JOINT OWNERS' GROUP
Motor-Operated Valves
Babcock & Wilcox Owners Group - Boiling Water Reactor Owners' Group
Westinghouse Owners Group

February 27, 2004

United States Nuclear Regulatory Commission
Document Control Desk
Washington DC 20555-0001

Attention: Chief, Information Management Branch
Division of Program Management

Subject: Joint Owners Group Program on Motor-Operated Valve Periodic Verification

BWROG Project Number 691
B&WOG Project Number 693
WOG Project Number 694

Reference:
(1) Generic Letter 96-05, "Periodic Verification of Design-Basis Capability of Safety-Related Motor-Operated Valves", dated September 18, 1996.
(2) "Joint BWR, Westinghouse and Combustion Engineering Owners Group Program on Motor-Operated Valve (MOV) Periodic Verification", MPR-1807 Revision 2, dated July 1997
(3) NRC "Safety Evaluation on Joint Owners' Group Program on Periodic Verification of Motor-Operated Valves Described in Topical Report MPR-1807 (Revision 2), dated October 30, 1997

Enclosure: Joint Owners' Group (JOG) Motor Operated Valve Periodic Verification Program Summary, MPR-2524 Revision 0, dated February 2004.

The Joint Owners Group (JOG) is submitting the enclosed final Topical Report on the JOG Motor-Operated Valve (MOV) Periodic Verification (PV) Program for NRC review and approval.

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As an industry-wide response to Reference (1), the Reference (2) JOG MOV PV Program Description outlined three phases:

Phase 1-Interim Static PV Testing:
Plants perform static PV testing at a frequency based on risk and margin.

Phase 2-Dynamic Testing Program:
Participating JOG plants dynamically test selected MOVs with flow and differential pressure (DP).

Phase3-Long-Term PV Testing
Based on dynamic test data collected in Phase 2, establish final test PV criteria and prepare a revised or replacement topical report.

The enclosed final Topical Report completes Phase 3. The report was prepared by MPR Associates, Inc., the contractor to the JOG for this effort. This JOG program has been supported by the Babcock & Wilcox Owners Group (B&WOG), Boiling Water Reactor Owners' Group (BWROG), Combustion Engineering Owners Group (CEOG) and Westinghouse Owners Group (WOG). The CEOG has now been combined into the WOG.

The enclosed report reflects the culmination of an extensive JOG expenditure of resources:

- Dynamic testing completed DP tests of 176 MOVs at 98 BWR and PWR plants. Each valve was tested three times over five years to address potential degradation (increases) in required thrust or torque. The MOVs cover a wide range of valve designs and service conditions that could potentially influence degradation. This testing required over 61,000 utility man-hours of effort.
- Evaluation of over 500 dynamic test packages by MPR. Test package activities included receipt, verification and approval of test data, archival of test data into a database, test data evaluation and preparation of the final JOG Program Topical Report. This evaluation of test data required over 28,000 man-hours.
- Fourteen Core Group meetings to analyze, evaluate and direct this JOG program. This JOG MOV Core Group, which includes representatives from each Owners Group, has expended over 8,000 man-hours of effort.
- Program oversight by project managers from each Owners Group, estimated at over 6,500 man-hours.

Total industry investment of resources for supporting the JOG MOV PV Program effort is estimated at over 52 man-years - the largest MOV testing program in the industry resulting in the most extensive set of MOV test data in existence.

Since 1997, the JOG leadership has met with the NRC staff eleven times to summarize the progress of the program, share progressive results of the testing, and discuss program-related issues. The Enclosure addresses matters raised by the NRC at these meetings. This report has been reviewed by all participating utilities and has received approval for submittal to the NRC by each Owners Group. Implementation of the JOG long-term MOV PV Program by participating JOG utilities will be after NRC review and issuance of a Safety Evaluation (SE).

The NRC approved Reference (2), developed by the JOG in response to Generic Letter 96-05, via the Reference (3) Safety Evaluation. One of the conditions and limitations in the Safety Evaluation was that "...JOG must submit for NRC review and approval a revision to (or replacement report for) the topical report following the JOG dynamic test program which describes the final test criteria for the long-term MOV Periodic Verification Program, and the justification for those criteria following completion of the JOG dynamic test program".

In response to this condition and limitation, the JOG is submitting the enclosed replacement Topical Report that describes the final test criteria for the long-term MOV Periodic Verification Program, and the justification for these criteria from the JOG dynamic test program. This JOG Topical Report establishes a generic, consistent approach for participating licensees to respond to Generic Letter 96-05. Utilizing the generic JOG approach will conserve NRC resources in reviewing licensee-specific responses to Generic Letter 96-05.

The JOG requests that a fee waiver be granted for NRC review of the JOG topical report pursuant to the provisions of 10 CFR 170.11, specifically:

1. The report is submitted as a generic industry approach in response to a Generic Letter (to respond to Generic Letter 96-05) in accordance with 10 CFR 170.11(a)(1)(i). The report does not result in an amendment to the license, does not result in the review of an alternate method or reanalysis to meet the requirements of the Generic Letter, and does not involve an unreviewed safety issue.

2. The report supports NRC generic regulatory improvements (Periodic Verification of Motor Operated Valves), in accordance with 10 CFR 170.11(a) (1) (iii).

Consistent with the Office of Nuclear Reactor Regulation, Office Instruction LIC-500, "Processing Request for Reviews of Topical Reports," the JOG requests that the NRC provide target dates for any Request(s) for Additional Information and for issuance of the Safety Evaluation for MPR-2524, Revision 0.

While this enclosed Topical Report has been endorsed by all three Owners Groups, it should not be interpreted as a commitment by any individual licensee. Each member licensee is responsible for its licensing commitments to the NRC.

It is the expectation of JOG participating utilities that new individual licensee commitment letters will not be required by the NRC for implementation of the JOG long-term MOV Periodic Verification Program; in that current licensee commitments described in each licensee's Generic Letter 96-05 response will be adequate.

If you have any questions regarding the attached or contents of this letter, please contact Dennis Kreps at 860-731-6632 or any of the undersigned.

Regards,

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MPR ASSOCIATES INC.
ENGINEERS

MPR-2524
Revision 0
February 2004

Joint Owners' Group (JOG) Motor Operated Valve Periodic Verification Program Summary

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 for

B&W Owners' Group

BWR Owners' Group

Westinghouse Owners' Group

MPR ASSOCIATES INC. ENGINEERS

Joint Owners' Group (JOG) Motor Operated Valve Periodic Verification Program Summary

MPR-2524
Revision 0

February 2004

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.

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Executive Summary

The Joint Owners' Group (JOG) Motor-Operated Valve (MOV) Periodic Verification (PV) Program helps nuclear power plants address US Nuclear Regulatory Commission (NRC) Generic Letter 96-05, *Periodic Verification of Design-Basis Capability of Safety-Related Motor-Operated Valves*. The B&W, BWR, CE and Westinghouse Owners' Groups supported the program, and 98 of the 103 active US nuclear power plant units participated. A Program Description Topical Report prepared at the beginning of the program was accepted by the NRC, subject to certain conditions and limitations, in an NRC Safety Evaluation. The Topical Report specified an interim PV testing approach, developed based on judgment and experience, and defined a test program to obtain long-term, repeat valve performance data to identify where degradation in required thrust (gate and globe valves) or torque (butterfly valves) could occur.

This report documents the conclusions and final PV approach for the JOG MOV PV program. These outcomes are based on the results from repeat testing of 176 MOVs in power plants, under conditions with flow and differential pressure (DP). The work to carry out these tests, summarize and approve the test results, and analyze the data has been the major effort of the program. The test matrix and results of these tests are summarized in this report.

For all four valve types tested for the JOG MOV PV Program, there is no age-related degradation (i.e., no increases in required thrust or torque due only to the passage of time, without DP stroking).

For most **gate valves**, there is no service-related degradation (i.e., no increases in required thrust due to DP stroking). For these valves, the valve factor (proportional to thrust required to overcome DP) is stable. Under certain conditions, however, increases in required thrust were observed. Specifically, gate valves with low initial valve factors, either due to disassembly of the valve or due to little or no DP stroking in service, are susceptible to increases in required thrust. These increases tend to occur progressively up to a plateau level as the valve accumulates DP strokes. These results show that there is a need to understand if gate valves are in a stable realm or not. Valves that are set up using a justified stable valve factor do not need to consider allowances for increases. Valves that are set up using a valve factor susceptible to increase need to add a margin allowance to cover future increases in required thrust.

For **butterfly valves**, there is no service-related degradation in required bearing torque. Butterfly valves with bronze bearings (the most common material) have stable bearing friction (proportional to bearing torque) in treated water systems and in untreated water systems where the valve has a bearing hub seal. Butterfly valves with bronze or 300 series stainless steel bearings in untreated water systems without a hub seal show significant variations in bearing friction unrelated to DP stroking, although there is no increasing or decreasing trend. Butterfly valves with non-metallic bearings show relatively stable bearing friction, with only small variations in both treated and untreated water. These results show that there is a need to understand if butterfly valves have stable bearing friction or are susceptible to variation. Valves that are set up using a justified bearing friction coefficient do not need to consider the effect of variations. Valves that are set up using a bearing friction coefficient susceptible to variations need to be justified by testing or corrected to achieve a set up that covers the variations.

For **balanced disk globe valves** and **unbalanced disk globe valves**, there is no service-related degradation in required thrust. For balanced disk globe valves, the DP thrust component is very small and the valve factor is stable. For unbalanced disk globe valves, testing confirmed a stable thrust in both water and steam service. In balanced disk globe valves, service in untreated water can lead to thrust variations, not related to DP thrust, that come and go. It appears that these variations are due to particulates interfering with disk motion.

Based on the results of the JOG MOV PV Program testing, a final PV approach for plant MOVs has been defined and justified. The approach, which is an adjusted version of the interim approach defined at the outset of the program, nominally calls for static testing of MOVs at a frequency dependent on margin and risk significance. A classification process is used to determine how each MOV is to be tested. Valves that are not susceptible to degradation are identified and static PV test intervals are specified. Applications of gate and butterfly valves that are susceptible to increases or variations in required thrust or torque are identified, and users are to add margin allowances (gate valves) or to verify by DP test (butterfly and gate valves) that the valve performance is stable. If these approaches are unworkable, the method specifies threshold values of disk-to-seat friction coefficient (gate valves) or bearing friction coefficient (butterfly valves), above which increases or variations will assuredly not occur.

The implementation guidance to use the JOG MOV PV Program approach is included with this report. This guidance covers obtaining the necessary information about the MOV, classifying it, and determining the PV test interval. Note that some MOVs have design attributes or are in applications that fall outside the scope of coverage of the JOG MOV PV Program final approach. For valves that are not covered by the JOG MOV PV Program approach, the individual plant is responsible for addressing and justifying the periodic verification approaches for these valves.

A schedule for plants to implement the final PV approach is provided following this summary.

JOG MOV PV Program Implementation Schedule

Implementation of the JOG MOV PV Program is suggested to be completed within six years from the date of issuance of the NRC Safety Evaluation (SE). During the six-year period, participants in the JOG MOV PV Program will be expected to complete the following aspects of their MOV programs:

- Continue PV testing of each valve in accordance with the interim PV Program until the final JOG MOV PV Program is implemented for that valve.
- Assess the applicability of this report (MPR-2524) and the NRC SE to specific plant Generic Letter 96-05 MOVs.
- Address MOVs in a priority of high-risk MOVs, medium-risk MOVs and low-risk MOVs such that all MOVs are addressed within the six-year period.
- Identify MOVs not covered by the JOG MOV PV Program and establish a plant PV program for these MOVs.
- Develop plant procedures, as required, to implement the plant MOV PV program.
- Establish and implement PV test frequencies for all MOVs included in Generic Letter 96-05 scope following the guidelines of the JOG MOV PV Program.
- Perform appropriate operability evaluations for any affected MOVs at the time of implementation. Assuming plants have previously addressed issues identified in JOG MOV PV Feedback Notices FN-01, FN-03 and FN-04, operability of MOVs during the implementation phase is not expected to be an issue. Issues found during implementation resulting in negative margin should be addressed by licensee corrective action programs.

Plant modifications driven by Generic Letter 96-05 and by implementation of the JOG MOV PV Program are not required to be completed within the six-year period as long as operability is justified by the licensee.

1 Introduction

Background

USNRC Generic Letter (GL) 89-10 (Reference 1) recommended that each nuclear power plant[1] establish a program to demonstrate that safety-related motor operated valves (MOVs) are capable of performing their design basis functions. Each plant implemented a program which included analyses of MOV design basis conditions and MOV performance, and testing to demonstrate MOV operability. These programs required major efforts and resources from each plant, including modifications of many MOVs. These efforts produced significant improvements in MOV design assurance and functional reliability.

Although GL 89-10 included recommendations for periodic verification of MOV performance, these elements were separately summarized by the NRC in GL 96-05 (Reference 2). GL 96-05 supersedes GL 89-10 and its supplements with regard to MOV periodic verification.

GL 96-05 requests that each plant:

> *Establish a program, or ensure the effectiveness of its current program, to verify on a periodic basis that safety-related MOVs continue to be capable of performing their safety functions within the current licensing basis of the facility. The program should ensure that changes in required performance resulting from degradation (such as those caused by age) can be properly identified and accounted for.*

To address GL 96-05, the nuclear industry recognized that there is a benefit if many plants can take advantage of the investments each plant made in their GL 89-10 programs and of subsequent testing. The Joint Owners' Group (JOG) MOV Periodic Verification (PV) Program was formed on this basis. Specifically, the Babcock & Wilcox Owners' Group (B&WOG), Boiling Water Reactor Owners' Group (BWROG), Combustion Engineering Owners' Group (CEOG)[2] and Westinghouse Owners' Group (WOG) joined together for the JOG MOV PV Program.

Briefly, the objective of the JOG MOV PV Program is to provide an approach for participating plants to use for periodic verification of safety-related MOVs. This objective is described more fully in Section 2. At the outset of the JOG MOV PV Program (1997), a Program Description Topical Report was prepared (Reference 3). This report described the "design" of the program, provided the underlying technical basis and included the methods that were to be used in the

[1] Throughout this document, "plant" is used to represent the "licensee" or "utility."
[2] During the course of the JOG MOV PV Program, the CEOG merged into the WOG.

program. This report was submitted by the Owners' Groups to the NRC, and the NRC subsequently issued a Safety Evaluation (Reference 4). The safety evaluation indicated that:

> *With the conditions and limitations described in the Safety Evaluation, the staff considers that the Joint Owners' Group (JOG) Program on MOV Periodic Verification serves as an acceptable industry-wide response to Generic Letter 96-05, "Periodic Verification of Design-Basis Capability of Safety-Related Motor-Operated Valves."*

Individual plants notified the NRC whether they were participants in the JOG MOV PV Program or whether they were implementing their own approach for periodic verification. Ninety-eight (98) of the 103 operating reactor units in the US participated in the JOG MOV PV Program.

The JOG MOV PV Program has been implemented using the approach described in Reference 3. As mentioned in the SE (Reference 4), the NRC required that the JOG MOV PV Program Topical Report be updated (or a new report issued) after the dynamic test program was carried out. This report meets that requirement.

PURPOSE

This report:

- Describes the content and results of the JOG MOV PV Program
- Presents the conclusions drawn from the program
- Defines and justifies an approach for periodic verification for use by participating plants
- Provides implementation guidance for the periodic verification approach

2 JOG MOV Periodic Verification Program Description

Program Description Topical Report and NRC Safety Evaluation

At the outset of the JOG MOV PV Program, a Program Description Topical Report was prepared and provided to the NRC (Reference 3). As presented in Reference 3, the objectives of the JOG MOV PV Program are:

1. *To provide an approach for member plants to use immediately in their GL 96-05 programs. The approach covers prioritization of MOVs based on importance and margin, and specifies intervals for static MOV testing.*

2. *To develop a basis for addressing the potential degradations (increases) in required thrust or torque under differential pressure (DP) conditions. The basis is supported by a set of planned tests to be performed in-plant, which cover the change in DP thrust or torque over a period of several years.*

3. *To use the basis from Item 2 to confirm, or if necessary to modify, the approach defined in Item 1.*

The first objective was satisfied by the Program Description Topical Report (Reference 3), which presented a recommended interim MOV periodic verification approach. The approach, developed based on engineering judgment, consists of periodic static (no flow or DP) testing at an interval based on the valve's margin and risk ranking. The report provided definitions of margin and gave guidance for determining risk ranking. Plants that committed to participate in the JOG MOV PV Program used this interim PV approach.

The second and third objectives listed above have been fulfilled by the work performed since the issuance of Reference 3, as described in this report.

The scope of the JOG MOV PV Program discussed in Reference 3 covers the potential degradation in *required* thrust or torque for most safety-related gate, butterfly, unbalanced disk globe and balanced disk globe valves. Reference 3 provides specific design attributes and fluid conditions that are covered by the program. As the program was carried out, a refined description of the program scope was prepared, as discussed in this report (Section 7).

The JOG MOV PV program does not cover potential degradation in actuator *available* thrust or torque. This element of potential degradation is the responsibility of each individual plant.

Reference 3 discusses required thrust or torque degradation mechanisms for gate, butterfly and balanced disk globe valves. These degradation mechanisms relate primarily to the potential increase in friction coefficient at sliding, load-bearing interfaces (disk-to-seat and guide-to-guide rail in gate valves, shaft-to-bearing in butterfly valves and disk-to-guide in balanced disk globe valves). No degradation mechanisms were identified for unbalanced disk globe valves. To understand potential degradation associated with the mechanisms for gate, butterfly and balanced disk globe valves and to confirm the absence of degradation for unbalanced disk globe valves, test data under DP conditions were needed. Reference 3 defined an in-plant dynamic test program to obtain these data. Over a five-year period, each participating nuclear power plant unit was to test two MOVs three times each, with repeat tests separated by at least a year. Reference 3 includes a specification that defines the requirements for testing and for preparing test data packages.

The results from each DP test were submitted to the program, in an ongoing basis over the five-year period. Reference 3 included a commitment that the data would be periodically reviewed to determine if any actions were needed based on the results. As discussed later in this section, this process was carried out.

The NRC issued a Safety Evaluation (Reference 4) that summarized the NRC's review of the JOG MOV PV Program and the Program Description Topical Report. The NRC accepted the approach defined in the Program Description Topical Report, subject to the following conditions and limitations (lettered as they appear in Reference 4).

A. *JOG must submit for NRC review and approval a revision to (or replacement report for) the topical report following the JOG dynamic test program which describes the final test criteria for the long-term MOV Periodic Verification Program, and the justification for those criteria.*

B. *Licensees that did not participate in the development of NEDC-32264*[3] *must justify their MOV risk categorization methodology as part of their implementation of the JOG program. The NRC staff is reviewing an MOV risk ranking methodology submitted by WOG for possible endorsement.*[4]

C. *Licensees implementing the JOG Program must address the NRC evaluation and conclusions on the JOG program provided in this SE (and in the supplement to be prepared after the results of the JOG dynamic test program are evaluated). JOG indicated that participating licensees will be requested, following issuance of this SE, to individually notify the NRC of their plans to implement the JOG program described in Revision 2 of the topical report. Participating licensees must justify any deviations from the JOG program.*

D. *Licensees implementing the JOG Program must determine any valves that are outside the scope of applicability of the JOG overall program or the JOG dynamic test*

[3] NEDC-32264 is the BWROG MOV risk-ranking methodology (Reference 5). The NRC issued an SE on the BWROG methodology (Reference 6).
[4] Subsequent to Reference 4, the NRC issued an SE on the WOG MOV risk ranking methodology. The WOG methodology and the NRC's SE are References 7 and 8, respectively.

program (or deleted from the JOG program scope), such as in terms of valve manufacturer, size, type, materials, or service conditions, and must justify a separate program for MOV periodic verification for these valves, materials, and service conditions not encompassed by the JOG program.

E. *Licensees implementing the JOG Program must address the information provided as a result of the program during and following the JOG dynamic test program. This responsibility includes notification of the NRC under 10 CFR Part 21, evaluation of experience for applicability, and consideration of effects on component operability, as appropriate.*

F. *Licensees must ensure that each MOV in the JOG program will have adequate margin (including consideration for aging-related degradation) to remain operable until the next scheduled test, regardless of its risk categorization or safety significance.*

G. *Licensees may retain their approach for MOV setup where it is justified that MOVs are properly evaluated for operability. However, when establishing test frequencies under the JOG program, licensees must apply uncertainties as appropriate in calculating actuator output or valve required thrust (or torque).*

H. *With the focus of the JOG program on the potential age-related increase in the thrust and torque required to operate the valves, licensees must address apart from the JOG program the thrust and torque delivered by the motor actuator. Licensees must address the effects of aging on rate-of-loading and stem friction coefficient under dynamic conditions, and other potential age-related effects such as spring-pack relaxation, and actuator and switch lubrication degradation.*

I. *The dynamic test sequence in the JOG program includes a static test preceding the dynamic test. JOG will evaluate available test information, to the extent possible, to determine whether the performance of a static test immediately preceding a dynamic test might affect the conclusions of the JOG program. The NRC staff will continue to monitor this issue on the basis of JOG data and NRC research results.*

J. *MOVs with scheduled test frequencies beyond 5 years will need to be grouped with other MOVs that will be tested on frequencies less than 5 years in order to validate assumptions for the longer test intervals. This review must include both valve thrust (or torque) requirements and actuator output capability.*

This final report resolves conditions and limitations A and I identified in the Safety Evaluation (Reference 4), and presents and justifies a recommended final approach for MOV periodic verification. The information presented in this report allows licensees to resolve conditions and limitations D, E and G. Conditions and limitations B, C, F and H are the responsibility of the licensee. Condition and limitation J is obviated by the completion of the JOG MOV PV Program.

DYNAMIC TEST PROGRAM

Test Matrix

The JOG MOV PV Program Description Topical Report (Reference 3) presents a test matrix of valves for DP testing[5], to provide the range of valve attributes and fluid conditions to address potential degradation. The matrix includes 150 valves (100 gate valves, 30 butterfly valves, 10 balanced disk globe valves and 10 unbalanced disk globe valves). A 25% attrition allowance was identified, as it was likely that some valves would not be able to fully complete the test sequence due to replacement, maintenance or other test difficulties. Therefore, the objective of the program was to obtain DP test data from at least 115 valves.

At the program outset, the participating plants were surveyed to identify the valves each plant was willing to repetitively DP test. From this master list of valves, two valves were selected from each unit, such that the aggregate set of valves best covered the desired matrix. Initially, this process produced a test matrix of 197 valves. However, as expected there were instances where the testing was not able to be completed and valves had to be dropped. The final test matrix includes 176 valves.

During the program, two steps were taken to ensure that the coverage of the program was adequate. First, the as-tested matrix was compared to the desired test matrix presented in Reference 3. Second, the participating plants were asked to identify MOVs that they judged might be outside the scope of coverage of the JOG MOV PV Program, or where the coverage might be unclear. This list of MOVs and applications was evaluated in light of the program test data to determine how each valve should be addressed.

When the as-tested matrix was compared to the desired matrix, a few limited instances were identified where the program scope envisioned by Reference 3 could not be achieved. These categories and the approach used in each case are listed below.

- Aloyco Split Wedge Gate Valves above 120°F

  For Aloyco split wedge gate valves that have in-service DP stroking above 120°F, the JOG Program covers the potential degradation in thrust for flow isolation (closing) and for opening. The potential degradation in thrust at hard-seating (closing) is covered only for valves that do not have in-service DP stroking above 120°F. Valves that are required to stroke against DP above 120°F as a design basis condition but not stroke in service against DP above 120°F are fully covered by the Program.

- Gate Valves with Stainless Steel Guides above 120°F

  The JOG Program does not cover gate valves with 300 series stainless steel (SS) versus 400 series SS guides or with self-mated 300 series SS guides, that stroke in

[5] "DP testing" and "dyanamic testing" are used interchangeably throughout this report to refer to testing of a valve with flow and differential pressure.

service against DP at a temperature above 120°F. Valves which are required to stroke against DP above 120°F as a design basis condition but not stroke in service against DP above 120°F are fully covered by the Program.

The information in Section 7 - *Implementation of JOG MOV Periodic Verification Approach,* incorporates these limitations.

When the plants were surveyed regarding valves that they judged might not be within the coverage of the program, a list of several valve design attributes and applications was generated. The valves on this list were evaluated in light of the data being obtained in the program. One of three outcomes was defined for each valve.

- The data in the program were sufficient to cover these valve design attributes and applications, and to justify including them in the program.
- The data in the program could be extended to cover these valve design attributes and applications.
- The program did not cover these design attributes and applications.

The information in Section 7 - *Implementation of JOG MOV Periodic Verification Approach,* covers the details of these classifications.

Test Data Handling

To ensure that data obtained from in-plant tests are satisfactory for use in the JOG MOV PV Program, a test specification is included in Reference 3 (also Reference 9). The participating plants that tested MOVs and submitted the data were required to follow the test specification, which includes requirements for:

- Test valve maintenance and material condition, including prior to and during the test program
- Test conditions
- Test instrumentation
- Test sequence
- Test data evaluation
- Test documentation

The goal of the test specification is to ensure that all valves and testing are properly controlled to achieve adequate consistency and quality from test results obtained from multiple plants. Importantly, the test specification requires that time-history data for stem thrust (or stem torque for butterfly valves) and DP be obtained. Further, the specification requires analyzing and summarizing the data in a prescribed manner, using consistent calculation methods.

When data were received from a plant, an inspection was performed to evaluate whether the test data met the requirements of the specification. The inspection followed a procedure and was documented. If deviations from the specification were identified, they were evaluated to determine if the data were satisfactory for use or if the test needed to be rejected. In a few cases, the acceptance of the test was contingent on the plant obtaining additional data or information in subsequent tests. Once the additional information was obtained, the test was accepted.

During the test data inspection process, adjustments to the data analysis were sometimes identified. An example is the calculation of bearing friction coefficient for butterfly valves with shaft offsets. The specification did not provide the necessary formula for this calculation. In cases like these, the inspectors performed and verified the needed additional evaluations. The plant was provided with a copy of adjustments performed by the inspectors.

For reference, 513 test packages were approved for use in the Program. Thirty-three (~6%) test packages were rejected due to deficiencies in the test. For 161 of the final 176 valves, all three test packages were approved; 15 of the valves had two test packages approved. These statistics show the difficulties of obtaining in-plant data and the need (as was satisfied in this program) of providing an attrition allowance. The final test matrix includes all valves for which DP test data were obtained and accepted for more than one test.

In the case of four gate valves, data from one stroke direction appeared unusual and were inconsistent with data from the other stroke direction and data from other similar valves. These unusual data were carefully reviewed, including detailed discussions with the respective plants, and no deficiencies in the tests or data analyses were found. Therefore, these data were kept in the program. However, because of the inconsistency with other data, these few results were treated as outliers and not included in detailed data evaluations. Each of these cases is discussed and justified in this report (Section 3-*Test Program Results for Gate Valves*).

Data Evaluation and Review by JOG Core Group[6]

Twice per year, the JOG MOV PV Program Core Group met to review the data that had been received in the JOG MOV PV Program. Appendix C contains a list of the Core Group Meeting dates. At each meeting, two approaches were used to evaluate the data. First, all of the data to date that met the "rapid attention" criterion as described in Reference 3 were reviewed. "Rapid attention" is defined as an increase in valve factor or bearing friction coefficient, beyond measurement uncertainty, exceeding 10%. As these tests were reviewed, a running log of observations and dispositions was created and maintained.

Second, the Core Group reviewed all of the program data to date, to ensure that trends and details in the data were observed and understood. These reviews led to numerous follow-up actions with individual plants to ensure that data in the program were properly evaluated and presented. In addition, the Core Group directed additional investigations and evaluations of the data.

[6] Oversight of the JOG MOV PV Program was provided by a Core Group consisting of 20 individuals representing the participating plants (5 from each of the four Owners' Groups). There were 4 Core Group Chairmen, one from each Owners' Group. Also, each Owners' Group had one Project Manager who provided logistical and organizational support. Toward the end of the program, the CEOG merged into the WOG.

The Core Group's reviews included the four cases of outlier data discussed above, and the Core Group concurred in the conclusions for these data.

Feedback to Program Participants

Where valves showed significant increases in valve factor or bearing friction coefficient, or where there were trends in data that reflected potential degradation, the Core Group determined what action and feedback to the program participants was needed.

When the Core Group determined that there was information learned from the test results that needed to be shared with the participants, a Feedback Notice (FN) was generated, approved and distributed. A total of four Feedback Notices were distributed during the program as listed in Table 2-1. The Feedback Notices were issued using the information and data on hand at the time. The complete information in this report supersedes the Feedback Notices.

NRC In-Process Reviews

Twice per year, the Core Group Chairmen and Project Managers met with the NRC to brief the NRC on the status and results of the program. Appendix D contains a list of the meeting dates. During these meetings, the NRC had the opportunity to ask questions and discuss the test data. Questions and comments that could not be fully resolved with the information on hand were noted for further discussion in subsequent meetings. Adjustments to the program or to the analyses of the data were made based on the NRC's input during these meetings.

FINAL PERIODIC VERIFICATION APPROACH

Based on the successful completion of the dynamic test program, this report defines the final JOG MOV periodic verification approach. Specifically, Section 7 of this report provides the implementation steps and guidance that participating plants should use to establish their long-term periodic verification program. The final approach has similarities to the interim approach. The comprehensive results from DP testing provide the basis for the final approach including, where needed, adjustments to the interim approach.

Table 2-1. Feedback Notices Issued in JOG MOV PV Program[7]

Number	Title	Applicable Revision at End of Program
FN-01	*Information on Increases in Required Thrust and Valve Factor for Gate Valves with Low Initial Valve Factors*	Revision 2, issued May 2002
FN-02	*Adjustment to JOG PV Program Coverage Based On In-Plant Test Matrix*	Revision 0, issued October 1999
FN-03	*Results and Observations from Gate Valve Tests Following Valve Disassembly and Reassembly*	Revision 0, issued February 2000
FN-04	*Results and Observations from Butterfly Valve Tests with Bronze Bearings in Untreated Water Systems*	Revision 0, issued September 2003

[7] All Feedback Notices are superseded by this report.

3 Test Program Results for Gate Valves

SUMMARY

For the majority of gate valves, disk-to-seat friction controls gate valve required DP thrust, and is the key mechanism affecting potential degradation. Gate valves show no evidence of age-related degradation (i.e., increases in required thrust due only to the passage of time). Gate valves show stable disk-to-seat friction and no evidence of service-related degradation (i.e., increases in required thrust due to DP stroking), except under particular conditions. Specifically, disassembly and reassembly of a gate valve tends to reduce the valve factor. This reduced value tends to increase as a result of DP stroking, to values typical of non-disassembled valves. Some non-disassembled gate valves, particularly those that are not DP stroked in service, also show low disk-to-seat valve factors. These valve factors increased during the course of DP testing in the JOG MOV PV Program.

Disk-to-guide friction occasionally controls required DP thrust in the opening direction, but is of negligible influence in the closing direction. Disk-to-guide friction was observed to be stable, with the exception of disassembled valves with self-mated carbon steel guides, self-mated 300 series stainless steel guides and 300 series vs. 17-4PH stainless steel guides. For these materials, disassembled valves show a slight decrease in guide friction, which tends to increase with DP stroking to values typical of other, non-disassembled valves. Guide valve factors for valves with carbon steel guides at elevated temperatures were higher than those observed in cold water, but the values remained stable.

Anchor/Darling double disk and Aloyco split wedge gate valves have additional mechanisms that affect hard seating at the end of closing strokes. The test results show that there is no degradation associated with these mechanisms.

APPROACH FOR GATE VALVES

The intent of the JOG MOV PV Program was to test gate valves with a range of design attributes and fluid conditions to determine if there were observable changes in required DP thrust which could be related to degradation. As described in the JOG MOV PV Program Description Topical Report (Reference 3), two potential mechanisms for degradation of gate valve DP thrust were identified.

- An increase in disk-to-seat friction due to DP stroking or effects of the fluid environment.

- An increase in guide friction due to DP stroking or effects of the fluid environment on Stellite guides, or due to corrosion of carbon steel guides, or due to wear or galling of non-hardfaced guides caused by DP stroking.

For the majority of gate valves, the required DP thrust is controlled by friction at the disk-to-seat interface. In some cases, disk guide-to-body guide friction can control the required thrust. The Topical Report (Reference 3) identified the key factors that can potentially influence the friction behavior for gate valves.

- Disk and seat material pair
- Disk and body guide material pair
- Fluid environment and temperature
- Cumulative DP strokes
- Current valve factor

Accordingly, it was judged important to identify test valves that cover an appropriate range of each key factor. The industry was surveyed to determine what gate valves were available for periodic DP testing. The 134 gate valves tested in the JOG MOV PV Program were selected from the valves identified in the survey results, to cover the desired key factors.

GATE VALVE TEST MATRIX AND APPLICABILITY

One-hundred and thirty-four gate valves were tested in the JOG MOV PV Program. Tables 3-1A and 3-1B summarize the design and application attributes of these valves and Table 3-2 summarizes the test conditions, including fluid and stroking conditions.

Key Factors Associated with Potential Degradation

As identified in Reference 3, the key factors associated with the potential degradation of gate valves are: disk-to-seat materials, disk-to-body guide surface materials, fluid medium and temperature, frequency of DP stroking, and current valve factor. The gate valves tested in the JOG MOV PV Program provided good coverage of these factors.

Disk to Seat Materials

Gate valves with the following disk-to-seat materials were tested:

- Stellite disk vs. Stellite seat (*117 valves*)
- 400 series Stainless Steel disk vs. 400 series Stainless Steel seat (*5 valves*)
- 400 series Stainless Steel disk vs. Stellite seat (*4 valves*)
- 400 series Stainless Steel disk vs. Monel seat (*4 valves*)
- Exelloy disk vs. Monel seat (*3 valves*)
- Deloro 50 disk vs. Deloro 50 seat (*1 valve*)

Consistent with the general population of motor-operated gate valves in nuclear power applications, the majority of tested valves have self-mated Stellite seats. The evaluation of this data is more extensive compared to the 17 valves with other, less prevalent, seat materials. Stellite for these valves, by design, is Stellite 6 or an equivalent grade. It is likely that some tested valves had Stellite 21 on a disk or seat face. These two grades of Stellite are similar and no attempt was made to distinguish them in the data.

Exelloy is a heat-treated 400 series Stainless Steel material used by Crane Valves. Depending on the heat treatment and corresponding hardness, the material may meet the requirements for ASTM 182/F6 or 351/CA15. Throughout this report, 400 series Stainless Steel and Exelloy are considered to be equivalent. Monel is a nickel-copper alloy that is highly resistant to salt water, and various acid and alkaline solutions. Deloro 50 is a cobalt-free, nickel-based hardfacing material that has been used sparingly in gate valves.

Disk-to-Body Guide Surface Materials

Gate valves with the following combinations of disk-to-body guide surface materials were tested, covering the predominant materials used in nuclear power plant applications:

- Carbon steel disk guide vs. Carbon steel body guide *(51 valves)*
- Carbon steel disk guide vs. 17-4 PH Stainless Steel body guide *(1 valve)*
- Stellite disk guide vs. Carbon steel body guide *(9 valves)*
- Stellite disk guide vs. 17-4PH Stainless Steel body guide *(13 valves)*
- Stellite disk guide vs. 300 series Stainless Steel body guide *(7 valves)*
- Stellite disk guide vs. Stellite body guide *(1 valve)*
- Stellite disk guide vs. Malcomized 410 Stainless Steel body guide *(2 valves)*
- 300 series Stainless Steel disk guide vs. 300 series Stainless Steel body guide *(17 valves)*
- 300 series Stainless Steel disk guide vs. 17-4 PH Stainless Steel body guide *(4 valves)*
- 300 series Stainless Steel disk guide vs. Carbon steel body guide *(4 valves)*
- 300 series Stainless Steel disk guide vs. Stellite body guide *(1 valve)*
- 400 series Stainless Steel disk guide vs. Carbon steel body guide *(1 valve)*

Some gate valves tested in the program (Anchor/Darling double disk and some Aloyco split wedge valves) do not have guides.

Type of Fluid

Gate valves were tested in clean (treated) water systems (*109 valves*), in raw (untreated) water systems (*14 valves*), and in steam systems (*11 valves*).

Fluid Temperature

Gate valves with the following temperature conditions were tested:

- valves in cold water (≤120°F) systems *(102 valves)*
- valves that operate in hot water (>120°F) systems, but were tested under cold conditions *(16 valves)*
- valves in hot water systems (test temperatures from 120° to 225°F)[8] *(5 valves)*
- valves in steam systems (test temperatures from 455° to 585°F) *(11 valves)*

[8] Three valves in hot water systems (G91.06, G99.04 and G99.05) had one JOG test performed at a temperature ≤120°F and the other JOG tests performed at temperatures >120°F.

Frequency of DP Stroking

Most gate valves in nuclear power applications are either not stroked against DP during normal operation, or accumulate very few strokes (e.g., during system testing). A few valves routinely stroke against DP during plant operation. The gate valves selected for testing included an extensive range of DP stroking between JOG test sequences (0 to 168 DP strokes). Table 3-2 provides the number of DP strokes between tests for each valve. This stroking information was provided in the test data package for each valve. The information was prepared by plant personnel using their records, experience and discussions with others. This information is approximate because the valves do not have stroke counters or monitors to precisely record their detailed operating histories. Although the information includes estimates, it was judged appropriate for use in understanding the trends of behavior.

For analysis purposes, the 134 tested valves were divided into three groups based on typical DP stroking information provided by the plants and based on the estimated DP strokes that occurred between JOG tests.

- Valves that are not typically DP stroked during normal operation are considered *NO* stroking valves. *(53 valves)*
- Valves that accumulate a few (approximately 1-4) DP strokes per year are considered *LOW* stroking valves. *(48 valves)*
- Valves that are stroked frequently against DP (≥5 strokes per year) are considered *HIGH* stroking valves. *(33 valves)*

Current Valve Factor

The 134 gate valves selected for testing exhibited a wide range of current valve factor at the program outset. Seventy-one (71) valves had baseline valve factors less than 0.4 and 63 valves had baseline valve factors of 0.4 or greater.

Additional Valve Design Attributes

In addition to the key factors described above, the tested gate valves provided good coverage of other valve design attributes and operating conditions. Although these additional design attributes and operating conditions are not identified in Reference 3 as important applicability factors for the data, it was judged prudent to cover an appropriate range of attributes and operating scenarios typical for nuclear power applications. The additional attributes/operating conditions are discussed below.

Valve Manufacturer

The gate valve test matrix covers the following manufacturers: Aloyco, Anchor/Darling, Borg-Warner, Crane, Pacific, Powell, Velan, Walworth and Westinghouse.

Valve Size

The test matrix covers ten unique sizes, ranging from 3 to 24 inches.

Pressure Class
The test matrix covers six unique ANSI pressure classes: 150, 300, 600, 900, 1500 and 2035.

Disk Type
The test matrix covers four different disk types: solid wedge (*24 valves*), flexible wedge (*83 valves*), Anchor/Darling double disk (*19 valves*) and Aloyco split wedge (*8 valves*). Most solid and flexible wedge gate valves have guide slots on the disk and guide rails on the body. A few gate valves have an inverted guide arrangement (rails on the disk and slots in the body). There are nine JOG valves with the inverted guide arrangement.

As discussed in Reference 3, solid and flexible wedge gate valves are considered to be equivalent with regard to the mechanisms which affect required thrust and potential degradation. Therefore, the data from one type is applicable to the other type as well. Anchor/Darling double disk and Aloyco split wedge gate valves have mechanisms that affect stem thrust which are different from flexible and solid wedge gate valves. In some portions of the stroke, the required thrust for double disk and split wedge valves is controlled by disk-to-seat sliding. During this portion of the stroke, the data from these valve types can be included with the data from flexible and solid wedge valves. At the end of the closing stroke, however, the required thrust to hard seat double disk and split wedge valves is controlled by other mechanisms. These mechanisms and the evaluation for degradation are discussed later in Topics D-*Hard Seating of Anchor/Darling Double Disk Gate Valves* and E-*Hard Seating of Aloyco Split Wedge Gate Valves.*

Normal Valve Position
The test matrix includes 63 valves that are normally open and 71 valves that are normally closed.

Stem Orientation
The test matrix includes 79 valves with vertical stems and 44 valves with horizontal stems (22 in a horizontal pipe and 22 in a vertical pipe). Eleven valves have other stem orientations, ranging from 20° to 120° from vertical.

History of Disassembly/Reassembly
The test matrix includes 40 valves that had internal valve maintenance within the two-year period preceding initial JOG testing. Internal maintenance includes disassembly of the valve, such that the body-to-bonnet seal is broken, and reassembly following maintenance. Ninety-four valves were not disassembled/reassembled within the two-year period preceding initial JOG testing.

Flow Rate
The test matrix covers water flow rates from 33 - 23,500 gpm and steam flow rates from 6700 - 275,000 lbm/hr. Using nominal valve size, these flow rates yield water velocities from 0.6 – 46.5 ft/sec and steam velocities from 16.8 to 114 ft/sec.

Differential Pressure
The test matrix covers valves with as-tested DP values ranging from 39 – 2845 psid. An approximate breakdown of as-tested DP and the number of valves tested in each range is below.

- 200 psid or less: *52 valves*

- 200-500 psid: *37 valves*
- 500-1000 psid: *11 valves*
- 1000-2000 psid: *24 valves*
- >2000 psid: *10 valves*

METHODS FOR ANALYZING GATE VALVE TEST DATA

The vast majority of valves tested in the JOG MOV PV Program were gate valves, and the amount of data collected for evaluation was extensive. This section describes how the data were analyzed and evaluated for degradation.

Seat and Guide Friction

As described earlier, degradation in required thrust for gate valves can be attributed to increases in disk-to-seat friction and increases in guide friction. During a typical gate valve closing stroke under dynamic conditions, the required thrust is initially controlled by packing and stem rejection forces until DP builds up across the disk. The DP then pushes the disk against the body guide, such that the required thrust is increased by friction at the disk guide-to-body guide interface. In valves with no guides or with ample guide clearance, the DP load in mid-stroke is reacted at the downstream seat ring. At the point where flow is stopped (i.e., the downstream disk ring covers the seat ring), the valve has transitioned from guide sliding to disk-to-seat sliding, such that the required thrust is controlled by friction at the disk-to-seat interface. Once the disk is hard-seated, disk motion stops, the DP thrust portion of the stroke ends, and the thrust increases until the actuator reaches control switch trip (CST). In the opening direction, the process reverses.

Although the required thrust during the guide-controlled and seat-controlled portions of the stroke are both controlled by the frictional interface of two surfaces, the analyses of the two are not directly comparable. Therefore, the analysis of the JOG MOV PV Program gate valve test data presented later in this section covers disk-to-seat friction and disk-to-guide friction separately.

Analysis of Test Data and Valve Factor Determination

In accordance with the JOG DP Test Specification (Reference 9), each plant that tested a gate valve prepared a test data package for each test of the valve. In each package, the test data were analyzed following standard procedures.

In the closing stroke, the measured stem thrust and measured pressure at points of running, flow isolation, initial wedging and the point of maximum stem thrust were identified and tabulated. The stem thrust at control switch trip and final condition were also recorded, but these values are not used in data analysis. For some gate valves, a "zone" of seating was identified, in which case two points of initial wedging were determined. Only the first point of wedging, however, is considered for the analysis of disk-to-seat friction[9]. In most cases, the point of maximum closing thrust occurs in the region of the stroke controlled by disk-to-seat sliding, and is usually equivalent to the first or second (if it exists) point of initial wedging. For the flow isolation, initial wedging, and maximum thrust points, the required DP thrust was determined and converted to a valve factor. See Reference 9 for examples of this analysis.

In the opening stroke, the measured stem thrust and measured pressure at points of cracking (unwedging), just after cracking, flow initiation, maximum stem thrust (after cracking) and running were identified and tabulated. In the opening stroke, the point of maximum thrust can occur in either the seat controlled (before flow initiation) or guide controlled (after flow initiation) region of the stroke. For the just after cracking, flow initiation, and maximum after cracking points, the required DP thrust was determined and converted to a valve factor. See Reference 9 for examples of this analysis.

In most cases, data were obtained for both closing and opening dynamic strokes. In a few instances, plants were unable to DP stroke the valve or could not achieve meaningful DP in a particular direction. In these cases, data for only one stroke direction was provided. About one-third of the gate valve tests had a single DP cycle (open, close or both). For the other two-thirds, two DP cycles were typically performed back-to-back.

For the purposes of addressing disk-to-seat friction, valve factors at the following points are considered: flow isolation, initial wedging (first point), just after cracking and flow initiation. The justification is that the required thrust at these points is always controlled by disk-to-seat sliding.

For the purpose of addressing disk-to-guide friction, valve factors at the following points are considered: maximum closing thrust and maximum after cracking in the opening stroke, when determined to occur during the guide controlled portion of the stroke (i.e., before flow isolation for closing and after flow initiation for opening). The justification for this approach is that the required thrust at these points is expected to be controlled by disk-to-guide sliding.

The JOG MOV PV Program equations for determining valve factor are provided in Appendix A.

Coefficient of Friction and Valve Factor

For some valves, the closing and opening valve factors may show different magnitudes. In these situations, it is difficult to combine close and open values together. As an alternate approach, the apparent disk-to-seat coefficient of friction (COF) is used to evaluate close and open data together. In general, valve factors are used to evaluate data trends. For determining quantitative results for the purposes of implementation, apparent disk-to-seat COFs are used.

[9] For solid and flexible wedge valves, the required thrust at the second point of wedging is attributed to mechanisms other than disk-to-seat friction and is not considered in the analysis of gate valve degradation. For Anchor/Darling double disk and Aloyco split wedge valves, the required thrust at the second wedging point is attributed to special seating mechanisms for these valve designs. Further discussion on the seating behavior for these valves is presented later in this section.

COF can be determined from valve factor using an adjustment for wedge angle. The equations are provided in Appendix A. For closing strokes of wedge gate valves, the disk-to-seat COF will be slightly lower than disk-to-seat valve factor. For opening strokes, the disk-to-seat COF will be slightly higher than disk-to-seat valve factor. For parallel disk valves, valve factor and COF are equal.

Determining Valve Factor for Valves with Parasitic Load

The JOG MOV PV Program methodology for calculating valve factor compares two points from the same measured stem thrust trace (i.e., same DP test) to determine the required DP thrust. Specifically, the difference in measured thrust between the identified point of interest (e.g., initial wedging) and the running portion of the stroke, adjusted for stem rejection, provides the required DP thrust at the point of interest (see Appendix A).

Some gate valves tested as part of the JOG MOV PV Program showed unusual behavior during the static and dynamic tests, requiring an alternate method to calculate valve factor. Specifically, the thrust increased to a higher-than-expected value as the disk approached the seated position. This phenomena, often referred to as "parasitic loading," is most readily identified during a static stroke, as shown in the example test traces in Figure 3-1. The top of Figure 3-1 shows the case where the valve experiences an increase in thrust at the end of the closing stroke, just before the valve seats. In this example, the thrust at seating (i.e., initial wedging) is 42%, or 201 lbs, higher than the thrust measured at the beginning of the stroke. The bottom of Figure 3-1 shows the case where the apparent packing load steadily increases as the valve strokes from open to closed. In this example, the thrust at seating is 179%, or 1572 lbs, higher than the thrust measured at the beginning of the stroke. These parasitic effects are also present in the dynamic test traces, although the magnitude of the effect can be masked by the DP thrust.

The concern is that this elevated load, which cannot be attributed to DP thrust, can influence (i.e., artificially inflate or deflate) the valve factors calculated using the standard JOG methodology. For JOG gate valves determined to have significant parasitic loads observable in the static and DP traces, an alternate valve factor method was developed. Specifically, the dynamic thrust at the point of interest (e.g. initial wedging) was compared to the static thrust at the identical point in the stroke. This method removes the "parasitic" effect measured in the static test from the overall DP thrust. The equations for calculating valve factors for valves with parasitic load are provided in Appendix A.

All 134 JOG gate valves were screened for parasitic loading. For each static test, the measured thrust at running and initial wedging were evaluated for significant differences. Valves which passed this screen had their thrust traces examined for a parasitic loading "fingerprint" in both static and DP traces. Twelve valves showed significant parasitic loading fingerprints in both static and DP strokes. For these valves, the alternative valve factor method was utilized.

Disassembly/Reassembly of Valves

A significant factor that affects evaluating gate valve data is disassembly and reassembly of the valve prior to performing DP testing. The JOG MOV PV Program Test Specification (Reference

9) recognized this factor, and did not permit any internal maintenance of the valve between the baseline and third test. There were no restrictions, however, on internal maintenance of the valve prior to the initial baseline JOG test. Of the 134 gate valves tested, 40 were disassembled for internal maintenance and then reassembled prior to the JOG baseline test[10].

The JOG Test Specification defines valve disassembly as the disassembly of the valve body-to-bonnet joint. Examples of typical valve internal maintenance activities include: disk or stem replacement, disk inspection, grinding/smoothing of the disk wedge or body rails, or valve modifications (e.g., installation of pressure relief ports to address pressure-locking).

In the evaluation of test data presented later in this section, the impact of disassembly/reassembly on gate valve required thrust is discussed in detail. Given its impact, valves that were disassembled/reassembled prior to the baseline test are identified separately on supporting plots and figures.

Description of Plots Used for Analysis

In the analyses of gate valve test results presented later in this section, several types of plotting techniques are used to display test data and results. A general description of these plots is provided below.

Valve Factor Trend Line Plots

These plots present the valve factors for each test of a valve, connected as a single line from the first test to the final test. A separate plot is typically generated for each point in the stroke where a valve factor is calculated. The y-axis provides the valve factor value. The x-axis provides the test sequence information. Baseline test data is indicated by a "B", second test data by an "S" and third test data by a "T". In cases where consecutive DP strokes were performed as part of a test series, these data are indicated by the numbers "1" and "2" (e.g., B1 and B2). See Figure 3-13 for an example of this plot.

Some trend line plots contain information related to specific valve design features or system attributes. Different line and symbol styles are used to convey this information. In these cases, the plot legend conveys the interpretation of this information.

These plots may also include the average valve factor or range of valve factors for the group of valves covered by the plot. This information is only calculated for the first stroke of each test (i.e., B1, S1 and T1). In all cases where this information is compared from one test to another test, identical valve populations are used. See Figure 3-2 for an example of this plot.

Average valve factors are typically included for plots containing data for three or more valves. For valves with valid baseline and second test data (first stroke), an average baseline and second test valve factor is calculated, and these points are connected by a

[10] The maintenance history for all gate valves was collected for the 2-year period preceding the baseline test, and all valves that were disassembled/reassembled in this period were identified. In some cases, the disassembly history of the valve beyond the 2 preceding years was collected where it was required to address the valve factor performance.

thick dark line. For valves with valid baseline, second and third test data (first stroke), an average valve factor is calculated for each test, and a dark-dashed line connects these points[11]. For each average line, information in the legend identifies the number of valves included in the average. Depending on the available data, the number of valves included in the average may vary from point-to-point in the stroke.

In cases where plots include data for disassembled/reassembled valves and non-disassembled valves together, the data for each are uniquely identified. In addition, average valve factors for disassembled and non-disassembled valves are calculated separately.

ΔValve Factor vs. Initial Valve Factor Plots

These plots present the observed change in valve factor between tests versus the initial (i.e., starting) valve factor as a single data point. The y-axis provides the change in valve factor values between first strokes (B1, S1 or T1) of subsequent tests. The x-axis provides the initial valve factor value. Specifically, the change in valve factor from the baseline to second test (B1 to S1) is plotted against the baseline test value (B1). Similarly, the change in valve factor from the second to third test (S1 to T1) is plotted against the second test value (S1). Changes from the baseline to second test and changes from the second to third tests are typically differentiated by symbol type. In cases where the plot includes data for disassembled/reassembled valves and non-disassembled valves together, the data for each are uniquely identified. See Figure 3-4 for an example of this plot.

Using this plotting technique, multiple points in the stroke can be shown together. For seat friction analyses, these plots include the data at all four points of interest (flow isolation, initial wedging, just after cracking and flow initiation). These plots may also contain information related to the overall performance of the data population included in the plot. One example is the least-squares (best fit) linear regression line through the data. Plotted as a solid dark line, this line provides an overall trend of the data.

For valves which show different closing and opening valve factors, it may be more instructive to use coefficients of friction values instead of valve factors. In these cases, a ΔCOF versus initial COF plot is used.

[11] Note that the population of valves used to calculate the baseline-to-second test average and baseline-to-second-to-third average may be different. Therefore, the calculated baseline and second test averages may be different depending on the average method used.

GATE VALVE TEST RESULTS AND ANALYSES

Due to the large number of gate valves tested in the JOG MOV PV Program, the discussion of the test results and analyses is extensive. The data have been evaluated in several manners, including analyzing valve factor trends by valve design attributes such as disk-to-seat material and disk-to-guide material. Additionally, the data have been evaluated to determine the effects of service and maintenance activities on valve factor, such as valve disassembly/reassembly, DP stroking, static testing and pipe draining/venting. The discussion of the gate valve test results and analyses presented throughout the remainder of this section is organized by the following topics.

Topic A: Evaluation of Disk-to-Seat Friction for Gate Valves with Self-Mated Stellite Seats
Topic B: Evaluation of Disk-to-Seat Friction for Gate Valves with Other (Non-Stellite) Seat Materials
Topic C: Evaluation of Disk-to-Guide Friction
Topic D: Hard Seating of Anchor/Darling Double Disk Gate Valves
Topic E: Hard Seating of Aloyco Split Wedge Gate Valves
Topic F: Effects of Valve Disassembly and Reassembly
Topic G: Effects of DP Stroking
Topic H: Effects of Static Testing
Topic I: Effects of Draining/Venting
Topic J: Other Gate Valve Evaluations
Topic K: Gate Valve Conclusions

A. EVALUATION OF DISK-TO-SEAT FRICTION FOR GATE VALVES WITH SELF-MATED STELLITE SEATS

Since disk-to-seat material is judged to be the primary influence on seat friction, the gate valve data are initially grouped for analysis based on this attribute. Valves tested with self-mated Stellite seats (117 valves) are evaluated first. Valves tested with other (non-Stellite) seat materials are discussed in Topic B. Other potential influences on degradation, including fluid medium and temperature, DP stroking and valve disassembly effects, are addressed within each group.

Gate valves with self-mated Stellite seats are separated into the following four groups based on fluid type and temperature (see Tables 3-1A and 3-1B):

- Valves that operate and are tested in cold treated water (≤120°F) systems *(78 valves)*
- Valves that operate and are tested in cold untreated water (≤120°F) systems *(11 valves)*
- Valves that operate in hot water (>120°F) systems, but are tested in cold water *(16 valves)*
- Valves that operate and are tested in hot water or steam systems *(12 valves)*

A.1 Cold Treated Water

For analysis purposes, the 78 valves with self-mated Stellite seats in cold treated water were divided into three groups according to the valve DP stroking frequency, including normal operation and in between JOG tests (see Table 3-2 for stroking categories).

- Valves that are not typically DP stroked during normal operation are considered *NO* stroking valves. *(33 valves)*
- Valves that accumulate a few (1-4) DP strokes per year are considered *LOW* stroking valves. *(29 valves)*
- Valves that are stroked frequently against DP (≥5 strokes per year) are considered *HIGH* stroking valves. *(16 valves)*

No DP Strokes

The JOG MOV PV Program tested thirty-three gate valves with Stellite seats in cold (≤120°F) treated water systems that are not typically DP stroked. Figures 3-2 and 3-3 show the average closing and opening valve factors across the three test series. Separate averages are shown for valves that were disassembled and then reassembled prior to the baseline test and valves that were not disassembled prior to the baseline test.

Twenty-three valves had no internal maintenance or valve disassembly in the two years prior to the baseline test. As seen in Figures 3-2 and 3-3, these valves exhibit a wide range of valve factors across the three tests, with similar ranges at all four points where disk-to-seat friction valve factors are calculated. In all cases, the average valve factor is stable across the three tests, indicating no apparent degradation.

Ten valves were disassembled for internal maintenance and reassembled prior to the baseline test. At all four points, the average baseline valve factor for disassembled valves is lower than for non-disassembled valves. As shown in Figures 3-2 and 3-3, the range of baseline valve factors for disassembled valves is typically narrower than for non-disassembled valves. The reduced baseline valve factors are attributed to the disassembly/reassembly of the valve. In the second test, the lower average baseline valve factors increase to values similar to non-disassembled valves. The average valve factor increases in the third test as well, although to a smaller degree. These increases in valve factor are attributed to DP stroking for JOG testing. The final average valve factors for disassembled valves are similar to the final average valve factors for non-disassembled valves.

Valve factors and changes in valve factors were examined for effects of normal valve position. Both normally open and normally closed valves were analyzed, and no apparent valve factor trend was observed. The data were also examined for effects of stem orientation. Both horizontal and vertical stems were analyzed, and no apparent valve factor trend was observed.

Figure 3-4 shows the change in valve factor between subsequent tests versus initial valve factor. As shown by the best fit trend line through the data, valves with low initial valve factors tend to show the largest increases between tests, and valves with high initial valve factors tend to be stable or decrease. In particular, valves that were disassembled/reassembled prior to the baseline test show a strong tendency to increase from low values. Some valves with low initial valve factors that were not disassembled also show increases, although the changes are smaller. The increase in valve factor from low initial values is attributed to DP stroking of the valves. Although these valves are not typically DP stroked during normal operation, the DP strokes performed during JOG testing appear to be the driver of the increases.

Low DP Strokes

The JOG MOV PV Program tested twenty-nine gate valves with Stellite seats in cold treated water systems with low DP stroking (1-4 DP strokes per year). Figures 3-5 and 3-6 show the average closing and opening valve factors across the three test series. Separate averages are shown for valves that were disassembled and then reassembled prior to the baseline test and for valves not disassembled prior to the baseline test.

Seventeen valves had no internal maintenance or valve disassembly in the two years prior to the baseline test. As shown in Figures 3-5 and 3-6, these valves exhibited a wide range of valve factors across all three tests, with points of "Initial Wedging" and "Just After Cracking" showing slightly larger ranges than points of "Flow Isolation" and "Flow Initiation." In all cases, the average valve factor is stable across the three tests, indicating no degradation.

Twelve valves were disassembled for internal maintenance and reassembled prior to the baseline test. As shown in Figures 3-5 and 3-6, the range of valve factors for disassembled valves is typically narrower than for non-disassembled valves. At all four points, the average baseline valve factors for disassembled valves is similar to or lower than for non-disassembled valves. The reduced baseline valve factors are attributed to the disassembly/reassembly of the valve. In the second test, the lower average baseline valve factors increase to values similar to non-disassembled valves. The average valve factor increases a similar degree in the third test as well. These increases in valve factor are attributed to DP stroking. The twelve valves had 0 to 4 DP strokes prior to the second test and 0 to 2 strokes prior to the third test.

The closing averages and ranges on Figure 3-5 exclude data from one disassembled valve, G32.02. The individual results for this valve are shown on Figure 3-5. The closing data for this valve show lower baseline valve factors that increase on the second and third tests, consistent with the performance of disassembled valves. However, the magnitudes of valve factor increase in the second and third tests and the final valve factor values are inconsistent with other valves within this group. Several evaluations were carried out to determine if there were unique configuration or application attributes that could help explain the unusual results. For example, valve attributes such as manufacturer, materials, etc., were evaluated and system attributes, such as water chemistry, were examined. The very high valve factors could not be correlated to any of these attributes. Based on these evaluations and considering the behavior of the remainder of valves in this group, the closing valve factors for G32.02 appear to be outliers.

Valve factors and changes in valve factors were examined for effects of normal valve position. Both normally open and normally closed valves were analyzed, and no apparent valve factor trend was observed. The data were also examined for effects of stem orientation. Both horizontal and vertical stems were analyzed, and no apparent valve factor trend was observed.

Figure 3-7 shows the change in valve factor between subsequent tests versus initial valve factor. The data does not include the outlier closing data for valve G32.02. As indicated by the best fit trend line through the data, valves with low initial valve factors tend to show the largest increases between tests, and valves with high initial valve factors tend to be stable or decrease. In particular, valves that were disassembled/reassembled prior to the baseline test show a strong tendency to increase from low values. The increase in valve factor from low initial values is attributed to the DP stroking of the valves.

High DP Strokes

The JOG MOV PV Program tested sixteen valves with Stellite seats in cold treated water systems with high DP stroking (≥5 DP strokes per year). Figures 3-8 and 3-9 show the average closing and opening valve factors across the three test series. Separate averages are shown for valves that were disassembled and then reassembled prior to the baseline test and valves that were not disassembled prior to the baseline test.

Nine valves had no internal maintenance or valve disassembly in the two years prior to the baseline test. As seen in Figures 3-8 and 3-9, these valves exhibit a wide range of valve factors across the three tests, with similar ranges at all points. In all cases, the average valve factor is stable across the three tests, indicating no apparent degradation.

Seven valves were disassembled for internal maintenance and reassembled prior to the baseline test. At all four points, the average baseline valve factor for disassembled valves is lower than for non-disassembled valves. The range of baseline valve factors for disassembled valves is typically narrower than for non-disassembled valves. The reduced baseline valve factors are attributed to the disassembly/reassembly of the valve. In the second test, the lower average baseline valve factors increase significantly. This increase in valve factor is attributed to DP stroking. In the third test, the average valve factor remains stable between the second and third tests at all four points. Additional DP stroking does not appear to affect the valve factor. The final average valve factors for disassembled valves are similar to average valve factors for non-disassembled valves.

The closing averages and ranges on Figure 3-8 exclude data from one disassembled valve, G27.10. The individual closing results for this valve are shown on Figure 3-8. This valve did not provide valid closing data in the baseline test. The data for G27.10 shows closing valve factors in the second and third tests that are significantly higher than other disassembled valves within this group. The valve had a very high number of DP strokes between JOG tests (88 strokes between baseline and second tests and 159 strokes between second and third tests). However, other valves within this group that had a similar number of DP strokes between tests did not exhibit equally high valve factors. Several evaluations were performed to determine if there were unique valve attributes such as manufacturer, materials, etc., that could help explain the unusual results. The high valve factors could not be correlated to any of these attributes. Based on these evaluations, and considering the behavior of the remainder of valves in this group, the closing valve factor data for G27.10 appear to be an outlier.

Valve factors and changes in valve factors were examined for effects of normal valve position. Both normally open and normally closed valves were analyzed, and no apparent valve factor trend was observed. The data were also examined for effects of stem orientation. Both horizontal and vertical stems were analyzed, and no apparent valve factor trend was observed.

Figure 3-10 shows the change in valve factor between subsequent tests versus initial valve factor. The data does not include the outlier closing data for valve G27.10. As shown by the best fit trend line through the data, valves with lower initial valve factors tend to show the largest increases between tests, and valves with high initial valve factors tend to be stable or decrease. Specifically, valves that were disassembled/reassembled prior to the baseline test show a strong tendency to increase from low values. Valves that were not disassembled prior to the baseline test tend to show a mixture of small increases and decreases between tests. The increase in valve factor from low initial values is attributed to DP stroking of the valves.

A.2 Cold Untreated Water

The JOG MOV PV Program tested eleven gate valves with Stellite seats in cold (≤120°F), untreated water systems. Figures 3-11 and 3-12 show the average closing and opening stroke valve factors across the three test series. Similar to the analysis for cold treated water, separate averages are shown for valves based on the number of DP strokes between JOG tests. Overall, the average valve factors show small increases and decreases between tests, but indicate no apparent degradation.

Five valves are not typically stroked against DP between tests. Three valves are typically stroked 4 to 8 times between tests and three valves are frequently stroked (7 to 158 DP strokes) between tests. As shown in Figures 3-11 and 3-12, valves with a higher frequency of DP strokes exhibit higher overall valve factors compared to the other valves. Valves that were not DP stroked between tests exhibit lower overall valve factors. Additionally, valves with higher overall valve factors show stable valve factors between tests while valves with lower overall valve factors show more variation in between tests. These variations include both increases and decreases, but do not indicate a degradation trend.

Two valves (G06.02 and G20.01) were disassembled and reassembled immediately prior to the baseline test. Both valves were not DP stroked in the time between disassembly/reassembly and the baseline test. However, G06.02 was DP stroked 8 and 0 times respectively, and G20.01 was DP stroked 4 times each, between tests. Figure 3-13 shows the individual closing valve factors for all eleven valves at the point of Initial Wedging. As seen in the figure, both G06.02 and G20.01 show lower baseline valve factors compared to the non-disassembled valves. This is consistent with other disassembled gate valves which exhibit low initial valve factors after disassembly/reassembly. At the point of Initial Wedging, the valve factors for G06.02 increase slightly in the second test and continue to increase slightly in the third test. The valve factors for G20.01 increase slightly in the second test and then decrease slightly in the third test. At other stroke points, both valves show slight changes. Based on the data from two valves, disassembly/reassembly does not appear to have as significant an effect on valves in cold untreated water as it does on valves in cold treated water.

Valve factors and changes in valve factors were also examined for effects of normal valve position. Both normally open and normally closed valves were analyzed, and no apparent valve factor trend was observed. The data were also examined for effects of stem and pipe orientation to address a specific degradation mechanism identified in the JOG Program Description Topical Report (Reference 3) for valves in untreated water systems. Specifically, valves with horizontal stems exposed to raw water were judged as being susceptible to effects of corrosion. All combinations and stem and pipe orientations were analyzed, and no apparent valve factor trend was observed.

Figure 3-14 shows the change in valve factor between subsequent tests versus initial valve factor. As shown by the best fit line through the data, the trend indicates that valves with lower initial valve factors tend to show the largest increases, and valves with higher initial valve factors tend to be stable or decrease. Overall, the valve factor trends for gate valves in cold untreated water systems are analogous to gate valves in cold treated water systems.

A.3 Hot Treated Water Systems, Tested in Cold Treated Water

The JOG MOV PV Program included sixteen gate valves with Stellite seats that normally operate in hot (>120°F), treated water systems which were tested in cold, treated water. These valves are typically located in RHR or safety injection systems, such that during normal plant operation they can be exposed to temperatures from 130 to 525°F. During the JOG tests, these valves experienced temperatures from 52 to 108°F. Figures 3-15 through 3-18 show the closing and opening valve factors for these valves across the three test series. Figures 3-15 and 3-16 show the average valve factors for valves that had no internal maintenance or valve disassembly prior to the baseline test. Figures 3-17 and 3-18 show the individual valve factors for valves that were disassembled and then reassembled prior to the baseline test.

Fourteen valves had no internal maintenance or valve disassembly in the two years prior to the baseline test. As shown in Figures 3-15 and 3-16, these valves exhibited a wide range of valve factors across all three tests, with points of "Initial Wedging" and "Just After Cracking" showing slightly larger ranges than points of "Flow Isolation" and "Flow Initiation." For all four points, the average valve factor increases slightly from the baseline to the second test. This increase is attributable to a few valves with low baseline valve factors that show increases. The average valve factor in the third test shows values similar to the second test. Overall, the change in valve factor from baseline to third is small and indicates stable seat friction behavior.

Two valves were disassembled for internal maintenance and reassembled prior to the baseline test. As shown in Figures 3-17 and 3-18, the two valves exhibit a range of baseline valve factors and, unlike other disassembled valves, one valve does not show low initial valve factors. This behavior is attributed to DP stroking between disassembly/reassembly and the JOG baseline test.

Valve G75.02 had four DP strokes between disassembly and the baseline test. Consistent with the effect of DP stroking between JOG tests on gate valves, DP stroking between disassembly/reassembly and the baseline test tends to increase valve factors. In the second and third tests, the valve factors for G75.02 are generally stable. Valve G75.09 had no DP strokes between disassembly/reassembly and the baseline test and shows low baseline valve factors that increase across the three tests. The increases from low baseline valve factors are attributed to the JOG DP stroking. This observation is consistent with disassembled gate valves with Stellite seats in cold treated water that are not normally DP stroked.

Valve factors and changes in valve factors were examined for effects of normal valve position. Both normally open and normally closed valves were analyzed, and no apparent valve factor trend was observed. The data were also examined for effects of stem orientation. Both horizontal and vertical stems were analyzed, and no apparent valve factor trend was observed.

Figure 3-19 shows the change in valve factor between subsequent tests versus initial valve factor. As indicated by the best fit trend line through the data, valves with low initial valve factors tend to show the largest increases between tests, and valves with high initial valve factors tend to be stable or decrease. Overall, the valve factor behavior of valves that normally operate in high temperature water systems but are tested cold is analogous to the behavior for other cold water gate valves.

A.4 Hot Water and Steam

The JOG MOV PV Program tested one gate valve with Stellite seats in a hot (> 120°F) treated water system and eleven gate valves with Stellite seats in steam systems. Figure 3-20 shows the closing and opening valve factors for the hot water valve. Figures 3-21 and 3-22 show the closing and opening valve factors for all valves in steam. Figures 3-23 and 3-24 show the average closing and opening valve factors across the three test series for all valves in steam. Separate averages are shown for valves disassembled and reassembled prior to the baseline test and valves that were not disassembled. For some steam valves, data is provided only in one stroke direction because of the difficulty in aligning plant systems to obtain data for both stroke directions. Also, points of flow isolation and flow initiation were not able to be determined for several valves, so the amount of data at these points is less.

As shown on Figure 3-20, the valve factors for the single valve tested in hot water (G79.02) are stable across the three test series, indicating no apparent degradation. No internal maintenance was performed on this valve prior to the baseline test. The test temperature for the valve was between 180-200°F and the valve was DP stroked 0 to 2 times between tests.

Eight valves in steam had no internal maintenance in the two years prior to the baseline test. As seen in Figures 3-23 and 3-24, the average valve factors are stable in the closing stroke and show a slight overall decrease in the opening stroke. For all points, there is no indication of degradation.

Three valves were disassembled for internal maintenance and reassembled prior to the baseline test. As shown in Figures 3-23 and 3-24, the average baseline valve factor at all four points for disassembled valves is less than or similar to the average baseline valve factor for non-disassembled valves. This effect is attributed to the disassembly/reassembly of the valve. The trend of a reduced initial valve factor is analogous to disassembled gate valves with Stellite seats in cold water, though to a lesser extent. In subsequent tests, the average baseline valve factor shows an increase in either the second or third test. The final average valve factors for disassembled valves are similar to or slightly higher than the average valve factors for the non-disassembled valves. Note that the opening stroke data for valve G60.02 were excluded from the averages for disassembled valves in Figure 3-24 as these valve factors were judged to be implausibly low (see Figure 3-22). The very low opening valve factors could not be correlated to any particular attribute and are considered outliers.

As shown in Figures 3-21 and 3-22, seven valves (both disassembled and non-disassembled) are DP stroked 5 or more times between tests. Three valves are stroked 1 to 4 times, and one valve is typically not DP stroked. Unlike valves in cold water, valves in steam with a higher frequency of DP strokes do not exhibit higher overall valve factors. Valves that are DP stroked less than 4 times between tests show valve factors that are generally higher than valves that are DP stroked 5 or more times. The single valve that is not DP stroked between tests shows among the highest valve factors. This trend is opposite to the trend observed for valves in water systems.

Valve factors and changes in valve factors were examined for effects of normal valve position. Both normally open and normally closed valves were analyzed, and no apparent valve factor trend was observed. The data were also examined for effects of stem orientation. Both horizontal and vertical stems were analyzed, with no apparent valve factor trend observed.

Figure 3-25 shows the change in valve factor between subsequent tests versus initial valve factor. The data does not include the outlier opening data for G60.02. As shown by the best fit trend line through the data, valves with lower initial valve factors tend to show the largest increases between tests, and valves with high initial valve factors tend to be stable or decrease. In particular, valves that were disassembled/reassembled prior to the baseline test show a strong tendency to increase from low values.

A.5 Grouping of Gate Valves with Self-Mated Stellite Seats for Determining Thresholds

In the analysis of gate valves with Stellite seats as discussed above, valves were grouped based on fluid type, temperature and the frequency of DP stroking. In general, all groups showed the same overall valve factor trend: valves with lower initial valve factors tend to increase with DP stroking to levels consistent with other valves in similar service conditions, while high initial valve factors tend to be stable or decrease with DP stroking. In particular, valves that were disassembled/reassembled prior to the baseline test showed a strong tendency to increase from low values with DP stroking to levels consistent with non-disassembled valves in similar service conditions.

In some cases, valves grouped by particular fluid types or temperature exhibited similar valve factor behavior to other groups. Accordingly, it is appropriate to combine some gate valve groups together for determining quantitative results for the purposes of a periodic verification implementation approach. Justification for combining these groups is presented below. For each group, a threshold is determined, representing the value above which increases are not expected. Appendix E provides the methods and justification for determining these thresholds.

Cold Treated Water

The majority (78 valves) of gate valves tested with Stellite seats are in cold (≤ 120°F) treated water systems. The data for these valves showed the trend that low initial valve factors, whether due to disassembly/reassembly or due to infrequent DP stroking, tend to increase with DP stroking, toward a stable level. The increase is driven by DP stoking, and valves with a higher number of DP strokes between tests exhibited larger valve factor increases. Further, the data showed the general trend that valves that DP stroke more often tend to have a higher level of stable valve factor. This trend is based on the estimated stroking information provided by the plants with each test package. Because this information is imprecise and because it is difficult for plants to monitor the extent of DP stroking of each valve, all of the cold water Stellite results are combined to determine thresholds for use in the final PV approach.

Cold Untreated Water

Eleven gate valves tested with Stellite seats are in cold untreated water systems. The data for these valves showed the trend that low initial valve factors tend to increase with DP stroking. Fundamentally, these valves behave in a similar manner to valves in treated water. Accordingly, for the purpose of determining thresholds, it is appropriate to combine the data for cold untreated water valves with valves in cold treated water.

Normally in Hot Water and Tested in Cold Water

Sixteen gate valves tested with Stellite seats are in systems that normally operate hot (>120°F), but were DP tested cold. The data for these valves show the trend that low initial valve factors, whether due to disassembly/reassembly or due to infrequent DP stroking, tend to increase with DP stroking. Fundamentally, these valves behave in a similar manner to valves that normally operate in cold water systems. Accordingly, for the purpose of determining thresholds, it is appropriate to combine the data for valves in hot water that are tested cold with valves that normally operate in cold treated water.

Hot Water

One valve was tested with Stellite seats in a hot water system. The data for this valve shows higher overall valve factors that are stable between tests. Fundamentally, this valve behaves in an identical manner to valves in cold water systems that show high initial valve factors that tend to be stable or decrease. Accordingly, for the purpose of determining thresholds, it is appropriate to combine the data for valves in hot water with valves in cold treated water.

Steam

Eleven valves were tested with Stellite seats in steam. The data for these valves show the trend that low initial valve factors, whether due to disassembly/reassembly or due to infrequent DP stroking, tend to increase with DP stroking, although the effect was observed to be smaller than for water valves. While the fundamental behavior for these valves is analogous to water valves, the unique qualities of steam service make it appropriate to evaluate these valves separately. Therefore, for the purpose of determining thresholds, steam valves are independently evaluated.

Threshold Coefficients of Friction

Based on the groupings discussed above, the table below provides the threshold values for gate valves with Stellite seats. Since these values are quantitative results based on the extensive test data, the valve factors have been converted to apparent disk-to-seat coefficient of friction (COF) values. The details of determining these values are provided in Appendix E.

Gate Valves with Self-mated Stellite Seats	Threshold COF
Water Systems	0.57
Steam Systems	0.58

B. Evaluation of Disk to Seat Friction for Gate Valves With Other (Non-Stellite) Seat Materials

Seventeen gate valves with disk-to-seat materials other than self-mated Stellite were tested as part of the JOG MOV PV Program. Since disk-to-seat material is judged to be the primary influence on seat friction behavior, the seventeen valves are grouped for analysis based on this attribute. Other potential influences on degradation, including fluid medium, fluid temperature, valve disassembly and DP stroking are addressed within each group. The four groups for analysis of gate valves with other seat materials are listed below.

- Self-mated 400 series stainless steel seats *(5 valves)*
- 400 series stainless steel vs. Stellite seats *(4 valves)*
- 400 series stainless steel (or Exelloy) vs. Monel seats *(7 valves)*
- Self-mated Deloro 50 seats *(1 valve)*

B.1 400 Series Stainless Steel Disk and Seat

The JOG MOV PV Program tested five valves with self-mated 400 series stainless steel seat materials. Figures 3-26 and 3-27 show the closing and opening valve factors across the three test series. In general, gate valves with self-mated 400 series stainless steel seats show valve factors of similar magnitude to gate valves with self-mated Stellite seats. Overall, the average valve factor shows a slight increase between the baseline and second tests, and a slight decrease between the second and third tests, indicating no apparent degradation.

All five valves are in water systems. Two valves are in treated water systems, and three valves are in untreated water systems. The normal water temperatures are less than 100°F, and the temperatures during DP testing are less than 85°F. Based on Figures 3-26 and 3-27, there is no apparent difference in behavior between valves in treated versus untreated water systems.

Three valves stroke frequently against DP with 8 – 18 strokes between tests. The other two valves (G88.01 and G89.03) are typically DP stroked 1 – 8 times between tests. Results indicate that the valves with a higher frequency of DP strokes exhibit higher overall valve factors that remain stable from test to test. The two valves with a lower frequency of DP strokes showed the largest valve factor variations between tests, and are discussed below.

Valve G88.01 shows a significant decrease in valve factor between the second and third tests. This decrease was verified by examining overlaid thrust plots for G88.01, which show a thrust decrease in the third test compared to the baseline and second tests, and by confirming that the system pressure and DP were similar among all three tests.

Valve G89.03 shows a significant increase in valve factor from the baseline to the second test. The baseline valve factors for G89.03 are low compared to the other valves. The valve factors increase at all points in the first stroke of the second test, and remain similar between the second and third tests. This valve is stroked four times per year in service under conditions where the system is operating and there is flow in the pipe. However, a review of the test procedure by plant personnel showed that the system configuration is expected to result in little or no DP across the valve at the time it is stroked. The JOG DP tests were likely the first tests for this valve with DP during stroking. Therefore, the low initial valve factors are expected, and the observed valve factor increase is consistent with other gate valves that exhibit low initial valve factors, either due to disassembly/reassembly or infrequent DP strokes, that increase with DP stroking.

Figure 3-28 shows the change in coefficient of friction (COF) between subsequent tests versus initial COF. As shown by the best fit line through the data, the trend in the data is the same as for self-mated Stellite seat valves. For this figure, the valve factors in Figures 3-26 and 3-27 have been converted to COF values. Valves with lower initial COFs tend to show the largest increase, and valves with higher initial COFs tend to be stable or decrease.

B.2 400 Series Stainless Steel Disk vs. Stellite Seat

The JOG Program tested four valves with a 400 series stainless steel disk face against a Stellite seat ring face. Figures 3-29 and 3-30 show the closing and opening valve factors across the three test series. In general, the valve factors for gate valves with 400 series stainless steel disk and Stellite seat ring faces exhibit higher overall valve factors than valves with self-mated Stellite or 400 series stainless steel seats. A mixture of minor increases and decreases are observed. Overall, the average valve factor is stable across all tests, indicating no apparent degradation.

All four valves are in treated water systems. Three valves are in systems with water temperatures less than 125°F, and are tested at temperatures up to 90°F. The three valves tested in cold water show similar performance. G92.02 shows increases on the opening strokes from baseline to second tests. As discussed below, it appears disassembly of this valve contributed to this result. G91.05 also shows increases from baseline to second tests on the opening strokes, followed by similar decreases from the second to third tests. The closing strokes show increases at initial wedging, but decreases at flow isolation. One valve (G91.06) is in a system in which the water temperature ranges up to 370°F, but DP tests were conducted at temperatures of 95°F, 225°F and 190°F on the baseline, second and third tests, respectively. This valve shows stable valve factors across the three tests.

Two valves are not typically DP stroked between tests, one valve (G92.02) is DP stroked 0 – 4 times between tests and one valve (G92.01) is frequently stroked (24 - 60 DP strokes between tests). Results indicate that valves with a higher number of DP strokes show higher overall valve factors that remain stable between tests. Valves with fewer DP strokes show lower initial valve factors, but larger changes between tests. In general, it appears that DP stroking tends to increase valve factors for low stroking valves or valves with low initial valve factors.

Three valves (G91.06, G92.01 and G92.02) were disassembled and reassembled prior to the baseline test. As discussed in Topic A.1-*Cold Treated Water*, gate valves with self-mated Stellite seats that were disassembled/reassembled prior to testing exhibit lower initial valve factors that increase to more typical values on subsequent DP stroking. G92.01 had 60 DP strokes performed between the disassembly/reassembly and the baseline test. Similar to other high DP stroking gate valves, this valve shows relatively stable valve factors across the three tests. Given the high number of DP strokes, this result is expected and the effects of disassembly are not apparent. Valves G91.06 and G92.02 were not stroked under DP between disassembly and the baseline test. As described previously, valve G91.06 was tested under cold water conditions in the baseline test and hot water conditions on the second and third tests, and shows stable valve factors across the three tests. Similar to self-mated Stellite valves that are disassembled, the valve factors for G92.02 show low initial values in the baseline test. Following the four DP strokes between the baseline and second tests, the valve factors show more typical values in the second test.

Figure 3-31 shows the change in COF between subsequent tests versus initial COF for all the data from Figures 3-29 and 3-30, converted from valve factors to COFs. As shown by the best fit line through the data, the trend in the data is the same as for self-mated Stellite seat valves. Valves with lower initial COFs tend to show the largest increase, and valves with higher initial COFs tend to be stable or decrease.

B.3 400 Series Stainless Steel (or Exelloy) Disk vs. Monel Seat

The JOG MOV PV Program tested four valves with a 400 series stainless steel disk against a Monel seat face and three valves with an Exelloy disk against a Monel seat face. Figures 3-32 and 3-33 show the closing and opening valve factors across the three test series. In general, the valve factors for gate valves with 400 series stainless steel (or Exelloy) disk and Monel seat ring faces exhibit higher overall valve factors than valves with self-mated Stellite or 400 series stainless steel seats. Overall, the average valve factor is stable across all tests, indicating no apparent degradation.

All seven valves are in treated water systems. Four valves are in systems with temperatures less than 95°F, and are tested at 80°F or less. Three valves are in systems with water temperatures up to 455°F, and are tested at temperatures >120°F (except two of these valves had one test each with temperatures ≤120°F). There appears to be no difference in valve factor performance based on fluid temperature.

Four valves are not typically DP stroked between tests, and three valves (G99.01, G99.02 and G99.04) are frequently stoked (2 - 24 DP strokes between tests). Results indicate that valves with a high number of DP strokes between tests showed higher overall valve factors than the valves that were not DP stroked.

One valve (G99.05) was disassembled and reassembled prior to the baseline test. Similar to self-mated Stellite valves that are disassembled, the valve factors for G99.05 exhibit low initial values in the baseline test that increase on subsequent DP stroking. This valve was not DP stroked between reassembly and the baseline test or in between JOG tests. In the second test, the valve factors increase to values similar to non-disassembled valves.

In general, valves with 400 series stainless steel (or Exelloy) disk and Monel seat ring faces show more variation in valve factor from test to test compared to other seat materials. Valves that show valve factor increases from the baseline to second tests tend to show similar decreases between the second and third tests, and vice versa. The overall change across all three tests, however, is small, indicating no degradation trend.

Figure 3-34 shows the change in COF between subsequent tests versus initial COF, for the data from Figures 3-32 and 3-33, converted from valve factors to COFs. As shown by the best fit line through the data, the trend in the data is the same as for self-mated Stellite seat valves. Valves with lower initial COFs tend to show the largest increase, and valves with higher initial COFs tend to be stable or decrease.

B.4 Deloro 50 Disk and Seat

The JOG program tested one valve (G98.01) with self-mated Deloro 50 disk and seat ring face materials. This valve operates in cold, treated water and is DP stroked 12 – 14 times between tests. Due to test limitations, only closing results are available for this valve. Figure 3-35 shows the closing valve factors across the three test series. Test results for G98.01 show a stable valve factor between the baseline and second tests, and a decrease in the third test. There is no apparent degradation observed for this valve.

B.5 Thresholds for Gate Valves with Other (Non-Stellite) Seat Materials

Similar to valves with self-mated Stellite seats (Topic A.5-*Grouping of Gate Valves with Self-Mated Stellite Seats for Determining Thresholds*), a threshold value is determined for each gate valve group with non-Stellite seats. These thresholds provide values above which increases are not expected. Appendix E provides the methods and justification for determining the thresholds.

Threshold values for self-mated 400 series stainless steel, 400 series stainless steel vs. Stellite and 400 series stainless steel (or Exelloy) vs. Monel seat materials are determined directly from the test data and are summarized in the table below. Since these values are quantitative results based on the extensive test data, the valve factors have been converted to apparent disk-to-seat coefficient of friction (COF) values. The details of determining these values are provided in Appendix E.

For self-mated Deloro 50 seat materials, only one valve was tested. Since Deloro 50 has similar friction properties to self-mated Stellite in cold water, data from self-mated Stellite seat materials was used to justify an appropriate threshold value for Deloro 50. The justification for this approach is described in Appendix E.

Gate Valves with non-Stellite Seats	Threshold COF
Self-mated 400 Series Stainless Steel	0.69
400 Series Stainless Steel vs. Stellite	0.70
400 Series Stainless Steel (or Exelloy) vs. Monel	0.71
Self-mated Deloro 50	Use value for self-mated Stellite in water systems

C. EVALUATION OF DISK-TO-GUIDE FRICTION

Although the required DP thrust for the majority of gate valves is controlled by disk-to-seat friction, in some cases disk-to-guide friction can control the required thrust. In these cases, the guide-controlled valve factors can be evaluated for degradation. The amount of guide data in the JOG MOV PV Program, however, is limited. Only 38 valves exhibited guide controlled valve factors in at least one test across the three test series[12].

Guide-controlled required thrust is more commonly revealed during a dynamic opening stroke, although a few dynamic closing strokes do provide meaningful data. For valves that exhibit guide-controlled required thrust in the closing stroke, the valve factor at the point of maximum thrust is used to evaluate degradation. For valves that exhibit guide controlled required thrust in the opening stroke, the valve factor at the point of maximum thrust (after cracking) is used to evaluate degradation.

In the analysis below, valve factor trend-line plots are used to evaluate changes in guide valve factors between tests. For the majority of the 38 valves with guide data, only one or two JOG tests provided useful guide valve factors. With such limited valve factor data, additional information related to the guide behavior during DP testing was needed. Accordingly, where guide valve factors were determined for at least one test of a valve, the measured stem thrust overlays and pressure traces from all three JOG tests were reviewed to determine the qualitative changes in performance between tests. As shown in the accompanying plots, tests with undetermined guide valve factors are identified as having either a stable, increasing or decreasing valve factor trend between tests, based on the qualitative review of the data.

Since disk-to-guide material is judged to be the primary influence on guide friction behavior, the 38 valves are grouped for analysis based on this attribute. Other potential influences on

[12] Double disk and split wedge valve designs typically do not have disk or body guide rails. Therefore, valve factors for these valve types are not included in the guide friction evaluation.

degradation, including fluid medium and temperature, valve disassembly and DP stroking are addressed within each group.

- Carbon Steel disk guide vs. Carbon Steel body guide *(14 valves)*
- Carbon Steel disk guide vs. 17-4PH Stainless Steel body guide *(1 valve)*
- Stellite disk guide vs. Carbon Steel body guide *(4 valves)*
- Stellite disk guide vs. 17-4PH Stainless Steel body guide *(4 valves)*
- Stellite disk guide vs. 300 series Stainless Steel body guide *(2 valves)*
- Stellite disk guide vs. Stellite body guide *(1 valve)*
- 300 series Stainless Steel disk guide vs. 300 series Stainless Steel body guide *(7 valves)*
- 300 series Stainless Steel disk guide vs. 17-4 PH Stainless Steel body guide *(3 valves)*
- 300 series Stainless Steel disk guide vs. Carbon Steel body guide (2 *valves*)

C.1 Carbon Steel Disk vs. Carbon Steel Body Guide

The JOG MOV PV Program tested 51 gate valves with self-mated carbon steel guides, 14 of which provided guide valve factors for at least one JOG test. Figures 3-36 and 3-37 show the closing and opening guide valve factors across the three test series. In general, gate valves with carbon steel guides show a mixture of small increases and decreases in valve factor between tests. The overall change across all three tests, however, is stable, indicating no degradation trend, with the exception of G10.01 discussed below.

Eleven valves are in treated water systems and two valves are in untreated water systems. Based on Figures 3-36 and 3-37, valves in untreated water systems show more variation in guide valve factor between tests than valves in treated water systems. Overall, there is no apparent difference in behavior between valves in treated versus untreated water systems.

One valve, G10.01, is in an untreated water system and shows the highest guide valve factors of all carbon steel guided valves. Additionally, the valve factor increases principally between the first and second strokes of the second test. The seat friction valve factors for G10.01, in contrast, are similar to other gate valves. Several evaluations were performed to examine factors that could explain the high guide valve factors. The high guide valve factors could not be correlated to any specific attribute. Based on these evaluations and considering the stable behavior of the other nine valves with carbon steel guides in untreated water, the valve factors for G10.01 appear to be outliers. It is hypothesized by the plant that the high closing guide valve factors are attributed to guide damage or trapped particulates.

Twelve valves are in water temperatures less than 118°F and are tested at temperatures up to 127°F. These cold water valves show mostly stable valve factors, with the untreated water valves showing greater variation as discussed above. One valve (G91.06) is in a system in which the water temperature ranges up to 370°F, but DP tests were conducted at temperatures of 95°F, 225°F and 190°F, respectively. The data show a small valve factor increase between the second and third tests. Thrust overlays show the guide performance in the baseline test is stable compared to the second test. Overall, the behavior is consistent with valves tested in cold water.

One valve (G36.01) is in steam and shows only one point of guide valve factor in the third test. Comparison of the thrust overlays shows stable behavior from the second to third tests. In the third test, the valve shows the highest guide valve factor (>0.6) of all valves with self-mated carbon steel guides (excluding the outlier). It appears the performance of this material in steam, although stable, contributes to high friction. It is plausible that some surface damage or galling has occurred. Due to the limited valve factor data for steam, test data for two other valves in steam (G41.02 and G41.06) with carbon steel guides were reviewed qualitatively. Although no guide valve factors were determined for these valves (i.e., required thrust was controlled by disk-to-seat friction), the overlaid thrust traces were examined to determine apparent guide behavior. Both valves showed stable guide behavior across all tests.

Seven valves (G15.01, G22.08, G22.09, G22.10, G27.18, G91.06 and G99.07) are not typically DP stroked between tests. Five valves are stroked infrequently with 1 – 8 DP strokes between tests, and two valves (G22.12 and G22.14) are stroked significantly (83 – 168 DP strokes) between tests. Valves G22.12 and G22.14 were disassembled prior to the baseline test and show lower initial guide valve factors as discussed below. For both valves, in the second test, the valve factors increase to mid-range values and are stable between the second and third tests, based on a qualitative review of the test data. Based on Figures 3-36 and 3-37 there is no definitive difference in guide friction behavior based on DP stroking.

Five valves were disassembled and reassembled prior to the baseline test. Based on Figures 3-36 and 3-37, and in examining overlaid thrust traces for the valves, disassembled/reassembled valves tend to show lower baseline valve factors, or lower required thrust during disk-to-guide sliding that increase in subsequent tests. However, the increases are typically small compared to seat friction valve factors for disassembled valves. The driver of the valve factor increase appears to be DP stroking.

C.2 Carbon Steel Disk vs. 17-4PH Stainless Steel Body Guide

The JOG MOV PV Program tested one gate valve with carbon steel vs. 17-4PH stainless steel guides (G20.01). This valve operates in cold, untreated water and is DP stroked 4 times between tests. This valve was disassembled/reassembled immediately prior to the baseline test. Figure 3-37 shows one point of guide valve factor across the three test series. A qualitative review of the thrust overlays during the disk-to-guide sliding shows stable thrust and valve factor behavior across the three test series. The overall guide valve factors are low and are bounded by the results for carbon steel guides. There are no other gate valves in the JOG Program with a carbon steel disk guide mated against a 17-4PH stainless steel body guide.

C.3 Stellite Disk vs. Carbon Steel Body Guide

The JOG MOV PV Program tested nine gate valves with Stellite vs. carbon steel guides, four of which provided guide valve factors for at least one JOG test. Figure 3-38 shows the opening guide valve factors across the three test series. In general, these valves show stable valve factors across the three test series, indicating no degradation trend.

All four valves are in treated water systems with temperatures less than 110°F, and are tested at temperatures less than 92°F. Two valves (G32.03 and G69.13) are not typically DP stroked between tests and two valves (G69.14 and G75.10) are DP stroked twice between tests. There is no apparent difference in guide friction behavior based on DP stroking.

Valve G69.13 was disassembled and reassembled prior to the baseline test. Based on Figure 3-38 and a qualitative review of the test data, the valve shows lower baseline guide valve factors that increase in the second test and decrease on the third test. The overall guide valve factor behavior for this valve is similar to the non-disassembled valves.

C.4 Stellite Disk vs. 17-4PH Stainless Steel Body Guide

The JOG MOV PV Program tested thirteen gate valves with Stellite vs. 17-4PH stainless steel guides, four of which provide guide valve factors for at least one JOG test. Figure 3-39 shows the opening guide valve factors across the three test series. In general, gate valves with Stellite vs. 17-4PH stainless steel guides show stable valve factors between tests, indicating no degradation trend.

All four valves are in treated water systems. Two valves are in systems with temperatures less than 130°F and tested in temperatures less than 120°F. Two valves (G69.01 and G75.02) are in systems with water temperatures up to 350°F, but are tested in temperatures less than 100°F. Based on Figure 3-39, the valve factors for these normally hot water valves are significantly higher than the two cold water valves. However, this behavior is not conclusive due to the limited amount of data.

Three valves are not typically DP stroked between tests. One valve (G75.02) is DP stroked 0 – 4 times between tests. Based on Figure 3-39, the valve factors for valve G75.02 are higher than for the three valves that were not DP stroked between tests.

Two valves were disassembled and reassembled prior to the baseline test. Based on Figure 3-39, one valve (G69.03) shows low baseline valve factors that increase slightly in the second and third tests. The other valve (G75.02) shows higher overall valve factors that are stable between tests. Between disassembly and the baseline test, G69.03 had no DP strokes whereas G75.02 had four DP strokes. Overall, the guide valve factor behavior for these valves is similar to non-disassembled valves.

C.5 Stellite Disk vs. 300 Series Stainless Steel Body Guide

The JOG MOV PV Program tested six gate valves with Stellite vs. 300 series stainless steel guides, two of which provide guide valve factors for at least one JOG test. Figure 3-39 shows the opening guide valve factors across the three test series. Valve G69.10 shows stable valve factors across the three test series. Valve G69.11 shows an increasing valve factor trend across the three test series, although all valve factors are expected to be bounded by the valve factors for G69.10.

Both valves are in treated water systems with water temperatures up to 170°F, but are tested at temperatures up to 83°F. Valve G69.11 is not typically DP stroked and shows lower valve factors compared to valve G69.10 that is DP stroked 2 – 3 times between tests. The lower valve factors for G69.11 are attributed to the low DP stroking frequency, and the increasing valve factor is attributed to DP strokes performed for JOG testing. This behavior is consistent with the seat friction behavior of gate valves that are infrequently stroked against DP.

C.6 Stellite Disk vs. Stellite Body Guide

The JOG MOV PV Program tested one gate valve with self-mated Stellite guides. Located in a treated water system with temperatures up to 105°F and tested in temperatures of 80 – 83°F, valve G69.05 is DP stroked 0 - 4 times between tests. Figure 3-40 shows stable guide valve factors between the baseline and second tests. Examination of thrust overlays shows the guide behavior is stable in the third test as well. As this valve was not disassembled, a stable valve factor is expected based on the extensive self-mated Stellite seat friction results. However, valves with self-mated Stellite guides that are disassembled would be likely to have reduced valve factors and subsequent increases, similar to disk-to-seat friction results.

C.7 300 Series Stainless Steel Disk vs. 300 Series Stainless Steel Body Guide

The JOG MOV PV Program tested fifteen gate valves with self-mated 300 series stainless steel guides, seven of which provided guide valve factors for at least one JOG test. Figure 3-41 shows the opening guide valve factors across the three test series. In general, gate valves with 300 series stainless steel guides show stable guide valve factors between tests, with the exception of valves disassembled prior to the baseline test as discussed below.

All seven valves are in treated water systems with temperatures less than 105°F and tested at temperatures of 94°F or less. Three valves (G44.05, G44.06 and G44.08) are not typically DP stroked between tests, two valves (G44.03 and G44.14) are stroked infrequently with 0 – 2 DP strokes, and two valves (G44.02 and G49.01) are stroked more frequently with 1 - 11 DP strokes between tests. In general, there is no apparent difference in guide friction behavior based on DP stroking.

Four valves were disassembled and reassembled prior to the baseline test. Based on Figure 3-41 and in examining overlaid thrust traces for the valves, disassembled/reassembled valves tend to show lower baseline valve factors, or lower required thrust during disk-to-guide sliding that increase in subsequent tests. However, these increases are small compared to seat friction valve factors for disassembled valves. The driver of this increase appears to be DP stroking.

C.8 300 Series Stainless Steel Disk vs. 17-4PH Stainless Steel Body Guide

The JOG MOV PV Program tested four gate valves with 300 series stainless steel disk vs. 17-4PH stainless steel guides, three of which showed guide valve factors for at least one JOG test. Figure 3-41 shows the opening guide valve factors across the three test series. Based on the observed valve factors and examination of the thrust overlays, gate valves with 300 series stainless steel vs. 17-4PH stainless steel guides show a stable valve factor trend between test strokes, excluding the disassembled valves as discussed below.

All three valves are located in treated water systems with temperatures less than 120°F, and tested at temperatures at 85°F or less. Two valves (G83.03 and G85.01) are not typically DP stroked between tests, while one valve (G83.02) is stroked against DP once between tests.

Valves G83.03 and G85.01 were both disassembled and reassembled prior to the baseline test. Based on Figure 3-41 and in examining overlaid thrust traces for the valves, disassembled/reassembled valves tend to show lower baseline valve factors, or lower required thrust during disk-to-guide sliding, that increase in subsequent tests. However, these increases are small compared to seat friction valve factors for disassembled valves. The driver of this increase appears to be DP stroking.

C.9 300 Series Stainless Steel Disk vs. Carbon Steel Body Guide

The JOG MOV PV Program tested four gate valves with 300 series stainless steel disk vs. carbon steel body guides, two of which provided guide valve factors for at least one JOG test. Figure 3-42 shows the opening guide valve factors across the three test series.

Both valves (G99.03 and G99.04) are in systems with water temperature up to 455°F, and are generally tested at temperatures above 120°F (G99.04 had one test performed at 80°F). Valve G99.03 is not typically DP stroked, and G99.04 was stroked against DP 2 – 3 times between tests. Both valves show higher overall valve factors compared to other guide material combinations. As addressed in the Topical Report (Reference 3), both carbon steel and 300 series stainless steel are susceptible to galling at elevated temperatures. Evaluation of overlaid thrust traces along with the guide valve factors show G99.04 has stable guide behavior between baseline and second tests and a decrease in valve factor in the third test. Valve G99.03 shows a slight increase in guide behavior between the baseline and second tests, but stable performance in the third test.

Due to limited data for cold water, test data for one other valve (G88.03) with 300 series stainless steel disk vs. carbon steel body guides tested in cold (~67°F) untreated water were qualitatively reviewed. Although no guide valve factors were determined for this valve (i.e., required thrust controlled by disk-to-seat friction), the overlaid thrust traces were examined to determine apparent guide behavior. This valve showed stable guide behavior across all tests.

D. HARD SEATING OF ANCHOR/DARLING DOUBLE DISK GATE VALVES

Anchor/Darling[13] double disk gate valves have a unique design that affects the required thrust at hard seating. As shown in Figure 3-43, the disk assembly is comprised of two parallel disks mounted on a disk carrier. The disk carrier includes an internal wedging mechanism (consisting of an upper wedge and a lower wedge) that spreads the disks to mate against the parallel seat ring faces at the end of a closing stroke. As an Anchor/Darling double disk gate valve closes against

[13] Anchor/Darling Valve Co. is now owned by Flowserve Corp.

DP, the downstream disk half is pressed against the downstream seat ring by the DP force, such that the required stem thrust is controlled by disk-to-seat friction. At the end of a DP closing stroke, additional thrust is required to spread the two disk halves apart and hard seat them against the seat rings. This additional thrust is attributable to friction at loaded surfaces in the internal wedge that slide against each other during the spreading process. The amount of additional thrust required to hard-seat the valve is affected by the installation orientation of the valve. The thrust increase is less for lower wedge downstream (LWD) and is greater for lower wedge upstream (LWU).[14]

Not all applications require disk hard seating in the closing direction. If hard seating is a requirement, then the actuator needs to supply the needed additional thrust. If hard seating is not a requirement, then the actuator is not required to supply the extra thrust, and the information in this section does not apply.

Because this additional thrust is due to sliding friction at metal interfaces, there is a concern with potential degradation, similar to disk-to-seat friction or guide friction. Accordingly, it is appropriate to analyze the data from A/D double disk gate valves to determine if degradation related to the hard seating mechanism is occurring.

The JOG MOV PV Program tested 19 Anchor/Darling double disk gate valves. Table 3-3 summarizes these valves and the conditions under which they were tested. Note that the results from DP testing of these valves have been included appropriately in other sections of this report analyzing disk-to-seat friction, and are grouped here for the purpose of evaluating potential degradation of the internal wedge mechanism (hard seating). As indicated on Table 3-3, one valve (G60.01) was controlled by a limit switch and does not hard seat. Data from this one valve is not considered in this section.

When data from Anchor/Darling double disk gate valves are analyzed, the thrust signature for DP closing strokes shows distinct features that reveal the action of the internal wedging mechanism (see Figure 3-44). Prior to the action of the internal wedge, the thrust is relatively stable and is attributable to disk-to-seat friction. As the internal wedge starts to expand (Point IW1), the thrust increases. When the wedge fully expands, the two disk halves hard seat against the seat rings (Point IW2). In some cases, valves showed only an IW1 point. This behavior is possible when certain internal dimensions are achieved by tolerance stack up that minimize or eliminate relative sliding in the internal wedge. The data for these valves did not provide useful information on potential degradation of the internal wedge.

Figure 3-45 (top graph) shows measured valve factors at IW1 for 18 Anchor/Darling double disk gate valves. These valve factors reflect disk-to-seat sliding. The bottom of Figure 3-45 shows measured valve factors at IW2 for 13 valves. These values reflect internal wedge sliding in addition to disk-to-seat sliding. As expected, the IW2 values are greater than the IW1 values for each valve, reflecting the additional internal wedge friction. Five valves do not have IW2 values (in four instances the wedge did not need to slide for the valve to hard seat and in one instance the valve tripped immediately following IW1).

[14] LWD is the vendor's recommended installation, but both configurations occur in service.

On Figure 3-45, some valves showed changes in disk-to-seat friction (upper graph) during JOG MOV PV Program tests. For example, valves that were disassembled prior to their baseline tests showed lower baseline valve factors that increased in subsequent tests. Other valves typically had stable valve factors. Changes in valve factor were also observed at IW2 for some valves. The key concern is whether changes in VF observed at hard seating (lower graph) reflect degradation beyond that expected by the observations in disk-to-seat friction (upper graph). To address this question, the data were screened to identify all valves with results at both disk-to-seat friction (IW1) and hard seating (IW2) during two separate, consecutive test sequences (e.g., baseline-to-second test or second-to-third test). There were 19 instances of these data, occurring on 12 different valves. On 14 of the 19 cases, the change in valve factor at IW2 moved in the same direction as that at IW1. This result is expected, as a change in disk-to-seat friction, by itself, tends to affect the thrust at both points. On 10 of the 14 cases, both the IW1 and IW2 valve factors increased. On the remaining four, both decreased. These four were dismissed from further consideration as they do not show degradation in DP thrust. On five of the 19 cases, the change in valve factor at IW2 moved in the opposite direction to that at IW1. For two of the five, the valve factor at IW2 increased when the valve factor at IW1 decreased. On the remaining three, the valve factor at IW2 decreased while the valve factor at IW1 increased. These latter three were dismissed from consideration as they do not show degradation at the hard seating point.

