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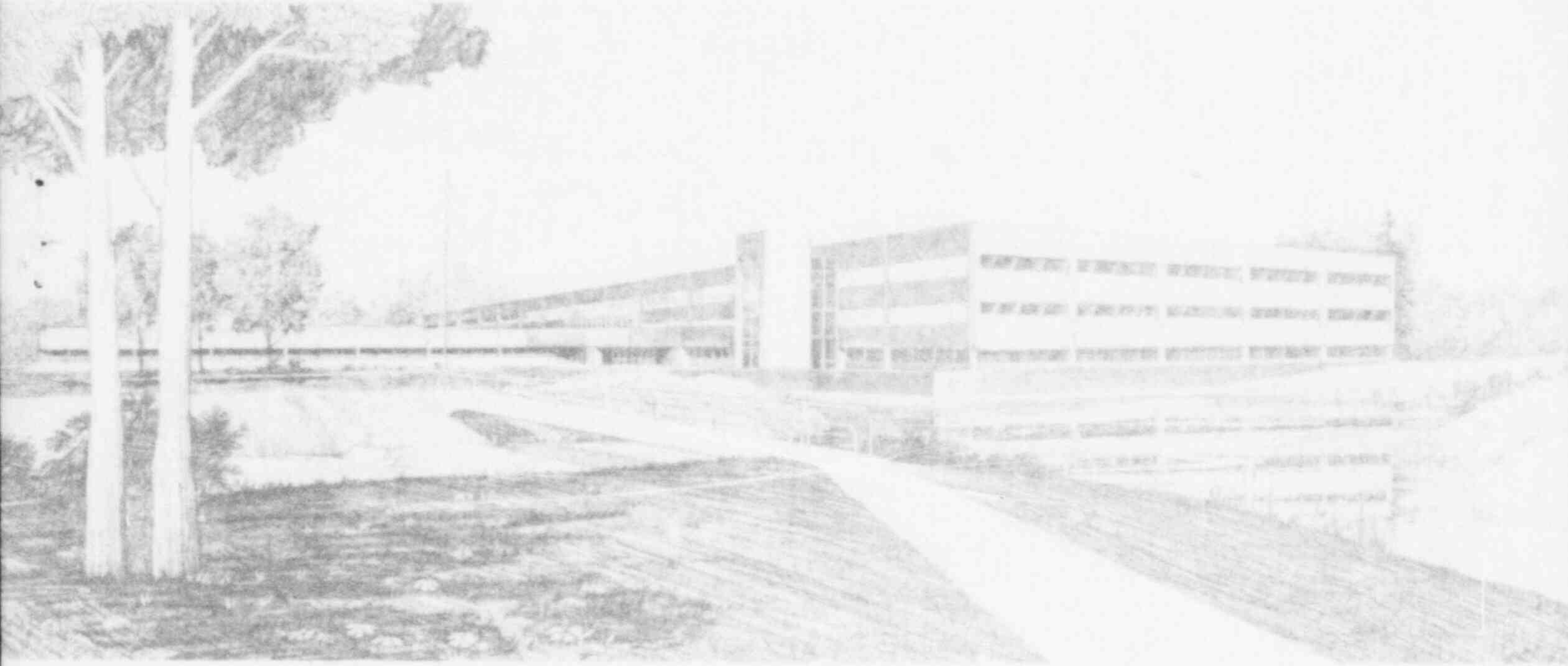

Idaho National Engineering Laboratory
Operated by the U.S. Department of Energy

Containment Purge and Vent Valve Test Program Final Report

Robert Steele, Jr.
John C. Watkins

September 1985

Prepared for the
U.S. Nuclear Regulatory Commission
Under DOE Contract No. DE-AC07-76IDO1570

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CONTAINMENT PURGE AND VENT VALVE TEST PROGRAM FINAL REPORT

Robert Steele, Jr.
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EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

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FIN No. A6322

ABSTRACT

This report presents the results of the containment purge and vent valve test program, conducted under the sponsorship of the United States Nuclear Regulatory Commission, Office of Nuclear Regulatory Research. The test program investigated valve functionality and leak integrity.

Three nuclear designed butterfly valves typical of those used in domestic nuclear power plant containment purge and vent applications were tested. For a comparison of response, two valves of the same size with differing internal designs were tested. For extrapolation insights, a larger sized valve was also tested.

The valve experiments were performed with various piping configurations and valve disc orientations to the flow to simulate various installation options in field applications. As a standard for comparing the effects of the installation options, testing was also performed in a standard ANSI test section. Dynamic flow tests were performed over the range of a design basis accident. Leak integrity testing was also performed and extended into severe accident conditions.

