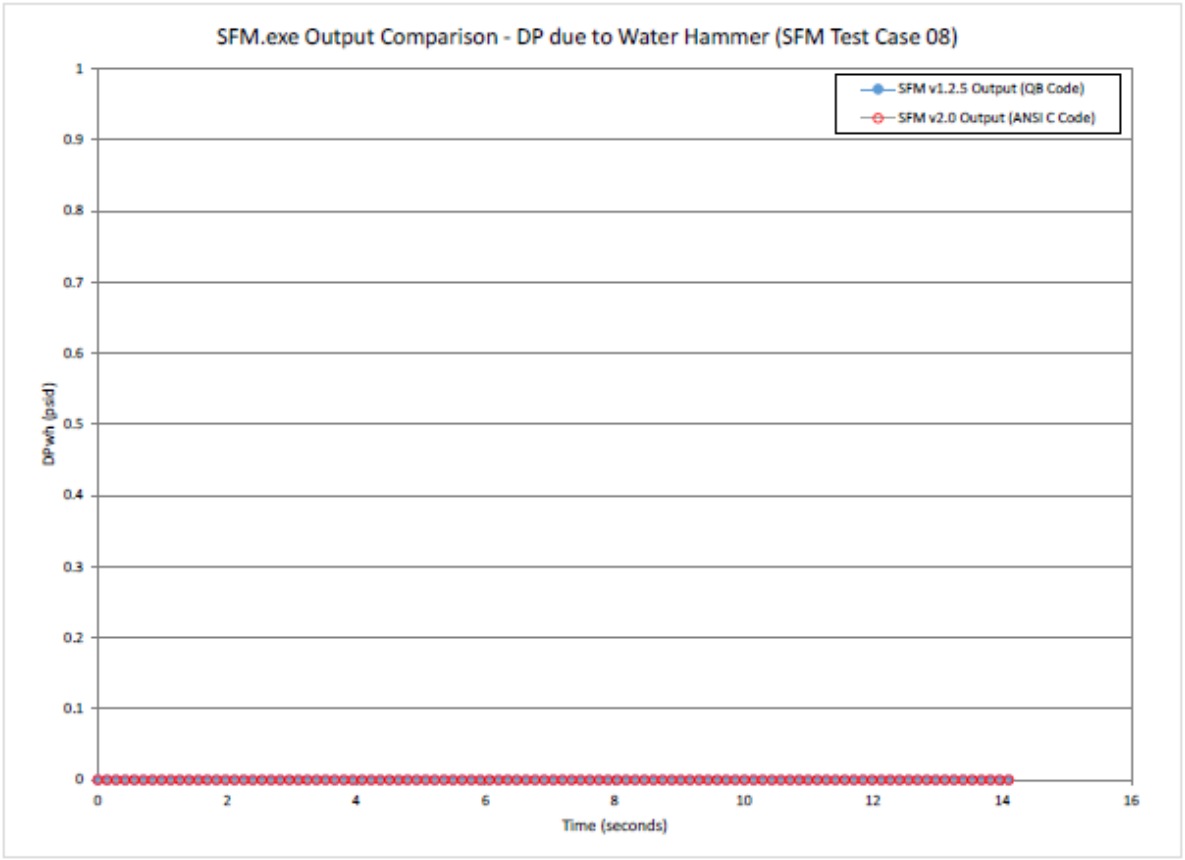


SFM Test Case 8

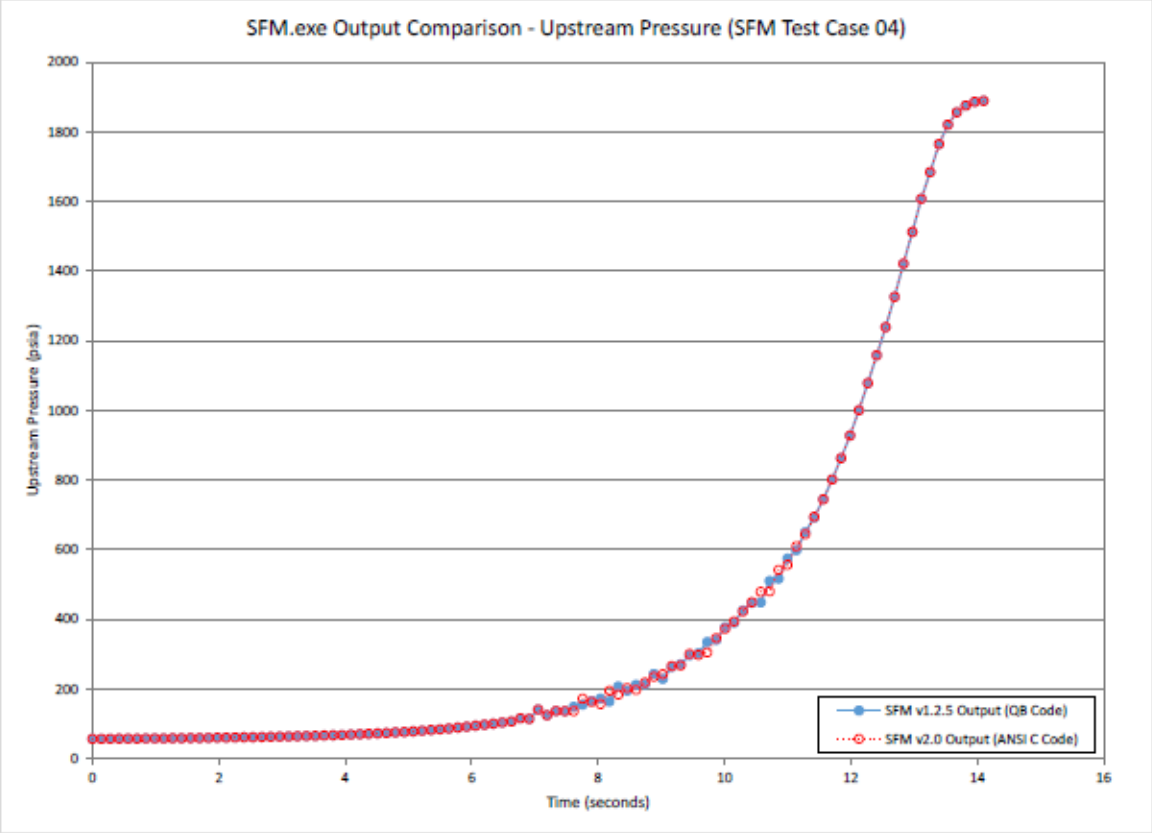


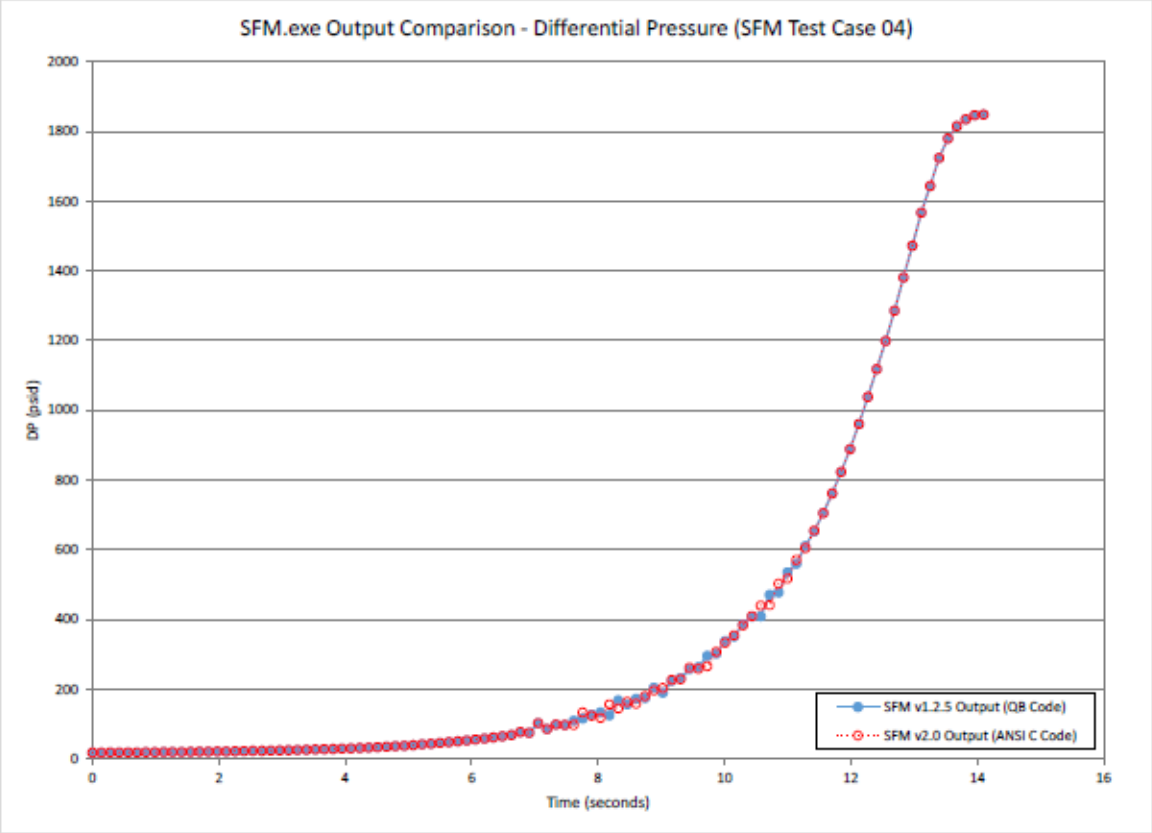


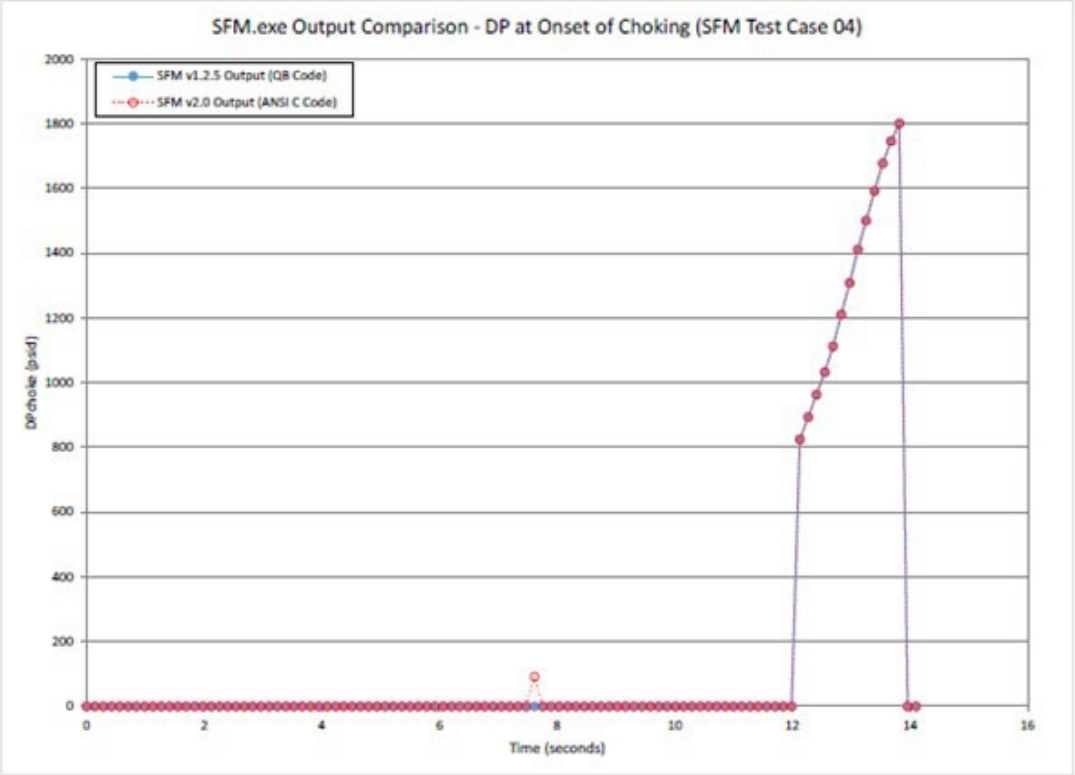

SFM.exe Output Comparison - DP at Onset of Choking (SFM Test Case 08)
SFM v1.2.5 Output (QB Code)
SFM v2.0 Output (ANSI C Code)
DPchoke (psid)
Time (seconds)
0
100
200
300
400
500
600
700
0
2
4
6
8
10
12
14
16


SFM.exe Output Comparison - DP due to Water Hammer (SFM Test Case 08)
SFM v1.2.5 Output (QB Code)
SFM v2.0 Output (ANSI C Code)
DPwh (psid)
Time (seconds)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14
16

SFM Test Case 4







Note: The difference in the above plot at 7.5 sec. is the result of SFM v2.0 predicting conditions just past the threshold for choked flow (and displaying a choke-limited DP), while SFM v1.2.5 predicted conditions just below the threshold for choked flow (and displaying 0 to indicate non-choked flow). The actual difference in predicted DP is small and is displayed in the prior plot.