For the 12 cases of interest (10 where both IW1 and IW2 increased and 2 where IW2 increased when IW1 decreased), the changes in valve factors at both IW1 and IW2 are plotted on Figure 3-46 (first two bars for each valve test). For the ten cases where both increased, the EPRI model for Anchor/Darling double disk gate valves was used to predict the amount of expected increase in the valve factor at IW2, based on the observed increase at IW1. The prediction is shown as a third bar next to the IW2 bar. The prediction considers the valve orientation where it is known; predictions for both orientations are shown where orientation is unknown. The results show that the observed change at IW2 tends to be less than or similar to the predicted amount, thus indicating that there does not appear to be degradation at the internal wedge. For two cases where the observed change exceeds the predicted amount (G54.04 and G60.03), the valve factor changes and the amount of excess are very small and judged to be within the measurement accuracy.

The two valves that show an increase at IW2 but a decrease at IW1 are also shown on Figure 3-46 (G54.03 S-T and G60.05 S-T). Both of these valves have small valve factor changes and the observed results do not indicate significant degradation. To confirm that these changes are of no concern, the changes from baseline to third (B-T) test on both valves were evaluated. In both cases the predicted change at IW2 bounds the observed change.

In summary, the JOG MOV PV Program test results from Anchor/Darling double disk gate valves indicate that the internal wedging mechanism that engages to hard-seat the valve is not degrading. Changes in disk-to-seat friction control the changes in valve factor at stroke points before and during hard seating. Hence, it is not necessary to consider the hard seating characteristic of Anchor/Darling double disk gate valves in the final PV approach for gate valves.

E. Hard Seating of Aloyco Split Wedge Gate Valves

Aloyco[15] split wedge gate valves have a unique design that affects the required thrust at hard seating. As shown in Figure 3-47, the disk assembly is comprised of two disk halves that are joined with a ball and socket joint at the hub. This joint permits the two disk halves to independently move, so that each can seat tightly against its mating seat ring when the valve is closed. As an Aloyco split wedge gate valve closes against DP, the downstream disk half is pressed against the downstream seat ring by the DP force, such that the required stem thrust is controlled by disk-to-seat friction. At the end of the stroke, additional thrust may be required to "conform" the two disk halves into the positions for them to hard seat against the seat rings. This additional thrust is attributable to friction at loaded surfaces in the ball and socket joint that slide against each other during the "conforming" process. The amount of additional thrust required to hard-seat the valve is affected by the installation orientation of the valve. The thrust increase is less for male disk upstream (MDU) and is greater for male disk downstream (MDD).[16]

Not all applications require disk hard seating in the closing direction. If hard seating is a requirement, then the actuator needs to supply the needed additional thrust. If hard seating is not a requirement, then the actuator does not need to supply the additional thrust, and the information in this section does not apply.

Because the additional thrust to hard seat the disk is due to sliding friction at metal interfaces, there is a concern with potential degradation, similar to disk-to-seat friction or guide friction. Accordingly, it is appropriate to analyze the data from Aloyco split wedge gate valves to determine if degradation related to the hard seating mechanism is occurring. The JOG MOV PV Program tested 8 Aloyco split wedge gate valves. Table 3-4 summarizes these valves and the conditions under which they were tested. Note that the results from tests of these valves have been included appropriately in other sections of this report analyzing disk-to-seat friction, and are grouped here for the purpose of evaluating the potential degradation of the hard seating mechanism.

When data from Aloyco split wedge gate valves are analyzed, the thrust signature for DP closing strokes shows features that reveal if the internal joint is affecting hard seating (Figure 3-48). Prior to motion in the joint, the thrust is relatively stable and is attributable to disk-to-seat friction. As the disks start to conform to the seat rings through motion in the joint (Point IW1), the thrust increases. Then, when the disk is fully conformed, the two disk halves hard seat against the seat rings (Point IW2).

Some Aloyco split wedge gate valves showed distinct IW1 and IW2 points and some valves showed only an IW1 point. This latter behavior is possible when certain internal dimensions are achieved by tolerance stackup that minimize or eliminate sliding in the joint. The data for valves with only an IW1 point did not provide useful information on potential degradation of the joint.

[15] The Aloyco valve line is now owned by Crane Valve Co.
[16] The vendor does not have a recommended installation orientation, and both configurations occur in service.

Figure 3-49 (top graph) shows measured valve factors at IW1 for the eight Aloyco split wedge gate valves. These valve factors reflect disk-to-seat sliding. The bottom of Figure 3-49 shows measured valve factors at IW2 for three valves. These values reflect internal joint sliding in addition to disk-to-seat sliding. As expected, the IW2 values are greater than the IW1 values for each valve, reflecting the additional internal joint friction. Five valves do not have IW2 values (in three instances the joint did not need to slide for the valve to hard seat and in two instances the valve tripped immediately following IW1).

On Figure 3-49, some valves showed changes in disk-to-seat friction (upper graph) during JOG MOV PV Program tests. Changes in valve factor were also observed at IW2 for some valves. The key concern is whether changes in valve factor observed at hard seating (lower graph) reflect degradation beyond that expected by the observations in disk-to-seat friction (upper graph). To address this question, the data were screened to identify all valves with results at both disk-to-seat friction (IW1) and hard seating (IW2) during two separate, consecutive test sequences (e.g., baseline-to-second test or second-to-third test). There were five instances of these data, occurring on three different valves. On one of the five cases, the valve factor at IW1 remained constant and the valve factor at IW2 decreased slightly. This case was dismissed from further consideration, as it does not show degradation in DP thrust. In the remaining four cases, the change in valve factor at IW2 moved in the same direction as that at IW1. This result is expected, as a change in disk-to-seat friction, by itself, tends to affect the thrust at both points. On two of the four cases, the IW1 and IW2 valve factors both increased. On the remaining two, both decreased. These latter two were dismissed from further consideration as they do not show degradation in DP thrust.

For the two cases of interest (where IW1 and IW2 both increased), the changes in valve factor at both IW1 and IW2 are plotted on Figure 3-50 (first two bars for each valve test). For both cases, the EPRI model for Aloyco split wedge gate valves was used to predict the amount of expected increase in the valve factor at IW2, based on the observed increase at IW1. The prediction is shown as a third bar next to the IW2 bar. The prediction considers the valve orientation where it is known; predictions for both orientations are shown where orientation is unknown. The results show that the observed change at IW2 is less than the predicted amount, thus indicating that there is no degradation at the internal joint.

In summary, the JOG MOV PV Program test results from Aloyco split wedge gate valves indicate that the internal ball-and-socket joint that engages to hard-seat the valve is not degrading. Changes in disk-to-seat friction control the changes in valve factor at stroke points before and during hard seating. Hence, it is not necessary to consider the hard seating characteristic of Aloyco split wedge gate valves in the final PV approach for gate valves.

F. Effects of Valve Disassembly and Reassembly

The JOG MOV PV Program Test Specification (Reference 9) defines valve disassembly as the disassembly of the bonnet-to-body joint for gate and globe valves. Internal valve maintenance, including valve disassembly, was not permitted between the baseline and third tests. However, there were no restrictions on valve disassembly and internal maintenance prior to the baseline test. Of the 134 gate valves tested in the JOG Program, 40 were disassembled for internal maintenance and reassembled within the 2-year period prior to the baseline JOG test. Typical internal maintenance activities included:

- disk or stem replacement
- disk inspection
- lapping of seats
- grinding/smoothing of disk wedge or body rails
- valve modifications such as installation of a pressure relief port in the bonnet

The 40 disassembled gate valves have been analyzed for disk-to-seat friction and disk-to-guide friction previously in this section. Based on the evaluation of these test results, it is apparent that:

- valve disassembly/reassembly tends to reduce valve factors
- subsequent DP stroking tends to increase valve factors to values consistent with non-disassembled valves

The following analysis evaluates all 40 disassembled valves, and provides the basis for conclusions regarding valve disassembly/reassembly.

F.1 Low Baseline Test Valve Factors

Gate valves that were disassembled prior to the baseline test tend to show lower required thrust and lower baseline test valve factors than non-disassembled valves. Figure 3-51 compares the average baseline test valve factors for disassembled valves and non-disassembled valves for all gate valves with self-mated Stellite seats. As the figure shows, the average baseline valve factor at all points of interest was 16-33% lower for disassembled valves than non-disassembled valves.

This trend is more apparent when considering the effect of DP strokes performed between valve disassembly/reassembly and the baseline JOG test. Table 3-5 summarizes the dates of valve disassembly, the baseline test dates, and the number of DP strokes performed between these events for the 40 disassembled valves. Twenty-nine valves had no DP strokes between valve reassembly and the baseline JOG test, eight valves were DP stroked 1 to 4 times, and three valves were DP stroked 6-60 times between reassembly and testing. Figure 3-52 shows the average baseline valve factors as a function of DP stroking between disassembly/reassembly and testing for the 36 disassembled valves with self-mated Stellite seats. As shown in the figure, valves with no DP stroking exhibited lower average baseline valve factors compared to valves which were DP stroked between reassembly and JOG testing.

F.2 Increase from Low Baseline Valve Factor with DP Stroking

Disassembled valves with low initial valve factors tend to increase with DP stroking up to a stable level. The increase in valve factor due to DP stroking is considered service-related degradation, and it is evident when data from baseline, second, and third JOG tests are compared. Figure 3-53 summarizes the average valve factors in each test for disassembled valves with self-mated Stellite seats.

As the figure shows, the average valve factor for disassembled valves increases from the baseline test to the third test. The figure also shows the increase in average valve factor is greater between the baseline and second tests, compared to the change between the second and third tests. The data suggest that a low initial valve factor is most sensitive to service-related degradation immediately after disassembly/reassembly, and becomes less sensitive in subsequent tests as DP strokes are accumulated.

The effect of valve disassembly on required thrust and valve factor, and the subsequent increase with stroking, is also apparent in the thrust traces for disassembled valves. Figure 3-54 shows the overlaid DP thrust traces for the three JOG tests of gate valve G44.10. This valve was disassembled/reassembled just prior to the baseline test. The thrust at seating (closing) and unseating (opening) during the baseline test is significantly lower compared to the subsequent tests. Following three DP strokes performed between the baseline and second tests, the second test shows a much higher required thrust. The thrust increases again in the third test (after performing 1 DP stroke between the second and third tests), although by a lesser amount.

The effects of DP stroking on valve factors are discussed in further detail in Topic G-*Effects of DP Stroking*.

F.3 Influence of Seat Materials

For valves with self-mated Stellite seats, the effect of valve disassembly is evident. As shown in Figures 3-51 to 3-54, valve disassembly reduces the friction coefficient for Stellite disk and seat ring surfaces, and this low friction tends to increase with DP stroking.

Data for disassembled valves with other disk-to-seat materials is limited. Three valves with 400 series Stainless Steel disk versus Stellite seat and one valve with Exelloy disk versus Monel seat were disassembled/reassembled prior to the JOG baseline test. Figures 3-55 and 3-56 show the valve factors for these valves.

Valve G99.05 (Exelloy/Monel seats) exhibits valve factor behavior similar to that of the disassembled gate valves with self-mated Stellite seats. As shown in Figures 3-55 and 3-56, the valve exhibits low baseline test valve factors that increase in the second test sequence. No third test data was obtained for this valve.

For the three valves with 400 series Stainless Steel versus Stellite seats, a mixture of valve factor behavior is observed. G92.01 had 60 DP strokes performed between the reassembly and the baseline test. Similar to other high DP stroking gate valves, this valve shows relatively stable valve factors across the three tests. Valves G91.06 and G92.02 were not DP stroked between reassembly and the baseline test. Similar to self-mated Stellite valves, G92.02 shows low initial valve factors in the baseline test. Following 4 DP strokes between the baseline and second tests, the valve factors show more typical values in the second test. No third test data was obtained for this valve. Valve G91.06 (hot water) shows stable valve factors across the three tests and does not appear to be affected by the disassembly. This valve was not DP stroked between JOG DP tests. As discussed in Topic B.2-*400 Series Stainless Steel Disk vs. Stellite Seat*, the effects of a temperature change between tests and recovery from disassembly are combined in the results for this valve.

F.4 Influence of Guide Materials

As discussed in Topic C-*Evaluation of Disk-to-Guide Friction*, the required DP thrust for most disassembled/reassembled valves in the JOG Program was controlled by disk-to-seat friction. Therefore, the data related to guide friction is limited. Fifteen disassembled valves had guide friction controlled thrust in at least one JOG DP test. Figures 3-57 through 3-59 show the data for these 15 valves separated by the material combinations. Where guide valve factors are not determined for a test, thrust overlays and pressure traces were reviewed to determine the qualitative guide friction trends between tests. The qualitative assessment of guide behavior is supplied in the figures, indicating stable, increasing or decreasing valve factor trends between tests. The figures include data for the following guide material combinations:

- Carbon Steel vs. Carbon Steel *(5 valves)*
- Carbon Steel vs. 17-4PH Stainless Steel *(1 valve)*
- 300 series Stainless Steel vs. 300 series Stainless Steel *(4 valves)*
- 300 series Stainless Steel vs. 17-4PH Stainless Steel *(2 valves)*
- Stellite vs. Carbon Steel *(1 valve)*
- Stellite vs. 17-4PH Stainless Steel *(2 valves)*

Although the available data is limited, disassembled valves with self-mated carbon steel, self-mated 300 series stainless steel and 300 series stainless steel disk vs. 17-4PH stainless steel body guides show guide friction behavior analogous to seat friction. Although the trend is not as strong as for seat friction, disassembly/reassembly results in initially low guide valve factors which tend to increase with DP stroking. After multiple DP strokes, the guide valve factors appear to reach stable values and additional DP stroking does not affect required DP thrust.

Sufficient data is not available to provide conclusive information regarding the effect of valve disassembly on guide valve factors for valves with other guide materials.

F.5 Fluid Type and Temperature

Thirty-three of the 40 disassembled valves were tested in cold (<120°F) treated water systems. Thirty-one of the 33 valves (94%) are characterized in Figures 3-51 to 3-53. Based on the results shown on these figures, the effect of disassembly is evident for valves in cold treated water.

Two disassembled valves (G06.02 and G20.01) tested in cold, untreated water show low baseline valve factors that remain relatively stable in subsequent tests. Both of these valves have self-mated Stellite disk and seat faces. Neither valve was DP stroked in the time between disassembly/reassembly and the baseline test. Valve G06.02 was DP stroked 8 and 0 times between JOG tests respectively, and G20.01 was DP stroked 4 times between each JOG test. As shown in Figures 3-60 and 3-61, DP stroking does not appear to affect the valve factors for valves in untreated water systems. However, sufficient data is not available to provide conclusive information regarding the effect of valve disassembly on valves in untreated water systems.

Two disassembled valves (G91.06 and G99.05) were tested in hot water.[17] G91.06 has a 400 series stainless steel disk face versus Stellite seat face and G99.05 has an Exelloy disk face versus Monel seat face. As shown in Figures 3-60 and 3-61, the valve factors for G91.06 are stable between tests and appear unaffected by disassembly. However, as discussed in Topic B.2-*400 Series Stainless Steel Disk vs. Stellite Seat*, this data includes the mixture of effects of temperature changes between tests and effects of disassembly. The valve factors for G99.05 shows an increase between baseline and second tests consistent with valve factor behavior of disassembled gate valves with self-mated Stellite seats. Sufficient data is not available to provide conclusive information regarding the effect of valve disassembly on valves in hot water systems.

Three disassembled valves are located in steam systems, all with self-mated Stellite disk and seat faces. Valves G60.01, G60.02 and G60.05 had 1, 24 and 0 DP strokes, respectively, between valve reassembly and the baseline JOG test. As shown in Figures 3-60 and 3-61, the valve factors exhibit a mixture of behavior between tests (per discussion in A.4-*Hot Water and Steam*, open data for G60.02 is excluded). However, as discussed previously, the average baseline valve factors for the disassembled steam valves are similar to or less than the average baseline valve factors for non-disassembled valves in steam. In addition, the final average valve factors for the disassembled valves are similar to or slightly higher than the valve factors for non-disassembled valves in steam. This reduced initial valve factor after disassembly and the increase in valve factor with subsequent DP stroking is analogous to the trend for gate valves with Stellite seats in cold, treated water, although the trend is not as strong for valves in steam.

G. Effects of DP Stroking

Based on the JOG MOV PV Program test results from 134 gate valves it is apparent that:

- Valves which are stroked frequently against DP tend to have higher overall valve factors than valves which are not typically stroked against DP
- Valves with low valve factors tend to increase with DP stroking (i.e., service-related degradation), resulting in valve factors near other similar valves. Valves with higher overall valve factors tend to remain stable with DP stroking

The following analysis evaluates the effects of DP stroking on all gate valves in the JOG MOV PV Program. Although all of the gate valve data have been addressed in other analyses in this section, including the effects of DP stroking, this section is intended to summarize the overall trends and conclusions.

[17] Valve G91.06 was tested in 95°F water in the baseline test, 225°F water in the second test, and 190°F water in the third test. Valve G99.05 was tested in 135°F water in the baseline test and 87°F water in the second test.

G.1 Valve Factor and DP Stroking

On average, valves that experience a high frequency of DP stroking tend to exhibit higher valve factors than valves not DP stroked. This trend is best observed by analyzing non-disassembled gate valves. Figure 3-62 shows the average baseline valve factors[18] for non-disassembled valves with self-mated Stellite seats in water as a function of the number of DP strokes performed per year prior to the baseline test. Figure 3-63 shows a similar analysis for non-disassembled valves with other (non-Stellite) seats in water.

The data in Figure 3-62 show a strong correlation between the amount of DP stroking and average baseline test valve factor for valves with self-mated Stellite seats. High DP stroking valves[19] exhibit higher average valve factors than low DP stroking valves and valves which were not DP stroked in the two years prior to the baseline test. The data in Figure 3-63 show that high DP stroking valves with non-Stellite seats also exhibit higher valve factors than valves that are DP stroked less frequently. However, the average valve factors for no DP stroking and low DP stroking valves with non-Stellite seats do not show the same trend exhibited by valves with self-mated Stellite seats (Figure 3-62). This inconsistency is explained by examining the population of valves in Figure 3-63. The valves with non-Stellite seats include four different disk-to-seat material combinations which have different coefficients of friction that affect valve factor. In addition, the total population of valves with non-Stellite seats is relatively small, such that test results from individual valves may skew the data slightly. Nonetheless, the overall conclusion supported by Figures 3-62 and 3-63 is that valves which are stroked frequently against DP tend to have higher valve factors than valves which are not typically stroked against DP.

G.2 Change in Valve Factor Due to DP Stroking

Low initial valve factors tend to increase as a result of DP stroking. This behavior is service-related degradation. Further, valves with low initial valve factors which experience a high number of DP strokes exhibit larger increases than valves with less frequent DP stroking. These trends are best observed by considering valves that have been disassembled/reassembled prior to the baseline test. As discussed in Topic F-*Effects of Valve Disassembly and Reassembly*, disassembled valves tend to show low valve factors immediately following disassembly. These low initial valve factors increase with subsequent DP stroking.

Figure 3-64 shows the average valve factors for disassembled valves across the three tests, considering the number of DP strokes between tests. In all three cases, the low baseline valve factors increase significantly in the second test. For valves that are stroked infrequently (no and low DP stroking), the increase in average valve factor is similar. Valves that are stroked most

[18] Average seat friction valve factors are calculated as the mean of four points of interest during the valve stroke (Flow Isolation, Initial Wedging, Just After Cracking and Flow Initiation).
[19] Valves that are typically stroked 5 or more times per year are "High" DP stroking valves. Valves that are typically DP stroked 1-4 times per year are "Low" DP stroking valves. Valves that are not typically DP stroked are "No" DP stroking valves.

frequently (high DP stroking) show the largest increase in valve factor from baseline to second test.

In the second and third test, the average valve factors for no and low DP stroking valves continue to increase, although the increases are smaller than the changes between baseline and second tests. This trend suggests these valve factors will eventually stabilize as more DP strokes are accumulated. For high DP stroking valves, the average valve factor is stable from the second to third test, suggesting that the valves are no longer sensitive to the accumulation of DP strokes. Additional DP stroking is not expected to affect these valve factors.

The tendency for low valve factors to increase from service-related degradation is also depicted in Figure 3-65. The figure shows the change in valve factor between subsequent tests versus initial valve factor for all disassembled/reassembled valves tested in water systems. The three dark solid lines show the best fit line for the no, low, and high DP stroking data. The slopes of these lines indicate that for all three groups, valves with lower initial valve factors tend to increase, and valves with higher initial valve factors tend to be stable or decrease.

G.3 Influence of Seat Materials

As shown in Figures 3-62 and 3-65, the effect of DP stroking is apparent for valves with Stellite seats tested in water systems.

Although the data for valves with non-Stellite seats is limited, Figure 3-63 also shows the correlation between higher initial valve factors and frequent DP stroking for these valves. The tendency for non-Stellite valves with low valve factors to increase is shown in Figure 3-66. The figure shows the change in valve factor between subsequent tests versus initial valve factor for all valves with non-Stellite seats, tested in water systems. As shown in the figure, low valve factors in water systems tend to increase while higher valve factors remain stable or decrease.

G.4 Influence of Guide Materials

The required DP thrust for most gate valves in the JOG MOV PV Program was controlled by disk-to-seat friction. Therefore, the data related to guide friction is limited. Thirty-eight valves exhibited guide friction controlled thrust in at least one JOG DP test. These data are discussed in detail in Topic C-*Evaluation of Disk-to-Guide Friction.*

Overall, the guide valve factors show a much weaker correlation with frequency of DP stroking than seat friction valve factors. However, valve disassembly/reassembly and subsequent DP stroking for several guide materials exhibit guide valve factor trends similar to those of seat friction valve factors. As discussed previously, disassembled gate valves with the following disk-to-body guide materials exhibit lower initial valve factors compared to non-disassembled valves, and show an increasing valve factor trend with subsequent DP stroking:

- Carbon Steel Disk vs. Carbon Steel Body Guides
- 300 Series Stainless Steel Disk vs. 300 Series Stainless Steel Body Guides
- 300 Series Stainless Steel Disk vs. 17-4PH Stainless Steel Body Guides

Sufficient guide valve factor data is not available to provide conclusive information regarding the effect of valve disassembly and subsequent DP stroking on valves with other disk-to-body guide materials.

G.5 Fluid Type and Temperature

The effect of DP stroking is apparent for valves in cold, treated water systems, as shown in Figures 3-62 through 3-66.

Fourteen valves were tested in untreated water. Nine of these valves have self-mated Stellite seats and were not disassembled prior to the baseline test. As shown in Figure 3-67, these valves exhibit similar behavior to valves in treated water, with respect to DP stroking. The untreated water valves which are stroked frequently against DP tend to have higher valve factors than valves which are not typically stroked against DP. The figure shows that the average valve factors for treated and untreated water are comparable. Further, as discussed in previous sections, untreated water valves with low initial valve factors tend to increase with DP stroking, resulting in stable valve factors near other similar valves.

Five gate valves were tested in hot water. Two valves are low DP stroking valves and three valves are no DP stroking valves. Figure 3-68 shows the opening stroke valve factors for the point of "Just After Cracking" for these valves. Valve factors at other points of interest during the valve stroke behave similarly to these valve factors. In general, the hot water valves exhibit higher average valve factors than no and low DP stroking cold water valves. In addition, the low DP stroking hot water valves appear to have slightly higher valve factors than the no DP stroking hot water valves, particularly for a given disk-to-seat material pair (G99.03 and G99.04 have seat materials of Exelloy versus Monel).

Valve G79.02, which has self-mated Stellite seats, exhibits relatively high valve factors which remain stable or decrease with DP stroking. This valve factor trend is consistent with trends observed for valves with Stellite seats and high initial valve factors in cold water. Valve G91.06 was disassembled/reassembled prior to the baseline test and exhibits the lowest valve factors of the five hot water valves, and does not exhibit the characteristic increase in valve factor after subsequent DP stroking. Note that the baseline, second and third test were performed at temperatures of 95°F, 225°F and 190°F, respectively. As discussed in Topic B.2-*400 Series Stainless Steel Disk vs. Stellite Seat*, effects of a temperature change and recovery from disassembly are mixed together in the data for this valve. Valve G99.05 was disassembled/reassembled prior to the baseline test and exhibits low initial valve factors that increase on subsequent DP stroking as discussed in Topic B.3-*400 Series Stainless Steel (or Exelloy) Disk vs. Monel Seat.*

Although the data for hot water valves are consistent with cold water results, the extent of hot water data (5 valves covering 3 materials) is not sufficient to support a clear conclusion.

Of the eleven gate valves tested in steam systems, eight were not disassembled/reassembled prior to the baseline test. Of the eight valves, five are typically DP stroked 5 or more times between tests and three are stroked between 1 and 4 times. Figure 3-69 shows the average seat friction valve factors for the non-disassembled steam valves across the three test series. As discussed in Topic A.4-*Hot Water and Steam*, steam valves do not appear to exhibit the same valve factor behavior as valves in cold water systems. Low DP stroking valves show valve factors that are generally higher than the valves factors of the high DP stroking valves. However, sufficient data is not available to provide conclusive information regarding the effect of DP stroking on current valve factor for valves in steam systems.

Three of the steam valves were disassembled/reassembled prior to the baseline test. Two of these steam valves are typically DP stroked 5 or more times between tests and one steam valve is not typically DP stroked. Similar to the non-disassembled steam valves, the disassembled valve with "no DP stroking" exhibited higher valve factors than the two valves with "high DP stroking." However, as shown in the individual test data presented for Stellite valves in steam, the behaviors of these valves across the three JOG test series are inconsistent, and the test data do not provide conclusive information regarding the effects of valve disassembly and DP stroking on valve factors for steam valves.

H. EFFECTS OF STATIC TESTING

This topic evaluates the effect on valve factor of performing a static test prior to a DP test. The evaluation is performed using results from gate valves with Stellite seats.

The JOG DP Test Specification (Reference 9) required that an instrumented static test of the valve be performed prior to the DP test strokes, within 30 days. The purpose of the static test was to capture the behavior of the valve prior to applying DP conditions and to ensure that static test results comparable to the DP results were obtained. One of the NRC's comments on this approach was that potential effects of this pre-DP static stroke would not be able to be discerned from the data. The NRC was particularly concerned if the pre-DP static stroke caused a decrease in the valve factor measured in subsequent DP tests.

A few gate valves tested in the JOG MOV PV Program did not satisfy the 30-day requirement, but instead had a time interval from static stroke to DP stroke exceeding 30 days. These data provided a useful source of information to evaluate the effects of a longer period on valve factor. In addition, many valves in the program had two consecutive sets of DP strokes performed as part of each test sequence. Although this DP stroke pair is slightly different from a static-DP stroke pair, the results from a DP stroke pair also provide a meaningful source of information to evaluate the effect of stroking on subsequent valve factor results.

Two types of evaluations were used to determine the effect of a pre-DP static test on a DP test valve factor.

1. Valves were identified that had a test sequence in which the time interval between the first DP stroke and the preceding static stroke was more than 29 days. For these valves, the valves factors for all available tests were compared, to determine if the lengthened interval prior to the DP stroke had an effect on valve factor.

2. For valves where the static test preceded the first DP stroke by less than 30 days in all test sequences, the change in valve factor between consecutive DP strokes during each test was examined as an indicator of the effect of stroking on subsequent behavior. The rationale was that whatever effect a static stroke might have on valve factor, the effect of a DP stroke should be greater. Therefore, if an effect exists, it should be revealed by this evaluation, although the magnitude will likely be overstated.

Figures 3-70 and 3-71 present the results of the analysis related to Item (1) above. There were 15 gate valves with the pre-DP static test performed more than 29 days prior to the first DP test. Note that this group includes four valves that were disassembled/reassembled prior to the baseline test. The data was evaluated to determine whether there is a trend in valve factor based on the length of time between the pre-DP static test and the first DP test. For example, for this data, higher valve factors in tests with longer static-to-DP test intervals would tend to indicate that a static test performed immediately prior to a DP test reduces the valve factor. Conversely, lower valve factors in tests with longer static-to-DP test intervals would tend to indicate that a static test performed immediately prior to a DP test increases the valve factor. In examining Figures 3-70 and 3-71, the results do not indicate any trend on valve factors, signifying that the static test has negligible influence on valve factor performance.

Figures 3-72 through 3-76 present the results of the analysis related to Item (2) above. These data are from test sequences with two consecutive DP strokes, for valves located in treated water or steam systems without internal maintenance preceding the test. The JOG Program data includes 143 such tests (102 tests for valves in cold water, 36 tests for valves normally in hot water and tested in cold water, and 5 tests for valves normally in hot water/steam). The data are evaluated to determine the effect of one DP stroke on the consecutive stroke. The histograms show the relative valve factor change between consecutive DP strokes. The data are further classified based on fluid temperature and by the number of days between the pre-DP static test and DP test. The results indicate that the effect of one DP stroke is to slightly increase the valve factor on the next stroke for valves tested in cold water. For valves tested in hot water and steam, the trend is reversed, i.e., a slight decrease in valve factor is observed from one stroke to the next. The time-period between the pre-DP static and initial DP test does not affect the result.

The effect of a static stroke would be expected to be much smaller than that of a DP stroke. Overall, the conclusion is that a static stroke may very slightly increase the valve factor for valves tested in cold water and may very slightly decrease the valve factor for valves tested in hot water or steam. Hence, the performance of a static stroke prior to a DP stroke is negligible and is not necessary to consider in the final PV approach for gate valves.

I. EFFECTS OF DRAINING/VENTING

This topic evaluates the effect on valve factor due to draining, venting and refilling the piping surrounding the MOV prior to DP testing. The evaluation is performed using results from the baseline and second tests for non-disassembled gate valves with a combination of seat materials, fluid type and temperature.

The JOG DP Test Specification (Reference 9) provided no limitations or restrictions on draining, venting, or refilling the system. However, for each JOG test, the plant was required to record whether the piping surrounding the MOV was drained/vented/refilled preceding the DP test. Because draining and venting the piping exposes the valve internals (i.e., frictional interfaces) to a different fluid environment for a short period, a potential concern is that this iteration could influence the friction behavior of the valve surfaces. Specifically, one of the NRC's comments on draining/venting was that the potential effect on valve factor could be similar to the effect of disassembly/reassembly of the valve whereby the internals are removed from the valve body and exposed to air. The NRC was particularly concerned if draining/venting caused a decrease in valve factor.

As discussed previously, for the non-disassembled gate valves with valid baseline and second test data, the average valve factors were stable between tests. These data were then separated by whether the surrounding piping was drained/vented/refilled prior to each test. Twenty-seven valves recorded draining prior to the baseline test and 23 valves recorded draining prior to the second test. The average change in valve factor between baseline and second test was evaluated for the following four cases to determine the effect of draining/venting/refilling on valve factor:

Case 1: Valves that were drained/vented/refilled prior to both the baseline and second tests. *(18 valves)*

Case 2: Valves that were drained/vented/refilled prior to the baseline test, but *not* prior to the second test. *(9 valves)*

Case 3: Valves that were *not* drained/vented/refilled prior to the baseline test, but were drained/vented/refilled prior to the second test. *(5 valves)*

Case 4: Valves that were *not* drained/vented/refilled prior to both the baseline and second tests. *(60 valves)*

Figure 3-77 presents the results of these four evaluations. The upper graph on Figure 3-77 covers valves that were drained prior to the baseline test, and compares the change in valve factor for valves drained versus not drained prior to the second test (Cases 1 and 2 above). As the figure shows, valves drained prior to both tests show no, or very small changes in valve factor. Valves that were not drained prior to the second test tended to show increases in valve factor, although the changes are small (about 0.03). These results suggest that draining/venting tends to slightly reduce the valve factor.

The lower graph on Figure 3-77 covers valves that were not drained before the baseline test, and compares the changes in valve factor for valves drained versus not drained prior to the second test (Cases 3 and 4 above). Valves that were not drained before both tests show stable valve factors between tests. Valves that were drained before the second test (but not before the baseline test) tend to show slight reductions in VF although the average change is small (<0.03). These results also suggest that draining/venting tends to slightly reduce the valve factor.

Overall, the conclusion is that draining/venting/refilling the piping surrounding the MOV may slightly reduce the valve factor in the subsequent DP test. The effect, however, is not as strong as the effect of valve disassembly/reassembly prior to DP testing. Hence, draining/venting/refilling piping prior to a DP stroke is negligible and is not necessary to consider in the final PV approach for gate valves.

J. OTHER GATE VALVE EVALUATIONS

As discussed earlier in this section, the amount of gate valve test data obtained in the JOG MOV PV Program was extensive. The analyses presented in Topics A through I document the observations and valve factor trends based on the primary factors influencing gate valve required thrust. In addition to these evaluations, the data were evaluated to examine the effects of numerous other factors. The additional factors evaluated are summarized below.

Valve Manufacturer

Valve Size

Valve Pressure Class

Valve Stem and Pipe Orientation

Normal Valve Position

Test Fluid Temperature vs. Normal Operating Fluid Temperature

Test Flow Rate

Load Factor (linear contact stress)

Valve Mean Seat Diameter

Stem Thrust Sensor Type

Valve Disk Type

Common Factors (if any) in Data with Opposite Trends than Expected
(e.g., high DP stroking valves with low valve factors)

Chemistry/Treatments of Treated Water Systems

Guide Arrangement (standard vs. inverted)

Common Factors (if any) in 5% of Data outside Threshold Values

To examine the effects of these other factors, the set of data obtained in the program was evaluated and analyzed to isolate the potential impact of the factor being investigated. For example, to examine the effect of a specific parameter such as stem orientation, the data were screened to identify similar groups of gate valve tests that had different stem orientations. Often in this process, the data were culled. For example, the changes in valve factor that occurred after disassembly and reassembly of a gate valve often overwhelmed other changes or effects. Therefore, in examining a factor such as stem orientation it was most useful to examine only gate valves that were not disassembled. These data were then sorted to find groups of gate valves with similar types of fluid conditions and extents of DP stoking (but different stem orientations) so that the effect of stem orientation could be discerned. The results were typically plotted and organized in several different ways and then reviewed to discern the results.

No significant valve factor trends or degradation trends were identified as a result of these evaluations. Hence, it is not necessary to consider these factors in the final PV approach for gate valves.

K. GATE VALVE CONCLUSIONS

Overall

1. There is no age-related degradation in required thrust. Specifically, there is no increase in required thrust due only to the passage of time (without DP stroking).

2. There is no service-related degradation (i.e., increases in required thrust due to DP stroking) except under certain instances. The observations from the test data and conditions for service-related degradation are described in detail in the conclusions below.

Disk-to-Seat Friction

3. For the vast majority of gate valve closing strokes, disk-to-seat friction controls the required DP thrust. Only when the friction coefficient is very low, for example due to disassembly of the valve, will disk-to-seat friction not control the required closing thrust. In these cases, the friction coefficient will likely rise as the valve is DP stroked and become controlling. Therefore, as long as valve closing strokes are setup based on typical friction coefficients reflective of valves that have been in service, guide friction does not need to be considered.

4. For most gate valve opening strokes, disk-to-seat friction controls the required DP thrust. However, some opening strokes can be controlled by guide friction even for typical disk-to-seat friction coefficients. Therefore, both seat and guide friction need to be considered for opening strokes.

5. For gate valves in water systems, disk-to-seat friction exhibits the following behavior:

   - Valves that are not disassembled show a range of valve factors, the majority of which remain stable with stroking.

   - Some valves with low valve factors show increases in consecutive tests, resulting in valve factors near other similar valves. Valves that do not stroke against DP in service are more likely to have low valve factors.

   - Valves that stroke frequently against DP tend to have higher valve factors than valves that are not typically stroked against DP; however, these higher values are typically stable.

   - Valves that are disassembled and reassembled tend to show reduced (low) valve factors which tend to increase with DP stroking to values near similar, non-disassembled valves.

   - Threshold values were determined for gate valves with self-mated Stellite seats in water systems and are summarized in Topic A.5-*Grouping of Gate Valves with Self-*

Mated Stellite Seats for Determining Thresholds. Threshold values for gate valves with other (non-Stellite) seats are summarized in Topic B.5-*Thresholds for Gate Valves with Other (Non-Stellite) Seat Materials.*

6. For gate valves in steam systems, the data are more limited than for water systems. The data cover only self-mated Stellite seats. Based on the data available, disk-to-seat friction in steam exhibits the following behavior:

    - Valves that are not disassembled show a range of valve factors which remain stable with stroking.
    - Valves that stroke frequently against DP tend to have lower valve factors than valves which are not typically stroked against DP. This trend is opposite to the trend observed for valves in water systems.
    - Valves that are disassembled and reassembled tend to show slightly reduced (low) valve factors. This trend is much weaker in steam than in water. For steam valves, the slightly reduced valve factors show slight increases with DP stroking.
    - The threshold value for gate valves in steam systems is summarized in Topic A.5-*Grouping of Gate Valves with Self-Mated Stellite Seats for Determining Thresholds.*

Disk-to-Guide Friction

7. Guide friction does not normally control required thrust for gate valve strokes. However, some opening strokes are controlled by guide friction.

8. The test results show stable valve factors and no service-related degradation for the following guide materials and applications:

Disk-to-Guide Material	Fluid Type	Fluid Temperature
Carbon Steel vs. Carbon Steel	Treated / Untreated	Cold Water (≤120°F) Hot Water (>120°F) Steam
Carbon Steel vs. 17-4PH Stainless Steel	Treated / Untreated	Cold Water (≤120°F)
Stellite vs. Carbon Steel	Treated	Cold Water (≤120°F)
Stellite vs. 17-4PH Stainless Steel	Treated	Cold Water (≤120°F)
Stellite vs. 300 Stainless Steel	Treated	Cold Water (≤120°F)
Stellite vs. Stellite	Treated	Cold Water (≤120°F)
300 Stainless Steel vs. 300 Stainless Steel	Treated	Cold Water (≤120°F)

Disk-to-Guide Material	Fluid Type	Fluid Temperature
300 Stainless Steel vs. 17-4PH Stainless Steel	Treated	Cold Water (≤120°F)
300 Stainless Steel vs. Carbon Steel	Treated / Untreated	Cold Water (≤120°F) Hot Water (>120°F)

9. The test results for the following guide materials and applications show that valves that are disassembled and reassembled have slightly lower initial valve factors that tend to increase with DP stroking to values similar to non-disassembled valves. The increase is analogous to valves with self-mated Stellite disk-to-seat friction, but is of lesser overall magnitude.

Disk-to-Guide Material	Fluid Type	Fluid Temperature
Carbon Steel vs. Carbon Steel	Treated	Cold Water (≤120°F)
300 Stainless Steel vs. 300 Stainless Steel	Treated	Cold Water (≤120°F)
300 Stainless Steel vs. 17-4PH Stainless Steel	Treated	Cold Water (≤120°F)

10. Three potential guide degradation mechanisms were identified at the outset of the JOG MOV PV Program. These mechanisms and the insights about them from the test data are as follows:

    a. *Wear from cumulative DP strokes increases guide clearances and leads to poor disk guiding:*

    Valves with carbon steel guides with a significant amount of DP stroking would be expected to show the greatest sensitivity to wear. The JOG test results for these valves do not show higher overall valve factors than valves that are not typically DP stroked or stroked infrequently. Valves with 300 series stainless steel guides did not show a trend based on DP stroking. Overall, valves with carbon steel guides and 300 series stainless steel guides show stable valve factors between tests, indicating no apparent degradation in guide friction. Guide wear, if it is occurring, is not affecting guide friction.

    b. *Corrosion increases guide clearances and leads to poor disk guiding:*

    Valves with carbon steel guides in untreated water systems would be most likely to corrode. Overall, guide valve factor trends between treated and untreated water systems show similar and stable valve factors, indicating no apparent degradation. Guide valve factors in untreated water systems show more variation between tests. One valve with carbon steel guides in an untreated water system shows high closing guide valve factors that increase on the subsequent tests. This same valve has typical seat valve factors and typical opening guide behavior. The observed closing result appears to be related to damage or accumulation of foreign material. Nine gate valves with carbon steel guides in untreated water showed stable valve factors. Based on the results from other valves, the single valve with an increase is judged to be an outlier, and not indicative of a systematic degradation trend.

c. *Guide galling at elevated temperatures significantly increases guide friction:*

Guide valve factors for valves with 300 series stainless steel vs. carbon steel guides tested at elevated temperatures are higher overall than other guide material combinations. Guide valve factors for valves with carbon steel guides tested at elevated temperatures show a mixture of mid-range and high-range values. There is no data for valves with self-mated 300 series stainless steel guides at elevated temperatures. Overall, valves with carbon steel guides and 300 series stainless steel vs. carbon steel guides tested in hot water or steam show stable valve factors between tests, indicating no apparent degradation. From this information, it appears possible that at elevated temperatures, guide surface damage or galling might have occurred, but the valve factor is stable.

Anchor/Darling Double Disk Gate Valves

11. For Anchor/Darling double disk gate valves, there is no degradation associated with the internal wedging (hard seating) mechanism. Changes in valve factor at hard seating do not indicate degradation beyond that indicated by changes in disk-to-seat friction. Hence, it is not necessary to consider the hard seating characteristic of Anchor/Darling double disk gate valves in the final PV approach for gate valves.

Aloyco Split Wedge Gate Valves

12. For Aloyco split wedge gate valves, there is no degradation associated with the internal joint (hard seating) mechanism. Changes in valve factor at hard seating do not indicate degradation beyond that indicated by changes in disk-to-seat friction. Hence, it is not necessary to consider the hard seating characteristic of Aloyco split wedge gate valves in the final PV approach for gate valves.

Effects of Static Testing

13. The effect of a static stroke prior to a DP stroke is expected to be much smaller than that of a DP stroke. A static stroke may very slightly increase the valve factor for valves tested in cold water and may very slightly decrease the valve factor for valves tested in hot water or steam. Overall, the effect of a static stroke prior to a DP stroke is negligible and is not necessary to consider in the final PV approach for gate valves.

Effects of Draining/Venting

14. Draining/venting/refilling the piping surrounding the MOV may slightly decrease the valve factor (0.03 or less), although the effect is much less than the effects of valve disassembly

on valve factor. Overall, the effect of draining/venting/refilling prior to a DP stroke is negligible and is not necessary to consider in the final PV approach for gate valves.

Other Gate Valve Evaluations

15. Additional valve attributes such as manufacturer, size, pressure class, stem and pipe orientation, normal valve position, disk type, etc., were determined to have no effect on valve factor or degradation trends. Hence, it is not necessary to consider these factors in the final PV approach for gate valves.

Table 3-1A. Attributes of JOG MOV PV Program Gate Valves (*5 Pages*)

JOG Test Matrix No.	Manufacturer	Size (in)	Pressure Class (lbs)	Disk Type	Disk Face Material	Seat Ring Face Material	Disk Guide Surface Material	Body Guide Surface Material
G01.02	Velan	6	300	Flex Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G06.01	Velan	12	150	Flex Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G06.02	Velan	12	150	Flex Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G08.01	Anchor/Darling	16	150	Flex Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G10.01	Anchor/Darling	18	150	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G10.02	Anchor/Darling	18	150	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G12.01	Velan	6	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G15.01	Velan	12	150	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G17.01	Walworth	24	150	Solid Wedge	Stellite	Stellite	Stellite	Carbon steel
G20.01	Borg-Warner	4	300	Flex Wedge	Stellite	Stellite	Carbon Steel	17-4 PH SS
G22.01	Velan	6	150	Flex Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G22.03	Borg-Warner	8	150	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G22.07	Anchor/Darling	12	900	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G22.08	Anchor/Darling	12	900	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G22.09	Walworth	8	150	Solid Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G22.10	Walworth	8	150	Solid Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G22.12	Anchor/Darling	18	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G22.14	Anchor/Darling	18	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G22.17	Anchor/Darling	18	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G22.19	Crane	14	900	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G22.20	Crane	14	900	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G22.21	Powell	24	900	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G22.22	Crane	24	900	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.01	Velan	6	150	Flex Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G27.04	Velan	3	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.05	Anchor/Darling	3	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel

Table 3-1A. Attributes of JOG MOV PV Program Gate Valves (*5 Pages*)

JOG Test Matrix No.	Manufacturer	Size (in)	Pressure Class (lbs)	Disk Type	Disk Face Material	Seat Ring Face Material	Disk Guide Surface Material	Body Guide Surface Material
G27.06	Velan	6	150	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.07	Anchor/Darling	12	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.08	Walworth	3	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.10	Anchor/Darling	4	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.11	Anchor/Darling	4	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.14	Velan	6	150	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.15	Velan	12	150	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.16	Anchor/Darling	4	600	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.17	Powell	3	300	Solid Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G27.18	Anchor/Darling	18	300	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G32.01	Velan	6	150	Flex Wedge	Stellite	Stellite	Stellite	Carbon steel
G32.02	Velan	6	150	Flex Wedge	Stellite	Stellite	Stellite	Carbon steel
G32.03	Crane	16	300	Solid Wedge	Stellite	Stellite	Stellite	Carbon steel
G32.04	Velan	4	900	Flex Wedge	Stellite	Stellite	Stellite	Carbon steel
G32.05	Crane	16	300	Solid Wedge	Stellite	Stellite	Stellite	Carbon Steel
G36.01	Anchor/Darling	3	900	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G41.02	Powell	10	900	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G41.06	Anchor/Darling	8	600	Flex Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G41.07	Velan	4	600	Flex Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G41.08	Powell	10	900	Flex Wedge	Stellite	Stellite	Carbon steel	Carbon steel
G44.02	Walworth	4	900	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.03	Walworth	4	900	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.04	Powell	4	300	Solid Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.05	Powell	4	300	Solid Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.06	Powell	4	300	Solid Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.08	Walworth	12	600	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.09	Anchor/Darling	6	900	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.10	Anchor/Darling	6	900	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS

Table 3-1A. Attributes of JOG MOV PV Program Gate Valves (*5 Pages*)

JOG Test Matrix No.	Manufacturer	Size (in)	Pressure Class (lbs)	Disk Type	Disk Face Material	Seat Ring Face Material	Disk Guide Surface Material	Body Guide Surface Material
G44.11	Anchor/Darling	6	900	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.12	Anchor/Darling	6	900	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.13	Anchor/Darling	6	900	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.14	Anchor/Darling	6	900	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.15	Anchor/Darling	8	150	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G44.17	Anchor/Darling	4	900	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G49.01	Anchor/Darling	6	300	Flex Wedge	Stellite	Stellite	300 series SS	300 series SS
G54.01	Anchor/Darling	3	1500	Double Disk	Stellite	Stellite	N/A	N/A
G54.02	Anchor/Darling	6	150	Double Disk	Stellite	Stellite	N/A	N/A
G54.03	Anchor/Darling	3	1500	Double Disk	Stellite	Stellite	N/A	N/A
G54.04	Anchor/Darling	4	900	Double Disk	Stellite	Stellite	N/A	N/A
G56.01	Anchor/Darling	4	1500	Double Disk	Stellite	Stellite	N/A	N/A
G56.02	Anchor/Darling	6	150	Double Disk	Stellite	Stellite	N/A	N/A
G56.03	Anchor/Darling	4	1500	Double Disk	Stellite	Stellite	N/A	N/A
G57.01	Anchor/Darling	6	300	Double Disk	Stellite	Stellite	N/A	N/A
G58.01	Anchor/Darling	4	300	Double Disk	Stellite	Stellite	N/A	N/A
G58.02	Anchor/Darling	8	150	Double Disk	Stellite	Stellite	N/A	N/A
G59.01	Anchor/Darling	4	900	Double Disk	Stellite	Stellite	N/A	N/A
G59.02	Anchor/Darling	6	300	Double Disk	Stellite	Stellite	N/A	N/A
G60.01	Anchor/Darling	10	600	Double Disk	Stellite	Stellite	N/A	N/A
G60.02	Anchor/Darling	4	900	Double Disk	Stellite	Stellite	N/A	N/A
G60.03	Anchor/Darling	4	600	Double Disk	Stellite	Stellite	N/A	N/A
G60.04	Anchor/Darling	10	900	Double Disk	Stellite	Stellite	N/A	N/A
G60.05	Anchor/Darling	4	600	Double Disk	Stellite	Stellite	N/A	N/A
G60.06	Anchor/Darling	4	600	Double Disk	Stellite	Stellite	N/A	N/A
G63.01	Aloyco	6	150	Split Wedge	Stellite	Stellite	Stellite	300 series SS
G63.02	Aloyco	6	300	Split Wedge	Stellite	Stellite	N/A	N/A
G63.03	Crane-Aloyco	8	300	Split Wedge	Stellite	Stellite	300 series SS	300 series SS

Table 3-1A. Attributes of JOG MOV PV Program Gate Valves (*5 Pages*)

JOG Test Matrix No.	Manufacturer	Size (in)	Pressure Class (lbs)	Disk Type	Disk Face Material	Seat Ring Face Material	Disk Guide Surface Material	Body Guide Surface Material
G63.04	Aloyco	6	150	Split Wedge	Stellite	Stellite	N/A	300 series SS
G63.05	Crane-Aloyco	6	300	Split Wedge	Stellite	Stellite	N/A	N/A
G63.06	Crane-Aloyco	6	300	Split Wedge	Stellite	Stellite	N/A	N/A
G65.01	Aloyco	8	150	Split Wedge	Stellite	Stellite	300 series SS	Stellite
G65.02	Crane-Aloyco	8	300	Split Wedge	Stellite	Stellite	300 series SS	300 series SS
G69.01	Westinghouse	8	316	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G69.02	Westinghouse	6	150	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G69.03	Westinghouse	3	2035	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G69.05	Velan	4	1500	Flex Wedge	Stellite	Stellite	Stellite	Stellite
G69.06	Westinghouse	6	900	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G69.07	Westinghouse	3	2035	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G69.08	Velan	12	300	Flex Wedge	Stellite	Stellite	Stellite	300 series SS
G69.09	Velan	6	1500	Flex Wedge	Stellite	Stellite	Stellite	300 series SS
G69.10	Velan	3	1500	Flex Wedge	Stellite	Stellite	Stellite	300 series SS
G69.11	Velan	3	1500	Flex Wedge	Stellite	Stellite	Stellite	300 series SS
G69.12	Westinghouse	10	300	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G69.13	Anchor/Darling	12	900	Flex Wedge	Stellite	Stellite	Stellite	Carbon steel
G69.14	Velan	16	150	Flex Wedge	Stellite	Stellite	Stellite	Carbon Steel
G75.01	Westinghouse	8	1525	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G75.02	Westinghouse	8	316	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G75.03	Westinghouse	4	900	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G75.06	Westinghouse	6	1525	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G75.07	Westinghouse	6	150	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G75.08	Velan	12	300	Flex Wedge	Stellite	Stellite	Stellite	300 series SS
G75.09	Westinghouse	3	1500	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS
G75.10	Velan	16	150	Flex Wedge	Stellite	Stellite	Stellite	Carbon Steel
G75.11	Velan	14	900	Flex Wedge	Stellite	Stellite	Stellite	300 series SS
G79.02	Westinghouse	12	1525	Flex Wedge	Stellite	Stellite	Stellite	17-4 PH SS

Table 3-1A. Attributes of JOG MOV PV Program Gate Valves (*5 Pages*)

JOG Test Matrix No.	Manufacturer	Size (in)	Pressure Class (lbs)	Disk Type	Disk Face Material	Seat Ring Face Material	Disk Guide Surface Material	Body Guide Surface Material
G83.01	Borg-Warner	3	1500	Flex Wedge	Stellite	Stellite	300 series SS	17-4 PH SS
G83.02	Borg-Warner	4	1500	Flex Wedge	Stellite	Stellite	300 series SS	17-4 PH SS
G83.03	Borg-Warner	4	900	Flex Wedge	Stellite	Stellite	300 series SS	17-4 PH SS
G85.01	Borg-Warner	4	1500	Flex Wedge	Stellite	Stellite	300 series SS	17-4 PH SS
G88.01	Powell	8	150	Solid Wedge	400 series SS	400 series SS	Carbon steel	Carbon steel
G88.03	Powell	12	150	Solid Wedge	400 series SS	400 series SS	300 series SS	Carbon Steel
G89.01	Powell	8	150	Solid Wedge	400 series SS	400 series SS	Carbon Steel	Carbon steel
G89.02	Powell	4	300	Solid Wedge	400 series SS	400 series SS	400 series SS	Carbon steel
G89.03	Walworth	12	150	Solid Wedge	400 series SS	400 series SS	Carbon steel	Carbon steel
G91.05	Powell	6	150	Solid Wedge	400 series SS	Stellite	Carbon steel	Carbon steel
G91.06	Crane	18	300	Solid Wedge	400 series SS	Stellite	Carbon Steel	Carbon Steel
G92.01	Powell	18	300	Flex Wedge	400 series SS	Stellite	Carbon steel	Carbon steel
G92.02	Walworth	18	300	Solid Wedge	400 series SS	Stellite	Carbon steel	Carbon steel
G92.03	Powell	3	900	Solid Wedge	Stellite	Stellite	Carbon Steel	Carbon Steel
G96.01	Crane	10	900	Flex Wedge	Stellite	Stellite	Stellite	Malcolmized 410 SS
G96.02	Crane	10	900	Flex Wedge	Stellite	Stellite	Stellite	Malcolmized 410 SS
G98.01	Anchor/Darling	16	300	Double Disk	Deloro 50	Deloro 50	N/A	N/A
G99.01	Crane	3	300	Solid Wedge	400 series SS	Monel	Carbon steel	Carbon steel
G99.02	Crane	3	300	Solid Wedge	400 series SS	Monel	Carbon steel	Carbon steel
G99.03	Crane	6	600	Solid Wedge	Exelloy	Monel	300 series SS	Carbon Steel
G99.04	Crane	6	600	Solid Wedge	Exelloy	Monel	300 series SS	Carbon Steel
G99.05	Crane	6	600	Solid Wedge	Exelloy	Monel	300 series SS	Carbon Steel
G99.06	Pacific	6	150	Flex Wedge	400 series SS	Monel	Carbon steel	Carbon steel
G99.07	Walworth	8	150	Solid Wedge	400 series SS	Monel	Carbon steel	Carbon steel

Table 3-1B. Attributes of JOG MOV PV Program Gate Valves (*5 Pages*)

JOG Test Matrix No.	Stem Orientation	Pipe Orientation	Normal Position	Fluid Type	Normal Fluid Temperature (°F)
G01.02	Vertical	Horizontal	closed	untreated water	80
G06.01	Horizontal	Vertical	closed	untreated water	80
G06.02	30° [20]	Horizontal	closed	untreated water	80
G08.01	Vertical	Horizontal	closed	untreated water	75
G10.01	Horizontal	Vertical	closed	untreated water	95
G10.02	Horizontal	Vertical	closed	untreated water	95
G12.01	Vertical	75° [20]	closed	untreated water	80
G15.01	Horizontal	Vertical	closed	untreated water	80
G17.01	Vertical	Horizontal	open	untreated water	80
G20.01	Vertical	Horizontal	closed	untreated water	80
G22.01	Horizontal	Horizontal	open	treated/closed loop water	117
G22.03	Horizontal	Vertical	open	treated/closed loop water	100
G22.07	Horizontal	Vertical	closed	treated/closed loop water	105
G22.08	Horizontal	Vertical	closed	treated/closed loop water	105
G22.09	Vertical	Horizontal	open	treated/closed loop water	100
G22.10	45° [20]	45° [20]	closed	treated/closed loop water	100
G22.12	Vertical	Horizontal	closed	treated/closed loop water	100
G22.14	Vertical	Horizontal	closed	treated/closed loop water	100
G22.17	20° [20]	Horizontal	closed	reactor coolant water	95
G22.19	120° [20]	Horizontal	closed	treated/closed loop water	90
G22.20	120° [20]	Horizontal	closed	treated/closed loop water	90
G22.21	Vertical	Horizontal	closed	reactor coolant water	90
G22.22	Vertical	Horizontal	closed	reactor coolant water	90
G27.01	Horizontal	Horizontal	open	treated/closed loop water	100
G27.04	Vertical	Horizontal	open	treated/closed loop water	90
G27.05	Horizontal	Vertical	open	feedwater	90

[20] Indicated degrees from vertical above valve

Table 3-1B. Attributes of JOG MOV PV Program Gate Valves (*5 Pages*)

JOG Test Matrix No.	Stem Orientation	Pipe Orientation	Normal Position	Fluid Type	Normal Fluid Temperature (°F)
G27.06	45° [20]	Horizontal	open	treated/closed loop water	100
G27.07	Horizontal	Vertical	open	treated/closed loop water	80
G27.08	Horizontal	Vertical	open	treated/closed loop water	80
G27.10	Vertical	Horizontal	open	treated/closed loop water	105
G27.11	Horizontal	Vertical	open	treated/closed loop water	105
G27.14	Horizontal	Horizontal	open	treated/closed loop water	117
G27.15	Vertical	Horizontal	closed	treated/closed loop water	123
G27.16	105° [20]	Horizontal	closed	treated/closed loop water	80
G27.17	Horizontal	Vertical	open	treated/closed loop water	87
G27.18	Vertical	Horizontal	closed	treated/closed loop water	85
G32.01	Vertical	Horizontal	open	treated/closed loop water	83
G32.02	Vertical	Horizontal	open	treated/closed loop water	83
G32.03	Horizontal	Vertical	closed	treated/closed loop water	95
G32.04	Vertical	Horizontal	open	feedwater	110
G32.05	Horizontal	Vertical	closed	treated/closed loop water	95
G36.01	Vertical	Horizontal	closed	steam	540
G41.02	Vertical	Horizontal	closed	steam	550
G41.06	Horizontal	Vertical	open	steam	532
G41.07	Vertical	Horizontal	open	steam	600
G41.08	Vertical	Horizontal	closed	steam	550
G44.02	Vertical	Horizontal	open	treated/closed loop water	105
G44.03	Horizontal	Horizontal	open	treated/closed loop water	105
G44.04	Horizontal	Horizontal	open	reactor coolant water	80
G44.05	Horizontal	Horizontal	open	reactor coolant water	80
G44.06	Horizontal	Horizontal	open	reactor coolant water	80
G44.08	Vertical	Horizontal	closed	treated/closed loop water	95
G44.09	Vertical	Horizontal	closed	feedwater	90
G44.10	Vertical	Horizontal	closed	feedwater	90

Table 3-1B. Attributes of JOG MOV PV Program Gate Valves (*5 Pages*)

JOG Test Matrix No.	Stem Orientation	Pipe Orientation	Normal Position	Fluid Type	Normal Fluid Temperature (°F)
G44.11	Vertical	Horizontal	closed	feedwater	90
G44.12	Vertical	Horizontal	closed	feedwater	90
G44.13	Vertical	Horizontal	closed	feedwater	90
G44.14	Vertical	Horizontal	closed	feedwater	90
G44.15	Vertical	Horizontal	closed	reactor coolant water	195
G44.17	Vertical	Horizontal	open	reactor coolant water	80
G49.01	Vertical	Horizontal	closed	treated/closed loop water	70
G54.01	Vertical	Horizontal	closed	treated/closed loop water	100
G54.02	Vertical	Horizontal	open	treated/closed loop water	95
G54.03	Vertical	Horizontal	closed	reactor coolant water	170
G54.04	Vertical	Horizontal	open	reactor coolant water	80
G56.01	Vertical	Horizontal	closed	reactor coolant water	105
G56.02	Vertical	Horizontal	open	treated/closed loop water	95
G56.03	Vertical	Horizontal	closed	reactor coolant water	105
G57.01	Horizontal	Horizontal	closed	treated/closed loop water	85
G58.01	Vertical	Horizontal	closed	treated/closed loop water	70
G58.02	Horizontal	Horizontal	open	untreated water	85
G59.01	Horizontal	Vertical	closed	feedwater	100
G59.02	Horizontal	Vertical	open	reactor coolant water	140
G60.01	Vertical	Horizontal	closed	steam	546
G60.02	Vertical	Horizontal	closed	steam	532
G60.03	Horizontal	Horizontal	closed	steam	532
G60.04	Vertical	Horizontal	closed	steam	550
G60.05	Horizontal	Vertical	closed	steam	580
G60.06	75°[20]	Horizontal	closed	steam	532
G63.01	Vertical	Horizontal	open	treated/closed loop water	85
G63.02	Horizontal	Vertical	closed	reactor coolant water	100
G63.03	25°[20]	Horizontal	open	reactor coolant water	300

Table 3-1B. Attributes of JOG MOV PV Program Gate Valves (*5 Pages*)

JOG Test Matrix No.	Stem Orientation	Pipe Orientation	Normal Position	Fluid Type	Normal Fluid Temperature (°F)
G63.04	Vertical	Horizontal	open	reactor coolant water	115
G63.05	Vertical	Horizontal	closed	reactor coolant water	90
G63.06	Vertical	Horizontal	closed	reactor coolant water	90
G65.01	Vertical	Horizontal	open	treated/closed loop water	95
G65.02	Vertical	Horizontal	open	reactor coolant water	300
G69.01	45° [20]	Horizontal	open	treated/closed loop water	350
G69.02	Vertical	Horizontal	closed	treated/closed loop water	80
G69.03	Vertical	Horizontal	closed	reactor coolant water	130
G69.05	Vertical	Horizontal	closed	reactor coolant water	105
G69.06	Vertical	Horizontal	open	reactor coolant water	95
G69.07	Vertical	Horizontal	open	reactor coolant water	105
G69.08	Vertical	Horizontal	closed	reactor coolant water	300
G69.09	Vertical	Horizontal	open	reactor coolant water	110
G69.10	Vertical	Horizontal	closed	reactor coolant water	170
G69.11	Vertical	Horizontal	closed	reactor coolant water	170
G69.12	Vertical	Horizontal	open	treated/closed loop water	350
G69.13	Vertical	Horizontal	closed	reactor coolant water	110
G69.14	Horizontal	Horizontal	open	treated/closed loop water	95
G75.01	Vertical	Horizontal	open	treated/closed loop water	350
G75.02	45° [20]	Horizontal	open	treated/closed loop water	350
G75.03	Vertical	Horizontal	open	treated/closed loop water	95
G75.06	Vertical	Horizontal	open	reactor coolant water	95
G75.07	Vertical	Horizontal	closed	treated/closed loop water	80
G75.08	Vertical	Horizontal	closed	reactor coolant water	300
G75.09	Vertical	Horizontal	closed	reactor coolant water	170
G75.10	Horizontal	Horizontal	open	treated/closed loop water	95
G75.11	Horizontal	Vertical	closed	reactor coolant water	525
G79.02	Vertical	Horizontal	closed	hot water	350

Table 3-1B. Attributes of JOG MOV PV Program Gate Valves (*5 Pages*)

JOG Test Matrix No.	Stem Orientation	Pipe Orientation	Normal Position	Fluid Type	Normal Fluid Temperature (°F)
G83.01	Horizontal	Horizontal	open	treated/closed loop water	155
G83.02	Horizontal	Horizontal	open	treated/closed loop water	105
G83.03	Vertical	Horizontal	open	feedwater	120
G85.01	Horizontal	Horizontal	open	treated/closed loop water	105
G88.01	Horizontal	Horizontal	open	treated/closed loop water	100
G88.03	Vertical	Horizontal	closed	untreated water	70
G89.01	Vertical	Horizontal	open	untreated water	70
G89.02	Vertical	Horizontal	open	treated/closed loop water	90
G89.03	Horizontal	Vertical	open	untreated water	85
G91.05	Vertical	Horizontal	open	treated/closed loop water	125
G91.06	Vertical	Horizontal	open	feedwater	370
G92.01	Horizontal	Horizontal	closed	reactor coolant water	84
G92.02	Horizontal	Horizontal	closed	treated/closed loop water	90
G92.03	Vertical	Horizontal	closed	feedwater	80
G96.01	Vertical	Horizontal	closed	treated/closed loop water	95
G96.02	Vertical	Horizontal	closed	treated/closed loop water	95
G98.01	Horizontal	Horizontal	closed	treated/closed loop water	100
G99.01	Vertical	Horizontal	open	treated/closed loop water	90
G99.02	Vertical	Horizontal	open	treated/closed loop water	90
G99.03	Horizontal	Horizontal	open	treated/closed loop water	455
G99.04	Horizontal	Horizontal	open	treated/closed loop water	455
G99.05	Horizontal	Horizontal	open	treated/closed loop water	455
G99.06	Vertical	Horizontal	open	treated/closed loop water	95
G99.07	Horizontal	Vertical	open	treated/closed loop water	70

Table 3-2. Test Conditions for JOG Gate Valves (*6 Pages*)

JOG Test Matrix No.	Flow Rate (gpm or labeled)	Flow Rate (ft/s) *(based on nominal valve size)*	Fluid Temperature (°F)	Close DP (psig)	Open DP (psig)	Number of DP Strokes			DP Stroking Class[21]
						Prior to Baseline Test (2 years)	Between Baseline and Second Tests	Between Second and Third Tests	
G01.02	700 - 715	7.9 - 8.1	62 - 68	71 - 78	69 - 76	0	0	0	No
G06.01	1654 - 2000	4.7 - 5.7	45 - 60	50 - 67	49 - 65	4	0	0	No
G06.02	1900 - 2009	5.4 - 5.7	49 - 62	45 - 59	45 - 51	4	8	0	Low
G08.01	2600	4.1	68 - 79	54 - 74	47 - 131	8	12	20	High
G10.01	6680 - 6800	8.4 - 8.6	45 - 50	110 - 119	113 - 122	5	0	0	Low
G10.02	6600 - 6800	8.3 - 8.6	45 - 51	114 - 126	115 - 123	19	158	48	High
G12.01	700 - 715	7.9 - 8.1	60 - 68	69 - 81	67 - 77	0	0	0	No
G15.01	1660 - 2000	4.7 - 5.7	49 - 60	41 - 57	43 - 54	4	0	0	No
G17.01	5600	4	41 - 49	51 - 92	87 - 101	1	0	NA[22]	No
G20.01	194 - 200	5.0 - 5.1	35 - 48	48 - 98	66 - 73	8	4	4	Low
G22.01	709 - 788	8.0 - 8.9	72 - 78	112 - 179	111 - 121	4	4	4	Low
G22.03	1007 - 1650	6.4 - 10.5	80 - 90	112 - 126	97 - 103	17	17	20	High
G22.07	7900 - 8000	22.4 - 22.7	104 - 126	245 - 255	238 - 250	0	0	NA[22]	No
G22.08	7600 - 8300	21.6 - 23.5	78 - 127	258 - 315	259 - 303	0	0	5	No
G22.09	984 - 1500	6.3 - 9.6	55 - 70	120 - 143	110 - 129	0	0	0	No
G22.10	934 - 1500	6.0 - 9.6	55 - 70	119 - 146	115 - 128	0	0	0	No
G22.12	23100 - 23200	29.1 - 29.3	59 - 78	328 - 353	321 - 350	83	118	83	High
G22.14	23000 - 23500	29.0 - 29.6	72 - 80	331 - 357	334 - 354	94	168	106	High
G22.17	10500	13.2	80	362 - 365	363 - 367	0	0	0	No
G22.19	14800 - 15000	30.8 - 31.3	70 - 81	306 - 313	310	0	1	2	Low
G22.20	15000	31.3	70 - 77	311 - 316	301 - 314	0	5	0	No
G22.21	7700 - 8100	5.5 - 5.7	83 - 96	250 - 261	248 - 259	0	1	1	Low

[21] Valves classified as "No" are not typically DP stroked during normal plant operation or in between JOG tests. Valves Classified as "Low" are typically DP stroked 1-4 times per year during normal plan operation or in between JOG tests. Valves classified as "High" are typically DP stroked ≥ 5 times per year during normal plant operation or in between JOG tests.
[22] Valve does not have a third test.

Table 3-2. Test Conditions for JOG Gate Valves (*6 Pages*)

JOG Test Matrix No.	Flow Rate (gpm or labeled)	Flow Rate (ft/s) *(based on nominal valve size)*	Fluid Temperature (°F)	Close DP (psig)	Open DP (psig)	Number of DP Strokes			DP Stroking Class[21]
						Prior to Baseline Test (2 years)	Between Baseline and Second Tests	Between Second and Third Tests	
G22.22	7700 - 8100	5.5 - 5.7	74 - 120	228 - 286	234 - 244	6	0	2	Low
G27.01	870 - 972	9.9 - 11.0	72 - 79	131 - 139	123 - 133	4	4	4	Low
G27.04	300	13.6	82 - 85	311 - 358	321 - 352	16	22	8	High
G27.05	540	24.5	78 - 88	266 - 282	320 - 338	8	5	8	High
G27.06	696 - 754	7.9 - 8.6	67 - 75	127 - 141	115 - 126	4	4	4	Low
G27.07	1900 - 2050	5.4 - 5.8	75 - 82	160 - 188	160 - 184	20	20	20	High
G27.08	475 - 515	21.6 - 23.4	60 - 78	283 - 301	283 - 300	26	6	8	High
G27.10	625	16	80 - 85	174 - 192	295 - 301	20	88	159	High
G27.11	648 - 649	16.5 - 16.6	84 - 85	191 - 192	296 - 302	20	60	NA[22]	High
G27.14	696 - 754	7.9 - 8.6	67 - 75	116 - 176	99 - 127	8	4	4	Low
G27.15	4500 - 6000	12.8 - 17.0	76 - 91	89 - 116	89 - 113	16	16	8	High
G27.16	500	12.8	90 - 97	1413 - 1495	1402 - 1494	41	93	47	High
G27.17	640	29	69 - 81	359 - 381	338 - 386	32	20	0	High
G27.18	11000 - 11400	13.9 - 14.4	84 - 86	312 - 345	308 - 330	0	0	0	No
G32.01	353	4.0	59 - 85	74 - 91	76 - 90	0	2	1	Low
G32.02	353	4.0	59 - 85	79 - 93	76 - 87	0	2	1	Low
G32.03	6000 - 8500	9.6-13.6	42	275 - 297	286 - 296	0	0	0	No
G32.04	280 - 320	7.1 - 8.2	69 - 80	1495 - 1569	1498 - 1565	0	0	0	No
G32.05	6000 - 8500	9.6 - 13.6	39 - 43	297 - 340	NA	0	0	0	No
G36.01	6700 - 7130 lb_m/hr	16.8 – 42.2	455 - 545	NA	458 - 564	7	2	2	Low
G41.02	195700 - 207250 lb_m/hr	47.2 – 50.0	536 - 538	936 - 984	928 - 948	30	21	12	High
G41.06	275000 lb_m/hr	114	528	800 - 820	880	0	4	NA[22]	Low
G41.07	32000 lb_m/hr	32.8	580	NA	874 - 916	2	2	NA[22]	Low
G41.08	195700 - 207250 lb_m/hr	43.0 – 50.0	538 - 548	NA	936 - 1033	30	21	12	High

Table 3-2. Test Conditions for JOG Gate Valves (*6 Pages*)

JOG Test Matrix No.	Flow Rate (gpm or labeled)	Flow Rate (ft/s) *(based on nominal valve size)*	Fluid Temperature (°F)	Close DP (psig)	Open DP (psig)	Number of DP Strokes			DP Stroking Class[21]
						Prior to Baseline Test (2 years)	Between Baseline and Second Tests	Between Second and Third Tests	
G44.02	600 - 640	15.3 - 16.3	90 - 93	1492 - 1533	1476 - 1511	8	11	1	High
G44.03	570 - 600	14.6 - 15.3	90 - 93	1491-1577	1466 - 1515	1	0	1	Low
G44.04	105-173	2.7 - 4.4	67-86	167-180	166-174	0	0	0	No
G44.05	178-188	4.5 - 4.8	79-82	166-179	174 - 196	0	0	0	No
G44.06	114-121	2.9 - 3.1	74 - 94	172 - 184	169-176	0	0	NA[22]	No
G44.08	4795-4829	13.6 - 13.7	80	338 - 375	329-357	0	0	0	No
G44.09	1533-1600	17.4 - 18.2	81-91	1737 - 1842	1607 - 1741	2	3	1	Low
G44.10	1550-1593	17.6 - 18.1	84-91	1755-1810	1588 - 1798	2	3	1	Low
G44.11	935 - 1640	10.6 - 18.6	85-99	1738 - 1800	1652 - 1762	1	0	1	Low
G44.12	950-1000	10.8 - 11.3	75-96	1756 - 1813	1620 - 1787	2	0	1	Low
G44.13	1500-1720	17.0 - 19.5	81 - 92	1771 - 1835	1596 - 1781	2	2	0	Low
G44.14	1600-1720	18.2 - 19.5	79-90	1703-1813	1664 - 1776	2	1	1	Low
G44.15	200-230	1.3 - 1.5	52 - 82	125-146	159 - 178	0	0	0	No
G44.17	33-35	0.8 - 0.9	74-79	1331-1461	1340 - 1385	0	0	0	No
G49.01	3600-3650	40.8 - 41.4	69 - 73	323-349	337 - 351	10	10	10	High
G54.01	300-430	13.6 - 19.5	71 - 83	1485 - 1532	1481 - 1526	1	10	10	High
G54.02	440	5	87 - 92	77 - 107	78 - 82	8	4	4	Low
G54.03	490	22.2	75 - 77	2435 - 2650	2547 - 2697	3	3	3	Low
G54.04	560-570	14.3 - 14.6	80 - 85	1518-1598	1515 - 1543	0	0	0	No
G56.01	470-484	12.0 - 12.4	81 - 83	2240 - 2287	2478 - 2604	4	0	0	No
G56.02	440	5	87 - 91	76 - 87	66 - 69	8	4	4	Low
G56.03	470-481	12.0 - 12.3	81 - 82	2291 - 2371	2465 - 2617	4	0	0	No
G57.01	2280-2320	25.9 - 26.3	67-74	197 - 271	180 - 222	0	0	0	No
G58.01	1400	35.7	72-78	76 - 147	111 - 138	8	4	4	Low
G58.02	1200	7.7	49 - 50	95 - 105	95 - 102	10	17	7	High
G59.01	320 - 350	8.2 - 8.9	72 - 78	1399 - 1409	1381 - 1407	1	2	2	Low
G59.02	2750 - 2800	31.2 - 31.8	80 - 82	174 - 193	173 - 190	4	4	4	Low

Table 3-2. Test Conditions for JOG Gate Valves (*6 Pages*)

JOG Test Matrix No.	Flow Rate (gpm or labeled)	Flow Rate (ft/s) *(based on nominal valve size)*	Fluid Temperature (°F)	Close DP (psig)	Open DP (psig)	Number of DP Strokes			DP Stroking Class[21]
						Prior to Baseline Test (2 years)	Between Baseline and Second Tests	Between Second and Third Tests	
G60.01	151800 – 170000 lb_m/hr	34 – 40.3	540 - 546	944 - 1033	952 - 1033	10	8	6	High
G60.02	37713 lb_m/hr	60.1	532	812 - 898	792 - 953	24	17	24	High
G60.03	27410 lb_m/hr	45.3	528	610 - 813	831 - 867	18	18	NA[22]	High
G60.04	184000 lb_m/hr	42.2	543	924 - 1020	959 - 1029	0	10	6	High
G60.05	27500 lb_m/hr	27.4	583 - 585	843 - 923	898 - 924	0	8	0	No
G60.06	27410 lb_m/hr	45.3	528	749 - 776	832 - 870	24	18	NA[22]	High
G63.01	961 - 1155	10.9 - 13.1	78 - 86	157 - 176	155 - 166	0	0	0	No
G63.02	800 - 820	0.1 - 9.3	84 - 85	242 - 286	239 - 285	0	0	0	No
G63.03	3550 - 3630	22.7 - 23.2	81 - 96	203 - 245	193 - 213	8	2	NA[22]	Low
G63.04	60 - 108	0.7 - 1.2	46 - 72	169 - 197	184 - 195	0	0	0	No
G63.05	3400 - 3600	38.6 - 40.8	90	164 - 183	152 - 161	0	0	0	No
G63.06	3600	40.8	90	137 - 173	141 - 154	0	4	0	No
G65.01	401 - 474	2.6 - 3.0	73 - 86	106 - 119	99 - 111	4	1	1	Low
G65.02	3570 - 3600	22.8 - 23	92	194 - 241	193 - 218	8	2	NA[22]	Low
G69.01	3300 - 3310	21.1	84 - 99	196 - 245	196 - 224	0	0	0	No
G69.02	565	6.4	67 - 73	131 - 171	174 - 193	4	4	0	Low
G69.03	584 - 620	26.5 - 28.1	75 - 120	2794 - 2845	2704 - 2827	8	0	0	No
G69.05	370 - 464	9.4 - 11.8	80 - 83	1167 - 1314	1381 - 1475	4	0	2	Low
G69.06	1500 - 1540	17.0 - 17.5	74	1543 - 1586	1483 - 1579	3	1	1	Low
G69.07	134 - 215	6.1 - 9.8	80 - 92	2592 - 2798	2648 - 2772	0	0	0	No
G69.08	1785 - 2280	5.1 - 6.5	92 - 108	158 - 185	150 - 182	9	2	0	Low
G69.09	640	7.3	104	1180 - 1314	1251 - 1276	2	0	NA[22]	No
G69.10	565 - 580	25.6 - 26.3	68 - 83	2459 - 2782	2522 - 2783	3	2	2	Low
G69.11	490	22.2	62 - 77	2509 - 2672	2575 - 2671	0	0	0	No
G69.12	3080 - 3635	12.6 - 14.8	79 - 84	215 - 314	209 - 238	0	0	0	No
G69.13	11500	32.6	80	369 - 391	336 - 367	0	0	0	No

Table 3-2. Test Conditions for JOG Gate Valves (*6 Pages*)

JOG Test Matrix No.	Flow Rate (gpm or labeled)	Flow Rate (ft/s) *(based on nominal valve size)*	Fluid Temperature (°F)	Close DP (psig)	Open DP (psig)	Number of DP Strokes: Prior to Baseline Test (2 years)	Number of DP Strokes: Between Baseline and Second Tests	Number of DP Strokes: Between Second and Third Tests	DP Stroking Class[21]
G69.14	2520 - 2730	4.0 - 4.3	84 - 92	73 - 80	73 - 75	2	2	2	Low
G75.01	3300 - 3500	21.1 - 22.3	74 - 87	199 - 251	195 - 207	0	0	0	No
G75.02	3200 - 3250	20.4 - 20.7	78 - 85	190 - 220	164 - 191	4	4	0	Low
G75.03	570 - 580	14.6 - 14.8	80 - 90	1509 - 1577	1501 - 1551	0	0	0	No
G75.06	1450 - 1480	16.5 - 16.8	70 - 75	1532 - 1596	1530 - 1599	2	5	0	Low
G75.07	125 - 127	1.4	77 - 100	70 - 168	161 - 174	0	2	0	Low
G75.08	1899 - 2463	5.4 - 7.0	97 - 107	159 - 185	156 - 182	0	0	0	No
G75.09	480 - 485	21.8 - 22.0	77	2562 - 2723	2585 - 2701	0	0	0	No
G75.10	2499 - 2556	4.0 - 4.1	87 - 91	71 - 79	69 - 78	2	2	2	Low
G75.11	5400 - 6000	11.3 - 12.5	104 - 108	120 - 140	116 - 126	0	0	0	No
G79.02	200	0.6	182 - 193	301 - 331	296 - 342	0	2	1	Low
G83.01	145 - 148	6.6 - 6.7	83 - 87	1215 - 2664	2620 - 2666	0	1	2	Low
G83.02	450 - 470	11.5 - 12.0	79 - 80	2442 - 2688	2458 - 2567	1	1	1	Low
G83.03	600	15.3	84 - 85	1583 - 1664	1561 - 1641	0	0	0	No
G85.01	580 - 590	14.8 -15.1	76 - 80	1553 - 1641	1534 - 1554	0	0	0	No
G88.01	1990 - 2100	12.7 - 13.4	55 - 72	57 - 71	58 - 60	1	8	4	Low
G88.03	4000	11.3	62 - 67	40 - 56	39 - 53	9	10	10	High
G89.01	1212 - 1380	7.7 - 8.8	51 - 75	93 - 115	86	18	10	11	High
G89.02	479 - 480	12.2 - 12.3	72-85	192 - 230	305 - 344	16	16	8	High
G89.03	1560 - 1780	4.4 - 5.0	58 - 73	127 - 136	129 - 135	4	4	4	Low
G91.05	850 - 882	9.6 - 10.0	65 - 83	91 - 193	84 - 114	0	0	6	No
G91.06	3000	3.8	95 - 225	366 - 378	359 - 363	1	0	0	No
G92.01	8200 - 8300	10.3 - 10.5	77 - 84	318 - 324	318 - 323	60	35	24	High
G92.02	9000	11.3	85 - 90	352 - 363	343 - 355	0	4	NA[22]	Low
G92.03	200	9.1	68 - 74	1315 - 1379	1225 - 1315	5	10	10	High
G96.01	6000	24.5	56 - 64	342 - 389	330 - 375	0	0	0	No
G96.02	6000	24.5	56 - 64	340 - 409	335 - 380	0	0	0	No

Table 3-2. Test Conditions for JOG Gate Valves (*6 Pages*)

JOG Test Matrix No.	Flow Rate (gpm or labeled)	Flow Rate (ft/s) *(based on nominal valve size)*	Fluid Temperature (°F)	Close DP (psig)	Open DP (psig)	Number of DP Strokes			DP Stroking Class[21]
						Prior to Baseline Test (2 years)	Between Baseline and Second Tests	Between Second and Third Tests	
G98.01	15400 - 15478	24.6 - 24.7	70 - 85	247 - 250	NA	12	14	14	High
G99.01	500	22.7	70 - 80	289 - 297	300 - 316	24	24	17	High
G99.02	500	22.7	70 - 77	290 - 300	303 - 317	24	24	12	High
G99.03	2285 - 2505	25.9 - 28.4	128 - 137	561 - 580	555 - 578	0	0	0	No
G99.04	1800 - 2400	20.4 - 27.2	80 - 139	574 - 604	566 - 610	0	3	2	Low
G99.05	2622 - 2625	29.8	87 - 135	573 - 583	563 - 587	0	0	NA[22]	No
G99.06	4100	46.5	77 - 80	126 - 134	117 - 127	0	0	0	No
G99.07	500	3.2	50	75 - 108	75 - 76	0	0	0	No

Table 3-3. Anchor/Darling Double Disk Gate Valves Evaluated for Hard Seating

JOG Test Matrix No.[23]	Size (inches)	Pressure Class (lbs)	Fluid	Disk Orientation[24]	Average DP at Initial Wedging (psi)
G54.01	3	1500	treated/closed loop water	LWD	1507
G54.02	6	150	treated/closed loop water		82
G54.03	3	1500	reactor coolant water	LWD	2587
G54.04	4	900	reactor coolant water	LWD	1543
G56.01	4	1500	reactor coolant water	LWD	2266
G56.02	6	150	treated/closed loop water		78
G56.03	4	1500	reactor coolant water	LWD	2328
G57.01	6	300	treated/closed loop water	LWD	234
G58.01	4	300	treated/closed loop water	LWU	117
G58.02	8	150	untreated water	LWD	98
G59.01	4	900	feedwater	LWU	1404
G59.02	6	300	reactor coolant water		186
G60.01[25]	10	600	steam	LWD	NA
G60.02	4	900	steam	LWU	877
G60.03	4	600	steam		712
G60.04	10	900	steam	LWD	975
G60.05	4	600	steam		889
G60.06	4	600	steam		763
G98.01	16	300	treated/closed loop water	LWD	248

[23] All valves have Stellite disk and seat faces except G98.01 which has Deloro 50 disk and seat faces.
[24] LWD is lower wedge downstream. LWU is lower wedge upstream. Orientation is not known for G54.02, G56.02, G59.02, G60.03, G60.05 and G60.06.
[25] G60.01 is limit switch controlled for its closing stroke and does not hard seat. Accordingly, no data from this valve is used.

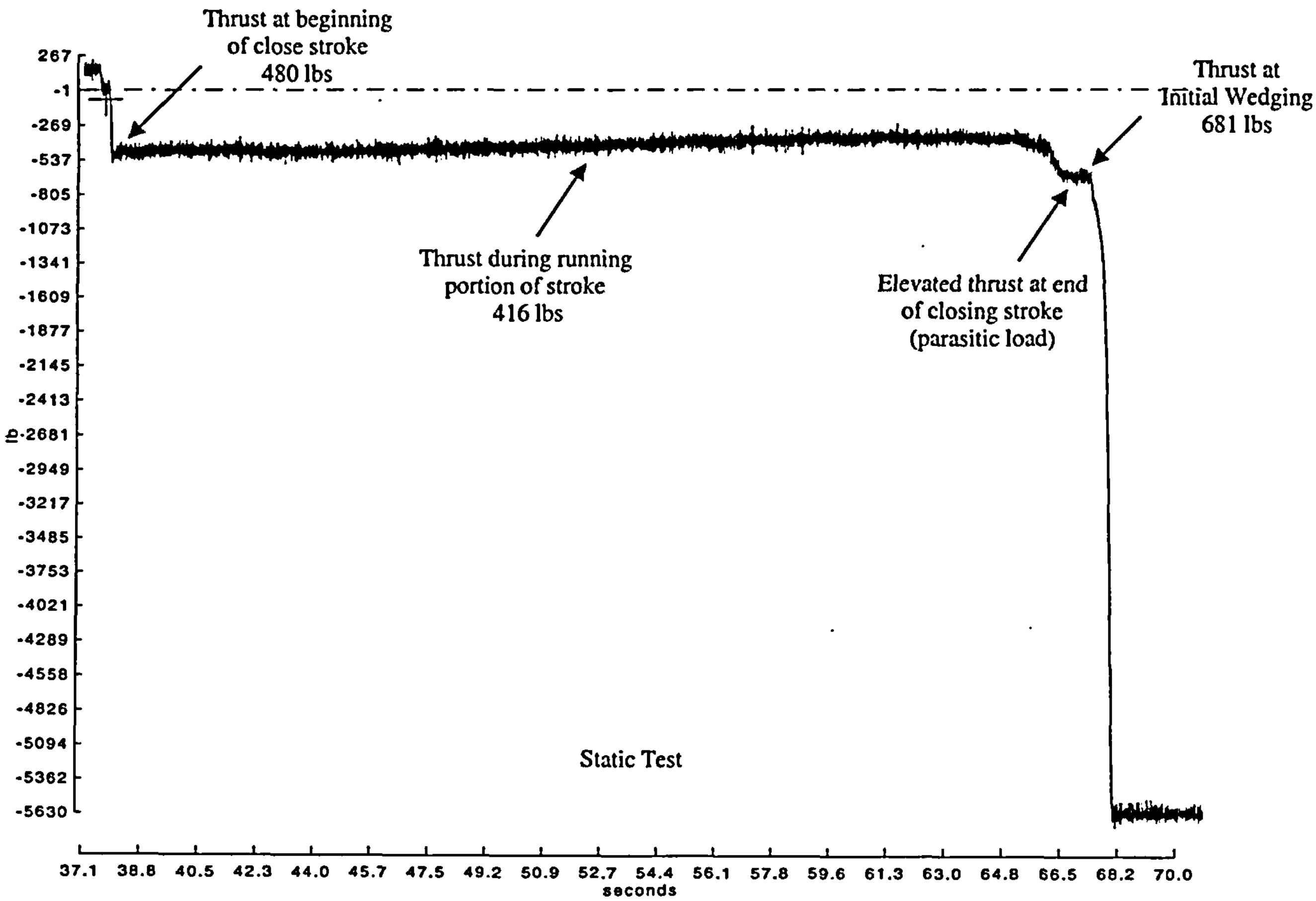
Table 3-4. Aloyco Split Wedge Gate Valves Evaluated for Hard Seating

JOG Test Matrix No.[26]	Size (inches)	Pressure Class (lbs)	Fluid	Disk Orientation[27]	Average DP at Initial Wedging (psi)
G63.01	6	150	treated/closed loop water	MDU	162
G63.02	6	300	reactor coolant water		270
G63.03	8	300	reactor coolant water	MDU	217
G63.04	6	150	reactor coolant water	MDD	185
G63.05	6	300	reactor coolant water		168
G63.06	6	300	reactor coolant water		140
G65.01	8	150	treated/closed loop water		112
G65.02	8	300	reactor coolant water	MDU	207

[26] All valves have Stellite disk and seat faces.
[27] MDD is male disk downstream. MDU is male disk upstream. Orientation is not known for G63.02, G63.05, G63.06 and G65.01.

Table 3-5. DP Strokes Performed Between Valve Disassembly/Reassembly and JOG Baseline Test

JOG Test Matrix No.	Date of JOG Baseline Test	Date of Valve Disassembly	No. of DP Strokes Between Valve Disassembly/Reassembly & JOG Baseline Test
G06.02	12/99	12/99	0
G20.01	10/97	10/97	0
G22.03	10/98	10/98	0
G22.07	11/99	10/99	1
G22.08	4/95	3/95	3
G22.12	5/98	4/98	0
G22.14	5/98	4/98	0
G22.19	5/97	4/97	0
G22.20	5/97	4/97	0
G22.22	11/97	4/96	6
G27.05	9/98	4/98	2
G27.08	11/97	10/97	2
G27.10	1/97	1/97	0
G32.01	1/98	10/97	0
G32.02	10/97	10/97	0
G32.04	12/98	11/98	0
G44.05	5/98	4/98	0
G44.06	11/98	11/98	0
G44.09	10/97	9/25/97	0
G44.10	10/97	10/97	0
G44.11	11/99	4/9/98	0
G44.12	4/98	4/9/98	0
G44.13	3/97	3/97	0
G44.14	3/97	3/97	0
G49.01	3/97	3/97	2
G59.01	4/98	3/98	0
G60.01	7/99	5/99	1
G60.02	11/95	93	24
G60.05	4/94	6/93	0
G69.02	4/99	6/97	4
G69.03	11/98	11/98	0
G69.13	2/97	2/97	0
G75.02	4/99	12/97	4
G75.09	5/99	5/99	0
G83.03	11/97	11/97	0
G85.01	3/95	2/95	0
G91.06	1/98	12/97	0
G92.01	8/98	96	60
G92.02	4/01	4/01	0
G99.05	5/00	4/00	0



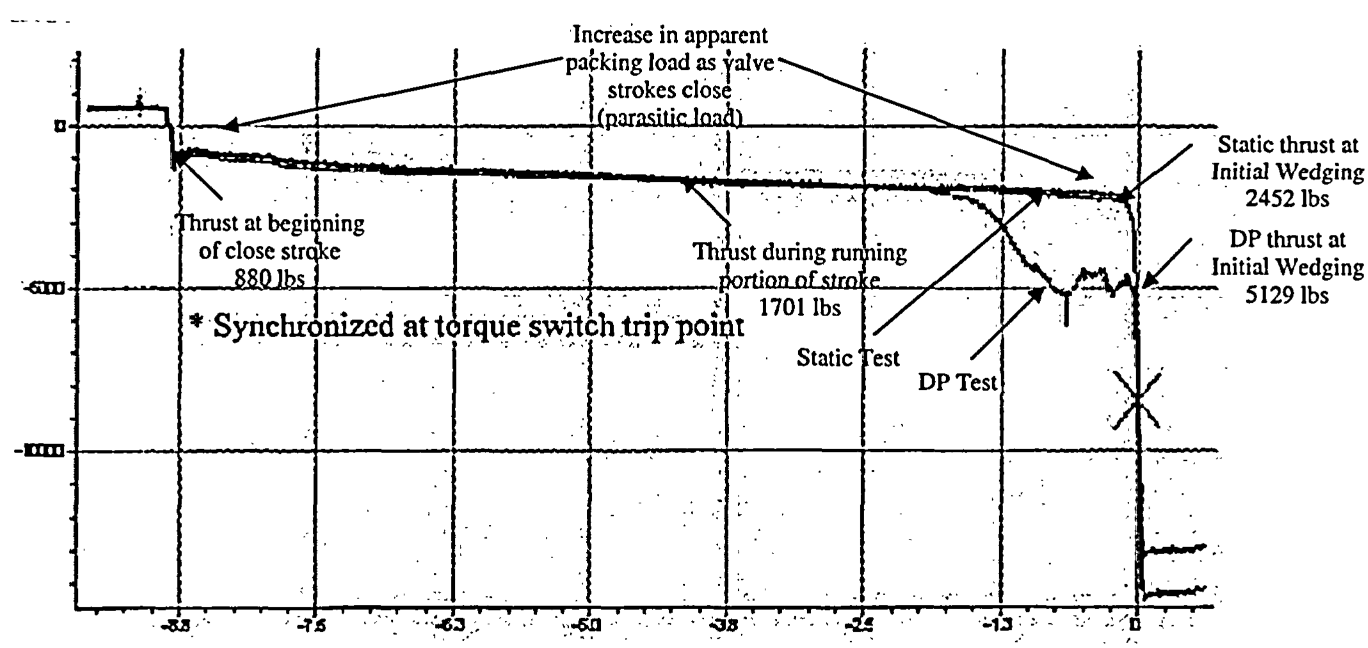
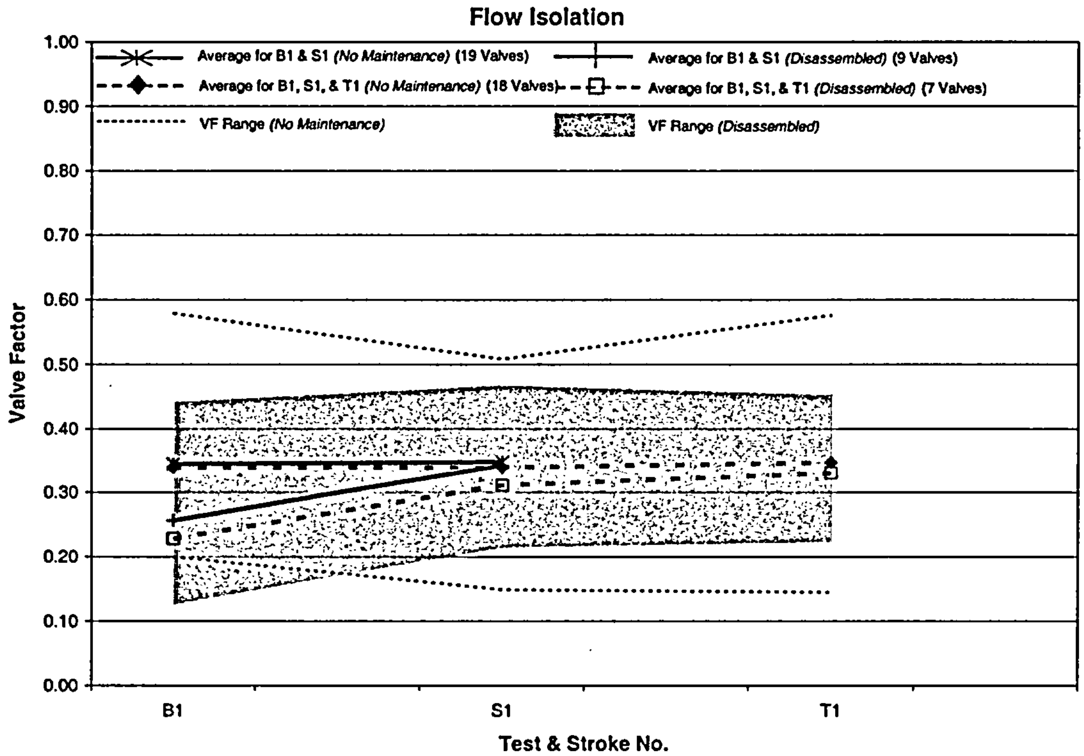


Figure 3-1. Examples of Parasitic Load Behavior in Gate Valves



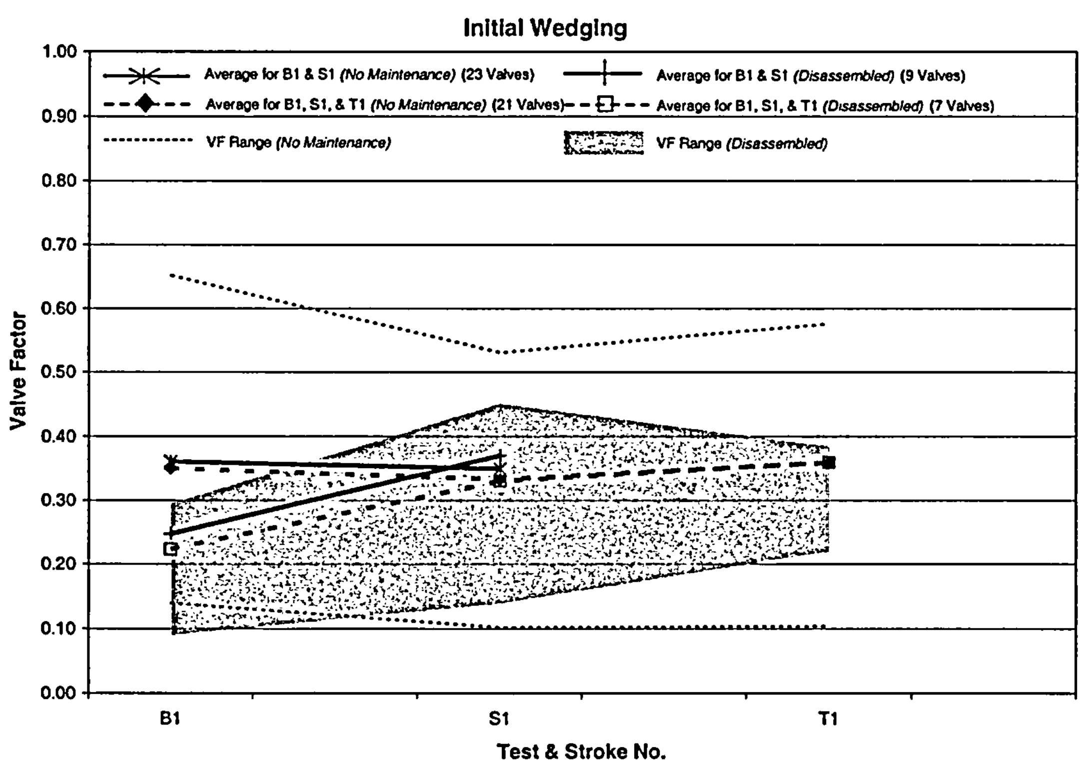
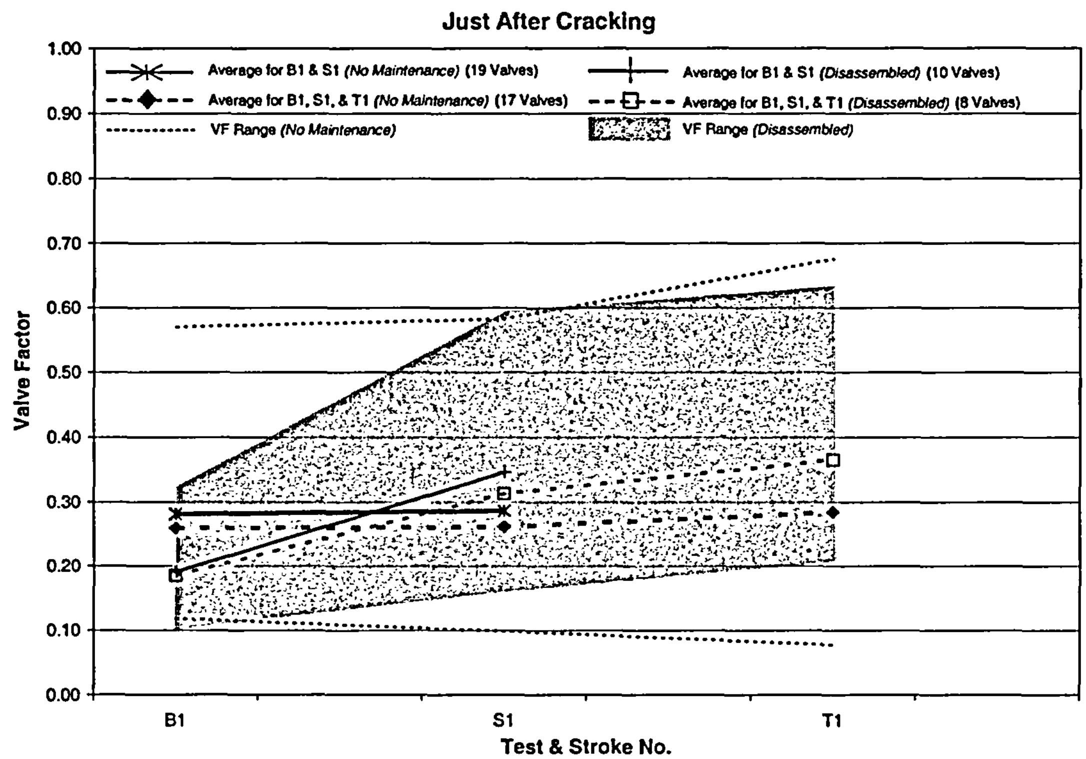


Figure 3-2. Close Valve Factors for Gate Valves with Stellite Seats in Cold Treated Water with No DP Strokes



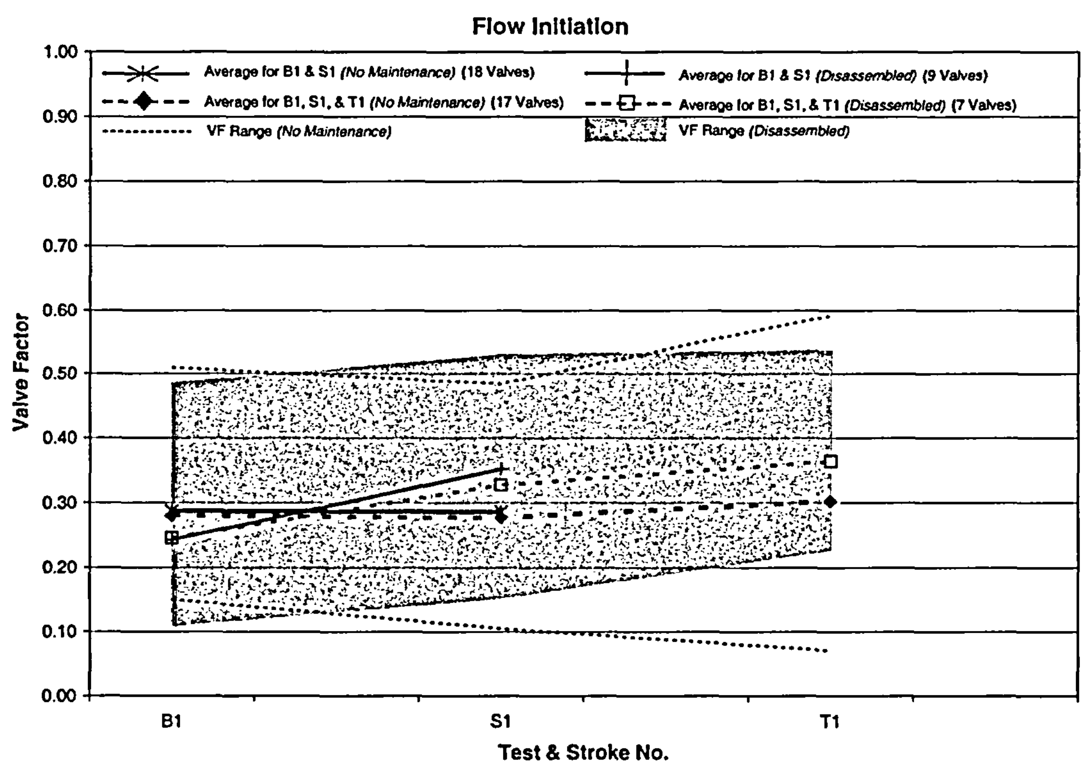


Figure 3-3. Open Valve Factors for Gate Valves with Stellite Seats in Cold Treated Water with No DP Strokes