Analysis of the test results produced a technical basis to assess industry purge and vent valve closing torque extrapolation methodology and quantified the influence of worst case piping geometry on valve torque response. It was also determined that some valve designs will leak in single isolation when exposed to design basis and severe accident environments.

FIN No. A6322—Environmental Qualification of Mechanical and Dynamic (including seismic) Qualification of Mechanical and Electrical Equipment Program

EXECUTIVE SUMMARY

This report describes the methods and presents the test results, conclusions and recommendations from the containment purge and vent valve testing which was conducted for the United States Nuclear Regulatory Commission, Office of Nuclear Regulatory Research. This research activity is one portion of the overall Environmental Qualification of Mechanical and Dynamic (including seismic) Qualification of Mechanical and Electrical Equipment Program (EDQP) FIN No. A6322. The results of this research include a proposed conservative, realistic valve torque extrapolation technique and the bounding of nonuniform valve inlet flow geometric effects.

The primary purpose of this research study was to determine the response characteristics of a nuclear containment purge or vent valve while it was closing against the rising pressure environment of a design basis loss-of-coolant accident and to gain insights into the leak integrity of an elastomer sealed valve exposed to such an environment.

The test hardware included three nuclear designed butterfly valves typical of those used in domestic nuclear power plant containment purge and vent applications. For a comparison of response, two eight inch nominal pipe size valves with differing internal designs were tested. To assist in the development of extrapolation guidelines for qualifying larger valves based on small valve test results, a 24 inch nominal pipe size valve was also tested.

The three valves initially selected to provide butterfly response understanding were 150 lb ANSI design. This design was selected to provide the highest magnitude torque response. The worst case response would provide a bounding technology or means for a conservative assessment of the mostly completed utility valve submittals. The response of the three valves was found to be the same in the positive torque orientation, including worst case geometric effects. Consequently, three valves provide a sufficient sample size from which to draw conclusions relative to response and relative to extrapolability of the performance of a scale model test valve to a larger valve.

The following summaries present the program results, conclusions, and recommendations. Each summary addresses the two sections of the program, flow testing and leak testing.

Summary of Results for the Dynamic Flow Tests

1. Valve experiments were performed with various piping configurations and valve disc orientations to the flow to simulate various field installations.

2. The eight inch valve response did not extrapolate in a conservative manner using the typical industry torque coefficient method based on a valve diameter cubed/differential pressure equation.

3. Geometrically similar valves of differing size have been considered by industry to have the same differential pressure when all other test conditions were the same. This was found not to be true for choked flow conditions.

4. Supersonic flow existed downstream of the valve during most of the valve cycle. This could affect the linearity of calculations using differential pressure.

5. Response plots depicting major valve response characteristics show similarity in positive torque response configurations and dissimilarity in negative torque response configurations.

6. Valve peak torque angle varied with pressure. However, when plotted against inlet pressure, the response was linear.

7. The positive torque response configuration upper bounds valve torque response.

8. The use of valve inlet pressure in torque extrapolation calculations provides a more reliable base than using differential pressure.

9. Extrapolation predictions of the torque of a larger valve, which were based on the test

results of two valves with known responses, show considerable variation.

10. The nonuniform inlet flow configuration (elbow immediately upstream of valve) developed the worst case torque response.

11. The nonuniform inlet flow torque response could be bounded by multiplying the nominal case by 1.5.

12. Valve response characteristics and peak torque linearity in the nonuniform inlet flow configuration exhibit characteristics similar to the nominal configuration with only a magnitude change.

Summary of Results From the Leak Integrity Tests

1. Leak integrity testing was performed in a pressure and temperature environment representative of accident conditions from design basis through severe accident conditions.

2. Accident environments [350°F (177°C), 120 psig] and prolonged closures did cause some purge valve leakage.

3. One eight inch purge valve did not leak during any accident environment test or in the posttest cooldown.

4. Leakage increased in some valve designs in cooldown periods after exposure to pressure and temperature.

Summary of Conclusions for the Dynamic Flow Test

Based on the testing and analysis performed during this study, torque measurements derived from a scale model valve at a given inlet pressure can be extrapolated to bound the torque requirements of a larger valve when:

1. The scale model valve is reasonably scaled to the larger valve with respect to disc shape, disc aspect ratio and disc size to nominal bore size.

2. The torque measurements used for extrapolating to larger valves were obtained with the scale model valve installed with the shaft upstream or shaft side of the valve disc closing toward the flow orientation.

3. The inlet pressure of the scale model valve is equal to or greater than the maximum inlet pressure of the larger valve.