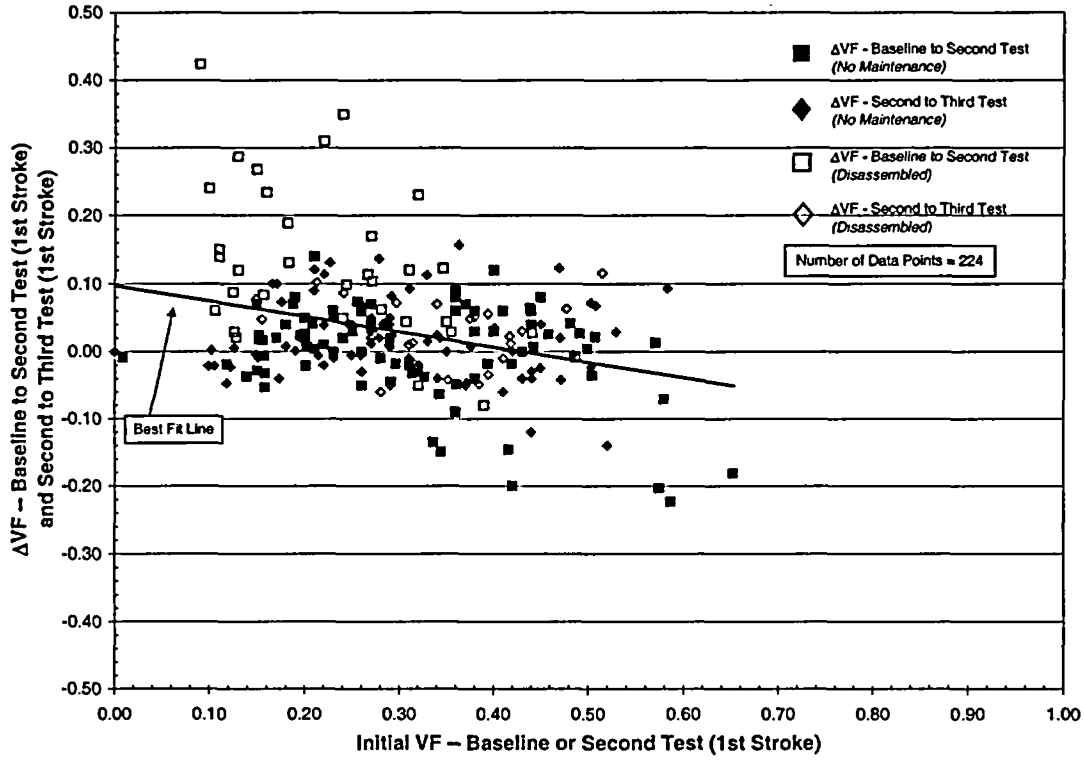
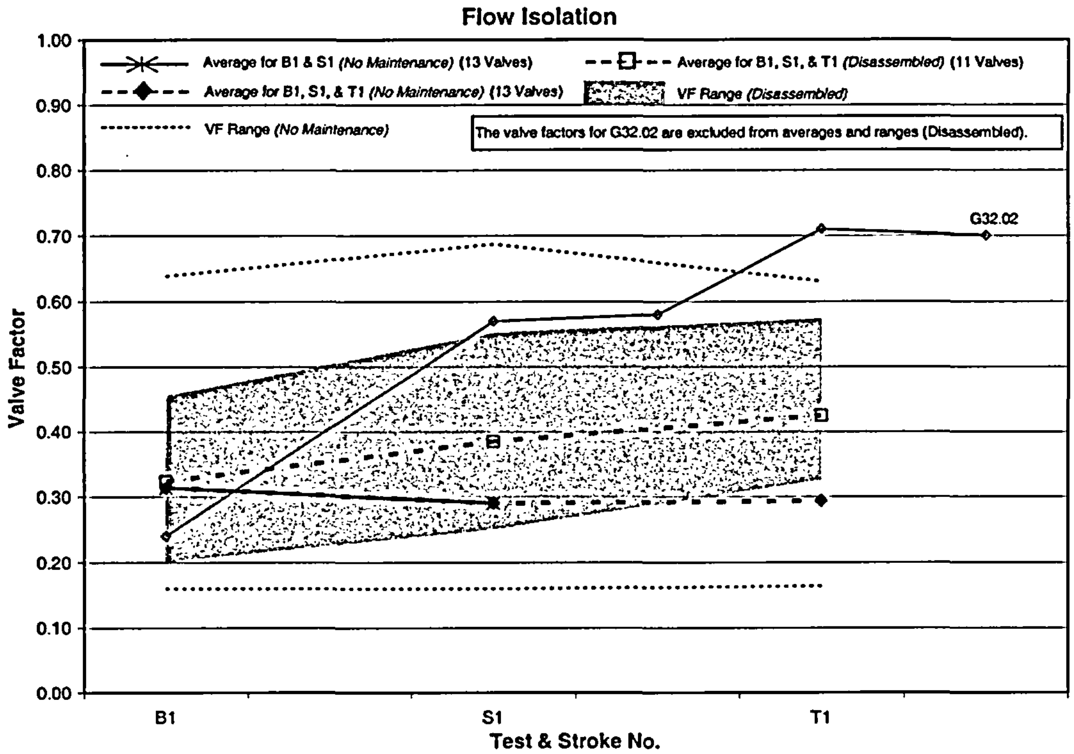


Figure 3-4. Change in Valve Factor vs. Initial Valve Factor for Gate Valves with Stellite Seats in Cold Treated Water Systems with No DP Strokes



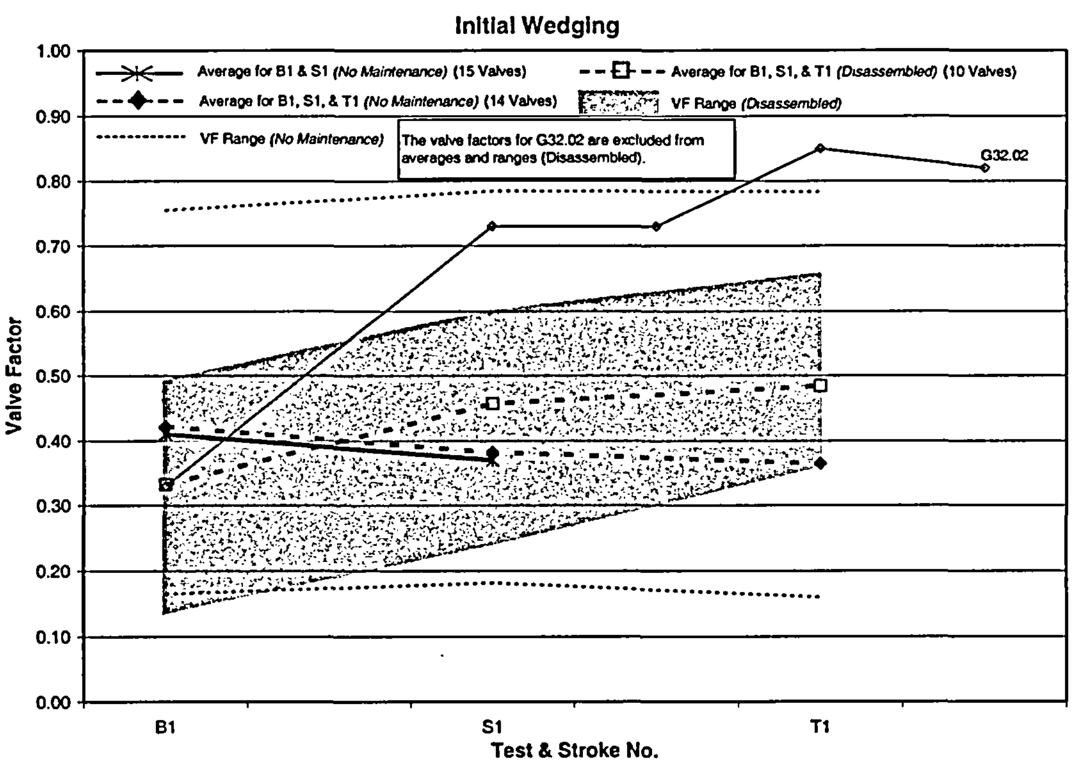


Figure 3-5. Close Valve Factors for Gate Valves with Stellite Seats in Cold Treated Water Systems with Low DP Stroking

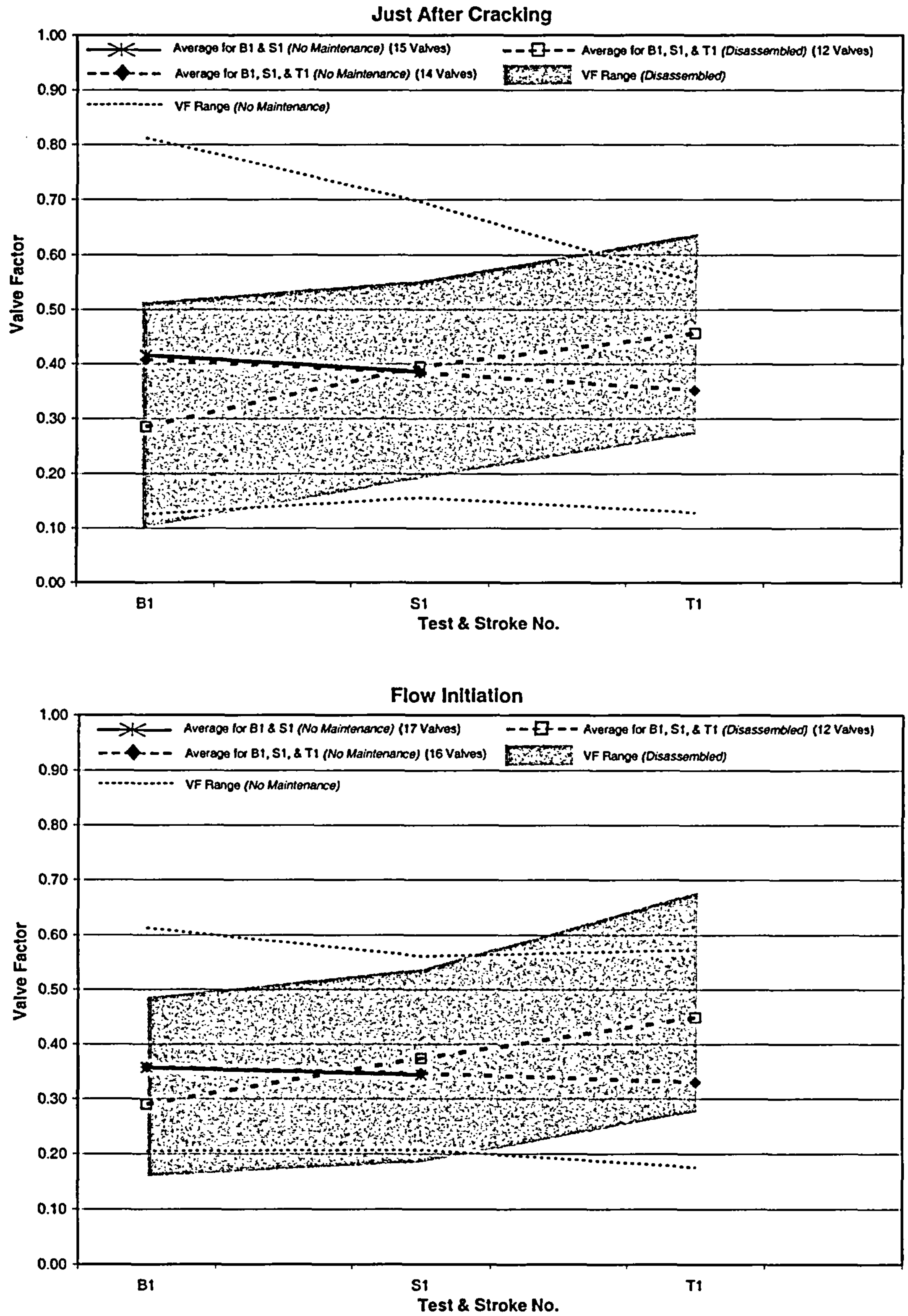


Figure 3-6. Open Valve Factors for Gate Valves with Stellite Seats in Cold Treated Water Systems with Low DP Stroking

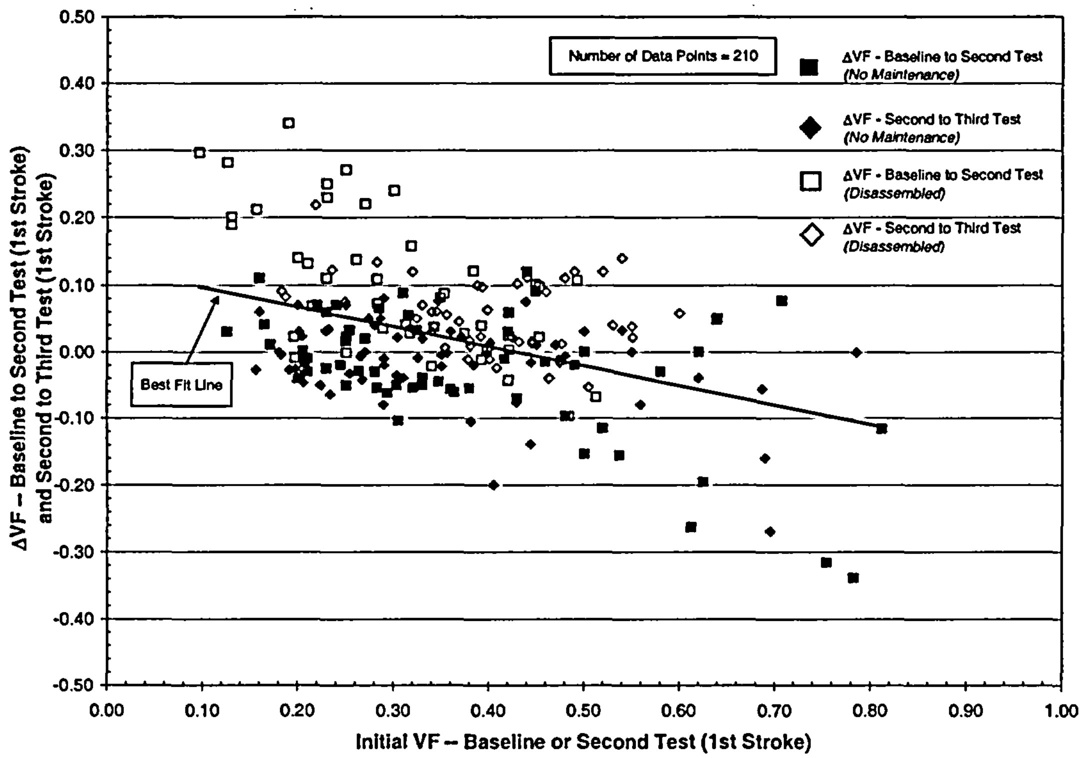


Figure 3-7. Change in Valve Factor vs. Initial Valve Factor for Gate Valves with Stellite Seats in Cold Treated Water Systems with Low DP Stroking

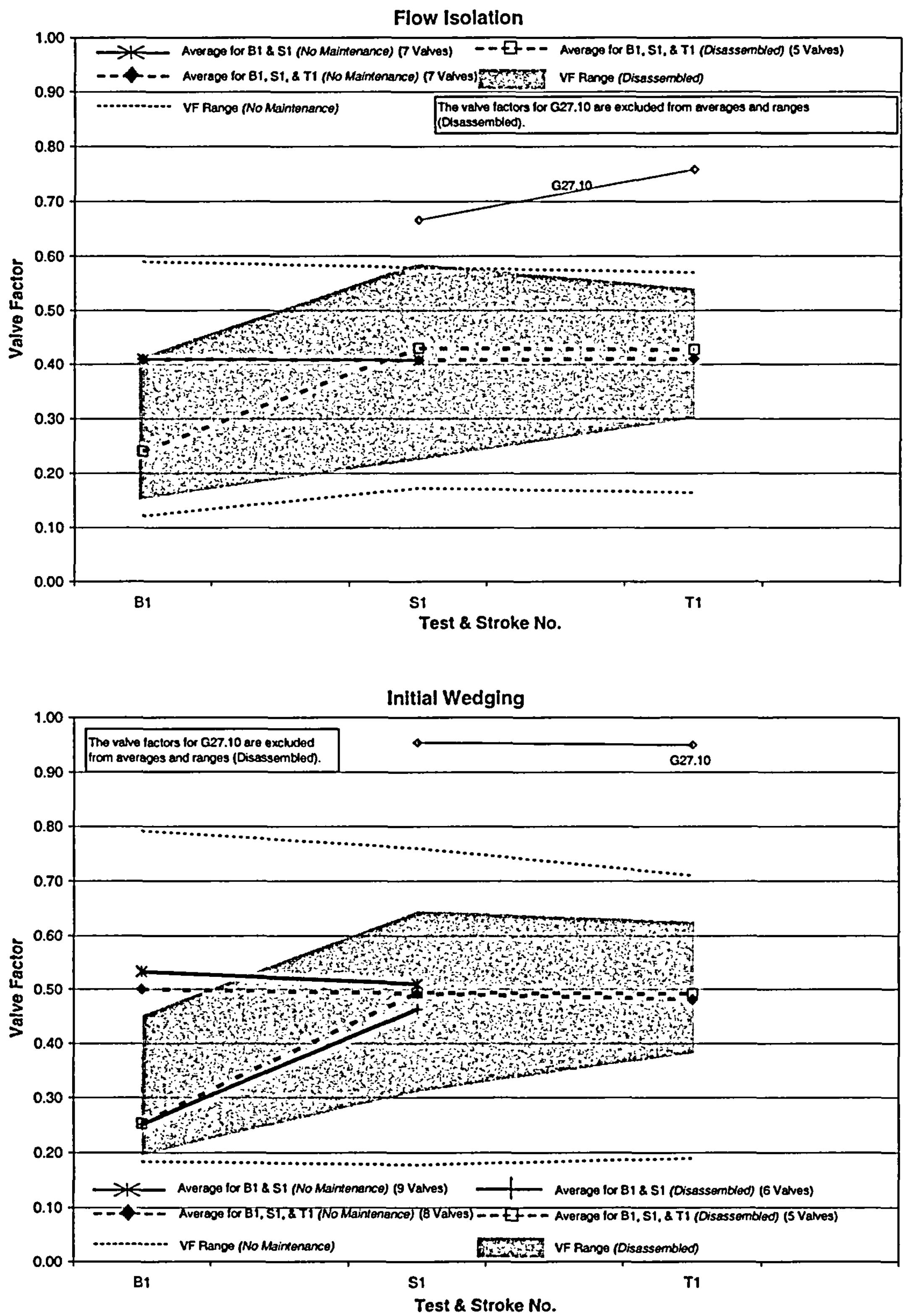
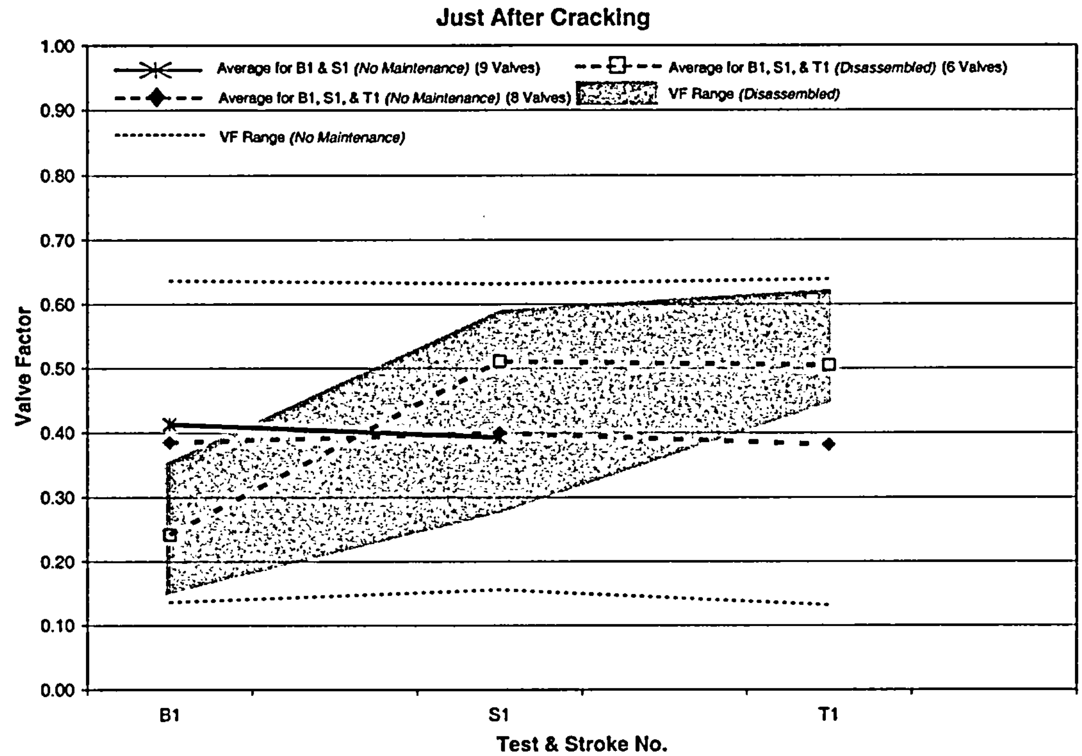


Figure 3-8. Close Valve Factors for Gate Valves with Stellite Seats in Cold Treated Water with High DP Strokes



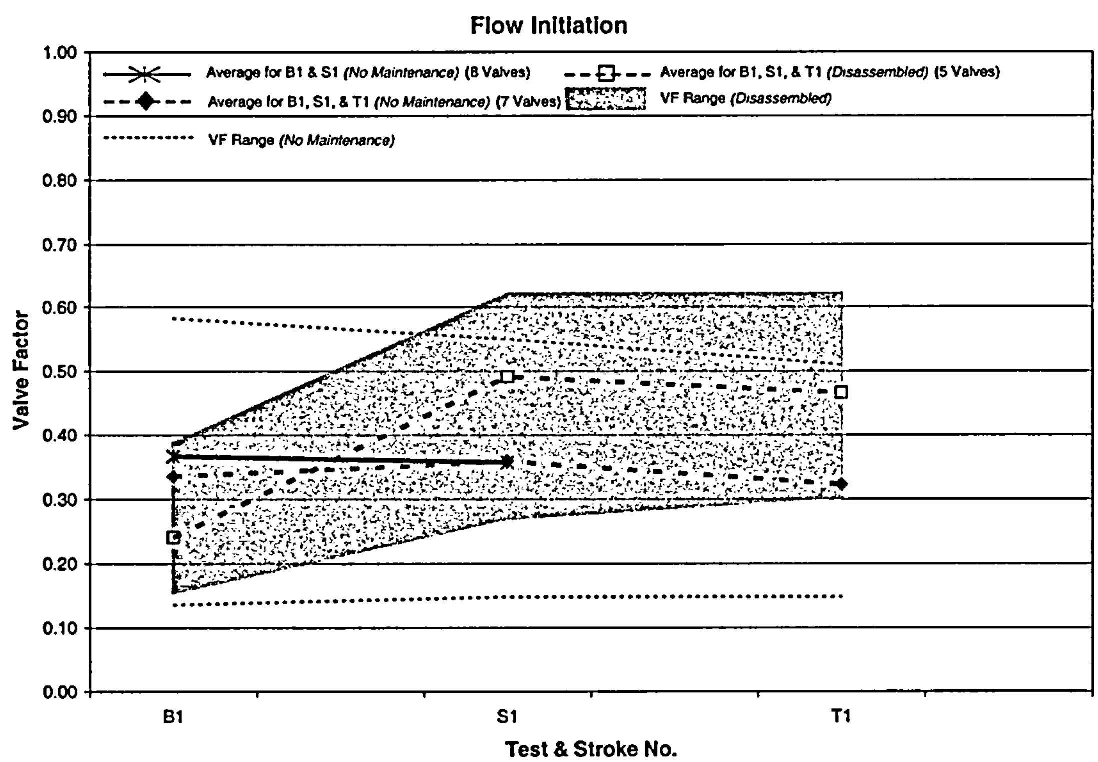


Figure 3-9. Open Valve Factors for Gate Valves with Stellite Seats in Cold Treated Water with High DP Strokes

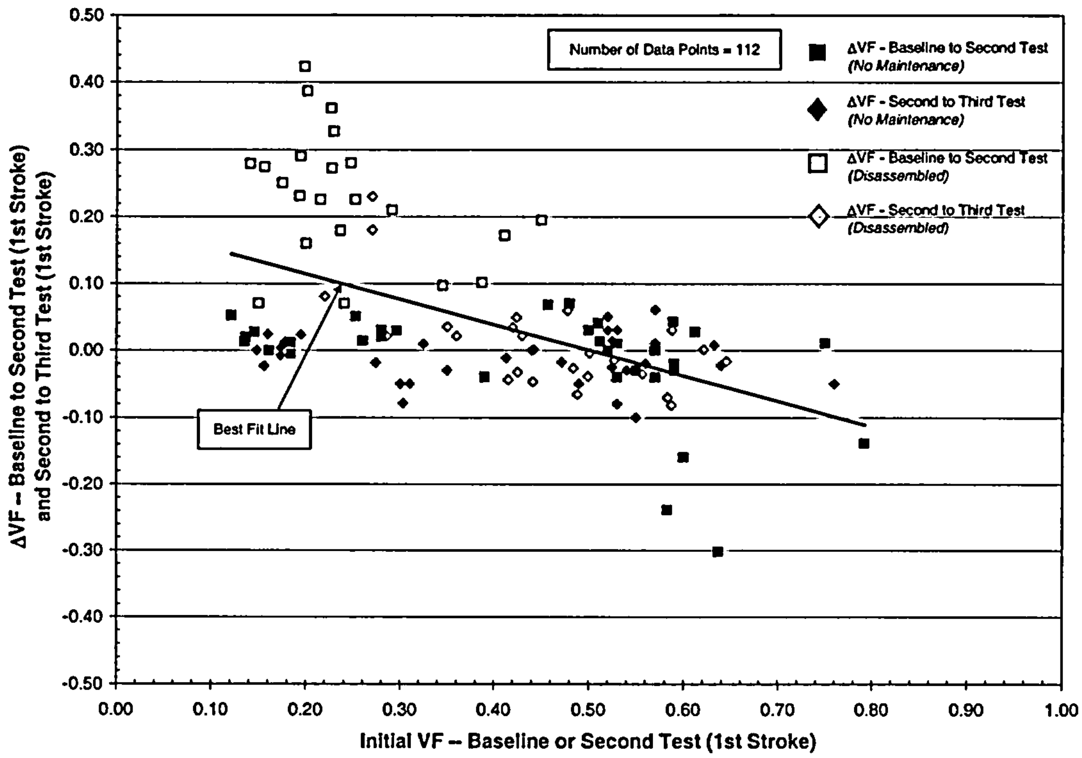
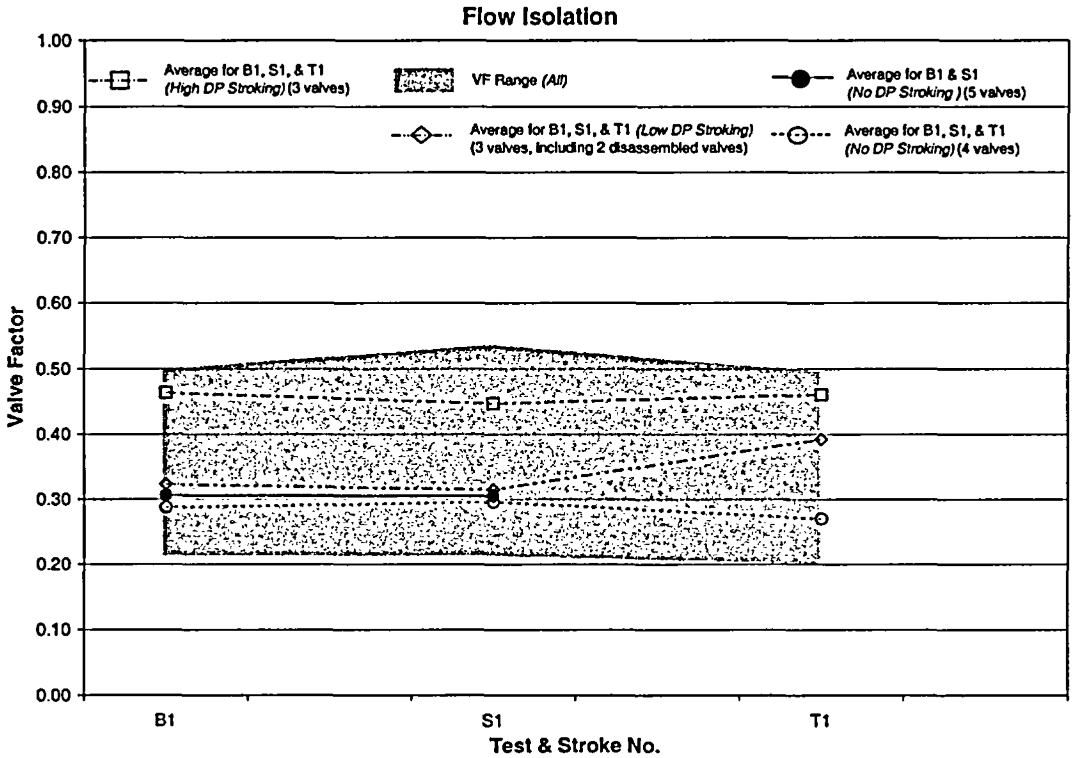


Figure 3-10. Change in Valve Factor vs. Initial Valve Factor for Gate Valves with Stellite Seats in Cold Treated Water with High DP Strokes



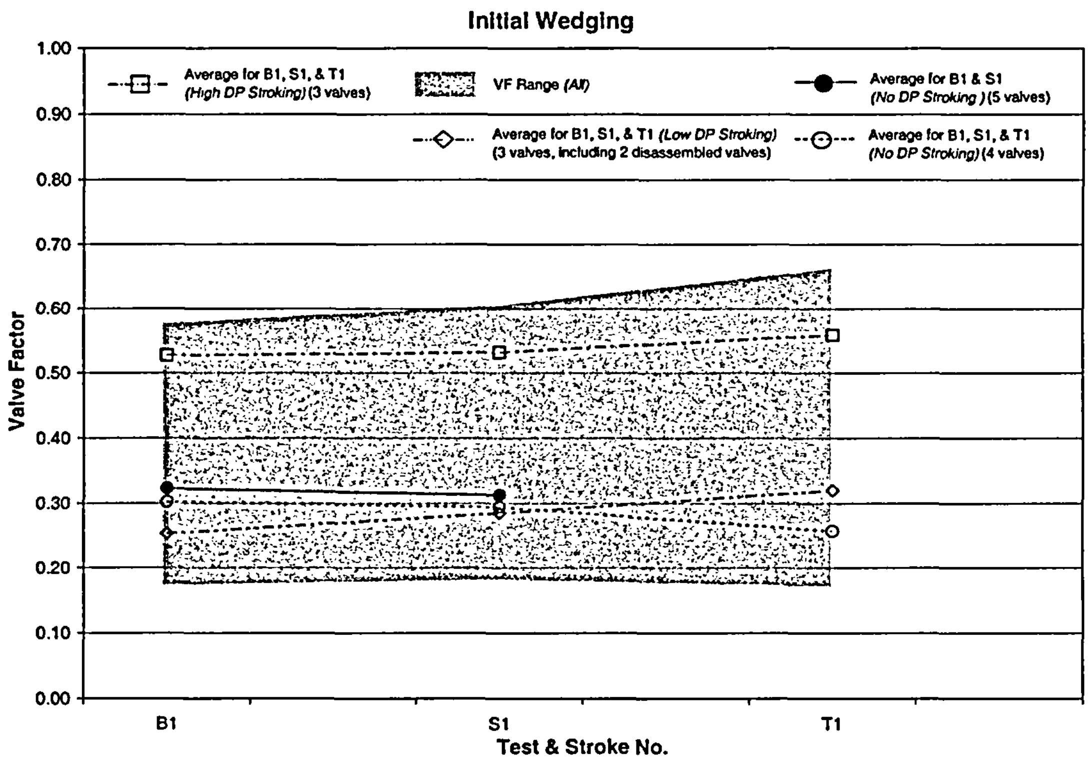
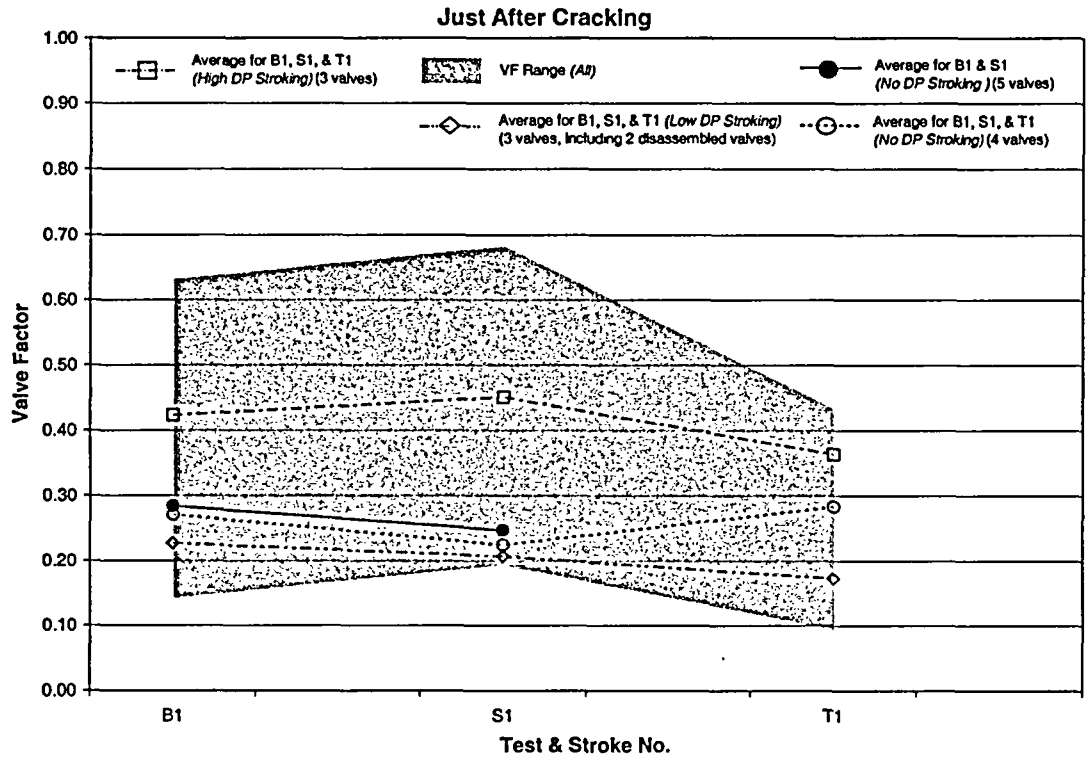


Figure 3-11. Close Average Valve Factors for Gate Valves with Stellite Seats in Cold Untreated Water Systems



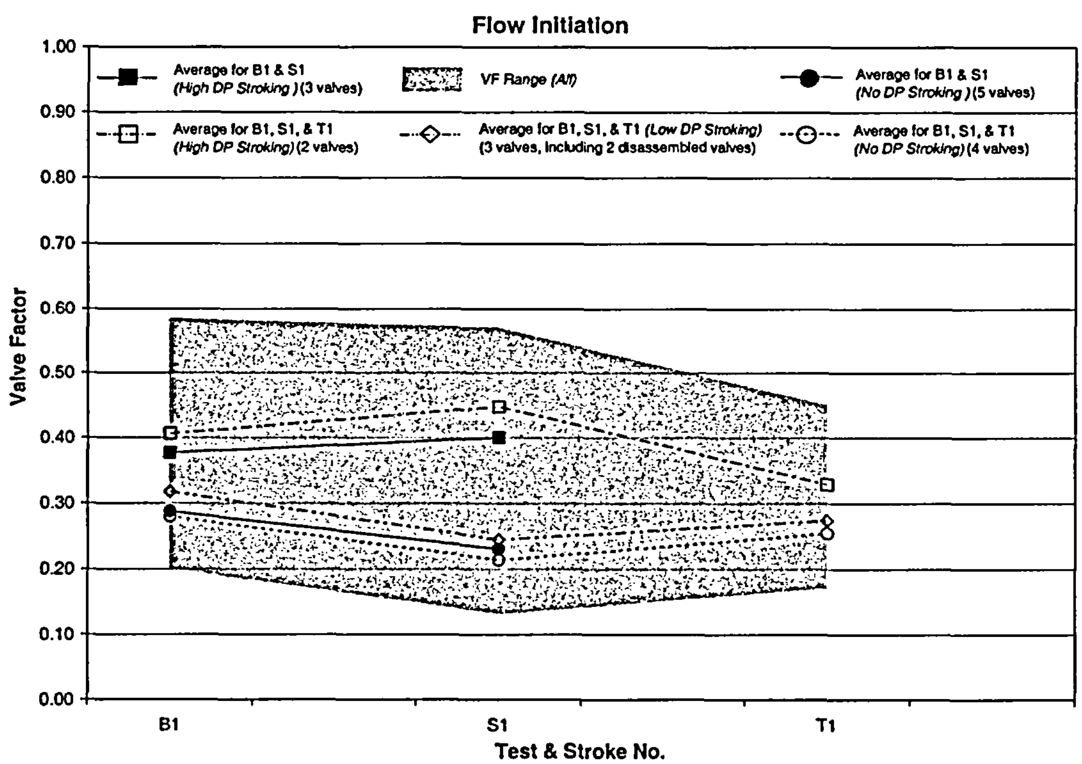


Figure 3-12. Open Average Valve Factors for Gate Valves with Stellite Seats in Cold Untreated Water Systems

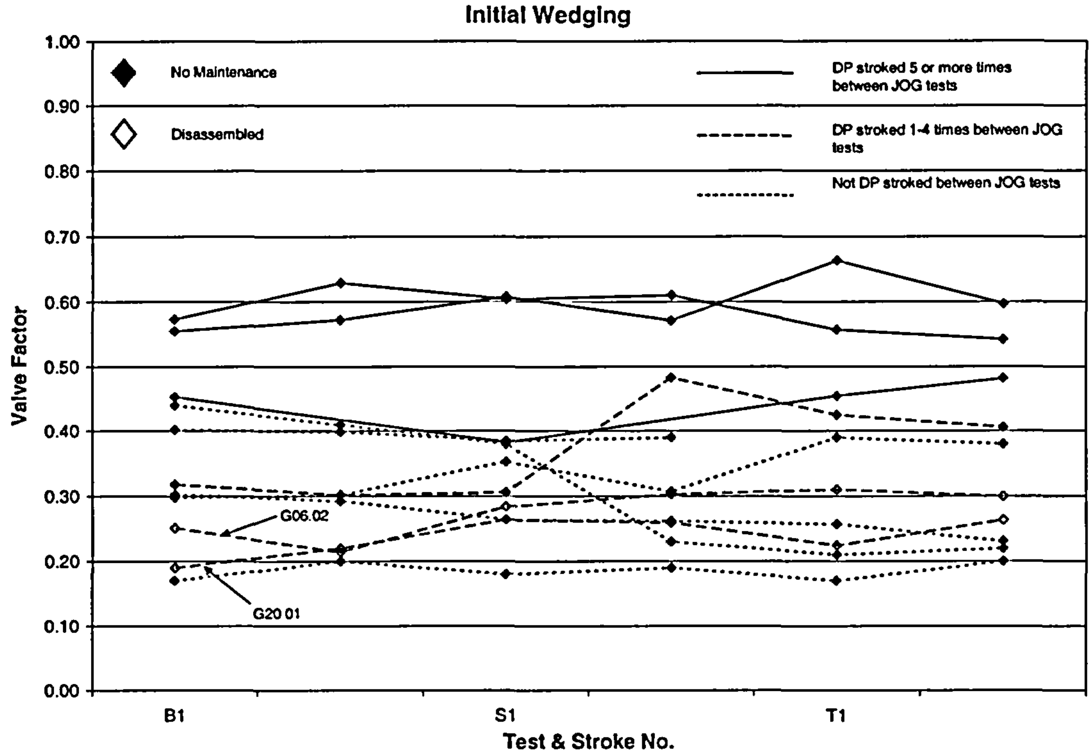


Figure 3-13. Close Valve Factors for Gate Valves with Stellite Seats in Cold Untreated Water Systems

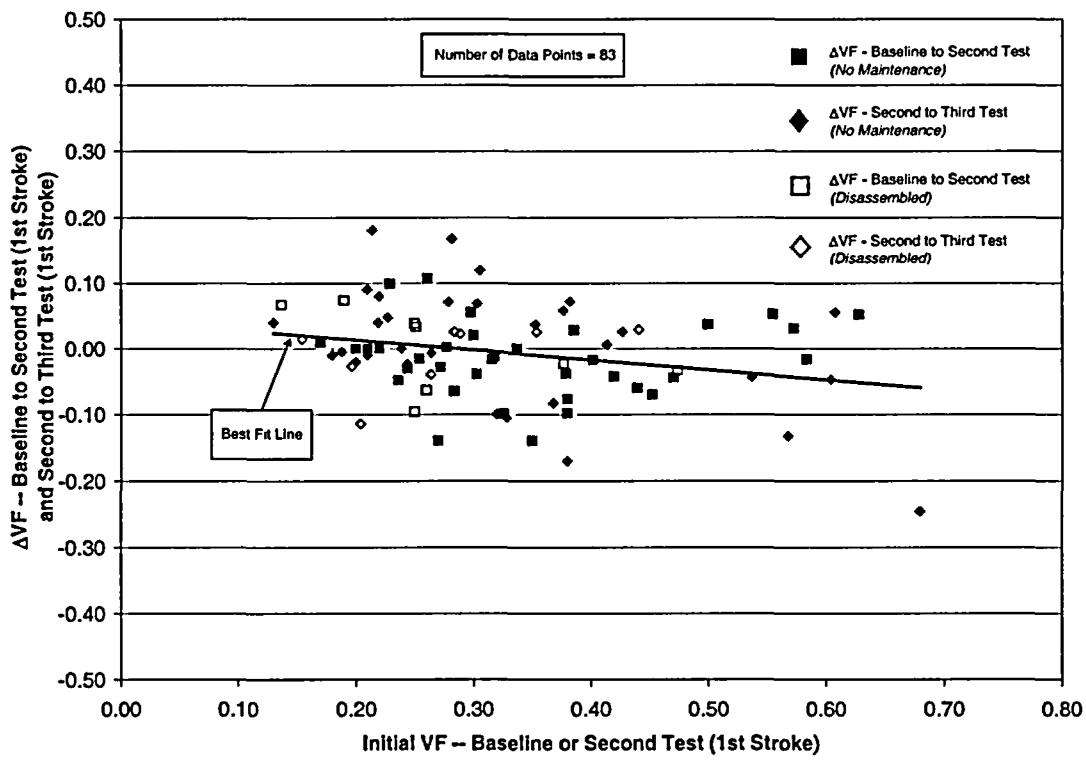
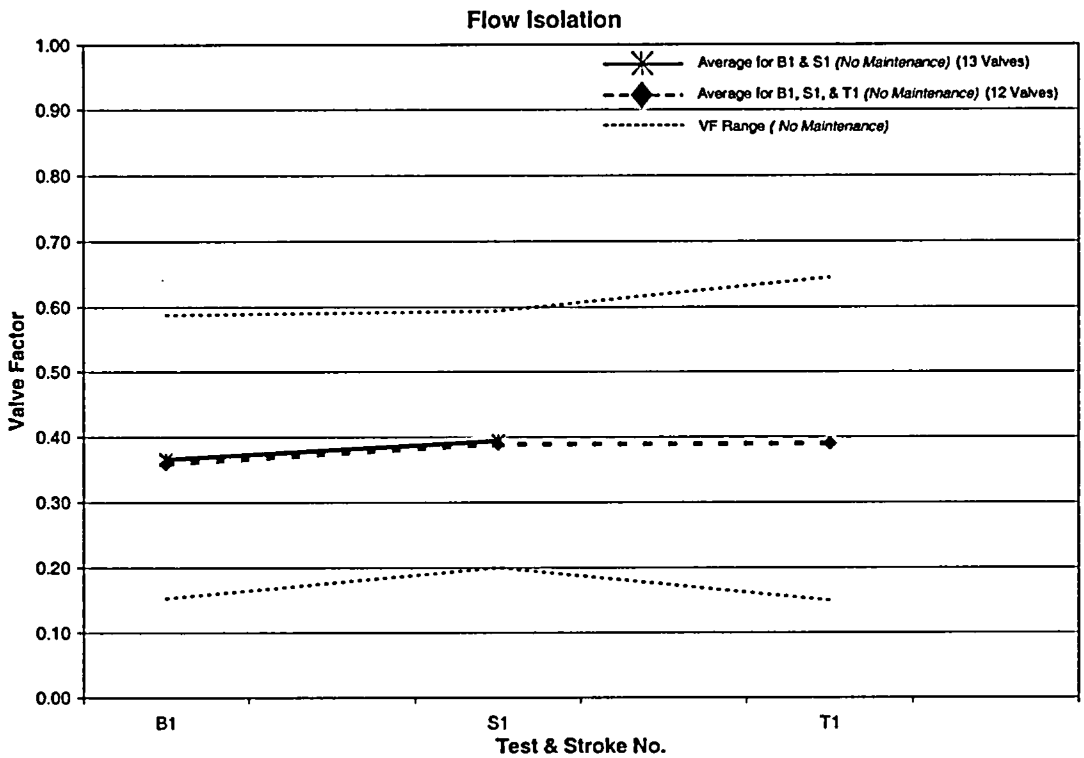


Figure 3-14. Change in Valve Factor vs. Initial Valve Factor for Gate Valves with Stellite Seats in Cold Untreated Water Systems



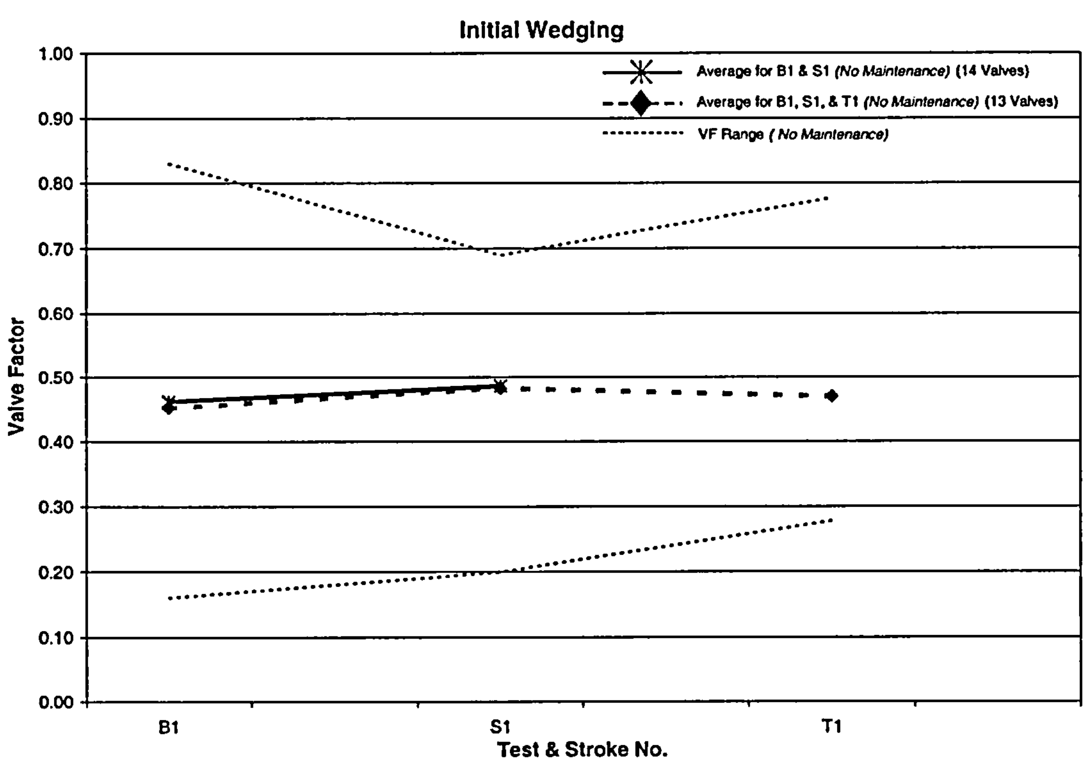
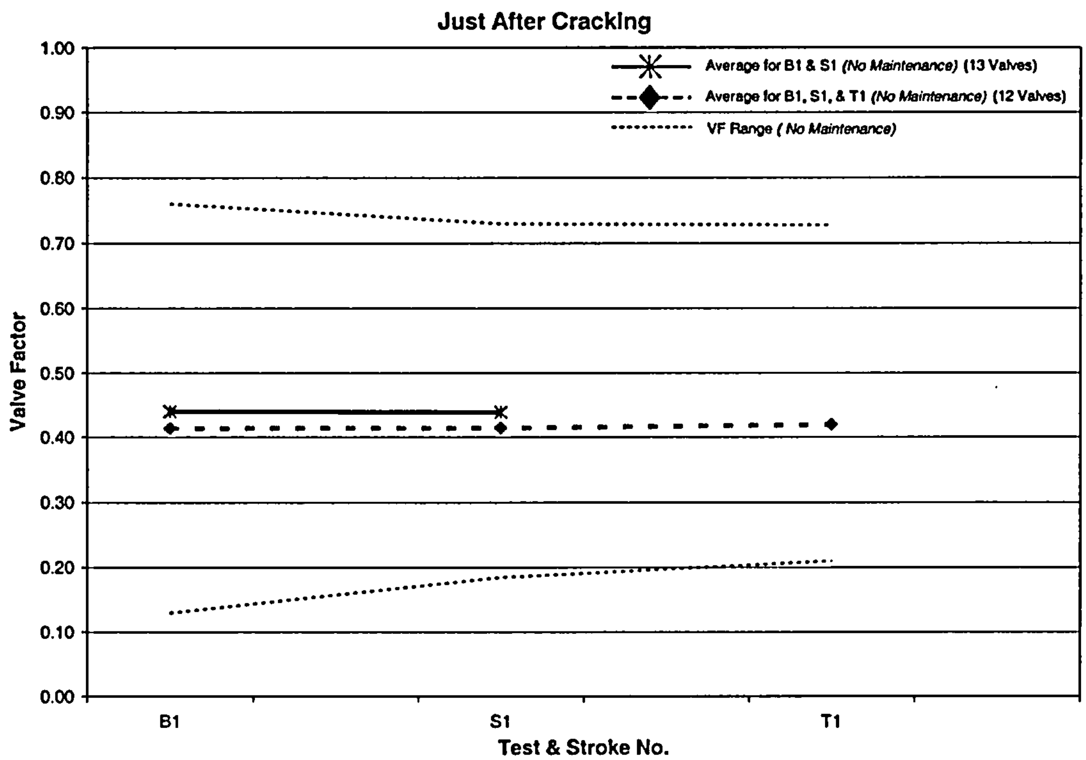


Figure 3-15. Close Valve Factors for Gate Valves with Stellite Seats in Hot Treated Water Systems and Tested in Cold Treated Water (No Maintenance)



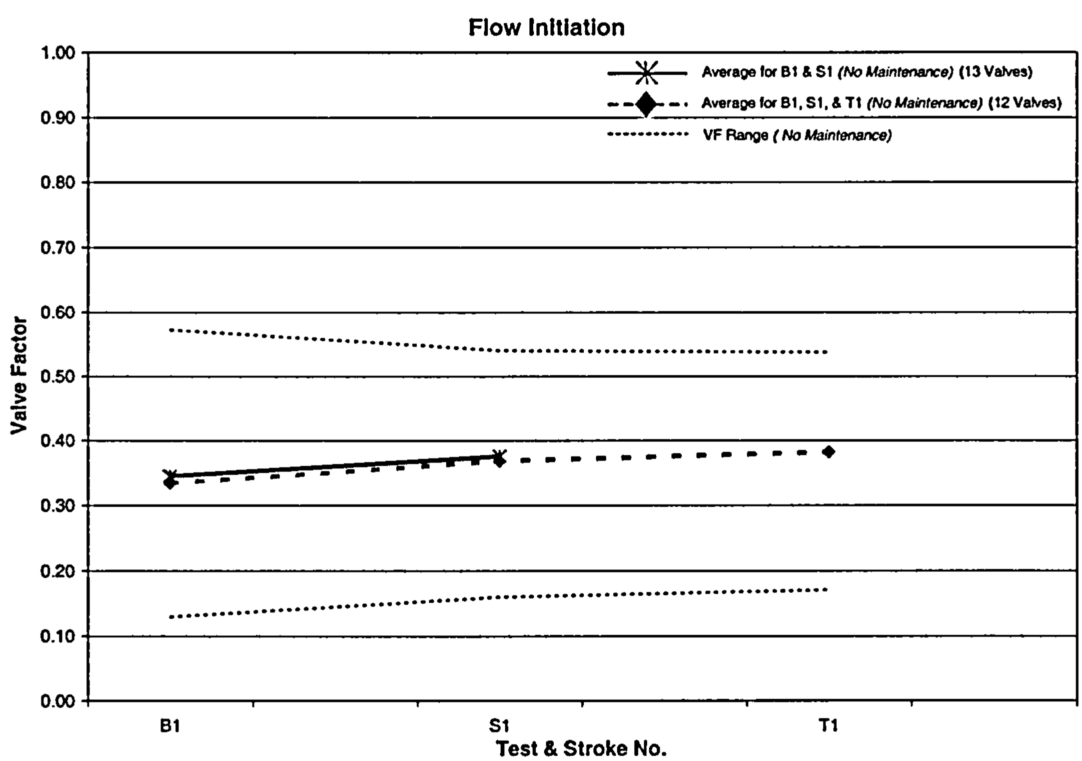


Figure 3-16. Open Valve Factors for Gate Valves with Stellite Seats in Hot Treated Water Systems and Tested in Cold Treated Water (No Maintenance)

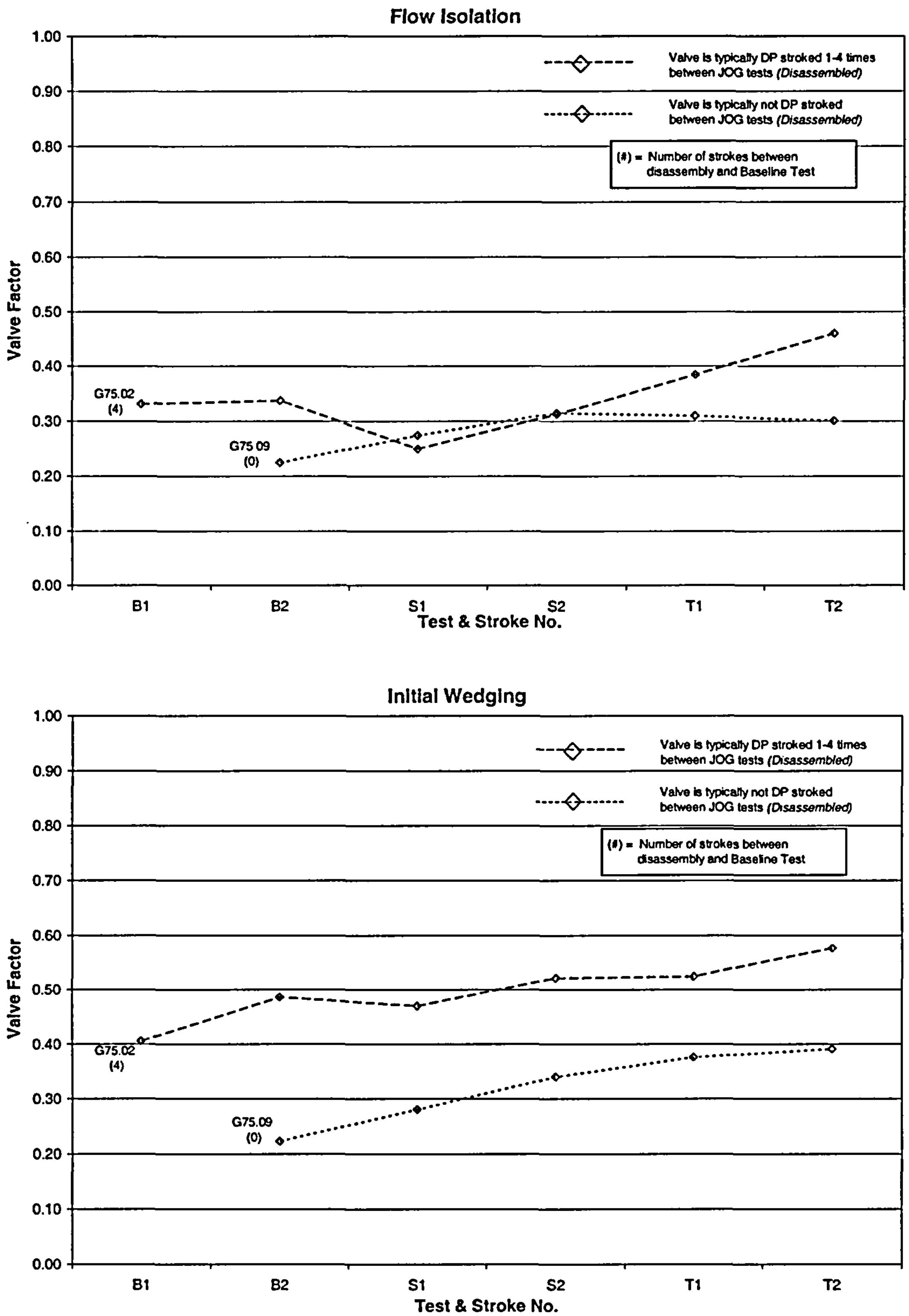
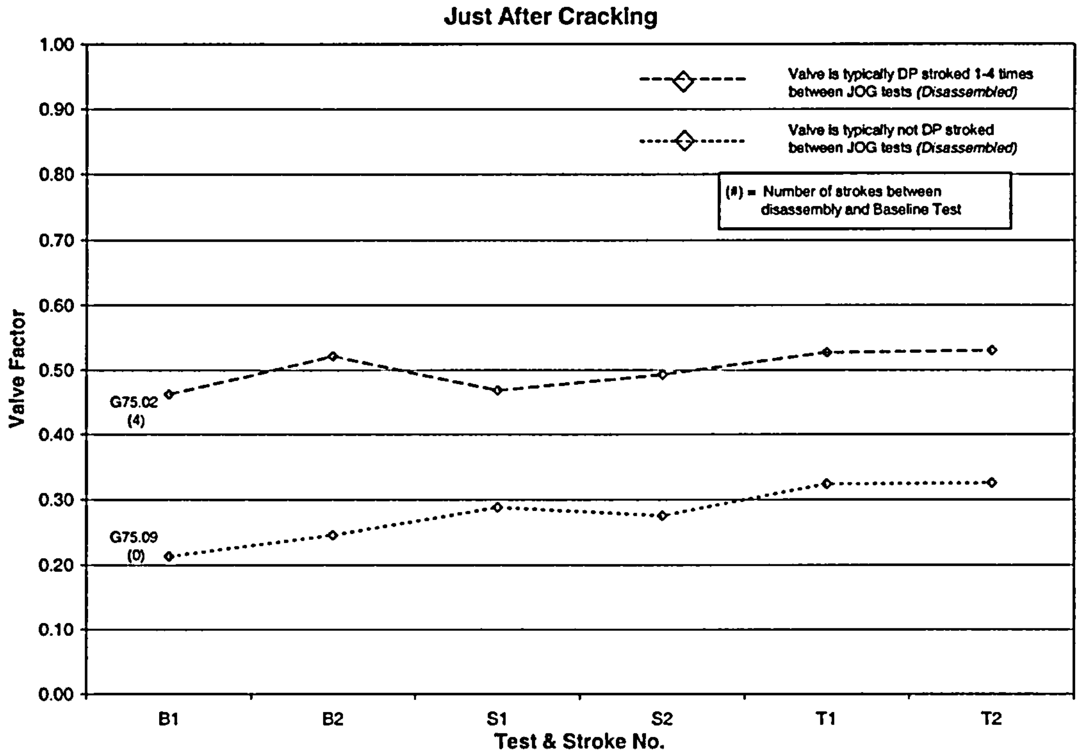


Figure 3-17. Close Valve Factors for Gate Valves with Stellite Seats in Hot Treated Water Systems and Tested in Cold Treated Water (Disassembled)



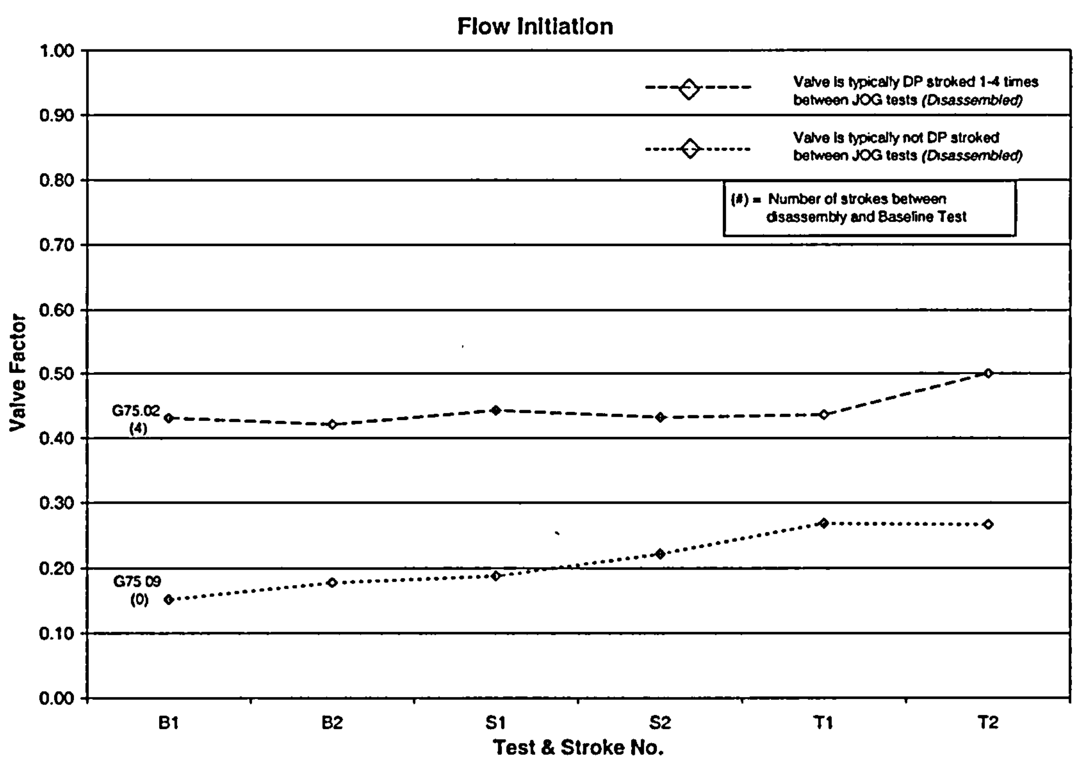


Figure 3-18. Open Valve Factors for Gate Valves with Stellite Seats in Hot Treated Water Systems and Tested in Cold Treated Water (Disassembled)

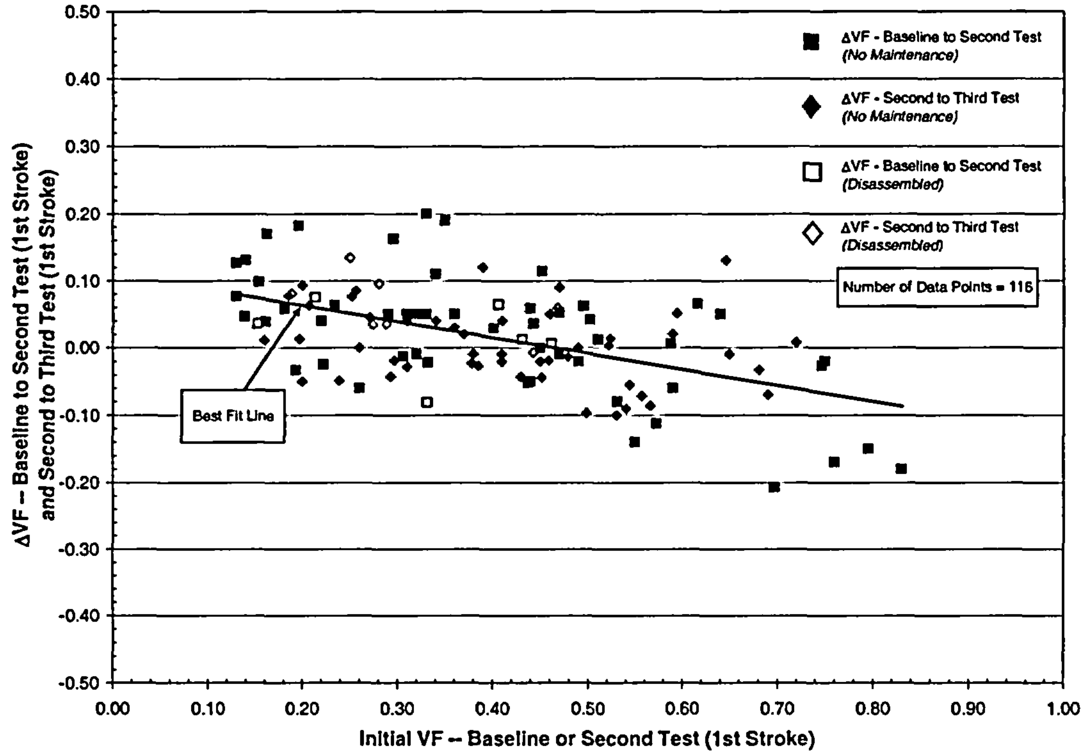


Figure 3-19. Change in Valve Factor vs. Initial Valve Factor for Gate Valves with Stellite Seats in Hot Treated Water Systems and Tested in Cold Treated Water

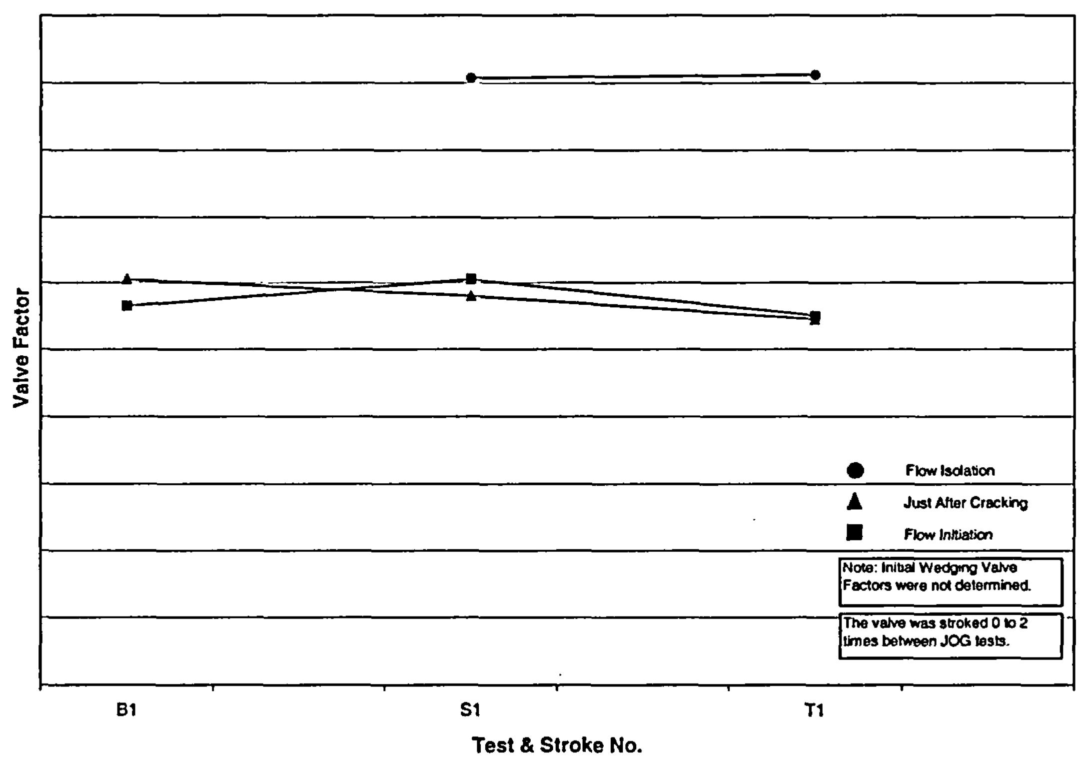


Figure 3-20. Close and Open Valve Factors for G79.02 – Gate Valve with Stellite Seats in Hot (>120°F) Water

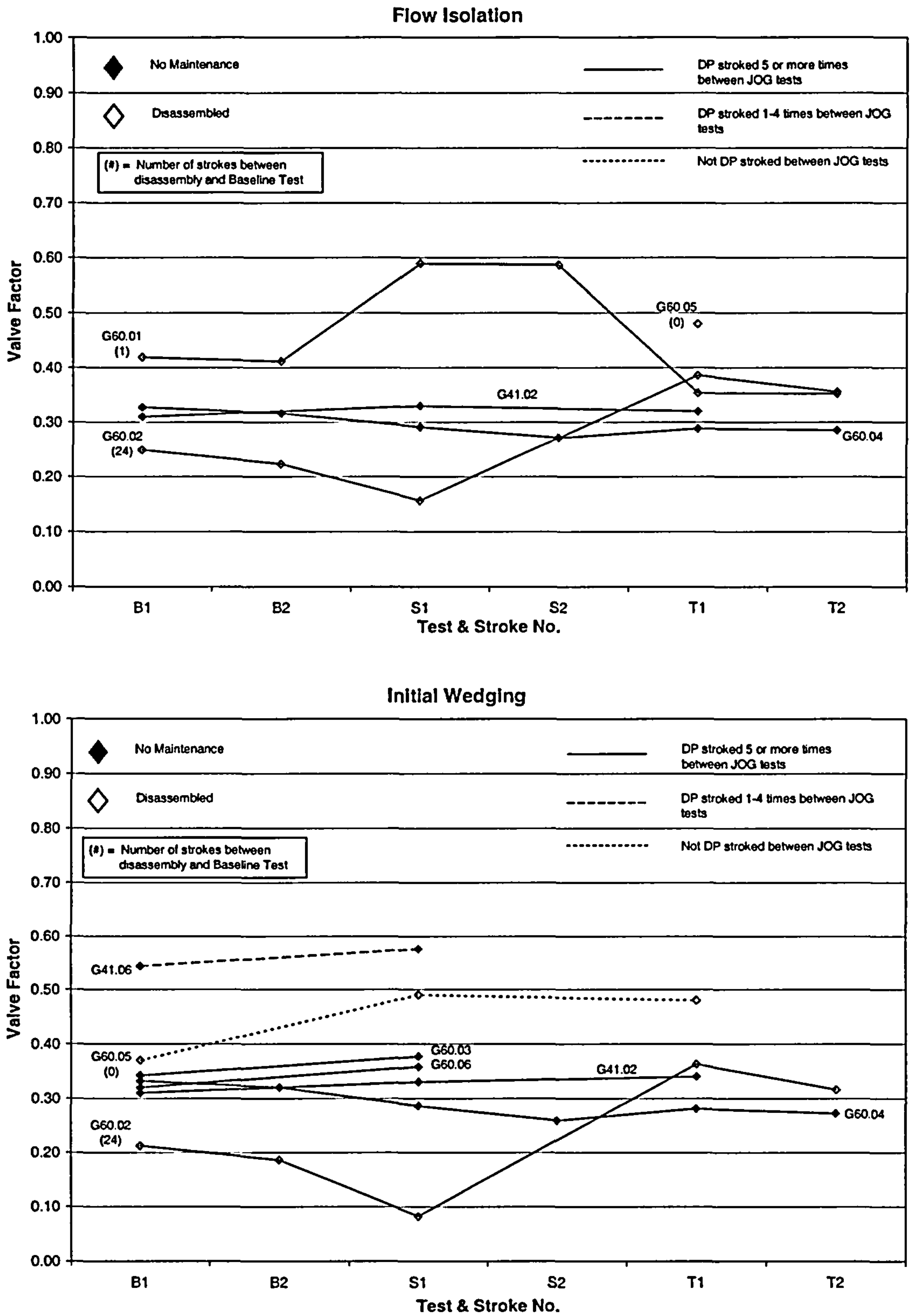


Figure 3-21. Close Valve Factors for Gate Valves with Stellite Seats in Steam

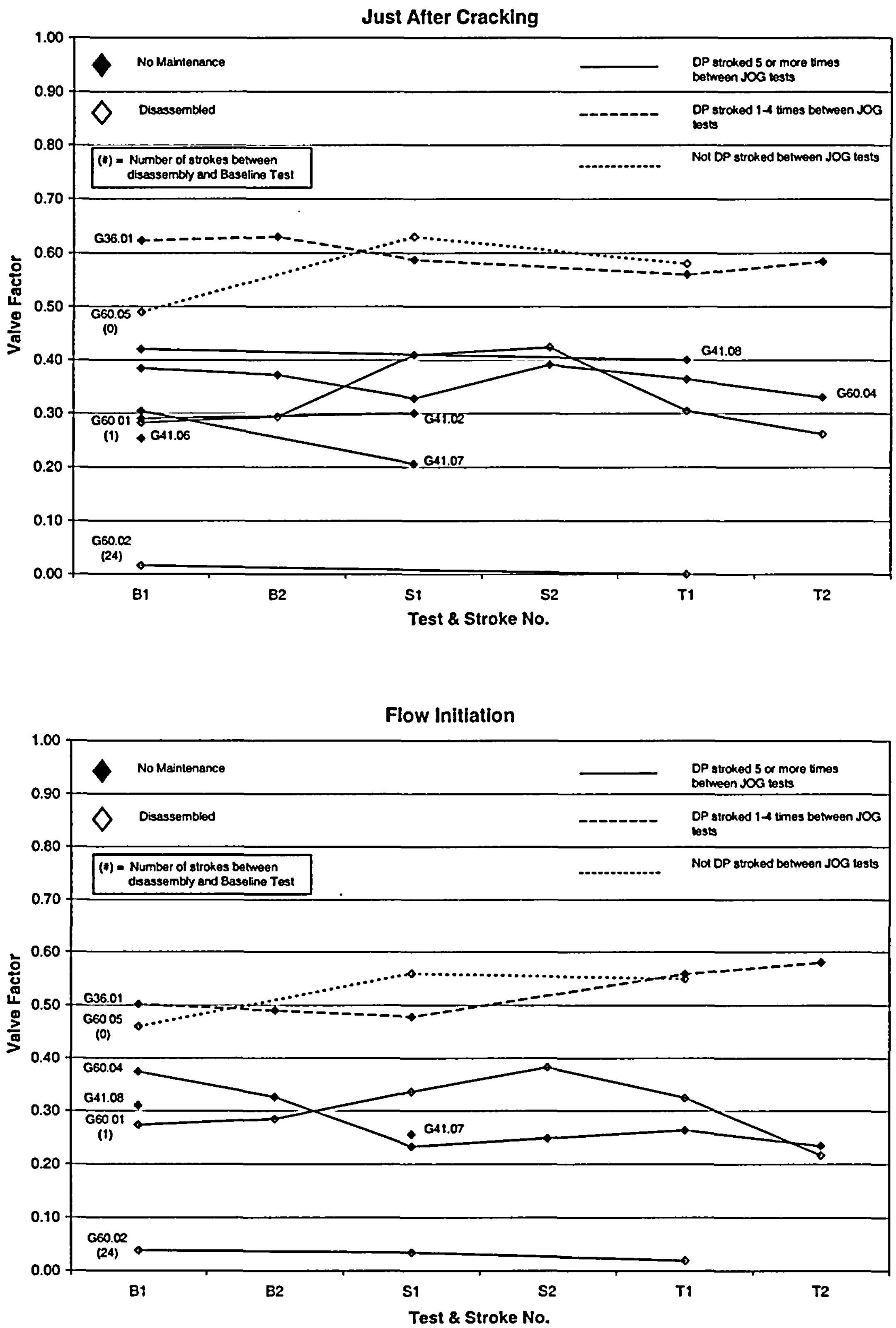
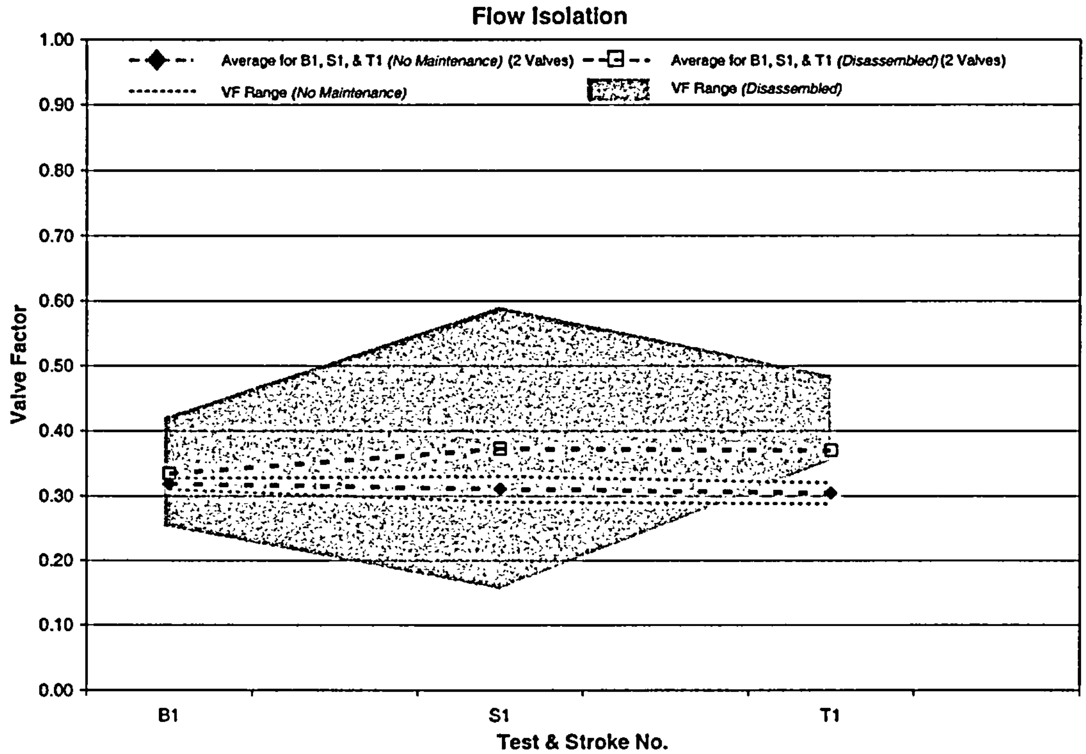


Figure 3-22. Open Valve Factors for Gate Valves with Stellite Seats in Steam



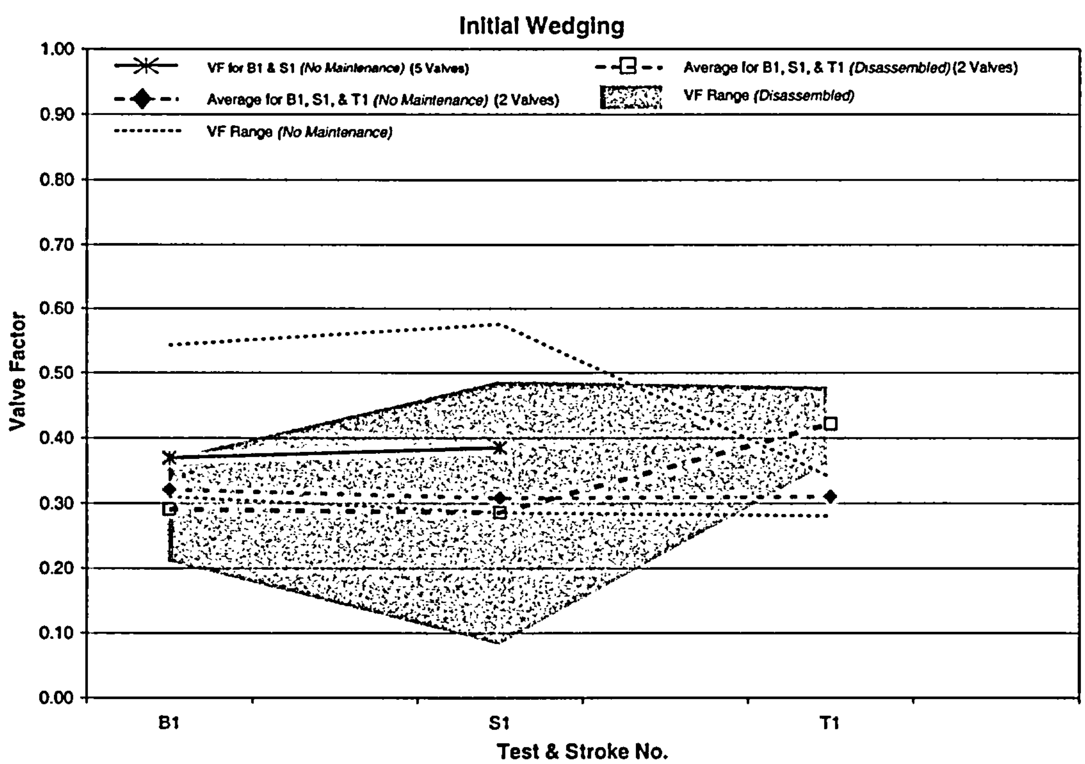


Figure 3-23. Close Average Valve Factors for Gate Valves with Stellite Seats in Steam

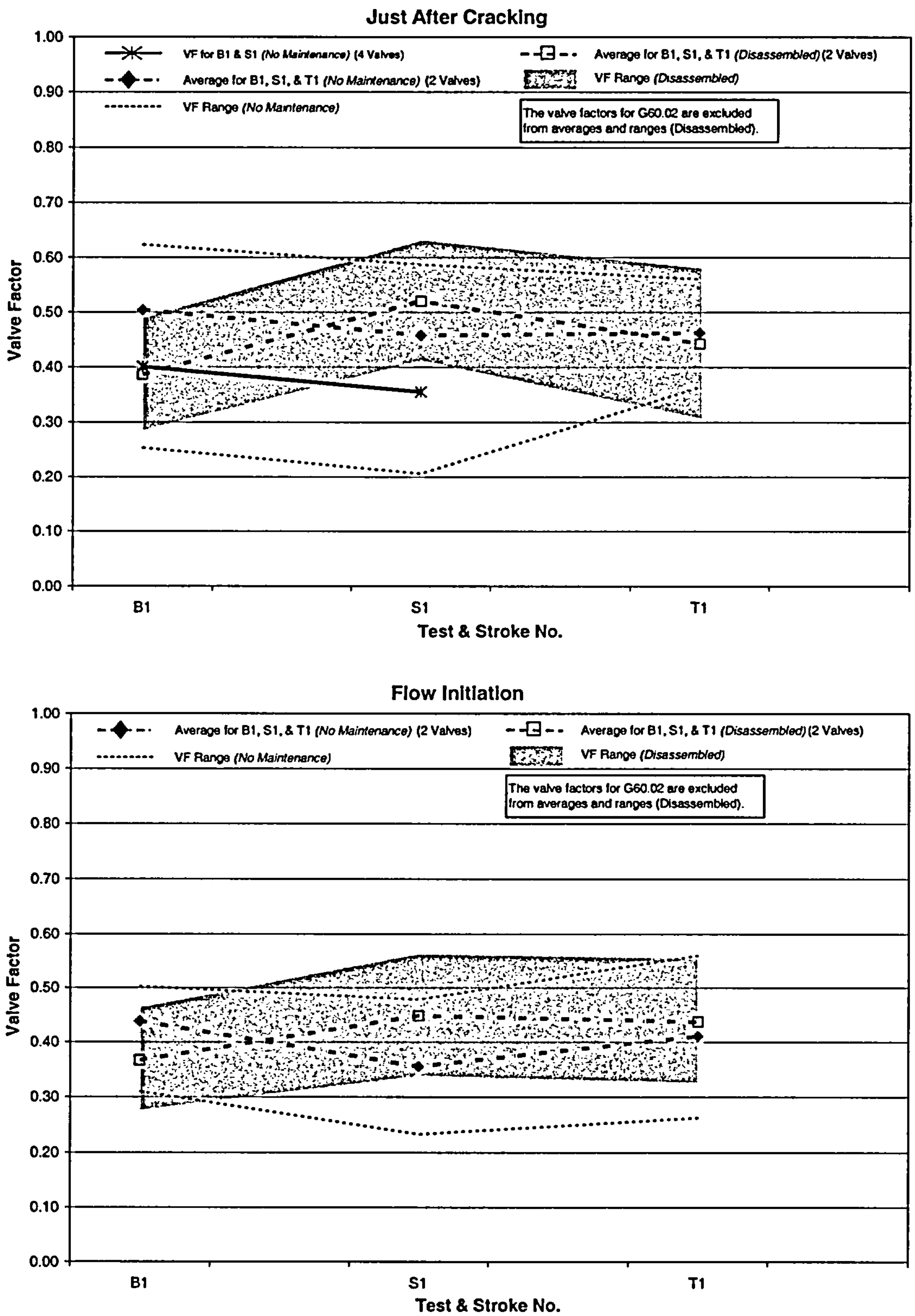


Figure 3-24. Open Average Valve Factors for Gate Valves with Stellite Seats in Steam

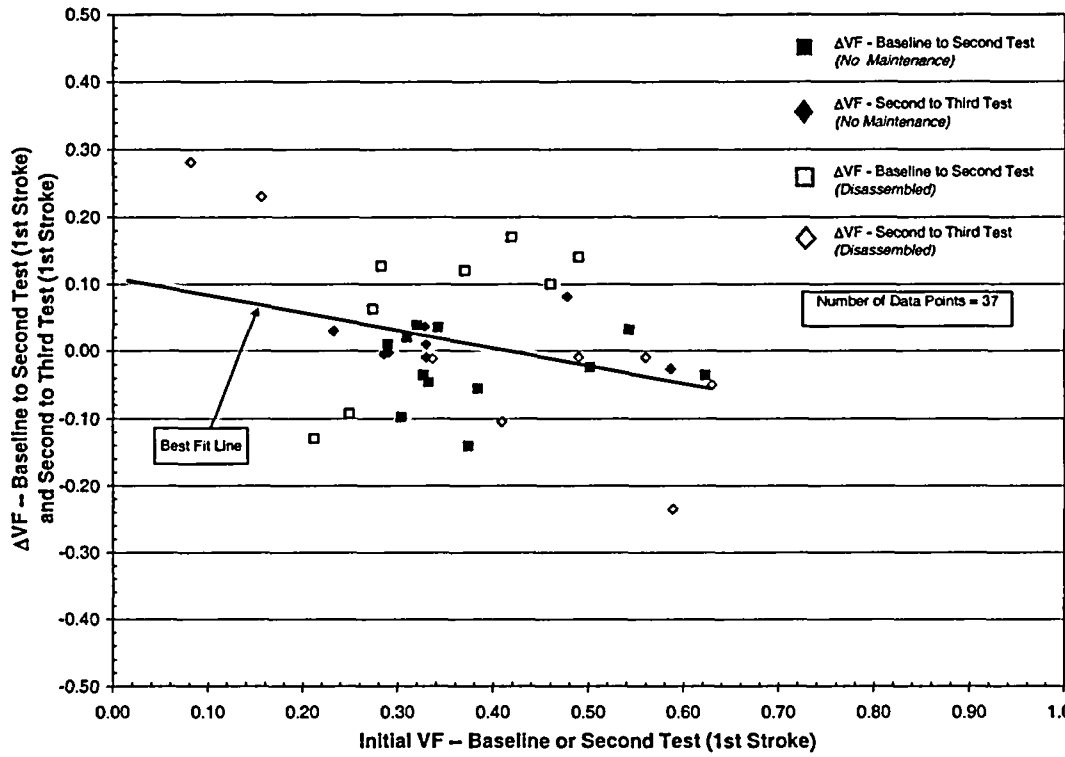
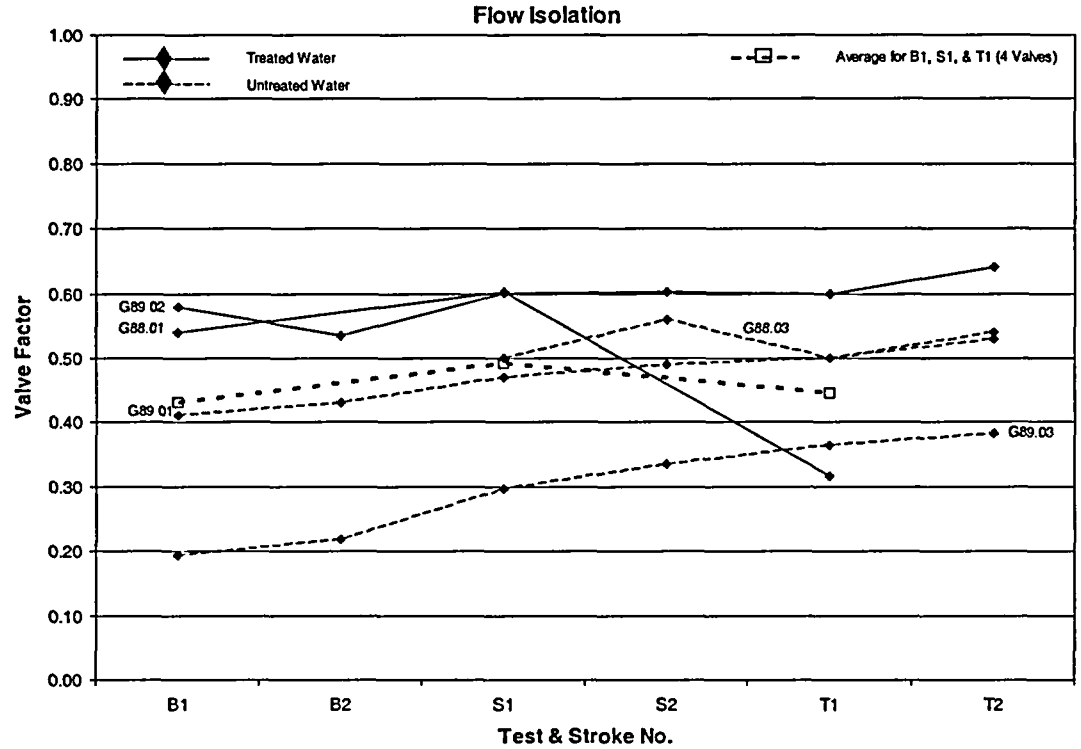


Figure 3-25. Change in Valve Factor vs. Initial Valve Factor for Gate Valves with Stellite Seats in Steam



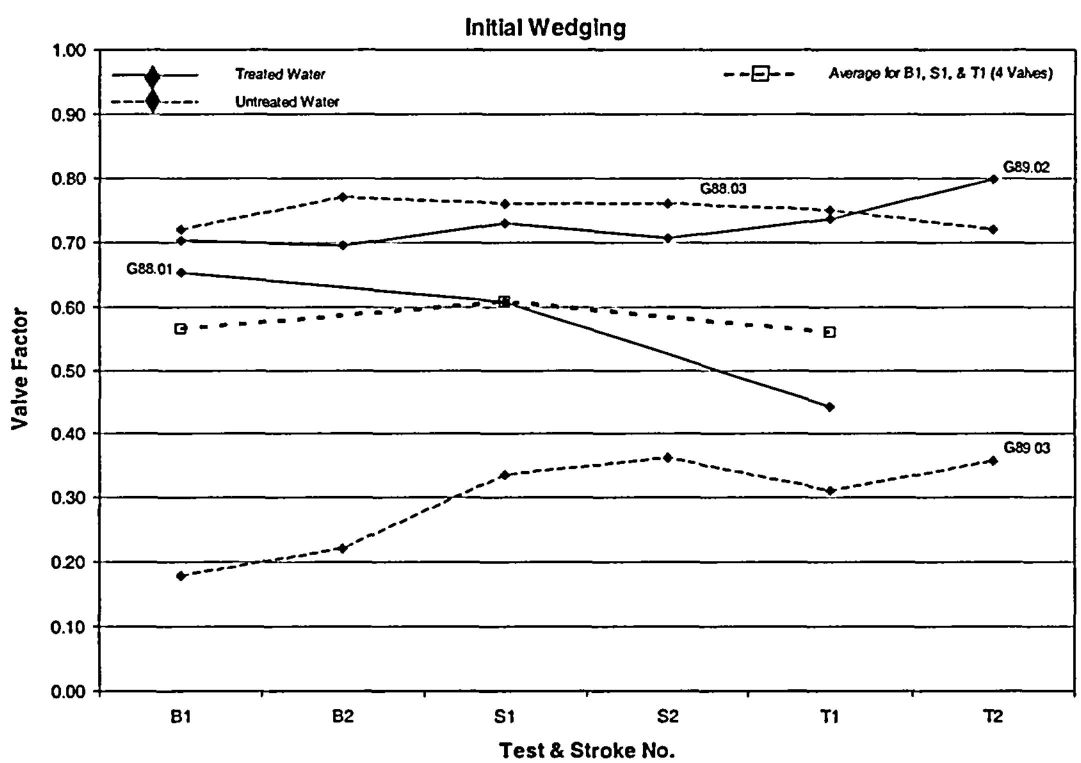
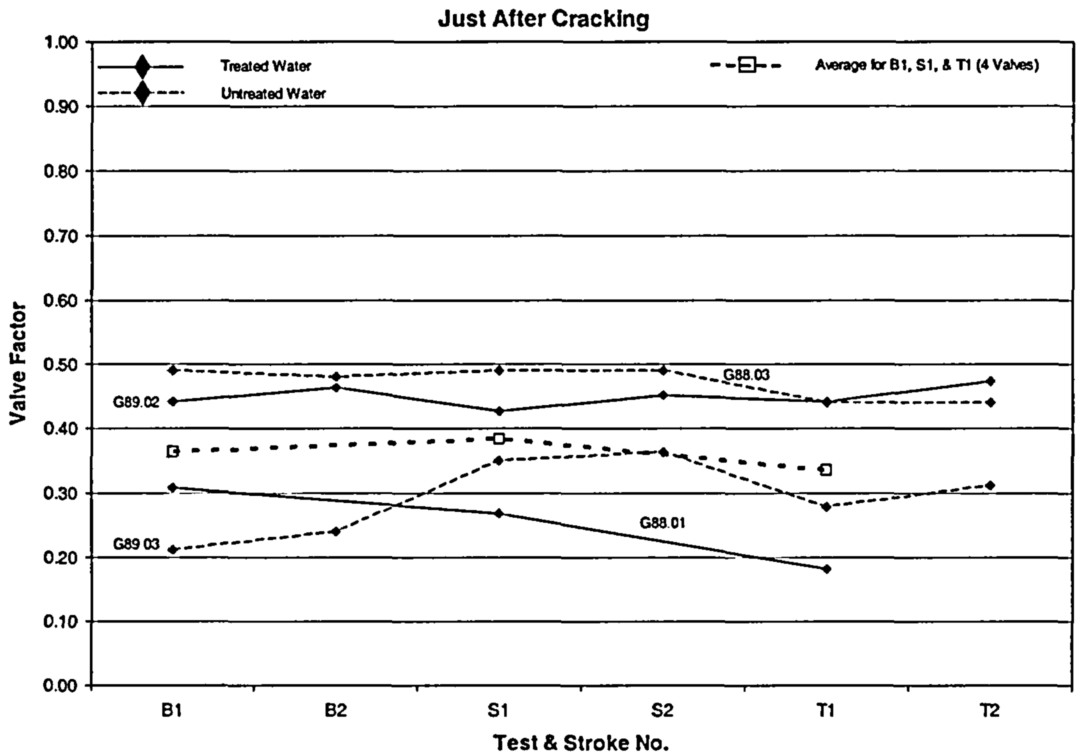


Figure 3-26. Close Valve Factors for Gate Valves with 400 Series Stainless Steel Disk and Seat Ring Faces



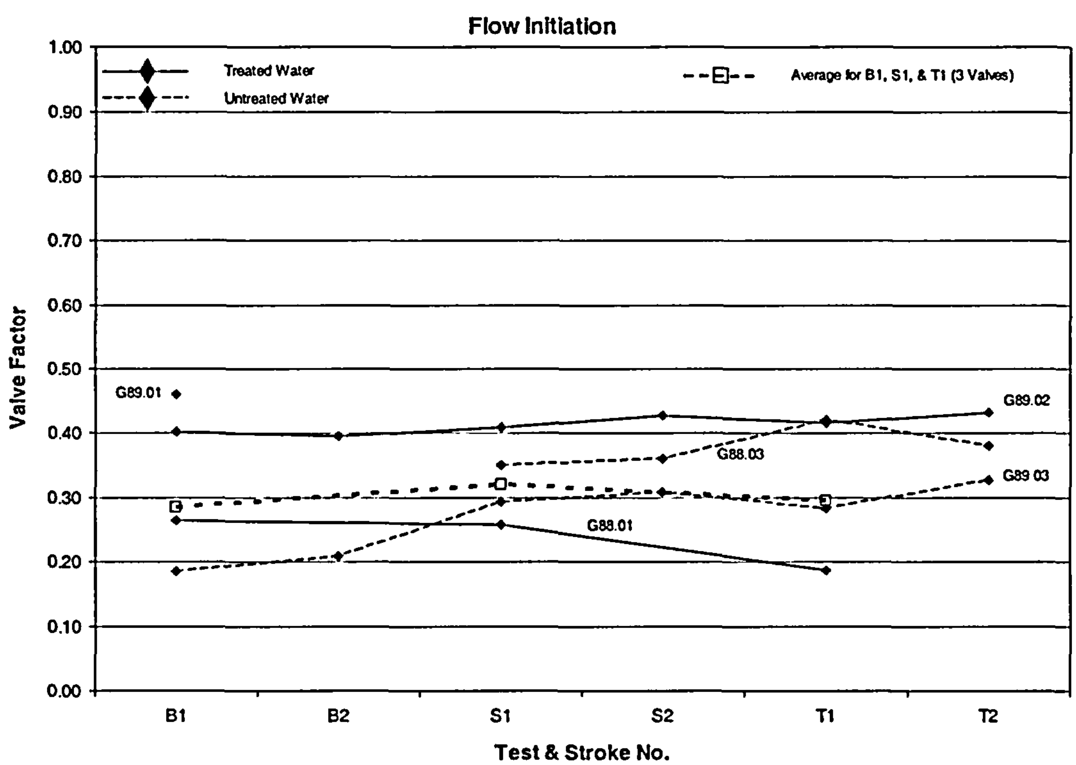


Figure 3-27. Open Valve Factors for Gate Valves with 400 Series Stainless Steel Disk and Seat Ring Faces

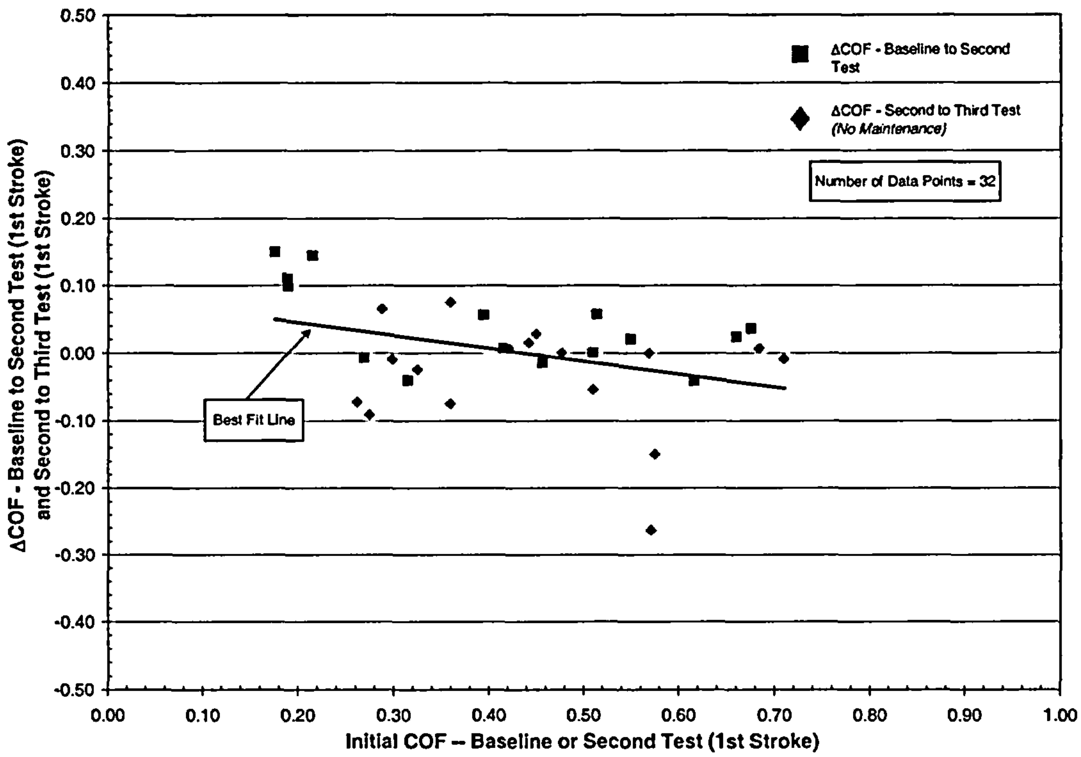
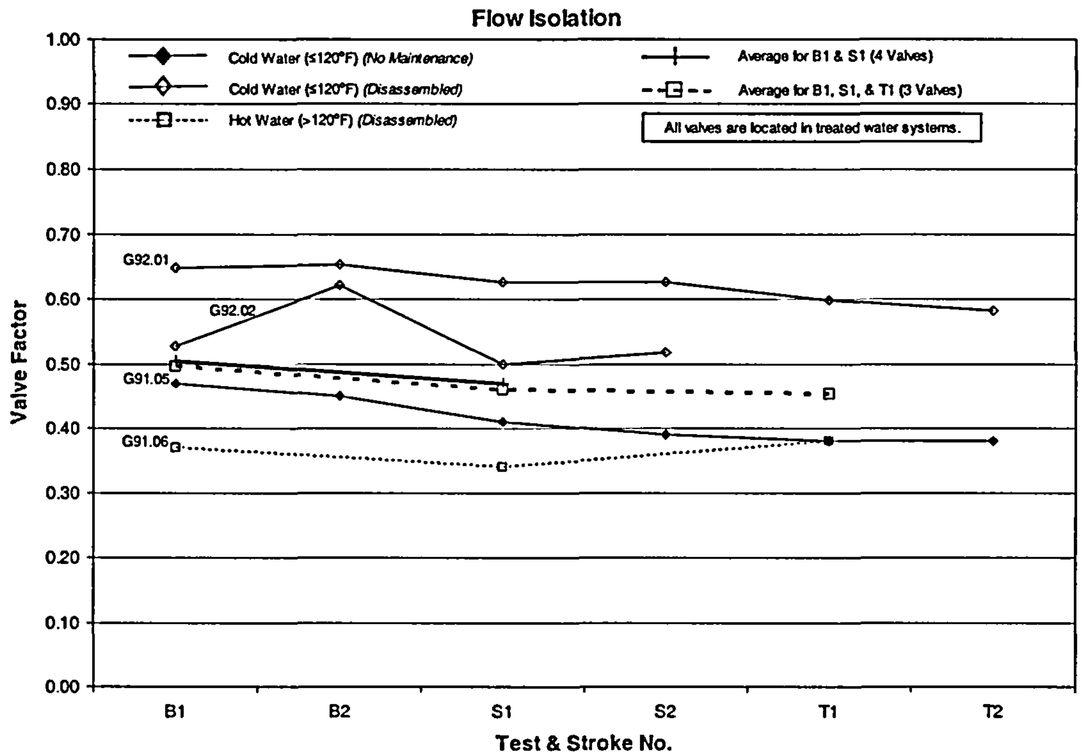


Figure 3-28. Change in Coefficient of Friction (COF) versus Initial COF for Gate Valves with 400 Series Stainless Steel Disk and Seat Ring Faces



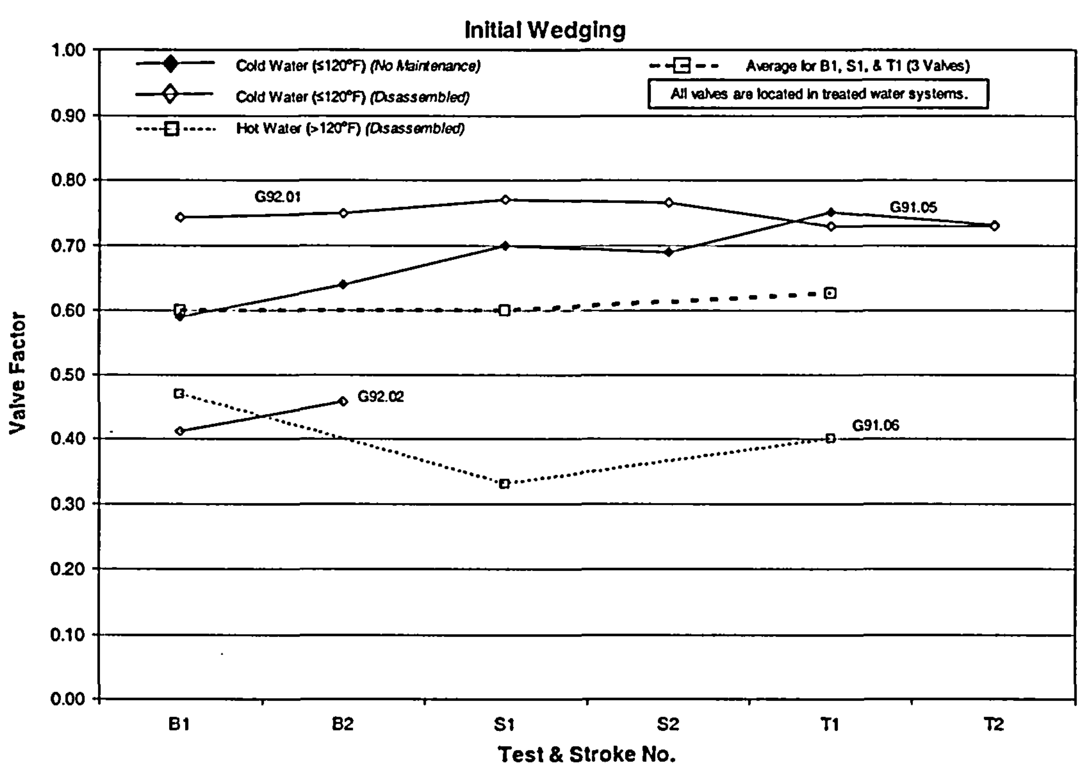
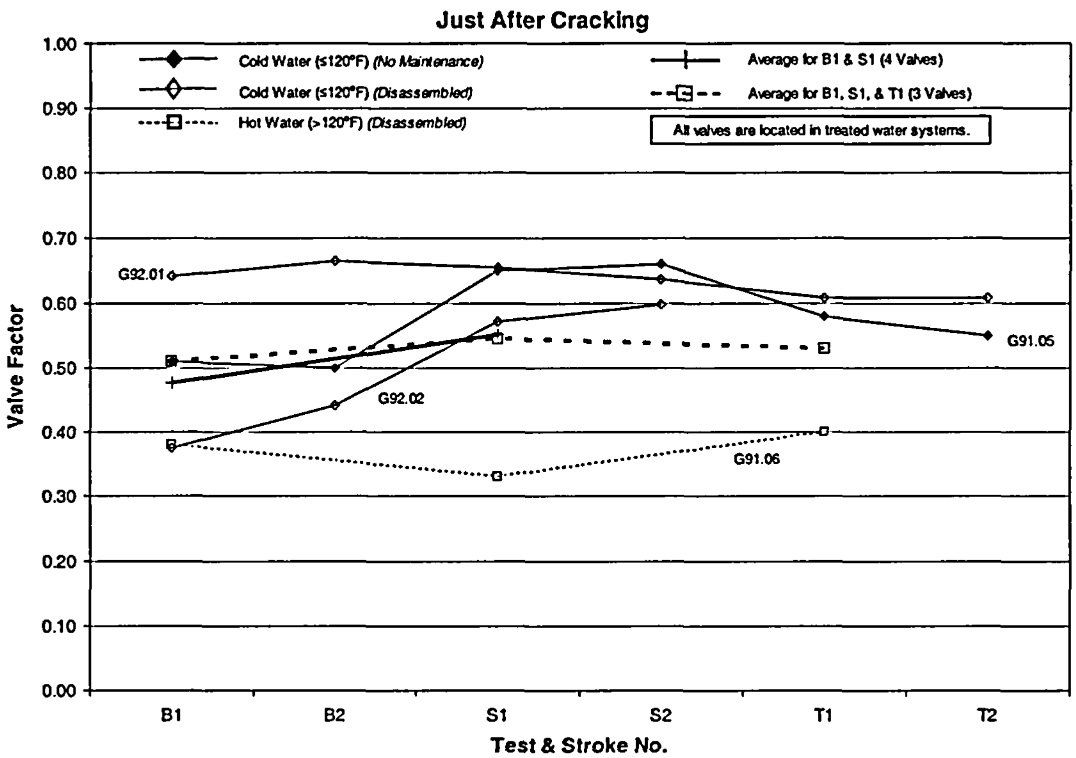


Figure 3-29. Close Valve Factors for Gate Valves with 400 Series Stainless Steel Disk and Stellite Seat Ring Faces



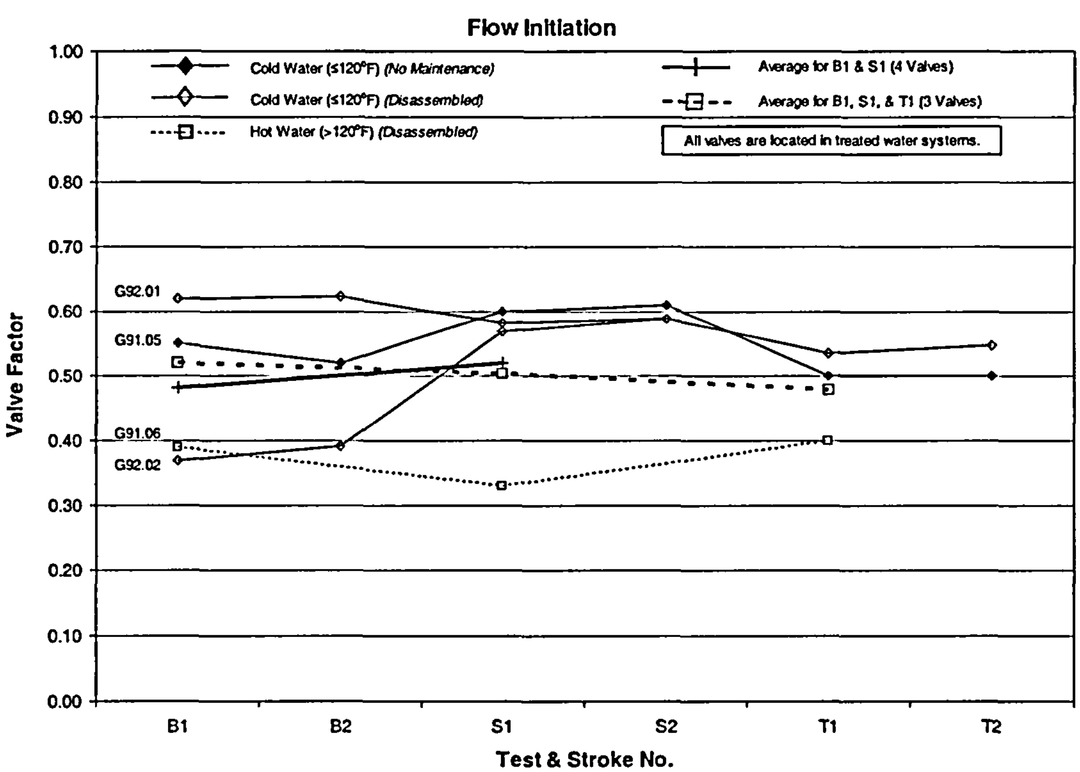


Figure 3-30. Open Valve Factors for Gate Valves with 400 Series Stainless Steel Disk and Stellite Seat Ring Faces

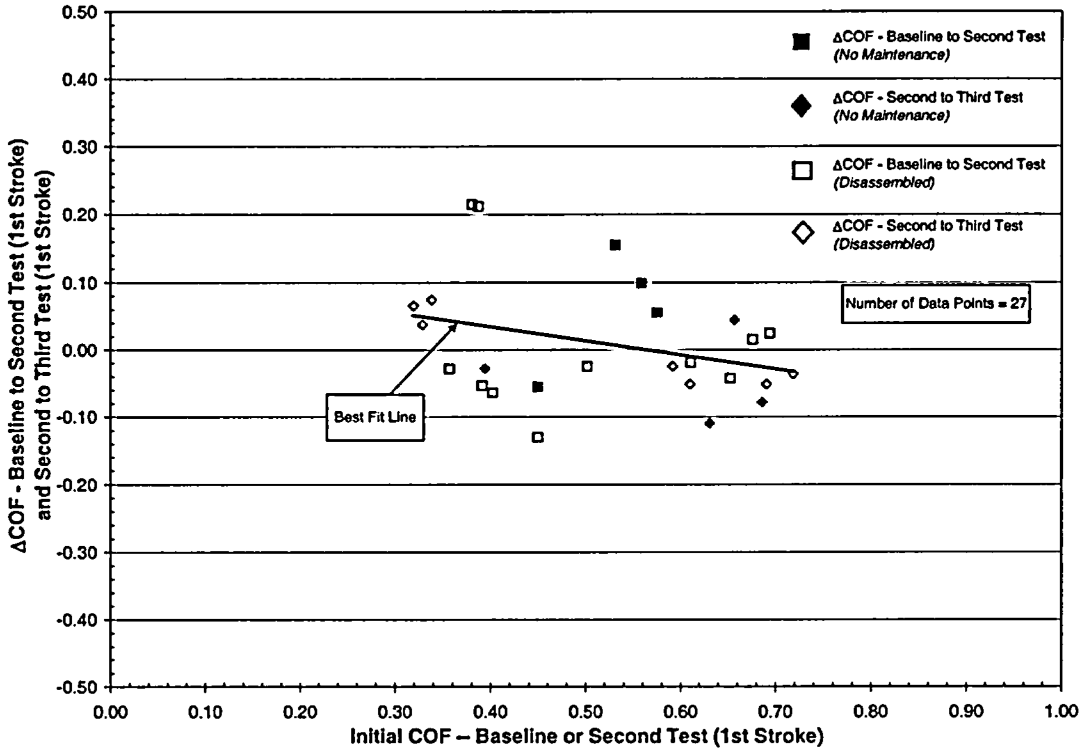
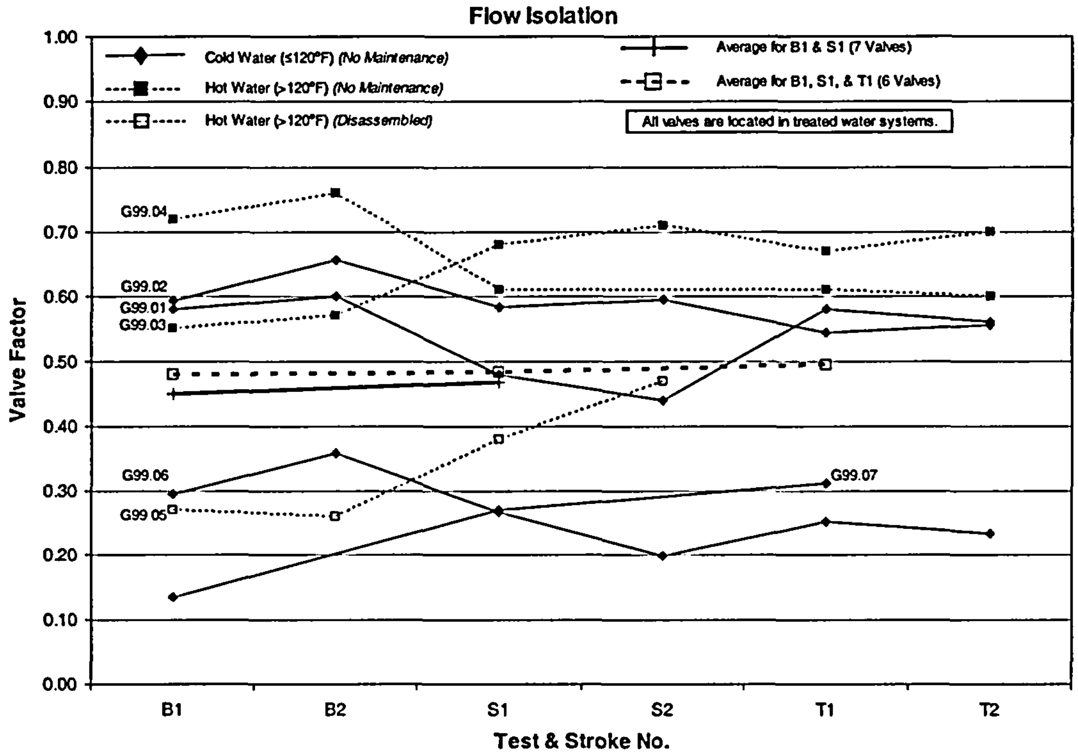


Figure 3-31. Change in Coefficient of Friction (COF) versus Initial COF for Gate Valves with 400 Series Stainless Steel Disk and Stellite Seat Ring Faces



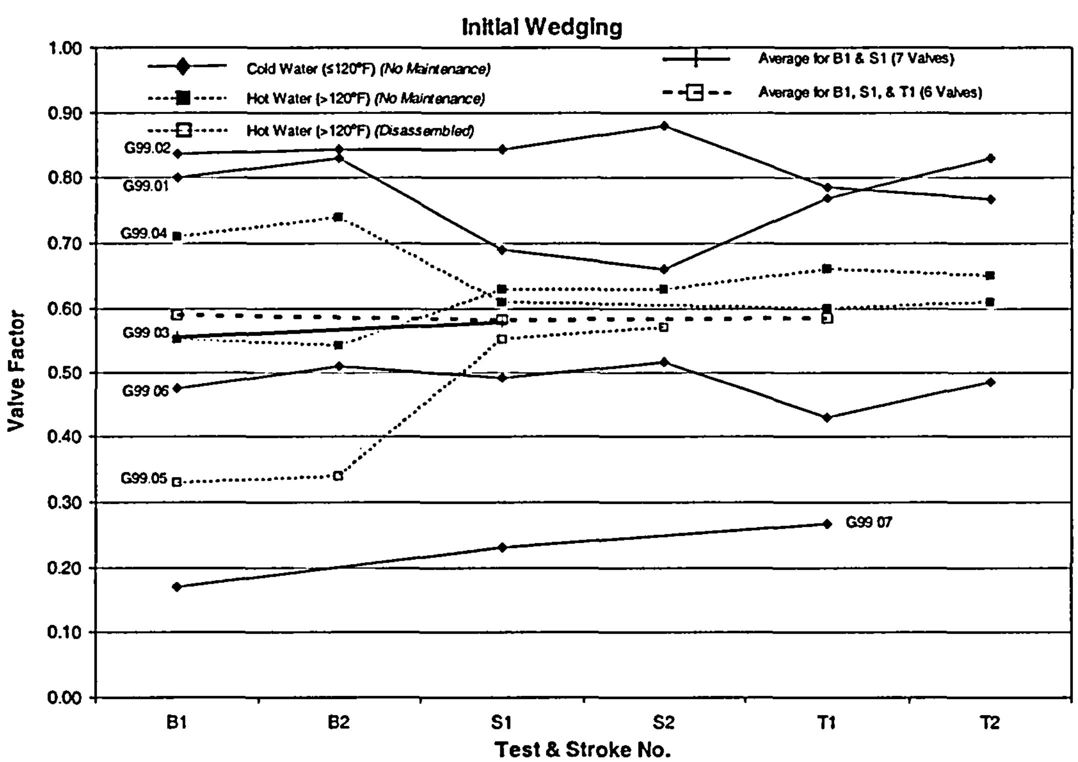
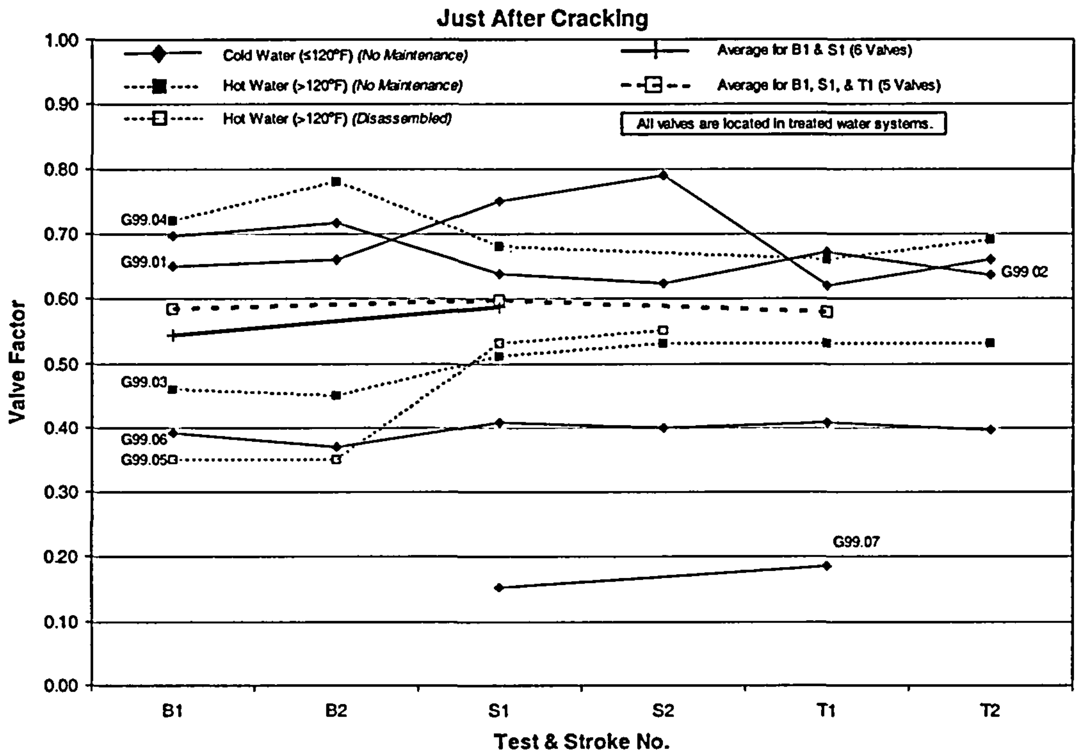


Figure 3-32. Close Valve Factors for Gate Valves with 400 Series Stainless Steel (or Exelloy) Disk and Monel Seat Ring Faces



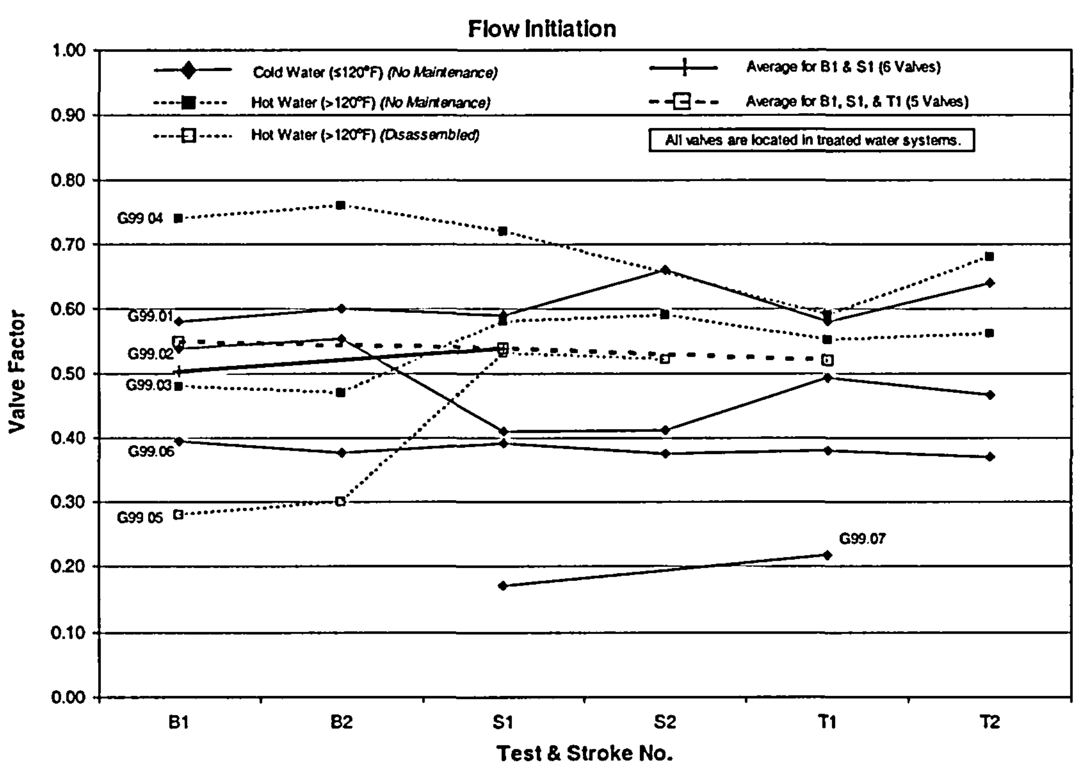


Figure 3-33. Open Valve Factors for Gate Valves with 400 Series Stainless Steel (or Exelloy) Disk and Monel Seat Ring Faces

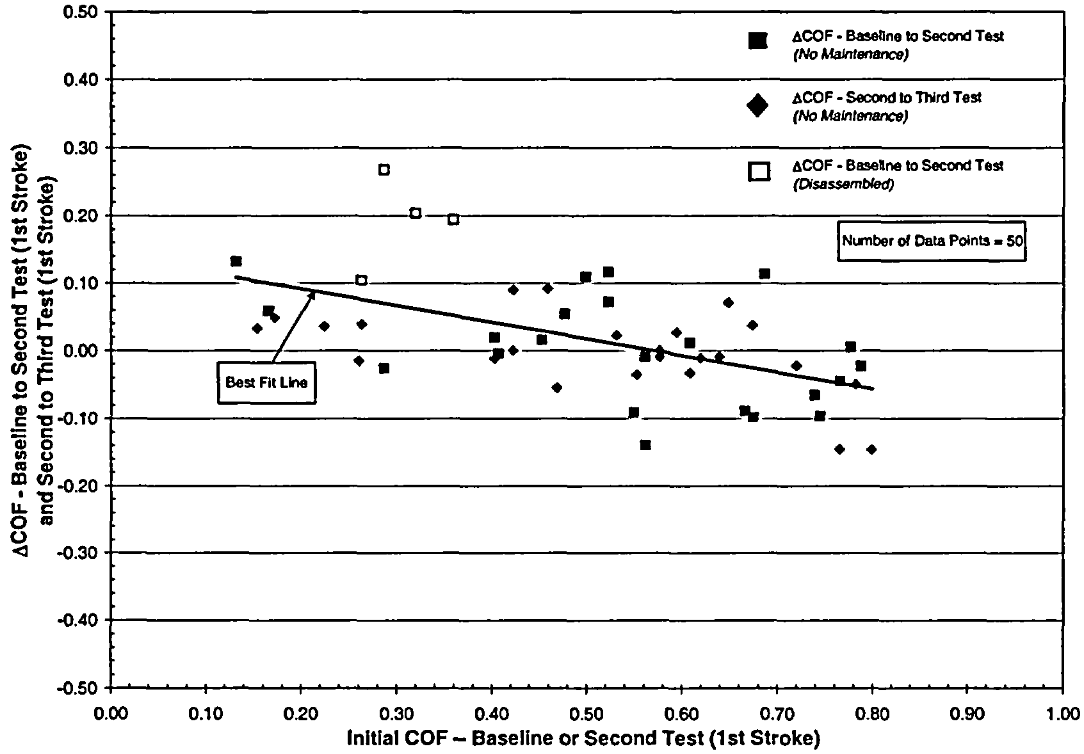
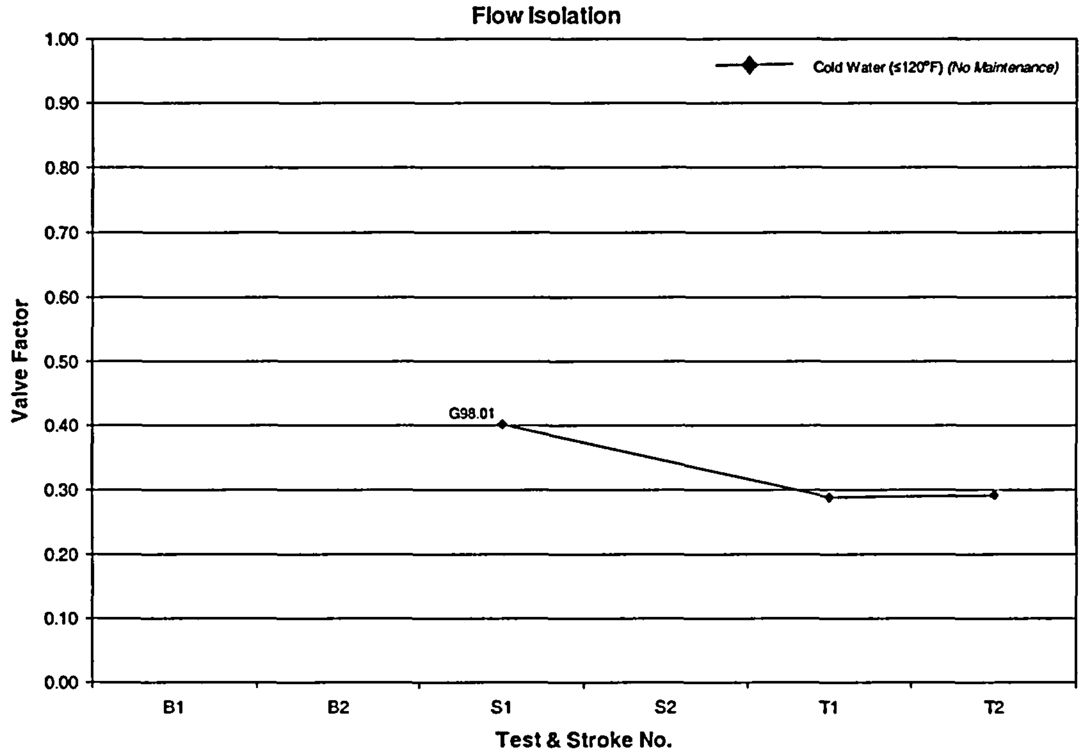


Figure 3-34. Change in Coefficient of Friction (COF) versus Initial COF for Gate Valves with 400 Series Stainless Steel (or Exelloy) Disk and Monel Seat Ring Faces



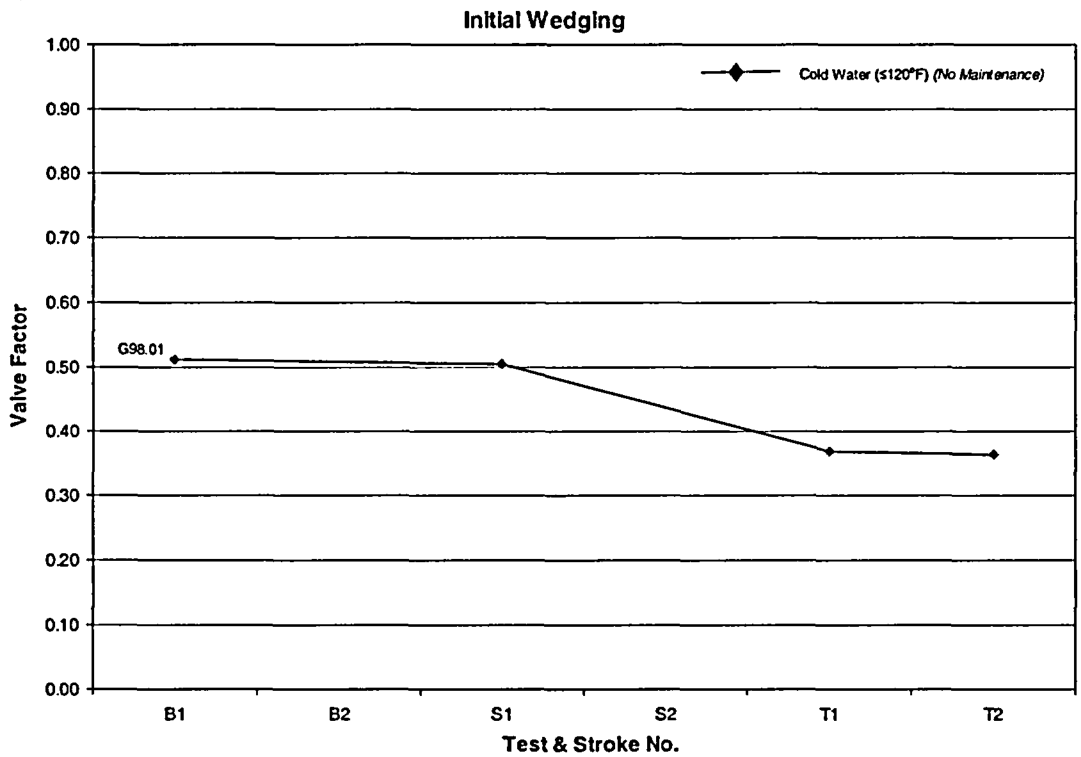


Figure 3-35. Close Valve Factors for Gate Valve with Deloro 50 Disk and Seat Faces

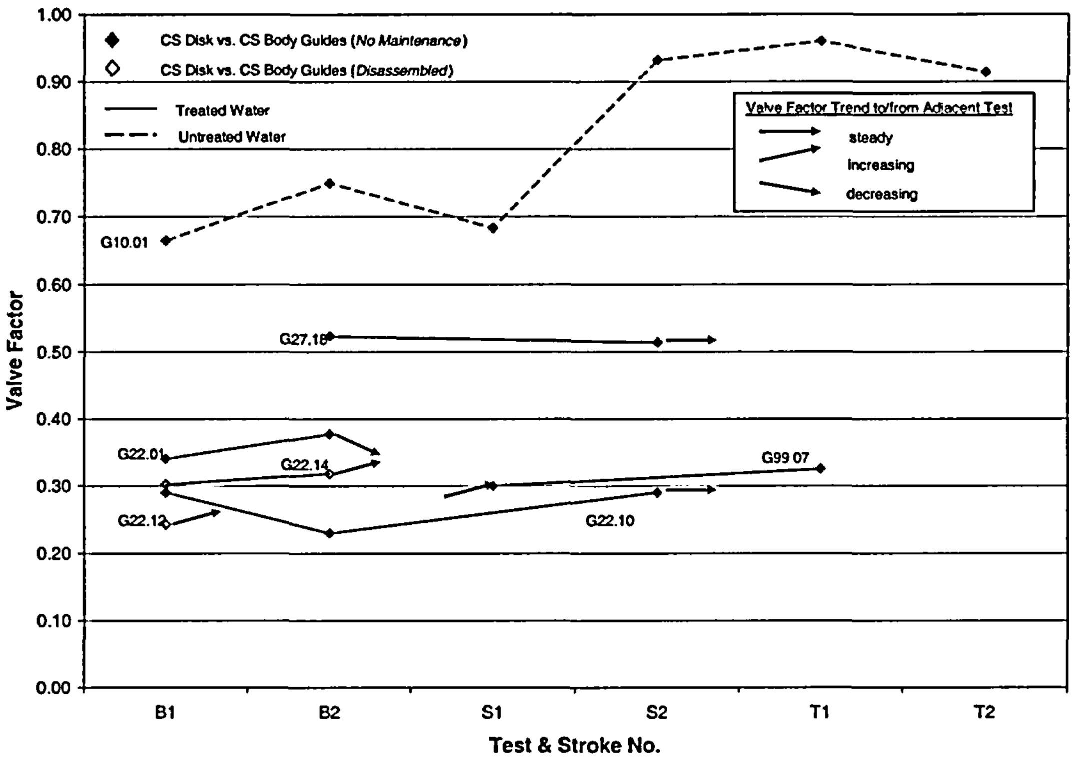


Figure 3-36. Close Guide Valve Factors for Gate Valves with Carbon Steel Disk vs. Carbon Steel Body Guides

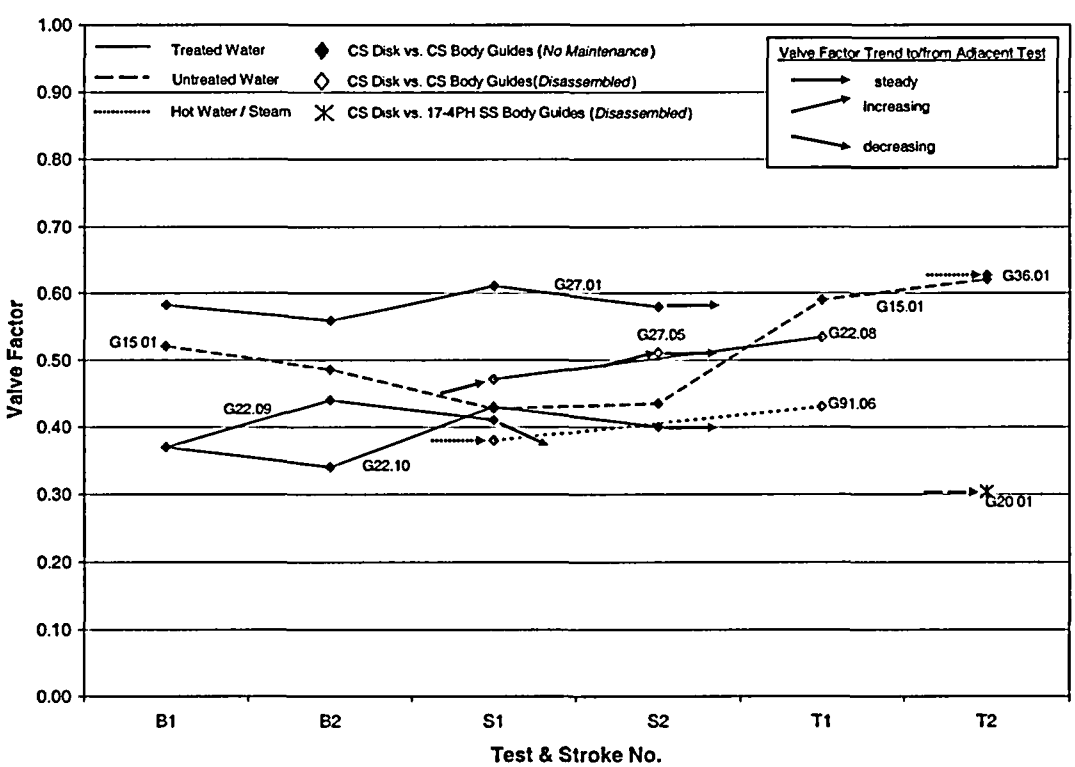


Figure 3-37. Open Guide Valve Factors for Gate Valves with Carbon Steel Disk vs. Carbon Steel or 17-4PH Stainless Steel Body Guides

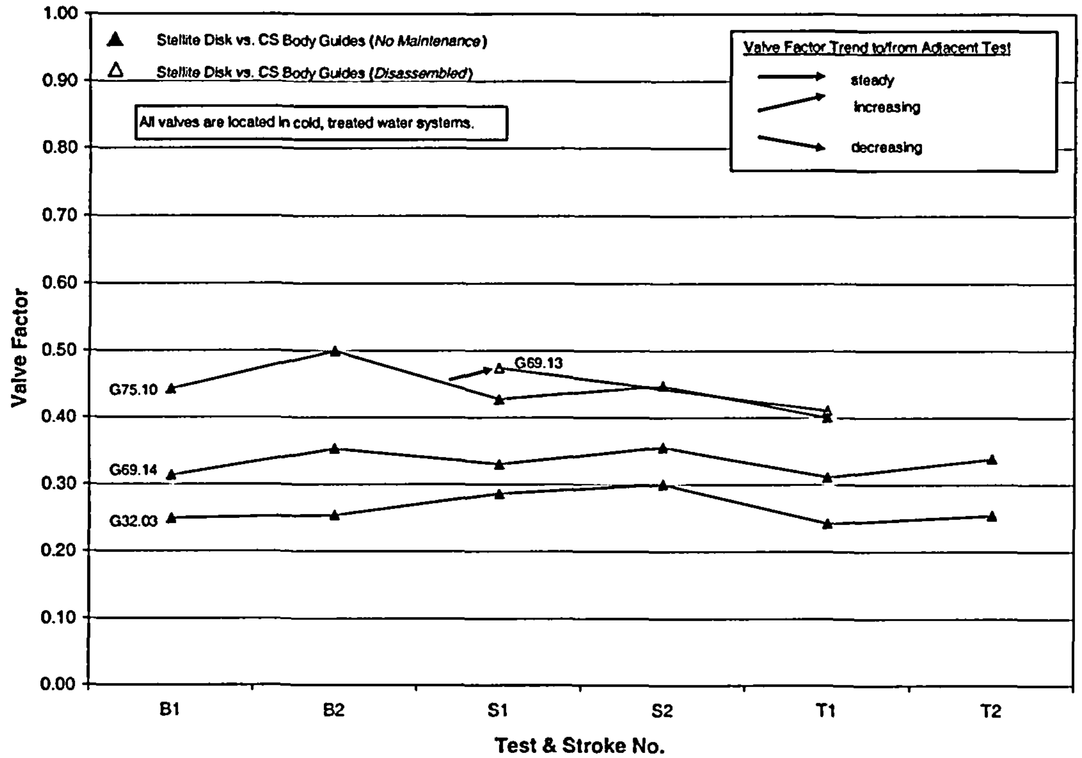


Figure 3-38. Open Guide Valve Factors for Gate Valves with Stellite Disk vs. Carbon Steel Body Guides

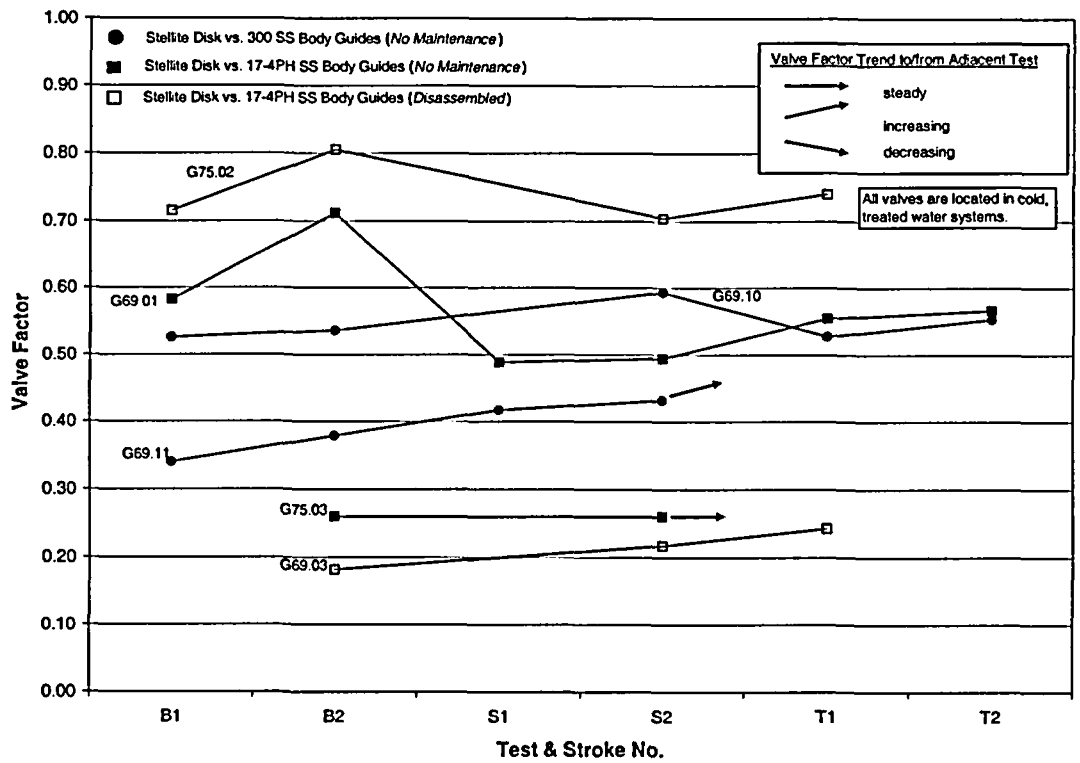


Figure 3-39. Open Guide Valve Factors for Gate Valves with Stellite Disk vs. 300 Series Stainless Steel or 17-4PH Stainless Steel Body Guides

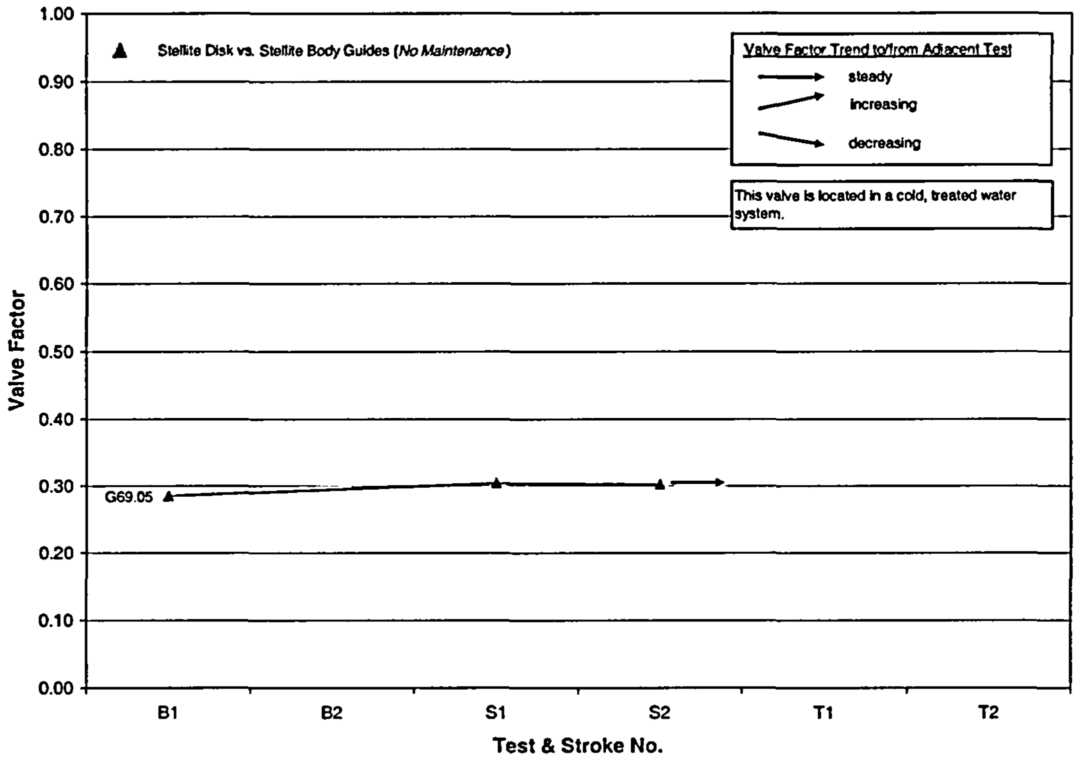


Figure 3-40. Open Guide Valve Factors for Gate Valves with Stellite Disk vs. Stellite Body Guides

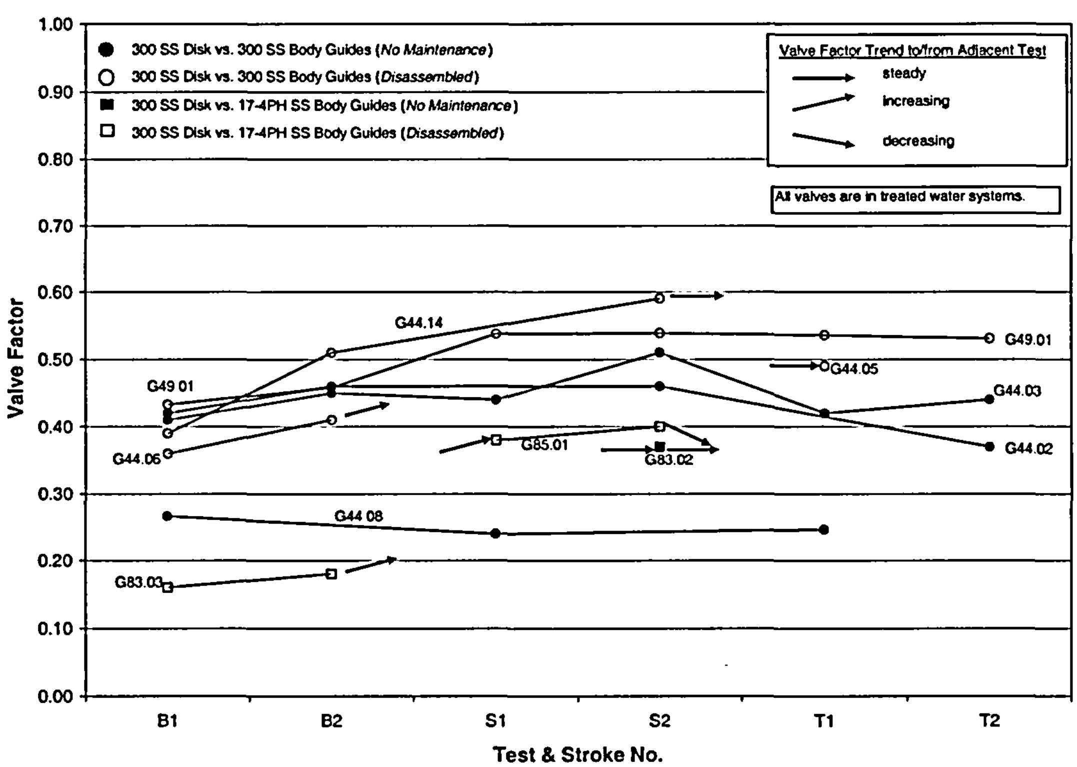


Figure 3-41. Open Guide Valve Factors for Gate Valves with 300 Series Stainless Steel Disk vs. 300 Series Stainless Steel or 17-4PH Stainless Steel Body Guides

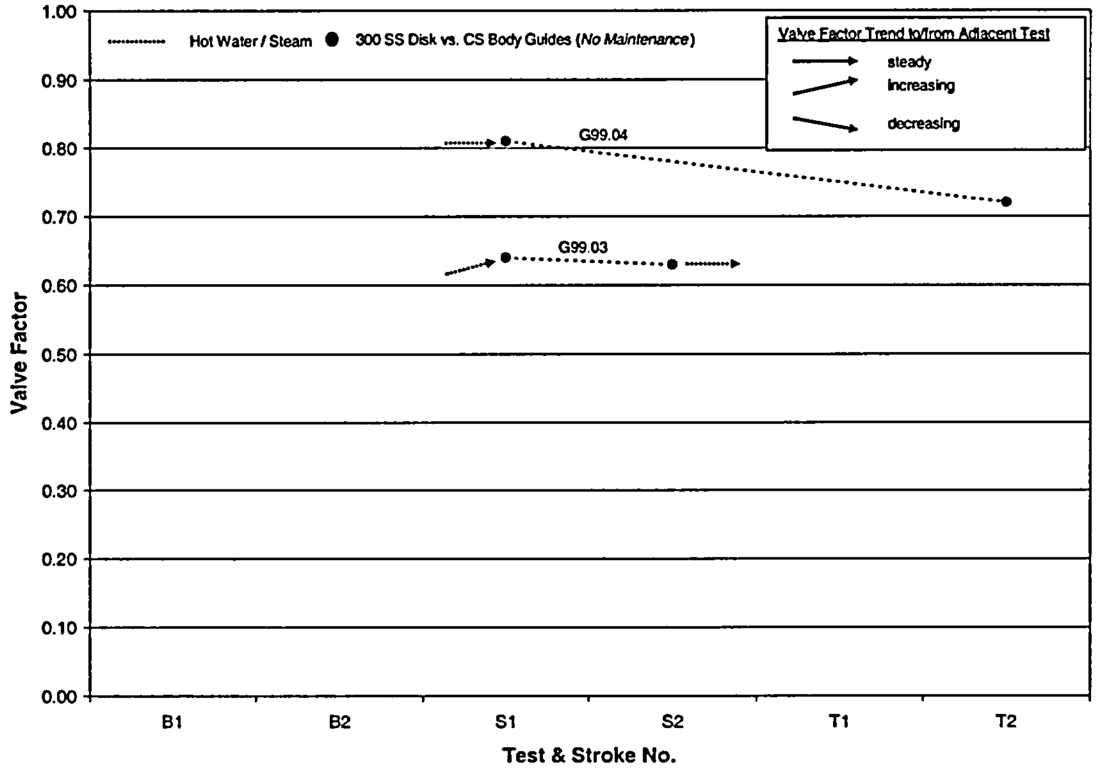


Figure 3-42. Open Guide Valve Factors for Gate Valves with 300 Series Stainless Steel Disk vs. Carbon Steel Body Guides

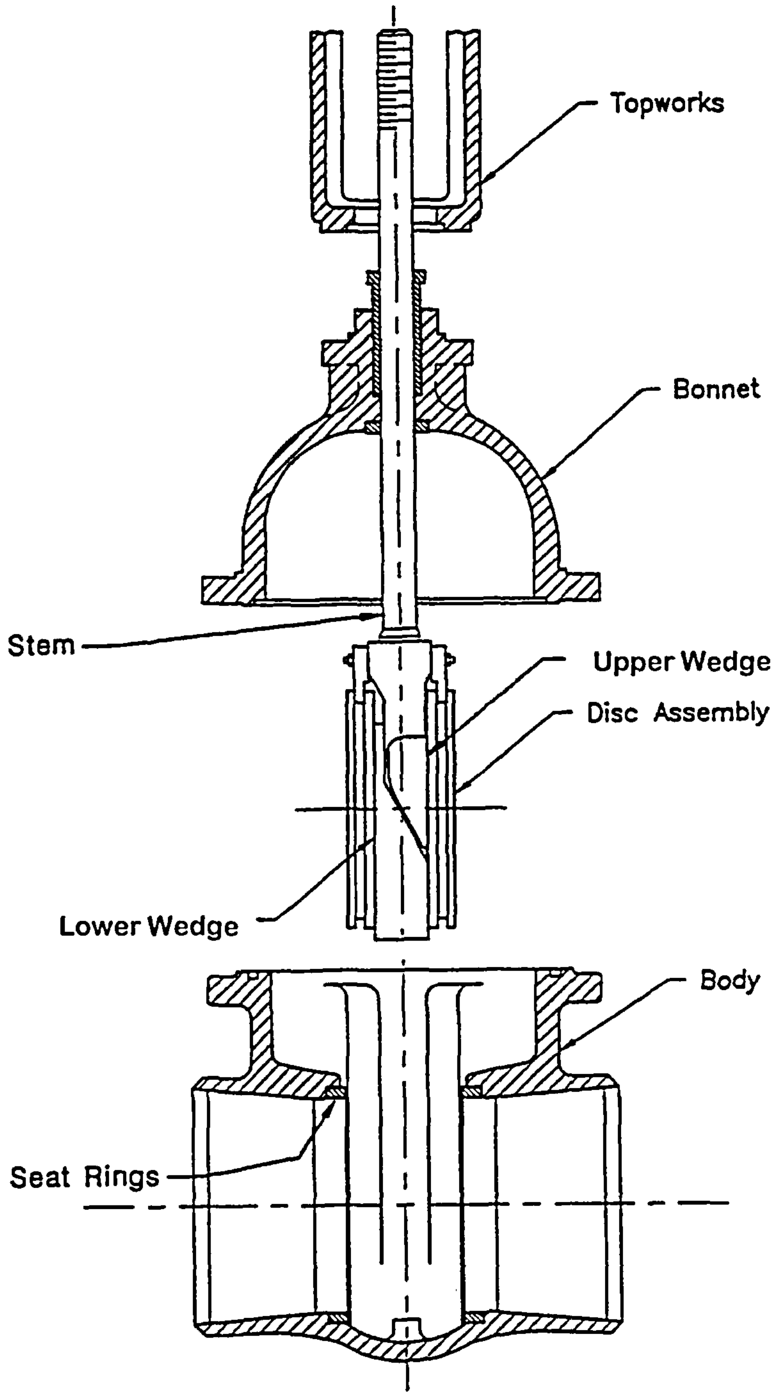


Figure 3-43. Anchor/Darling Double Disk Gate Valve

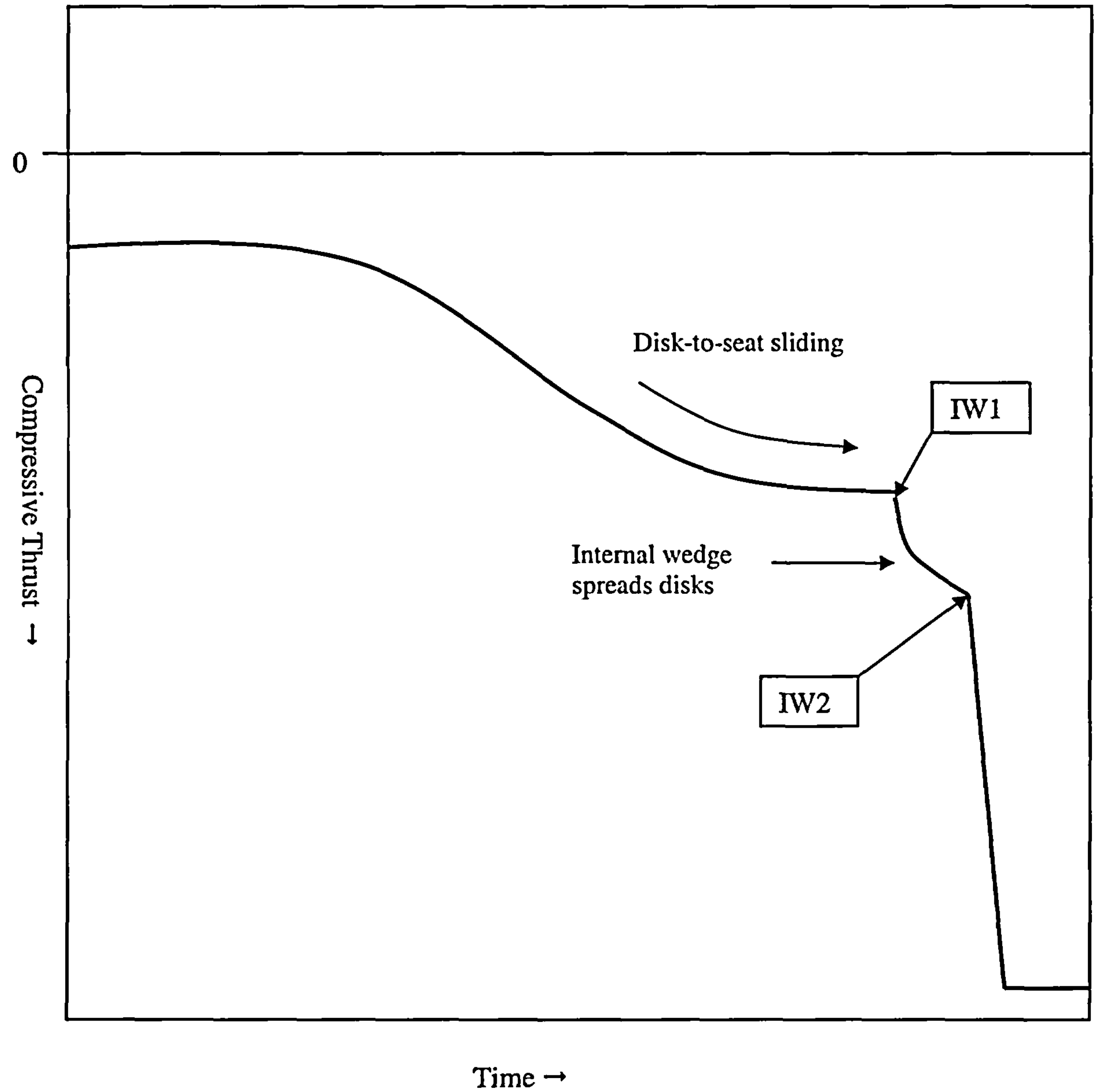


Figure 3-44. Typical DP Closing Thrust Trace at Hard Seating of an Anchor/Darling Double Disk Gate Valve

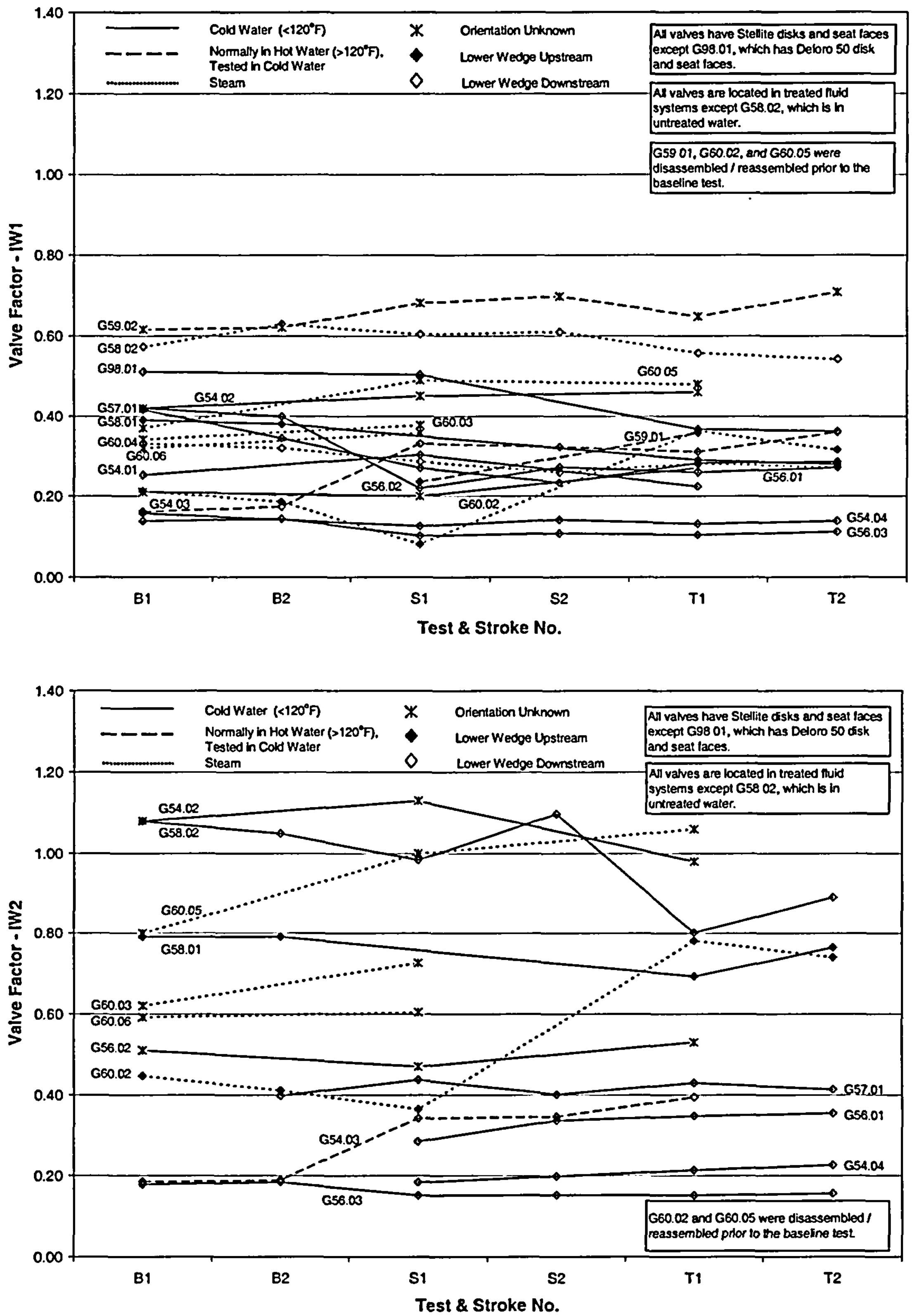


Figure 3-45. Valve Factors at 1st and 2nd Initial Wedging Points for Anchor/Darling Double Disk Gate Valves

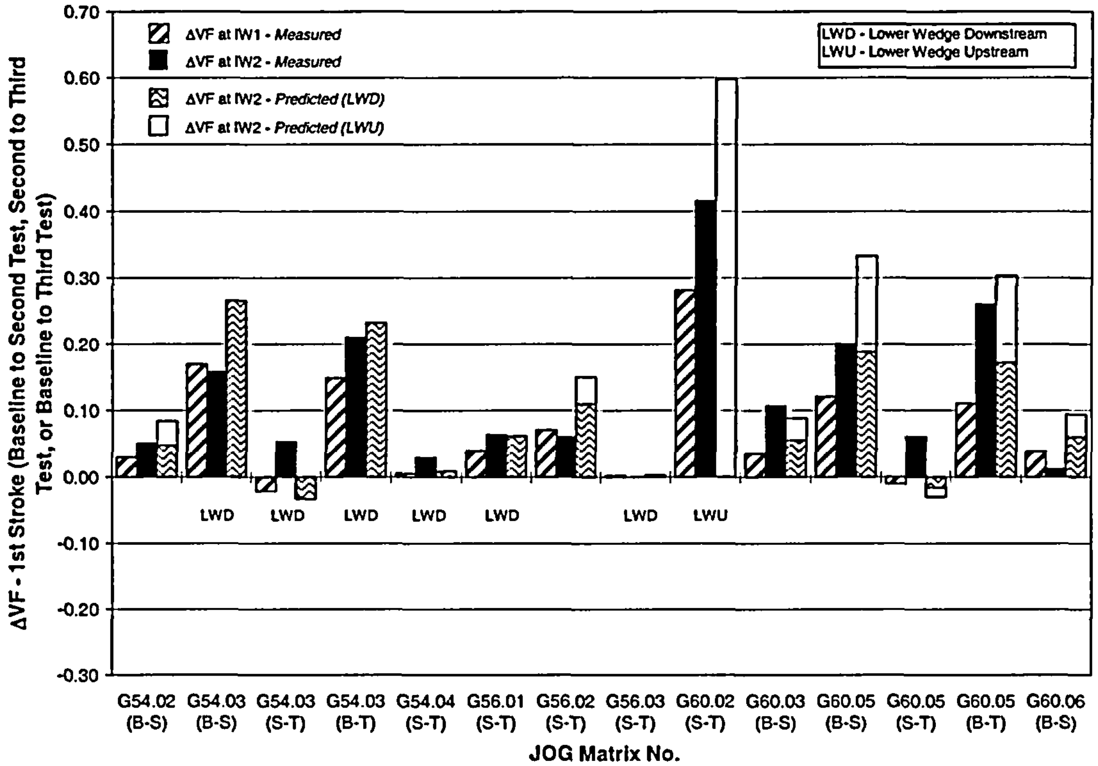


Figure 3-46. Changes in Valve Factor Between Tests at 1st and 2nd Initial Wedging Points for Anchor/Darling Double Disk Gate Valves

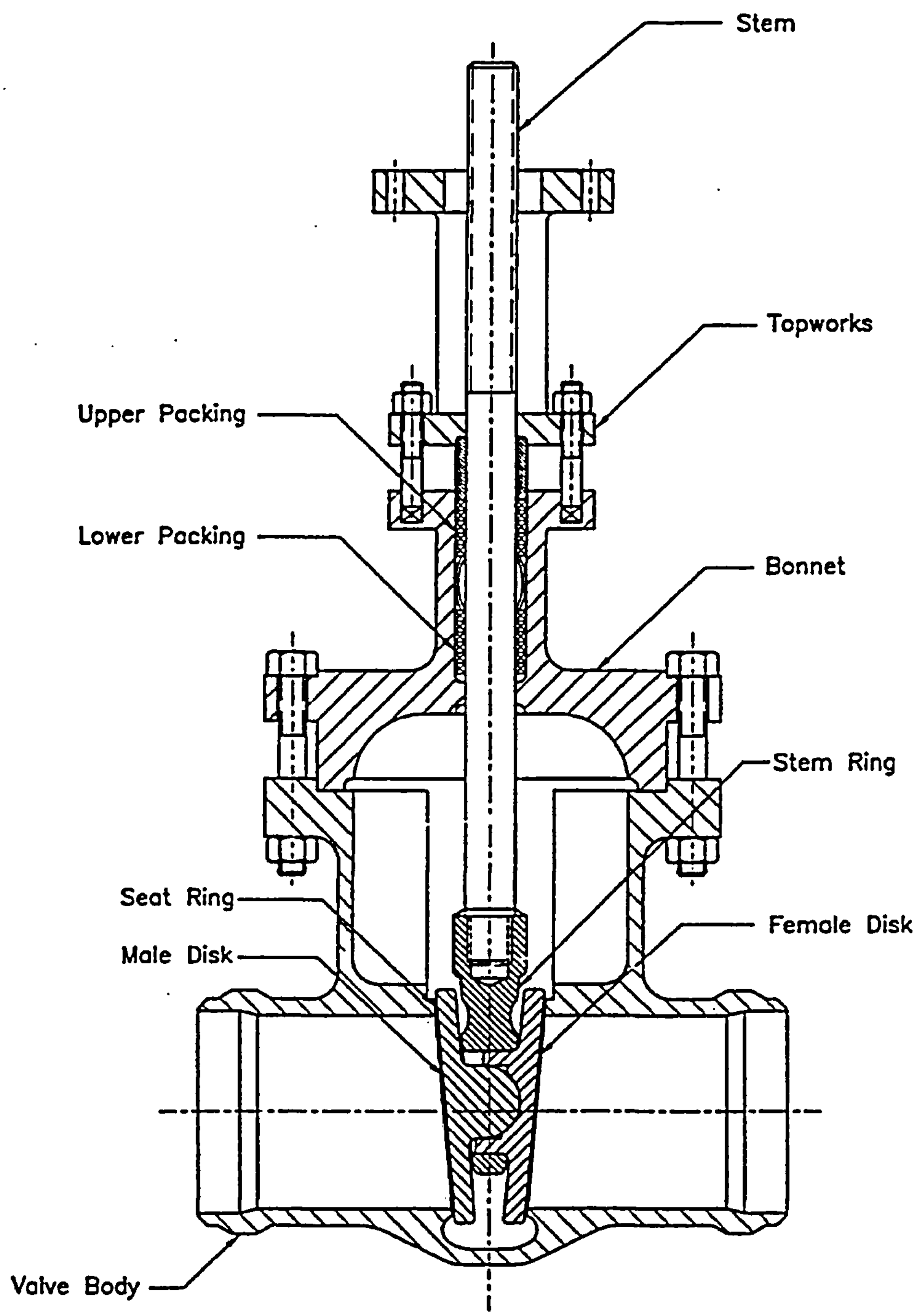


Figure 3-47. Aloyco Split Wedge Gate Valve

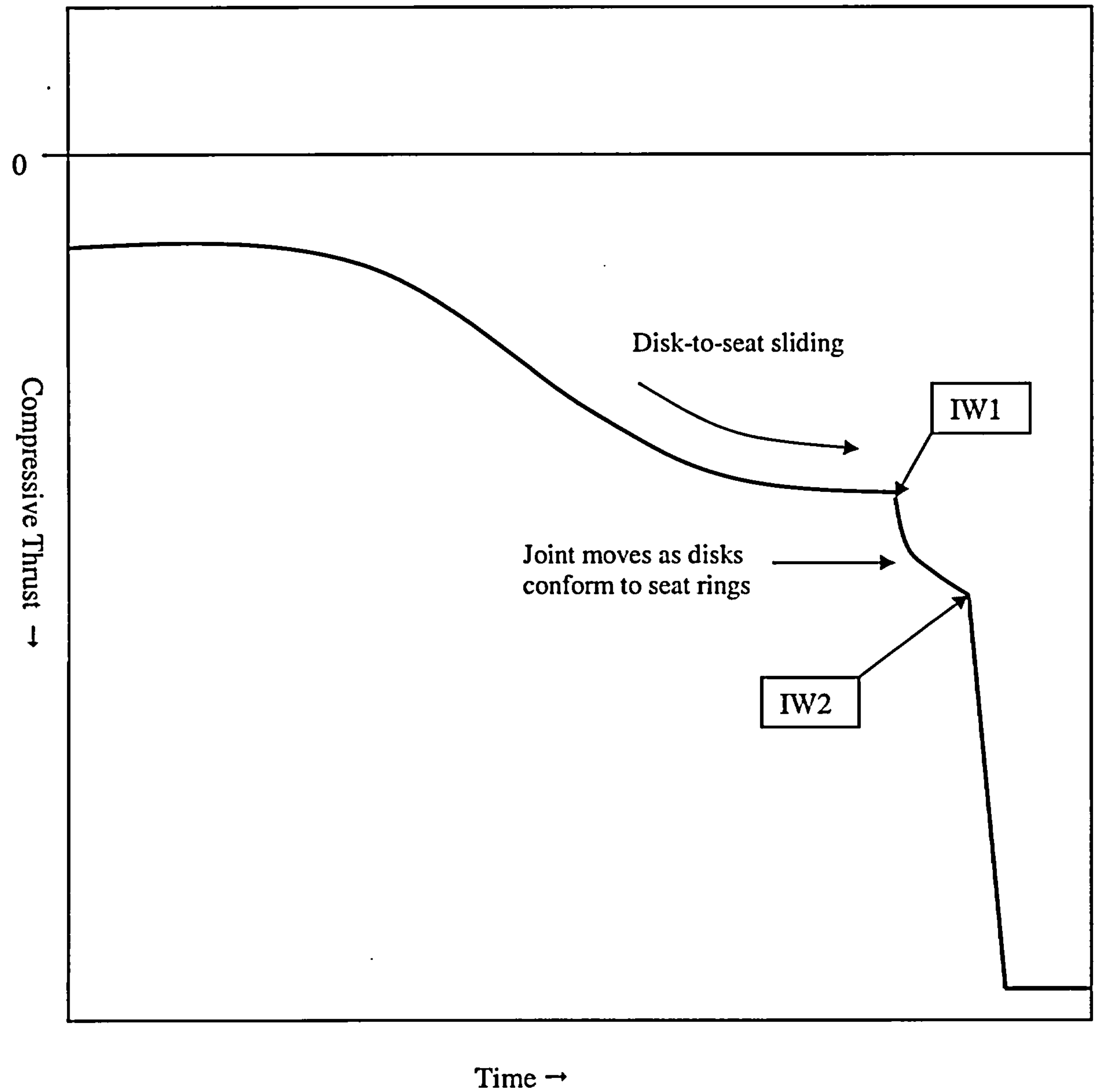


Figure 3-48. Typical DP Closing Thrust Trace at Hard Seating of an Aloyco Split Wedge Gate Valve

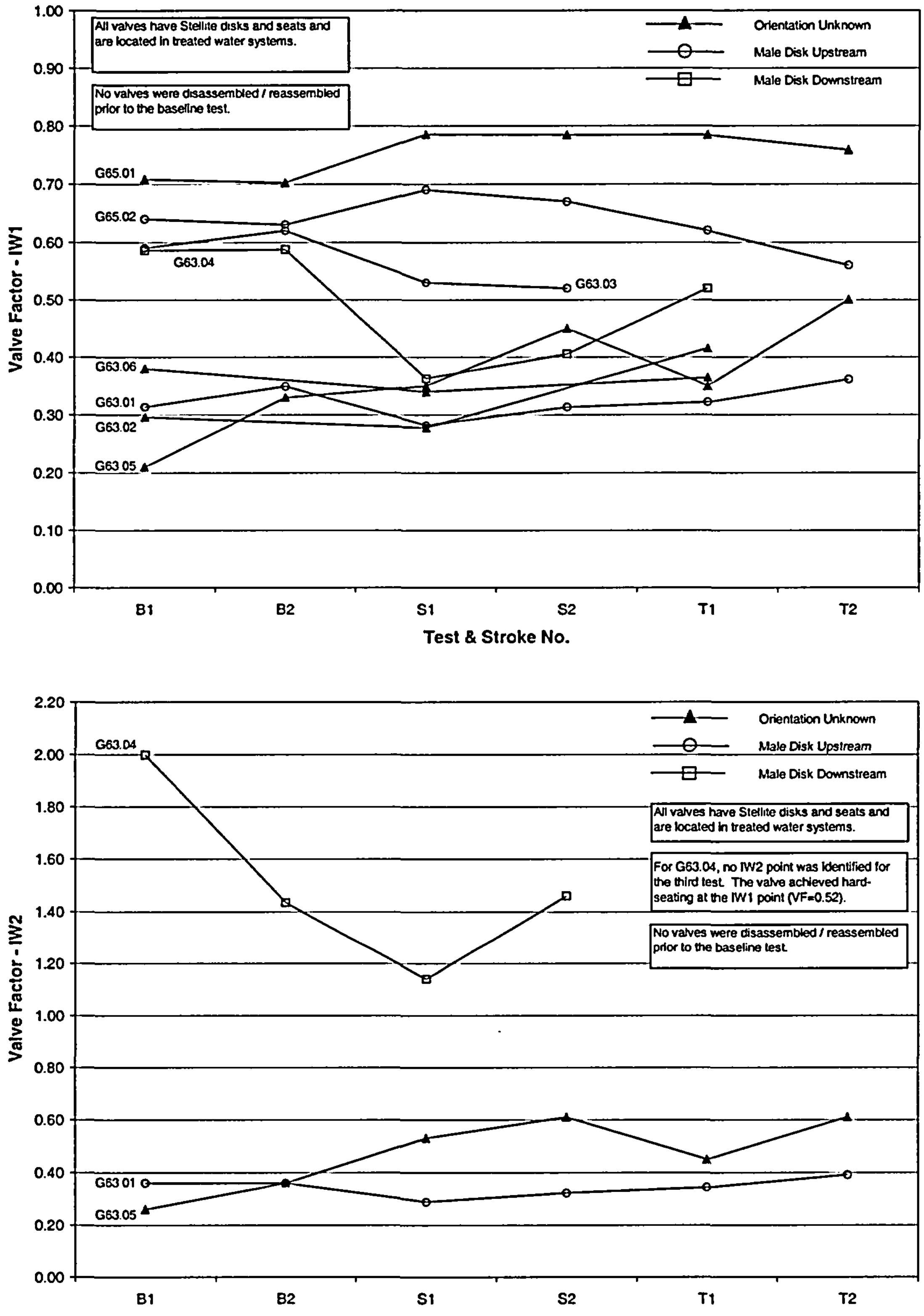


Figure 3-49. Valve Factors at 1st and 2nd Initial Wedging Points for Aloyco Split Wedge Gate Valves

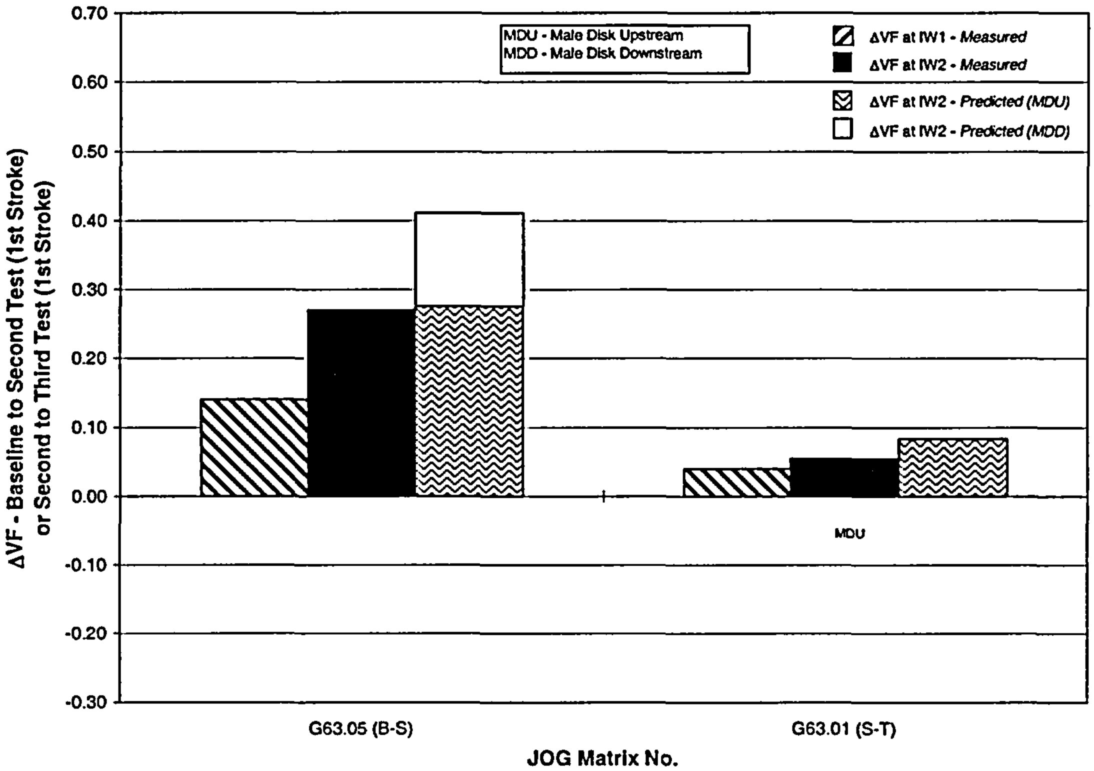


Figure 3-50. Changes in Valve Factor Between Tests at 1st and 2nd Initial Wedging Points for Aloyco Split Wedge Gate Valves

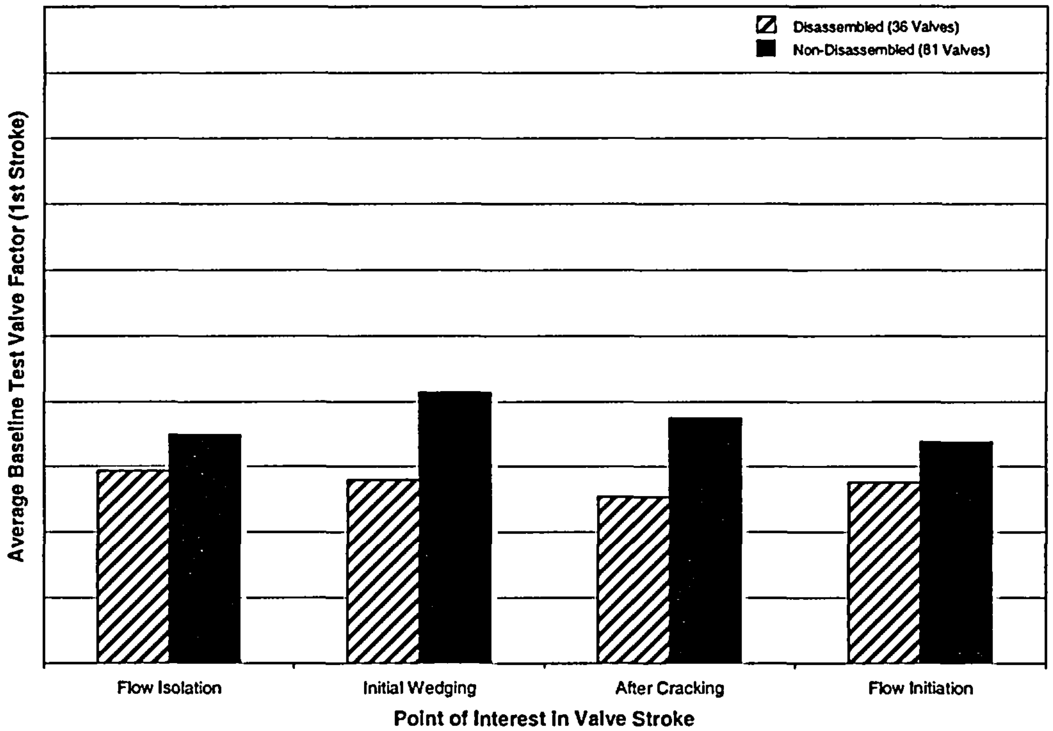


Figure 3-51. Comparison of Average Baseline Test Valve Factors for Disassembled and Non-Disassembled Gate Valves with Self-Mated Stellite Seat Materials

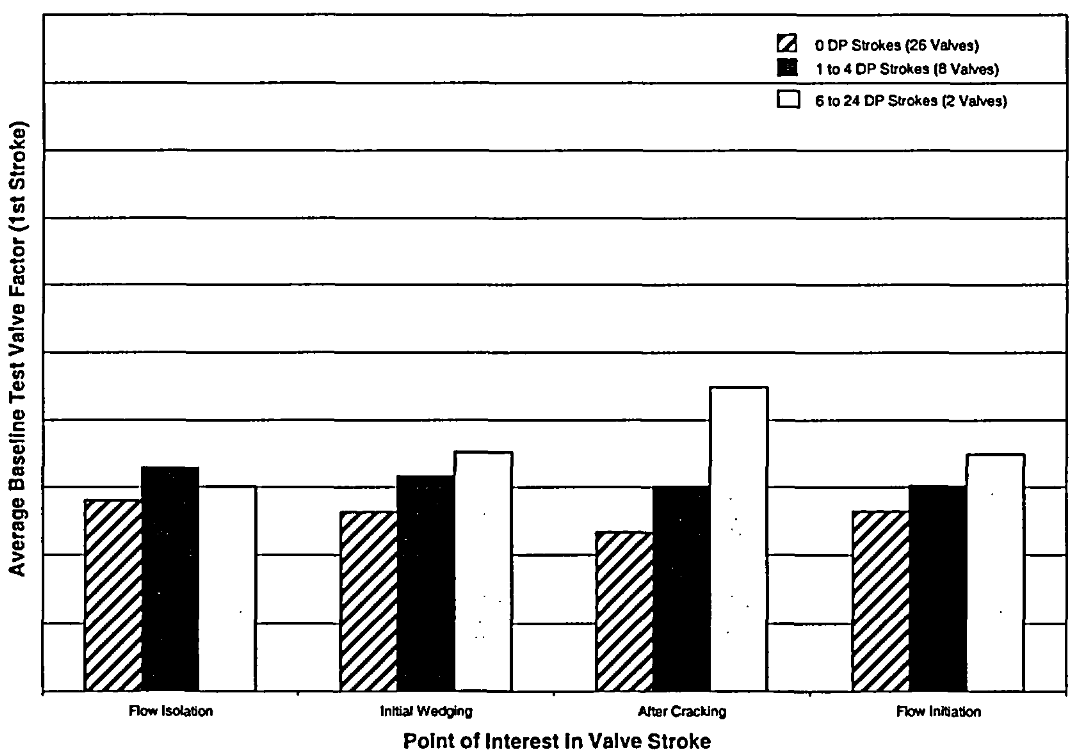


Figure 3-52. Average Baseline Valve Factors for Disassembled Gate Valves with Self-Mated Stellite Seat Materials, Considering the Number of DP Strokes Between Valve Disassembly/Reassembly and Baseline JOG Test

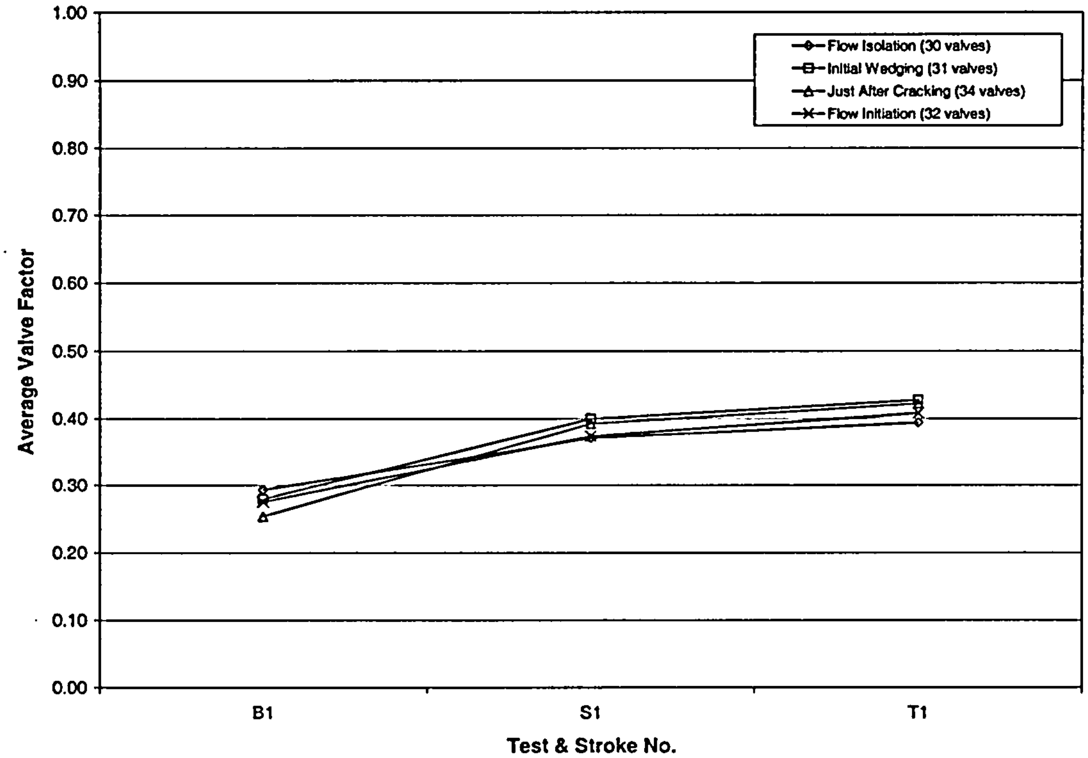
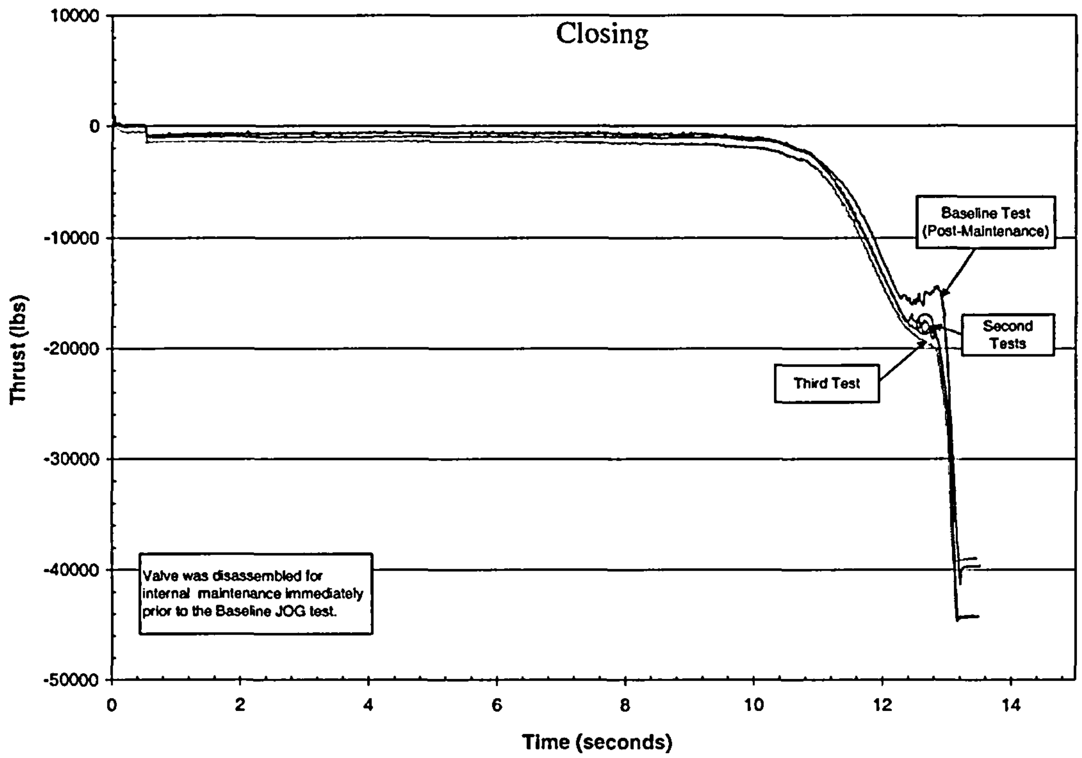


Figure 3-53. Average Valve Factors for Disassembled Gate Valves with Self-Mated Stellite Seat Materials



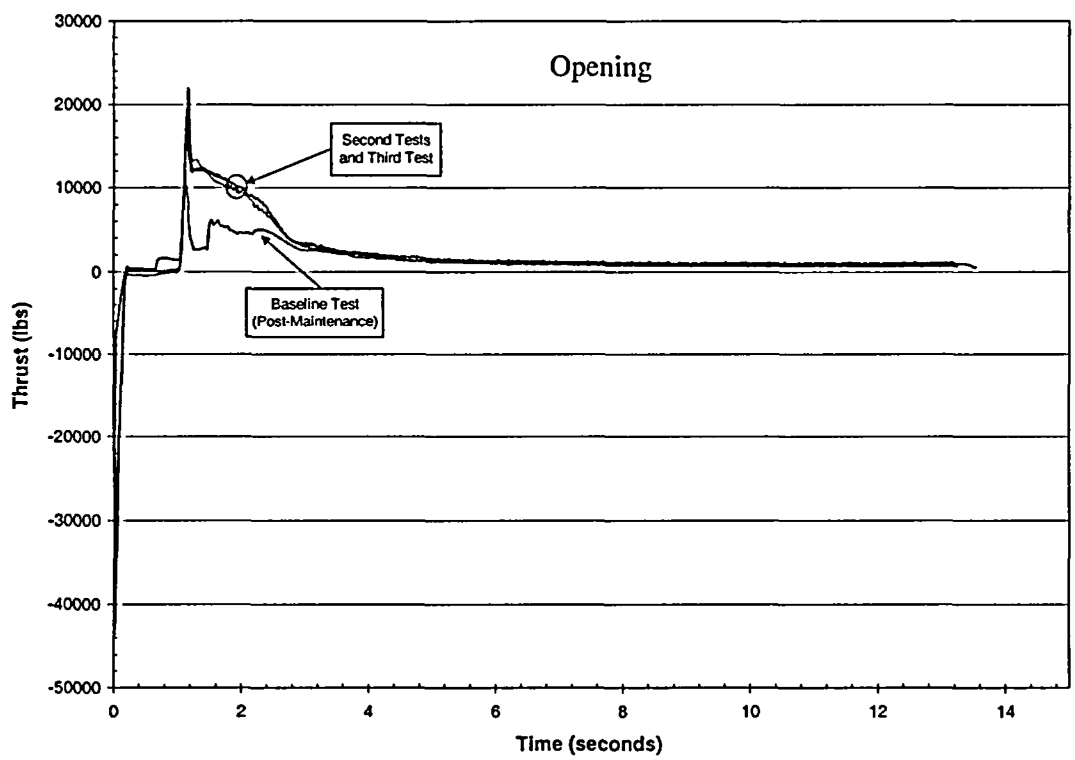


Figure 3-54. Closing and Opening Stroke Thrust Overlays for Disassembled Gate Valve G44.10

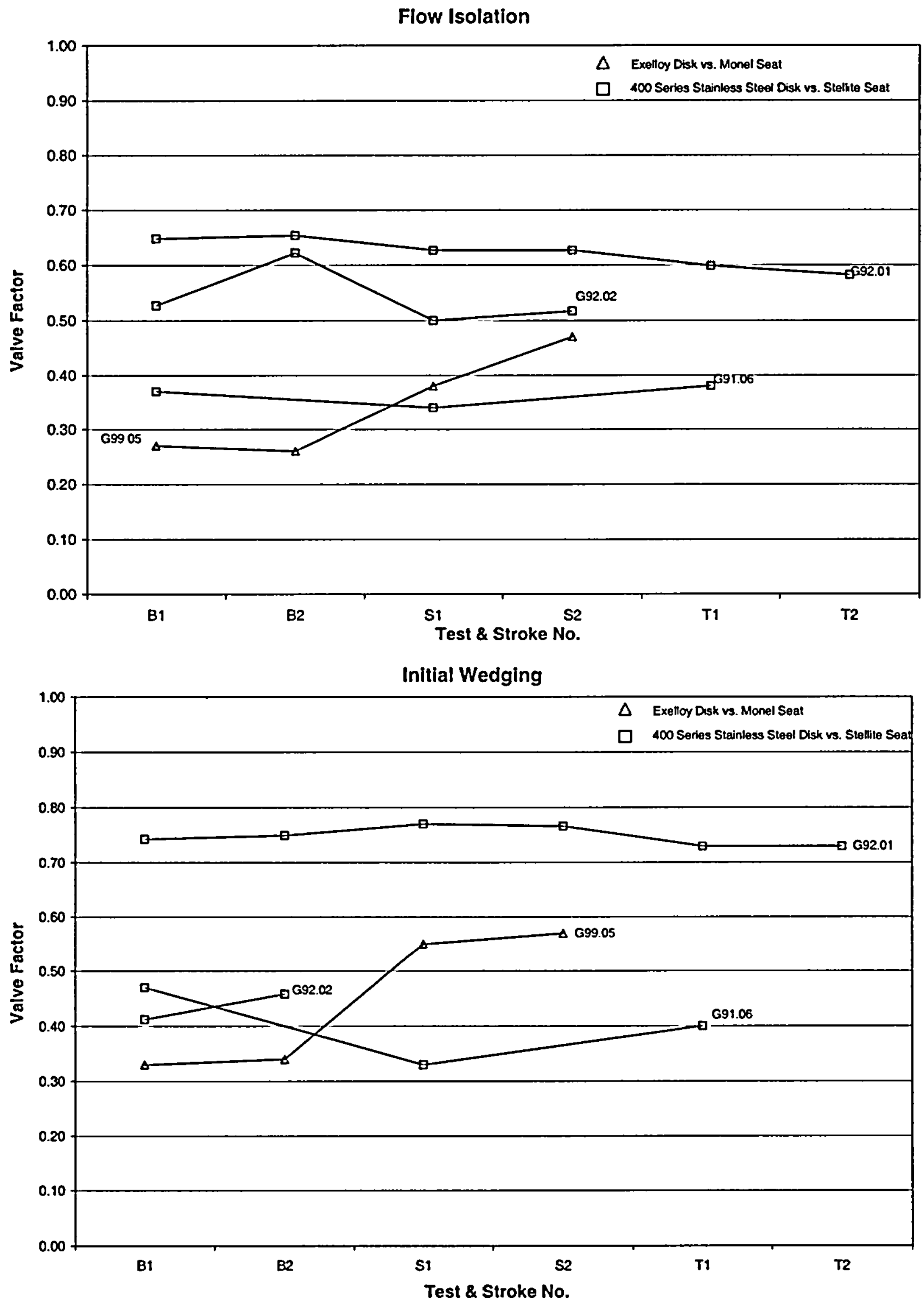
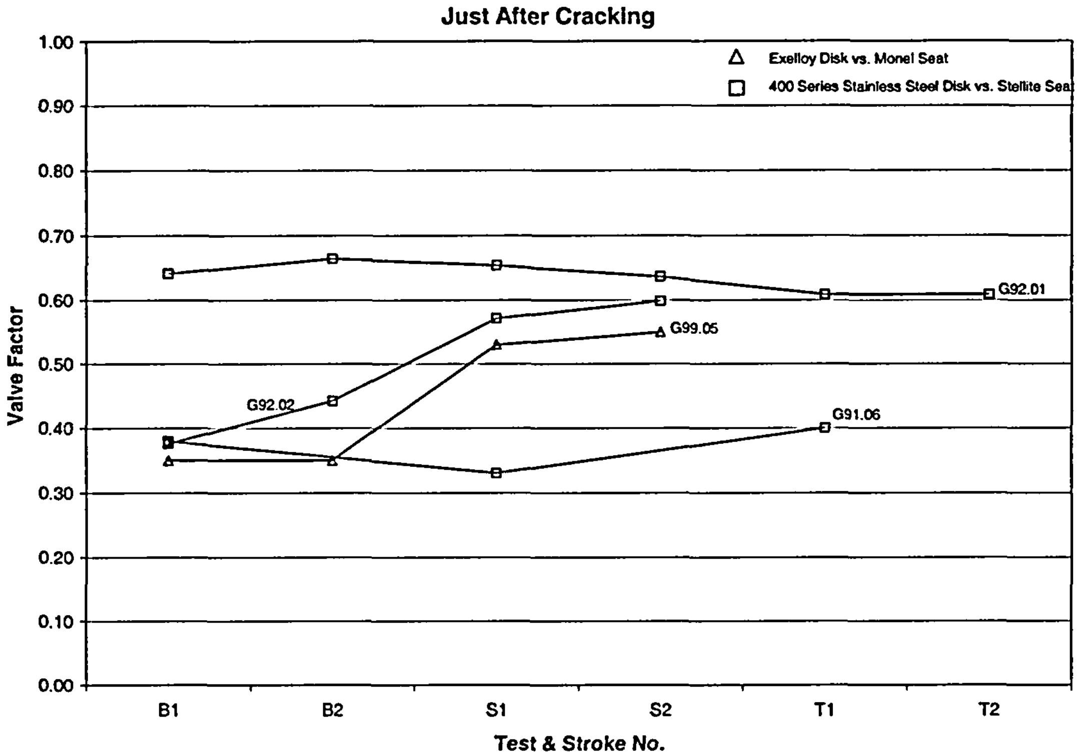


Figure 3-55. Close Valve Factors for Disassembled Gate Valves with 400 Series Stainless Steel Disk vs. Stellite Seat or Exelloy Disk vs. Monel Seat



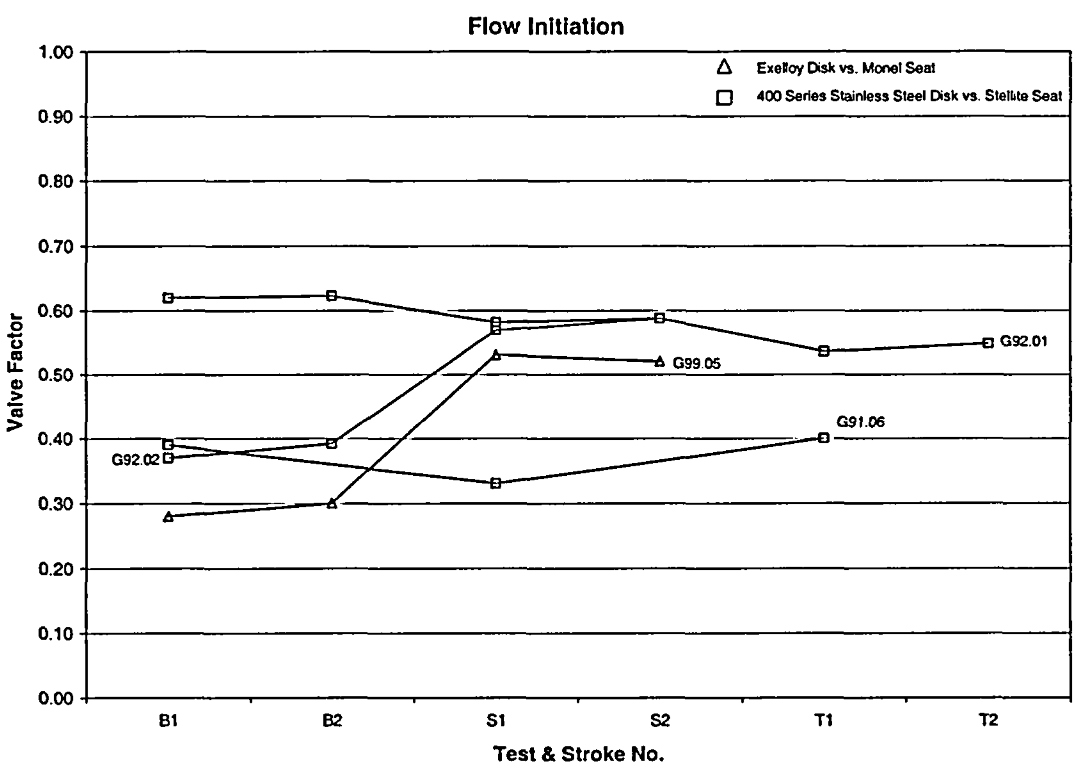


Figure 3-56. Open Valve Factors for Disassembled Gate Valves with 400 Series Stainless Steel Disk vs. Stellite Seat or Exelloy Disk vs. Monel Seat

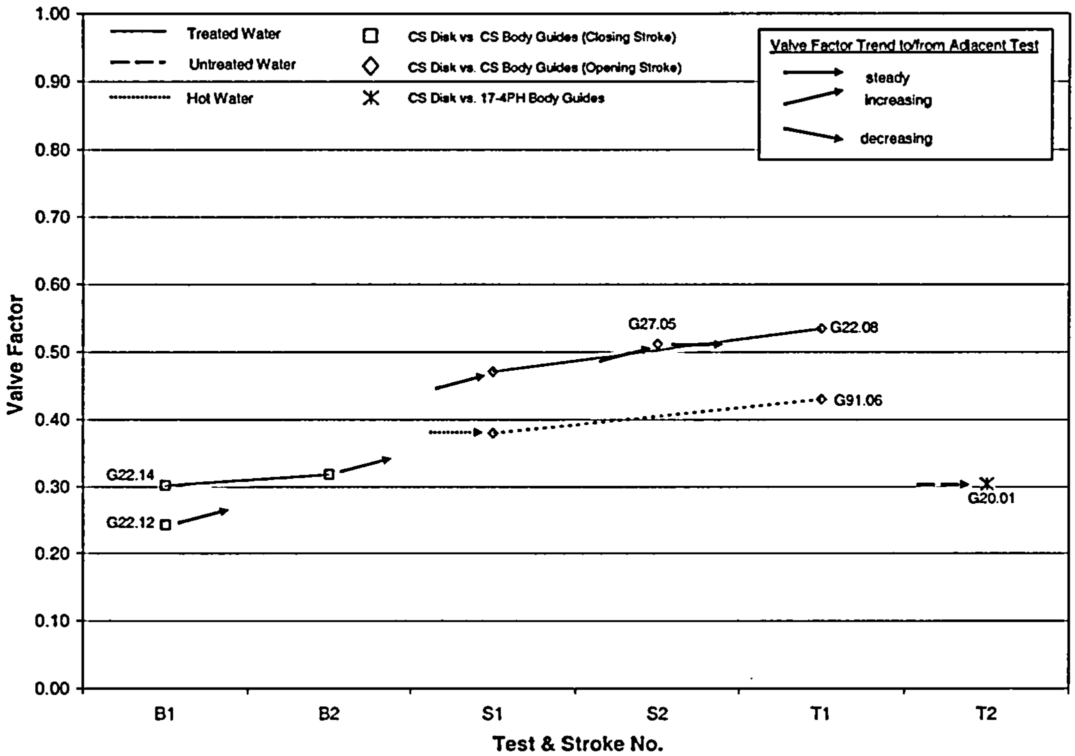


Figure 3-57. Guide Valve Factors for Disassembled Gate Valves with Self-Mated Carbon Steel and Carbon Steel vs. 17-4PH Stainless Steel Guides

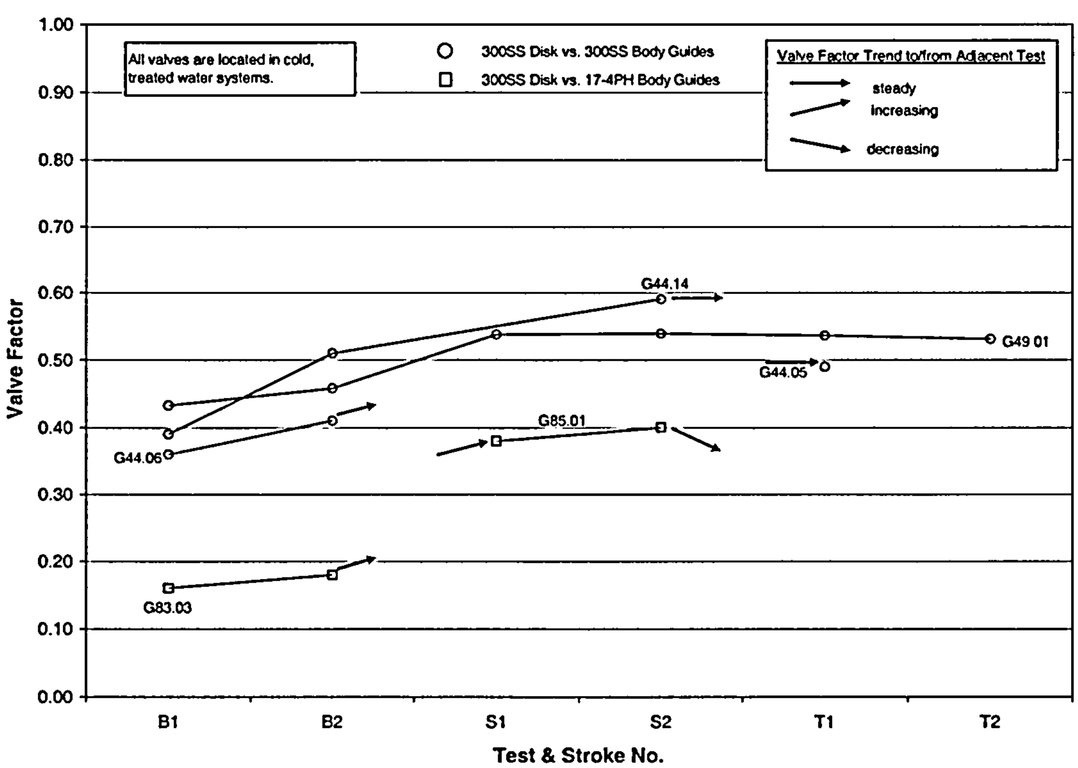


Figure 3-58. Guide Valve Factors for Disassembled Gate Valves with Self-Mated 300 Series Stainless Steel and 300 Series Stainless Steel vs. 17-4PH Stainless Steel Guides

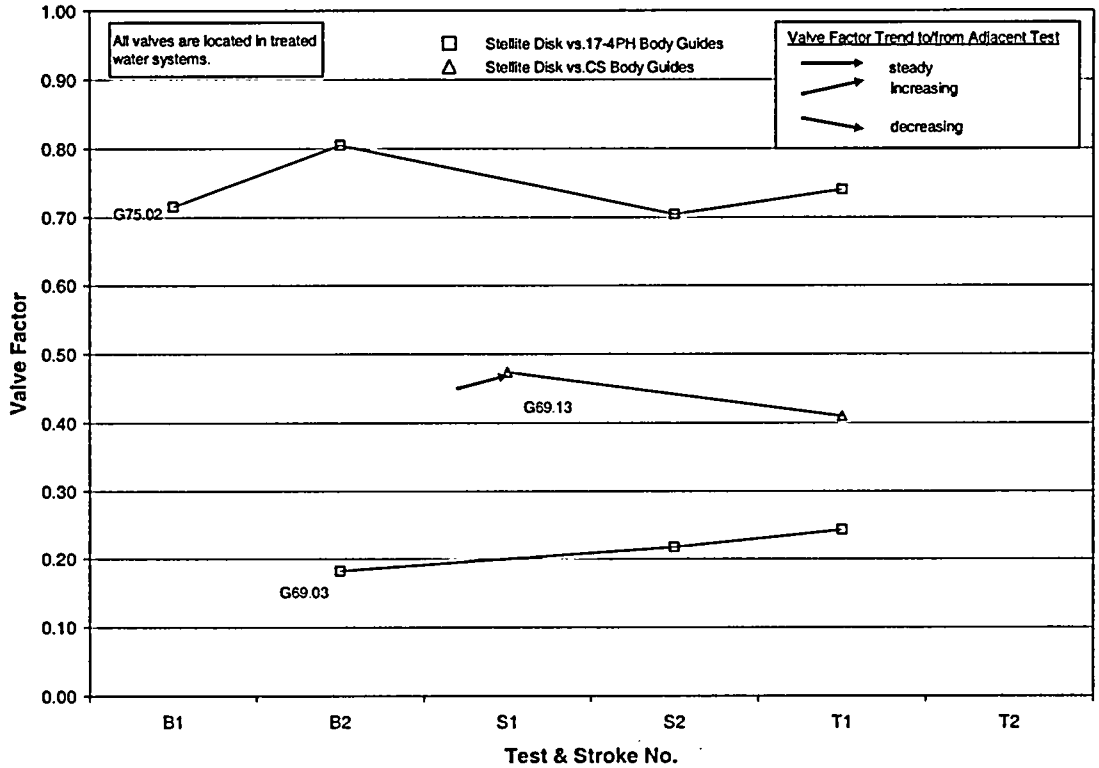
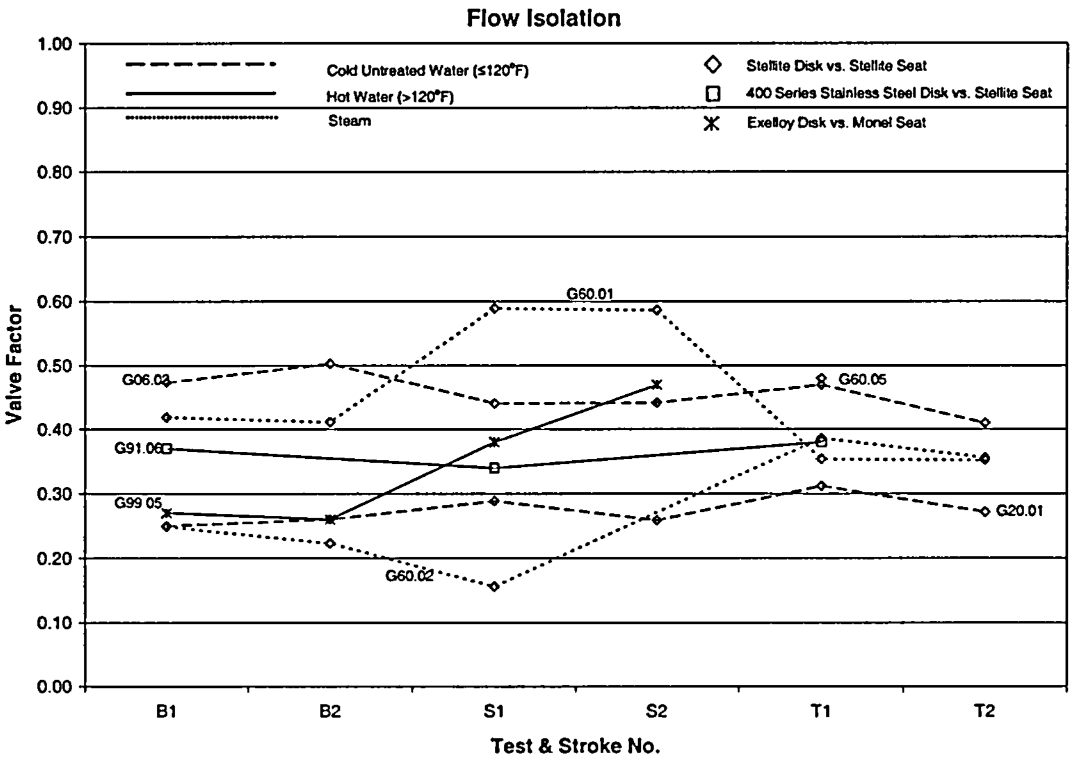


Figure 3-59. Guide Valve Factors for Disassembled Gate Valves with Other Guide Materials



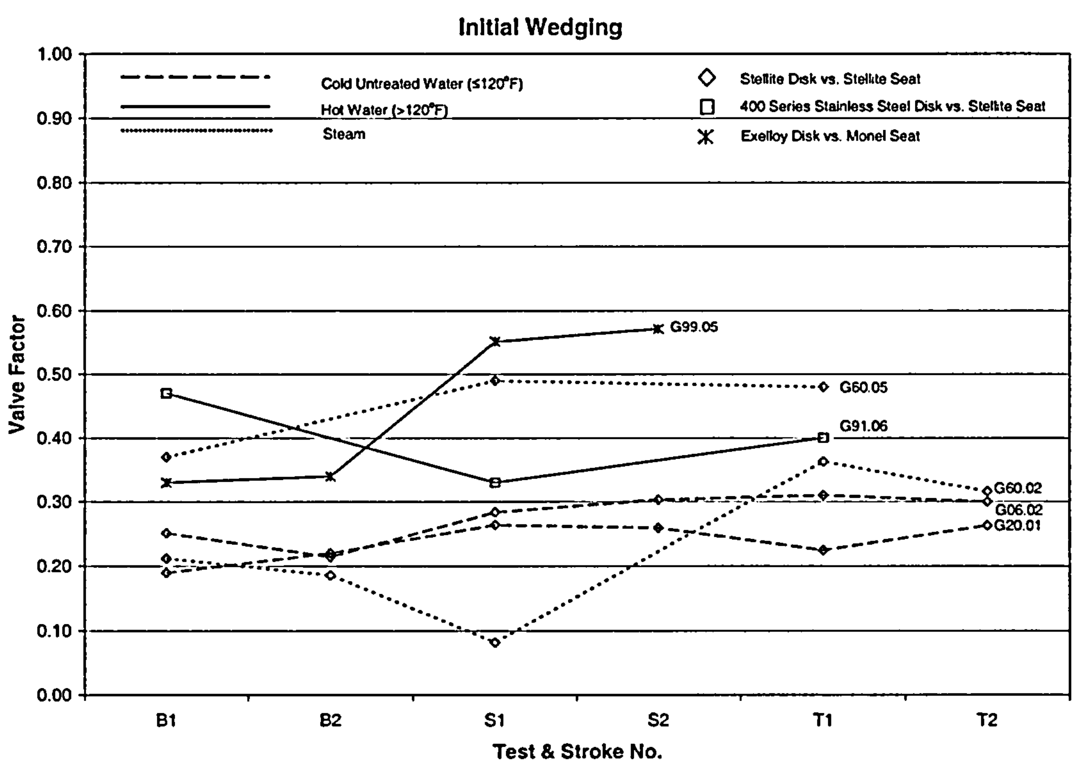
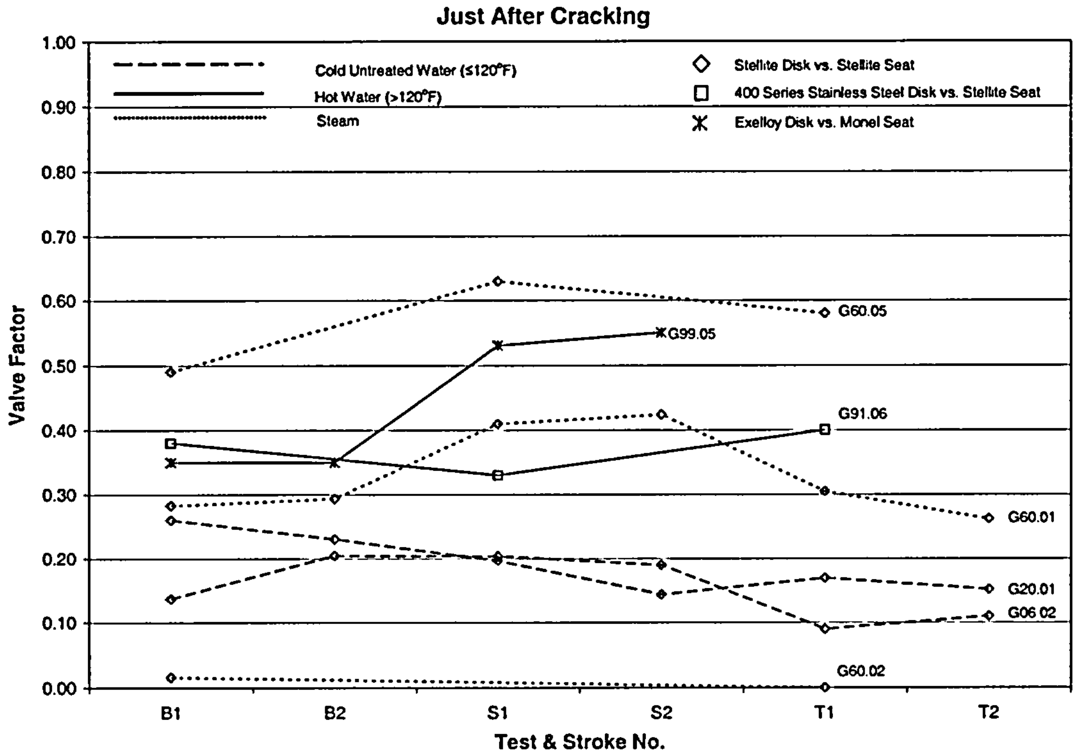


Figure 3-60. Close Valve Factors for Disassembled Gate Valves in Untreated Water, Hot Water or Steam



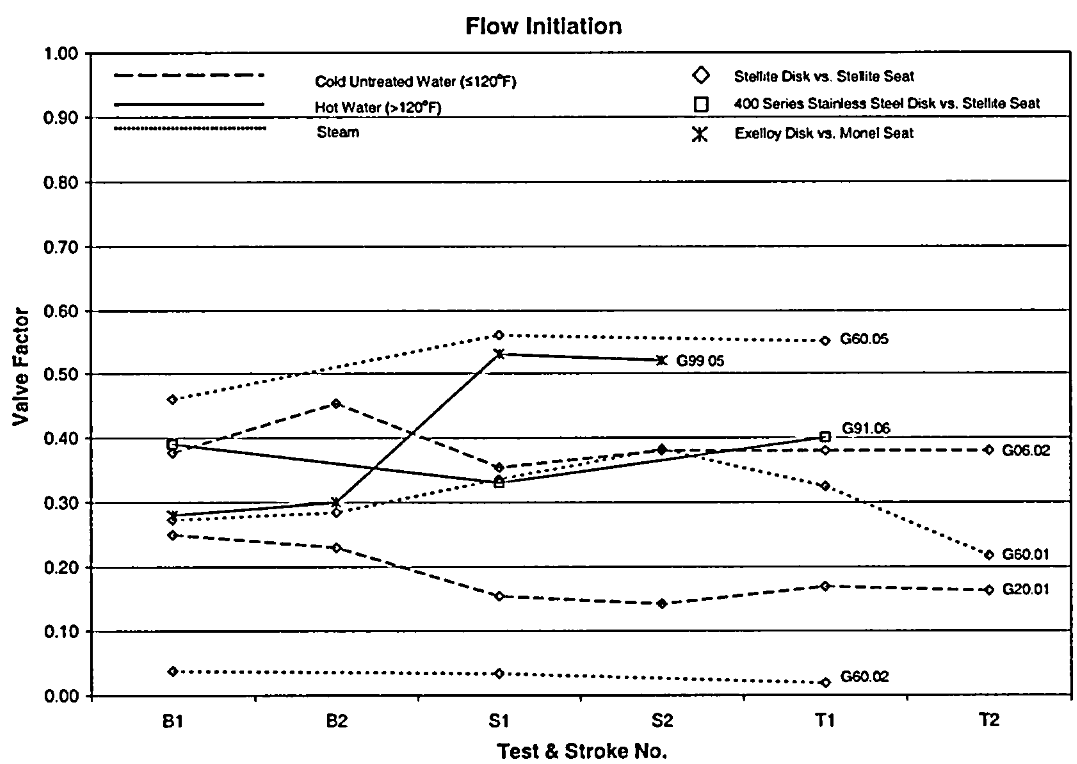


Figure 3-61. Open Valve Factors for Disassembled Gate Valves in Untreated Water, Hot Water or Steam

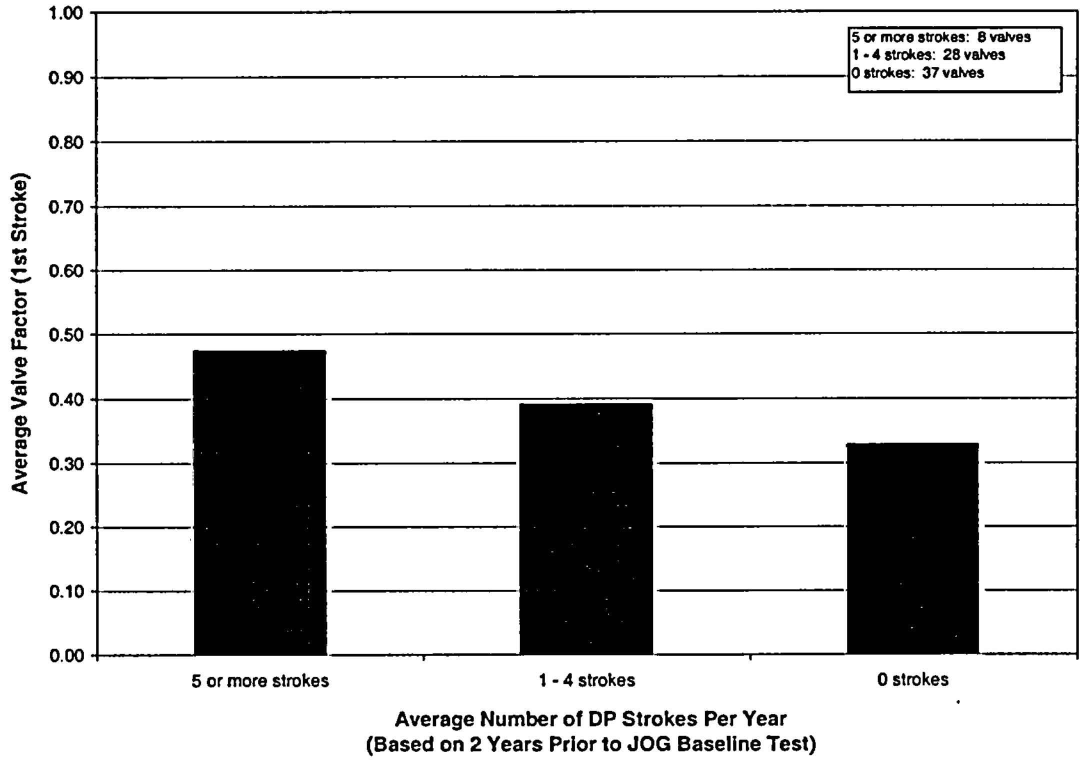


Figure 3-62. Comparison of Baseline Test Valve Factors for Non-Disassembled Gate Valves with Self-Mated Stellite Seat Materials in Water

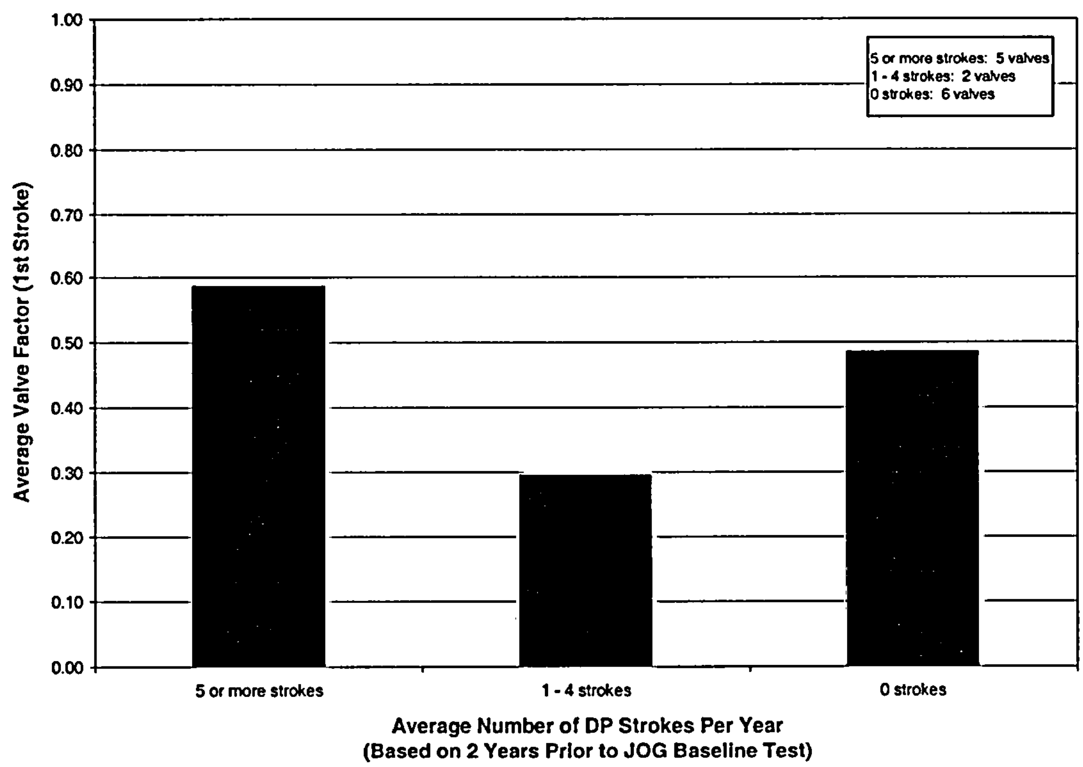


Figure 3-63. Comparison of Baseline Test Valve Factors for Non-Disassembled Gate Valves with Other (Non-Stellite) Seat Materials in Water

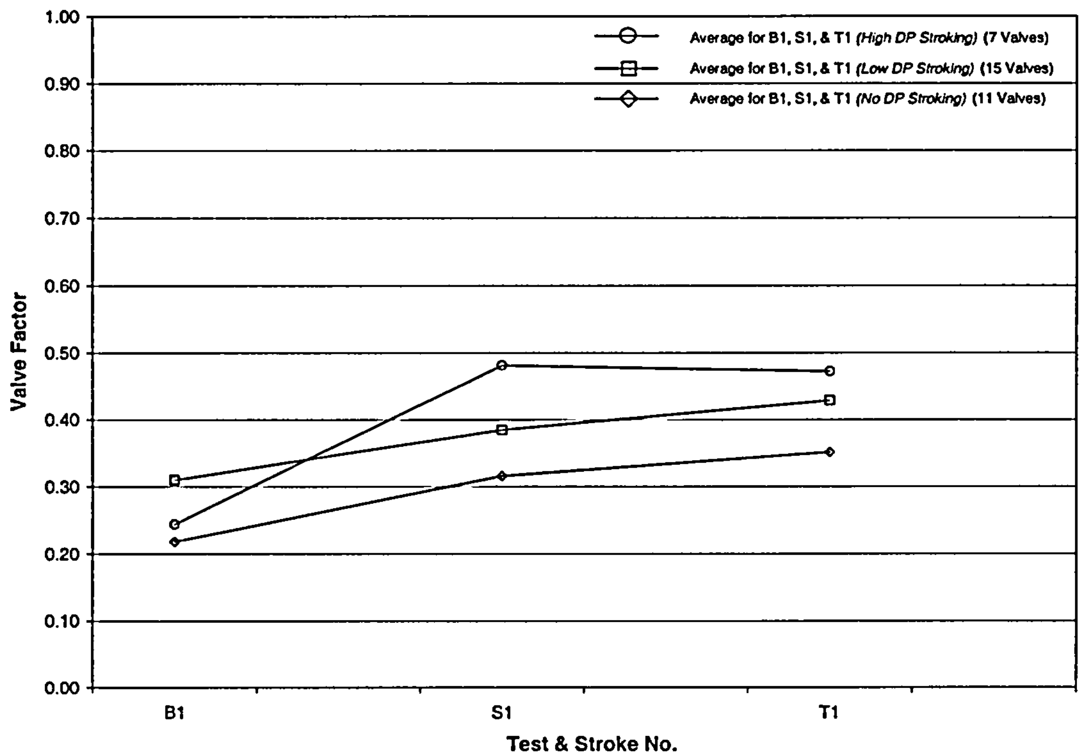


Figure 3-64. Average Valve Factors for Disassembled Gate Valves with Self-Mated Stellite Seats in Water Systems

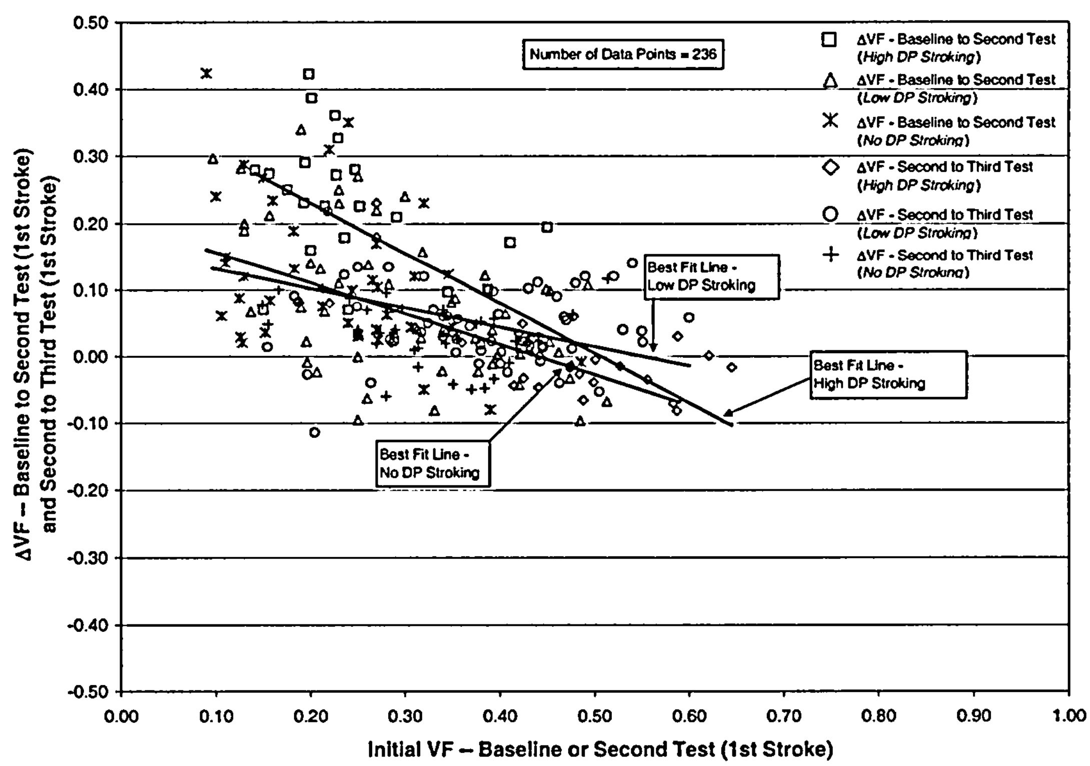


Figure 3-65. Change in Valve Factor vs. Initial Valve Factor for Disassembled Gate Valves with Self-Mated Stellite Seats in Water Systems

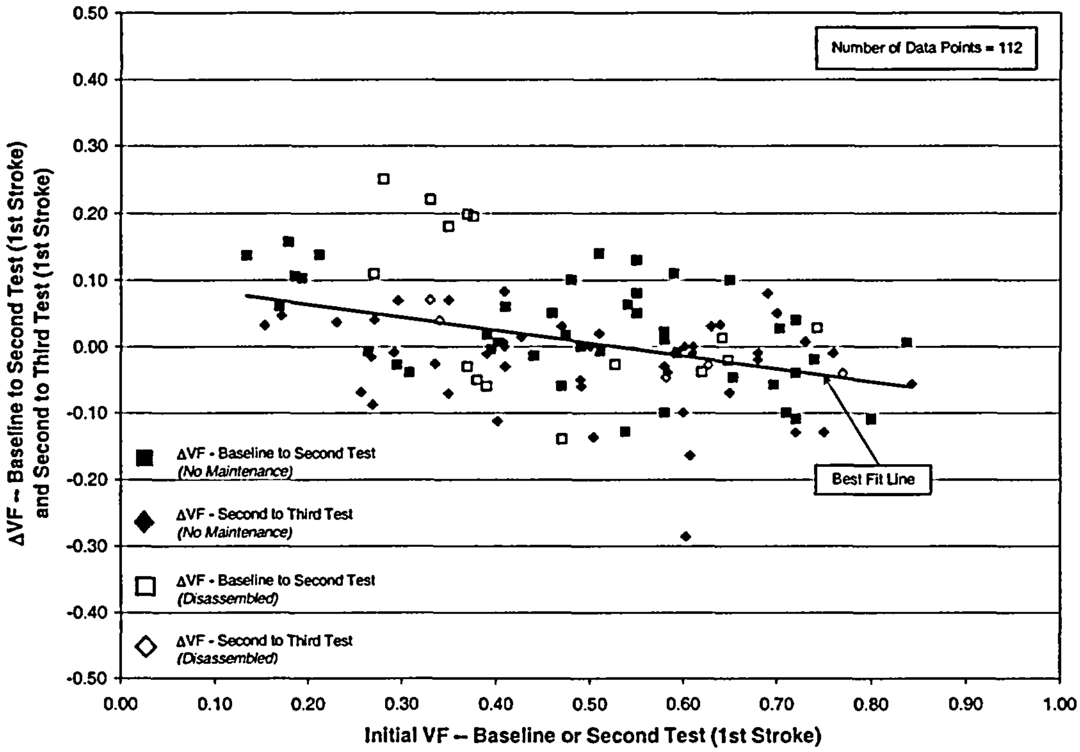


Figure 3-66. Change in Valve Factor vs. Initial Valve Factor for Gate Valves with Non-Stellite Seats in Water Systems

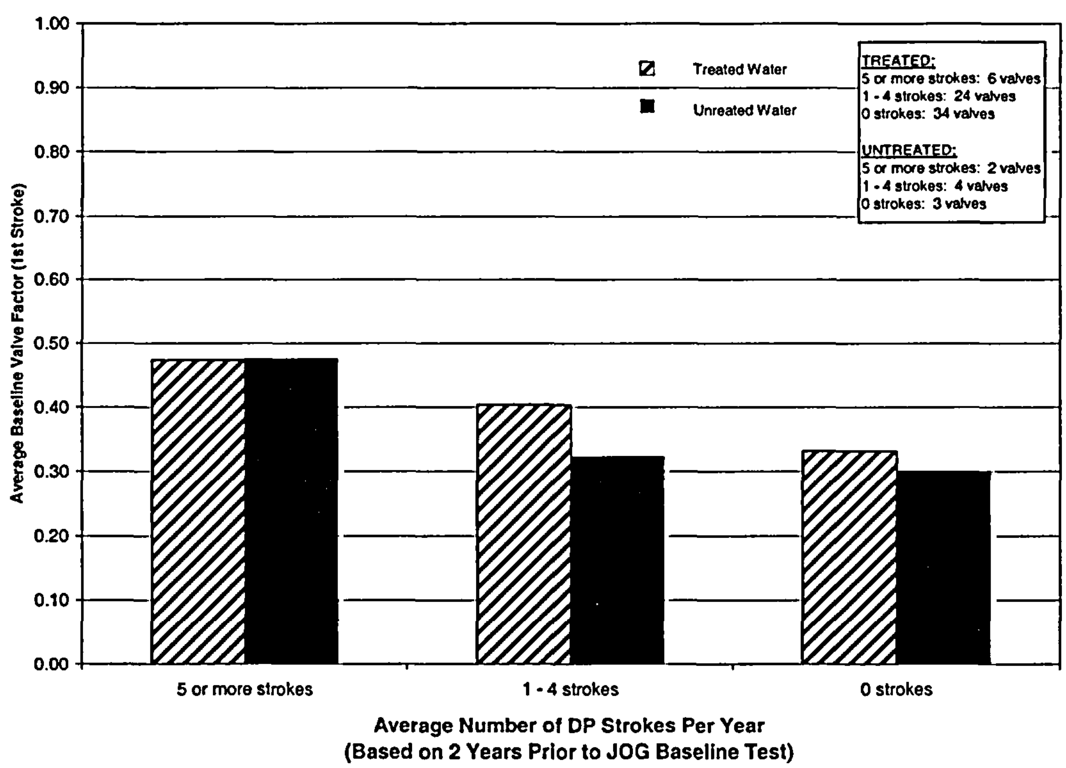


Figure 3-67. Comparison of Baseline Test Valve Factors for Non-Disassembled Gate Valves with Self-Mated Stellite Seats in Treated and Untreated Water

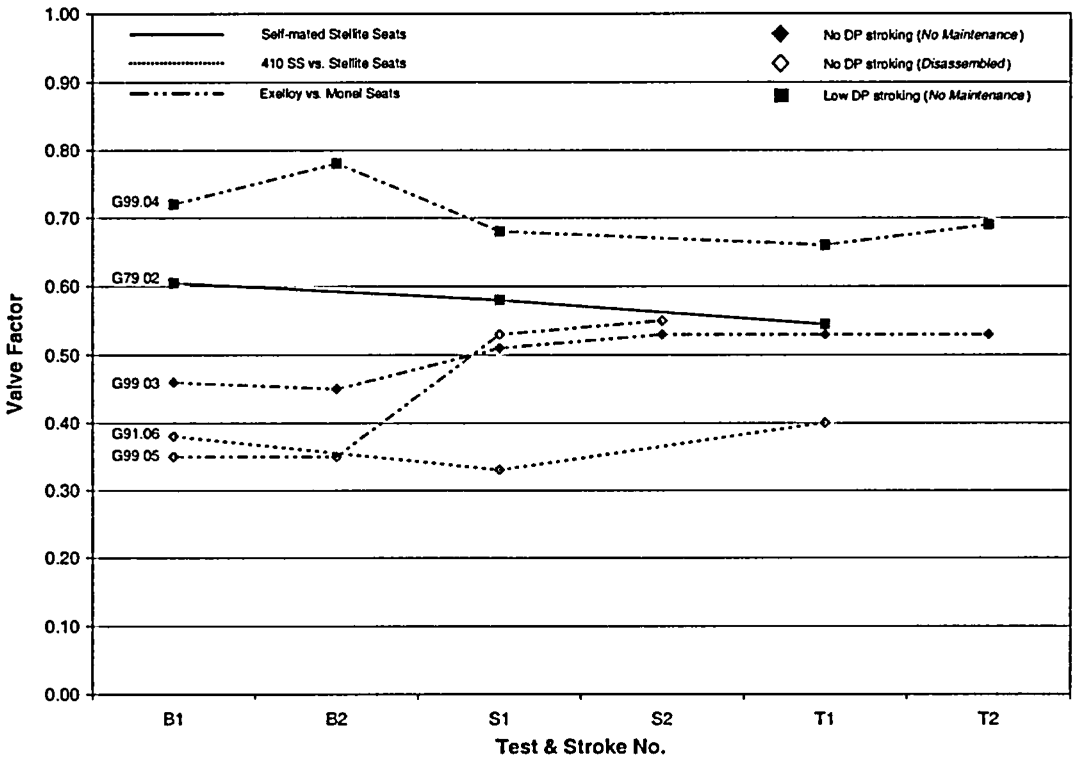


Figure 3-68. Valve Factors at Just After Cracking for Gate Valves in Hot Water Systems

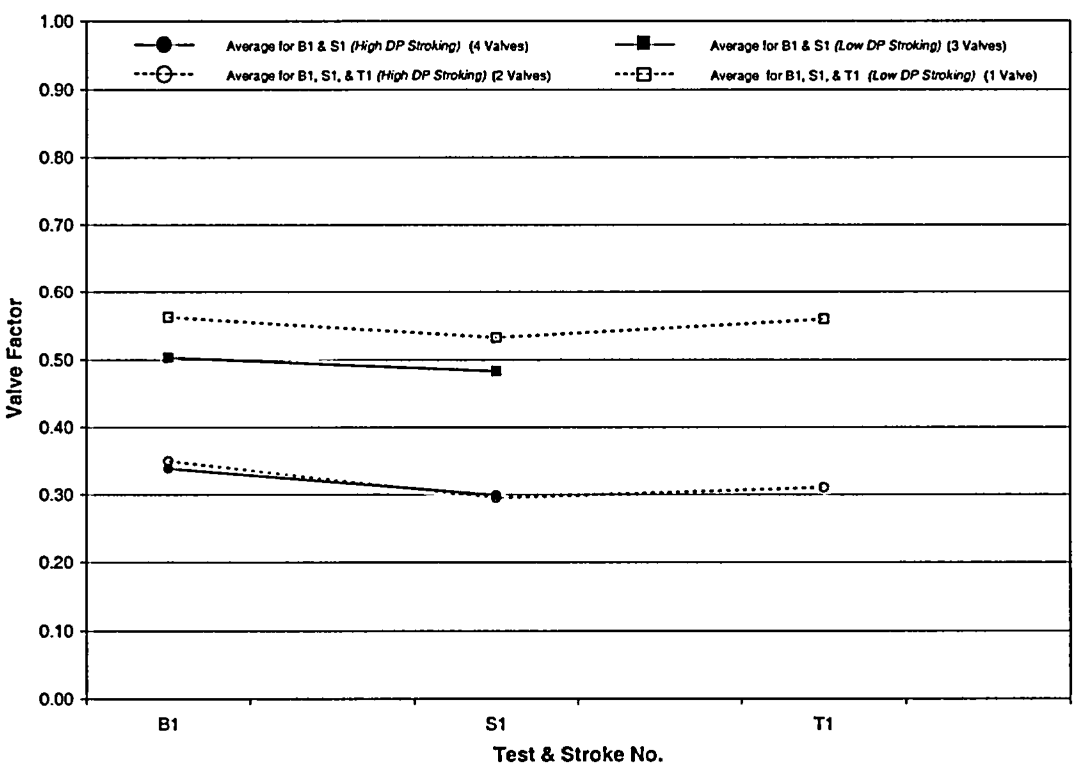
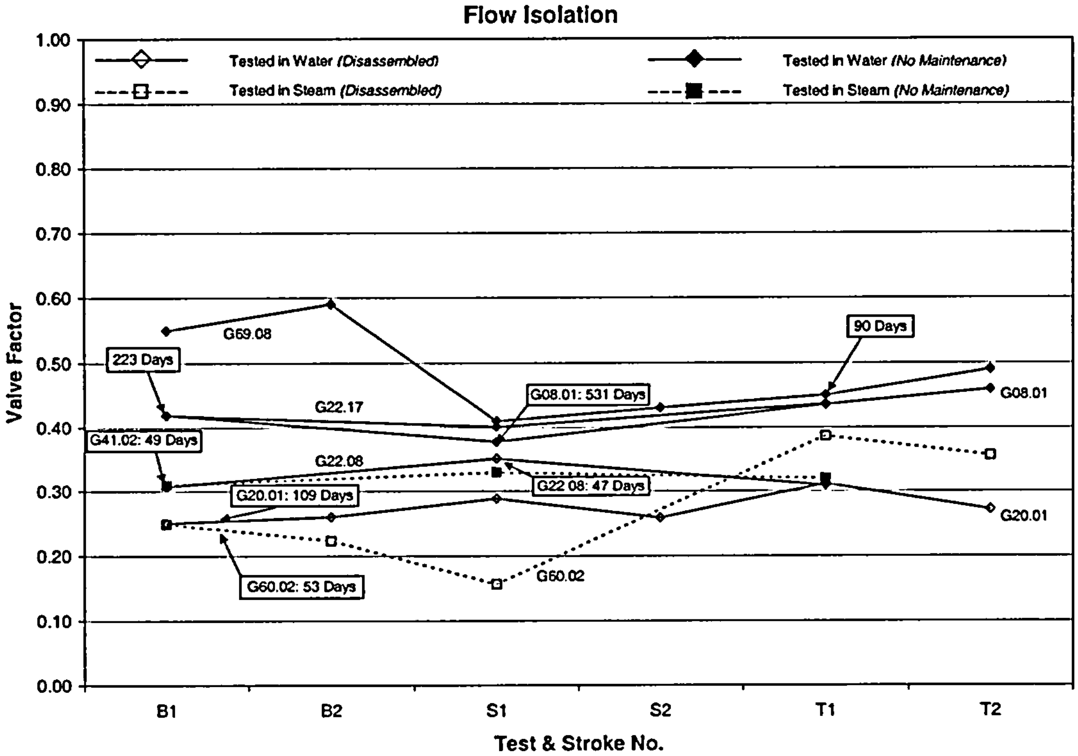


Figure 3-69. Average Seat Friction Valve Factors for Non-Disassembled Valves in Steam Systems



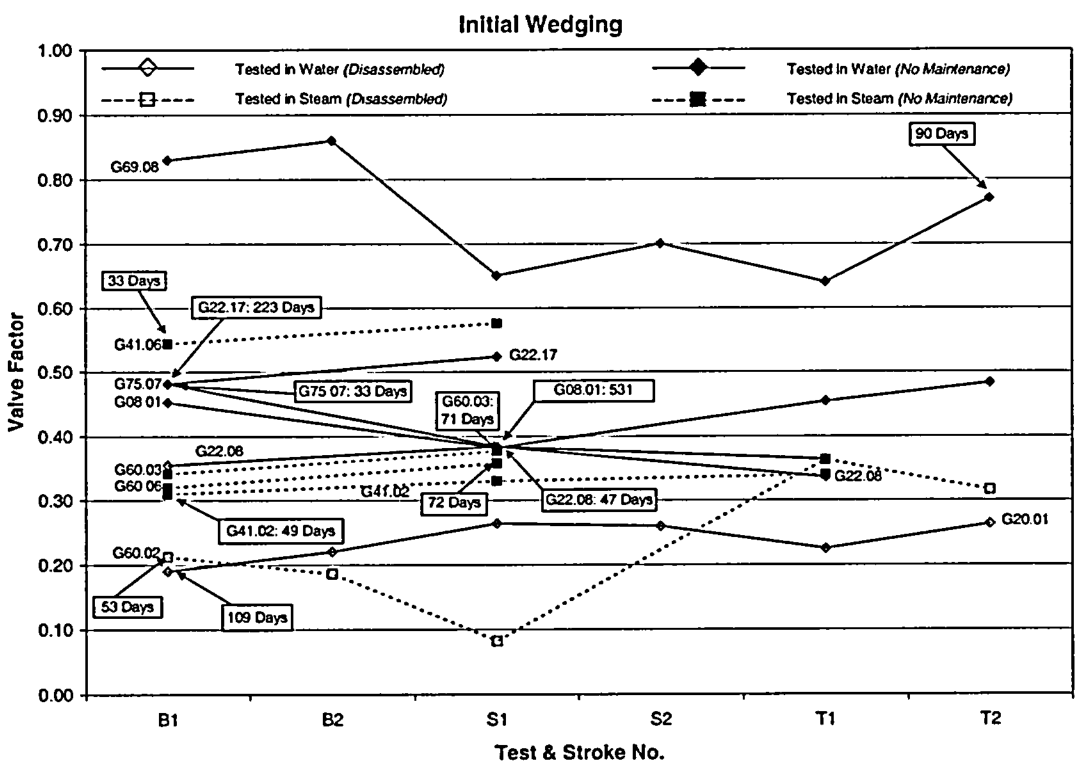


Figure 3-70. Close Valve Factors for Gate Valves with Stellite Seats – DP Stroke > 29 Days After Static Stroke

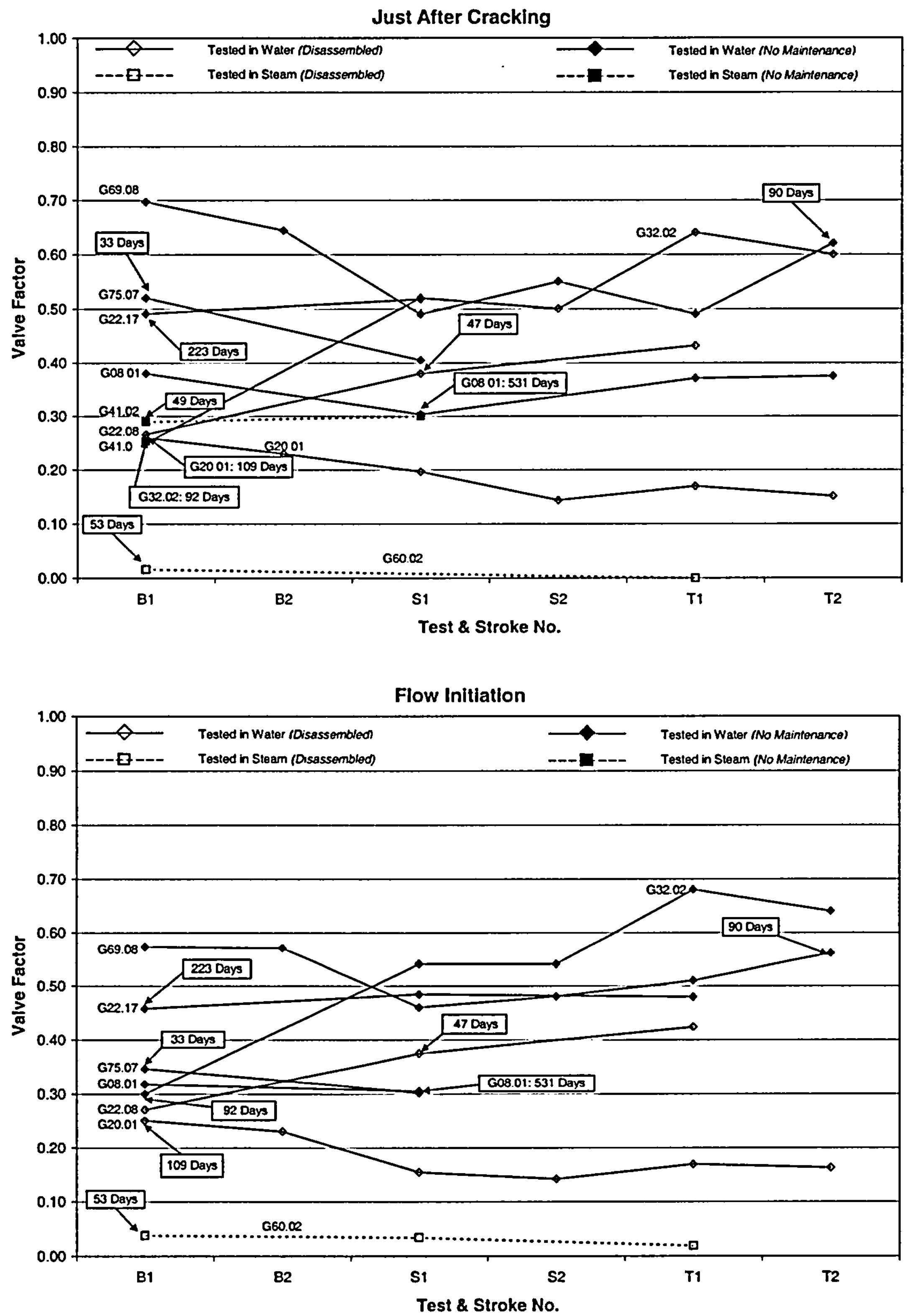
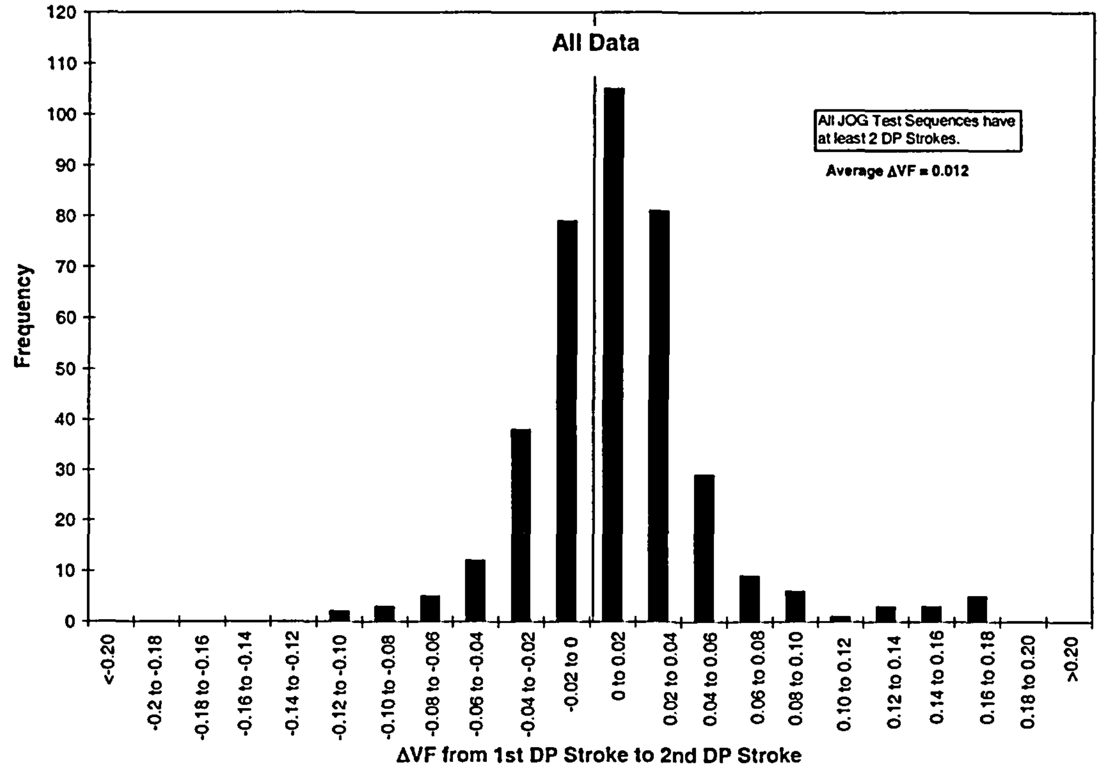


Figure 3-71. Open Valve Factors for Gate Valves with Stellite Seats – DP Stroke > 29 Days After Static Stroke



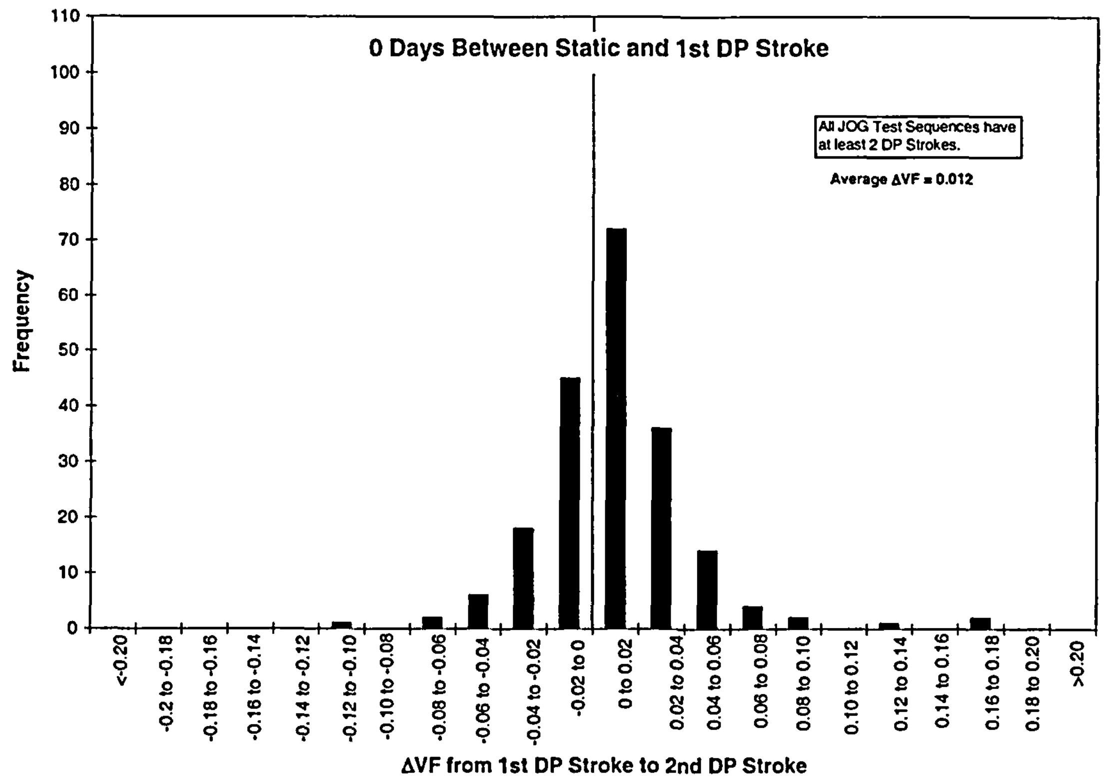
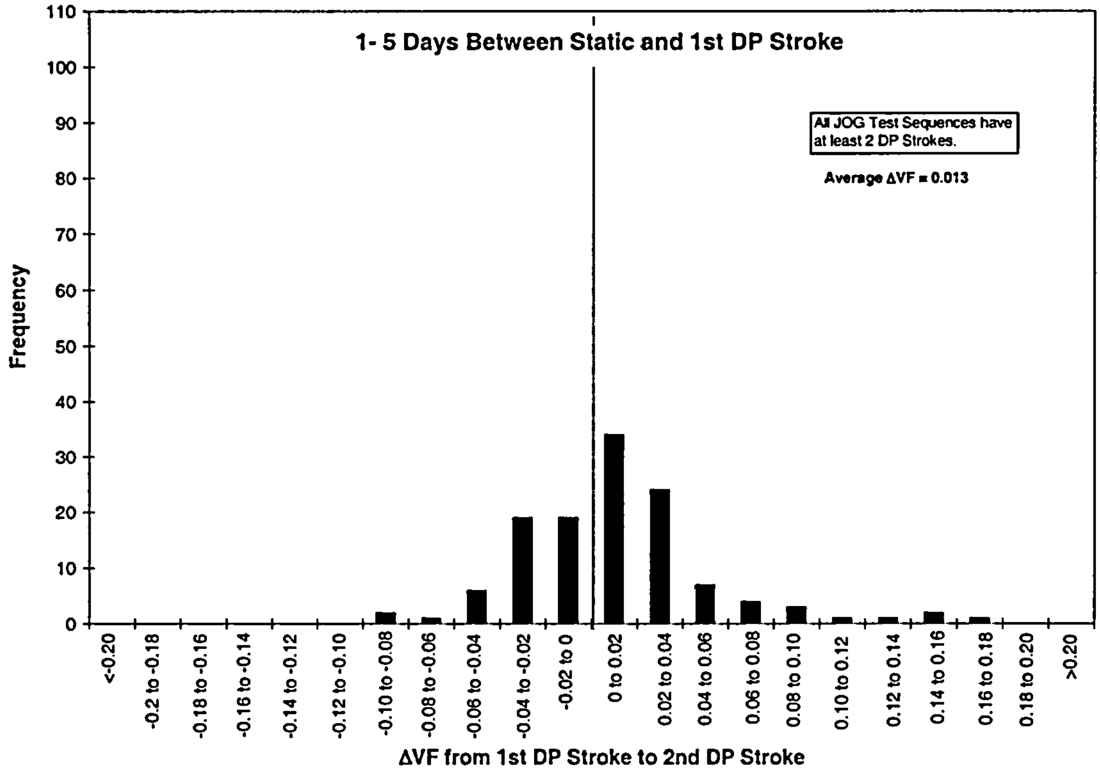


Figure 3-72. Δ Valve Factor (stroke-to-stroke) for Gate Valves with Stellite Seats in Cold Treated Water (No Maintenance)



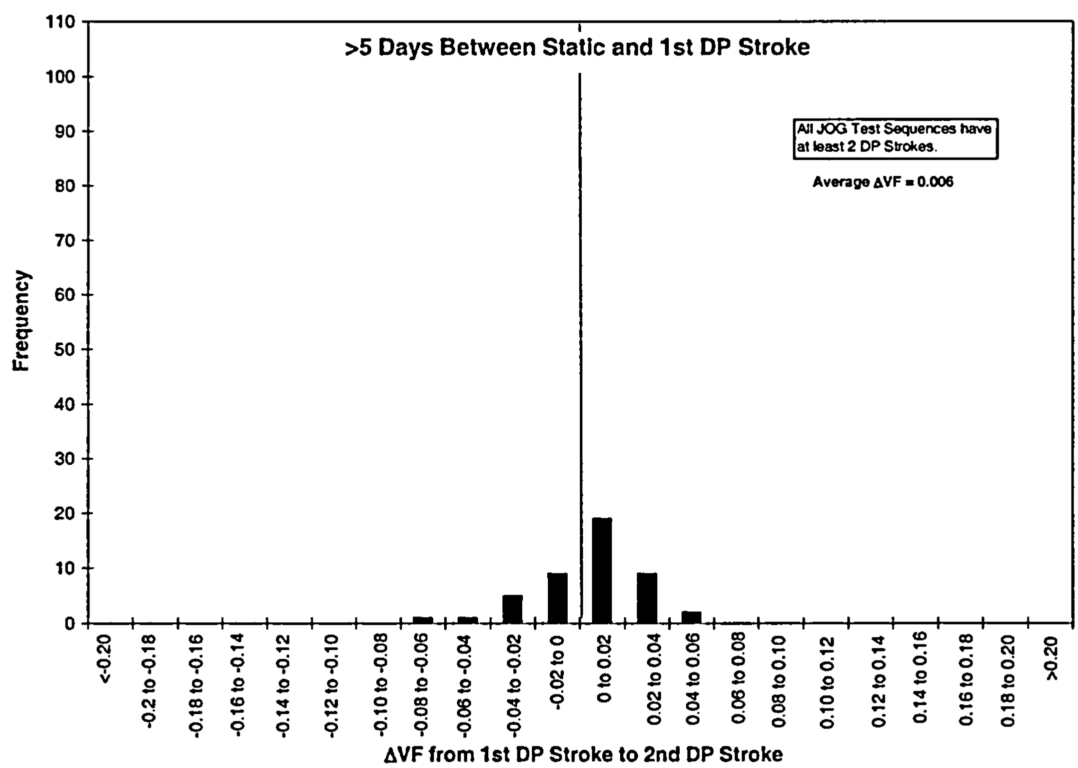
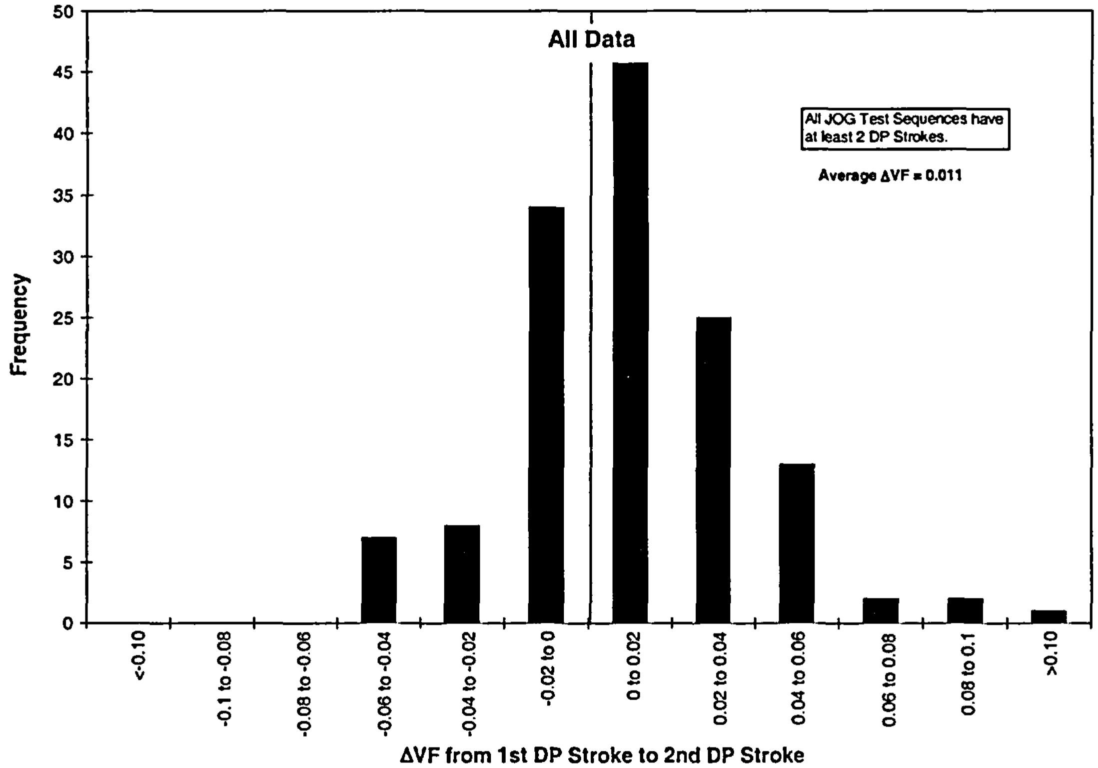


Figure 3-73. Δ Valve Factor (stroke-to-stroke) for Gate Valves with Stellite Seats in Cold Treated Water (No Maintenance)



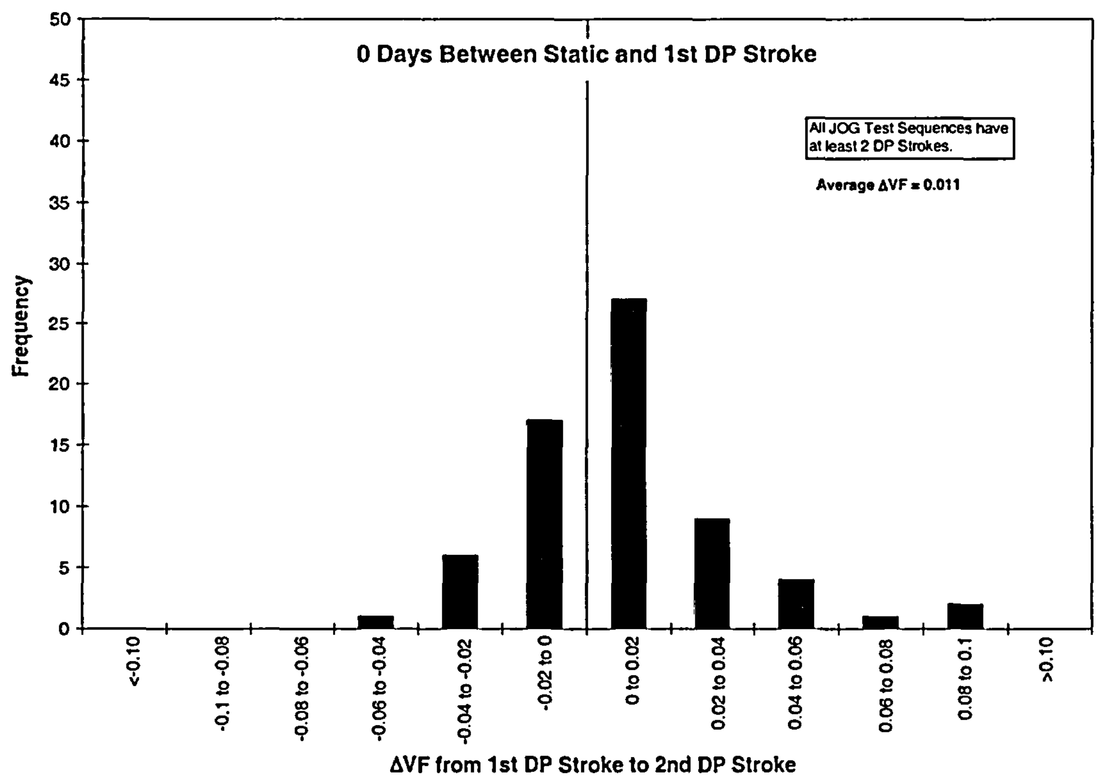
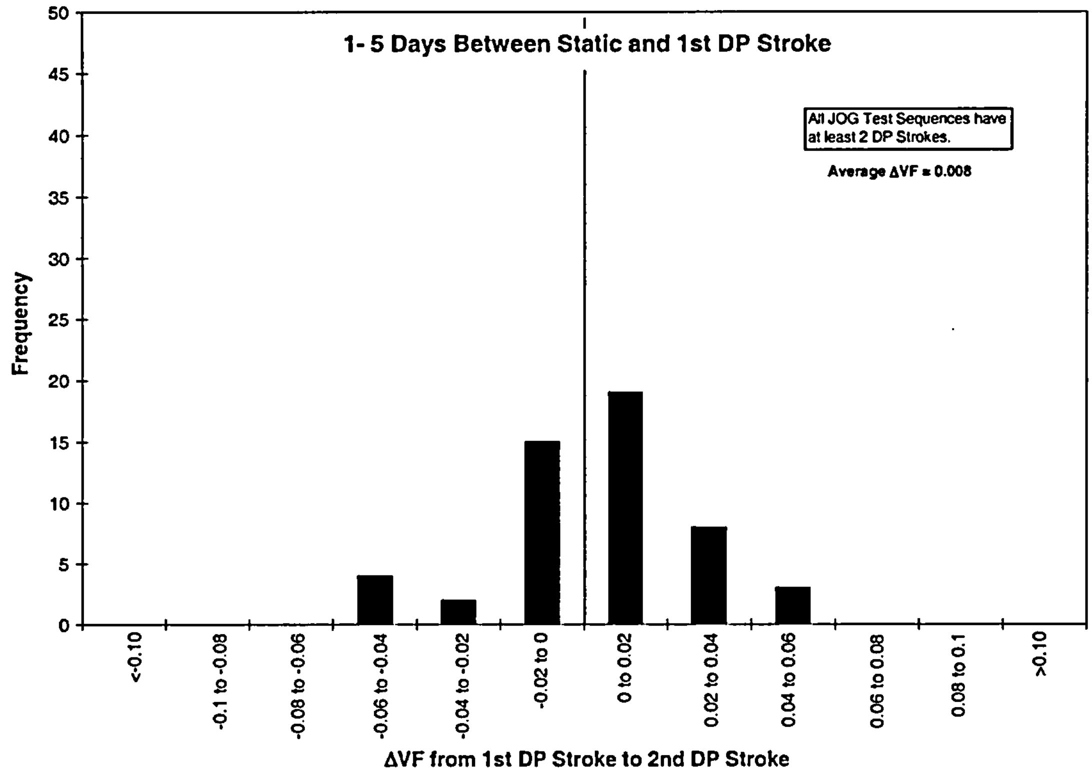


Figure 3-74. Δ Valve Factor (stroke-to-stroke) for Gate Valves with Stellite Seats in Normally Hot / Tested Cold Treated Water (No Maintenance)



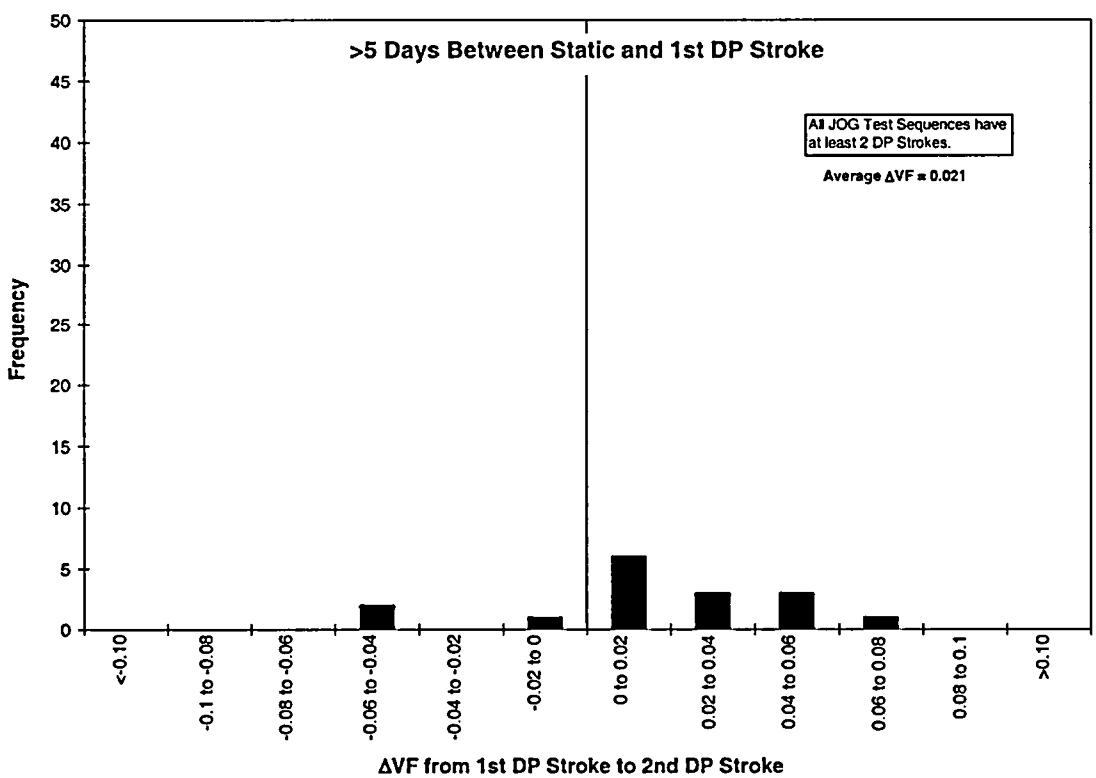
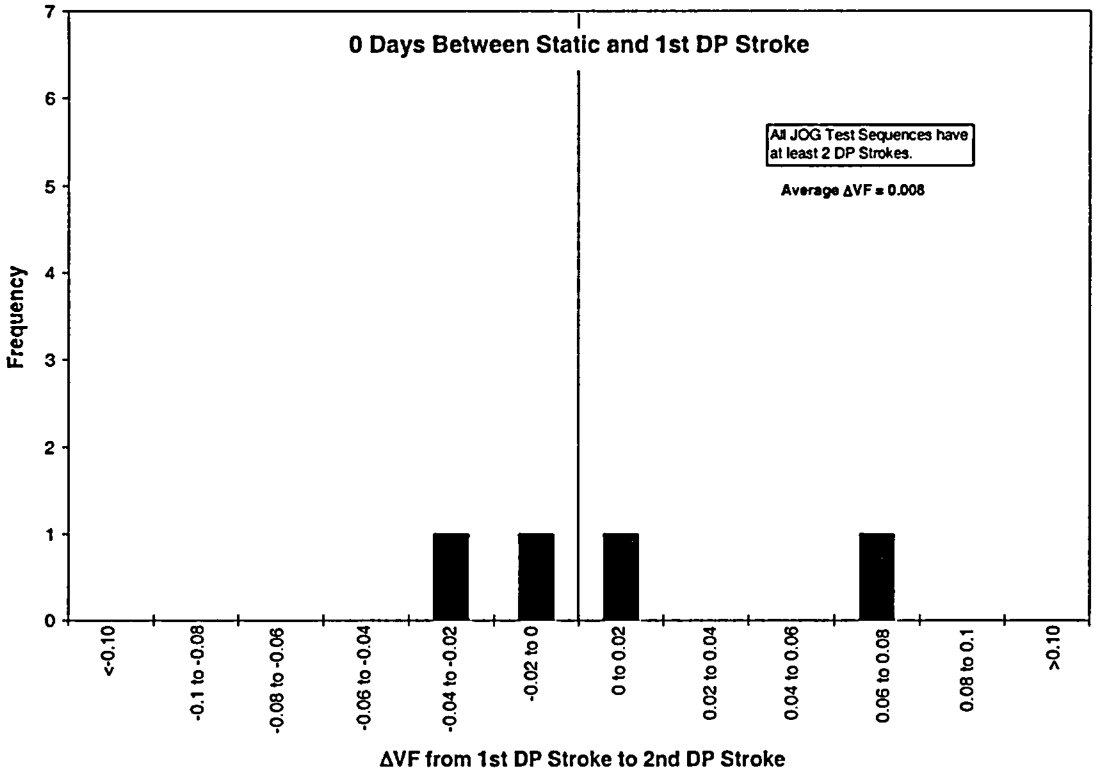


Figure 3-75. Δ Valve Factor (Stroke-to-Stroke) for Gate Valves with Stellite Seats in Normally Hot / Tested Cold Treated Water (No Maintenance)



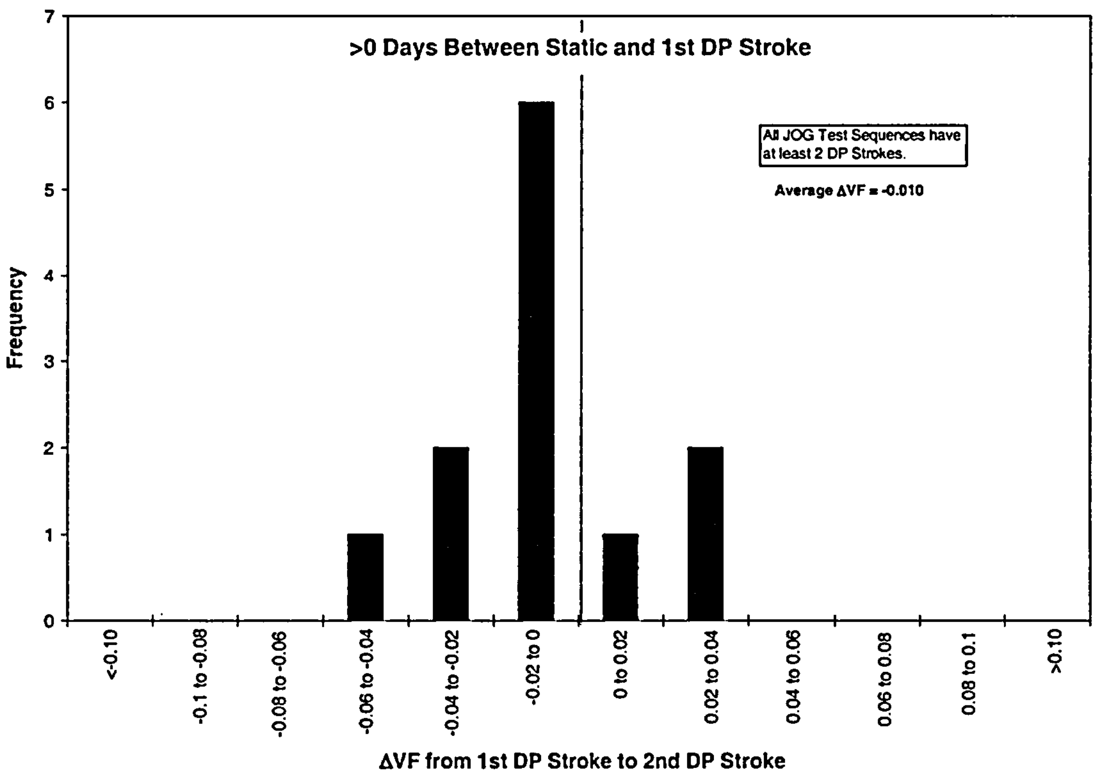


Figure 3-76. Δ Valve Factor (Stroke-to-Stroke) for Gate Valves with Stellite Seats in Hot Water / Steam Systems (No Maintenance)

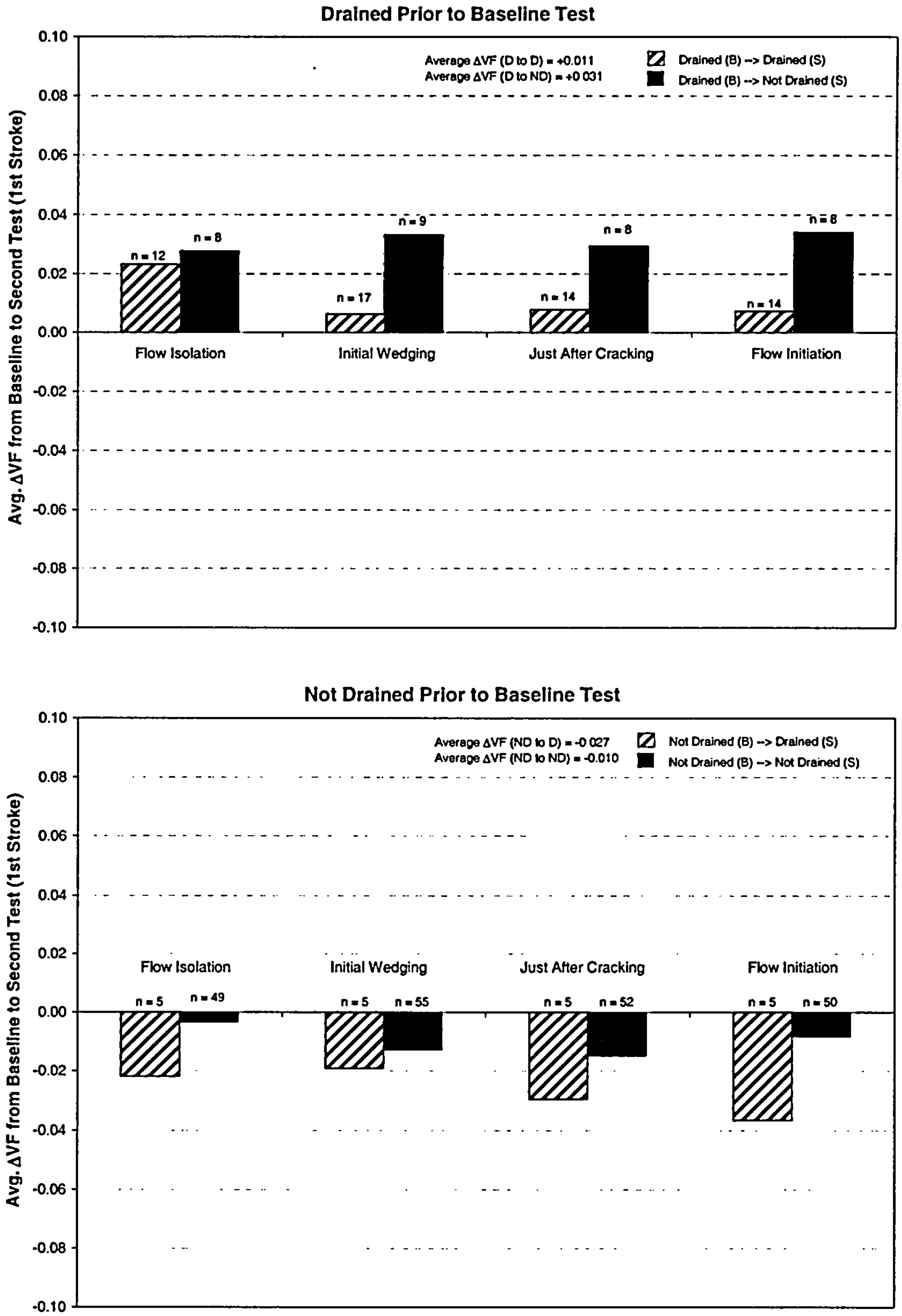


Figure 3-77. Average Change in Valve Factor (Baseline to Second Test) for Non-Disassembled Gate Valves to Evaluate the Effects of Draining/Venting/Refilling

4 Test Program Results for Butterfly Valves

SUMMARY

Twenty-three butterfly valves were tested as part of the JOG MOV PV Program, representing the variety of valve design attributes and fluid conditions found in typical nuclear applications for butterfly valves. The results from these twenty-three valves indicate there is no age-related or service-related degradation in required bearing torque. The valves were categorized into four groups based on bearing material and fluid medium. The results from the four valves with bronze bearings in treated water indicate that the bearing friction coefficient is relatively stable. The results from the seven valves with bronze bearings in untreated water indicate that the three valves with hub seals exhibit behavior similar to that of bronze bearings in treated water. For the four valves without hub seals, there is significant variation in the bearing friction coefficient. This variation is unrelated to DP stroking, and there is no overall increasing or decreasing trend. Similar variation was observed for one valve with a 300 series stainless steel bearing in untreated water without a hub seal. The results from the eleven valves with non-metallic bearings show small variations in bearing friction coefficient unrelated to DP stroking, and without an increasing or decreasing trend.

APPROACH FOR BUTTERFLY VALVES

The intent of the JOG MOV PV Program was to test several butterfly valves to determine if there were observable changes in the required DP torque which could be related to degradation. As described in the JOG MOV PV Program Description Topical Report (Reference 3), only the bearing torque component of the required DP torque needs to be evaluated for degradation under dynamic conditions.

The bearing torque is directly proportional to the bearing friction, which is primarily affected by the bearing material. The Topical Report identifies two mechanisms for degradation of the bearing friction coefficient:

- Wear of bearing material from cumulative stroking
- Accumulation of particulates (from the fluid) in the bearing

Accordingly, it was judged important to identify test valves that covered a variety of bearing materials and that are tested in both treated and untreated fluid systems. The industry was surveyed to determine which butterfly valves were available for periodic DP testing. The primary bearing materials for butterfly valves used in nuclear service are (1) bronze bearings against a stainless steel shaft, and (2) Teflon-lined bearings (with a stainless steel backing or in a fiberglass carrier) against a stainless steel shaft. Other bearing materials are used in nuclear service on a limited basis. Butterfly valves are used extensively in both treated and untreated water applications. The valves selected for testing in the JOG MOV PV Program were chosen to be representative of these survey results.

Butterfly Valve Test Matrix and Applicability

Twenty-three butterfly valves were tested in the JOG MOV PV Program. Table 4-1 summarizes the design attributes of the valves and Table 4-2 summarizes the fluid conditions for the tests.

Key Factors Associated with Potential Degradation

As identified in Reference 3, the key factors associated with the potential degradation of butterfly valve bearing friction are: bearing material, shaft material, fluid medium, DP stroking frequency, and stem orientation. The twenty-three butterfly valves tested in the JOG MOV PV Program provided good coverage of all five factors.

Bearing Material
The twenty-three valves cover the following bearing materials:

- Bronze *(9 valves)*
- Bronze impregnated with graphite *(2 valves)*
- 300 series stainless steel *(1 valve)*
- Teflon on a fiberglass carrier *(6 valves)*
- Teflon on a stainless steel substrate *(1 valve)*
- Tefzel *(1 valve)*
- Nomex *(1 valve)*
- Nylatron *(1 valve)*
- Polyethylene on a stainless steel substrate *(1 valve)*

Shaft Material
The twenty-three valves cover the following shaft materials: 17-4 PH stainless steel, 300 series stainless steel, 400 series stainless steel, and Monel K-500.

Type of Fluid
The test matrix contains thirteen valves in untreated water systems and ten valves in treated water systems.

There are no valves tested in compressible flow, such as steam or air. There are a few butterfly valves in nuclear power plant service, however, that are in air or nitrogen service. Reference 18 showed that, using data from testing performed by INEL under NRC sponsorship (Reference 11), bearing friction coefficient behavior in air was observed to be similar to that in treated water. Accordingly, application of the JOG MOV PV Program results to valves in air or nitrogen service appears reasonable.

Frequency of DP Stroking
The twenty-three valves cover a wide range of DP stroking frequency. Two of the valves are stroked extensively during normal operations and accumulate about 50 DP strokes per year.

Eleven other valves are also considered to have a high DP stroking frequency, with 6-15 DP strokes per year. Ten of the valves are stroked less frequently under DP conditions during normal service, with less than 5 DP strokes per year.

Stem Orientation
Sixteen valves have the stem mounted vertically. Six valves have a horizontal stem orientation. One valve has the stem mounted at 45° from vertical.

Additional Valve Design Attributes

In addition to the key factors identified above, the twenty-three butterfly valves provided good coverage of other valve design attributes and operating conditions. Although these additional design attributes and operating conditions are not identified in Reference 3 as important applicability factors for the data, it was judged prudent to cover an appropriate range of attributes and operating scenarios for nuclear power applications. The additional attributes/operating conditions are discussed below.

Valve Manufacturer
The test matrix covers nine valve manufacturers: Ace, Allis-Chalmers, Clow, Contromatics, Crane/Flowseal, Fisher, Henry Pratt, Hills-McCanna, and Jamesbury.

Valve Size
The test matrix covers valves ranging in size from 6 to 96 inches.

Pressure Class
The test matrix covers three unique ANSI pressure classes: 25, 125, and 150.

Normal Valve Position
Fifteen of the test valves are normally open and eight are normally closed.

Fluid Temperature
The tests cover fluid temperatures from 36°F to 100°F.

Flow Rate
The water flow rates present during the dynamic tests were used to calculate water velocities, using the nominal valve size. The water velocities range from 4.1 to 23.0 ft/sec.

Differential Pressure
Three of the valves had a test DP of 55 psi or less, fourteen had a DP between 55 and 90 psi, and six had a test DP greater than 90 psi.

BUTTERFLY VALVE TEST RESULTS AND ANALYSES

In accordance with the JOG DP Test Specification (Reference 9), each plant that tested a butterfly valve prepared a test data package for each test of the valve. In each package, the test data were analyzed following standardized procedures. The bearing torque and bearing coefficient of friction were determined from the difference between the unseating torques under static and dynamic conditions. In a few cases, the measured data at unseating could not be meaningfully interpreted. In these cases, the bearing friction coefficient was determined using a point in the open stroke just after unseating, but prior to any hydrodynamic loads on the disk. Additionally, for double-offset and triple-offset butterfly valves, the calculation of the bearing coefficient was adjusted to account for the hydrostatic torque introduced by the offset.

Since the bearing material and fluid medium are judged to be the most important influences on bearing friction, the twenty-three tested valves are grouped for analysis based on these attributes. Other influences on bearing friction coefficient degradation are considered within these groups. The valves are separated into the four following groups:

- Bronze Bearings in Treated Water Systems *(4 valves)*
- Bronze Bearings in Untreated Water Systems *(7 valves)*
- 300 Series Stainless Steel Bearings in Untreated Water Systems *(1 valve)*
- Non-Metallic Bearings in Treated and Untreated Water Systems *(11 valves)*

Bronze Bearings in Treated Water Systems

Figure 4-1 shows the bearing friction coefficients for each stroke in the three test sequences for butterfly valves with bronze bearings in treated water systems. Average values for the first stroke in each sequence are shown by the dashed line (all 4 valves) and by the solid line (3 valves, excluding B11.1). Overall, the data show that there are no significant increases in the bearing friction between tests. The general trend for consecutive (same day) dynamic stroking (e.g. B1 and B2) is a stable or slight decrease in bearing friction. The exception is for valve B11.1, which is discussed below.

Figure 4-2 shows the change in bearing friction coefficient from baseline to second, second to third, and baseline to third test sequences. Changes in bearing friction from test to test are generally small. The exception is valve B11.1, which is discussed in detail below.

Butterfly valve B11.1 shows a significant apparent decrease in bearing friction coefficient from the baseline to second test. The cause of this decrease is related to the baseline static test behavior. The baseline test shows a much lower static unseating torque (133 ft-lbs) than the second and third tests (213 to 224.5 ft-lbs). Under dynamic conditions, the unseating behavior is more consistent across the three tests, as seen in the overlaid dynamic torque traces for B11.1 shown in Figure 4-3. The DP traces for all three tests are almost identical in the beginning of the stroke. The conclusion from this figure is that the apparent change in bearing friction from baseline to second test is attributable to the unusually low static seating torque in the baseline test and that the bearing friction behavior is stable across the three tests.

Valves B12.1, B13.1, and B15.1 all exhibit relatively stable bearing friction over the three tests. Although B12.1 and B13.1 show slight increases in bearing friction from the baseline to second test, the third test results show that the bearing friction returns to a level slightly below the baseline tests. As shown by the average bearing friction coefficient of the three valves, denoted by the solid line in Figure 4-1, the overall changes are small and the bearing friction is stable.

From the small number of valves tested in this category, it is difficult to assess the influence of DP stroking, stem orientation, or normal position on bearing friction degradation. However, the four valves cover the range of conditions for these attributes, and all valves show no indication of degradation.

Bronze Bearings in Untreated Water Systems

Figure 4-4 shows the bearing friction coefficients for each stroke in the three test sequences for butterfly valves with bronze bearings in untreated water systems. Separate averages are shown for valves without hub seals (4 valves) and valves with hubs seals (3 valves).

Figure 4-5 shows the change in bearing friction from baseline to second, second to third, and baseline to third test sequences. Both Figures 4-4 and 4-5 show that the four valves without hub seals have large variations in bearing friction coefficient, although the observed changes do not indicate an increasing or decreasing trend. The maximum bearing friction coefficient for these four valves is 0.46. The maximum increase between tests (first stroke to first stroke) is 0.22 (a change from 0.24 to 0.46). In contrast, the three valves with hub seals show small changes (<0.05) in bearing friction from test to test. A bearing friction coefficient of 0.39 bounds 95% of all the COF data from butterfly valves with bronze bearings.

The four valves without hub seals (B01.1, B03.2, B06.1, and B07.1) show significant variations in bearing friction coefficient. The most significant changes are observed between tests performed a year or more apart (e.g. B1 to S1). In addition, large changes are also observed between consecutive (same day) DP strokes (e.g. B1 to B2). Figures 4-6 and 4-7 provide example analyses of bearing friction coefficient considering the effects of measurement uncertainty. For each calculated bearing friction coefficient, there is an uncertainty associated with the measurement of pressure and torque during testing. These measurement uncertainties, each random, are combined statistically to produce a band of uncertainty around the measured bearing friction coefficients. As the examples show, it is certain that a change in bearing friction coefficient, beyond that which may be explained by measurement uncertainty, occurred between tests.

Valve B06.1 shows the highest value of bearing friction and the largest increase in bearing friction of all seven valves, with an increase of 0.22 from the baseline test (0.24) to the second test (0.46). In the third test, the bearing friction showed a decrease of similar magnitude, returning to a friction level slightly below the baseline results. The overlay of the dynamic torque traces from the three tests in Figure 4-8 clearly shows the increase in required torque for the second test. In general, the bearing friction for this valve appears to drift from test to test, although the pattern does not suggest degradation is occurring. While some of the observed change in bearing friction can be explained by measurement uncertainty of the test data, this explanation alone cannot account for the magnitude of change observed. As shown in Figure 4-6, even the *minimum* potential change from test to test, considering measurement error, is significant.

Valve B01.1 shows the largest variation in bearing friction for all seven valves. The bearing friction coefficient increases 0.14 from the baseline test to the second test (B1 to S1) and then decreases 0.31 from the second test to the third test (S1 to T1), to a level below the baseline test. Although this variation in bearing friction is significant, bearing friction is not a major contributor to the required DP torque for this valve. Because of the valve's offset shaft design, a large torque is required to overcome the offset of the DP force on the disk to open under DP conditions. For B01.1, this offset torque is about 75% of the required DP torque at unseating. Figure 4-9 shows a comparison of the torque components for B01.1 over the three tests. The large offset torque was relatively constant between tests. The bearing torque is a small component, but its changes are reflected in the total torque. Valve B01.1 includes a simple O-ring seal between the shaft and the bearing, at the inboard edge of each bearing sleeve. Based on the results of the testing, this simple seal does not appear to be sufficient to exclude the effects of untreated water.

Valve B07.1 shows a stable bearing friction coefficient from the baseline test to the first stroke of the second test. In the third test, the bearing friction increases 0.10 from the second test, considering the first stroke. As shown in Figure 4-7, an analysis of the measurement uncertainty for the data shows that the change in bearing friction exceeds that which could be attributed to measurement uncertainty. Valve B07.1 includes an elastomeric "shaft seal" at the mid-point of one of the two bearing sleeves. It appears that this shaft seal is designed to protect the packing. It is not in a position to exclude untreated water from the bearing, as confirmed by the test results.

Valve B03.2 shows the largest variation in bearing friction between consecutive DP strokes. In the baseline test, the bearing friction increases 0.16 from the first to second stroke. The bearing friction is relatively constant, however, between the first stroke of the second and third tests.

Valves B09.1, B09.3, and B09.4 all show relatively low bearing friction coefficients that remain stable over the three test sequences. As shown in Figure 4-5, the magnitude of change is small, less than 0.05. The stability of these three valves is attributable to their symmetric disk design which includes a hub seal. The hub seal is the penetration in the elastomeric valve seat where the shaft penetrates the valve body. The elastomeric properties of the hub seal provide a seal around the shaft and prevent particles from the fluid from entering the bearing. In effect, the hub seal creates a clean fluid environment for the bearing. Accordingly, the bearing friction behavior for butterfly valves with bronze bearings and hub seals in untreated water is analogous to that of butterfly valves with bronze bearings in treated water. This is shown clearly in Figure 4-10, which shows the change in bearing friction coefficient versus the initial bearing friction coefficient for all butterfly valves with bronze bearings. The figure shows that the three valves in untreated water systems with hub seals behave similar to the valves in treated water. Only the valves in untreated water without hub seals show significant variations.

Although DP stroking was identified as a key factor associated with potential degradation, it is not apparent that the observed variation in bearing friction for valves without a hub seal can be related to or explained by the frequency of DP stroking the valves undergo during normal service. All four valves received at least 4 DP strokes between JOG tests, with some valves receiving many more (5 to 17). Regardless of the frequency, the variation in bearing friction was still observed. Furthermore, given the fact that the variations occurred both on consecutive (same day) strokes as well as between tests, DP stroking does not appear to be the mechanism causing the observed changes. Thus, valves that are typically not stroked under DP conditions are judged to be susceptible to this variation as well.

Based on the data for all seven valves, stem orientation and normal position are deemed not to be significant influences on changes in bearing friction for these valves. The seven valves cover the range of conditions for these attributes.

300 Series Stainless Steel Bearings in Untreated Water Systems

The JOG MOV PV Program tested one valve with a 300 series stainless steel bearing paired against a 17-4PH stainless steel shaft. Figure 4-11 shows the bearing friction coefficients across three tests for valve B08.1. This valve shows a significant increase in bearing friction from the baseline test (0.37) to the first stroke of the second test (0.50 at S1). The bearing friction shows a significant decrease from the second to third test, returning to a friction level slightly above the baseline result. In general, the bearing friction for this valve appears to drift from test to test, although the behavior is not indicative of degradation (i.e., no increasing or decreasing trend).

This valve operates in cold, untreated water and is DP stroked 6-20 times between tests. The shaft of this valve is offset from the disk and the valve does not contain a hub seal. The variation in bearing friction in untreated water for this valve appears to be analogous to valves with bronze bearings in untreated water without hub seals. However, the values of bearing friction for this valve are higher than those for valves with bronze bearings.

Non-Metallic Bearings

Eleven valves with non-metallic bearings were tested in the JOG MOV PV Program. The following bearing materials were tested:

- Teflon lined bearings in a fiberglass carrier *(6 valves)*
- Teflon lined bearing on a stainless steel substrate *(1 valve)*
- Tefzel *(1 valve)*
- Nylatron *(1 valve)*
- Nomex *(1 valve)*
- Polyethylene-lined with a stainless steel backing *(1 valve)*

Tefzel is a derivative of Teflon and, based upon vendor information, is considered similar to Teflon-lined bearings. The other three materials for which only one valve is tested are considered to be unique within the JOG butterfly valve matrix. Each group is discussed separately below. Figure 4-12 shows the change in bearing friction from baseline to second, second to third and baseline to third test sequence for all 11 valves with non-metallic bearings.

Teflon Lined Bearings in a Fiberglass Carrier

Figure 4-13 shows bearing friction coefficients for the six valves with Teflon lined bearings in a Fiberglass carrier. Valves in both treated and untreated water systems are included in this group. In general, these valves show lower overall friction coefficients compared to valves with bronze bearings and show a stable bearing friction coefficient across the three tests, as indicated by the average lines on the figure. The maximum bearing friction coefficient for these six valves is 0.13 and the maximum increase between tests (first stroke to first stroke) is 0.06. Because two of the 33 data points are at the maximum value, this bounding value (0.13) is also the value that bounds 95% of all the COF data for these valves.

Figure 4-14 shows the change in bearing friction versus initial friction value for all valves with Teflon bearings, including the one valve with stainless steel backing (7 valves). Valves with low initial bearing friction tend to show the largest increase, although the friction values for all valves are relatively low. Both Figures 4-13 and 4-14 show that the four valves in untreated water systems tend to show higher bearing friction coefficients and more variation than the valves in treated water, although there does not appear to be a systematic trend that can be related to degradation. This observation is similar to that of bronze bearing valves in untreated water without hub seals. The variation for the Teflon valves, however, is less pronounced than for valves with bronze bearings, suggesting a lower sensitivity to the accumulation of particulates in the Teflon bearing.

Valve B20.1 shows the largest variation in bearing friction of all six valves. The bearing friction decreases from the baseline to the second test and then increases from the second to the third test, to a level similar to the baseline. The overlay of the dynamic torque traces from the three tests in Figure 4-15 shows the change in required torque between tests. While some of the observed change in bearing friction may be attributable to measurement uncertainty, Figure 4-16 shows this explanation alone cannot account for the magnitude of change being observed.

Valve B30.2 shows an increase in the bearing friction from the baseline to the second test, and continues to increase in the third test, but to a smaller degree. The baseline bearing friction coefficient, however, started at a much lower value than the other five fiberglass/Teflon valves. The observed increases bring the bearing coefficient to a value closer to the median bearing coefficient for this group. Figure 4-17 shows the measured bearing friction coefficients and the associated band of uncertainty around the measured values. Within the band of bearing friction coefficient uncertainty, a "series alley" is defined by the minimum value of the upper uncertainty line and the maximum value of the lower uncertainty line. As shown by the figure, the measured data mostly fall within the "series alley," indicating the observed changes could possibly be explained by uncertainty. Regardless, the maximum value observed for this valve (in the third test) is less than the average value for all Teflon/fiberglass valves, indicating that the performance of this valve is reasonable.

In general, frequency of DP stroking does not appear to have an effect on the bearing friction coefficient. Additionally, stem orientation and normal position do not appear to be significant influences on changes in bearing friction for these six Teflon/fiberglass valves.

Tefzel and Teflon Lined Bearings with a Stainless Steel Backing
Figure 4-18 shows bearing friction coefficients for the two valves with a Tefzel or Teflon-lined bearing with a stainless steel backing. Based on engineering judgment, these materials are expected to perform similarly to valves with Teflon-lined bearings in fiberglass carriers. Therefore, the average COF values from the Teflon/fiberglass valves are shown on this figure.

Valve B22.4 has the Tefzel bearing material. The manufacturer's literature on Tefzel (which is a Teflon derivative) indicates that it has a higher coefficient of friction than Teflon when running against metal. The data for B22.4 shows higher bearing friction coefficients than the Teflon bearings, supporting the manufacturer's information. The changes in bearing friction for this valve, however, are small, indicating that Tefzel has a stable bearing performance, like Teflon.

Valve B25.3 has the Teflon-lined bearing with a stainless steel backing. The bearing coefficient of friction has an increase from the baseline test to the second test. The third test shows bearing friction values similar to the second test. The baseline bearing coefficient, however, started at a value much lower than other Teflon bearing valves (similar to B30.2). As with B30.2, the observed increase brings the bearing coefficient close to the average value for valves with Teflon bearings. Figure 4-19 shows that the observed increase exceeds the measurement uncertainty. This valve is located in an untreated water system. Similar to other butterfly valves in untreated water, the observed change may be variation attributed to the fluid medium.

As identified in Reference 3, cumulative stroking is a potential degradation mechanism for butterfly valves with Teflon-lined bearings. Specifically, the stroking could produce wear-through of the Teflon lining and result in bearing friction increases. In general, the data does not show evidence of detrimental wear of Teflon bearings as a result of cumulative stroking. All seven butterfly valves with Teflon-lined bearings were DP stroked prior to one or more of the three JOG tests (1 to 36 strokes). No differences in bearing friction were observed for valves with either low or high frequency DP stroking, and the small changes in bearing friction for these valves cannot be correlated to the frequency of DP stroking.

Other Materials
Figure 4-20 shows the bearing coefficients for the three valves tested with Nomex, Nylatron, and Polyethylene lined bearings on a stainless steel backing.

Valve B22.3 has the Nomex bearing. The bearing friction coefficient decreases 0.03 from the baseline test to the second test. In the third test, the bearing friction increases a similar magnitude and returns to a level similar to the baseline test. There is no indication of degradation.

Valve B30.3 has the Polyethylene lined bearing on a stainless steel backing. Located in a treated water system, this valve shows essentially a constant bearing friction across all three tests. There is no indication of degradation.

Valve B16.3 has the Nylatron bearing and is located in an untreated water system. Similar to other raw water valves, the bearing friction tends to drift from test to test, with the minimum value on the second test and the maximum value on the third test. The values are below those from the other two valves on this graph.

BUTTERFLY VALVE CONCLUSIONS

1. There is no age-related degradation in required bearing torque. Specifically, there is no increase in the required bearing torque due only to the passage of time (without DP stroking).

2. There is no service-related degradation in required bearing torque. Specifically, there is no increase in the required bearing torque due to DP stroking.

3. For butterfly valves with bronze bearings in treated water systems, the bearing friction coefficient does not degrade and is relatively stable.

4. For butterfly valves with bronze bearings in untreated water systems with hub seals, the bearing friction coefficient does not degrade and is stable, demonstrating behavior analogous to valves with bronze bearings in treated water systems.

5. For butterfly valves with bronze bearings in untreated water systems without hub seals, there is significant variation (increases and decreases) in the bearing friction coefficient. This variation is unrelated to DP stroking, and there is no overall increasing or decreasing trend. A bearing friction coefficient of 0.39 bounds 95% of all the COF data from all butterfly valves with bronze bearings.

6. For butterfly valves with 300 series stainless steel bearings against a 17-4PH stainless steel shaft in untreated water systems without hub seals, there is significant variation (increases and decreases) in the bearing friction coefficient. This variation is unrelated to DP stroking, and there is no overall increasing or decreasing trend. A maximum COF of 0.50 was observed.

7. For butterfly valves with bearings made of Teflon in a fiberglass carrier, Teflon on a stainless steel substrate, or Tefzel, the bearing coefficient is stable in treated water. In untreated water, there are slight variations (increases and decreases) in bearing friction coefficient. A few valves with low initial bearing friction coefficients increased during testing to values more typical of the average. A bearing friction coefficient of 0.13 is the bounding value of all the COF data from butterfly valves with Teflon/fiberglass and Teflon/stainless steel bearings in both treated and untreated water. This bounding value (0.13) is also the value that bounds 95% of the COF data. For Tefzel, a Teflon derivative expected to have higher friction, the maximum observed COF was 0.23.

8. For butterfly valves with bearings made of Nomex, Polyethylene, or Nylatron, the bearing friction was observed to be generally stable, with small variations in untreated water comparable to those observed for Teflon bearings. A maximum COF of 0.23 was observed

for Nomex, Polyethylene, and Nylatron, covering both treated and untreated water applications.

9. Shaft material was not found to affect bearing friction performance. All tested butterfly valves have similar stainless steel type shaft materials, with the exception of one valve with a Monel K-500 shaft.

10. The amount of DP stroking, stem orientation and normal position were not found to affect bearing friction performance (i.e., COF variation and magnitude). Accordingly, it is not necessary to consider these factors in the final PV approach for butterfly valves.

Table 4-1. Attributes of JOG MOV PV Program Butterfly Valves

JOG Test Matrix No.	Manufacturer	Size (in)	Pressure Class (lbs)	Shaft Material	Bearing Material	Stem Orientation	Normal Position	Fluid Type	Normal Fluid Temp. (°F)	No. of DP Strokes Per Year
B01.1[1]	Clow	10	150	Monel-K 500	Bronze	Horizontal	Open	Untreated Water	95	6
B03.2[1]	Clow	20	150	400 series SS	Bronze	Horizontal	Open	Untreated Water	80	6
B06.1[2]	Crane/Flowseal	6	150	17-4 PH SS	Bronze	Vertical	Open	Untreated Water	105	4
B07.1	Henry Pratt	30	150	17-4 PH SS	Bronze	Horizontal	Closed	Untreated Water	80	8
B08.1	Contromatics	14	150	17-4 PH SS	300 series SS	Horizontal	Closed	Untreated Water	121	10
B09.1[3]	Ace	20	125	300 series SS	Bronze/Graphite	Vertical	Closed	Untreated Water	85	50 - 100
B09.3[3]	Henry Pratt	6	150	17-4 PH SS	Bronze	Vertical	Closed	Untreated Water	90	12
B09.4[3]	Henry Pratt	6	150	17-4 PH SS	Bronze	Vertical	Closed	Untreated Water	90	12
B11.1	Contromatics	10	150	300 series SS	Bronze	Horizontal	Open	Treated Water	80	10
B12.1	Fisher	8	150	17-4 PH SS	Bronze/Graphite	45°	Open	Treated Water	105	2
B13.1	Contramatics	10	150	17-4 PH SS	Bronze	Vertical	Open	Treated Water	80	10
B15.1[3]	Henry Pratt	14	150	17-4 PH SS	Bronze	Vertical	Closed	Treated Water	105	0 - 2
B16.1	Henry Pratt	24	150	17-4 PH SS	Fiberglass / Teflon	Vertical	Closed	Untreated Water	95	12
B16.2	Henry Pratt	96	25	300 series SS	Fiberglass / Teflon	Vertical	Open	Untreated Water	95	5
B16.3[3]	Henry Pratt	18	150	17-4 PH SS	Nylatron	Vertical	Open	Untreated Water	75	0 - 5
B20.1	Henry Pratt	24	150	17-4 PH SS	Fiberglass / Teflon	Horizontal	Closed	Untreated Water	80	2
B22.1	Henry Pratt	10	150	17-4 PH SS	Fiberglass / Teflon	Vertical	Open	Treated Water	105	8
B22.2	Henry Pratt	10	150	17-4 PH SS	Fiberglass / Teflon	Vertical	Open	Treated Water	105	8
B22.3[2]	Jamesbury	16	150	17-4 PH SS	Nomex	Vertical	Open	Treated Water	80	50
B22.4	Hills-McCanna	16	150	17-4 PH SS	Tefzel	Vertical	Open	Treated Water	105	0 - 1
B25.3	Allis-Chalmers	24	150	300 series SS	SS / Teflon	Vertical	Open	Untreated Water	95	0 - 2
B30.2	Henry Pratt	12	150	17-4 PH SS	Fiberglass / Teflon	Vertical	Open	Treated Water	95	0 - 5
B30.3[2]	Jamesbury	12	150	17-4 PH SS	SS / Polyethylene	Vertical	Open	Treated Water	94	0 - 1

Notes:
1. Valve is a triple-offset design.
2. Valve is a double-offset design.
3. Valve is symmetric design with hub seal.

Table 4-2. Flow Conditions for JOG Butterfly Valve Tests

JOG Test Matrix No.	Flow Rate (gpm)	Flow Rate (ft/s) *(based on nominal valve size)*	Open Test DP (psig)	Test Temperature (°F)
B01.1	1650	6.7	78 - 85	53 - 66
B03.2	9010 - 12500	9.2 - 12.8	54 - 66	45 - 60
B06.1	1800 - 1915	21.6 - 23.0	56 - 66	65 - 75
B07.1	13510 - 15700	6.6 - 7.6	84 - 124	54 - 74
B08.1	5250 - 6200	13.1 - 15.5	80 - 87	45 - 84
B09.1	6500 - 6900	7.9 - 8.3	48 - 52	67 - 75
B09.3	1000 - 1040	11.3 - 11.8	73 - 78	67 - 92
B09.4	865 - 940	9.8 - 10.7	65 - 71	65 - 90
B11.1	1700	7.4	72 - 77	72 - 80
B12.1	1485 - 1757	9.5 - 11.2	73 - 89	70 - 73
B13.1	1700 - 2175	7.4 - 9.5	71 - 78	72 - 80
B15.1	5500 - 6000	12.7 - 13.9	79 - 94	62 - 72
B16.1	10,500 - 14,000	7.4 - 9.9	14.8 - 22	72 - 78
B16.2	190,000 - 200,000	8.4 - 8.9	8.9 - 9.6	58 - 65
B16.3	5600 - 7525	7.1 - 9.5	58 - 63	36 - 70
B20.1	11,188 - 13,590	7.9 - 9.6	94 - 111	60 - 73
B22.1	998 - 1200	4.1 - 4.9	84 - 98	74 - 100
B22.2	1100 - 1159	4.5 - 4.7	82 - 95	74 - 100
B22.3	5700	9.1	70 - 76	81 - 87
B22.4	4900 - 5100	7.8 - 8.1	94 - 99	75 - 90
B25.3	17,500 - 19,300	12.4 - 13.7	83 - 87	72 - 87
B30.2	1880 - 2020	5.3 - 5.7	75 - 83	78 - 85
B30.3	2020 - 2100	5.7 - 6.0	58 - 67	91 - 96

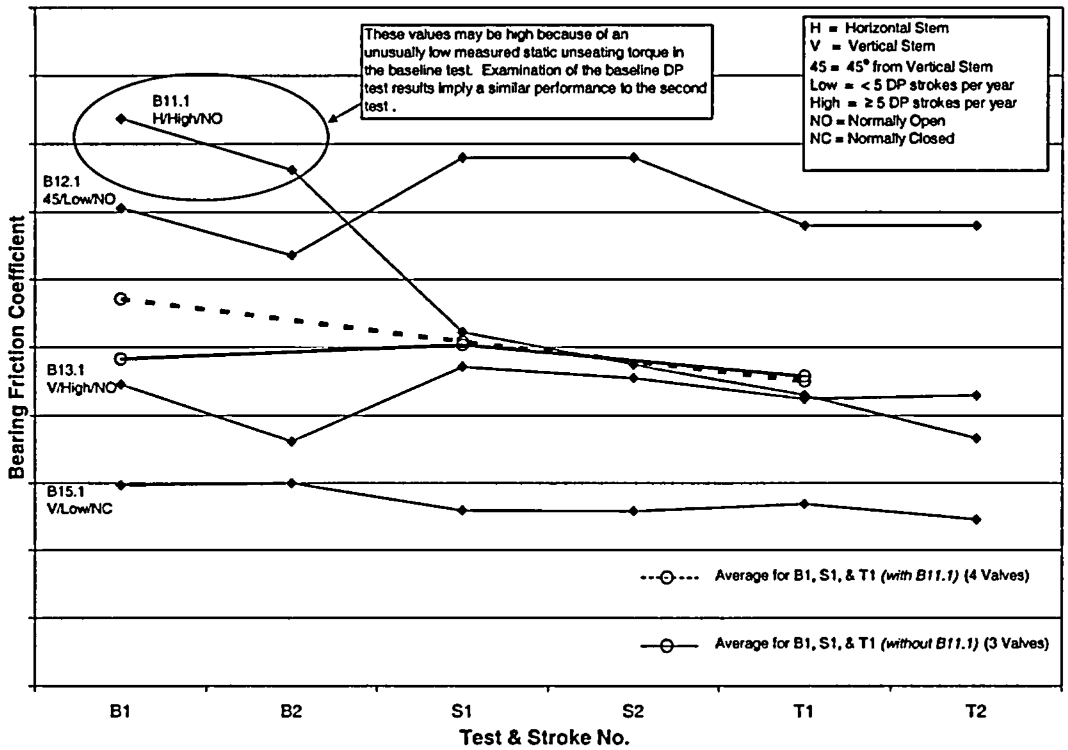


Figure 4-1. Bearing Friction Coefficient for Butterfly Valves with Bronze Bearings in Treated Water

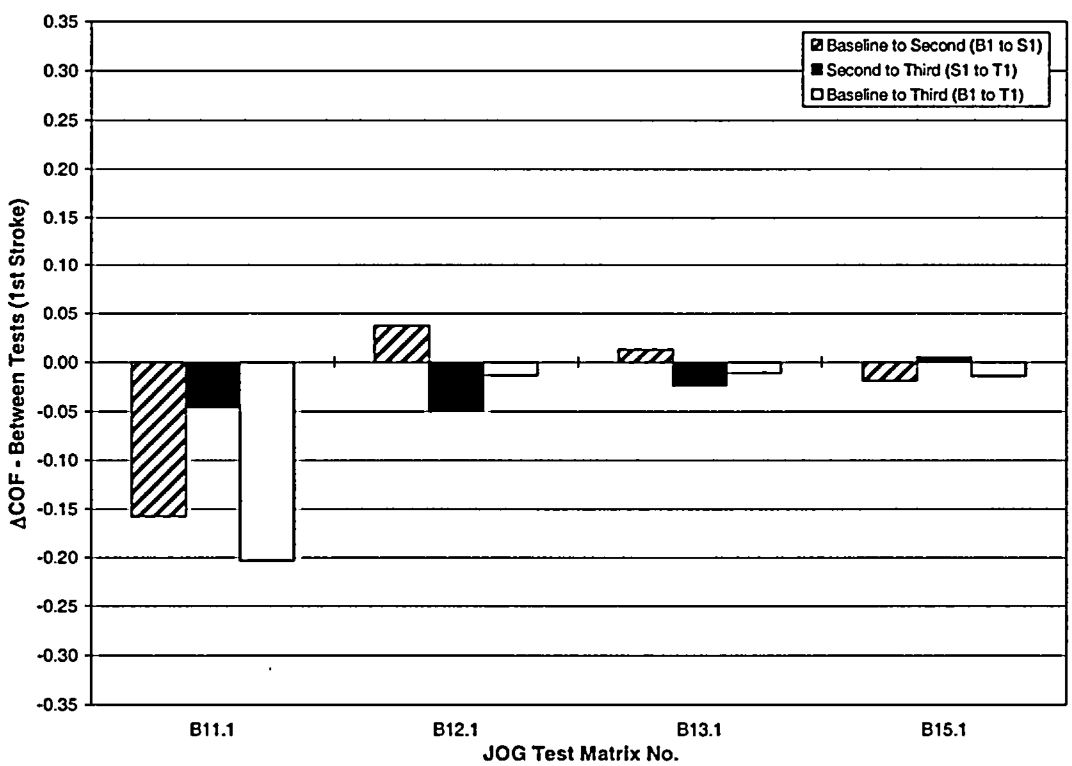


Figure 4-2. Change in Bearing Friction Coefficient for Butterfly Valves with Bronze Bearings in Treated Water

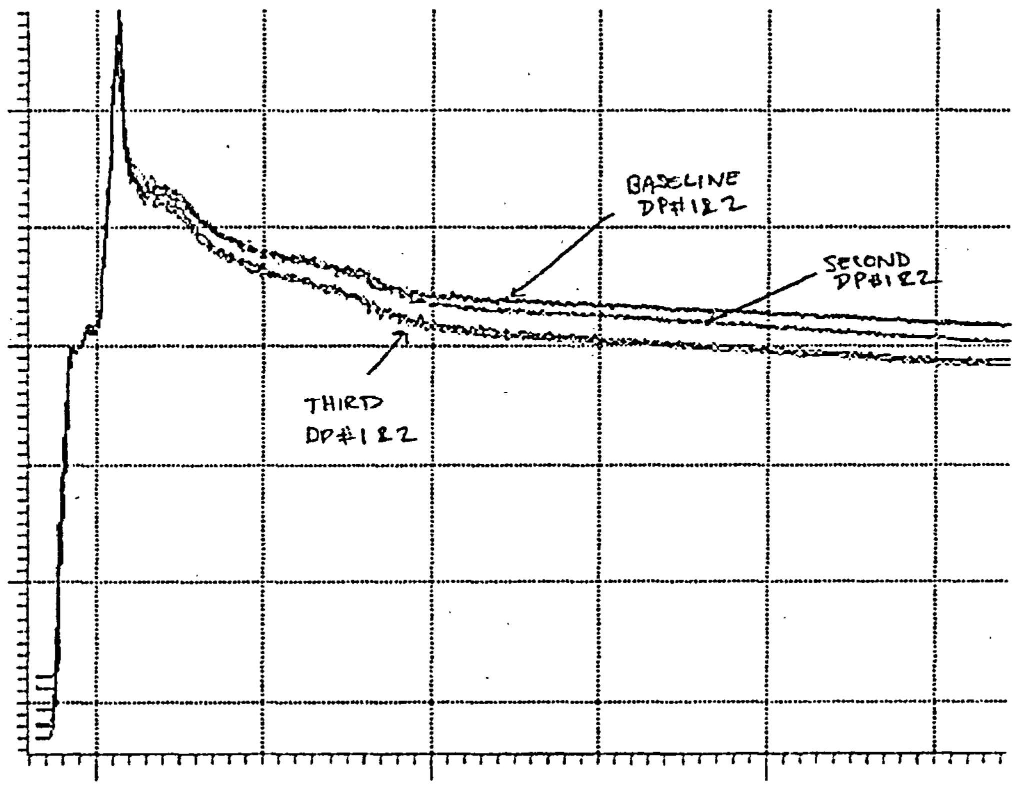


Figure 4-3. Torque Overlay for DP Opening Strokes of B11.1

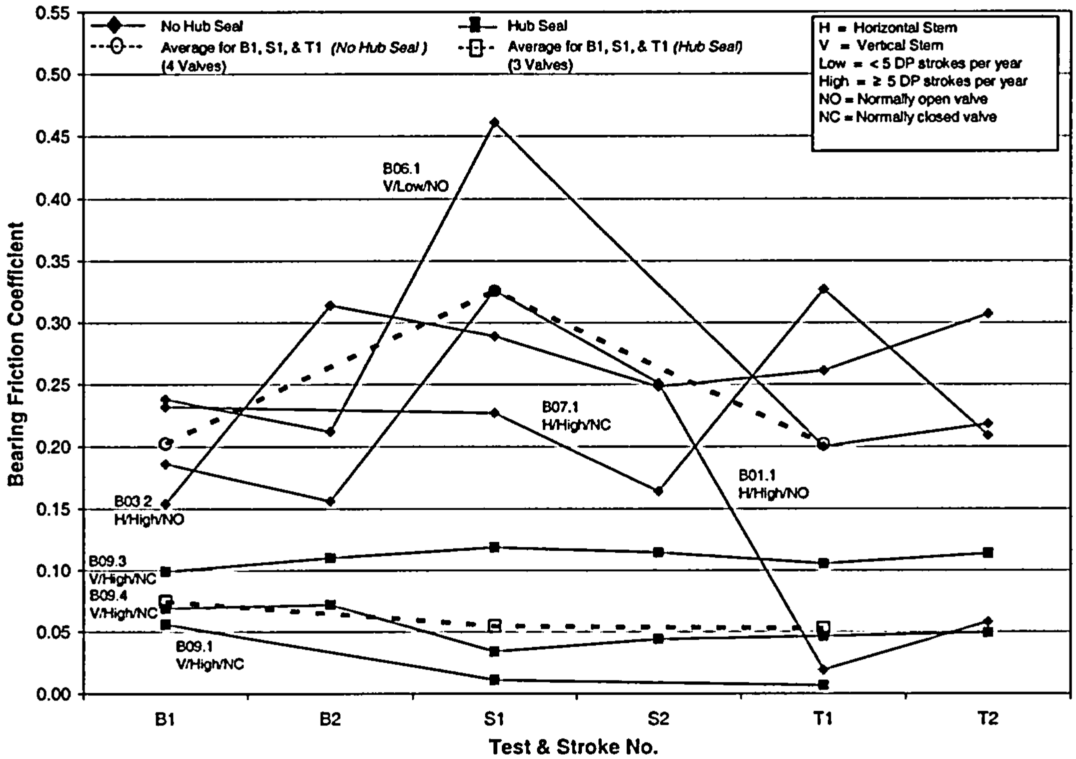


Figure 4-4. Bearing Friction Coefficient for Butterfly Valves with Bronze Bearings in Untreated Water

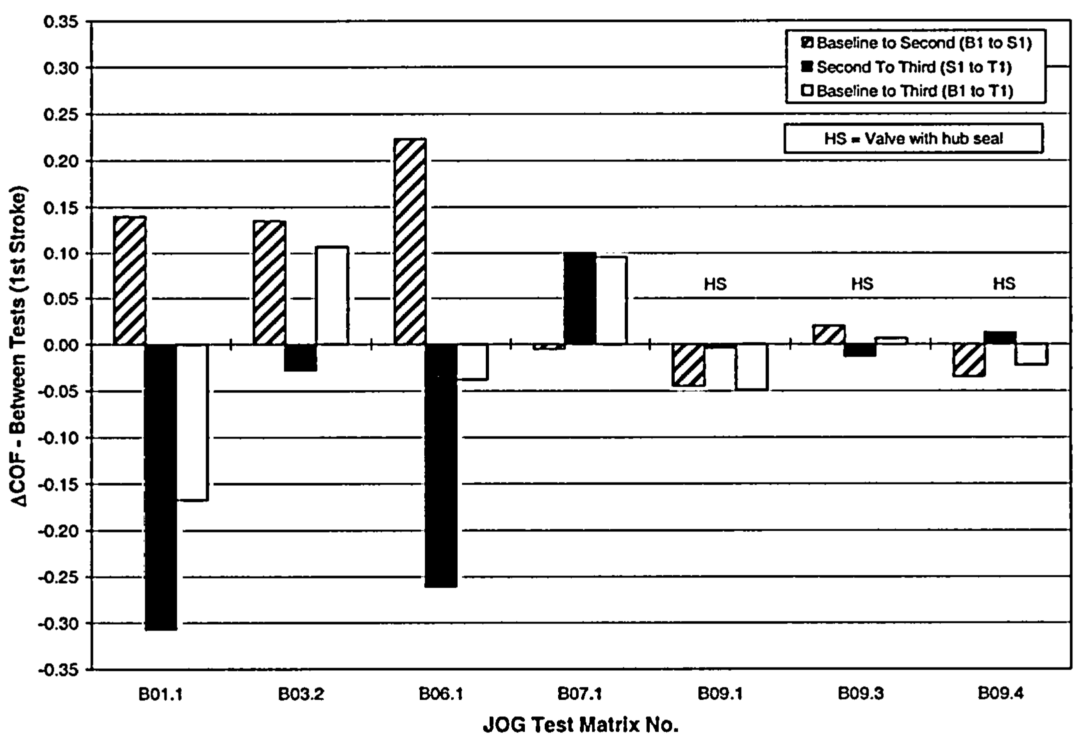


Figure 4-5. Change in Bearing Friction Coefficient for Butterfly Valves with Bronze Bearings in Untreated Water

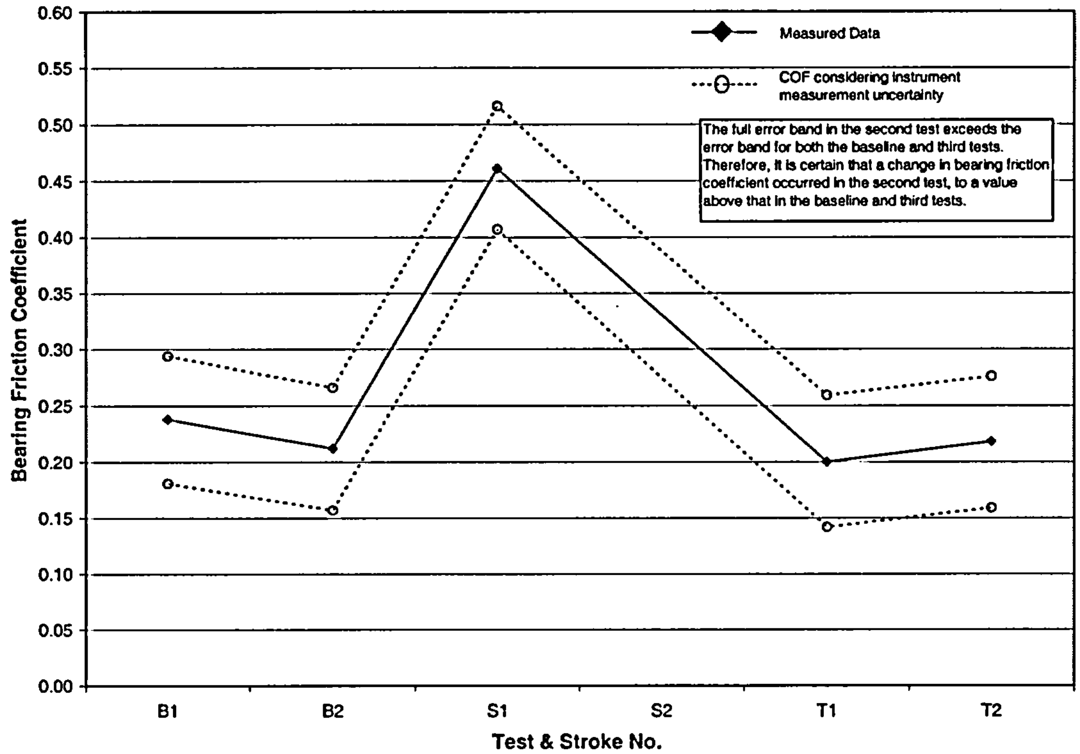


Figure 4-6. Bearing Friction Coefficient for B06.1 with Instrument Measurement Uncertainty

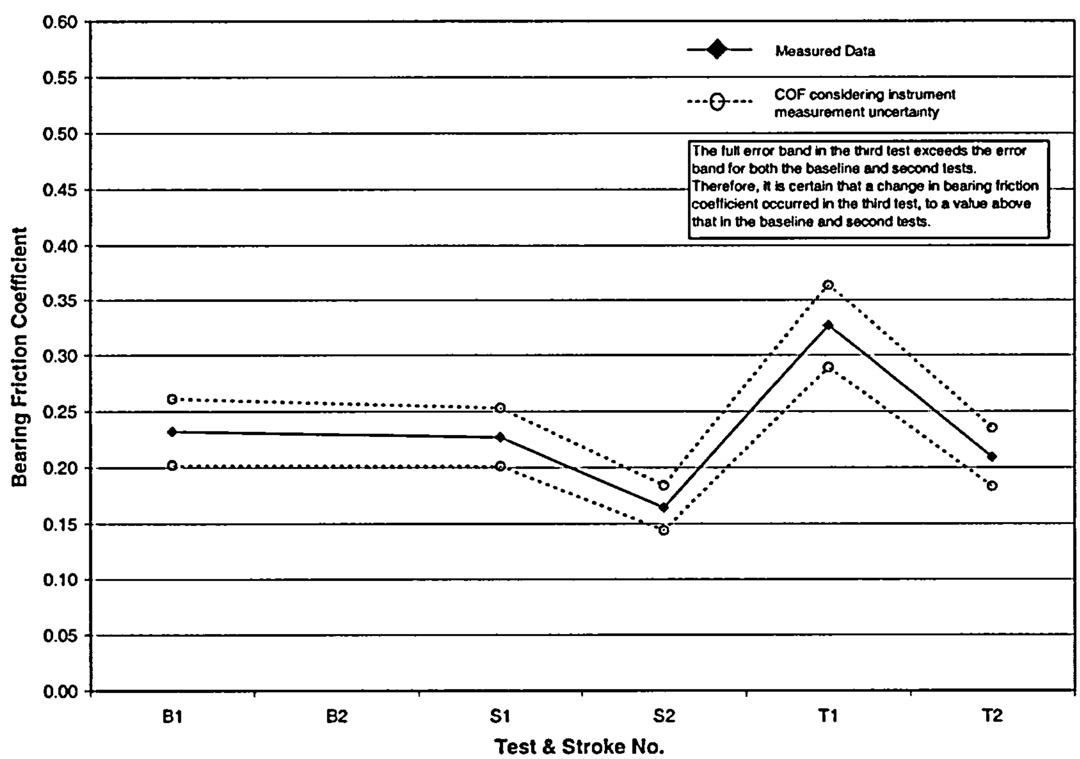


Figure 4-7. Bearing Friction Coefficient for B07.1 with Instrument Measurement Uncertainty

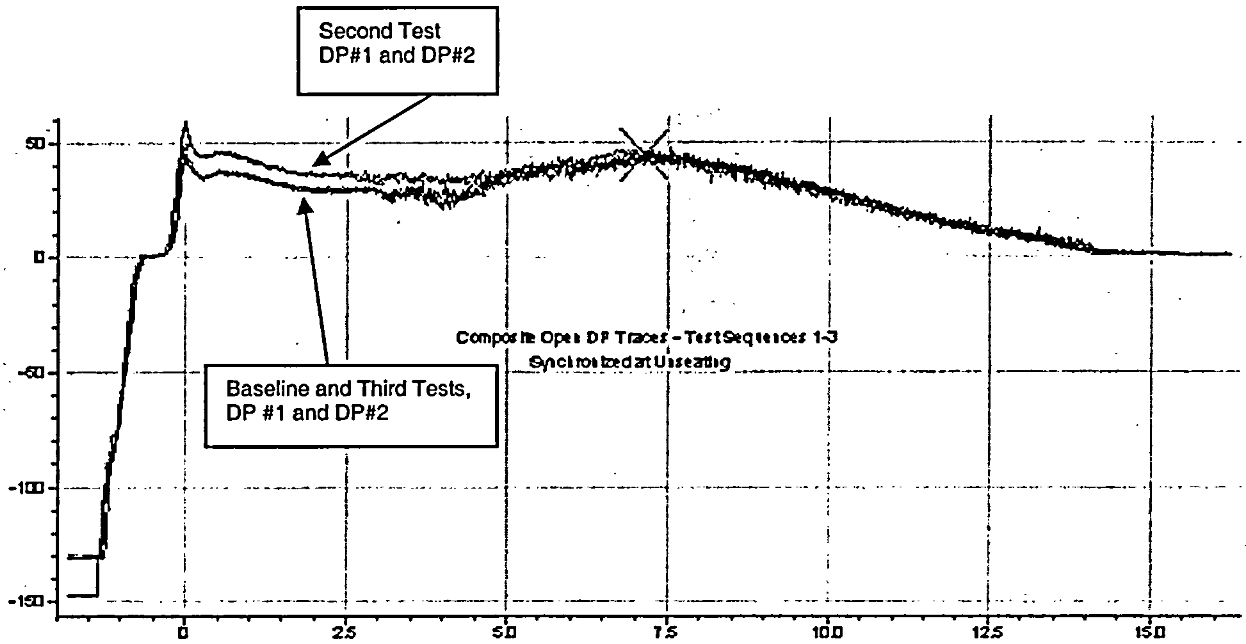


Figure 4-8. Opening Torque Overlay for B06.1

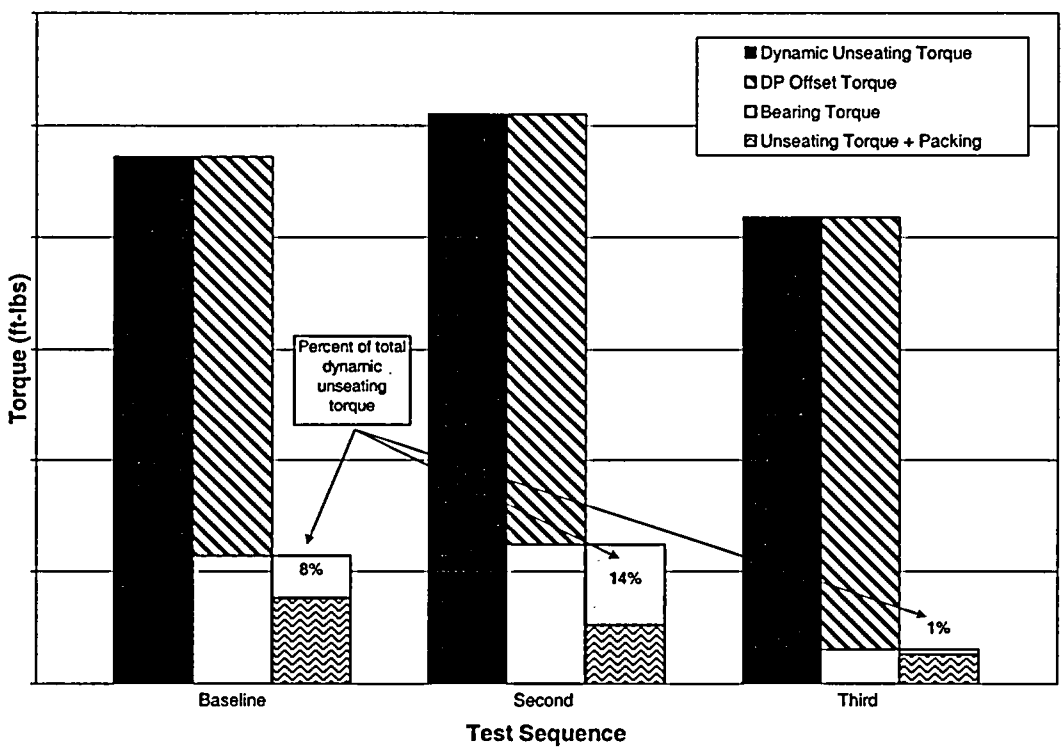


Figure 4-9. Comparison of Torque Components for B01.1

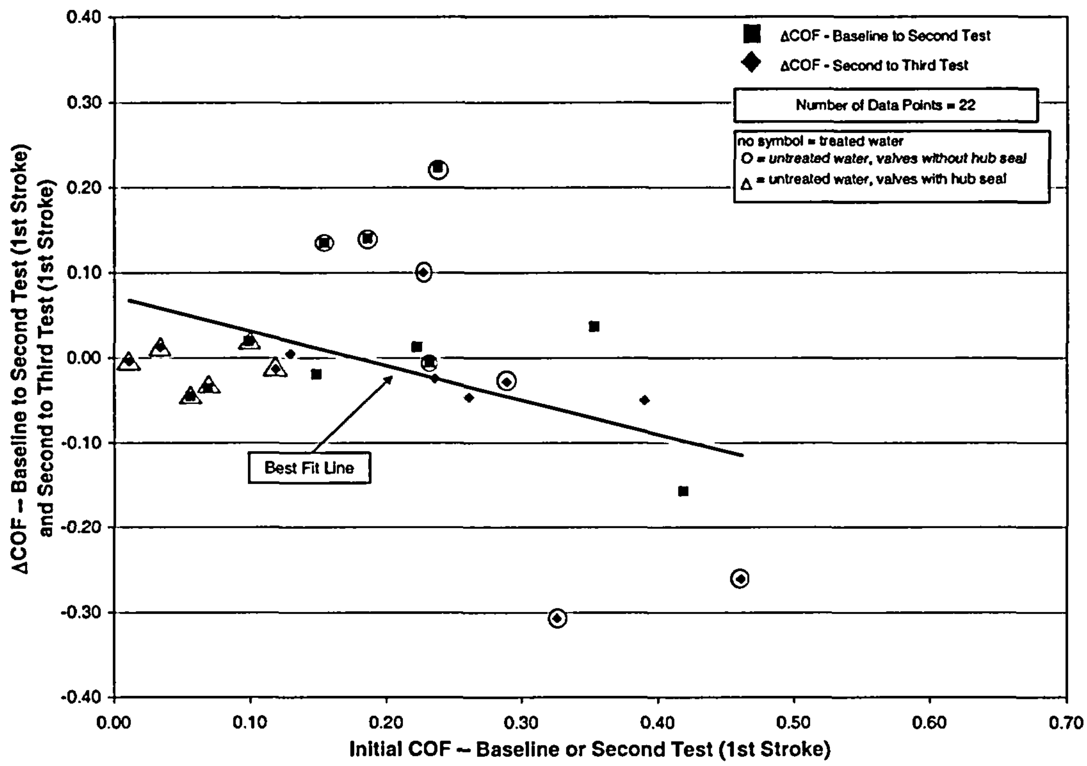


Figure 4-10. Change in Bearing Friction Coefficient vs. Initial Bearing Friction Coefficient for Butterfly Valves with Bronze Bearings in Water Systems

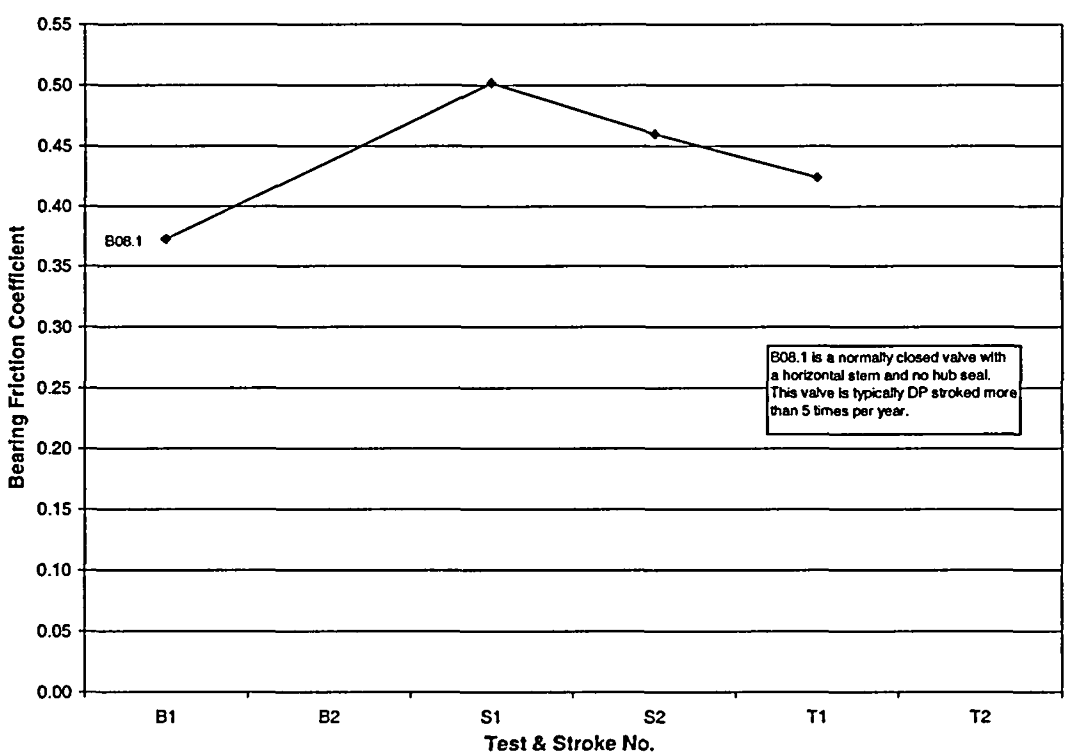


Figure 4-11. Bearing Friction Coefficient for Butterfly Valve with 300 Series Stainless Steel Bearing in an Untreated Water System

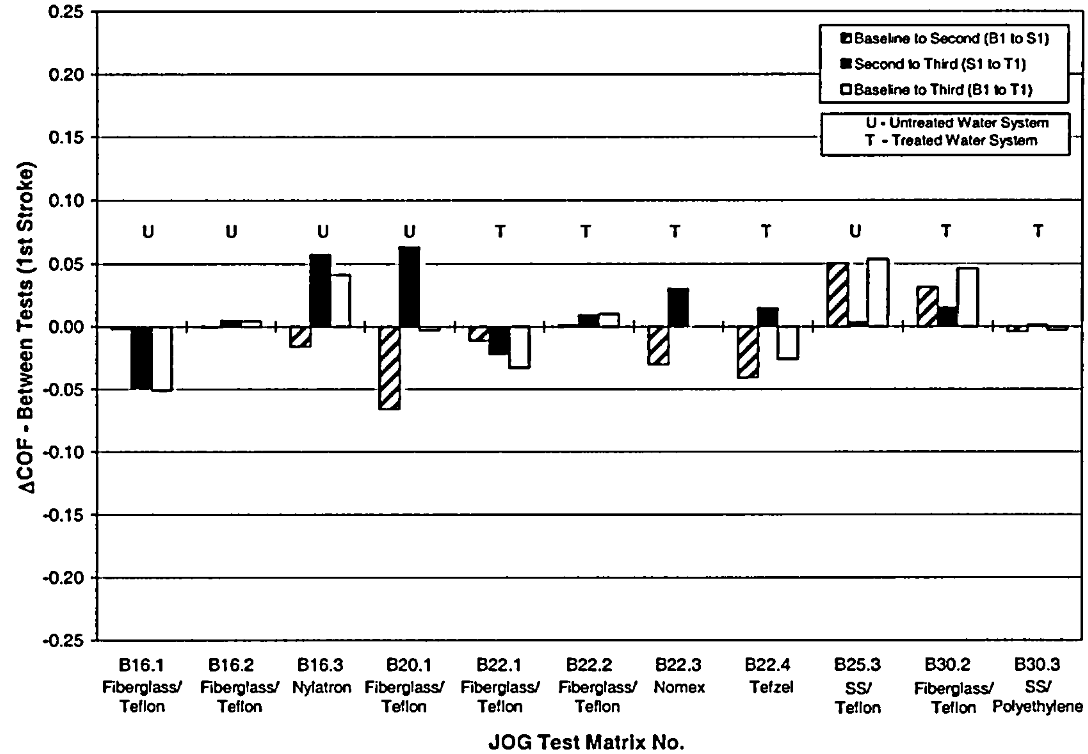


Figure 4-12. Change in Bearing Friction Coefficient for Butterfly Valves with Non-Metallic Bearings

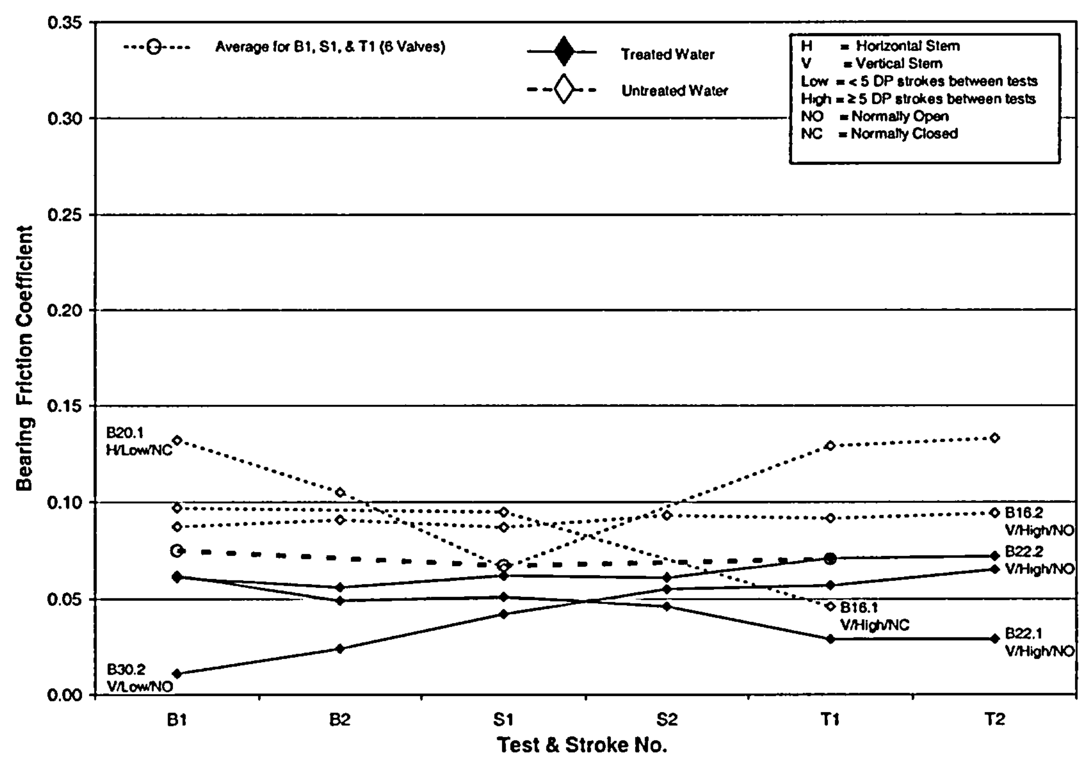


Figure 4-13. Bearing Friction Coefficient for Butterfly Valves with Teflon Lined Bearings in Fiberglass Carriers

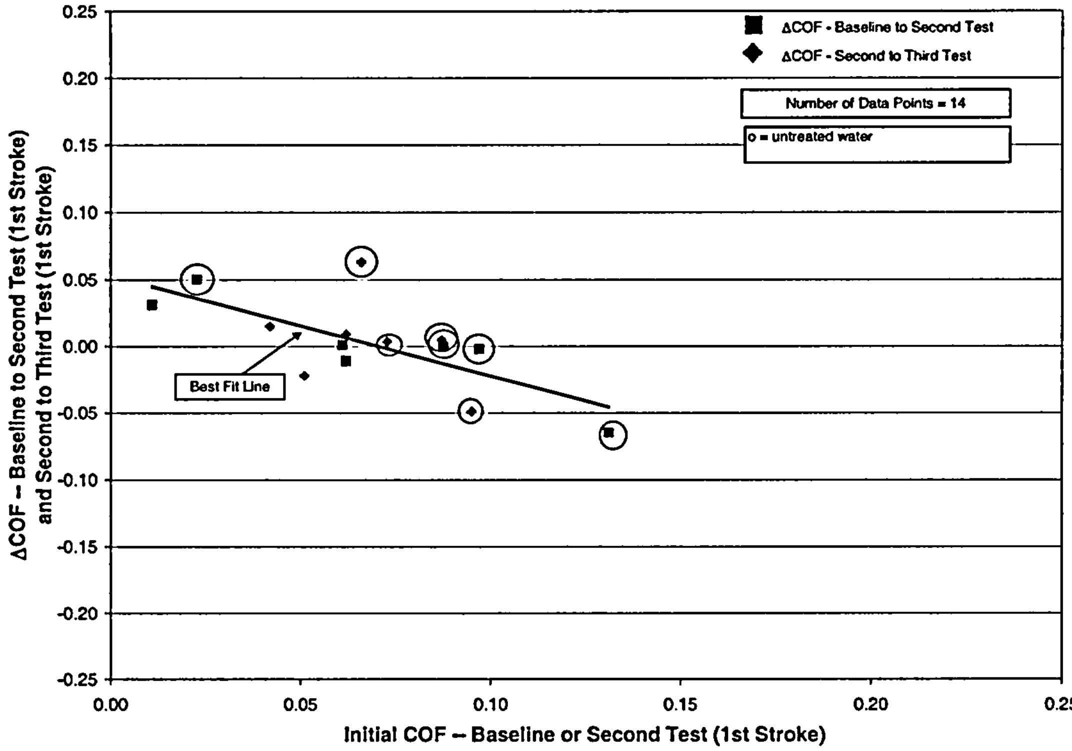


Figure 4-14. Change in Bearing Friction Coefficient vs. Initial Bearing Friction Coefficient for Butterfly Valves with Teflon/Fiberglass or Teflon/Stainless Steel Bearings

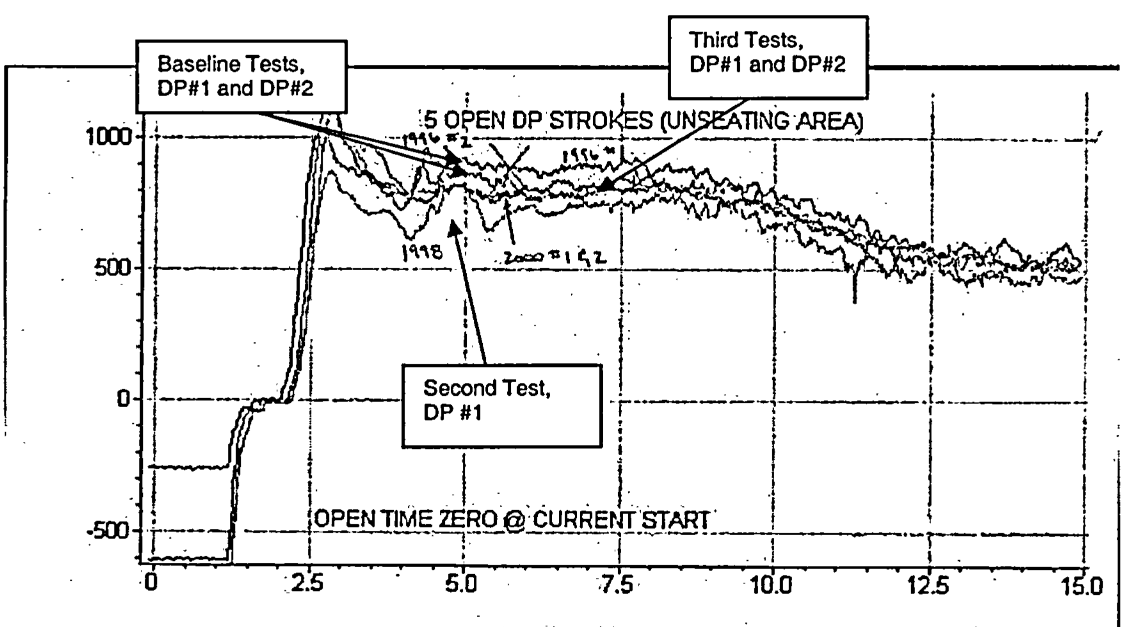


Figure 4-15. Opening Torque Overlay for B20.1

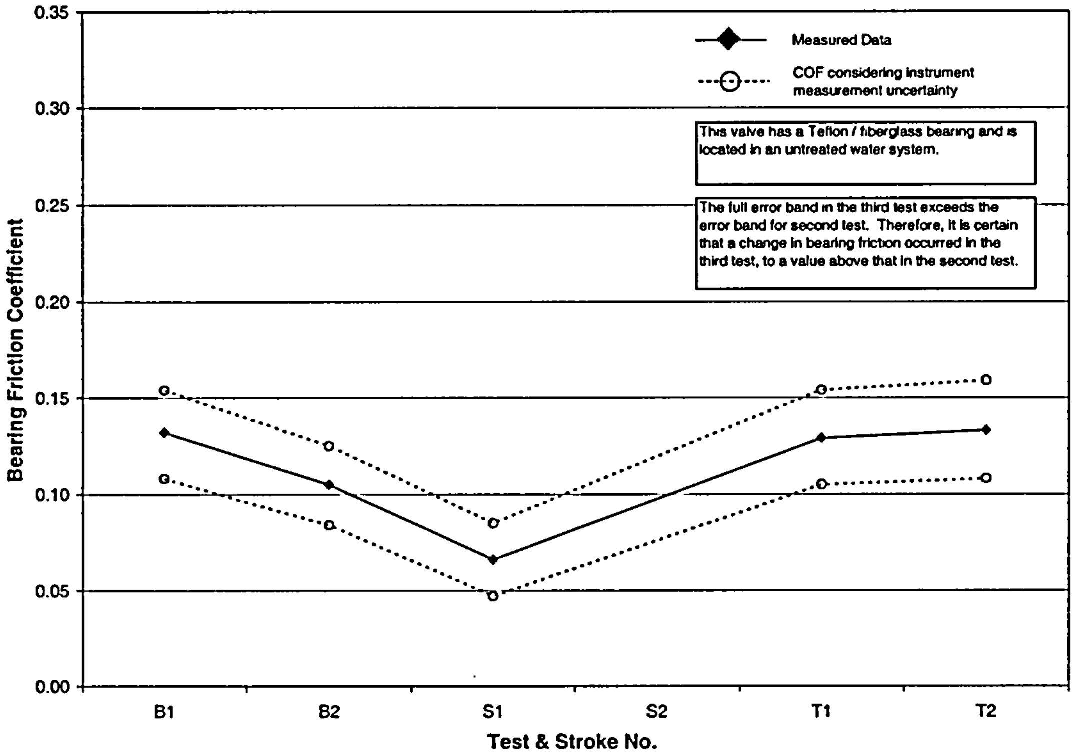


Figure 4-16. Bearing Friction Coefficient for B20.1 with Instrument Measurement Uncertainty

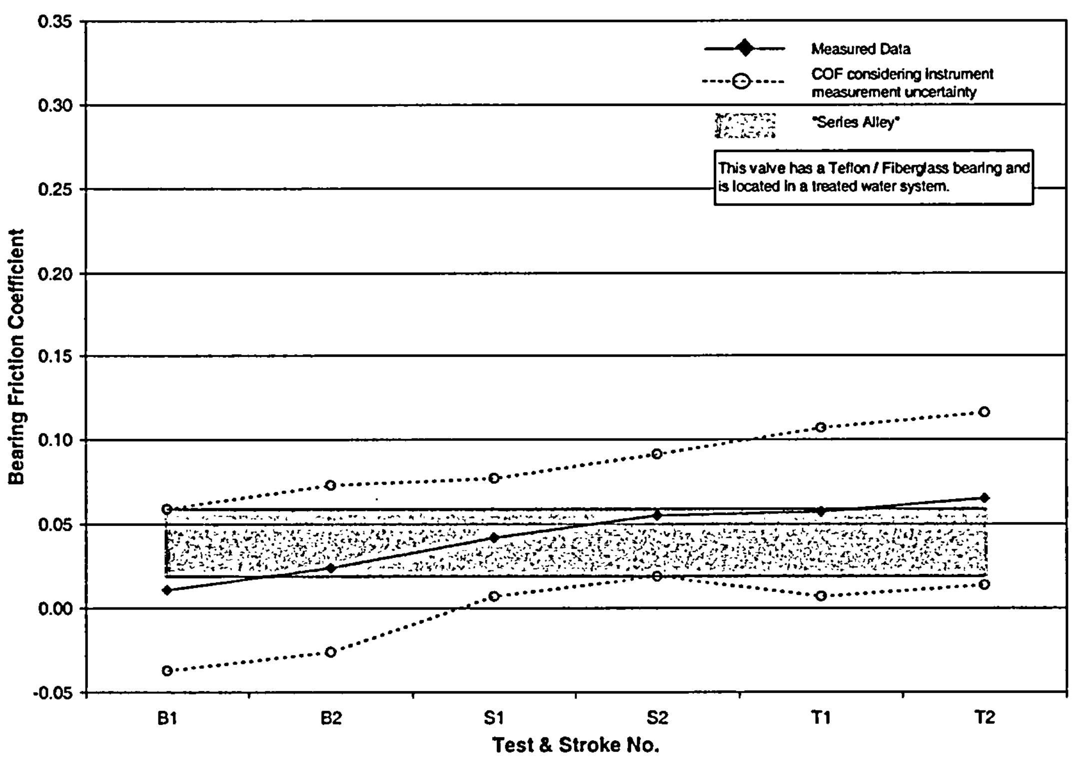


Figure 4-17. Bearing Friction Coefficient for B30.2 with Instrument Measurement Uncertainty

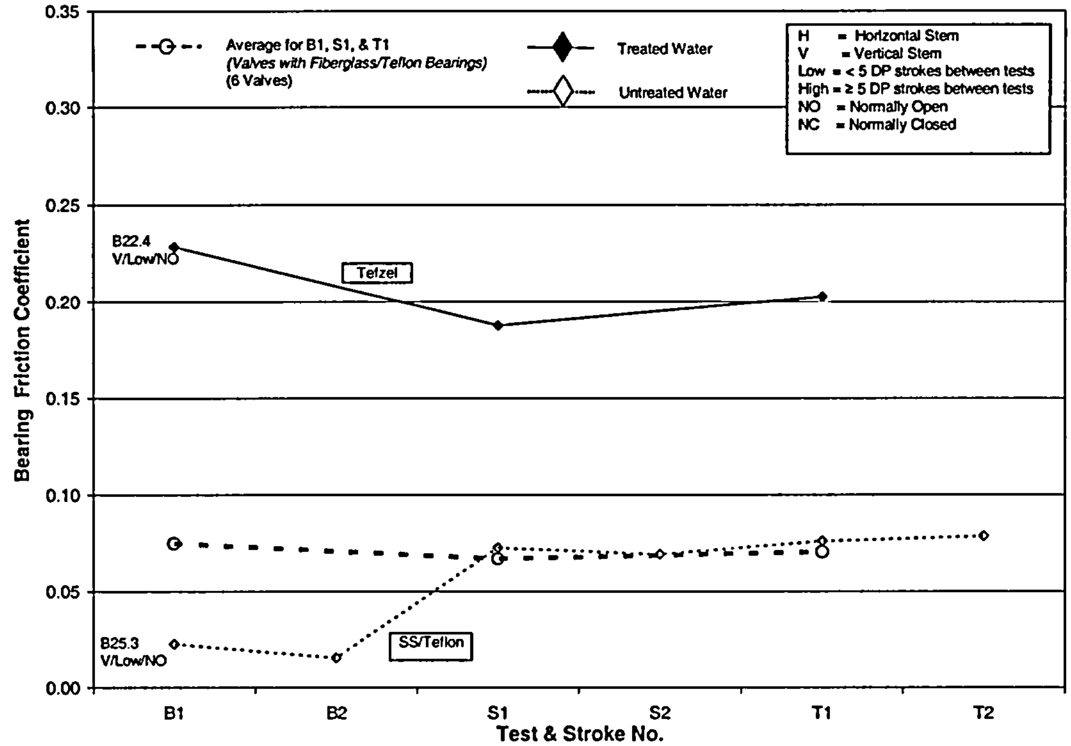


Figure 4-18. Bearing Friction Coefficient for Butterfly Valves with Tefzel and Teflon-Lined Bearings on Stainless Steel Backings

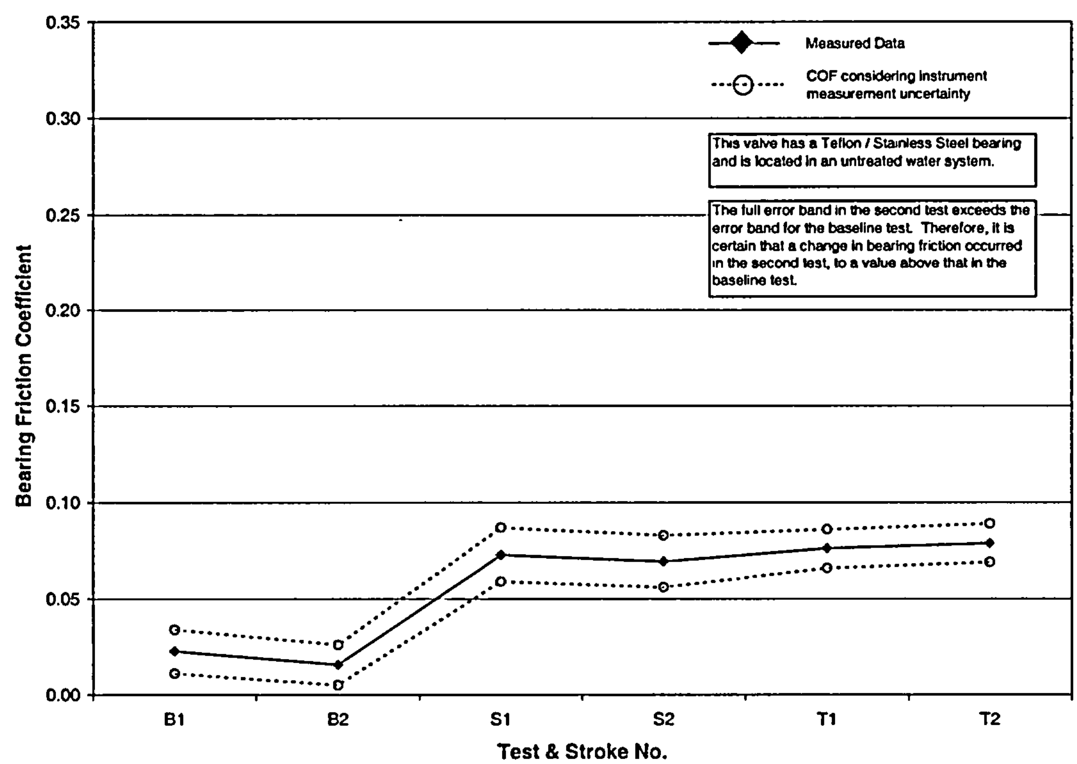


Figure 4-19. Bearing Friction Coefficient for B25.3 with Instrument Measurement Uncertainty

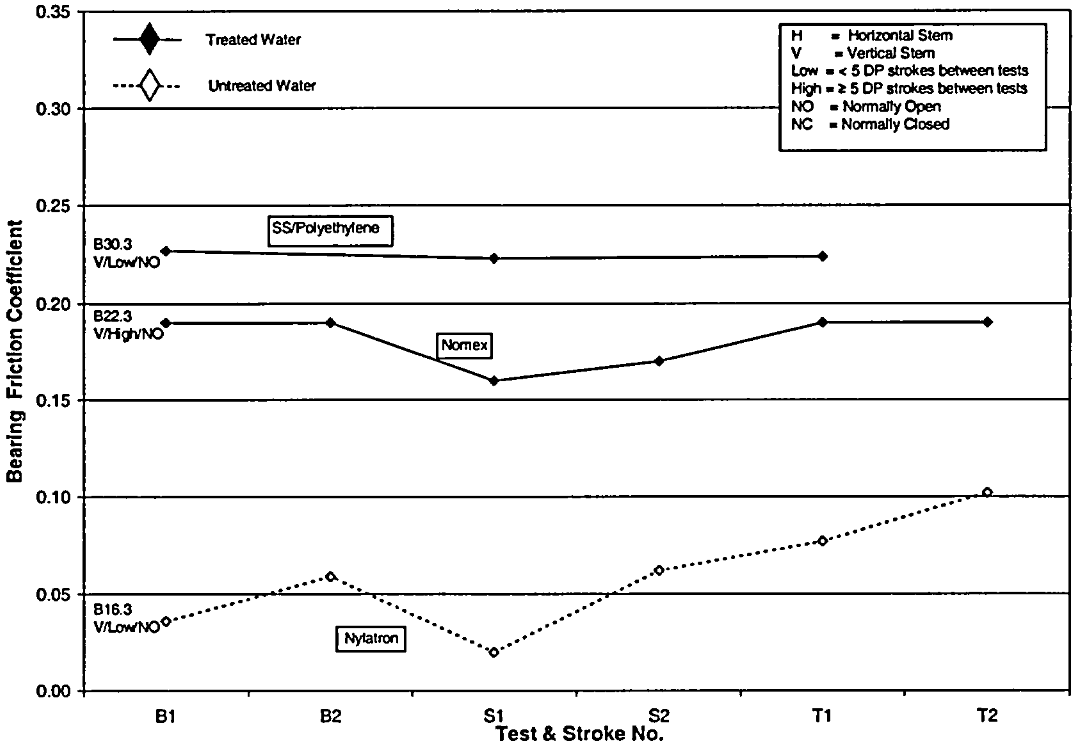


Figure 4-20. Bearing Friction Coefficient for Butterfly Valves with Other Non-Metallic Bearing Materials

5 Test Program Results for Balanced Disk Globe Valves

SUMMARY

Seven balanced disk globe valves were tested as part of the JOG MOV PV Program, representing the variety of valve design attributes and fluid conditions found in typical nuclear applications for balanced disk globe valves. The results from these seven valves indicate there is no age-related or service-related degradation of the required DP thrust. As expected, the DP thrust for balanced disk globe valves is small, and the valve factors are relatively low. Accordingly, the required DP thrust is insensitive to degradation.

Balanced disk globe valves in untreated water systems may be subject to variations in required thrust unrelated to DP thrust. These variations are likely attributable to the buildup of foreign material in the valve and not indicative of degradation. The buildup of foreign material did not significantly affect the DP thrust for these valves.

APPROACH FOR BALANCED DISK GLOBE VALVES

The intent of the JOG MOV PV Program was to test several balanced disk globe valves to determine if there were observable changes in the required DP thrust which could be related to degradation. A mechanism for potential degradation was identified in the JOG MOV PV Program Description Topical Report (Reference 3). Specifically, friction between the disk and its guiding surface is a contributor to the required DP thrust. In a balanced disk design, the guiding surface is provided by the inside wall of the cylindrical cage in which the disk moves. The friction coefficient between the disk and its guiding surface depends primarily on the materials of the two surfaces and the temperature; however, it may also be affected by contact configuration (e.g., flat-on-flat), contact stress and fluid medium. As described in Reference 3, the friction coefficient at the disk-to-body guide interface could potentially increase due to cumulative DP stroking, exposure to certain fluids and temperatures, or a combination of these influences.

It was judged important to identify valves for JOG MOV PV testing that had an appropriate range of disk-to-body guide material pairs and that were tested over an appropriate range of temperatures. The industry was surveyed to determine what valves were available to test. The survey confirmed that, in general, balanced disk globe valves are not used to a large extent in safety-related MOVs.[28] Based on the survey results for the valves available for DP testing, the primary disk-to-body guide material pairs are Stellite or a hardened steel (400 series stainless

[28] Member plants have over 30 balanced disk globe valves which can be DP tested (about 3% of the total valves in the survey).

steel or 17-4PH stainless steel) paired with a mild steel (carbon steel or 300 series stainless steel). Additionally, the survey identified that most balanced disk globe valves are located in low temperature ($\leq$120°F) water systems. The valves selected for testing in the JOG MOV PV Program were chosen to be representative of these survey results.

BALANCED DISK GLOBE VALVE TEST MATRIX AND APPLICABILITY

Seven balanced disk globe valves were tested in the JOG MOV PV Program. Table 5-1 summarizes the design attributes of these seven valves and Table 5-2 summarizes the fluid conditions for the tests.

Key Factors Associated with Potential Degradation

As identified in Reference 3, the key factors associated with the potential degradation of balanced disk globe valves are: disk-to-body guide materials, fluid medium and the amount of DP stroking. The seven balanced disk globe valves tested in the JOG MOV PV Program provided good coverage of all three factors.

Disk-to-Body Guide Materials[29]

The seven valves cover the following guide surface materials: Stellite, hardened steels (400 series stainless steel and 17-4PH stainless steel), mild steels (carbon steel and 300 series stainless steel) and bronze. In four valves, hardened steel is paired with mild steel. In two valves, hardened steel is paired with hardened steel or Stellite, and in one valve, mild steel is paired with bronze. The combination of mild steel with bronze is unusual and was not originally planned to be included in the JOG MOV PV Program, but was chosen based on the available test valves.

No balanced disk globe valves with Stellite-carbon steel or self-mated 300 series stainless steel guide material pairs were available for testing. Although these material pairs are rare in balanced disk globe valves, results from gate valve tests provide the necessary insights for the behavior of these material pairs. Specifically, both of these material pairs showed stable performance in gate valve guide slot-to-guide rail sliding (Section 3 – *Evaluation of Disk-to-Guide Friction*).

Type of Fluid

All seven valves are in water systems, with three in untreated water and four in treated water. The balance between treated and untreated water is useful, although in nuclear power plant service it is likely that a greater majority of balanced disk globe valves (i.e., more than 4/7) are used in treated water systems.

There were no valves tested in compressible flow, such as steam or air. Based on the industry survey, it appears that the majority of balanced disk globe valve applications (within safety related MOVs at least) are in water systems.

[29] In some balanced disk globe valves, the disk does not contact the body guide surface; instead, only the disk seal ring bears against the guide. In this case the materials of the seal ring and body guide should be considered. For all seven valves in the JOG MOV PV Program, direct disk-to-body guide contact occurs.

As discussed for gate valves (Section 3), air versus water is not a major influence on metal friction, and application of the JOG MOV PV Program results to valves in air appears reasonable, at least with regard to friction coefficient. However, it is possible that a compressible flow application could result in more side load on the disk than a water flow application with similar DP. Tests of unbalanced disk globe valves in the JOG MOV PV Program provide useful insight in this regard. Specifically, the unbalanced disk globe valve results showed no indication of degradation in required DP thrust (Section 6) for the three valves tested in compressible flow (steam) systems.

For balanced disk globe valves in steam flow, the elevated temperature associated with steam could affect the potential changes in friction coefficient at the guide interface. The results from gate valves provide additional insight in this regard. Specifically, the gate valve results showed stability of guide friction in steam flow similar to water flow (Section 3). The mechanism for friction at the guide interface is consistent between gate valves and balanced disk globe valves. Therefore, it is appropriate to conclude that potential changes in the friction coefficient at the guide interface in balanced disk globe valves are not affected by the elevated temperatures in steam applications.

Frequency of DP Stroking

One of the valves (BG01.1) is stroked extensively during normal operations, and accumulates about 75 DP strokes per year. All of the other valves are stroked less frequently. One valve, BG08.1, is not DP stroked under normal service conditions.

Additional Valve Design Attributes

In addition to the key factors identified above, the seven balanced disk globe valves provided good coverage of other valve design attributes and operating conditions. Although these additional design attributes and operating conditions are not identified in Reference 3 as important applicability factors for the data, it was judged prudent to cover an appropriate range of attributes and operating scenarios for nuclear power applications. The additional attributes/operating conditions are discussed below.

Valve Manufacturer

The test matrix covers four valve manufacturers: CCI, Copes-Vulcan, Fisher and Valtek.

Valve Size

The test matrix covers valves ranging in size from 2 to 16 inches.

Pressure Class

The test matrix covers three unique ANSI pressure classes: 150, 300, and 900 lbs.

Normal Valve Position

Three of the test valves are normally open and four are normally closed.

Flow Direction
Two of the test valves have overseat flow and five have underseat flow. The required thrust is affected by flow direction, and many balanced disk globe valves were designed for flow in a particular direction (i.e., not intended to be bi-directional).

Stem Orientation
Six valves have the stem mounted vertically, above the valve. One valve has a horizontal stem orientation.

Fluid Temperature
The tests cover fluid temperatures from 49 to 94°F, which is a typical range for tests in water systems.

Flow Rate
The water flow rates present during the DP tests were used to calculate water velocities, using both the nominal pipe diameter and the seat diameter. The pipe velocities range from 11 to 48 ft/sec, and the seat velocities range from 10 to 86 ft/sec. This range is extensive and is likely to cover the vast majority of applications.

Differential Pressure
Four of the valves had a test DP of approximately 200 psi or less, one had a DP of approximately 650 psi, and two had a DP of approximately 1500 psi. This range suitably covers typical nuclear power plant applications.

Non-Test Matrix Valve Covered by JOG MOV PV Program

While the JOG MOV PV Program was underway, the participating plants were surveyed to collect information on valves and applications that they judged to be outside the scope of the program. Plant personnel identified one balanced disk globe valve design which they thought might not be covered by the JOG MOV PV Program test matrix. This valve is the trip and throttle valve (e.g., Gimpel and Schutte & Koerting valves) which is typically used on Terry turbines and has steam flow rather than water flow. Several plants noted that these valves are within their GL 96-05 scope.

Valve Description
Figure 5-1 shows an example of a trip and throttle valve. These valves have several unique design features. First, each valve has a separate internal pilot valve, which is a small unbalanced disk globe valve. When the pilot is open, the valve main disk is partially pressure balanced, i.e., a hybrid of balanced and unbalanced designs. The hybrid nature occurs because there is an orificed flow path from the upstream pipe to the space above the valve disk. When the pilot is open, flow proceeds from the upstream piping to the space above the disk and then through the balancing holes in the disk. The pressure drops along this flow path are such that the pressure above the disk is greater than that below the disk, but less than the upstream pressure.

In addition to the pressure balancing arrangement described above, this valve includes a spring that is normally held in the compressed state. For an emergency trip (closure), the spring is released and the valve is closed rapidly by the spring without the motor-operator. Subsequent actuation (by the motor-operator) in the closing direction recompresses the spring without moving the valve disk. This actuator stroke is a demand that the actuator is required to meet.

Finally, these valves include a rotating-to-non-rotating stem junction, with a bearing. The actuator needs to supply the necessary torque to turn the bearing, during every stroke.

Justification of Coverage under JOG MOV PV Program

The JOG MOV PV Program does not provide information related to degradation of the thrust or torque required to recharge the spring or to drive the stem junction bearing. This constraint does not strongly affect plants as these components are outside the valve and can be tested separately to the extent necessary.

Within the valve, all of the potential degradation effects are covered by the tests in the JOG MOV PV Program even though these types of valves were not tested in the PV Program. The effects of steam flow on disk loading are covered by the unbalanced disk globe valve tests (Section 6), and the effects of steam on metal friction are covered by the gate valve tests (Section 3).

BALANCED DISK GLOBE VALVE TEST RESULTS AND ANALYSES

In accordance with the JOG DP Test Specification (Reference 9), each plant that tested a balanced disk globe valve prepared a test data package for each test of the valve. In this package, the test data were analyzed following standard procedures. In the closing stroke, the measured stem thrust at seating and at the maximum point up to seating were identified and tabulated, and the valve factors were calculated at those points. In the opening stroke, the measured stem thrust at unseating and at the maximum thrust point were identified and tabulated, and the valve factors were calculated at those points. In most cases, the maximum thrusts were at the seating and unseating points. It is important to note that the JOG valve factor equations may differ from equations used by valve manufacturers and vendors. The JOG valve factor equations are provided in Appendix A.

The required DP thrust for balanced disk globe valves is affected by the imbalance area of the disk and by disk-to-body guide friction. Usually the imbalance area is close to zero, and there is a required DP thrust due to friction in both directions. However, in some valves, the imbalance area is large enough that the imbalance force exceeds the friction force. In this case, the valve will have a self-actuating DP thrust in the direction favored by the imbalance. Due to imbalance, two of the valves (BG05.1 and BG07.1) had a self-actuating DP thrust in the closing direction. For these two valves, valve factors were calculated only in the opening direction. Similarly, one valve (BG01.1) had a self-actuating DP thrust in the opening direction, and valve factors for this valve were calculated only in the closing direction. For the seven tested valves, Table 5-3 summarizes the stroke directions for which valve factors were calculated.

The first observation related to the balanced disk globe valve results is that the DP thrust is relatively small. Table 5-4 summarizes the approximate maximum DP thrust for each valve.

Five of the seven valves have maximum DP thrusts less than 1,000 lbs. In the cases of the two valves with maximum DP thrusts greater than or equal to 1,000 lbs, the majority of the load is attributable to the pressure imbalance load component. Small DP thrusts (e.g., less than 1,000 lbs) are a challenge to measure and to interpret with precision. Accordingly, the trace marking and interpretation were carefully reviewed for each valve to ensure that the interpretation was as accurate as possible. Furthermore, as discussed later in this section, uncertainty analyses show that variations in valve factor between JOG tests are within instrument uncertainty.

Figures 5-2 and 5-3 show the valve factors for closing strokes at the points of maximum thrust and seating, respectively. Results for five valves are presented. The results for BG01.1 are not on Figure 5-2 (maximum thrust) because the maximum closing thrust occurred during the running portion of the stroke due to a high stem rejection load. In other words, the downstream pressure was highest at running, and that caused the stem rejection load and the total thrust to be highest at running. It is not appropriate (nor possible) to calculate a valve factor at the running condition.

The valve factors for all five valves are low (less than 0.05) and are constant throughout the three test series. This result indicates that there is no degradation in required thrust for these valves. Further, the low valve factors imply that the magnitudes of required DP thrust for these valves are small. Hence, even if degradation of the DP thrust was occurring, the overall required thrust for the valve would not be strongly affected.

The conclusion from Figures 5-2 and 5-3 is that the valve factors are not degrading. The dark dashed line on each graph shows the average valve factor (for the five valves), for the first stroke of each of the baseline, second and third tests. As can be seen, the trend is constant. Figure 5-4 provides the measured thrust overlay for the BG01.1 (as an example) in the closing direction. In this plot, the measured thrust from the first, second and third tests are plotted together. The close correspondence of the thrust traces from separate tests can be clearly seen.

Figures 5-5 and 5-6 show the valve factors for opening strokes at the points of unseating and maximum thrust, respectively. Results for six valves are presented. Two of the valves (BG05.1 and BG07.1) have a significant self-closing thrust component due to disk imbalance. Accordingly, the opening valve factors for these valves are higher than the opening valve factors for the other balanced disk globe valves. The majority of this increased thrust demand is attributable to the imbalance load of these two valves. For the other four valves (BG06.1, BG08.1, BG10.1 and BG10.2), the valve factors are low (less than 0.15), and there are no indications of increasing trends.

BG10.1 showed a decrease in valve factor between the first and second strokes of the baseline test (Figure 5-6, B1 to B2,). This apparent decrease is attributable to a thrust increase just after unseating in the first stroke of the baseline test that was not present in subsequent tests. BG06.1 showed a small unwedging load in the baseline test of about 200-300 lbs. This unwedging behavior dissipated (and eventually disappeared) in the second test sequence; however, the behavior reappeared in the third test sequence. This behavior explains the changes observed for B06.1 in Figures 5-5 and 5-6. BG05.1 showed a small increase in required thrust and valve factor between the first and second strokes of the second test. This small increase in valve factor is bounded by measurement uncertainty, as discussed below.

Figure 5-7 shows the valve factors at unseating for BG05.1, considering the effects of measurement uncertainty. For each calculated valve factor, there is an uncertainty associated with the measurement of pressure/DP and thrust during testing. These instrument uncertainties, each random, are combined statistically to produce a band of uncertainty around the measured valve factors. Within the band of valve factor uncertainty, a "series alley" is defined by the minimum value of the upper uncertainty line and the maximum value of the lower uncertainty line. The presence of a "series alley" indicates that it is possible (although not certain) that measured uncertainty accounts for the observed variations. All measured valve factors for valve BG05.1 fall within the defined "series alley". This observation does not prove that the valve factor variations are attributable to measurement uncertainty, but shows that it is likely a significant contributor to the observed results. This result is consistent with the overall conclusion (from the population of data) that the valve factors for balanced disk globe valves are steady.

The conclusion from Figures 5-5 through 5-7 is that the valve factors are not degrading. The dark dashed line on each of Figures 5-5 and 5-6 show the average valve factor (for the six valves), for the first stroke of each of the baseline, second and third tests. As can be seen, the trend is constant. Figure 5-8 provides the measured thrust overlay for BG07.1 (as an example) in the opening direction. In this plot, the measured thrust from the first, second and third tests are plotted together. The close correspondence of the thrust traces from separate tests can be clearly seen.

BALANCED DISK GLOBE VALVES IN UNTREATED WATER SYSTEMS

Three of the seven balanced disk globe valves (BG06.1, BG10.1 and BG10.2) are in untreated water systems. The results of these tests showed some unique observations, which appeared to be related to this particular application. Specifically, all three valves showed unexpected thrust variations during testing. However, none of these variations significantly affected the DP thrust and no degradation trend was observed. The observations from these tests are discussed below.

For BG06.1 and BG10.1, the seating behavior of the valves changed during the JOG MOV PV Program tests (Figures 5-9 and 5-10). In the baseline DP test, the thrust trace for each valve showed the expected sharp "corner" at seating. This behavior indicates that the disk seats against the seat ring, thereby stopping the disk and producing a sharp thrust increase as the actuator continues to turn. In the second DP test, the thrust trace for each valve showed a rounded transition at seating instead of the sharp "corner". This behavior implies that the disk is gradually seating and is not stopping immediately upon contact with the seat. In the third DP test, the thrust trace for each valve showed seating behavior similar to the baseline test.

The most likely explanation for the change in seating behavior is foreign material intermittently lodging and dislodging in the valves. Prior to the second DP test, foreign material from the system may have accumulated in the region around the seat. As the disk closed, the material was either crushed or displaced. In both cases, the valve's ability to perform its function was not degraded. The return of the sharp seating behavior in the third test indicates that the mechanism is a performance variation that may fluctuate, and is not a degradation trend.

For BG10.2, the thrust traces in the opening and closing DP strokes on the third test revealed unusual behavior. Specifically, the running region of the stroke (prior to the buildup of DP during closing and after the dissipation of DP during opening) showed a temporary thrust increase. Figure 5-11 shows opening thrust trace overlays, which highlights the unusual behavior. Once again, these observations are consistent with the accumulation of foreign material in a portion of the valve.

Balanced Disk Globe Valve Conclusions

1. There is no age-related degradation in required thrust. Specifically, there is no increase in the required DP thrust due only to the passage of time (without DP stroking).

2. There is no service-related degradation in the required thrust. Specifically, there is no increase in the required DP thrust due to DP stroking.

3. As expected, the required DP thrust is small, and the valve factors are relatively low for balanced disk globe valves. Accordingly, the required DP thrust is insensitive to degradation.

4. The seven balanced disk globe valves tested in the JOG MOV PV Program showed relatively constant DP thrust across the three test series, as indicated by valve factor. Therefore, there does not appear to be any degradation associated with the required DP thrust.

5. Balanced disk globe valves in untreated water systems could be subject to variations in required thrust unrelated to DP thrust. It appears that the increases could be related to buildup of foreign material in the valve, and the decreases associated with release of the material. However, the buildup of foreign material in the three JOG valves did not significantly affect the DP thrust, and no degradation trend was observed.

6. Based on results for unbalanced disk globe valves, no degradation is expected for compressible flow (flashing water or steam) applications, up to flow rates covered by JOG testing.

Table 5-1. Attributes of JOG MOV PV Program Balanced Disk Globe Valves

JOG Test Matrix No.	Manufacturer	Size (in)	Pressure Class (lbs)	Disk Guide Surface Material	Body Guide Surface Material	Seat Diameter (in)
BG01.1	Fisher	4	900	Stellite	17-4 PH SS	3.529
BG05.1	Fisher	4	300	300 series SS	400 series SS	4.375
BG06.1	Copes Vulcan	10	150	400 series SS	400 series SS	10.453
BG07.1	Valtek	10	900	300 series SS	bronze	5.875
BG08.1	CCI	2	900	400 series SS	carbon steel	1.491
BG10.1	Copes Vulcan	12	150	17-4 PH SS	SS	11.9
BG10.2	Copes Vulcan	16	150	17-4 PH SS	SS	13.6

JOG Test Matrix No.	Stem Orientation	Normal Position	Fluid Type	Normal Fluid Temperature (°F)	No. of Total Strokes Per Year	No. of DP Strokes Per Year
BG01.1	vertical	open	treated water	100	100	75
BG05.1	vertical	open	treated water	120	12	6
BG06.1	horizontal	closed	untreated water	65	6	1
BG07.1	vertical	closed	treated water	90	14	4
BG08.1	vertical	open	treated water	80	20	0
BG10.1	vertical	closed	untreated water	85	4	4
BG10.2	vertical	closed	untreated water	85	4	4

Table 5-2. Flow Conditions for JOG Balanced Disk Globe Valve Tests

JOG Test Matrix No.	Flow Direction	Flow rate (ft/sec) *(pipe diameter)*	Flow rate (ft/sec) *(seat diameter)*	Closing Test DP (psi)	Open Test DP (psi)	Test Temperature (°F)
BG01.1	overseat	13.7	17.5	1784 - 1920	1523 - 1720	71 - 83
BG05.1	underseat	44.4	37.1	210 - 229	208 - 242	87 - 94
BG06.1	underseat	10.8	9.9	99 - 101	93 - 99	49 - 61
BG07.1	underseat	19.8	57.4	1376 - 1523	1331 - 1451	65 - 87
BG08.1	overseat	48.0	86.4	594 - 677	569 - 657	78 - 83
BG10.1	underseat	17.7	18.0	85 - 117	84 - 115	54 - 75
BG10.2	underseat	13.1	18.1	103 - 111	101 - 109	52 - 80

Table 5-3. Stroke Directions for Which Valve Factors Were Calculated

JOG Test Matrix No.	Closing Valve Factor? *(DP thrust resists closing)*	Opening Valve Factor? *(DP thrust resists opening)*
BG01.1	Yes	No
BG05.1	No	Yes
BG06.1	Yes	Yes
BG07.1	No	Yes
BG08.1	Yes	Yes
BG10.1	Yes	Yes
BG10.2	Yes	Yes

Table 5-4. Maximum DP Thrust

JOG Test Matrix No.	Approximate Maximum DP Thrust (lbs)	Comment
BG01.1	800	None
BG05.1	1000	Majority of DP Thrust is due to pressure imbalance component
BG06.1	900	None
BG07.1	8000	Majority of DP Thrust is due to pressure imbalance component
BG08.1	140	None
BG10.1	600	None
BG10.2	800	None

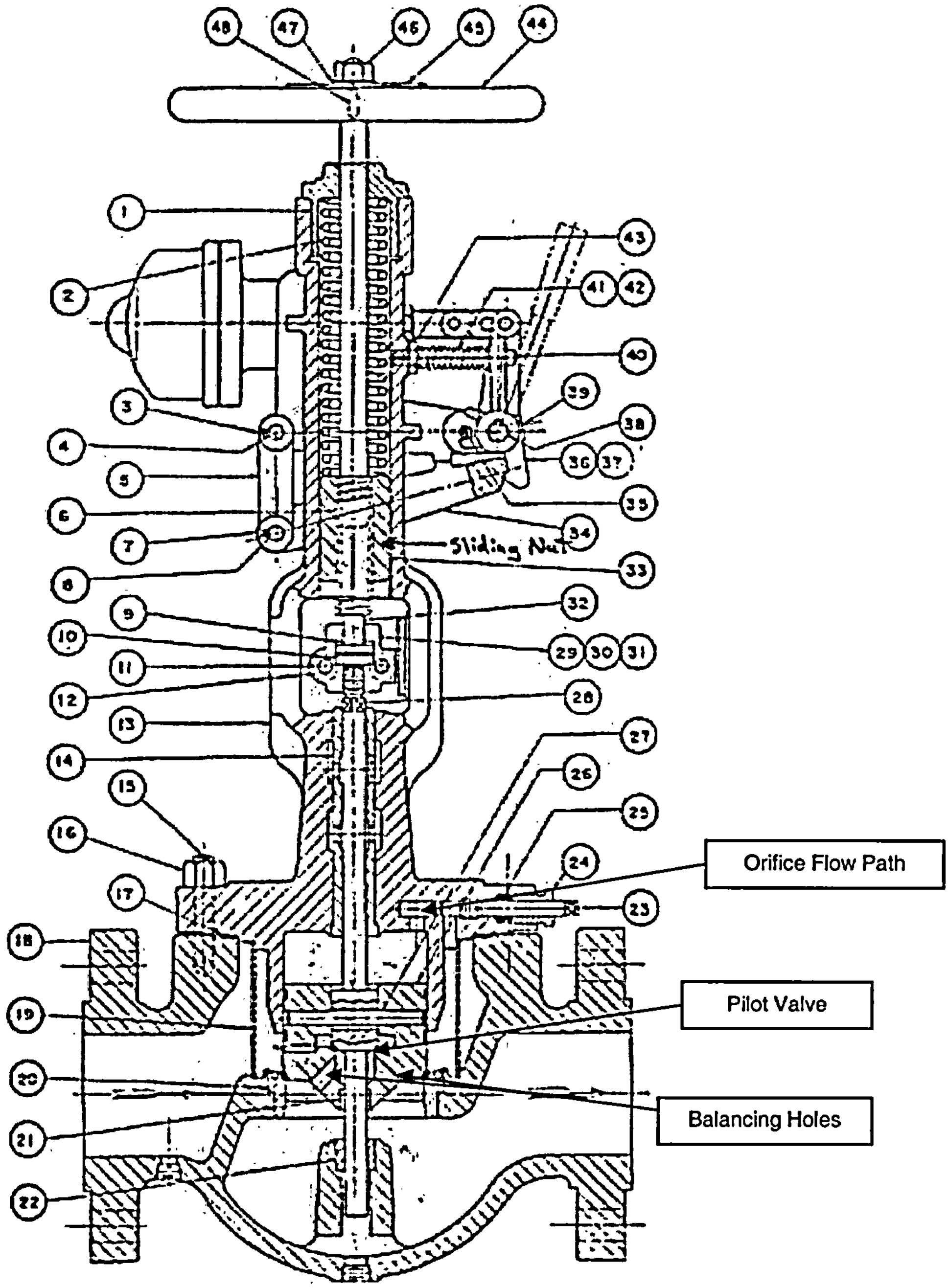


Figure 5-1. Trip and Throttle Valve used on Terry Turbines (steam flow)

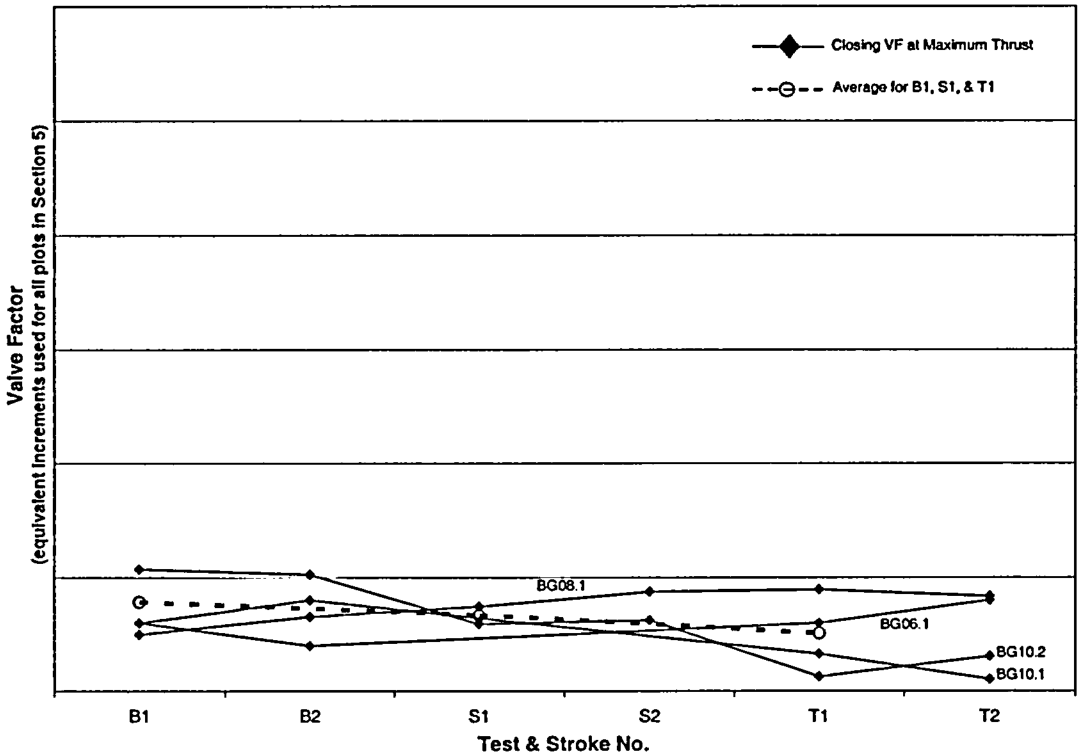


Figure 5-2. Closing Valve Factors at Maximum Thrust for Balanced Disk Globe Valves

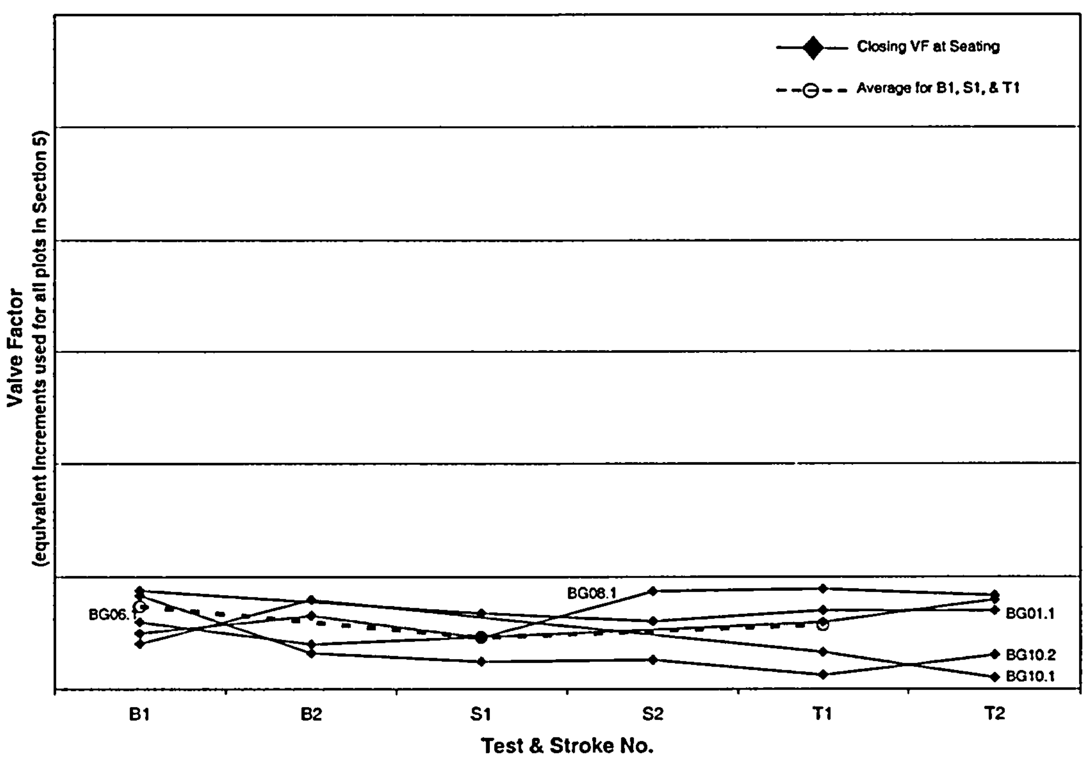


Figure 5-3. Closing Valve Factors at Seating for Balanced Disk Globe Valves

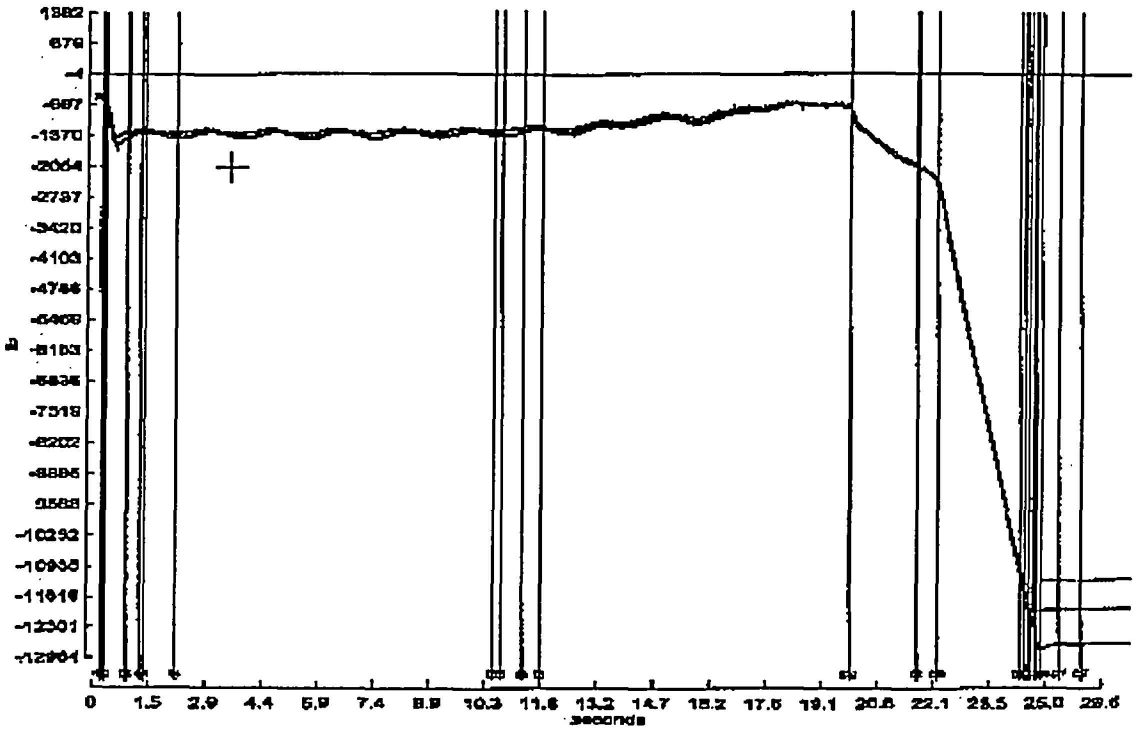


Figure 5-4. Thrust Overlay for Closing Strokes of Valve BG01.1

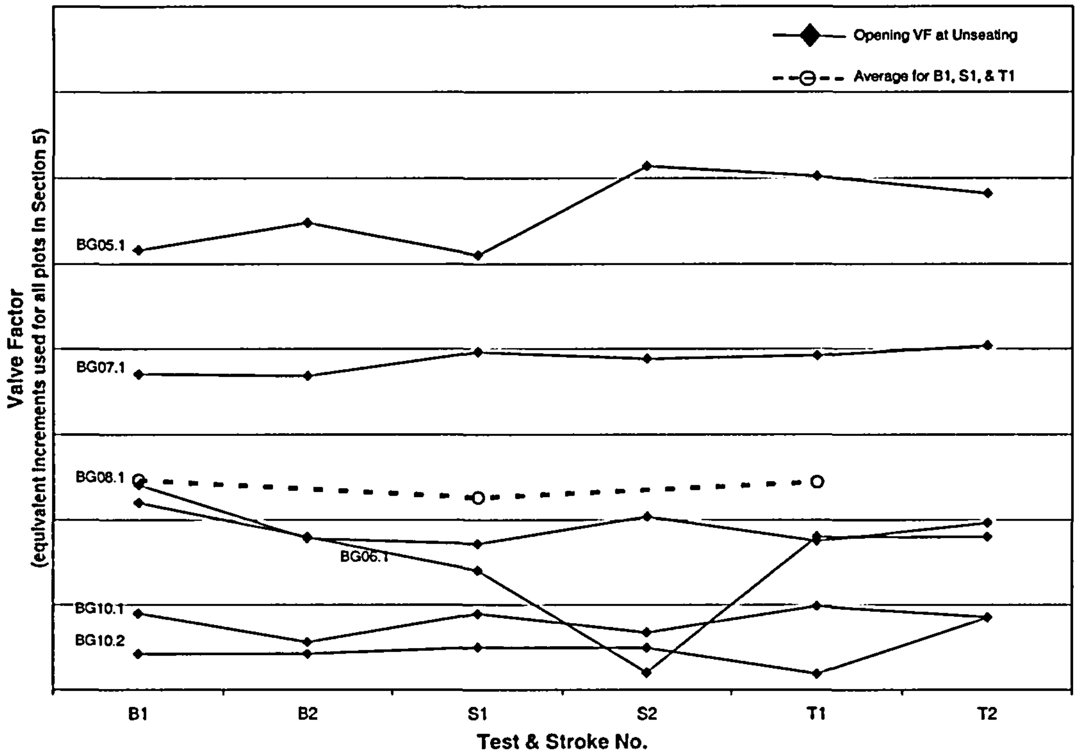


Figure 5-5. Opening Valve Factors at Unseating for Balanced Disk Globe Valves

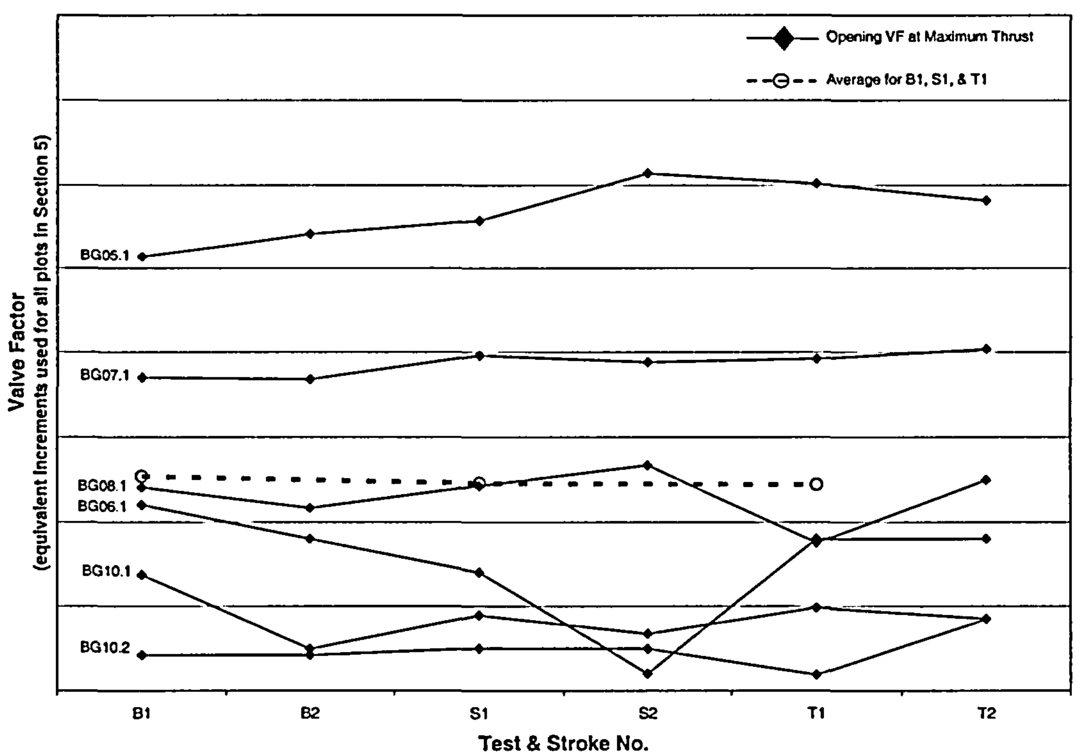


Figure 5-6. Opening Valve Factors at Maximum Thrust for Balanced Disk Globe Valves

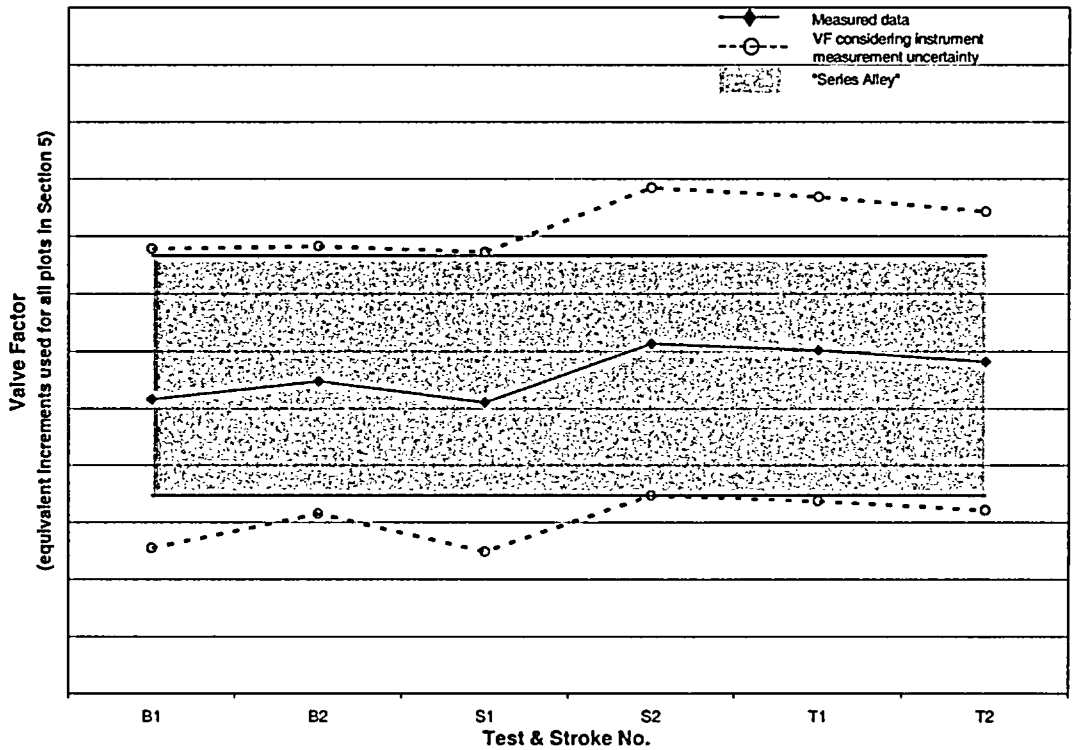


Figure 5-7. Valve Factors at Unseating for BG05.1 with Instrument Measurement Uncertainty

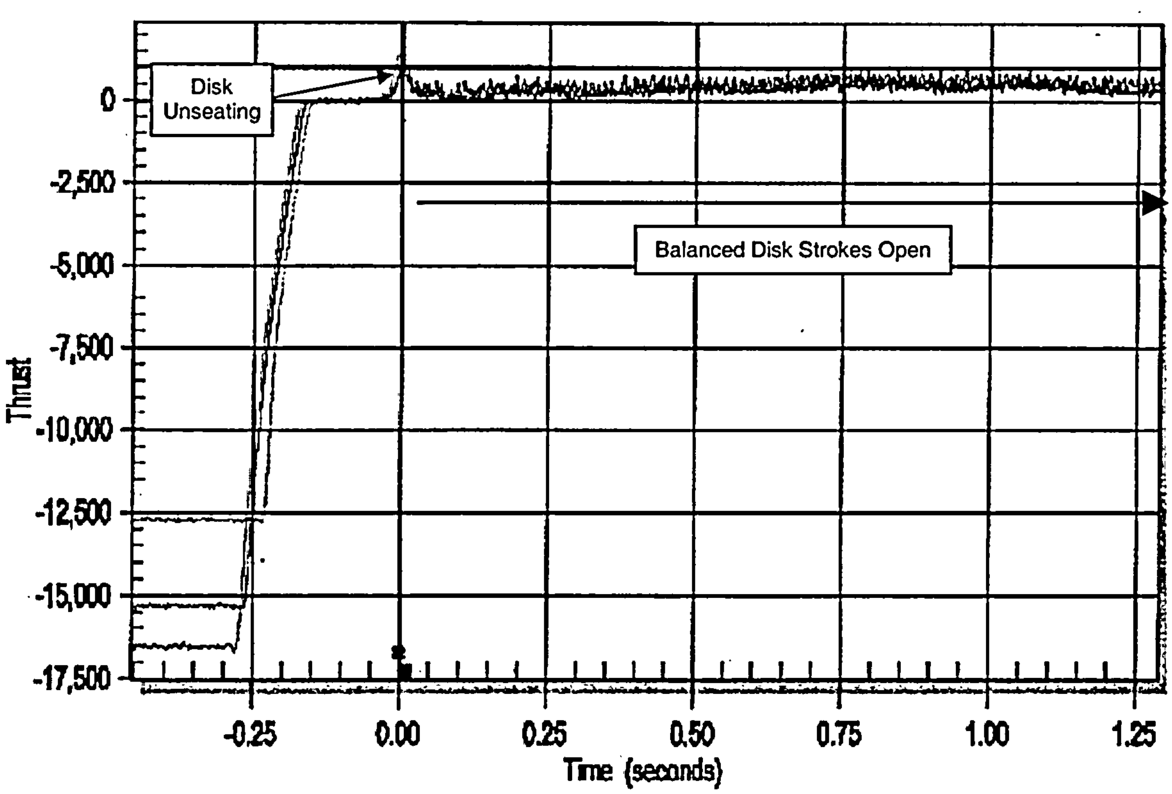


Figure 5-8. Thrust Overlay for Opening Strokes of BG07.1

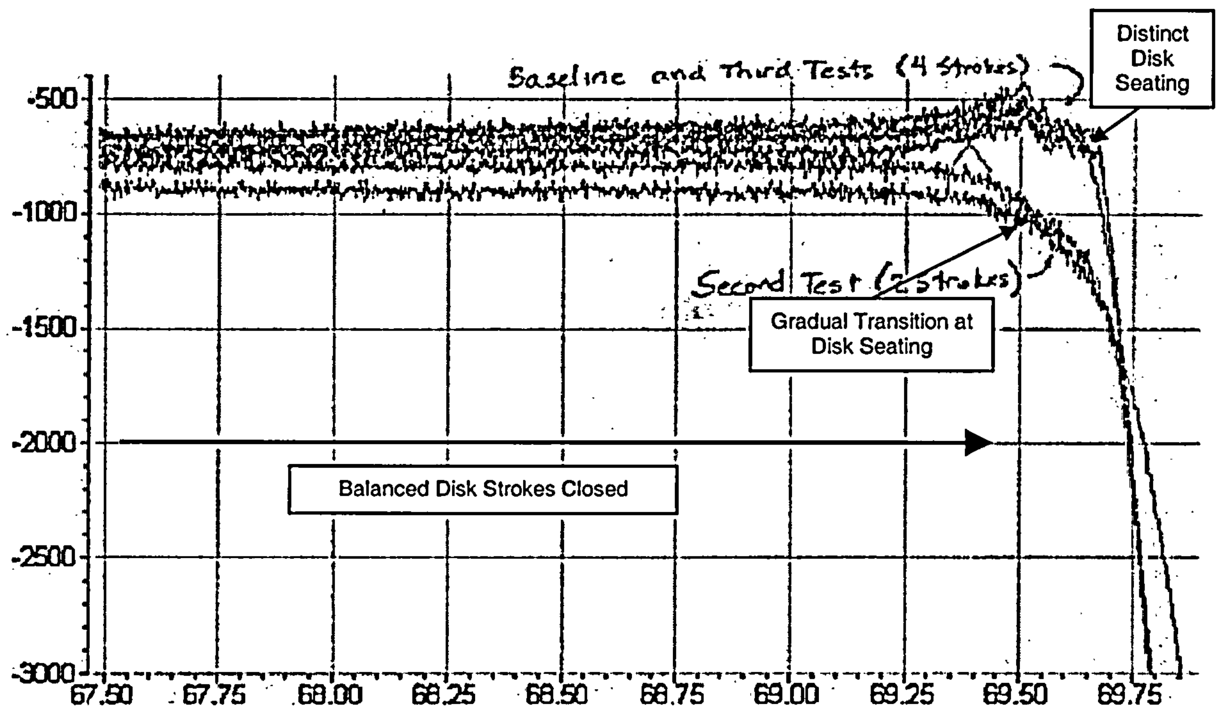


Figure 5-9. Thrust Overlay for Closing Strokes of BG06.1

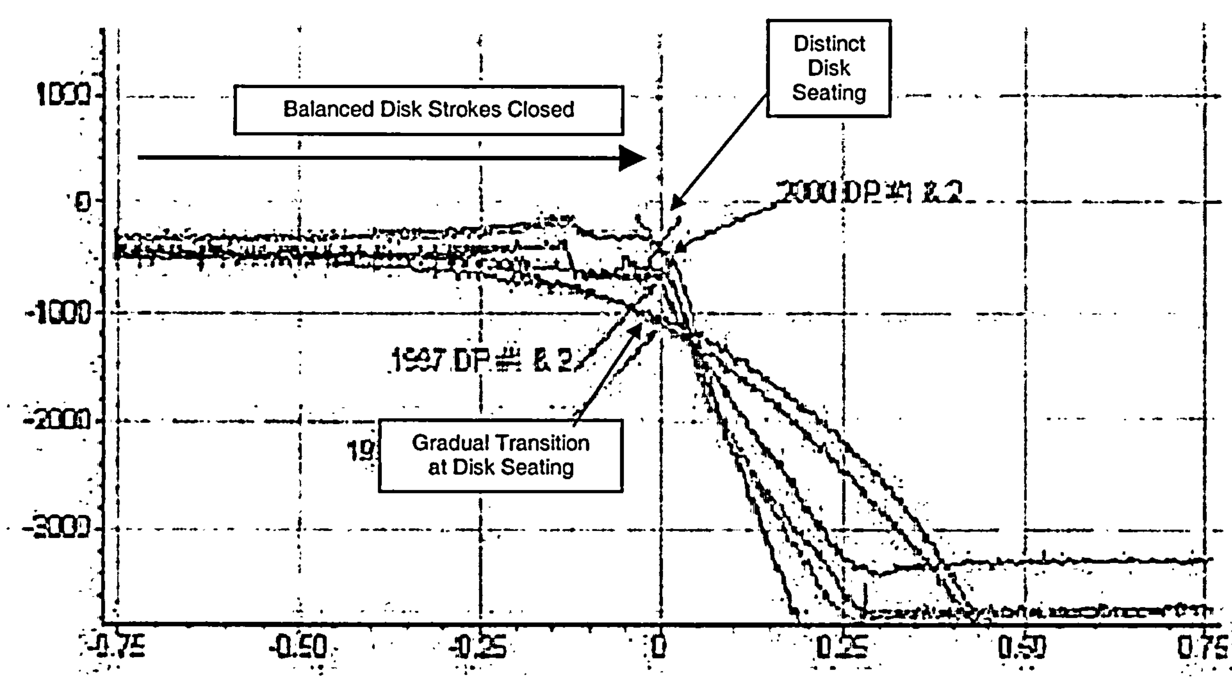


Figure 5-10. Thrust Overlay for Closing Strokes of BG10.1

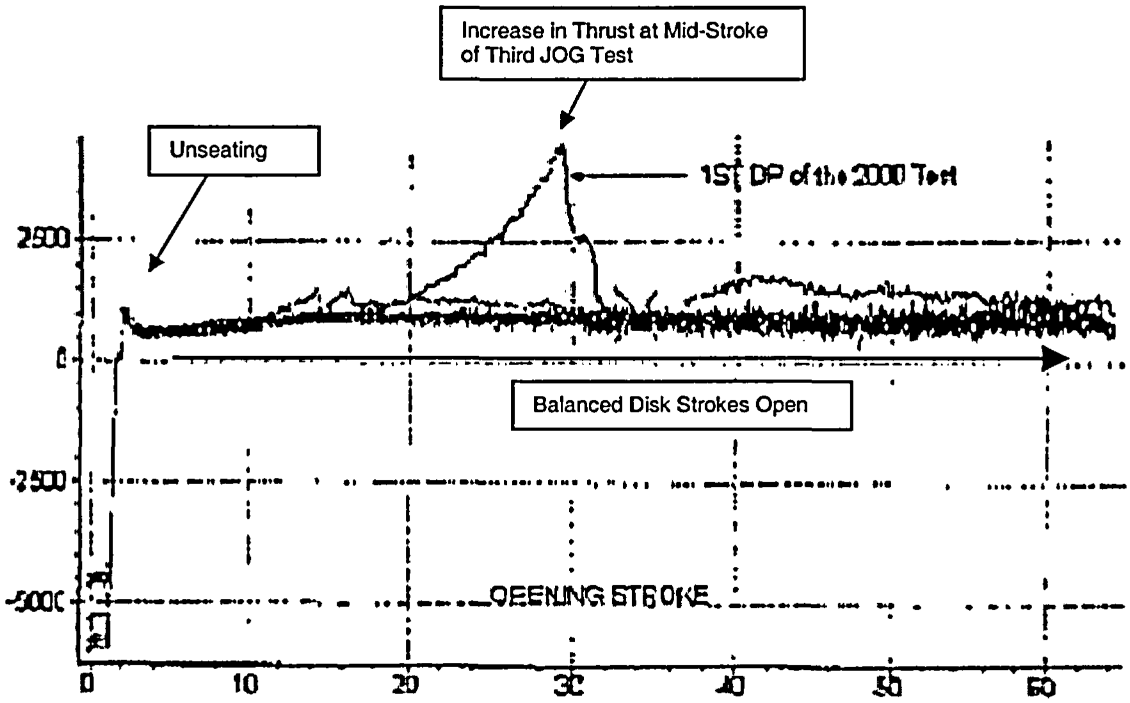


Figure 5-11. Thrust Overlay for Opening Strokes of BG10.2

6 Test Program Results for Unbalanced Disk Globe Valves

Summary

Twelve unbalanced disk globe valves were tested as part of the JOG MOV PV Program, representing the variety of valve design attributes and fluid conditions found in typical nuclear applications for unbalanced disk globe valves. The results from the nine valves in water systems indicate there is no age-related or service-related degradation of the required DP thrust. The results for the three valves in steam systems also show a steady behavior between tests, indicating no degradation of the required DP thrust.

Approach for Unbalanced Disk Globe Valves

The JOG MOV PV Program Description Topical Report (Reference 3) identified no mechanisms for degradation of required thrust in unbalanced disk globe valves. Accordingly, the intent of the JOG MOV PV Program was to DP test several unbalanced disk globe valves to confirm the absence of degradation. Twelve valves were selected for DP testing from those offered by the participating plants.

Insights from Experience and Other Testing

Based on industry experience, the disk-to-body friction component of required thrust for unbalanced disk globe valves is typically small, as compared to the required DP thrust, and may be considered negligible. However, tests in the EPRI MOV Program indicate that some unbalanced disk globe valve designs in specific flow conditions can have significant disk-to-body friction loads as the result of side loading of the disk. Results for EPRI valve #48 (Reference 12), tested in flashing water under blowdown conditions, showed a valve factor of 1.5, suggesting that as much as 50% of the required thrust could be attributable to friction loads. There is a potential concern that conditions beyond those tested by JOG could lead to elevated disk side loads and friction loads.

Unbalanced Disk Globe Valve Test Matrix and Applicability

Twelve unbalanced disk globe valves were tested in the JOG MOV PV Program. Table 6-1 summarizes the design attributes of these twelve valves and Table 6-2 summarizes the fluid conditions for the tests. Although Reference 3 identified no degradation mechanisms for unbalanced disk globe valves, the twelve tested valves provided good coverage of design attributes and operating conditions for nuclear power applications. These attributes and conditions are summarized below.

Valve Manufacturer
The test matrix covers six valve manufacturers: Anchor/Darling, Fisher, Powell, Valtek, Velan and Walworth.

Valve Size
The text matrix covers valves ranging in size from 2 to 18 inches.

Pressure Class
The test matrix covers three unique ANSI pressure classes: 300, 600 and 1500 lbs.

Valve Design
Eleven of the test valves have T-pattern body design and one has a Y-pattern body design.

Disk-to-Body Guide Materials
The test matrix covers the following guide materials: Stellite, Inconel, hardened steels (400 series stainless steel, 17-4PH stainless steel) and mild steels (carbon steel and 300 series stainless steel). In five valves, the guides are self-mated Stellite or Stellite paired with mild steel. In four valves, mild steel is paired with mild steel. In three valves, mild steel is paired with either hardened steel or Inconel.

Normal Valve Position
Eleven test valves are normally closed and one is normally open.

Flow Direction
Eleven of the test valves have underseat flow and one valve has overseat flow.

Stem Orientation
Nine valves have the stem mounted vertically. Two valves have horizontal stems. One valve (Y-pattern) has the stem mounted 25° from vertical.

Stem Design
All twelve valves have rising stems. No valves tested have rising/rotating stems.

Type of Fluid
Eight of the test valves are in treated water systems, one valve is in untreated water, and three valves are in steam systems.

Fluid Temperature
The nine valves in water systems are tested at temperatures ranging from 50°F to 110°F. The normal temperatures for these valves range up to 130°F. The three valves in steam systems are tested at temperatures between 522°F and 583°F, which are the approximate normal temperatures for these systems.

Flow Rate
For the nine valves in water systems, the water flow rates present during the DP tests were used to calculate water velocities, using both the nominal pipe diameter and the seat diameter. The pipe velocities range from 6 to 34 ft/sec, and the seat velocities range from 7 to 42 ft/sec. This range is extensive, and is likely to cover the majority of nuclear power plant applications. Two of the valves tested in steam have flow velocities of approximately 41 ft/sec based on pipe area and approximately 55 ft/sec based on seat area. The third valve tested in steam has a flow velocity of approximately 18 ft/sec based on both pipe and seat area. These velocities are calculated using the saturated steam density at the upstream pressure.

Frequency of DP Stroking
Ten valves are typically DP stroked under normal operating conditions, ranging in frequency from 4 to 30 strokes per year. Two valves are not typically DP stroked.

Differential Pressure
Six valves had a test DP of 400 psi or less, five had a DP between 900 and 1,600 psi, and one had a DP of approximately 2,600 psi.

UNBALANCED DISK GLOBE VALVE TEST RESULTS AND ANALYSES

In accordance with the JOG DP Test Specification (Reference 9), each plant that tested an unbalanced disk globe valve prepared a test data package for each test of the valve. In this package, the test data were analyzed using standard procedures.

For the eleven valves with underseat flow, the closing stroke measured stem thrust at seating and the point of maximum thrust were identified and tabulated, and valve factors were calculated at those points. In most cases, the point of maximum thrust occurred at the seating point. For one valve (UG14), the DP and thrust during the closing stroke were small because the downstream piping only partially depressurized during the closing stroke. For this valve, a separate method was developed to determine a valve factor for the opening stroke, which was a self-actuating stroke (compressive thrust) with a higher DP and stem thrust.

For the single valve with overseat flow (UG11), the opening stroke maximum stem thrust occurred at unseating, and a valve factor was calculated at this point. Additionally, due to the presence of a small unwedging load, a valve factor at the point just after unseating was also determined. The valve factor at this alternate point is a more reliable indicator of DP thrust and is used in lieu of the unseating valve factor.

All valve factors for unbalanced disk globe valves in the JOG MOV PV Program are calculated based on mean seat diameter. This methodology may not result in a valve factor that is applicable for use in calculating required thrust since the required thrust for some valves is controlled by the guide area. However, this methodology provides an adequate method to evaluate changes in valve factor between tests, which is the parameter of interest for evaluating degradation.

Unbalanced Disk Globe Valves in Water Systems

Figure 6-1 shows valve factors for the nine valves tested in water systems. The dashed line shows the average valve factor (for the eight valves with three tests) for the first DP stroke of each of the baseline, second and third tests (e.g., B1, S1 and T1). Figure 6-2 shows the change in valve factor between tests considering the first DP stroke of each test. The valve factors for UG01, UG09, UG11[30] and UG12 are relatively constant across the test series, indicating there is no degradation in required thrust for these valves. For the other five valves, the valve factors show small variations between tests. In all cases, however, these small variations in valve factor are within the measurement uncertainty, as discussed below.

Figures 6-3, 6-4 and 6-5 show valve factor uncertainty analyses, applied to the three valves with the largest valve factor variations between tests (UG02, UG04 and UG08). The valve factor uncertainties are determined from the uncertainty associated with measurements of pressure and thrust during testing. These measurement uncertainties, each random, are combined statistically to produce a band of uncertainty around the measured valve factors. Within the band of valve factor uncertainty, a "series alley" is defined by the minimum value of the upper uncertainty line and the maximum value of the lower uncertainty line. The presence of a "series alley" indicates that it is possible (although not certain) that measured uncertainty accounts for the observed variations. For the three valves analyzed, all measured valve factors fall within the "series alleys". These observations do not prove that the variations are attributable to measurement uncertainty, but show that it is likely a significant contributor to the observed results. These results support the overall conclusion (from the population of data) that the valve factors for unbalanced disk globe valves are steady.

The conclusion from Figures 6-1 through 6-5 is that the valve factors are not degrading. The average factor line on Figure 6-1 shows that the trend is constant, indicating no change in the required DP thrust for unbalanced disk globe valves. Figure 6-6 provides an example of a measured thrust overlay for an unbalanced disk globe valve tested in a water system. The measured closing thrust from the first, second and third tests of UG04 are plotted together. The close correspondence of the thrust traces from separate tests can be clearly seen.

Unbalanced Disk Globe Valves in Steam Systems

Figure 6-7 shows valve factors for the three valves tested in steam flow. Figure 6-8 shows the change in valve factor between tests considering the first DP stroke of each test (e.g., B1, S1 and T1). The details for each valve are discussed below.

Valve UG07

The valve factors for the three tests match closely, as confirmed by the thrust overlay in Figure 6-9.

Valve UG13

In all three tests of valve UG13, the DP and thrust transients during the valve closing stroke exhibit a unique behavior. Specifically, the pressure transient of the system causes a

[30] For valve UG11, valid data from only two tests were obtained.

peak in DP and thrust prior to seating. The valve factors for both the points of maximum thrust and seating are shown in Figures 6-7 and 6-8. Valid DP measurements were not obtained in the second test, thus reliable valve factors could not be calculated for this test. However, as seen in Figure 6-10, the closing thrust traces for all three tests overlay closely, indicating that there is no degradation of the required thrust.

Valve UG14

As seen in Figures 6-7 and 6-8, the valve factor at seating for valve UG14 increases significantly from the baseline to the third test[31]. Figure 6-11 shows that it is possible that this change is attributable to measurement uncertainty; however, the "series alley" is narrow and the valve factors calculated from the test data are outside this band. The width of the uncertainty band in Figure 6-11 is affected by the relatively low DP during seating (approximately 20% of the upstream pressure). Most of the depressurization of the downstream piping occurs after the valve seats. Since the valve strokes closed against a low DP, the required thrust at seating is relatively low and the uncertainty associated with the thrust and DP measurements (as a percentage of measured value) is high. Therefore, there is not high confidence that these results show a particular conclusion, and other ways to analyze the data were investigated.

To obtain a more accurate indicator of valve performance, the valve factors for UG14 are also analyzed for the opening stroke (self-actuating stroke), where the DP is approximately equal to the upstream pressure. Figures 6-7 and 6-12 provide the valve factor data and uncertainty analysis for the point of maximum compressive thrust during the opening stroke (near unseating) of UG14. As shown in the figures, the valve factor is relatively constant from the baseline to the third test[32]. In addition, the uncertainty band for the opening stroke valve factor analysis is considerably narrower than the band for the closing stroke data and the variations in valve factor are bounded by the measurement uncertainty. These results support the conclusion that the valve factors for UG14 are stable.

Additionally, Figure 6-13 shows the measured DC motor current near seating for all three closing strokes of UG14. DC motor current is directly proportional to motor torque. Motor torque is proportional to stem thrust but can also be affected by actuator gear efficiency and stem friction. The close correspondence of the three curves in Figure 6-13 in the region leading up to disk seating suggests (but does not prove) that the stem thrust is constant.

UNBALANCED DISK GLOBE VALVE CONCLUSIONS

1. There is no age-related degradation in required thrust. Specifically, there is no increase in the required DP thrust due only to the passage of time (without DP stroking).

[31] Valid second test thrust and valve factor data was not obtained for UG14.

[32] Note that for a self-actuating stroke, a *decrease* in valve factor indicates a potential increase in friction effects. The direction of change in valve factor for UG14 opening stroke data is consistent with the closing stroke results, but the magnitude of the change is very small.

2. There is no service-related degradation in required thrust. Specifically, there is no increase in the required DP thrust due to DP stroking.

3. The nine unbalanced disk globe valves tested in the JOG MOV PV Program in water systems show stable valve factors, supporting the initial JOG MOV PV Program conclusion that there is no degradation associated with the required DP thrust.

4. The results for the three valves in steam systems show steady behavior between tests, indicating no degradation of the required DP thrust.

5. Based on results from EPRI testing, valves with high compressible flow rates could lead to elevated disk side loads and friction loads. Accordingly, no degradation is expected for compressible flow applications, up to flow rates covered by JOG testing.

Table 6-1. Attributes of JOG MOV PV Program Unbalanced Disk Globe Valves

JOG Test Matrix No.	Valve Manufacturer	Size (in)	Pressure Class (lbs)	Valve Design	Disk Guide Surface Material	Body Guide Surface Material
UG01	Valtek	16	300	T-pattern	Inconel	300 series SS
UG02	Fisher Controls	6	300	T-pattern	300 series SS	17-4 PH SS
UG03	Powell	4	600	T-pattern	Stellite	Stellite
UG04	Anchor/Darling	18	300	T-pattern	Carbon Steel	Carbon Steel
UG07	Walworth	4	600	T-pattern	Carbon Steel	Carbon Steel
UG08	Velan	2	1500	T-pattern	Stellite	300 series SS
UG09	Anchor/Darling	18	300	T-pattern	Carbon Steel	Carbon Steel
UG10	Velan	2	1500	T-pattern	Stellite	Stellite
UG11	Velan	2	1500	Y-pattern	Stellite	300 series SS
UG12	Velan	2	1500	T-pattern	Stellite	Carbon Steel
UG13	Walworth	4	600	T-pattern	Carbon Steel	Carbon Steel
UG14	Powell	3	600	T-pattern	400 series SS	Carbon Steel

JOG Test Matrix No.	Stem Design	Stem Orientation	Normal Position	Type of Fluid	Normal Fluid Temp. (°F)	No. of Total Strokes Per Year	No. of DP Strokes Per Year
UG01	rising only	vertical	closed	treated water	90	16	8
UG02	rising only	vertical	closed	untreated water	80	25	21
UG03	rising only	horizontal	closed	treated water	113	19	4
UG04	rising only	vertical	closed	treated water	95	40	30
UG07	rising only	vertical	closed	steam	580	16	16
UG08	rising only	horizontal	closed	treated water	120	4	0
UG09	rising only	vertical	closed	treated water	100	33	28
UG10	rising only	vertical	open	treated water	130	10	0
UG11	rising only	25° from vertical	closed	treated water	110	15	5
UG12	rising only	vertical	closed	treated water	103	24	16
UG13	rising only	vertical	closed	steam	580	16	12
UG14	rising only	vertical	closed	steam	518	8	4

Table 6-2. Flow Conditions for JOG Unbalanced Disk Globe Valve Tests

JOG Test Matrix No.	Flow Direction	Flow Rate (ft/sec) *(pipe diameter)*	Flow Rate (ft/sec) *(seat diameter)*	Closing Test DP (psi)	Open Test DP (psi)	Test Temperature (°F)
UG01	underseat	26.9	35.7	229 – 241	N/A	70 – 86
UG02	underseat	8.0	33.5	383 – 394	N/A	50 – 80
UG03	underseat	16.0	22.7	1429 – 1452	N/A	77 – 93
UG04	underseat	13.2	16.8	363 – 371	N/A	80
UG07	underseat	41.2	54.7	915 – 948	N/A	583
UG08	underseat	7.0	8.0	984 – 1209	N/A	94 – 110
UG09	underseat	32.6	42.3	341 – 351	N/A	74 – 85
UG10	underseat	6.2	7.0	2527 – 2673	N/A	91 – 96
UG11	overseat	34.0	37.6	N/A	1221 – 1272	102
UG12	underseat	8.7	14.5	1383 – 1554	N/A	88 – 91
UG13	underseat	41.2	54.7	252 – 280	N/A	583
UG14	underseat	18.3	17.7	154 – 161	805 - 813	522

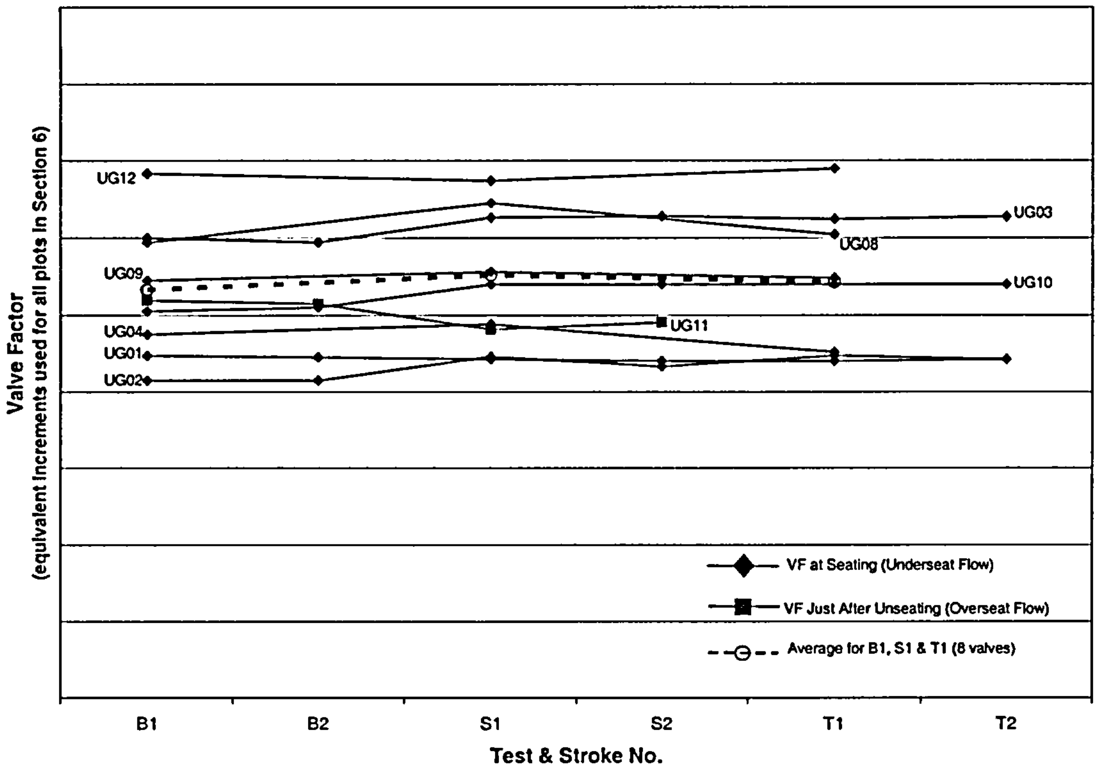


Figure 6-1. Valve Factors for Unbalanced Disk Globe Valves in Water Systems

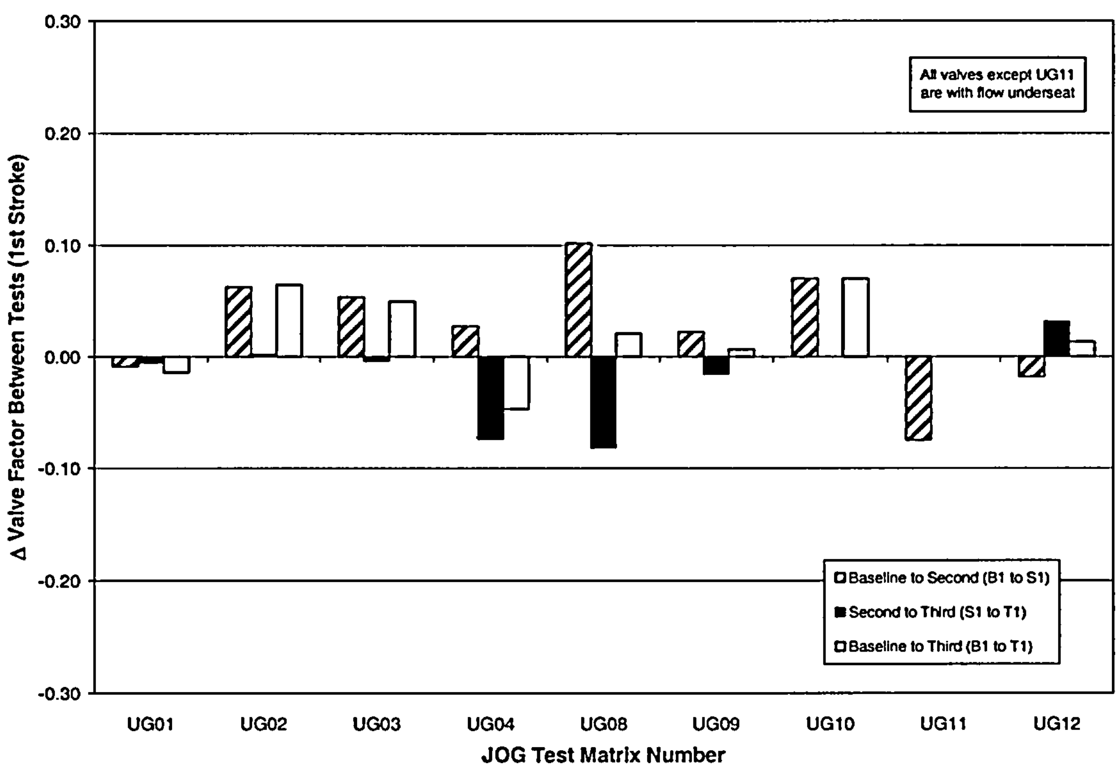


Figure 6-2. Change in Valve Factor for Unbalanced Disk Globe Valves in Water Systems

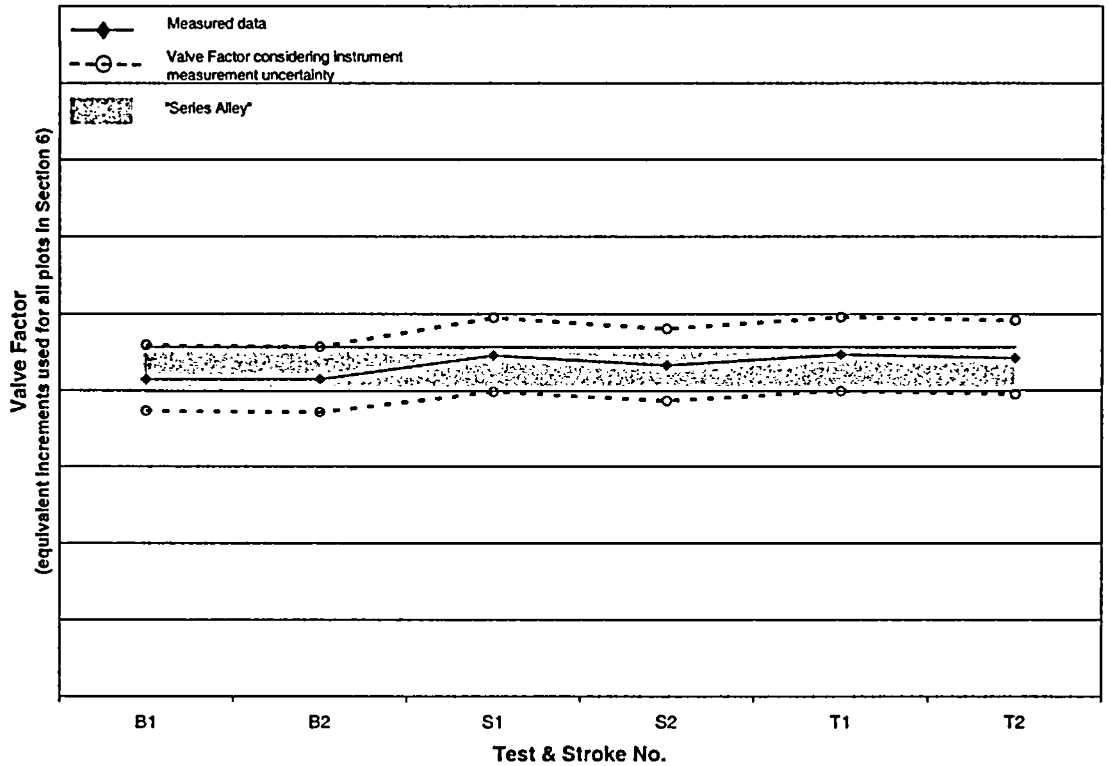


Figure 6-3. Valve Factors at Seating for UG02 with Instrument Measurement Uncertainty

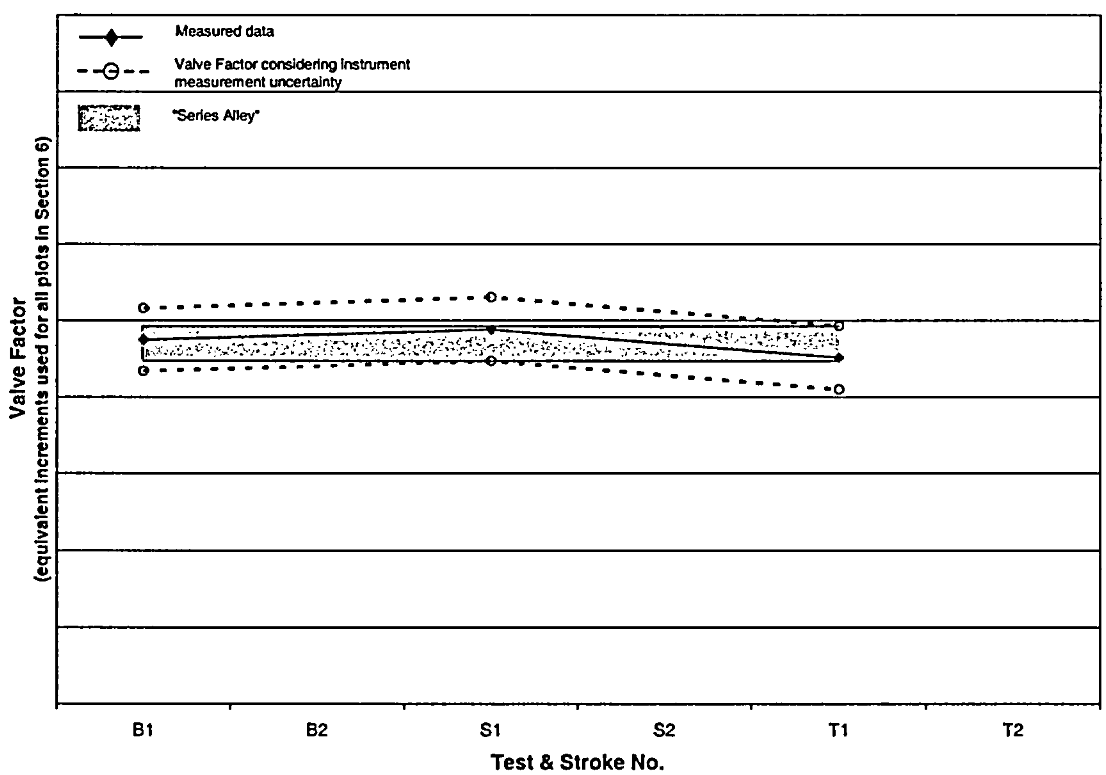


Figure 6-4. Valve Factors at Seating for UG04 with Instrument Measurement Uncertainty

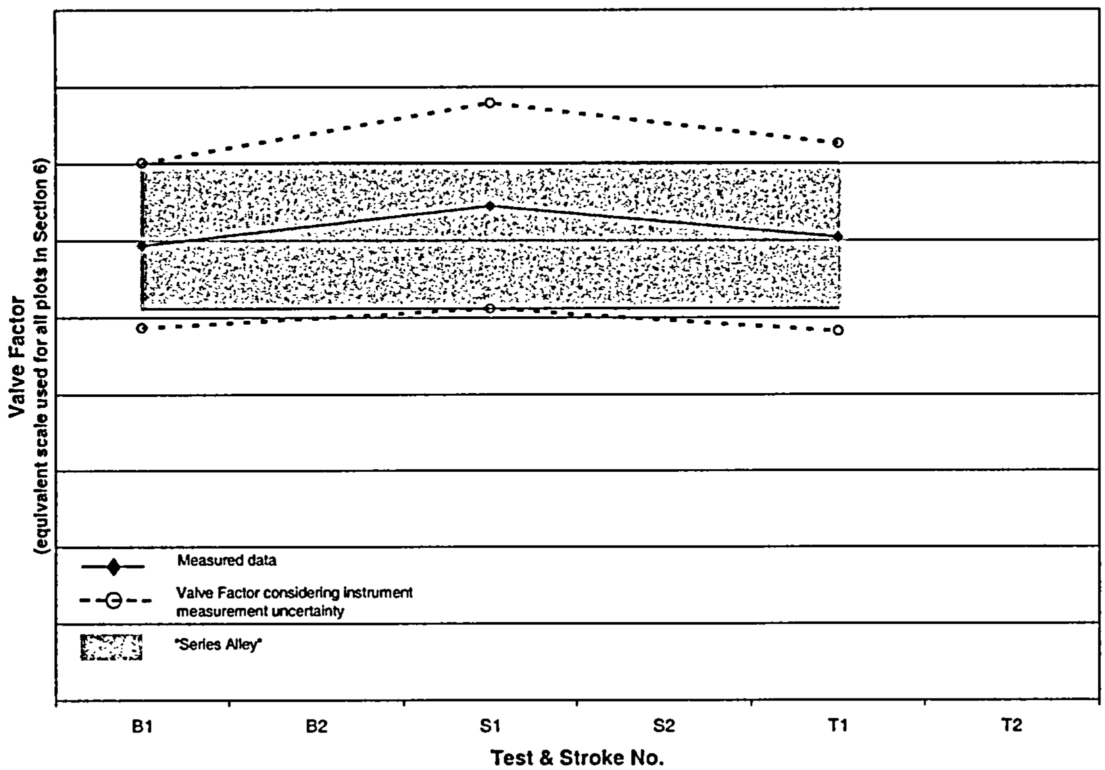


Figure 6-5. Valve Factors at Seating for UG08 with Instrument Measurement Uncertainty

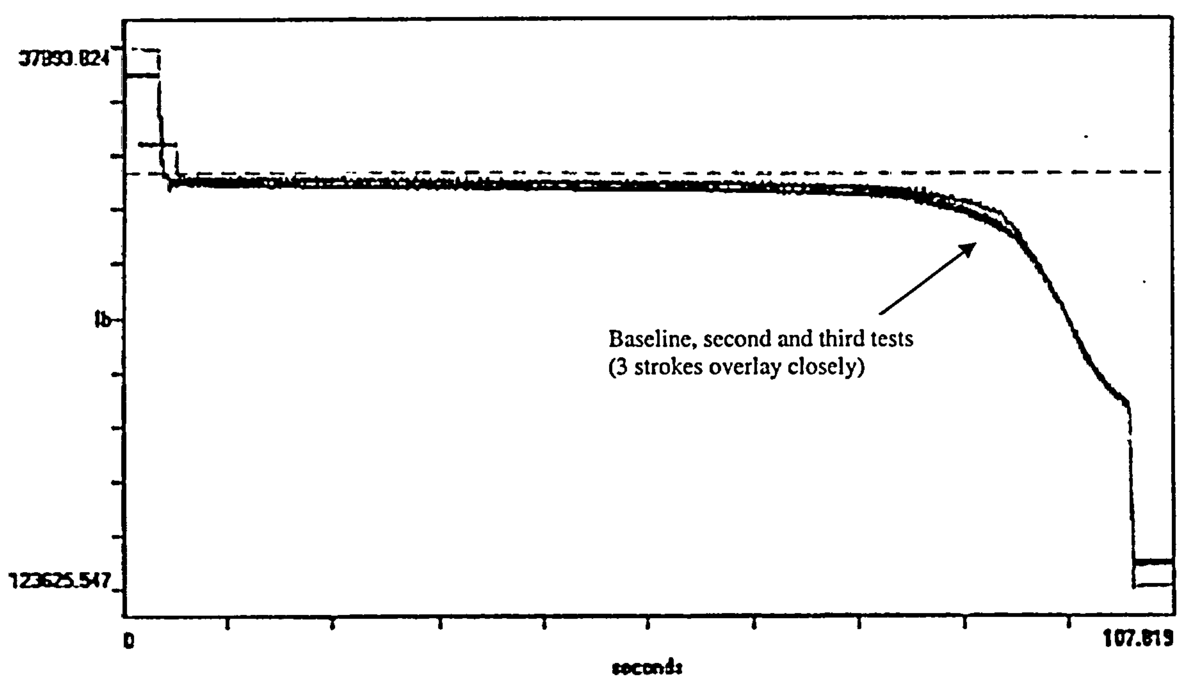


Figure 6-6. Thrust Overlay for Closing Strokes of UG04

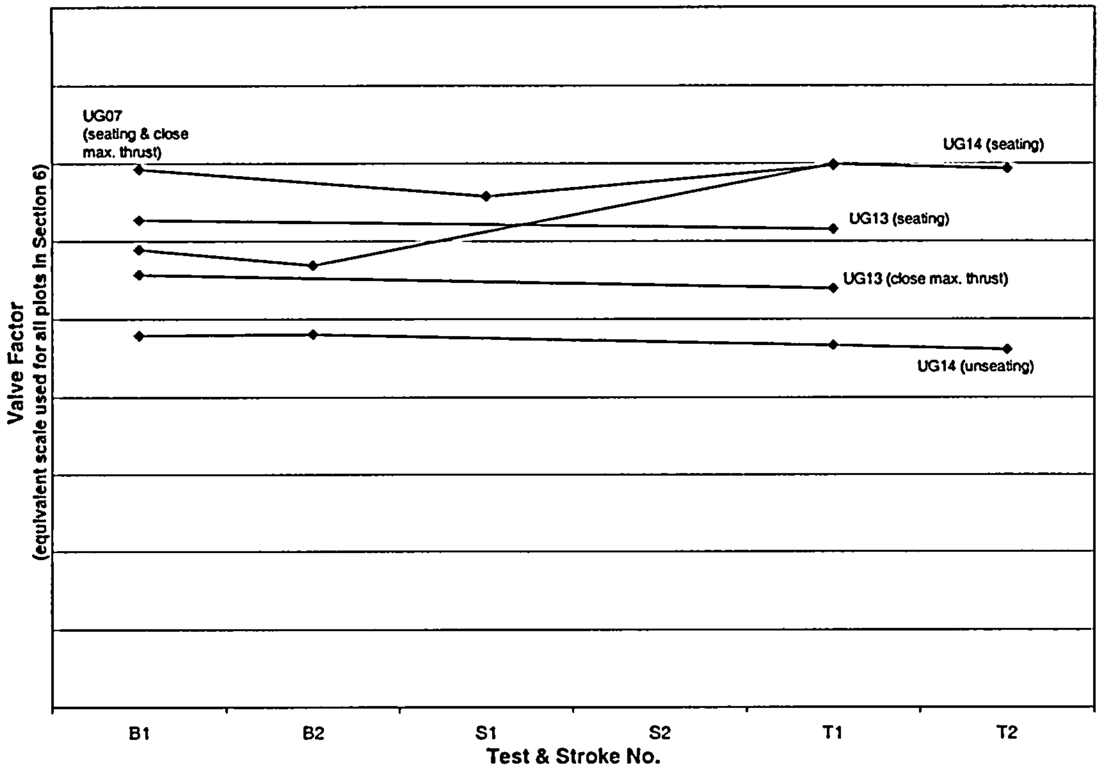


Figure 6-7. Valve Factors for Unbalanced Disk Globe Valves in Steam Systems

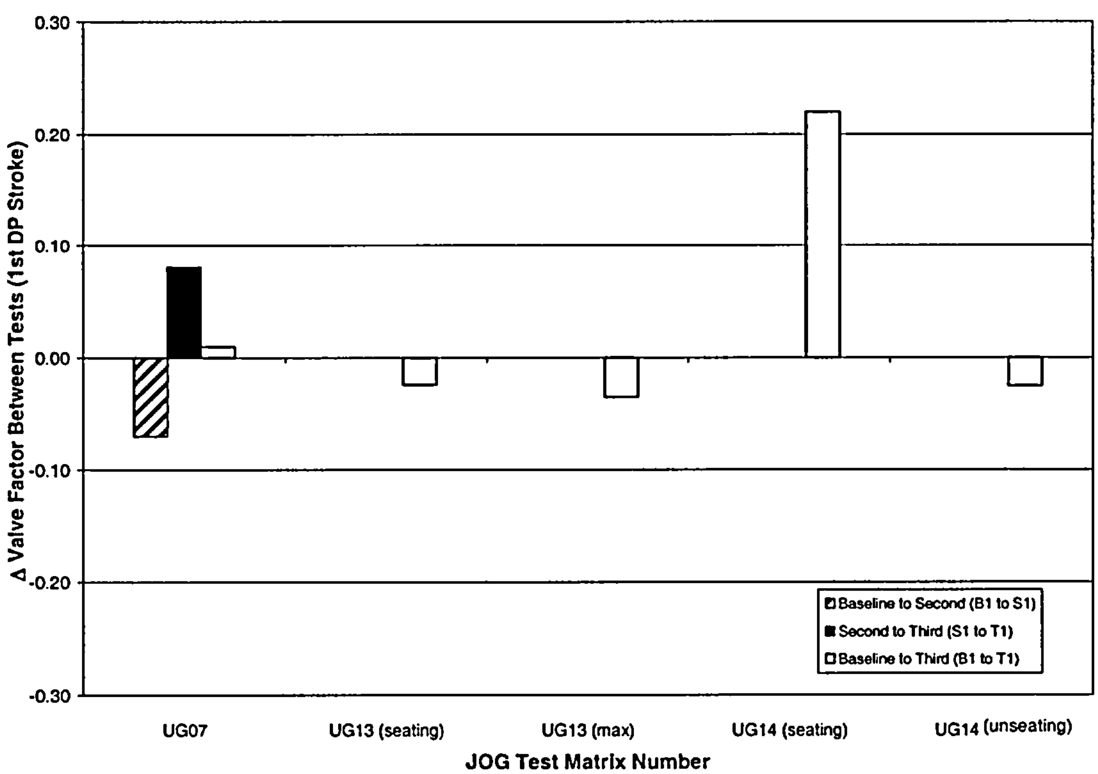


Figure 6-8. Change in Valve Factor for Unbalanced Disk Globe Valves in Steam Systems

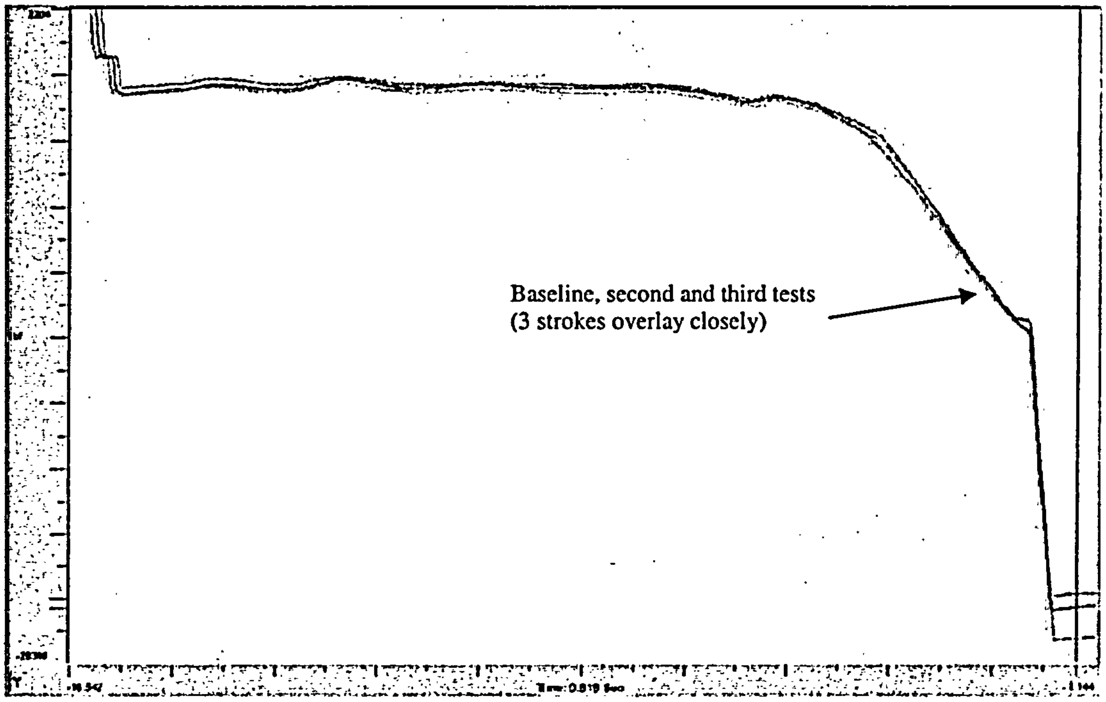


Figure 6-9. Thrust Overlay for Closing Strokes of UG07

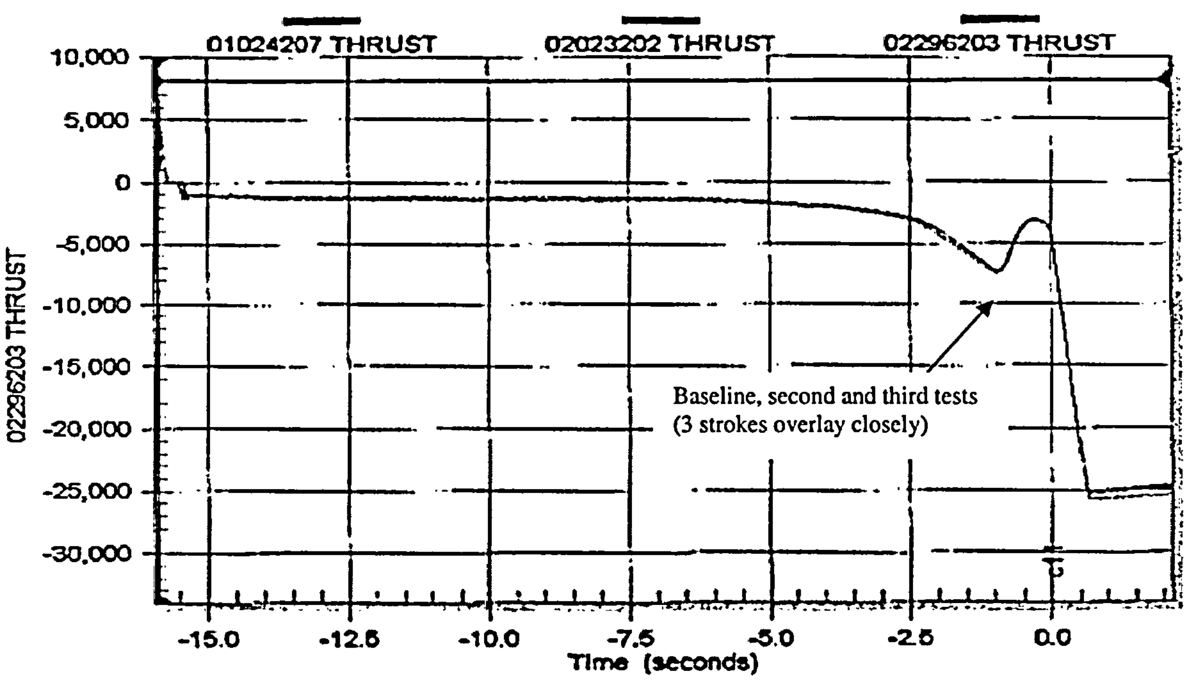


Figure 6-10. Thrust Overlay for Closing Strokes of UG13

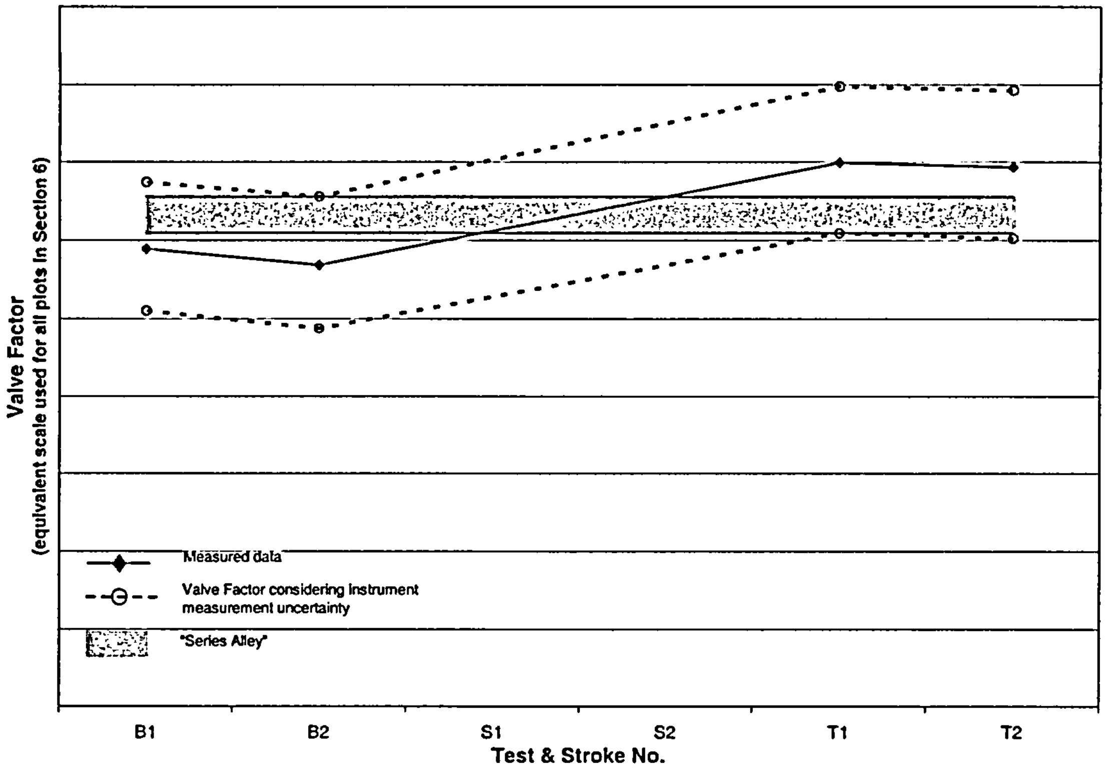


Figure 6-11. Valve Factors at Seating for UG14 with Instrument Measurement Uncertainty

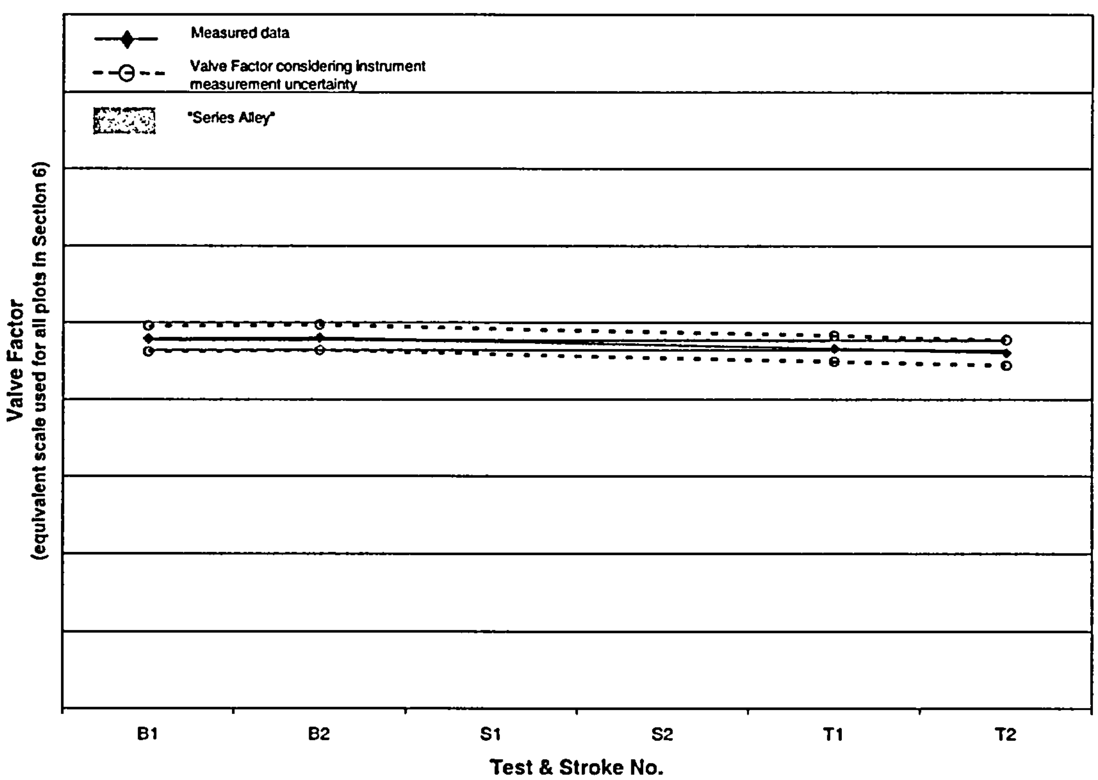


Figure 6-12. Valve Factors at Unseating for UG14 with Instrument Measurement Uncertainty

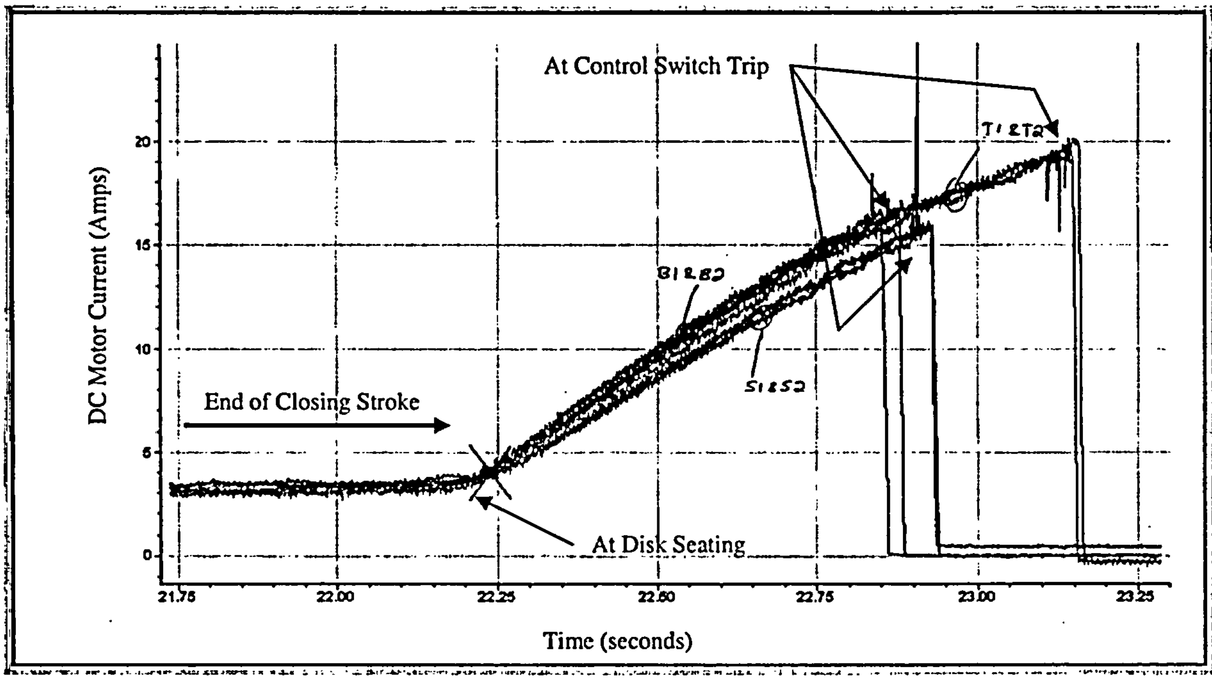


Figure 6-13. DC Motor Current Overlay for UG14

7 Implementation of JOG MOV Periodic Verification Approach

The JOG MOV PV Program Description Topical Report (Reference 3) identified a PV approach to be followed in the interim period while the DP testing in the JOG MOV PV Program was being carried out. The interim PV approach called for static testing using an interval between tests based on margin and risk ranking. Guidance for determining margin and risk ranking were included with the PV approach. A table defined nine PV test intervals based on the various combinations of high, medium and low risk ranking along with high, medium and low margin. Generally, higher risk rankings or lower margins led to shorter intervals between periodic tests.

Based on the results from DP testing in the JOG MOV PV Program, a final PV approach, which is an adjusted version of that originally identified in the JOG MOV PV Program Description Topical Report, has been defined and is specified here. The final test criteria are included in the final JOG MOV PV approach. The overall approach is summarized briefly, followed by sections that give the application details for gate, butterfly, balanced disk globe and unbalanced disk globe valves.

Step 1: Obtain Needed MOV Information → Step 2: Determine Classification of Valve → Step 3: Determine PV Approach for Valve

Overview of Final PV Approach

Each MOV[33] is classified into one of four classes as discussed below. For each valve type, a flow chart process is used to determine the classification. Although multiple paths for classification are presented, there is no preferential path. Table 7-1 gives a reference table for determining the periodic verification interval for static testing, based on margin and risk ranking (like the interim program). Use of this table for different classes of valves is covered in the discussion below. Note that, like the interim program, this PV approach addresses the potential degradation in required thrust or torque. Appropriate allowances for actuator degradation need to be included in the calculation of margin. The justification of actuator degradation is the responsibility of the individual plant.

[33] The JOG MOV PV Program is based on each plant defining and justifying their scope of valves which needs to be considered for GL96-05.

Class A

Class A valves are not susceptible to degradation, as supported directly by testing performed in the JOG MOV PV Program or other suitable basis (e.g., EPRI PPM). For these valves, static PV testing is only needed to verify proper MOV setup and to quantify margin, as well as to provide any needed plant-unique information on actuator performance or potential actuator degradation.

For Class A valves with positive margin, the interval between static PV tests is based on the "High Margin" column of Table 7-1: six years for high risk valves and ten years for medium and low risk valves. The justification is that, because there is no susceptibility to degradation in required thrust, the longest interval is acceptable for all such valves.

Class B

Class B valves are not susceptible to degradation. This conclusion is based on the test results in the JOG MOV PV Program, extended by analysis and engineering judgment to configurations and conditions beyond those tested. For these valves, static PV testing is only needed to verify proper MOV setup and to quantify margin, as well as to provide any needed plant-unique information on actuator performance or potential actuator degradation.

For Class B valves, the interval for static PV testing is determined from Table 7-1. The justification for this approach is that Class B valves are not susceptible to degradation in required thrust, but the certainty of that conclusion is not as high as for Class A. Therefore, the full use of the table, rather than just the high margin column, balances the decreased certainty.

Class C

Class C valves are susceptible to changes in required thrust or torque, as shown by test results in the JOG MOV PV Program. Potential increases in required thrust or torque need to be taken into account in the setup, surveillance and evaluation of these valves.

Class C valves are handled using a process that tends to force changes in the valve or its setup so that it can be reclassified as Class A or B. For gate valves, an allowance needs to be considered in computing the valve's margin. If the margin (including allowance) is positive, static PV testing in accordance with the intervals in Table 7-1 is to be used. For all butterfly valves and for gate valves where the margin is less than zero, either (a) the valve is to be DP tested (rather than static tested) at a 2 year interval, with the first DP test to occur at the next available opportunity, not to exceed 2 years, **or** (b) the MOV or its setup is to be modified such that it covers potential increases or variations in required thrust or torque. Globe valves cannot, by the process outlined in this report, be Class C.

Class D

Valves in Class D are not covered by the JOG MOV PV Program. Individual plants are responsible for justifying the PV approaches for these valves.

Table 7-1. Reference Table for Periodic Verification

Risk Ranking[2]	**PV Test Interval (years) for...**		
	Low Margin[1]	Medium Margin[1]	High Margin[1]
High Risk	2	4	6
Medium Risk	4	8	10
Low Risk	6	10	10

Notes:

1. Criteria for MOV Margin Categories

   Low Margin: JOG MOV PV Margin < 5%
   Medium Margin: 5% ≤ JOG MOV PV Margin < 10%
   High Margin: 10% ≤ JOG MOV PV Margin

   Definition and equations for determining margin are provided in Appendix A.

2. Criteria for Risk Categories

   High Risk
   Medium Risk
   Low Risk
   } Based on Owners' Group or utility-specific criteria.

INFORMATION NEEDED ON MOV APPLICATIONS TO APPLY JOG MOV PV PROGRAM APPROACH

The JOG MOV periodic verification approach can be applied to gate, butterfly, balanced disk globe and unbalanced disk globe valves. For these four valve types, the information required to apply the JOG MOV PV approach for each candidate valve is identified in a separate table for each valve type. Users need to ensure that they have this required information for each valve to which the JOG MOV PV approach is to be applied.

Whenever the information obtained for classifying a MOV is changed, the impact of the new information on the valve classification should be evaluated.

IMPLEMENTATION FOR GATE VALVES

Figure 7-1 summarizes the recommended approach for gate valves, which can be used to determine the class into which each gate valve falls. Table 7-2 lists the information needed to implement the approach. The explanation and justification for the approach is described below.

From Section 3, the key conclusions for gate valves are summarized below.

- Gate valves have no age-related degradation of required thrust due only to the passage of time (without DP stroking).

- For the majority of gate valves tested in the JOG MOV PV Program, there is no service-related degradation of required thrust due to DP stroking. The valve factors for the majority of valves tested do not show a susceptibility to increase (exceptions discussed below).

- Gate valves with low initial valve factors, either due to disassembly of the valve or due to little or no DP stroking *in situ*, may be susceptible to increase. Increases in required thrust tend to occur progressively up to a plateau level as the valve accumulates DP strokes. However, not all valves with low initial valve factors showed valve factor increases, and a low initial valve factor is not a guarantee that the valve factor will increase.

- Because valves with low valve factors are more susceptible to increases than valves with high valve factors, the PV approach needs to consider the valve factor currently used for MOV setup and margin determination, and its basis. For example, the required thrust for a gate valve evaluated using the EPRI PPM with default friction coefficients would not be expected to rise above the PPM value. However, the required thrust for a gate valve that is evaluated based on a single DP test of that valve, carried out after that valve was disassembled and reassembled, would likely increase.

Method to Determine Gate Valve Classification

To determine the classification for a gate valve, it is necessary to consider the following key parameters.

- The type of the valve
- The nature of the typical DP stroking that the valve undergoes
- The disk-to-seat materials
- The disk-to-body guide materials
- The type of fluid in the system in which the valve is located
- The valve factor or apparent disk-to-seat coefficient of friction (as defined in this report) associated with the required thrust used to determine margin for the valve

Using the information collected per Table 7-2, the following method can be used to determine the classification for gate valves. Figure 7-1 provides a flow chart of the method. For each step, the criterion states what the user needs to evaluate. The basis and justification explains how the criterion was developed and justified using the JOG MOV PV Program data.

Step 1: PPM and TUM Screen

If a gate valve has its required thrust determined using the EPRI PPM or if the valve is evaluated using the Thrust Uncertainty Method (TUM) of the PPM, then the valve should be evaluated against Steps 1.1 and 1.2 below.

Valves that have not been evaluated using the EPRI PPM or TUM need to be further evaluated in Step 2.

Step 1.1: PPM Screen

Criterion

If the following statements are all true for a gate valve that has its required thrust determined using the EPRI PPM (without TUM), then the valve is considered to be Class A.

- The guidance in the EPRI documentation (Reference 13) and the conditions and limitations in the NRC SE (References 14 and 15) are adhered to.

- Default friction coefficients are used.

- The valve is predictable.

- The margin as defined in the JOG MOV PV Program is > 0.

Some PPM evaluations used the PPM beyond its nominal applicability limits. In these cases, a valve that otherwise satisfies the four bullets above can be classified as Class B if the user has documented a satisfactory technical justification for using the PPM in that application.

Step 1.2: TUM Screen

Criterion

If the valve is evaluated using the Thrust Uncertainty Method (TUM) of the PPM, and the following statements are all true, then the valve is considered to be Class B.

- The guidance in the EPRI documentation (Reference 16) and the conditions and limitations in the NRC SE (Reference 17) are adhered to.
- Default friction coefficients are used.
- The valve is predictable.
- The margin as defined in the JOG MOV PV Program is greater than the minimum acceptable margin specified in the EPRI documentation.

If neither of the criteria in Steps 1.1 and 1.2 is satisfied, then the valve needs to be further evaluated in Step 2.

Basis and Justification

As long as the default friction coefficients are used, the EPRI PPM provides justified predictions of required thrust for gate valves, which are expected to apply throughout the life of the valve. The EPRI PPM was justified against test data, which included the effects of valve DP stroking. The NRC issued a Safety Evaluation (References 14 and 15) accepting the PPM, and stated in GL 96-05 that:

> *Hence, the staff would find it acceptable if a licensee applied the EPRI methodology (in accordance with this generic letter and the conditions or limitations contained in the NRC staff's safety evaluation (SE)) in establishing a program for periodic verification of MOV design-basis capability.*

For PPM evaluations that used the PPM beyond its nominal applicability limits, the user is responsible for justifying the use of the PPM for the specific application. An example is gate valves with inverted guides, which are beyond the nominal PPM applicability limits. Some plants documented additional evaluations that justified how to apply the PPM for these valves and verified the extension of the method against test data. To recognize the potential for reduced certainty in these cases, Class B is specified rather than Class A.

The PPM TUM folds the thrust prediction process in with the valve set up process. The TUM determines a minimum torque switch trip setting to be used in valve setup. Validation of the TUM showed that it provided as much conservatism for its parameter of interest (torque switch trip setpoint) as did the PPM for its parameter of interest (required thrust). Nonetheless, because the TUM effectively allowed the valve to be set up to a lower torque switch setpoint than would be determined using the PPM separately from the setup process, an additional minimum margin requirement was imposed. To recognize this difference that use of the TUM introduces, Class B is specified rather than Class A.

Step 2: Screen for Special Characteristics Not Covered by JOG Testing

Criterion

As identified in Section 2, two categories of gate valves with special characteristics are not within the scope of coverage of the JOG MOV PV Program. Specifically, valves that meet either of the following two conditions are classified as Class D.

- Aloyco split wedge gate valves that are required to hard seat in the closing direction as part of their design basis function and which stroke against DP in the closing direction in service while at a temperature above 120°F. Valves that are required to stroke against DP above 120°F as a design basis condition but not stroke in service against DP above 120°F are fully covered by the Program.

- Solid or flexible wedge gate valves with 300 series stainless steel versus 400 series stainless steel guides or with self-mated 300 series stainless steel guides, that stroke against DP in service while at a temperature above 120°F. Valves that are required to stroke against DP above 120°F as a design basis condition but not stroke in service against DP above 120°F are fully covered by the Program.

Valves that do not meet either of the above conditions need to be further evaluated in Step 3.

Basis and Justification

In both of the conditions identified above, there is a degradation mechanism (stainless steel galling) that is of concern. For Aloyco split wedge gate valves, the disk ball-to-socket joint is the interface of concern. The JOG MOV PV Program obtained data for sliding of self-mated 300 series stainless steel guides and ball-to-socket joints, but only at temperatures below 120°F. These results are also used to cover the 300 series-400 series stainless steel pair. Although the JOG MOV PV Program results show no evidence of galling, the susceptibility to galling and the severity of galling increase with temperature. Therefore, the lack of data above 120°F means that these conditions cannot justifiably be covered.

Step 3: Valve Configuration and Application Information (CAI) Screen

Valves are evaluated according to their design configuration and in service application conditions. The CAI screen includes criteria for: valve type, disk-to-seat materials, fluid conditions, amount of DP stroking, design basis function and disk-to-guide materials. The CAI Rating Chart (Table 7-3) is used to perform this evaluation and produces one of four ratings: 0, 1, 2 or 3.

- Valves which receive a CAI Rating of "0" have design attributes covered by the valves tested in the JOG MOV PV Program, and have a design basis requirement to open or close only under static conditions (i.e., no flow or DP). Accordingly, there is no need to consider how these valves behave under DP conditions. These valves can be classified as Class A without any additional evaluation.

- Valves which receive a CAI Rating of "1" have design attributes and are in applications covered directly by the valves tested in the JOG MOV PV Program. These valves can be classified as Class A, B or C, subject to the evaluations in Steps 4 through 6.

- Valves which receive a CAI Rating of "2" have design attributes and/or are in applications covered by extension of the valves tested in the JOG MOV PV Program. These valves can be classified as Class B or C (but not Class A), subject to the evaluations in Steps 4 through 6.

- Valves which receive a CAI Rating of "3" have design attributes or are in applications that are not covered by the JOG MOV PV Program. These valves are classified as Class D.

Each of the criteria in Table 7-3 and its justification are discussed below.

Step 3.1: Valve Type Screen

Criterion

Testing in the JOG MOV PV Program covered flexible wedge, solid wedge, Anchor/Darling double disk and Aloyco split wedge gate valves. These valve types are included in the coverage of the program and valves of these types can have a CAI rating of 0, 1, 2 or 3, subject to evaluation of the other criteria (Steps 3.2 through 3.6).

Three valve types have been identified that were not tested directly in the JOG MOV PV Program, but are sufficiently similar to the valve types discussed above that they can have a rating of 0, 2 or 3 (but not a 1), subject to evaluation of the other criteria (Steps 3.2 through 3.6). The three valve types are listed below.

- Parallel disk gate valve without internal wedge. Parallel disk gate valves in nuclear service have been manufactured by several manufacturers, for example Copes-Vulcan, Target Rock, Hopkinsons and Atwood & Morrill. There may be other manufacturers as well.

- Chapman split wedge gate valve.

- WKM parallel expanding gate valves.

Basis and Justification

For valve types tested directly in the program (flexible wedge, solid wedge, Anchor/Darling double disk and Aloyco split wedge gate valves), this testing provides the basis for coverage, subject to the evaluation of other criteria related to applicability.

For the three valve types covered by extension of the test data, the justification is given below.

- Parallel disk gate valve without internal wedge: These valves are covered by extension because, subject to the applicability of other parameters (materials, etc.), the valve's required thrust is controlled by disk-to-seat sliding. Disk-to-seat sliding was the mechanism most extensively studied in the JOG MOV PV Program testing. Accordingly, the lessons learned from the testing of solid and flexible wedge gate valves (appropriately adjusted for wedge angle) and from testing of Anchor/Darling double disk gate valves can be applied to the parallel disk gate valve without internal wedge.

- Chapman split wedge gate valve: This valve is similar to a flexible wedge gate valve that has been cut through the disk hub at the plane of symmetry. These valves are covered by extension because, subject to the applicability of other parameters (materials, etc.), the valve's required thrust is controlled by disk-to-seat sliding, although it is plausible under some conditions that guide sliding could be the controlling mechanism. The guides in the Chapman split wedge gate valve have a slot (or groove) in the body which mates with rails on each side of the disk. This guide configuration was covered by testing of several Powell valves in the JOG MOV PV Program.

- WKM parallel expanding gate valves: Like the parallel disk gate valve, the disk in these gates valves slides on the seat ring for the entire stroke. These valves are covered by extension because, subject to the applicability of other parameters (materials, etc.), the potential degradation in required thrust is controlled by disk-to-seat sliding.

Step 3.2: DP Stroking Screen

Criterion

Valves that have a design basis function to operate only under static conditions (regardless of in-service stroking) have a CAI Rating of 0, as long as the valve seat materials are covered by the JOG MOV PV Program (Step 3.3 below).

Valves that have a design basis function to operate under DP conditions but *do not* stroke against DP in-service have a CAI Rating of 1, as long as the valve seat and guide materials are covered by the JOG MOV PV Program (Steps 3.3, 3.5 and 3.6 below). The fluid type (Step 3.4) does not need to be evaluated.

Valves that have a design basis function to operate under DP conditions and *do* stroke against DP in-service need to be further evaluated according to all steps below.

Appendix B provides guidance for how to determine whether a valve strokes under DP conditions.

Basis and Justification

DP stroking affects the process by which the valve factor increases. Valves that do not stroke against DP do not engage the mechanism that increases disk-to-seat friction with stroking.

Step 3.3: Disk-to-Seat Material Screen

Criterion

The following four disk-to-seat material combinations were tested in the JOG MOV PV Program. They are included in the program coverage and valves with these materials can have a CAI rating of 0, 1, 2 or 3, subject to evaluation of the other factors.

- Stellite – Stellite
- 13 Cr stainless steel[34] – 13 Cr stainless steel
- 13 Cr stainless steel – Stellite
- 13 Cr stainless steel– Monel

The following disk-to-seat material combination was only tested to a limited extent in the JOG MOV PV Program, and is covered by extension. Valves with this material pair can have a rating of 0, 2 or 3 (but not 1), subject to evaluation of other criteria.

- Deloro 50 – Deloro 50

Basis and Justification

For the four pairs that were tested directly in the program, this testing provides the basis for coverage, subject to the evaluation of other criteria related to applicability.

The JOG MOV PV Program does not distinguish grades of Stellite (e.g., Stellite 6 vs. Stellite 21). Other programs have shown that the different grades of Stellite have similar friction and wear properties (e.g., work performed by Edward Valves documented in the EPRI MOV Program report TR-103119). Although Stellite 6 is most commonly specified for valve initial fabrication, many plants allow substitution of Stellite 21 for Stellite 6 in valve repairs and it is likely that some of the JOG MOV PV test valves have Stellite 21 on selected faces.

For Deloro 50, the JOG DP testing covers one valve with this pair. This valve is tested in water flow (<120°F), and shows behavior similar to the Stellite valves. The application of the program to this material is limited to water flow at temperatures less than 120°F.

Step 3.4: Fluid Type Screen

Criterion

The following four fluid types were tested in the JOG MOV PV Program. They are included in the program coverage and valves in these fluid types can have a rating of 1, 2 or 3, subject to evaluation of the other criteria. These fluid types refer to conditions under which the valve strokes against DP in service.

[34] *13 Cr stainless steel* has a nominal 12 to 13% Chromium, and includes 400 series stainless steels and Exelloy face materials

- Untreated water[35], at temperatures up to 120°F
- Treated water, at temperatures up to 120°F.
- Water (treated and untreated), at temperatures greater than 120°F
- Steam

The following fluid types are covered by extension of the test data, i.e., they can have a rating of 2 or 3 (but not 1), subject to evaluation of other criteria.

- Air
- Nitrogen

Basis and Justification
For the four fluids that were tested directly in the program, this testing provides the basis for coverage, subject to the evaluation of other criteria related to applicability.

For air and nitrogen, separate effects testing in the EPRI Program indicated that the influence of air versus water on friction at gate valve interfaces is not strong. It is acceptable to use the results from the JOG MOV PV Program (water and steam) for air and nitrogen.

Step 3.5: Design Basis Function Screen

Criterion
Valves that have guides and have an opening DP design basis function[36] need to be evaluated regarding their guide behavior in Step 3.6 below. For valves that do not have guides or do not have an opening DP design basis function, the results of Steps 3.1 through 3.4 provide the complete CAI rating basis and Step 3.6 does not need to be evaluated.

Basis and Justification
For the vast majority of gate valve closing strokes, disk-to-seat friction controls the required DP thrust and guide friction does not need to be considered. Only when the disk-to-seat friction coefficient is very low (e.g., due to disassembly of the valve) will disk-to-seat friction not control the required closing thrust. In this case, the disk-to-seat friction coefficient will likely rise as the valve is DP stroked and become controlling. Therefore, as long as valve closing strokes are setup based on typical friction coefficients reflective of valves that have been in service, guide friction does not need to be considered.

For most gate valve opening strokes, disk-to-seat friction controls the required DP thrust. However, some opening strokes can be controlled by guide friction even for typical disk-to-seat friction coefficients. Therefore, both seat and guide friction need to be considered for opening strokes.

[35] Untreated Water refers to valves in raw water (e.g., service water) systems.
[36] Valves with an opening DP design basis function include (1) valves with a DP open only function and (2) valves with a DP open and close function.

Step 3.6: Disk-to-Body Guide Material Screen

Criterion

The following guide material combinations are covered by the JOG MOV PV Program. Valves with these materials can have a rating of 1, 2 or 3, subject to evaluation of the other criteria (Steps 3.1 through 3.5).

- Stellite – Stellite
- Stellite – carbon steel
- Stellite – 300 series stainless steel
- Stellite – 17-4PH stainless steel
- Stellite – 13 Cr stainless steel
- Carbon steel – carbon steel
- Carbon steel – 17-4PH stainless steel
- 13 Cr stainless steel – carbon steel
- 300 series stainless steel – carbon steel
- 300 series stainless steel – 17-4PH stainless steel
- 300 series stainless steel – 300 series stainless steel
- 13 Cr stainless steel – 300 series stainless steel

For certain combinations of guide materials and fluid conditions, test data was not obtained directly in the JOG MOV PV Program. In these cases, the guide material and fluid condition combinations are covered by extension, i.e., they can have a rating of 2 (but not 1). This rating, however, can be improved if diagnostic DP test results show the valve's required thrust in the open direction is controlled by disk-to-seat friction[37]. If the open required thrust is controlled by seat friction, the CAI rating can be set to 1. Table 7-3 uses a * to indicate the guide material and fluid conditions to which this provision applies.

For the following gate valve types and guide designs, the guide materials do not need to be evaluated. Valves with these designs can be assumed to have no guides for the purpose of gate valve classification (see Table 7-2).

- Anchor/Darling double disk gate valve
- Aloyco split wedge gate valve with disk arm hook type disk guide[38]
- Aloyco split wedge gate valve with body guide plate type disk guide[38]
- Parallel disk gate valve without internal wedge
- WKM parallel expanding gate valve

Basis and Justification

The first eleven pairs listed were tested directly in the program, and this testing provides the basis for coverage by the program, subject to the evaluation of other criteria related to applicability (Steps 3.1 through 3.5).

[37] See Section 3 - *Methods for Analyzing Gate Valve Test Data* for additional information on analyzing disk-to-seat friction and guide friction from DP test data.

[38] See Reference 13 for descriptions of Aloyco split wedge gate valve disk guides types.

The 13 Cr stainless steel – 300 series stainless steel material pair was not tested, but this combination is judged to be similar to, and bounded by, self-mated 300 series stainless steel.

For the guide materials and fluid condition combinations indicated with a * in Table 7-3, the CAI rating was conservatively set to "2" since test data was not obtained directly in the program covering these conditions. A review of plant-specific DP test results, however, could indicate if the open required thrust is seat or guide controlled. If the open required thrust is determined to be controlled by the seat, then the guide behavior (and thus materials) is irrelevant and the valve CAI rating is determined based on Steps 3.1 through 3.4 entirely. Guidance is provided in Section 3 - *Methods for Analyzing Gate Valve Test Data* for analyzing DP test data and evaluating seat vs. guide friction. It is the plant's responsibility to determine the applicability of plant DP test data to the setup and evaluation of the valve being classified.

For Anchor/Darling double disk gate valves, Aloyco split wedge gate valves with the listed guide types, parallel disk gate valves and WKM parallel expanding gate valves, the disk bears against the seat ring and controls the required thrust for all strokes. Accordingly, these valves can be considered to have no guides.

Step 4: Required Thrust Qualifying Basis Screen

Valves which have design attributes and are in applications covered by the JOG MOV PV Program (i.e., a CAI rating of 1 or 2) need to be further evaluated for the basis of the required thrust being used to determine margin for the valve, as described below.

Criterion

Valves that meet the criteria for having a "qualifying basis" for required thrust are not susceptible to degradation. Therefore, these valves can be classified as Class A or B, subject to their CAI rating (Step 3). Valves that do not meet the criteria for having a "qualifying basis" for required thrust need to be evaluated further (Step 5).

Gate valve required thrust (used to determine valve margin) has a "qualifying basis" if it meets one of the following two criteria, i.e., either Criterion 4.1 or Criterion 4.2.

Criterion 4.1
The valve's required thrust is based on DP testing of that specific valve, and the testing satisfies all of the following four bullets.

- The required thrust for the valve must satisfy one of the conditions in the table below (either a, b or c).

a.	Required thrust is based on test results after multiple DP strokes that condition the valve up to a stable level of friction, with no valve disassembly during the multiple DP strokes and test(s). Plants are responsible for justifying that the DP strokes produce a reliable friction plateau.
b.	Required thrust is based on the maximum result from two (or more) DP tests provided that: - The full set of tests occurs more than 5 years after the preceding valve disassembly (or initial installation). - The valve strokes against DP in-service at least 5 times during the period between the preceding valve disassembly (or initial installation) and the test.
c.	Required thrust is based on the result from a single DP test, provided that: - The test occurs more than 5 years after the preceding valve disassembly (or initial installation). - The valve strokes against DP in-service at least 5 times during the period between the preceding valve disassembly (or initial installation) and the test. - A value of 0.06 is added to the coefficient of friction determined from the test. The 0.06 value covers variation and measurement error observed in the JOG test data.

- The plant is responsible for justifying that (1) results under the specific test conditions (DP, fluid, temperature) can be applied to or adjusted to cover the design basis conditions, (2) measurement accuracy is considered.

- The DP test(s) from which the required thrust information is obtained had the same stroking direction and flow direction as the design basis conditions to which the results are applied.

- The valve in service (to which the results are applied) is still the "tested" valve, i.e., no disallowing modifications have occurred and there is no adverse change in the valve service conditions.

    - Disallowing modifications include replacement or weld repair of the disk or downstream seat ring. Lapping of the seats is not considered a disallowing modification. (Example 1: A valve is disassembled after DP testing to replace only a bonnet seal. This valve is still the "tested" valve and the prior testing is eligible to be a qualifying basis. Example 2: A valve is disassembled after DP testing and the disk is replaced. This valve is no longer the "tested" valve and the prior testing is not a qualifying basis.)

- Adverse changes in service conditions include a change from a valve that does not DP stroke in service to a valve that does DP stroke in service (per Appendix B), or an increase in the DP (by more than 20%) that occurs during DP stroking.

Criterion 4.2

The valve's required thrust is based on DP testing of other similar valves in a group containing the specific valve, and the testing satisfies all of the following three bullets.

- At least two valves are DP tested in accordance with the first bullet of Criterion 4.1 (a, b or c in the table above), and the test results are applied to the specific valve being evaluated. In place of a valve with two (or more) DP tests (option b), single DP tests of two separate valves may be used, as long as all the tests occur more than five years after the preceding valve disassembly (or initial installation). In total, at least four tests are required to satisfy option b, using one of the following:

  - 2 tests from each of 2 valves
  - 2 tests from one valve and one test from each of two other valves
  - 1 test from each of 4 valves

- The plant is responsible for justifying that (1) results under the specific test conditions (DP, fluid, temperature) can be applied to or adjusted to cover the design basis conditions of the valve being evaluated, and (2) measurement accuracy is considered.

- The plant is responsible to justify the makeup of a group of valves. At minimum, for tested valves to be "similar" to a valve to which the test results are applied:

  - The tested valves shall have the same disk-to-seat material pair as the valve to which the results are applied.

  - The tested valves shall have the same fluid type (water or steam) as the valve to which the results are applied.

  - For evaluation of a valve's opening stroke, the tested valves shall have the same disk guide-to-body guide material pair as the valve to which the results are applied. For evaluating closing strokes, this requirement does not need to be satisfied.

  - The DP tests on the tested valves shall have the same stroking direction as the design basis conditions to which the results are applied.

Basis and Justification
The results in Section 3 show that valve factors are not susceptible to increases for the majority of gate valves. Valves with low valve factors (either due to disassembly or no stroking) can show increases with DP stroking. However, not all valves with low valve factors increase. Therefore, plants that have a basis to show their valve factors are stable can justifiably use these values to setup the valve and determine margin.

Section 3 showed that valves that stroke against DP in service and have not been recently disassembled do not show increases in valve factor. To ensure that a sufficient time has elapsed so that the behavior is stabilized, five years after disassembly is specified. This time exceeds the two years used in the JOG MOV PV Program tests, to be certain that valves that normally stroke against DP in service have accumulated sufficient DP stroking to stabilize (i.e., five years worth of DP stroking under typical service conditions).

Further, because JOG testing showed that there is minor test-to-test variation even among stable valves, methods to account for this variation are specified. For plants with only a single DP test, an allowance of 0.06 is added to the apparent disk-to-seat coefficient of friction (COF) determined from the test. Figure 7-2 shows the observed COF variation between subsequent DP strokes in valves with stable disk-to-seat friction. This figure includes data for valves where it was highly likely the results would be stable. Specifically, valves that were not disassembled in the two years prior to the start of JOG testing and which are routinely DP stroked in service were considered. For 95% of the data, an allowance of 0.06 covers the observed COF variation. Although some of this variation is due to measurement uncertainty in the JOG MOV PV Program test data, there was no practical way to remove this component of the result. Therefore, the full value (0.06) is conservatively specified.

Some plants prefer to deliberately stroke a new or re-assembled valve under DP conditions repetitively and ensure that stable friction is obtained. This approach was used in a few of the JOG test valves as well and was observed to be effective.

When tests of a specific valve are used as the basis for justifying the required thrust and margin of that valve, the tests need to have the same flow direction and stroking direction as the valve's design basis conditions, for the results to be applicable. Flow direction needs to be matched so that the same set of disk-to-seat sliding surfaces is engaged. Stroke direction needs to be matched so that the applicable mechanisms affecting required thrust are captured.

Further, when tests of a specific valve are used as the basis for justifying the required thrust and margin of that valve, it needs to be verified that the valve is still in a configuration that matches the test results. Changes in material condition (i.e., disk or seat ring repair or replacement) or in service conditions (amount of stroking under DP or increase in DP) after the testing could potentially invalidate the test results.

When tests of other valves are used to justify a valve's required thrust and margin, it is important to ensure that the tested valves appropriately match the valve under evaluation. Matching of disk-to-seat materials and stroking direction is essential. Matching of fluid (water or steam) is needed to ensure applicability of the results. Matching of disk guide-to-body guide materials is needed for opening strokes because test results showed that guide friction is a potential influence in this stroke direction.

Step 5: Coefficient of Friction Threshold Screen

Criterion

Valves that do not meet the criteria for having a "qualifying basis" for required thrust (Step 4) need to be evaluated to determine if the valve is set up (and margin evaluated) using a coefficient of friction (COF)[39] that is susceptible to increase. For each combination of disk-to-seat material and fluid type tested in the JOG Program, a threshold COF is determined. The threshold is the value above which the COF does not increase, based on testing in the JOG MOV PV Program. Table 7-4 provides the threshold values.

Valves that are set up (and margin evaluated) using a COF greater than or equal to the applicable threshold COF are not susceptible to degradation. Therefore, these valves can be classified as Class A or B, subject to their CAI rating (Step 3).

Valves that are set up using a COF less than the applicable threshold COF are susceptible to increases and are classified as Class C.

Each plant is responsible for the design bases for its gate valves. Although a plant can decide to conservatively increase its gate valve disk-to-seat COFs to meet these thresholds, it is not acceptable to decrease a plant specific COF to the threshold value.

Basis and Justification

As described in Section 3, the threshold values provide COF values above which increases in COF are not expected. The COF thresholds in Table 7-4 are taken from analyses of the gate valve data. Specifically, the analyses which evaluated the change in COF against the starting COF were used. See Appendix E for additional explanation on how the threshold values were determined.

Periodic Verification Approach for Gate Valves in Class C

For gate valves determined to be in Class C, an allowance needs to be considered in computing the valve's margin. Table 7-4 lists the coefficient of friction (COF) allowances that need to be considered for each Class C valve. The allowance is calculated using the existing COF utilized in setting up the valve. The allowance defines the amount of COF increase that needs to be added to the existing COF for each two-year period moving forward. The adjusted COF need not exceed the threshold values in Table 7-4, however.

As an example, consider the case of a Class C valve that is set up (and whose margin is determined) based on a friction coefficient COF_0. To cover the first two-year period moving

[39] Coefficient of friction (COF) relates exclusively to the thrust required to overcome DP. Appendix A includes equations showing how to determine valve factor and COF from test data or from total required thrust.

forward[40], the valve needs to have its margin evaluated using (COF_o + $allowance_o$). To cover the next two-year period, the valve needs to have its margin evaluated using (COF_o + $allowance_o$ + $allowance_1$), where $allowance_1$ is determined using (COF_o + $allowance_o$) as the existing COF. This process repeats for each two-year period, but the maximum COF that needs to be considered is the value shown on Table 7-4. If the valve is DP tested during this time and a new COF is determined, then the valve should be reclassified, considering the new friction coefficient.

When the COF allowance is added into the margin evaluation of the valve, the valve's margin will decrease. The required static PV test interval is then determined, with the reduced margin, using Table 7-1. If the margin with the COF allowance included becomes less than zero, then either: (a) the valve should be DP tested (rather than static tested) at a 2 year interval, with the first DP test to occur at the next available opportunity, not to exceed 2 years, **or** (b) the MOV or its setup should be modified such that the margin is positive. Note that if DP testing is conducted, the COF should be "reset" to the new value (if higher than the current value).

Alternatively, the allowance factor does not need to be considered if either: (a) the COF is reset to the applicable threshold value for that valve (Table 7-4), **or** (b) a valid qualifying basis for required thrust is determined for the valve. If either of these conditions is satisfied, then the margin for the valve should be reevaluated and the valve reclassified, considering the new information, using Steps 1-5 and Figure 7-1.

[40] This process, where needed, should start when the plant starts implementing the final JOG MOV PV method described in this report.

Table 7-2. Information Needed to Evaluate Gate Valves for Periodic Verification (*2 Pages*)

Category	Attribute	Information Needed
Design Information	Size	DMS – Mean Seat Diameter
		W – Wedge half-angle, in degrees
	Disk Style	T – type of gate valve; must be one of the following • Flexible wedge (single piece disk) [T=1] • Solid wedge (single piece disk) [T=1] • Anchor/Darling double disk [T=2] • Aloyco split wedge [T=3] • Parallel disk without wedge[41] [T=11] • Chapman split wedge [T=12] • WKM parallel expanding [T=13] • Other [T=30]
	Disk-to-Seat Materials	S – Materials of Disk-to-Seat Interface; must be one of the following: • Stellite[42] – Stellite [S=1] • 13 Cr stainless steel[43] – 13 Cr stainless steel [S=2] • 13 Cr stainless steel – Stellite [S=3] • 13 Cr stainless steel – Monel [S=4] • Deloro 50 – Deloro 50 [S=11] • Other [S=30]
	Disk-to-Body Guide Materials	G – Materials of Disk-to-Body Guide Interface; must be one of the following: • No guides[44] [G=0] • Stellite – Stellite [G=1] • Stellite – carbon steel [G=2] • Stellite – 300 series stainless steel [G=3] • Stellite – 17-4PH [G=4] • Stellite – 13 Cr stainless steel [G=5] • Carbon steel – carbon steel [G=6] • Carbon steel – 17-4PH [G=7] • 13 Cr stainless steel – carbon steel [G=8] • 300 series stainless steel – carbon steel [G=9] • 300 series stainless steel – 17-4PH [G=10] • 300 series stainless steel – 300 series stainless steel [G=11] • 13 Cr stainless steel – 300 series stainless steel [G=15] • Other [G=30]

[41] Manufacturers of this type of valve include Copes-Vulcan, Target Rock, Atwood & Morrill and Hopkinsons
[42] *Stellite* refers to any grade of Stellite
[43] *13 Cr stainless steel* has a nominal 12 to 13% Chromium, and includes 400 series stainless steels and Exelloy face materials
[44] See Section 7, Step 3.6 for a list of valve types for which the guide materials do not need to be considered (i.e., assume G=0).

Table 7-2. Information Needed to Evaluate Gate Valves for Periodic Verification (*2 Pages*)

Category	Attribute	Information Needed
Application/ Service	DP Stroking	DPS – Maximum Differential Pressure during DP strokes
		DS – In the full course of plant activities, does the valve stroke while there is DP across the valve?[45] (YES or NO)
	Fluid Type	F – Type of fluid in pipe during DP stroking; must be one of the following: • Untreated (raw) water ≤ 120°F [F=1] • Treated water ≤ 120°F [F=2] • Water > 120°F [F=3] • Steam [F=4] • Air or nitrogen ≤ 120°F [F=11] • Air or nitrogen > 120°F [F=12] • Other [F=30]
	Risk	RSK - Risk Ranking (HIGH, MEDIUM or LOW)
	Design Basis Function	DBF – must be one of the following • Static (open and/or close) only [S] • DP Open only [O] • DP Close only [C] • DP Open and Close [O/C]
Setup	Parameters	MAR – Margin for Successful Operation under Design Basis Conditions
		BAS – Basis for Required Thrust; must be one of the following • EPRI PPM, with default friction coefficients [BAS=PPM] • EPRI PPM with TUM, including required minimum margin [BAS=TUM] • Other
		VF – Current Valve Factor (or Disk-to-Seat Coefficient of Friction) Associated with the Required Thrust used to Determine Margin for the Valve
Test Information		To justify a valve has a valid "qualifying basis," information related to the test used to determine the valve factor or COF is needed. See Step 4 of the Gate Valve Implementation Method for additional information.

[45] Consider normal operations, testing, shutdown, maintenance, etc. See Appendix B for additional guidance.

Table 7-3. CAI Rating Chart for Gate Valves (3 *Pages*)

T Disk Style	DS DP Stroking	S Disk-to-Seat Materials	F Fluid Type	DBF Design Basis Function	G Disk-to-Body Guide Materials	Rating = 0	1	2	3
Step 3.1	*Step 3.2*	*Step 3.3*	*Step 3.4*	*Steps 3.2 & 3.5*	*Step 3.6*				
1, 2 or 3 Flex Wedge, Solid Wedge, A/D Double Disk or Aloyco Split Wedge	N/A	1 thru 11	N/A	S	All	√			
		30	N/A	S	All				√
	No	1 thru 11	N/A	C	All		√		
			N/A	O or O/C	0 thru 15		√		
					30				√
		30	N/A	All	All				√
	Yes	1 Stellite vs. Stellite	1 or 2 Water $\leq$120°F	C	All		√		
				O or O/C	0 thru 15		√		
					30				√
			3 or 4 Water >120°F or Steam	C	All		√		
				O or O/C	0 thru 6		√		
					7 thru 10			√*	
					11 thru 30				√
			11 $Air/N_2 \leq 120$°F	C	All			√	
				O or O/C	0 thru 15			√	
					30				√
			12 $Air/N_2 > 120$°F	C	All			√	
				O or O/C	0 thru 10			√	
					11 thru 30				√
			30	All	All				√
		2 13Cr SS vs. 13Cr SS	1 or 2 Water $\leq$120°F	C	All		√		
				O or O/C	0 thru 15		√		
					30				√
			3, 4, 12 or 30 Water >120°F, $Air/N_2 > 120$°F, Steam or Other	All	All				√
			11 $Air/N_2 \leq 120$°F	C	All			√	
				O or O/C	0 thru 15			√	
					30				√

Table 7-3. CAI Rating Chart for Gate Valves (3 *Pages*)

T Disk Style	DS DP Stroking	S Disk-to-Seat Materials	F Fluid Type	DBF Design Basis Function	G Disk-to-Body Guide Materials	Rating = 0	1	2	3
Step 3.1	*Step 3.2*	*Step 3.3*	*Step 3.4*	*Steps 3.2 & 3.5*	*Step 3.6*				
1, 2 or 3 Flex Wedge, Solid Wedge, A/D Double Disk or Aloyco Split Wedge	Yes	3 13Cr SS vs. Stellite	1 or 2 Water ≤120°F	C	All		√		
				O or O/C	0 thru 15		√		
					30				√
			3 Water >120°F	C	All		√		
				O or O/C	0 thru 6		√		
					7 thru 10			√*	
					11 thru 30				√
			4 or 30 Steam or Other	All	All				√
			11 Air/N_2≤120°F	C	All			√	
				O or O/C	0 thru 15			√	
					30				√
			12 Air/N_2>120°F	C	All			√	
				O or O/C	0 thru 10			√	
					11 thru 30				√
		4 13Cr SS vs. Monel	1 or 2 Water ≤120°F	C	All		√		
				O or O/C	0 thru 15		√		
					30				√
			3 Water >120°F	C	All		√		
				O or O/C	0 thru 6		√		
					7 thru 10			√*	
					11 thru 30				√
			4 or 30 Steam or Other	All	All				√
			11 Air/N_2≤120°F	C	All			√	
				O or O/C	0 thru 15			√	
					30				√
			12 Air/N_2>120°F	C	All			√	
				O or O/C	0 thru 10			√	
					11 thru 30				√
		11 D50 vs. D50	1 or 2 Water ≤120°F	C	All			√	
				O or O/C	0 thru 15			√	
					30				√
			3, 4, 11, 12 or 30	All	All				√
		30 Other	All	All	All				√

Table 7-3. CAI Rating Chart for Gate Valves (3 *Pages*)

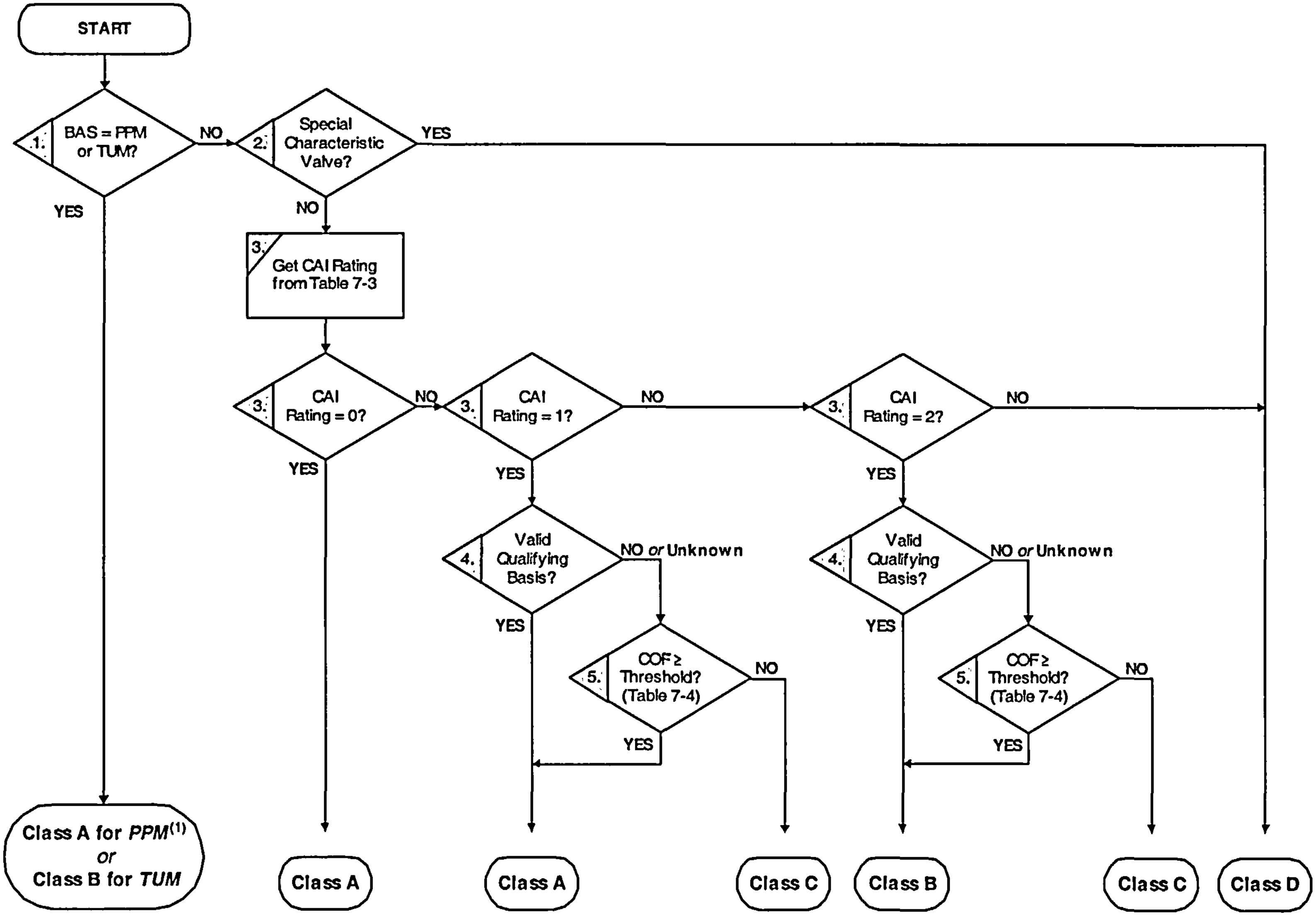
<u>T</u> Disk Style	<u>DS</u> DP Stroking	<u>S</u> Disk-to-Seat Materials	<u>F</u> Fluid Type	<u>DBF</u> Design Basis Function	<u>G</u> Disk-to-Body Guide Materials	Rating = <u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
Step 3.1	*Step 3.2*	*Step 3.3*	*Step 3.4*	*Steps 3.2 & 3.5*	*Step 3.6*				
11, 12 or 13 Parallel Disk, Chapman Split Wedge or WKM Parallel Expanding	N/A	1 thru 11	N/A	S	All	√			
		30	N/A	S	All				√
	No	1 thru 11	N/A	C	All			√	
			N/A	O or O/C	0 thru 15			√	
					30				√
		30	N/A	All	All				√
	Yes	1 Stellite vs. Stellite	1, 2 or 11 Water or Air/N_2 ≤120°F	C	All			√	
				O or O/C	0 thru 15			√	
					30				√
			3, 4 or 12 Water or Air/N_2 >120°F or Steam	C	All			√	
				O or O/C	0 thru 10			√	
					11 thru 30				√
			30	All	All				√
		2 13Cr SS vs. 13Cr SS	1, 2 or 11 Water or Air/N_2 ≤120°F	C	All			√	
				O or O/C	0 thru 15			√	
					30				√
			3, 4, 12 or 30	All	All				√
		3 13Cr SS vs. Stellite	1, 2 or 11 Water or Air/N_2 ≤120°F	C	All			√	
				O or O/C	0 thru 15			√	
					30				√
			3 or 12 Water or Air/N_2 >120°F	C	All			√	
				O or O/C	0 thru 10			√	
					11 thru 30				√
			4 or 30	All	All				√
		4 13Cr SS vs. Monel	1, 2 or 11 Water or Air/N_2 ≤120°F	C	All			√	
				O or O/C	0 thru 15			√	
					30				√
			3 or 12 Water or Air/N_2 >120°F	C	All			√	
				O or O/C	0 thru 10			√	
					11 or 30				√
			4 or 30	All	All				√
		11 D50 vs. D50	1 or 2 Water ≤120°F	C	All			√	
				O or O/C	0 thru 15			√	
					30				√
			3, 4, 11, 12 or 30	All	All				√
		30	All	All	All				√
30	All	All	All	All	All				√

* Rating can be set to "1" if DP testing shows that required thrust is not controlled by guide friction.

Table 7-4. COF Threshold Values and COF Allowances for Gate Valves

Category		Threshold COF	Allowance (ΔCOF) for 2-year period	Reference
Disk-to-Seat Materials	**Fluid Type & Temperature**			
Self-mated Stellite	Water or Air/N_2 All temperatures	0.57	0.34 – (*COF**0.48)	Figure E-2
	Steam	0.58	0.32 – (*COF**0.46)	Figure E-3
Self-mated 13 Cr Stainless Steel	Water or Air/N_2 ≤ 120°F	0.69	0.20 – (*COF**0.25)	Figure E-4
13 Cr Stainless Steel vs. Stellite	Water or Air/N_2 All temperatures	0.70	0.40 – (*COF**0.54)	Figure E-5
13 Cr Stainless Steel vs. Monel	Water or Air/N_2 All temperatures	0.71	0.34 – (*COF**0.34)	Figure E-6
Self-mated Deloro50	Water ≤ 120°F	Use values for self-mated Stellite in water		*See discussion in Appendix E*

Note: *COF* used in the Allowance refers to the current value of apparent disk-to-seat friction coefficient used for valve setup and margin determination.



Note 1: PPM evaluations beyond the nominal applicability limits (i.e., "best available data") are considered Class B. See Gate Valve Method Step 1 for additional discussion.

Figure 7-1. Classification of Gate Valves

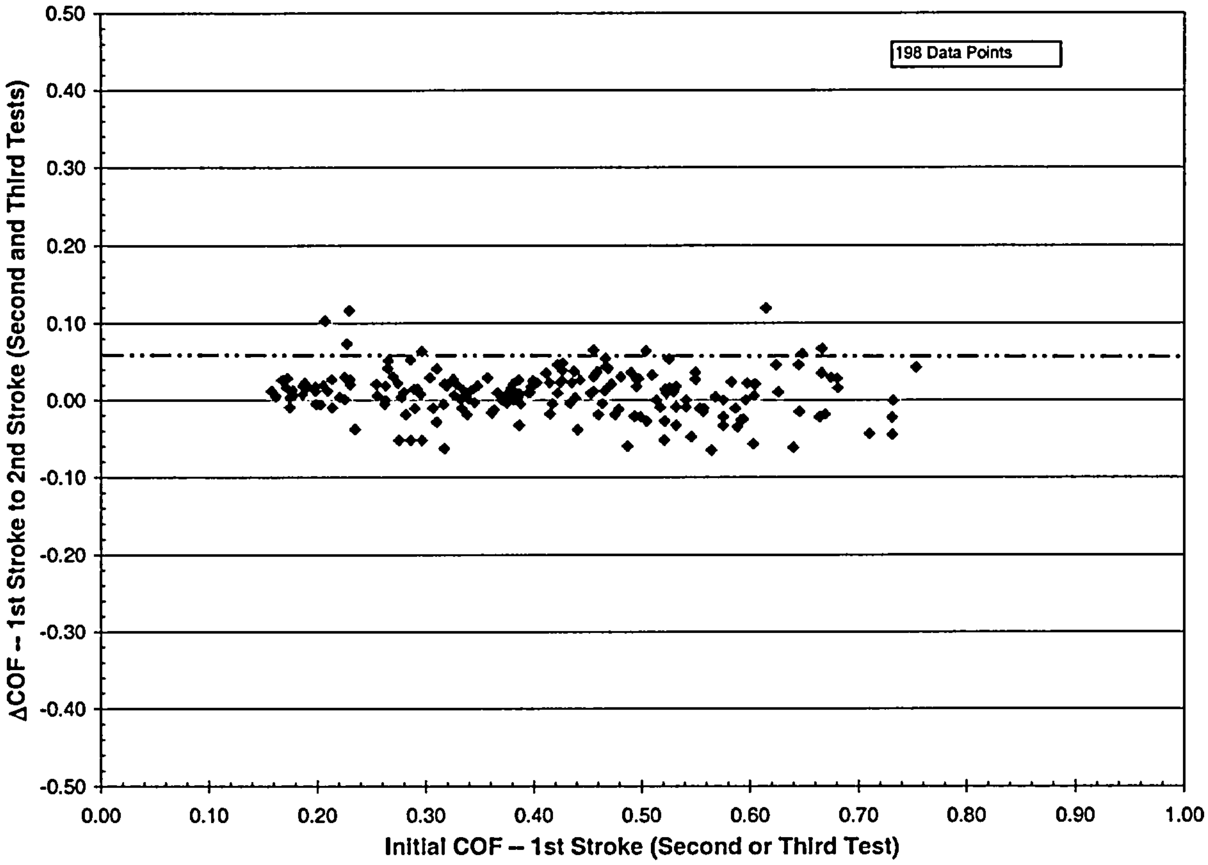


Figure 7-2. Variation in COF Between Strokes for Gate Valves with Stellite Seats in Water Systems with Stable Behavior

Implementation for Butterfly Valves

Figure 7-3 summarizes the recommended approach for butterfly valves, which can be used to determine the class into which each butterfly valve falls. Table 7-5 lists the information needed to implement the approach. The explanation and justification for the approach is described below.

From Section 4, the conclusions for butterfly valves are summarized below.

- For butterfly valves, there is no age-related or service-related degradation in required bearing torque.
- For butterfly valves with bronze bearings in treated water systems, bearing friction coefficients were observed to be stable and not susceptible to change.
- For butterfly valves with bronze bearings in untreated water systems with hub seals, bearing friction coefficients were observed to be stable and not susceptible to change.
- For butterfly valves with bronze bearings or 300 series stainless steel bearings in untreated water systems without hub seals, significant variations in bearing friction were observed, although there is no increasing or decreasing trend. Further, it appeared that stroking under DP conditions was not necessarily required to bring about the change.
- For butterfly valves with non-metallic bearings, small variations in bearing friction were observed, particularly for valves with low friction coefficients, although there is no increasing or decreasing trend. Further, it appeared that stroking under DP conditions was not necessarily required to bring about the change.

Method to Determine Butterfly Valve Classification

To determine the classification for into which a butterfly valve falls, it is necessary to consider the following key parameters.

- The shaft material
- The bearing material
- The design basis function of the valve
- The type of fluid in the system in which the valve is located
- The presence or absence of a hub seal
- The current bearing friction coefficient used to determine margin for the valve

Using the information collected per Table 7-5, the following method can be used to determine the classification for butterfly valves. Figure 7-3 provides a flow chart of the method. For each step, the criterion states what the user needs to evaluate. The basis and justification explains how the criterion was developed and justified using the JOG MOV PV Program data.

Step 1: PPM Screen

Criterion

If the following statements are all true for a butterfly valve that has its required torque determined using the EPRI PPM, then the valve is considered to be Class A.

- The guidance in the EPRI documentation (Reference 13) and the conditions and limitations in the NRC SE (References 14 and 15) are adhered to.
- The bearing material is bronze or non-bronze metal, and the bearing friction coefficients recommended in the EPRI guidance are used.
- The margin as defined in the JOG MOV PV Program is > 0.

Some PPM evaluations used the PPM beyond its nominal applicability limits. In these cases, a valve that otherwise satisfies the three bullets above can be classified as Class B if the user has documented a satisfactory technical justification for using the PPM in that application.

If the conditions above are not satisfied, then the valve needs to be further evaluated as discussed below (Steps 2 through 4).

Basis and Justification

As long as the EPRI-recommended friction coefficients are used, the EPRI PPM provides justified predictions of required torque for butterfly valves, which are expected to apply throughout the life of the valve. The EPRI PPM was extensively justified against test data. The EPRI method recommends using a bounding bearing friction coefficient of 0.6 for bronze bearings in untreated water systems. This value bounds the observations from the JOG MOV PV Program testing.

For PPM evaluations that used the PPM beyond its nominal applicability limits, the user is responsible for justifying the use of the PPM for the specific application. To recognize the potential for reduced certainty in these cases, Class B is specified rather than Class A.

Step 2: Valve Configuration and Application Information (CAI) Screen

Valves are evaluated according to their design configuration and in service application conditions. The CAI screen includes criteria for: design basis function, bearing material, shaft material, fluid conditions, and the presence of a hub seal. The butterfly valve CAI Rating Chart (Table 7-6) is used to perform this evaluation and produces one of four ratings: 0, 1, 2 or 3.

- Valves which receive a CAI Rating of "0" meet one of the following characteristics:
  - The valves have design attributes and are in applications covered directly by the valves tested in the JOG MOV PV Program, and the test results for these valves

show no evidence of increases in bearing coefficient of friction. Accordingly, these valves can be classified as Class A without any additional evaluation.

- The valves have design attributes covered by the valves tested in the JOG MOV PV Program, and have a design basis requirement to open or close only under static conditions (i.e., no flow or DP). Accordingly, there is no need to consider how these valves behave under DP conditions. Therefore, these valves can be classified as Class A without any additional evaluation.

- Valves which receive a CAI Rating of "1" have design attributes and are in applications covered directly by the valves tested in the JOG MOV PV Program. These valves can be classified as Class A or C, subject to the additional evaluations in Steps 3 and 4.

- Valves which receive a CAI Rating of "2" have design attributes or are in applications covered by extension of the valves tested in the JOG MOV PV Program. These valves are classified as Class B or C (not Class A), subject to the additional evaluations in Steps 3 and 4.

- Valves which receive a CAI Rating of "3" have design attributes or are in applications that are not covered by the JOG MOV PV Program. These valves are classified as Class D.

Each of the criteria in Table 7-6 and its justification are discussed below.

Step 2.1: Design Basis Function Screen

Criterion

Valves that have a design basis function to operate only under static conditions have a CAI Rating of 0, as long as the valve bearing and shaft materials are covered by the JOG MOV PV Program (Steps 2.2 and 2.3 below).

Valves that have a design basis function to operate under DP conditions need to be further evaluated according to the steps below.

Basis and Justification

Valves that only have a static design basis function do not have to be concerned with variations in bearing friction. Static PV testing is all that is required to verify proper setup and margin evaluation.

Step 2.2: Bearing Material Screen

Criterion

The bearing material is considered to be the most important influence on bearing performance. The bearing materials listed below are covered directly by the JOG MOV PV Program data. Bronze bearings under specific design and fluid conditions are the only bearing material that can have a CAI rating of 0 (i.e., no degradation) for valves with a DP design basis function. Outside of these conditions, valves with the following bearing materials can have a CAI rating of 1, 2 or 3, subject to evaluation of the other criteria (Steps 2.1 and 2.3 through 2.5).

- Bronze or Bronze/graphite
- Teflon on a fiberglass carrier
- Teflon on a stainless steel substrate
- Tefzel

The following bearing materials were tested to a limited extent in the JOG MOV PV Program, and are covered by extension. Accordingly, they can have a CAI rating of 0, 2 or 3 (but not 1), subject to evaluation of other criteria (Steps 2.1 and 2.3 through 2.5).

- Nomex
- Nylatron
- Polyethylene
- 300 series stainless steel
- Stellite

Basis and Justification

As discussed in Section 4 – *Test Program Results for Butterfly Valves*, bronze bearings in treated water or in untreated water with a hub seal are the only butterfly valve configurations with no observed variation (i.e., CAI rating of 0). Otherwise, for valves with bronze and Teflon bearing materials, the JOG test results provide the basis for coverage, subject to the evaluation of the other criteria related to applicability. Tefzel is included with the coverage of Teflon bearings because of its similarity to Teflon and due to the stable test results observed in the program.

For Nomex, Nylatron, Polyethylene and 300 series stainless steel bearings, the JOG MOV PV Program testing covers only one valve of each type.

Stellite bearings were not tested in the JOG MOV PV Program. They are covered by extension based on the test results for gate valves. Specifically, results for gate valves with Stellite disk guides running against 300 series Stainless Steel or 17-4PH stainless steel body guides showed stable valve factors (see Section 3 – *Evaluation of Disk-to-Guide Friction*). A Stellite bearing running against a stainless steel shaft would be expected to perform similarly.

Other butterfly valves have metallic and non-metallic bearing materials not covered by the JOG MOV PV Program. Examples include nonmetallic bearings made of PEEK or other plastics. The lack of data on these bearing types means that they are not within the scope of the JOG MOV PV Program.

Step 2.3: Shaft Material Screen

Criterion

The following shaft materials were tested in the JOG MOV PV Program and are covered by the data. Valves with these shaft materials can have a CAI rating of 0, 1, 2 or 3, subject to evaluation of the other criteria (Steps 2.1, 2.2, 2.4 and 2.5).

- 300 series stainless steel
- 400 series stainless steel
- 17-4PH stainless steel

The following shaft materials were either not tested or only tested to a limited extent in the JOG MOV PV Program, and are covered by extension. Accordingly, they can have a CAI rating of 0, 2 or 3 (but not 1), subject to the evaluation of other criteria (Steps 2.1, 2.2, 2.4 and 2.5).

- Monel K-500
- Other hard, smooth, corrosion resistant materials, such as heat treated aluminum

For the case of a valve with a 300 series stainless steel bearing, only a 17-4PH stainless steel shaft is covered.

Basis and Justification

For typical shaft-to-bearing material pairs, the shaft material is the more durable material and is not expected to influence the bearing performance as significantly as the bearing material. Because of the abundance of data, the three stainless steel shaft materials are included under rating 0 or 1.

The Monel K-500 shaft material is grouped under rating 2 (for valves with a DP design basis function) because of the small amount of JOG test data obtained. Other shaft materials for butterfly valves that provide a hard, smooth corrosion resistant bearing surface are also grouped under rating 2.

The JOG MOV PV Program obtained only limited data for 300 series stainless steel bearings running against a 17-4PH stainless steel shaft. Accordingly, this material pair is covered by the limited data. This data, however, cannot be extended to cover other shaft materials. The concern is that other stainless steel shaft materials (e.g., 300 or 400 series) may influence the bearing performance.

Step 2.4: Fluid Type Screen

Criterion

The following two fluid types were tested in the JOG MOV PV Program and are covered directly by the test data, i.e., can have a rating of 0, 1, 2 or 3, subject to evaluation of the other criteria (Steps 2.1 through 2.3 and 2.5). These fluid types refer to conditions under which the valve strokes against DP in service.

- Treated water, up to temperatures of 150°F
- Untreated water[46], up to temperatures of 150°F

The following fluid types are covered by extension of the test data. i.e., they can have a CAI rating of 2 or 3 (but not 0 or 1), subject to evaluation of other criteria (Steps 2.1 thru 2.3 and 2.5).

- Air, up to temperatures of 150°F
- Nitrogen, up to temperatures of 150°F
- Treated Water, at temperatures greater than 150°F
- Untreated Water, at temperatures greater than 150°F

Basis and Justification
For the two fluids that were tested directly in the program, this testing provides the basis for coverage, subject to the evaluation of other criteria related to applicability. The testing in the program covered temperatures up to about 100°F. Use of 150°F as a threshold is based on engineering judgment and is a reasonable extension.

All of the JOG test data was obtained in water systems. There are a few butterfly valves in nuclear power plant service that are in air or nitrogen service. Reference 18 showed that, using data from tests performed by INEL under NRC sponsorship (Reference 11), bearing friction coefficient behavior in air was observed to be similar to that in treated water. Accordingly, the bearing materials included under ratings of 0 or 1 above (for water service) are included under a rating of 2 here (for air and nitrogen service).

Step 2.5: Hub Seal Screen

Criterion
Valves with the configurations identified below should be evaluated for the presence of a hub seal. Butterfly valves with a symmetric disk and shaft design contain a hub seal. The hub seal is the penetration in the elastomeric valve seat where the shaft penetrates the body. Valves with an offset shaft design most likely do not contain a hub seal, but this determination should be verified against vendor design information. Test results in the JOG MOV PV Program showed that neither a simple shaft-to-bearing O-ring seal nor an elastomeric "shaft seal" at the mid-point of one of the bearing sleeves is sufficient to exclude the effects of untreated water.

- Bronze bearings in untreated water

  Valves that meet this configuration <u>and</u> contain a hub seal have a CAI rating of 0 or 2, subject to the shaft material screen (Step 2.3). Valves that meet this configuration but <u>do not</u> contain a hub seal have a CAI rating of 1 or 2, subject to the shaft material screen (Step 2.3).

[46] Untreated Water refers to valves in raw water (e.g., service water) systems.

- Stellite bearings in untreated water, up to 150°F

  Valves that meet this configuration and contain a hub seal have a CAI rating of 2. Valves that meet this configuration but do not contain a hub seal have a CAI rating of 3.

Otherwise, this parameter is not needed and valves should be evaluated further (Step 3).

Basis and Justification
As discussed in Section 4, test results for valves with bronze bearings in untreated water with a hub seal showed stable bearing friction across the three test series. The hub seal acts as a barrier between the fluid and bearing, creating a fluid environment at the bearing that is less susceptible to particulates (i.e., analogous to treated water). Accordingly, these valves can have a CAI rating of 0 (no degradation).

As discussed in Step 2.2, valves with Stellite bearings in untreated water with a hub seal are expected to show stable bearing friction, similar to treated water valves, extended by engineering judgment based on the guide friction results for gate valves. Since valves of this material are covered by extension, they can have a CAI rating of 2.

Step 3: Bearing Friction Qualifying Basis Screen

Valves which have design attributes and are in applications covered by the JOG MOV PV Program (i.e., a CAI rating of 1 or 2) need to be further evaluated for the basis of the bearing friction component of required torque being used to determine margin for the valve.

Criterion
Valves that meet the criteria for having a "qualifying basis" for bearing friction are not susceptible to variation above the qualifying basis. Therefore, these valves can be classified as Class A or B, subject to their CAI rating (Step 2). Valves that do not meet the criteria for having a "qualifying basis" for bearing friction need to be evaluated further (Step 4).

Butterfly valve bearing friction used to determine required torque (for evaluating valve margin) has a "qualifying basis" if it meets either of the following criteria, i.e., Criterion 3.1 or 3.2.

Criterion 3.1
The valve's bearing friction (or total torque under DP conditions, including bearing friction) is determined from DP testing of that specific valve, and the testing satisfies all of the following three bullets.

- The valve is DP tested at least three (3) times over a total time period of four (4) or more years, with the full set of tests occurring at least 1 year after the preceding valve disassembly (or initial installation). Additionally, there should be no valve disassembly occurring during the time period of the tests. The maximum bearing friction coefficient value (or maximum total torque under DP conditions) from that series of tests is used.

- The plant is responsible for (1) justifying that results under the specific test conditions (DP, fluid, temperature) can be applied to or adjusted to cover the design basis conditions, and (2) considering measurement accuracy.

- The valve in service is still the "tested" valve, i.e. the valve has not been replaced after the tests. Further, neither the shaft nor bearing(s) has been replaced after the tests.

Criterion 3.2
The valve's bearing friction (or total torque under DP conditions, including bearing friction) is determined from DP testing of other similar valves, and the testing satisfies all of the following three bullets.

- At least two (2) tests from each of two (2) valves are used, with the full set of tests occurring at least 1 year after the preceding valve disassembly (or initial installation). Additionally, there should be no valve disassembly occurring during the time period of the tests on each valve. The test results for bearing friction coefficient (or total torque under DP conditions) should be applied to the specific valve being evaluated. In place of two tests from each of two valves, single DP tests of four separate valves may be used that meet the same criteria. In total, at least four tests are required to satisfy this criterion, using one of the following:

    - 2 tests from each of 2 valves
    - 2 tests from one valve and one test from each of 2 other valves
    - 1 test from each of 4 valves

- The plant is responsible for (1) justifying that results under the specific test conditions (DP, fluid, temperature) can be applied to or adjusted to cover the design basis conditions of the valve being evaluated, and (2) considering measurement accuracy.

- The plant is responsible to justify the set of valves used as a group. At minimum, for tested valves to be considered similar to a valve to which the results are applied, the tested valves shall have the same bearing-to-shaft material pair, fluid type, and presence or absence of a hub seal as the valve to which the results are applied.

Basis and Justification

The results in Section 4 show that for (a) butterfly valves in raw water systems that have bronze or 300 series stainless steel bearings without a hub seal and (b) butterfly valves with non-metallic bearings, there is variation in bearing friction coefficient but no increasing or decreasing trend. Accordingly, a single test of a butterfly valve under these conditions is not adequate to provide a bearing friction coefficient that covers the range of values that occurs in service. Multiple tests, though, reveal a suitable range of bearing friction.

The JOG MOV PV Program provided a basis for suitable limit values for bearing friction coefficient. However, not all valves will have a range of bearing friction that extends up to this limit. To provide a means to understand the suitable bearing friction range for a specific valve, this step allows use of in-plant test data to justify a value. To ensure that the value considers the range of possible results, at least three tests of a specific valve are required or at least four total tests from two or more similar valves are required. The choice of three tests for a valve is based on the observations in the JOG MOV PV Program, where three tests were used. Valves that were susceptible to variation showed a distinct peak value in the three test series. Most valves showed their peak within the first two tests, and the use of three tests is considered an appropriate approach (Criterion 3.1)

When valves other than the specific valve are tested, it is important to obtain a wider sample of data, because one individual valve may not exhibit the same range of friction coefficient as another. The use of four data points from two or more valves provides a way to obtain the wider sample (Criterion 3.2). The selection of four data points and two or more valves is based on judgment.

Step 4: Coefficient of Friction Threshold Screen

Criterion

Valves that have a CAI rating of 1 or 2 need to be evaluated to determine if the valve is set up (and margin evaluated) using a bearing coefficient of friction that is susceptible to variation. For each combination of bearing material and fluid type tested in the JOG MOV PV Program, a threshold coefficient of friction is determined. The threshold is the value above which the friction coefficient does not increase, based on testing in the JOG MOV PV Program. Table 7-7 provides the threshold values.

Valves that are set up (and margin evaluated) using a bearing friction coefficient greater than or equal to the applicable threshold value are not susceptible to increases in bearing friction. Therefore, these valves can be classified as Class A or B, subject to their CAI rating (Step 2).

Valves that are set up using a bearing friction coefficient less than the applicable threshold value are susceptible to increases in bearing friction, and are classified as Class C.

No threshold evaluation is required for valves with bronze or Stellite bearings under certain conditions.

Each plant is responsible for the design bases for its butterfly valves. Although a plant can decide to conservatively increase its butterfly valve bearing COFs to meet these thresholds, it is not acceptable to decrease a plant specific COF to the threshold value.

Basis and Justification

The bearing friction coefficient thresholds in Table 7-7 are taken from analyses of the butterfly valve data, using a deterministic approach based on engineering judgment. The threshold value for bronze bearings bounds 95% of the measured results for all butterfly valves with bronze bearings. This approach is slightly more conservative (and was judged to be more suitable) than simply bounding 95% of the results for bronze bearings in untreated water without hub seals, where the data were more limited.

The threshold value for Teflon bearings bounds 100% of the measured results. Although there were sufficient data for this material to consider a less bounding approach, the result from these other approaches was very close to the maximum measured value, and the bounding value was conservatively chosen.

For Tefzel bearings, the maximum measured result is used as the threshold. Although data were obtained only for one valve with this bearing material, the measured results are stable and are consistent with values indicated by the material manufacturer. Therefore, use of the maximum measured value is appropriate.

For other non-metallic bearings (Nomex, Nylatron and Polyethylene), the maximum measured value from this group (which occurred for Polyethylene) is used. The Polyethylene value was constant across three tests. The values for Nylatron and Nomex, although lower, showed some variations and increases during the tests. Use of the higher value (observed for Polyethylene) provides an appropriate margin.

For 300 series stainless steel bearings, data were obtained for only one valve and the results showed variations. For this material a threshold of 0.60, which is 20% greater than the maximum measured value (0.5), was selected. The higher value was chosen to provide margin and to be consistent with typical maximum values of metal-to-metal friction.

Valves with bronze and Stellite bearings under certain conditions (identified in Table 7-7) are covered by extension; however, the mechanism for bearing friction coefficient variation is not present. Accordingly, a threshold evaluation for these valve types is not required.

Periodic Verification Approach for Butterfly Valves in Class C

Butterfly valves determined to be in Class C should undergo a process that allows them to satisfy the Qualifying Basis (Step 3) or the Threshold Coefficient of Friction (Step 4).

<u>Option 1</u>
The valve should be DP tested (rather than static tested) at a 2 year interval, with the first DP test to occur at the next available opportunity, not to exceed 2 years. After each DP test, the COF should be "reset" to the new value determined from testing (if higher than the current value) and the margin should be re-evaluated. DP testing should continue until sufficient data has been obtained to satisfy the bearing friction Qualifying Basis in Step 3. Once this condition is satisfied, the valve should be reclassified, using Steps 1-4 and Figure 7-3.

<u>Option 2</u>
The valve should be re-evaluated, and modified if necessary, so that it has positive margin with a bearing friction coefficient equal to the threshold value specified in Table 7-7. If this option is used, the valve should be reclassified using Steps 1-4 and Figure 7-3.

Table 7-5. Information Needed to Evaluate Butterfly Valves for Periodic Verification

Category	Attribute	Information Needed
Design Information	Size	DDK – Disk Diameter
	Shaft-Bearing Interface	S – Shaft Surface Material that mates with bearing; must be one of the following: • 300 series stainless steel [S=1] • 400 series stainless steel [S=2] • 17-4PH stainless steel [S=3] • Other stainless steel, Monel or smooth metallic shaft [S=11] • Other [S=30]
		B – Bearing Surface Material that mates with shaft; must be one of the following: • Bronze or Bronze/Graphite[B=1] • Teflon in a fiberglass carrier [B=2] • Teflon on stainless steel backing [B=3] • Tefzel [B=4] • Nomex [B=11] • Nylatron [B=12] • Polyethelyne [B=13] • 300 series stainless steel [B=14] • Stellite [B=15] • Other [B=30]
	Hub Seal	HS – Does the valve seat include a Hub Seal? (YES or NO)
Application/ Service	Fluid Type	F – Type of Fluid in pipe during DP stroking; must be one of the following: • Treated water ≤ 150°F [F=1] • Untreated (raw) water ≤ 150°F [F=2] • Air or nitrogen ≤ 150°F [F=11] • Treated water > 150°F [F=12] • Untreated (raw) water > 150°F [F=13] • Other [F=30]
	Risk	RSK - Risk Ranking (HIGH, MEDIUM or LOW)
	Design Basis Function	DBF - Must be one of the following • Static (open and/or close) only • DP (open and/or close)
Setup	Parameters	MAR – Margin for Successful Operation under Design Basis Conditions
		BAS – Basis for Required Torque; must be one of the following • EPRI PPM, with recommended maximum bearing friction coefficient [BAS=PPM] • Other
		COF – Current Bearing Friction Coefficient Associated with the Required Torque used to Determine Margin for the Valve
Test Information		To justify a bearing friction coefficient has a valid "qualifying basis," information related to the test used to determine the bearing COF is needed. See Step 3 of the Butterfly Valve Implementation Method for additional information.

Table 7-6. CAI Rating Chart for Butterfly Valves (*2 pages*)

DBF Design Basis Function	B Bearing Material	S Shaft Material	F Fluid Type	HS Hub Seal	Rating =			
Step 2.1	*Step 2.2*	*Step 2.3*	*Step 2.4*	*Step 2.5*	0	1	2	3
Static	1 thru 15	1 thru 11	N/A	N/A	√			
		30	N/A	N/A				√
	30	All	N/A	N/A				√
DP	1 Bronze or Bronze/Graphite	1, 2 or 3	1 Treated Water ≤150°F	All	√			
			2 Untreated Water ≤150°F	Yes	√			
				No		√		
			11 Air/N_2 ≤150°F	All			√	
			12 or 13 Water >150°F	All			√	
			30 Other	All				√
		11	1, 2 or 11 Water or Air/N_2 ≤150°F	All			√	
			12, 13 or 30 Water >150°F or Other	All				√
		30	All	All				√
	2, 3 or 4 Teflon/Fiberglass, Teflon/SS, or Tefzel	1, 2 or 3	1 or 2 Water ≤150°F	All		√		
			11 Air/N_2 ≤150°F	All			√	
			12 or 13 Water >150°F	All			√	
			30 Other	All				√
		11	1, 2 or 11 Water or Air/N_2 ≤150°F	All			√	
			12, 13 or 30 Water >150°F or Other	All				√
		30	All	All				√
	11, 12 or 13 Nomex, Nylatron, or Polyethelyne	1, 2, 3 or 11	1, 2 or 11 Water or Air/N_2 ≤150°F	All			√	
			12, 13 or 30 Water >150°F or Other	All				√
		30	All	All				√

Table 7-6. CAI Rating Chart for Butterfly Valves (*2 pages*)

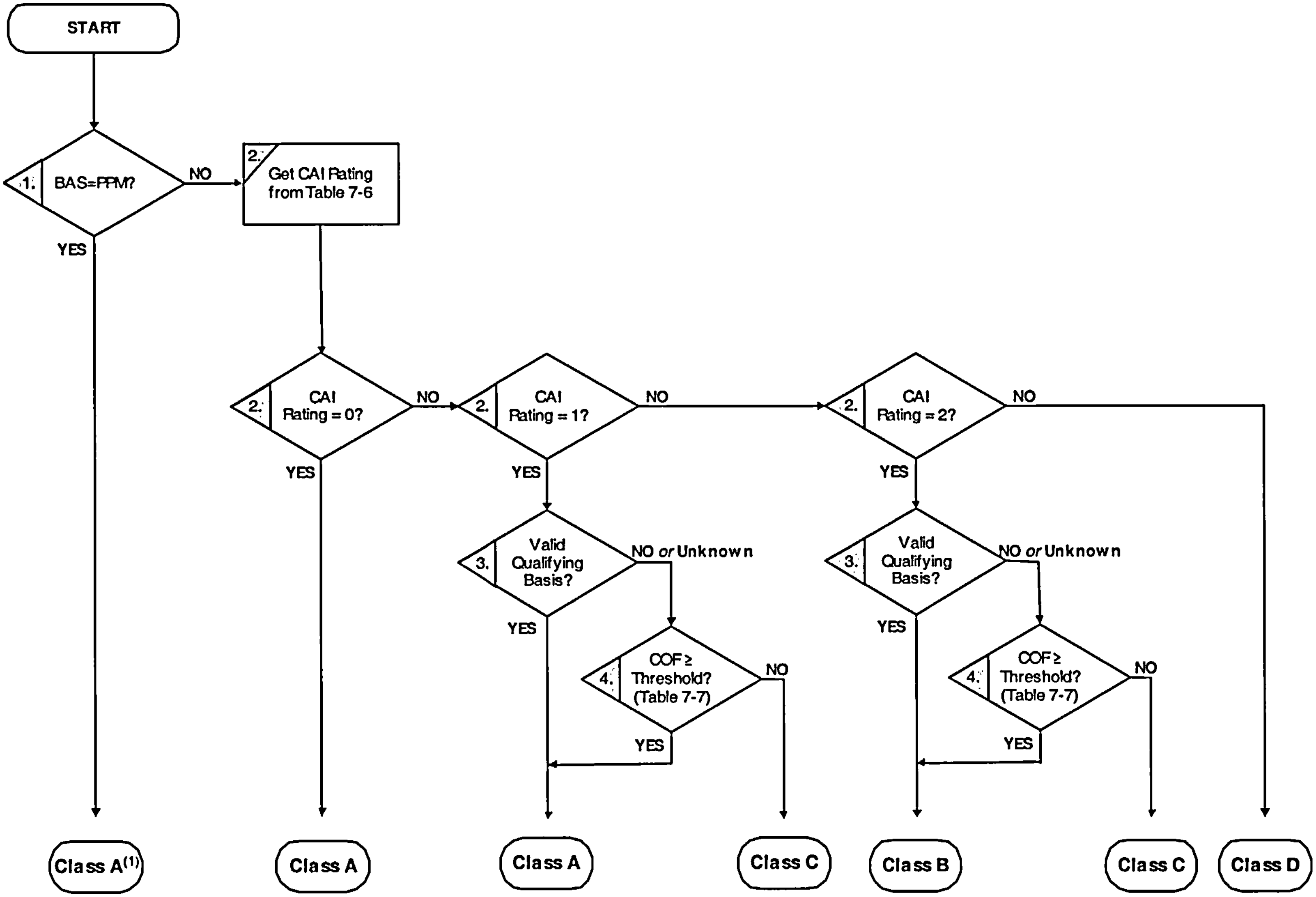
DBF Design Basis Function	B Bearing Material	S Shaft Material	F Fluid Type	HS Hub Seal	Rating =			
					0	1	2	3
Step 2.1	*Step 2.2*	*Step 2.3*	*Step 2.4*	*Step 2.5*				
DP	14 300 series SS	3	1, 2 or 11 Water or Air/$N_2 \le 150$°F	All			√	
			12, 13 or 30 Water >150°F or Other	All				√
		1, 2, 11 or 30	All	All				√
	15 Stellite	1, 2 or 3	1 or 11 Treated Water or Air/$N_2 \le 150$°F	All			√	
			2 Untreated Water ≤ 150°F	Yes			√	
				No				√
			12, 13 or 30 Water >150°F or Other	All				√
		11 or 30	All	All				√
	30	All	All	All				√

Table 7-7. COF Threshold Values for Butterfly Valves

Category			Threshold COF
Bearing Material	**Fluid and Temperature**	**Hub Seal**	
Bronze	Treated Water, All Temperatures or Air/$N_2 \leq 150°F$	N/A	See Note 1
	Untreated Water, All Temperatures	Yes	See Note 1
		No	0.39
Teflon on a Fiberglass carrier Teflon on a stainless steel substrate	All Water, All Temperatures or Air/$N_2 \leq 150°F$	N/A	0.13
Tefzel	All Water, All Temperatures or Air/$N_2 \leq 150°F$	N/A	0.23
Nomex Nylatron Polyethylene	All Water $\leq 150°F$ or Air/$N_2 \leq 150°F$	N/A	0.23
300 series SS	All Water $\leq 150°F$ or Air/$N_2 \leq 150°F$	N/A	0.60
Stellite	Treated Water $\leq 150°F$	N/A	See Note 1
	Untreated Water $\leq 150°F$	Yes	

Notes:

1. No threshold evaluation is required for valves under the conditions identified. The answer to the question "COF ≥ Threshold" on Figure 7-3 is taken to be "YES."



Note 1: PPM evaluations beyond the nominal applicability limits (i.e., "best available data") are considered Class B. See Butterfly Valve Method Step 1 for additional discussion.

Figure 7-3. Classification of Butterfly Valves

Implementation for Balanced Disk Globe Valves

Figure 7-4 summarizes the recommended approach for balanced disk globe valves, which can be used to determine the class into which each balanced disk globe valve falls. Table 7-8 lists the information needed to implement the approach. The explanation and justification for the approach is described below.

From Section 5, the conclusions for balanced disk globe valves are summarized below.

- For balanced disk globe valves, there is no age-related or service-related degradation in required thrust. Valve factors were observed to be steady and not susceptible to change. Further, the DP thrust was observed to be small in comparison to other thrust components (packing and stem rejection load), demonstrating that these valves are insensitive to changes in DP thrust.

- Valves in raw water systems were observed to have variations in thrust that did not seem to be related to DP, i.e., they occurred in portions of the stroke other than those affected by DP load. Accordingly, it is necessary for plants to be aware of these conditions but there is no need (or basis) to recommend an increase in valve factor.

Method to Determine Balanced Disk Globe Valve Classification

To determine the classification into which a balanced disk globe valve falls, it is necessary to consider the following key parameters.

- The disk-to-body guide materials
- The extent of DP stroking
- The fluid conditions

Using the information collected per Table 7-8, the following method can be used to determine the classification for balanced disk globe valves. Figure 7-4 provides a flow chart of the method. For each step, the criterion states what the user needs to evaluate. The basis and justification explains how the criterion was developed and justified using the JOG MOV PV Program data.

Typical trip and throttle valves (Gimpel and Shutte & Koerting) are justified for coverage in the JOG MOV PV Program as balanced disk globe valves (see Section 5 – *Non-Test Matrix Valve Covered by JOG MOV PV Program*). Accordingly, the implementation method for balanced disk globe valves can be used to classify these valves.

Step 1: PPM Screen

Criterion

If the following statements are all true for a balanced disk globe valve that has its required thrust determined using the EPRI PPM, then the valve is considered to be Class A.

- The guidance in the EPRI documentation (Reference 13) and the conditions and limitations in the NRC SE (References 14 and 15) are adhered to.

- The default method for determining disk side load is used.

- The margin as defined in the JOG MOV PV Program is > 0.

Some PPM evaluations used the PPM beyond its nominal applicability limits. In these cases, a valve that otherwise satisfies the three bullets above can be classified as Class B if the user has documented a satisfactory technical justification for using the PPM in that application.

If the conditions above are not satisfied, then the valve needs to be further evaluated as discussed below (Steps 2 and 3).

Basis and Justification
The EPRI PPM was shown to be a justified thrust prediction method through comparison with test data. For PPM evaluations that used the PPM beyond its nominal applicability limits, the user is responsible for justifying the use of the PPM for the specific application. To recognize the potential for reduced certainty in these cases, Class B is specified rather than Class A.

Step 2: Valve Configuration and Application Information (CAI) Screen

Valves are evaluated according to their design configuration and in service application conditions. The CAI screen includes criteria for: disk-to-body guide material, extent of DP stroking and fluid conditions. The balanced disk globe valve CAI Rating Chart (Table 7-9) is used to perform this evaluation and produces one of four ratings: 0, 1, 2 or 3.

- Valves which receive a CAI Rating of "0" have design attributes covered by the valves tested in the JOG MOV PV Program, and have a design basis requirement to open or close only under static conditions (i.e., no flow or DP). These valves can be classified as Class A or B*, subject to the additional evaluation in Step 3.

- Valves which receive a CAI Rating of "1" have design attributes and are in applications covered directly by the valves tested in the JOG MOV PV Program. These valves can be classified as Class A or B*, subject to the additional evaluation in Step 3.

- Valves which receive a CAI Rating of "2" have design attributes and/or are in applications covered by extension of the valves tested in the JOG MOV PV Program. These valves can be classified as Class B or B* (but not Class A), subject to the additional evaluation in Step 3.

- Valves which receive a CAI Rating of "3" have design attributes or are in applications that are not covered by the JOG MOV PV Program. These valves are classified as Class D.

Each of the criteria in Table 7-9 and its justification are discussed below.

Step 2.1: Disk-to-Body Guide Material Screen

Criterion

The following disk-to-body guide material combinations are covered by the JOG MOV PV Program. Valves with these guide materials can have a CAI rating of 0, 1, 2 or 3, subject to evaluation of the other factors (Steps 2.2 and 2.3).

- Stellite - Stellite
- Stellite – 17-4PH stainless steel
- Stellite – 400 series stainless steel
- 400 series stainless steel – 400 series stainless steel
- 400 series stainless steel – 17-4PH stainless steel
- 400 series stainless steel – 300 series stainless steel
- 400 series stainless steel – carbon steel
- 17-4PH stainless steel – 300 series stainless steel
- 17-4PH stainless steel – carbon steel
- 300 series stainless steel – bronze

The following guide material combinations are covered by extension. Valves with these guide materials can have a CAI rating of 0, 2 or 3 (but not 1), subject to evaluation of other factors (Steps 2.2 and 2.3).

- Stellite – 300 series stainless steel
- Stellite – carbon steel
- 300 series stainless steel – 300 series stainless steel

In some balanced disk globe valves, the disk does not contact the body guide surface; instead, only the disk seal ring bears against the guide. In this case, the materials of the seal ring and body guide should be considered in evaluating Step 2.1.

Basis and Justification

For the six material pairs tested directly in the program, this testing provides the basis for coverage, subject to the evaluation of other criteria related to applicability. For the four material pairs not directly tested, these material combinations are judged to be similar to, and bounded by, the material combinations tested.

For the material pairs covered by extension, results from gate valve tests showed these material pairs had stable performance in gate valve disk-to-guide friction (see Section 3). Therefore, it is reasonable to extend the coverage of balanced disk globe valves to include these materials.

Step 2.2: DP Stroking Screen

Criterion

Valves that have a design basis function to operate only under static conditions (regardless of in-service stroking) have a CAI rating of 0, as long as the valve disk-to-body guide materials are covered by the JOG MOV PV Program. The fluid type (Step 2.3) does not need to be evaluated.

Valves that have a design basis function to operate under DP conditions but *do not* stroke against DP in-service have a CAI rating of 1 or 2, as long as the valve guide materials are covered by the JOG Program (Step 2.1 above). The fluid type (Step 2.3) does not need to be evaluated.

Valves that have a design basis function to operate under DP conditions and *do* stroke against DP in-service have a CAI rating of 1, 2 or 3, subject to the evaluation of other factors (Steps 2.1 and 2.3).

Appendix B provides guidance for how to determine whether a valve strokes under DP conditions.

Basis and Justification

For valves that have a design basis function to operate only under static conditions, there is no need to consider how these valves behave under DP conditions. These valves can have a CAI rating of 0 without any additional evaluation.

Valves that do not stroke against DP at all do not have a mechanism to increase in valve factor, regardless of fluid conditions.

Step 2.3: Fluid Conditions Screen

Criterion

The following fluid types were tested in the JOG MOV PV Program. They are included in the Program coverage and valves in these fluid conditions can have a CAI rating of 1 or 2, subject to evaluation of the other criteria (Steps 2.1 and 2.2). These fluid types refer to conditions under which the valve strokes against DP in service.

- Treated water, at temperatures up to 150°F
  (up to 120°F for valves with 300-300 or 300-400 series stainless steel guides)

- Untreated water[47], at temperatures up to 150°F
  (up to 120°F for valves with 300-300 or 300-400 series stainless steel guides)

[47] Untreated Water refers to valves in raw water (e.g., service water) systems.

The following fluid types are covered by extension of the data, i.e., they can have a rating of 2 or 3 (but not 0 or 1), subject to evaluation of other factors (Steps 2.1 and 2.2). These fluid types refer to conditions under which the valve strokes against DP in service.

- Treated water above 150°F, non-flashing
- Untreated water above 150°F, non-flashing
- Steam, up to a flow rate of 86 ft/sec[48]
- Air or Nitrogen, up to a flow rate of 86 ft/sec
  (up to 120°F for valves with 300-300 or 300-400 series stainless steel guides)

Applications with flashing water or with high compressible flow rates (> 86 ft/sec) have a CAI Rating of 3. Also, valves with self-mated 300 series or 300 series-400 series stainless steel guides in any application with fluid temperatures above 120°F have a CAI Rating of 3.

Basis and Justification
All of the balanced disk globe valve tests were performed in water systems, at temperatures up to about 100°F. A threshold of 150°F for applicability is reasonable because this range is within the conditions of normal, incompressible flow. However, a potential friction degradation mechanism (galling) in valves with self-mated 300 series or 300 series-400 series stainless steel guides means that the limit of the gate valve guide data (120°F) should not be exceeded for this material combination.

Guide friction results from gate valve tests show that the balanced disk globe valve guide material pairs perform reliably in elevated temperature water and in steam. However, there are no data for self-mated 300 series or 300 series-400 series stainless steel above 120°F, and these material pairs are not justified above that temperature.

For incompressible (non-flashing) water above 150°F, the mechanisms are identical to cold water (≤150°F), so the results can be extended to this application. The results from unbalanced disk globe valve testing in steam confirm that temperature, by itself, does not change the behavior.

For air and nitrogen, results from friction testing in the EPRI MOV Program indicate little difference between air and water. Accordingly, it is reasonable to extend the JOG MOV PV Program results to cover air and nitrogen. Further, the results from unbalanced disk globe valve testing in steam confirm that gas flow (up to velocities of 55 ft/sec) does not change the behavior. Although the maximum tested compressible flow rate was 55 ft/sec, the maximum flow rate for all globe valve tests (balanced and unbalanced) was 86 ft/sec, which was selected as the maximum value to be covered by the JOG MOV PV Program.

Under fluid conditions with flashing flow or compressible flow at high flow rates, the side load mechanisms on the disk could be affected, and disk-to-guide friction could become more important. Therefore, these conditions are excluded from applicability.

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[48] Flow rate for globe valves calculated using the valve seat diameter. See Appendix A for applicable equations.

Step 3: Untreated Water Screen

Criterion

Valves that have a CAI rating of 0, 1 or 2 need to be further evaluated to determine if they are in raw water applications. If so, they have a classification of B*. The periodic verification requirements for these valves are identical to Class B, but there is a warning regarding a potentially unusual mechanism, as discussed below.

Basis and Justification

Balanced disk globe valves in raw water service showed that there could be increases in required thrust unrelated to DP thrust. It appeared that these changes in thrust are attributable to build-up and release of particulate material inside the valve. Separate guidance to deal with these valves is summarized below.

Periodic Verification Approach for Balanced Disk Globe Valves in Raw Water

As discussed in Section 5, balanced disk globe valves in untreated (raw) water systems showed periods of elevated thrust in some tests, but it appeared that the thrust was not related to the effect of DP. These results were evaluated and reported within the industry by the specific plants carrying out these tests. It appeared that the intermittent build-up of solid material in the valve could be contributing to the observed behavior. Accordingly, for balanced disk globe valves in raw water systems, plants need to adhere to the following warning.

- Plants with valves in Class B* should review the results of static tests to identify if there is evidence of thrust increases that might be related to this effect. Specifically, the concern would be observed as increased running load in either the closing or opening stroke. If periods of increased thrust are observed, the valves should either be exercised to potentially work out the obstruction, or an increased required thrust (to cover the observed effect) should be used.

- Plants with valves in Class B* should consider exercising these valves (stroking, but not necessarily with diagnostic instrumentation) periodically to reduce the susceptibility of the valve to thrust increases. One plant that observed this effect found that stroking the valve tended to clear it and that periodic exercising was effective at keeping it clean.

Table 7-8. Information Needed to Evaluate Balanced Disk Globe Valves for Periodic Verification (*2 pages*)

Category	Attribute	Information Needed
Design Information	Size	DMS – Mean Seat Diameter
	Disk-to-Body Guide Materials	G - Materials of Disk-to-Body Guide interface[49]; must be one of the following: • Stellite[50] - Stellite [G=1] • Stellite – 17-4PH stainless steel [G=2] • Stellite – 400 series stainless steel [G=3] • 400 series stainless steel – 400 series stainless steel [G=4] • 400 series stainless steel – 17-4PH stainless steel [G=5] • 400 series stainless steel – 300 series stainless steel [G=6] • 400 series stainless steel – carbon steel [G=7] • 17-4PH stainless steel – 300 series stainless steel [G=8] • 17-4PH stainless steel – carbon steel [G=9] • 300 series stainless steel – bronze [G=10] • Stellite – 300 series stainless steel [G=11] • Stellite – carbon steel [G=12] • 300 series stainless steel – 300 series stainless steel [G=13] • Other [G=30]
Application/ Service	DP Stroking	DPS – Maximum Differential Pressure during DP strokes
		DS – In the full course of plant activities, does the valve stroke while there is DP across the valve?[51] (YES or NO)
	Fluid Type	F – Type of fluid in pipe during DP stroking; must be one of: • Untreated (raw) water ≤ 150°F *(≤120°F for G=6 or 13)* [F=1] • Treated water ≤ 150°F *(≤120°F for G=6 or 13)* [F=2] • Untreated water > 150°F *(>120°F for G=6 or 13);* non-flashing [F=11] • Treated water > 150°F *(>120°F for G=6 or 13)*; non-flashing [F=12] • Steam [F=13] • Air or nitrogen ≤ 120°F [F=14] • Air or nitrogen > 120°F [F=15] • Water > 150°F *(>120°F for G=6 or 13)*; flashing [F=20] • Other [F=30]
	Flow Rate	FR – Flow Rate
	Risk	RSK - Risk Ranking (HIGH, MEDIUM or LOW)

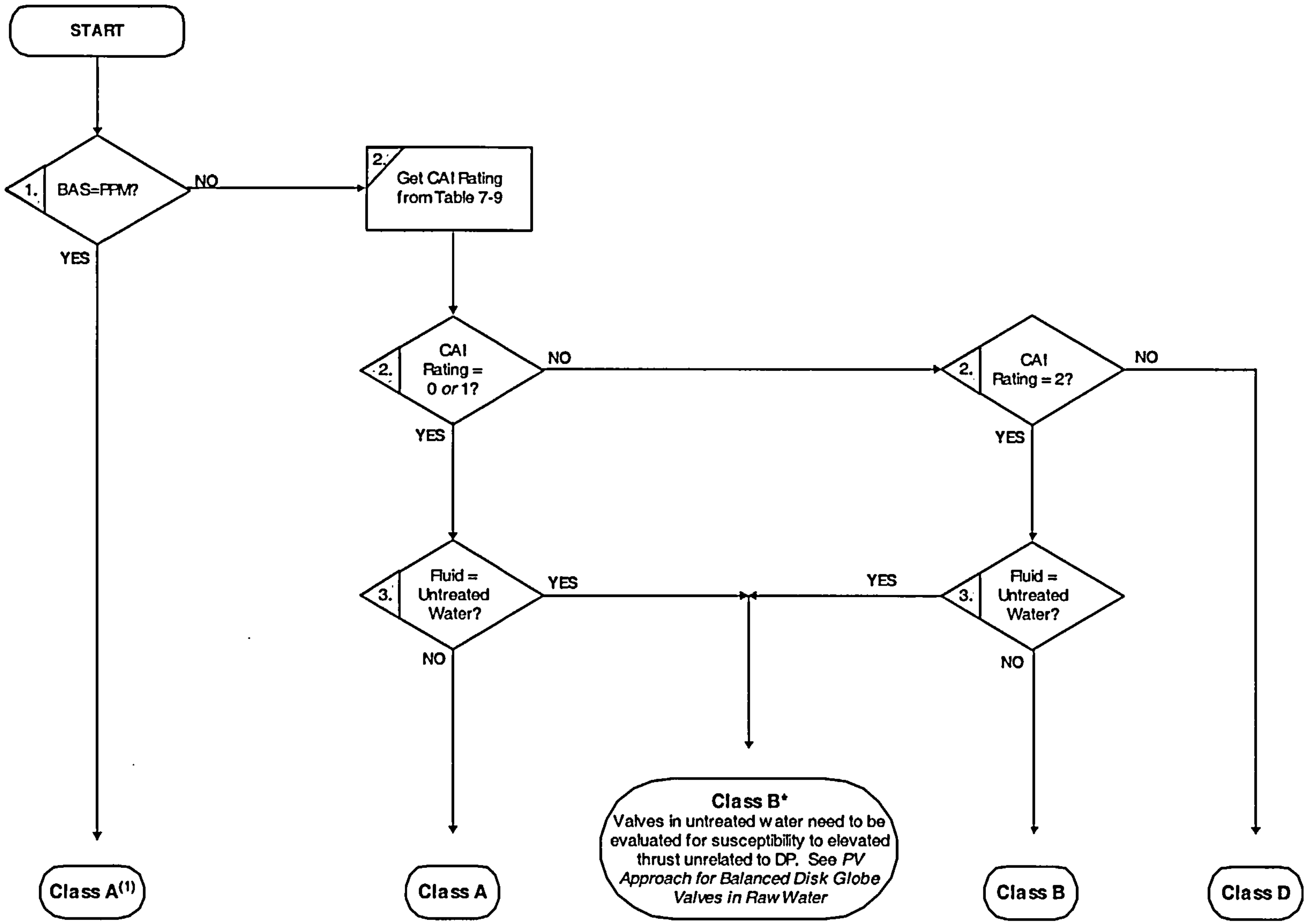
[49] In some balanced disk globe valves, the disk does not contact the body guide surface; instead, only the disk seal ring bears against the guide. In this case the materials of the seal ring and body guide should be considered.
[50] *Stellite* refers to any grade of Stellite
[51] Consider normal operations, testing, shutdown, maintenance, etc. See Appendix B for additional guidance.

Table 7-8. Information Needed to Evaluate Balanced Disk Globe Valves for Periodic Verification (*2 pages*)

Category	Attribute	Information Needed
Application/ Service	Design Basis Function	DBF - must be one of the following • Static (open and/or close) only [S] • DP Open only [O] • DP Close only [C] • DP Open and Close [O/C]
Setup	Parameters	MAR – Margin for Successful Operation under Design Basis Conditions
		BAS – Basis for Required Thrust; must be one of the following • EPRI PPM, with default side load calculation [BAS=PPM] • Other

Table 7-9. CAI Rating Chart for Balanced Disk Globe Valves

G Disk-to-Body Guide Materials	DS DP Stroking	DBF Design Basis Function	F Fluid Type	FR Flow Rate	Rating =			
					0	1	2	3
Step 2.1	*Step 2.2*		*Step 2.3*					
1 thru 5 and 7 thru 10	N/A	S	N/A	N/A	√			
	No	O, C or O/C	N/A	N/A		√		
	Yes	O, C or O/C	1 or 2	All		√		
			11 or 12	All			√	
			13,14, or 15	≤ 86 ft/s			√	
				> 86 ft/s				√
			20 or 30	All				√
6	N/A	S	N/A	N/A	√			
	No	O, C or O/C	N/A	N/A		√		
	Yes	O, C or O/C	1 or 2	All		√		
			14	≤ 86 ft/s			√	
				> 86 ft/s				√
			11, 12, 13, 15, 20 or 30					√
11 or 12	N/A	S	N/A	N/A	√			
	No	O, C or O/C	N/A	N/A			√	
	Yes	O, C or O/C	1, 2, 11, or 12	All			√	
			13, 14, or 15	≤ 86 ft/s			√	
				> 86 ft/s				√
			20 or 30	All				√
13	N/A	S	N/A	N/A	√			
	No	O, C or O/C	N/A	N/A			√	
	Yes	O, C or O/C	1 or 2	All			√	
			14	≤ 86 ft/s			√	
				> 86 ft/s				√
			11, 12, 13, 15, 20 or 30	All				√
30	All	All	All	All				√



Note 1: PPM evaluations beyond the nominal applicability limits (i.e., "best available data") are considered Class B. See Balanced Globe Valve Method Step 1 for additional discussion.

Figure 7-4. Classification of Balanced Disk Globe Valves

IMPLEMENTATION FOR UNBALANCED DISK GLOBE VALVES

Figure 7-5 summarizes the recommended approach for unbalanced disk globe valves, which can be used to determine the class into which each unbalanced disk globe valve falls. Table 7-10 lists the information needed to implement the approach. The explanation and justification for the approach is described below.

From Section 6, unbalanced disk globe valves were found to have steady valve factors with no age-related or service-related degradation of required DP thrust. No unusual conditions were identified that required special evaluation. Therefore, there are no unbalanced disk globe valves classified as Class C.

Method to Determine Unbalanced Disk Globe Valve Classification

To determine the classification into which an unbalanced disk globe valve falls, it is necessary to consider the following key parameters.

- The extent of DP stroking
- The fluid conditions

Using the information collected per Table 7-10, the following method can be used to determine the classification for unbalanced disk globe valves. Figure 7-5 provides a flow chart of the method. For each step, the criterion states what the user needs to evaluate. The basis and justification explains how the criterion was developed and justified using the JOG MOV PV Program data.

Typical trip and throttle valves (Gimpel and Shutte & Koerting) are justified for coverage in the JOG MOV PV Program as balanced disk globe valves (see Section 5 – *Non-Test Matrix Valve Covered by JOG MOV PV Program*). The implementation method for balanced disk globe valves should be used to classify these valves.

Step 1: PPM Screen

Criterion

If the following statements are all true for an unbalanced disk globe valve that has its required thrust determined using the EPRI PPM, then the valve is considered to be Class A.

- The guidance in the EPRI documentation (Reference 13) and the conditions and limitations in the NRC SE (References 14 and 15) are adhered to.

- The recommended method for determining disk DP area is used.

- The margin as defined in the JOG MOV PV Program is > 0.

Some PPM evaluations used the PPM beyond its nominal applicability limits. In these cases, a valve that otherwise satisfies the three bullets above can be classified as Class B if the user has documented a satisfactory technical justification for using the PPM in that application.

If the condition above is not satisfied, then the valve needs to be further evaluated as discussed below (Steps 2 through 4).

Basis and Justification
The EPRI PPM was shown to be a justified thrust prediction method through comparison with test data. For PPM evaluations that used the PPM beyond its nominal applicability limits, the user is responsible for justifying the use of the PPM for the specific application. To recognize the potential for reduced certainty in these cases, Class B is specified rather than Class A.

Step 2: DP Stroking Screen

Criterion
Valves that *do not* stroke against DP in-service are classified as Class A. Also, valves that have a design basis function to operate only under static conditions are classified as Class A.

Valves that *do* stroke against DP in-service need to be further evaluated based on other considerations (Steps 3 and 4).

Appendix B provides guidance for how to determine whether a valve strokes under DP conditions.

Basis and Justification
Valves that do not stroke against DP at all do not have a mechanism to increase in valve factor. For valves that have a design basis function to operate only under static conditions, there is no need to consider how these valves behave under DP conditions. These valves can be classified as Class A without any additional evaluation.

Step 3: Screen for Special Characteristics Not Covered by JOG Testing

Criterion
Valves that have rising/rotating stems and that stroke against DP in the open direction with flow overseat are classified as Class D.

Otherwise, the valve should be evaluated as discussed in Step 4.

Basis and Justification
Valves with rising/rotating stems and overseat flow that open against DP have an additional sliding friction mechanism that increases the required demand on the actuator. The additional friction occurs at the stem-to-disk interface. JOG MOV PV Program

testing did not cover this mechanism; therefore, this set of conditions is excluded from coverage. It appears that this combination of conditions occurs very rarely in globe valves.

Note that valves that have rising/rotating stems with overseat flow and that stroke against DP only in the closing direction (or do not stroke against DP) are not excluded from coverage. The additional mechanism potentially subject to degradation applies only to opening strokes. Also, rising/rotating stem valves with flow underseat are not excluded from coverage. With flow underseat, there are no DP thrust mechanisms associated with the rising/rotating stem connection, beyond the behavior observable in static testing.

Step 4: Fluid Conditions Screen

Criterion

The following fluid types are directly covered by the test data from the JOG MOV PV Program. Valves operating in these fluid conditions are classified as Class A. These fluid types refer to conditions under which the valve strokes against DP in service.

- Water systems up to a temperature of 150°F
- Steam, Air or Nitrogen systems up to a flow rate of 86 ft/sec[52]

Applications with non-flashing water above 150°F are covered by extension (i.e., they are classified as Class B).

Applications with flashing water or with steam, air or nitrogen flow rates in excess of 86 ft/sec are excluded from coverage because of a lack of data and a potential concern that these conditions could lead to elevated disk side loads and friction loads.

Basis and Justification

All of the unbalanced disk globe valve tests were performed in water or steam systems. The water tests covered temperatures up to about 110°F. A threshold of 150°F for applicability is reasonable because this range is within the conditions of normal, incompressible flow.

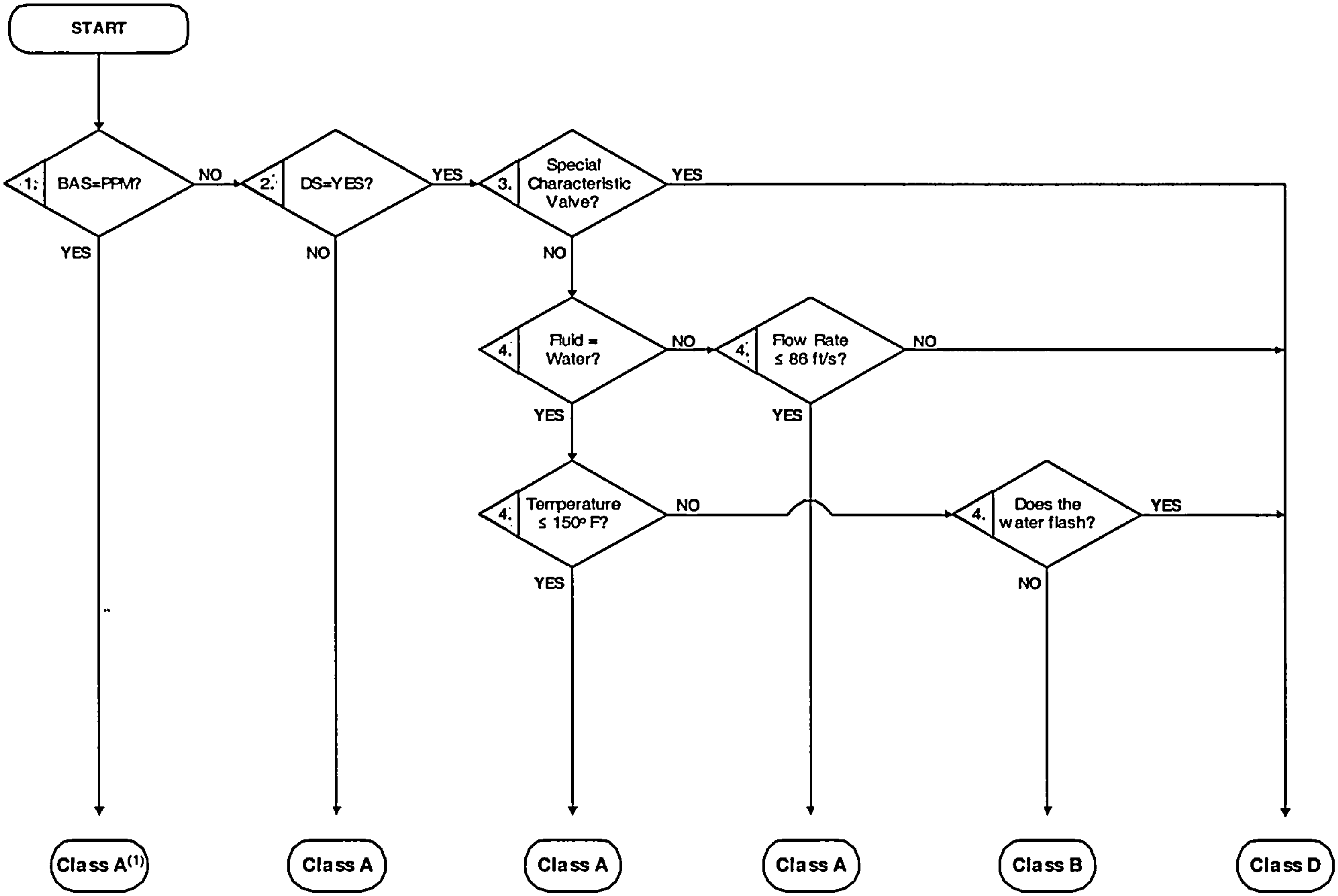
Under fluid conditions with flashing flow or compressible flow at high flow rates, the side load mechanisms on the disk could be affected, and disk-to-seat friction could become more important (Reference 12). Therefore, these conditions are excluded from applicability. Although the maximum tested compressible flow rates was 55 ft/sec, the maximum flow rate for all globe valve tests (balanced and unbalanced) was 86 ft/sec, which was selected as the maximum value to be covered by the JOG MOV PV Program.

[52] Flow rate for globe valves calculated using the valve seat diameter. See Appendix A for applicable equations.

Table 7-10. Information Needed to Evaluate Unbalanced Disk Globe Valves for Periodic Verification

Category	Attribute	Information Needed
Design Information	Size	DMS – Mean Seat Diameter
	Disk Details	STD – Stem motion against disk; must be one of • Rising only • Rising and Rotating
Application/ Service	DP Stroking	DPS – Maximum Differential Pressure during DP strokes
		DS? – In the full course of plant activities, does the valve stroke while there is DP across the valve?[53] (YES or NO)
	Fluid Type	F – Type of fluid in pipe during DP stroking; must be one of the following: • Water ≤ 150°F • Water > 150°F; non-flashing • Water > 150°F; flashing • Steam • Air or nitrogen • Other
	Flow Rate	FR – Flow Rate
	Flow Direction	FD – Flow Direction; must be one of the following: • Overseat • Underseat
	Risk	RSK - Risk Ranking (HIGH, MEDIUM or LOW)
	Design Basis Function	DBF – Must be one of the following • Static (open and/or close) only [S] • DP Open only [O] • DP Close only [C] • DP Open and Close [O/C]
Setup	Parameters	MAR – Margin for Successful Operation under Design Basis Conditions
		BAS – Basis for Required Thrust; must be one of the following • EPRI PPM [BAS=PPM] • Other

[53] Consider normal operations, testing, shutdown, maintenance, etc. See Appendix B for additional guidance.



Note 1: PPM evaluations beyond the nominal applicability limits (i.e., "best available data") are considered Class B. See Unbalanced Globe Valve Method Step 1 for additional discussion.

Figure 7-5. Classification of Unbalanced Disk Globe Valves

GUIDANCE FOR VALVES IN CLASS D

For any valve (gate, butterfly or globe) classified as Class D using the JOG MOV PV Program Approach above, the following evaluations may be performed. Any information learned as part of these evaluations should be incorporated into a plant-specific periodic verification program.

- Perform *in situ* DP tests of the excluded valve or similar valves under the conditions that were not covered by the JOG MOV PV Program, and evaluate the results for degradation.
- Perform laboratory type testing of the valve(s) or sub-components to specifically address the degradation mechanism that was not covered by the JOG MOV PV Program (e.g., potential galling of self-mated 300 series stainless steel surfaces at temperatures above 120°F)
- Obtain information from other industry sources that provide insight on the conditions that were not covered by the JOG MOV PV Program.

8 References

1. *Safety Related Motor-Operated Valve Testing and Surveillance,* United States Nuclear Regulatory Commission Generic Letter 89-10, June 28, 1989.

2. *Periodic Verification of Design-Basis Capability of Safety-Related Motor-Operated Valves*, United States Nuclear Regulatory Commission, Generic Letter 96-05, September 18, 1996.

3. *Joint BWR, Westinghouse and Combustion Engineering Owners' Group Program on Motor-Operated Valve Periodic Verification,* MPR-1807, Revision 2 July 1997.

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A

JOG Equations and Formulas

GATE VALVE FACTOR EQUATIONS FROM TEST DATA

These equations are used in the JOG MOV PV Program to determine valve factor from test data, when there is negligible effect of parasitic load. They can be similarly used by plants to evaluate test data.

Closing Stroke:

$$VF = \frac{\left|Thrust - Thrust_{running}\right| - \left(P_{UP} - P_{UP\text{-}RUNNING}\right) * \left(\frac{\pi * d_{stem}^2}{4}\right)}{DP * \left(\frac{\pi * d_{mean\,seat}^2}{4}\right)}$$

Opening Stroke:

$$VF = \frac{\left|Thrust - Thrust_{running}\right| + \left(P_{UP} - P_{UP\text{-}RUNNING}\right) * \left(\frac{\pi * d_{stem}^2}{4}\right)}{DP * \left(\frac{\pi * d_{mean\,seat}^2}{4}\right)}$$

Thrust:	Stem thrust at the time point being evaluated, lbs
$Thrust_{running}$:	Stem thrust at the "Running Load" point, lbs
P_{UP}:	Upstream pressure at the time point being evaluated, psig
$P_{UP\text{-}RUNNING}$:	Upstream pressure at "Running Load" point, psig
d_{stem}:	Stem diameter at packing, inches
$d_{mean\ seat}$:	Seat ring surface mean diameter, inches
DP:	Differential pressure at the time point being evaluated, psig

Gate Valve Factor Equations from Required Thrust

These equations can be used by plants to determine valve factor if the required thrust is known.

Closing Stroke:

$$VF = \frac{Thrust_{REQUIRED} - Thrust_{PACKING} - P_{UP} * \left(\frac{\pi * d_{stem}^2}{4} \right)}{DP * \left(\frac{\pi * d_{meanseat}^2}{4} \right)}$$

Opening Stroke:

$$VF = \frac{Thrust_{REQUIRED} - Thrust_{PACKING} + P_{UP} * \left(\frac{\pi * d_{stem}^2}{4} \right)}{DP * \left(\frac{\pi * d_{meanseat}^2}{4} \right)}$$

$Thrust_{REQUIRED}$:	Required dynamic thrust, lbs
$Thrust_{PACKING}$:	Packing load, lbs
P_{UP}:	Upstream pressure with valve closed, psig
d_{stem}:	Stem diameter at packing, inches
$d_{mean\ seat}$:	Seat ring surface mean diameter, inches
DP:	Differential pressure with valve closed, psig

Parasitic Load Gate Valve Factor Equations

These equations are used in the JOG MOV PV Program to determine valve factor from gate valve test data, when there is an effect of parasitic load. They can be similarly used by plants to evaluate test data.

Closing Stroke:

$$VF = \frac{\left|Thrust_{DP} - Thrust_{STATIC}\right| - \left(P_{UP\text{-}DP} - P_{UP\text{-}STATIC}\right) * \left(\frac{\pi * d_{stem}^2}{4}\right)}{DP * \left(\frac{\pi * d_{meanseat}^2}{4}\right)}$$

Opening Stroke:

$$VF = \frac{\left|Thrust_{DP} - Thrust_{STATIC}\right| + \left(P_{UP\text{-}DP} - P_{UP\text{-}STATIC}\right) * \left(\frac{\pi * d_{stem}^2}{4}\right)}{DP * \left(\frac{\pi * d_{meanseat}^2}{4}\right)}$$

$Thrust_{DP}$:	DP stem thrust at the time point being evaluated, lbs
$Thrust_{STATIC}$:	Static stem thrust at the time point being evaluated, lbs
$P_{UP\text{-}DP}$:	DP upstream pressure at the time point being evaluated, psig
$P_{UP\text{-}STATIC}$:	Static upstream pressure at "Running Load" point, psig
d_{stem}:	Stem diameter at packing, inches
$d_{mean\ seat}$:	Seat ring surface mean diameter, inches
DP:	Differential pressure at the time point being evaluated, psig

GLOBE VALVE FACTOR EQUATIONS

These equations are used in the JOG MOV PV Program to determine valve factor from test data. They can be similarly used by plants to evaluate test data.

Closing - Balanced disk globe valves with underseat flow:

$$VF=\frac{\left|Thrust - Thrust_{running}\right| - (P_{up} - P_{up-running})*\left(\frac{\pi * d^2_{stem}}{4}\right)}{DP*\left(\frac{\pi * d^2_{seat}}{4}\right)}$$

Closing - Balanced disk globe valves with overseat flow and unbalanced disk globe valves with underseat flow:

$$VF=\frac{\left|Thrust - Thrust_{running}\right| - (P_{up} - DP - P_{up-running} + DP_{running})*\left(\frac{\pi * d^2_{stem}}{4}\right)}{DP*\left(\frac{\pi * d^2_{seat}}{4}\right)}$$

Opening - Balanced disk globe valves with underseat flow and unbalanced disk globe valves with overseat flow:

$$VF=\frac{\left|Thrust - Thrust_{running}\right| + (P_{up} - P_{up-running})*\left(\frac{\pi * d^2_{stem}}{4}\right)}{DP*\left(\frac{\pi * d^2_{seat}}{4}\right)}$$

Opening - Balanced disk globe valves with overseat flow:

$$VF=\frac{\left|Thrust - Thrust_{running}\right| + (P_{up} - DP - P_{up-running} + DP_{running})*\left(\frac{\pi * d^2_{stem}}{4}\right)}{DP*\left(\frac{\pi * d^2_{seat}}{4}\right)}$$

Thrust:	Stem thrust at the time point being evaluated, lbs
$Thrust_{running}$:	Stem thrust at the "Running Load" point, lbs
P_{up}:	Upstream pressure at the time point being evaluated, psig
$P_{up\text{-}running}$:	Upstream pressure at "Running Load" point, psig
d_{stem}:	Stem diameter at packing, inches
d_{seat}:	Seat ring seat surface mean diameter, inches
DP:	Differential pressure at the time point being evaluated, psig

BUTTERFLY VALVE BEARING COF EQUATIONS FROM TEST DATA

These equations are used in the JOG MOV PV Program to determine bearing friction coefficient from test data. They can be similarly used by plants to evaluate test data.

Opening COF for Symmetric and Single-Offset Valves:

$$\mu_b = \frac{24 * (\tau_{DPO} - \tau_{STO})}{DP * A_{DISK} * d_{STEM}}$$

Opening COF for Double and Triple-Offset Valves:

$$\mu_b = \frac{24 * [(\tau_{DPO} \pm \tau_{OFFSET}) - \tau_{STO}]}{DP * A_{DISK} * d_{STEM}} \quad \text{where} \quad \tau_{OFFSET} = DP * A_{DISK} * L$$

τ_{DPO}:	Unseating torque for DP test, ft-lbs
τ_{STO}:	Unseating torque for static test, ft-lbs
τ_{OFFSET}:	Unseating torque due to offset, ft-lbs
DP:	DP at unseating during DP stroke, psi
A_{DISK}:	Area of disk, in^2
d_{STEM}:	Stem diameter at bearing, inches
L:	Offset length, ft

The offset length (L) is the length, along the centerline of the disk, from the disk center point to the perpendicular projection of the shaft center onto the plane of the disk.

For valves where the offset torque (τ_{OFFSET}) resists opening, it should be subtracted from the dynamic unseating torque (τ_{DPO}) in the equation above. If the offset torque assists opening, it should be added to the dynamic unseating torque.

Butterfly Valve Bearing COF Equations from Required Torque

These equations can be used by plants to determine bearing friction coefficient if the required torque (at unseating) is known.

Opening COF for Symmetric and Single-Offset Valves:

$$\mu_b = \frac{24 * (\tau_{REQUIRED} - \tau_{PACKING} - \tau_{SEAT})}{DP * A_{DISK} * d_{STEM}}$$

Opening COF for Double and Triple-Offset Valves:

$$\mu_b = \frac{24 * [(\tau_{REQUIRED} \pm \tau_{OFFSET}) - \tau_{PACKING} - \tau_{SEAT}]}{DP * A_{DISK} * d_{STEM}} \quad \text{where} \quad \tau_{OFFSET} = DP * A_{DISK} * L$$

$\tau_{REQUIRED}$:	Required dynamic unseating torque, ft-lbs
$\tau_{PACKING}$:	Packing torque, ft-lbs
τ_{SEAT}:	Seat torque, ft-lbs
τ_{OFFSET}:	Unseating torque due to offset, ft-lbs
DP:	DP at unseating, psi
A_{DISK}:	Area of disk, in^2
d_{STEM}:	Stem diameter at bearing, inches
L:	Offset length, ft

The offset length (L) is the length, along the centerline of the disk, from the disk center point to the perpendicular projection of the shaft center onto the plane of the disk.

For valves where the offset torque (τ_{OFFSET}) resists opening, it should be subtracted from the required dynamic unseating torque ($\tau_{REQUIRED}$) in the equation above. If the offset torque assists opening, it should be added to the required dynamic unseating torque.

CONVERTING BETWEEN VALVE FACTOR AND COEFFICIENT OF FRICTION (COF)

These equations are used in the JOG MOV PV program to convert between valve factor and COF for gate valves. They can be similarly used by plants.

Closing Stroke:

$$\mu = \frac{\cos\theta}{\frac{1}{VF} + \sin\theta}$$

$$VF = \frac{\mu}{\cos\theta - \mu\sin\theta}$$

Opening Stroke:

$$\mu = \frac{\cos\theta}{\frac{1}{VF} - \sin\theta}$$

$$VF = \frac{\mu}{\cos\theta + \mu\sin\theta}$$

θ = wedge half-angle, degrees
μ = disk-to-seat COF

FLOW VELOCITY EQUATION

These equations are used in the JOG MOV PV program to determine flow velocity based on the seat area. They can be similarly used by plants.

Water Flow:

$$V = \frac{0.408 \cdot Q}{d_{SEAT}^2}$$

Steam Flow:

$$V = \frac{0.0509 \cdot W}{d_{SEAT}^2 \cdot \rho}$$

V = flow velocity, ft/sec
Q = Volumetric flow rate, gpm
W = Mass flow rate, lb/hr
d_{SEAT} = Seat ring surface mean diameter, in
ρ = weight density of steam, lb/ft^3

MARGIN EQUATIONS

These equations are identical to those defined at the outset of the JOG MOV PV Program, in MPR-1807, Rev. 2.

For gate and globe valves:

$$\text{Margin (\%)} = \frac{\text{Adjusted Actuator Output Thrust - Adjusted Required Thrust}}{\text{Adjusted Required Thrust}} x100$$

For butterfly valves:

$$\text{Margin (\%)} = \frac{\text{Adjusted Actuator Output Torque - Adjusted Required Torque}}{\text{Adjusted Required Torque}} x100$$

Definition of Terms:

<u>Actuator Output Thrust</u>

- For torque switch controlled valves, actuator output thrust is the stem thrust measured at control switch trip in diagnostic testing.
- For non-torque switch controlled valves, actuator output thrust is the assured stem thrust produced by the motor, gearing and stem nut at design basis conditions, with appropriate consideration for structural weak link limits.

<u>Required Thrust</u>
Required thrust is the calculated stem thrust to stroke the valve at design basis conditions (from the MOV calculation of record).

<u>Adjusted Actuator Output Thrust and Adjusted Required Thrust</u>
Adjusted actuator output thrust and adjusted required thrust are the actuator output thrust and required thrust as defined above, adjusted for the effect of items which tend to reduce or degrade the actuator output thrust. Some plants apply these adjustments to the actuator output thrust, whereas others include it in required thrust, or a mixture of the two approaches is used. Regardless of which approach is used, each plant is responsible to appropriately apply the adjustments to actuator output thrust or required thrust, for calculations of margin in the JOG Program. The following items should be considered for the adjustments:

- Test equipment inaccuracy
- Torque switch repeatability
- Rate-of-loading
- Spring pack relaxation

- Stem lubricant degradation

Actuator Output Torque

- For butterfly valves with no torque switch control, actuator output torque is the assured stem torque produced by the motor and gearing (including quarter-turn unit gearing) at design basis conditions, with appropriate consideration for structural weak link limits.
- For butterfly valves with torque switches active in the control circuit, actuator output torque is the lesser of the value as defined above, or the stem torque measured at torque switch trip in diagnostic testing.

Required Torque

Required torque is the calculated stem torque to stroke the valve at design basis conditions (from the MOV calculation of record).

Adjusted Actuator Output Torque and Adjusted Required Torque

Adjusted actuator output torque and adjusted required torque are the actuator output torque and required torque as defined above, adjusted for the effect of items which tend to reduce or degrade the actuator output torque or increase the seat torque component of required torque. Some plants apply these adjustments to the actuator output torque whereas others include it in required torque, or a mixture of the two approaches is used. Regardless of which approach is used, each plant is responsible to appropriately apply the adjustments to actuator output torque or required torque, for calculations of margin in the JOG Program. The following items are to be considered for the adjustments:

- Test equipment inaccuracy
- Torque switch repeatability
- Spring pack relaxation
- Seat degradation (e.g., hardening)

B DP Stroking Definition

To state that a valve strokes under DP conditions means that during normal plant operation, startups and shutdowns, expected transients and testing of systems and equipment, the valve moves through all or part of its stroke while there is non-negligible DP across the valve in the design-basis flow direction. "Non-negligible DP" is defined in the table below.

For each full or partial open-to-close or close-to-open stroke with non-negligible DP, the stroke counts as one DP stroke. In the case of a hydrostatic stroke (i.e., DP due to fluid pressure build-up on one side of a closed valve with no flow through the system), each full or partial close-to-open hydrostatic stroke with non-negligible DP counts as one-half of a DP stroke.

Special, infrequent valve strokes (deliberate or inadvertent) under DP conditions during a scenario that is not expected to be repeated do not count as DP stroking. For example:

- A new heat exchanger is installed and must undergo a one-time test during which a valve is DP stroked. The valve does not otherwise DP stroke. The one-time test does not count as DP stroking.

- An unexpected transient occurs, during which a valve is DP stroked. The valve does not otherwise DP stroke. The transient does not count as DP stroking.

DP is non-negligible if it meets the following criteria.

<u>Gate and Globe Valves</u>

ANSI Class	Maximum Cold Working Pressure*	DP is non-negligible if it is...
150	285 psi	> 15 psi
300	740 psi	> 35 psi
600	1480 psi	> 75 psi
900	2220 psi	> 110 psi
1500	3705 psi	> 150 psi

* per ASME/ANSI B16.34 – 1998 for nominal carbon steel materials

<u>Butterfly Valves</u>

No guidance needed.

Basis/Justification

For Gate valves, the key consideration is that DP stroking potentially increases disk-to-seat friction. The presence of some load between the disk and seat faces during stroking is needed for the effect to occur. By judgment, a DP equal to 5% of the maximum cold working pressure of the valve is used to set a reasonable threshold. This choice will likely ensure that the disk-to-seat contact stress during stroking is less than 1 ksi. In other words, typical valves are designed to have seat contact stresses of 20 ksi or less at maximum DP. The value of 20 ksi is based on valves that have narrow seat ring faces. Valves that utilize wide seat ring faces (e.g., 3/8 to 3/4 inch) will likely have contact stresses much less than 20 ksi and also support this justification.

The DP calculated as described above (5% of the maximum working pressure) is rounded to the nearest 5 psi. For ANSI Class 1500, the value is conservatively reduced by 20%. The rationale is that, although nuclear power plants use Class 1500 valves, the working pressures in nuclear plant service do not approach the class limits. Accordingly, it is possible that these valves were designed such that full contact stress is achieved at a lower pressure, and the 20% reduction covers that possibility.

For hydrostatic strokes (DP without flow), the amount of sliding between the disk and seat faces while they are loaded will be less than for a normal DP stroke (DP with flow). Accordingly, the potential increase in disk-to-seat friction caused by hydrostatic strokes will be less than the potential increases for a normal DP stroke. To account for the effect of reduced sliding, hydrostatic strokes should be counted as one-half of a normal DP stroke. The use of one-half was selected based on judgment.

For globe valves, there are no concerns or effects related to DP stroking, and the presence or absence of DP stroking does not strongly affect the PV approach for these valves. For convenience, the same criteria used for gate valves are applied for globe valves.

For butterfly valves, test results showed that DP stroking does not affect the changes in bearing friction coefficient. Accordingly, the presence or absence of DP stroking does not need to be considered in the PV approach.

C JOG MOV PV Program Core Group Meetings

Throughout the course of the JOG MOV Periodic Verification Program, the JOG MOV PV Core Group assembled to review the test data obtained in the program to date, and to assess the progress of the program. The JOG MOV PV Core Group is comprised of utility representatives from each of the four NSSS Owners' Groups. Each Owners' Group was represented by a Chairman and Project Manager.

Typically, JOG MOV PV Core Group meetings occurred twice per year. The dates of these meetings are summarized below.

Meeting Dates
February 4 – 5, 1998
August 25 – 26, 1998
February 9 – 10, 1999
August 17 – 18, 1999
February 8 – 10, 2000
August 8 – 10, 2000
February 14 – 16, 2001
August 7 - 9, 2001
February 12 – 14, 2002
August 6 – 8, 2002
February 4 - 6, 2003
June 3 - 5, 2003
July 15 - 17, 2003
November 17-20, 2003

D JOG-NRC Meetings

Approximately twice per year, the JOG MOV PV Core Group met with NRC staff to update the status of the JOG MOV PV Program, and summarize the results obtained to date. Typically, the JOG MOV PV Core Group was represented at these meetings by the four Chairmen and four Project Managers. The dates of these meetings are summarized below. Following each meeting, the NRC issued meeting minutes as the official meeting record.

Meeting Date	Meeting Minutes		
	Reference	Issue Date	ADAMS Accession Number
March 31, 1998	NRC Memorandum to T. Essig (NRC-NRR) from C. Craig (NRC-NRR)	April 13, 1998	ACN9803090045
October 15, 1998	NRC Memorandum to T. Essig (NRC-NRR) from P. Wen (NRC-NRR)	October 29, 1998	ACN9811130258
April 14, 1999	NRC Memorandum to C. Carpenter (NRC-NRR) from P. Wen (NRC-NRR)	April 20, 1999	ACN9904300028
October 13, 1999	NRC Memorandum to S. Richards (NRC-NRR) from J. Cushing (NRC-NRR)	November 15, 1999	ML993260281
April 19, 2000	NRC Memorandum to S. Richards (NRC-NRR) from J. Cushing (NRC-NRR)	May 4, 2000	ML003711826
October 11, 2000	NRC Memorandum to S. Richards (NRC-NRR) from J. Cushing (NRC-NRR)	November 3, 2000	ML003766635
May 9, 2001	NRC Memorandum to S. Richards (NRC-NRR) from J. Cushing (NRC-NRR)	June 13, 2001	ML011570017
October 17, 2001	NRC Memorandum to S. Richards (NRC-NRR) from J. Cushing (NRC-NRR)	November 14, 2001	ML013090449
May 8, 2002	NRC Memorandum to C. Holden (NRC-NRR) from G. Shukla (NRC-NRR)	May 29, 2002	ML021400556
October 16, 2002	NRC Memorandum to E. Imbro (NRC-NRR) from D. Terao (NRC-NRR)	December 6, 2002	ML023400477
October 1-2, 2003	NRC Memorandum to E. Imbro (NRC-NRR) from D. Terao (NRC-NRR)	October 14, 2003	ML032801390

E Gate Valve Thresholds and Allowances

PURPOSE

This appendix describes evaluations of gate valve data that support implementation of the JOG periodic verification approach. Specifically, threshold values of disk-to-seat coefficient of friction (COF), as described in Sections 3.A.5 and 3.B.5 and as used in Section 7 (Table 7-4), are determined in this appendix. These thresholds provide the COFs above which increases in COF are not expected. Further, COF allowances as utilized in Section 7 (Table 7-4) are determined in this appendix. These allowances provide the amount of increase in COF that should be considered for valves that are susceptible to increase (Class C valves).

USE OF DISK-TO-SEAT COF RATHER THAN VALVE FACTOR

Valves with non-zero wedge angles have different closing and opening valve factors, for a constant disk-to-seat COF. Therefore, it is more appropriate to use COF values instead of valve factors in these quantitative evaluations of gate valve data. COF values can be converted to valve factors (and vice versa) using the equations provided in Appendix A.

DISK-TO-SEAT COF THRESHOLDS

As discussed in Section 3, gate valves tend to have stable disk-to-seat friction except under the following conditions.

- Valves that are disassembled and reassembled tend to have a reduced valve factor (or COF) which tends to increase with DP stroking, up to a level similar to non-disassembled valves.

- Valves with low valve factors (or COFs) that are not normally stroked against DP in service can experience increases in valve factor (or COF) with DP stroking, up to levels consistent with other similar valves.

Gate valves with stable disk-to-seat friction have minor variations in COF from test-to-test, but no increasing or decreasing trend. Some of the variation is due to, for example, uncertainty in the test measurements. Some of the variation, however, can be due to random variation in disk-to-seat friction.

Results from valves that are nominally stable were analyzed to understand the variation in disk-to-seat friction. Figure E-1 shows COF results from gate valves with self-mated Stellite seats in water systems that have stable behavior. The figure shows changes in COF (ΔCOF) from the second to third test plotted against the initial COF (i.e., second test). The ΔCOF values are evenly spread among positive and negative values and there is no apparent trend with COF.

Figure E-1 was prepared by considering data under conditions where it was highly likely that the results would be stable. Specifically, valves that were not disassembled in the two years prior to the start of JOG testing and which are routinely DP stroked in service were considered. Although this approach does not necessarily capture every possible data point reflective of stable valves, it is a sufficient sample to understand the population.

Results from valves that are susceptible to increases in COF were analyzed to establish a threshold COF, above which increases in COF are not expected to occur. Figure E-2 shows a plot of ΔCOF versus COF for gate valves with Stellite seats in water systems that are susceptible to increases in COF. The data on this plot includes results from all valves that were disassembled in the two years prior to JOG testing and from non-disassembled valves with low initial COFs that increased during JOG testing. To determine which non-disassembled valves had such increases, a measured COF increase (beyond measurement uncertainty) of 10% was used as a criterion.

As seen on the figure, there is a systematic trend in these COF results – valves with lower COFs tend to show the largest increases, and valves with higher COFs tend to show little or no increase. The figure includes a trend line through the data, and the data are scattered above and below the trend line.

A threshold COF is established using a deterministic approach, based on engineering judgment, which bounds 95% of the COF data. This is shown by the dashed lines on Figure E-2 labeled *Threshold Boundary*. The intersection of a -45° line and a horizontal line at ΔCOF = 0 creates a wedge-shaped boundary. For points on the -45° line, COF + ΔCOF = constant. In other words, all data points on such a line will end up at the same final COF after the change in COF (ΔCOF) occurs. Points to the left of the line will end up at a lower COF and points to the right will end up at a higher COF. The ΔCOF=0 line is also used as a discriminator because points with negative ΔCOF (below the line) are not a concern regarding potential increases in COF. This threshold boundary can be positioned until a place is found where 5% of the data lie to the right of the -45° line and above the ΔCOF=0 line (i.e., within the 135° wedge). In this position, the intercept of the -45° line with the x-axis (ΔCOF=0) is the threshold COF. For 95% of the data, COF increases will not result in a final COF exceeding the threshold.

Because the evaluation of threshold COF is determined based on a discrete number of data points, the 95% / 5% discrimination is applied as follows.

Number of Data Points	Number in 5% Group
0 - 9	0
10 - 29	1
30 - 49	2
50 - 69	3
70 - 89	4
90 - 109	5
110 - 129	6
130 - 149	7
150 - 169	8
170 - 189	9
190 - 209	10
210 - 229	11
230 - 249	12
250 - 269	13
270 - 289	14

Using this approach, a threshold value that bound 95% of the data (i.e., 270 out of the 284 data points in Figure E-2) for Stellite valves in water systems is determined and summarized below.

Disk-to-Seat Materials	**Fluid Type & Temperature**	**Threshold COF**	**Figure Number**
Self-mated Stellite	Water All temperatures	0.57	E-2

For gate valves with Stellite seats in steam applications, an approach similar to that for water systems was evaluated. However, due to the limited amount of data for steam valves, the data for stable valves could not be distinguished from valves that showed systematic increases in COF. Accordingly, Figure E-3 shows a plot of ΔCOF versus COF for all steam valves, combining the data for valves with stable COFs and those susceptible to increases. The threshold COF is established using a deterministic approach that bounds 95% of the COF data and is summarized below.

Disk-to-Seat Materials	**Fluid Type & Temperature**	**Threshold COF**	**Figure Number**
Self-mated Stellite	Steam	0.58	E-3

For gate valves with other (non self-mated Stellite) disk-to-seat materials, the data were insufficient to distinguish stable valves from valves that showed systematic increases in COF. Similar to the approach for Stellite valves in steam, all of the COF data were used to determine a threshold. Figures E-4, E-5 and E-6 provide ΔCOF versus COF plots for gate valves with the following disk-to-seat material combinations.

- Self-mated 400 series Stainless Steel disk and seat (Figure E-4)
- 400 series Stainless Steel disk versus Stellite seat (Figure E-5)
- 400 series Stainless Steel (or Exelloy) disk versus Monel seat (Figure E-6)

In each figure, the threshold COF is established using a deterministic approach that bounds 95% of the COF data. This approach is shown by the dashed lines on the figures labeled *Threshold Boundary*.

For self-mated Deloro 50, only one valve was tested in the JOG program. Based on the results of this single valve, a maximum COF of 0.51 was observed (see Figure 3-35). Other evaluations of this material (Reference 10) show that Deloro 50 has similar friction behavior to Stellite at room temperature. This similarity is supported by the JOG test results. The threshold determined for Stellite valves (see above) bounds the data for the single Deloro 50 valve. Accordingly, for the purpose of determining thresholds, valves with Deloro 50 seat materials that are DP stroked in low temperature water systems (≤120°F) should use the threshold determined for Stellite valves.

The threshold values for valves with non-Stellite seat materials are summarized below.

Disk-to-Seat Materials	Fluid Type & Temperature	Threshold COF	Figure Number
Self-mated 400 series Stainless Steel	Water ≤ 120°F	0.69	E-4
400 series Stainless Steel vs. Stellite	Water All temperatures	0.70	E-5
400 series Stainless Steel (or Exelloy) vs. Monel	Water All temperatures	0.71	E-6
Self-mated Deloro 50	Water ≤ 120°F	Use value for self-mated Stellite in water	

DISK-TO-SEAT COF ALLOWANCES

For gate valves that are susceptible to increases in disk-to-seat COF, an appropriate allowance needs to be specified so that the amount of increase can be accounted for in the setup and margin of the valve. As discussed in the evaluation of the data above, the amount of increase depends on the current disk-to-seat COF. Specifically, valves with low COFs exhibit larger increases and valves with higher COFs (but still below the threshold values) exhibit smaller increases. Accordingly, rather than specify a single value for allowance, a sliding scale is used.

For self-mated Stellite valves in water systems, the equation below provides a reasonable approach, based on engineering judgment, to define an allowance. At any given value of disk-to-seat COF up to the threshold, the equation provides a value of ΔCOF that is suitable to add the current value, to cover a time period typical of that between tests in the JOG MOV PV Program. Two years is taken as the time period. For values of disk-to-seat COF less than 0.45, it will take approximately four years (i.e., two incremental COF increases to cover each two year period) to reach the threshold value. Values of disk-to-seat COF above 0.45 will reach the threshold value in two years (i.e., one incremental COF increase).

- Self-mated Stellite valves in water $\Delta COF = 0.34 - (COF*0.48)$

For self-mated Stellite valves in steam, a similar equation is provided below. For values of disk-to-seat COF less than 0.49, it will typically take four years to reach the threshold value. Values of COF above 0.49 will reach the threshold value in two years.

- Self-mated Stellite valves in steam $\Delta COF = 0.32 - (COF*0.46)$

For non-Stellite valves, a similar sliding scale is used to define the allowance for three of the material categories, although the threshold values are higher than for Stellite. Accordingly, very low values of disk-to-seat COF may take longer than four years to reach the threshold values. The equations are as follows:

- Valves with self-mated 400 series stainless steel disks and seats $\Delta COF = 0.20 - (COF*0.25)$
- Valves with 400 series stainless steel disks vs. Stellite seats $\Delta COF = 0.40 - (COF*0.54)$
- Valves with 400 series stainless steel (or Exelloy) disks vs. Monel seats $\Delta COF = 0.34 - (COF*0.34)$

For valves with Deloro 50, the allowance specified for self-mated Stellite in water is used. This approach is consistent with the use of self-mated Stellite thresholds for Deloro 50.

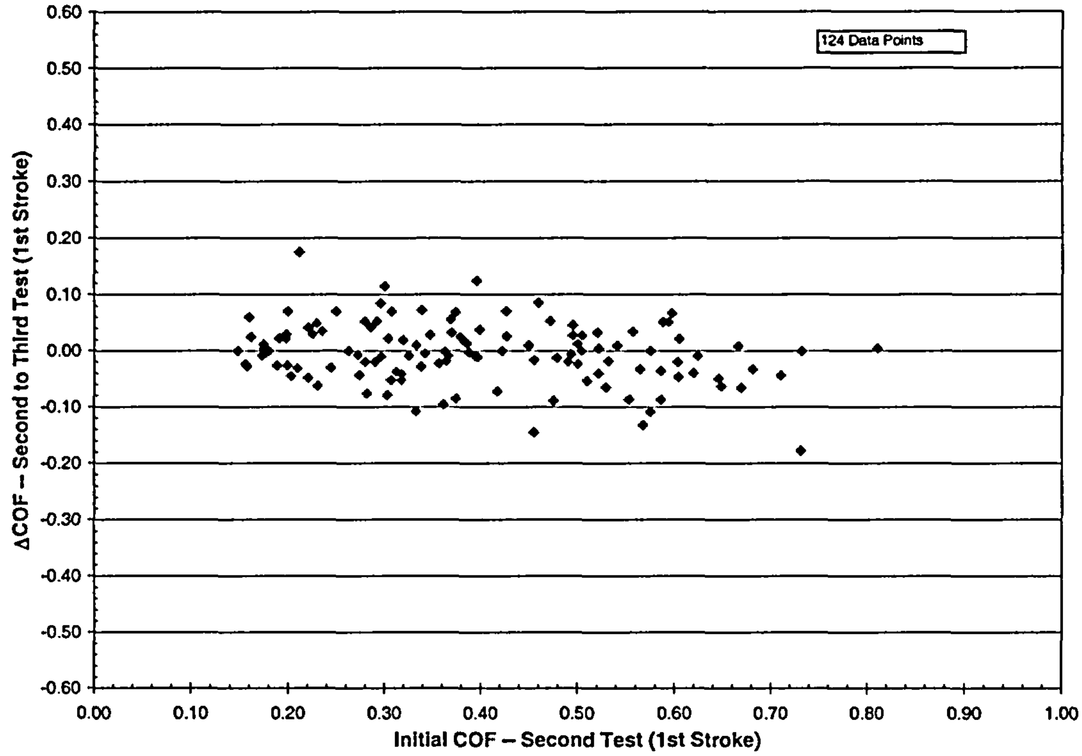

Figure E-1. Change in COF vs. Initial COF for Gate Valves with Stellite Seats in Water Systems with Stable Behavior

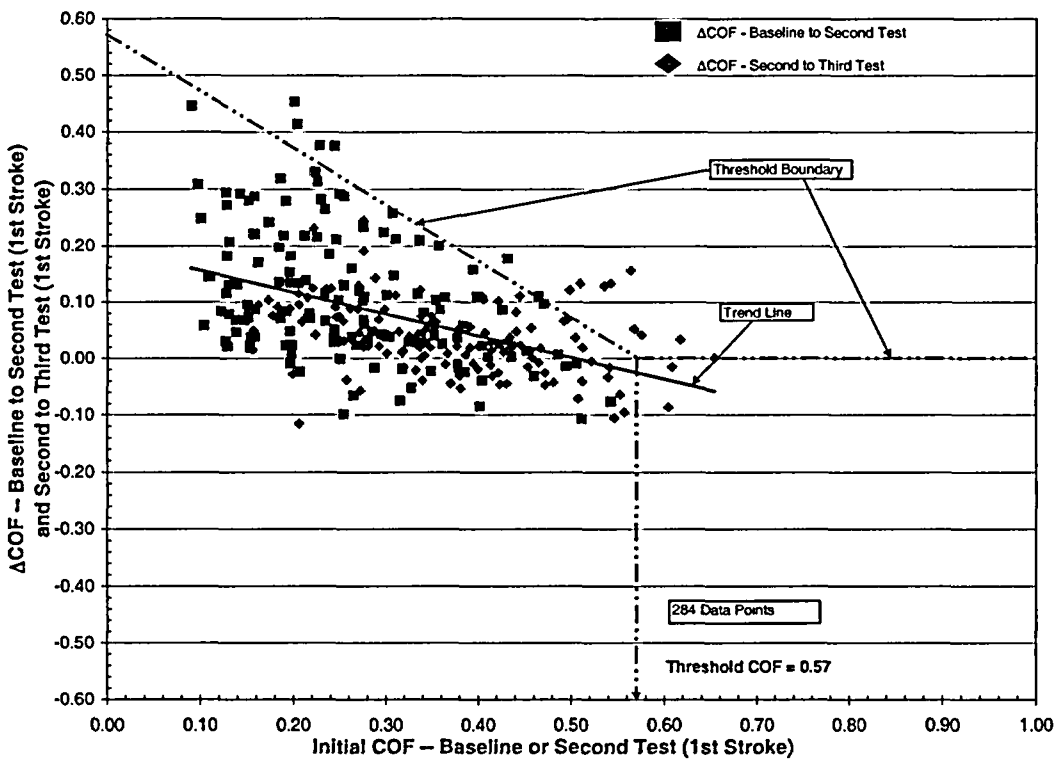

Figure E-2. Change in COF vs. Initial COF for Gate Valves with Stellite Seats in Water Systems that Show Increases in COF

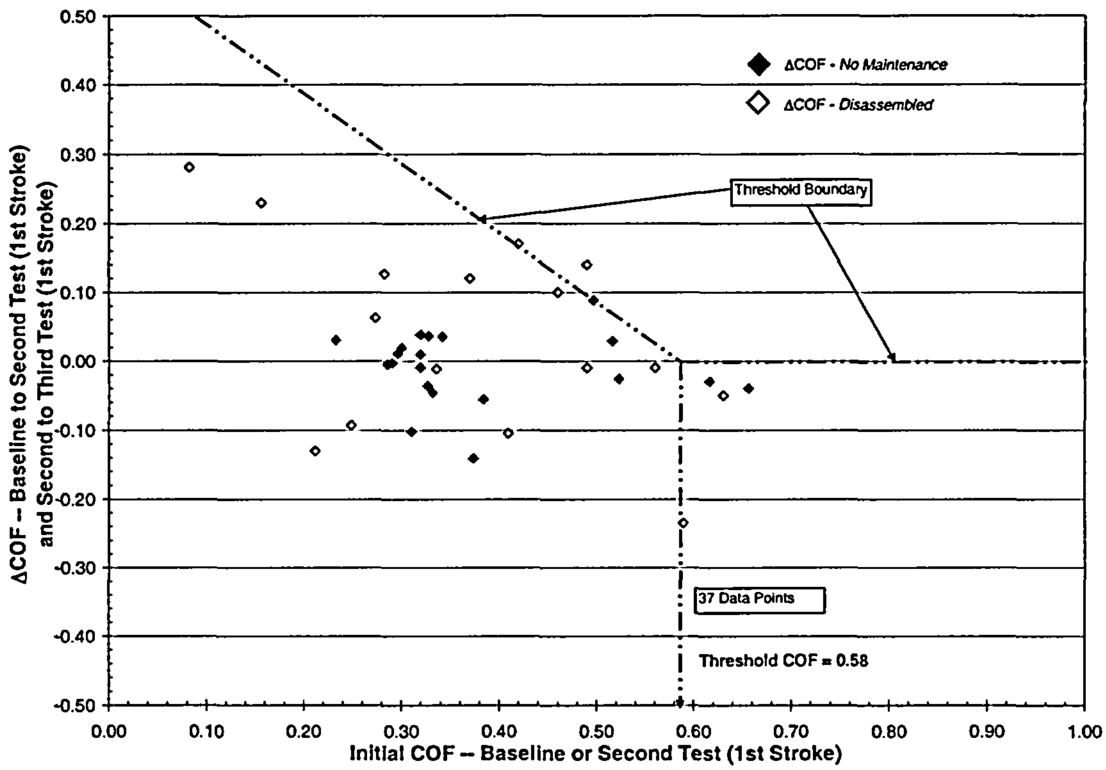

Figure E-3. Change in COF vs. Initial COF for All Gate Valves in Steam

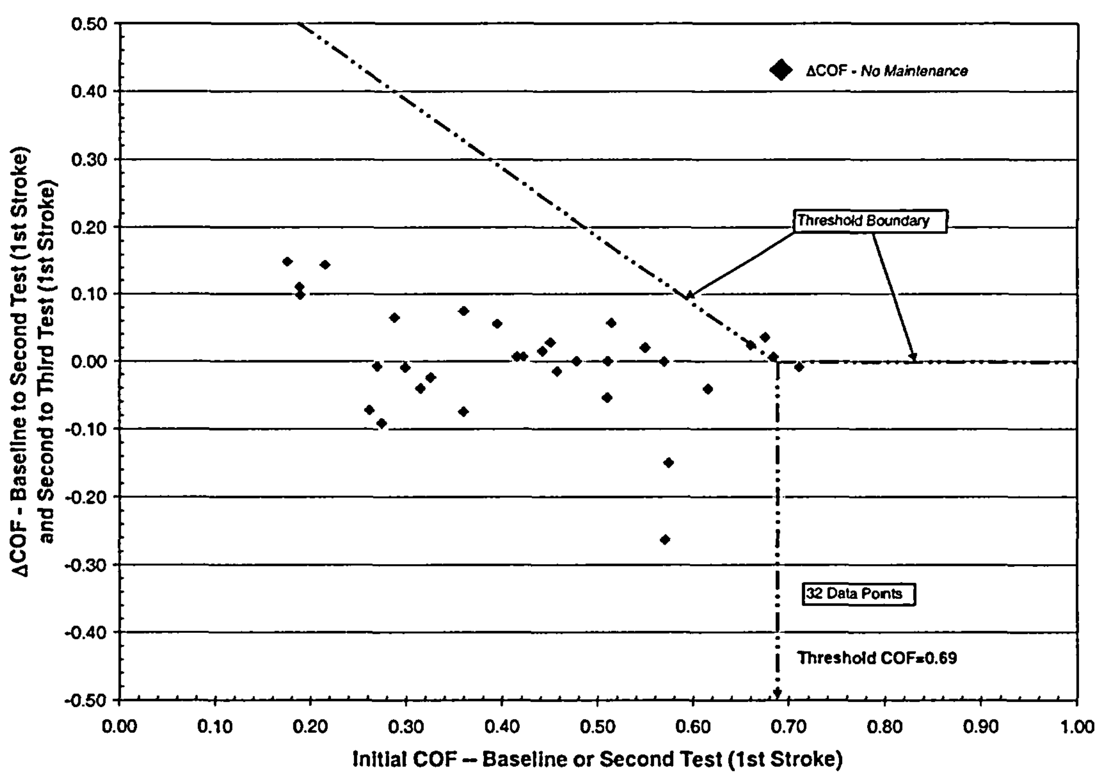

Figure E-4. Change in COF vs. Initial COF for Gate Valves with Self-mated 400 series Stainless Steel Seats

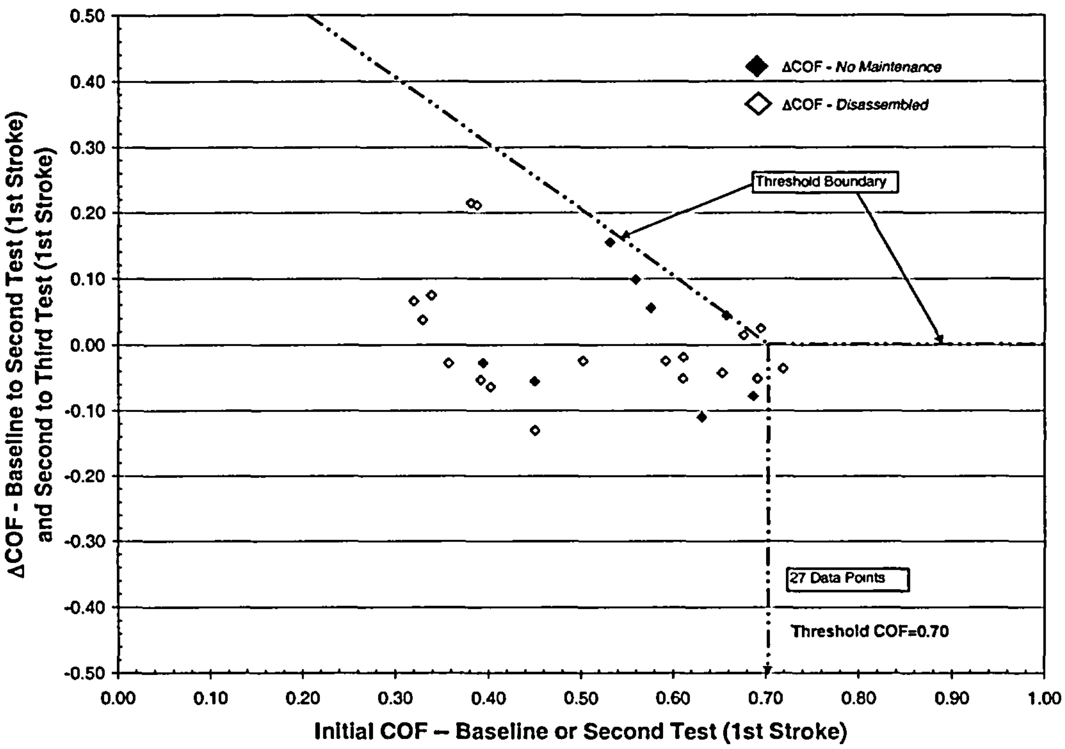

Figure E-5. Change in COF vs. Initial COF for Gate Valves with 400 series Stainless Steel Disks vs. Stellite Seats

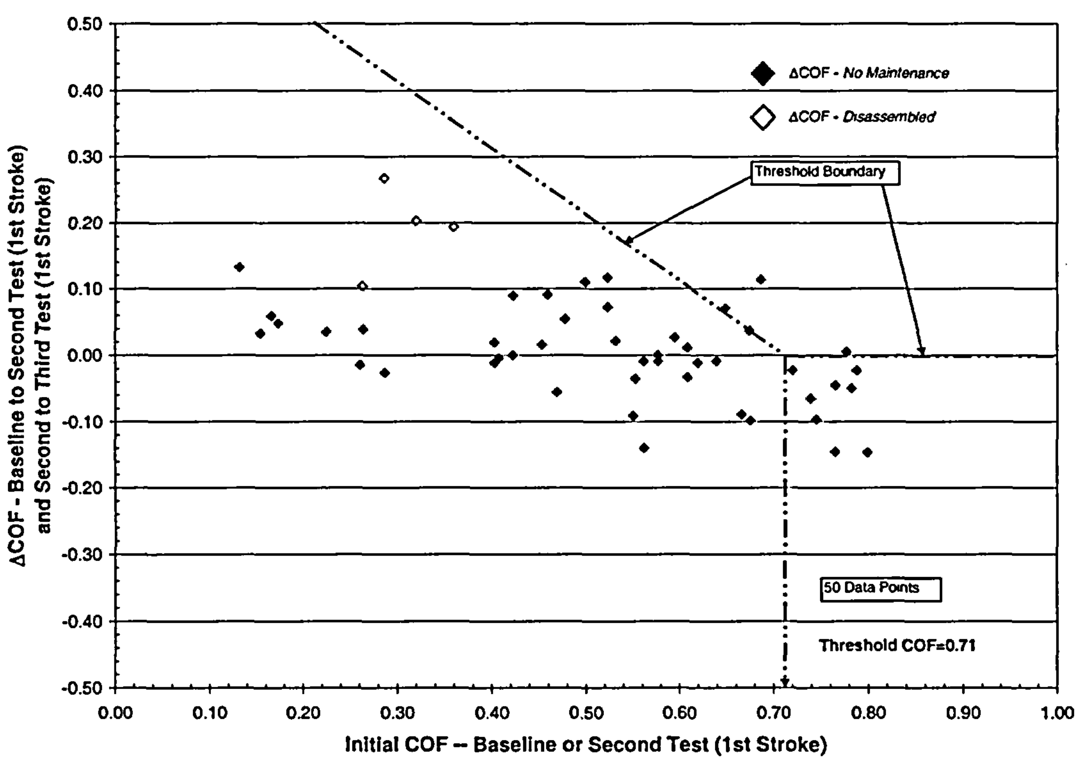

Figure E-6. Change in COF vs. Initial COF for Gate Valves with 400 series Stainless Steel Disks (or Exelloy) vs. Monel Seats

F NRC Comments & Responses

[Later]

G NRC Safety Evaluation

[Later]