4. One of the following expressions is used for extrapolating the scale model valve results.

$$LVT_T = \frac{LVD^3}{SVD^3} SVT_d - LVT_b$$

$$LVT_T = \frac{LVD^3}{SVD^3} (SVT_T + SVT_b) - LVT_b$$

5. Nonuniform inlet flow to the larger valve is accounted for by multiplying the nominal or straight inlet prediction by 1.5.

6. The extrapolation range is limited to the guidelines of ANSI B16.41, "The candidate valve shall be limited in basic inside diameter between 50 and 200% of the test valve diameter."

Summary of Conclusions for the Leak Integrity Tests

1. Elastomers used for sealing purge and vent valves are near material property limits under accident environments.

2. Elastomer performance characteristics can be optimized by design.

3. Purge and vent valves using elastomer seals of ethylene propylene terpolymer (EPT) in some design configurations will leak in postaccident cooldown environments.

Summary of Recommendations for Additional Dynamic Flow Testing

1. Complete an accurate survey of containment purge and vent valve used in each

nuclear power plant, including such items as operational status (open, closed, blocked), installation orientation, size, manufacturer, model, disc style, and seal design.

2. Review the survey for safety questions not answered by this program.

3. Perform the subsequent work which would help resolve the outstanding issues identified by 1 and 2 above.

Summary of Recommendations for Additional Leak Integrity Testing

1. Perform scoping leak tests on all purge and vent valve seal designs identified in 1 above which were not covered in this program or in other work.

2. Determine the impact on safety of any valve leakage identified during this program.

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CONTAINMENT PURGE AND VENT VALVE TEST PROGRAM FINAL REPORT

INTRODUCTION AND OBJECTIVES

The containment purge and vent systems are an important part of the containment ventilating system in a commercial nuclear power plant. These systems, unlike many other systems in the plant, are not closed-loop piping systems. These systems normally contain butterfly valves in series, which are part of the Containment Isolation System (CIS). These valves are the primary boundary which protects the outside-containment environment from an accidental release. Current regulatory guidelines restrict the use of these systems to varying degrees, on a plant specific basis. The degree of restriction is based on an analytical assessment of each valve in the system and its predicted response to a Design Basis Accident (DBA).

The ability of the containment purge and vent valves to close in the rising pressure environment of a Design Basis (DB) Loss-of-Coolant Accident (LOCA) has been identified as a safety issue. The issue was originally identified in NUREG 0660, *NRC Action Plan as a Result of the TMI-2 Accident*, Item II.E.4.2, and subsequently in NUREG 0737, *Clarification of TMI Action Plans Requirements*. Containment isolation valve leak integrity is also a subject of this safety issue. These issues formed the basis for the Purge and Vent Valve Test Program performed as part of the Environmental Qualification of Mechanical and Dynamic (including seismic) Qualification of Mechanical and Electrical Equipment Program (EDQP), FIN A6322.

The objective of the dynamic flow test portion of the program was to develop an experimental data base to assess industry valve closing torque and extrapolation methodology. This assessment could then provide a conservative methodology with which to predict purge and vent valve closing torque requirements.

The objective of the leak integrity portion of the program was to evaluate nuclear designed elastomerically sealed purge and vent valves ability to remain bubble tight during and after both design basis and severe accident scenarios.

BACKGROUND

The "butterfly" valve is a generic term for a rotating disc in-line valve. Figures 1 and 2 present two typical butterfly valve internal designs. In Figure 1, the elastomer seal is part of the body and in Figure 2, the elastomer seal is part of the disc assembly. These types of valves have been manufactured and supplied for a number of years. Operability assumptions have been based to a large degree on empirical information obtained from work with incompressible fluids. Previous experimental work with compressible fluids (for the most part) has been done at very low pressure, at very low pressure drops, or with very small valves. The operability issue concerning containment purge and vent valves was raised after the TMI-2 incident. The first question dealt with valve actuator sizing. Would an actuator stall and fail to close a valve because of the dynamic loads that might result from a high differential pressure across the containment boundary resulting from a DB-LOCA? The second question dealt with stress margins. If the actuator was able to close the valve, did the components have sufficient stress margins to withstand the loads imposed during the closure? The stress margins are totally dependent on the analysis of the predicted loads and are not part of this study.

An analytical assessment of the valve loads resulting from the increasing pressure environment of a DB-LOCA was difficult. Empirical information is lacking for the dynamic response of a butterfly valve in a compressible fluid flow. It was also expected that nonuniform inlet flow configurations would impact the dynamic response of a valve.

Prior to this program, the most comprehensive published work on the subject was performed for Allis-Chalmers by the National Aeronautics and Space Administration (NASA)-Langley. The Langley program tested three disc configurations in a six inch valve body. The disc configurations were identified by aspect ratio which is defined as the

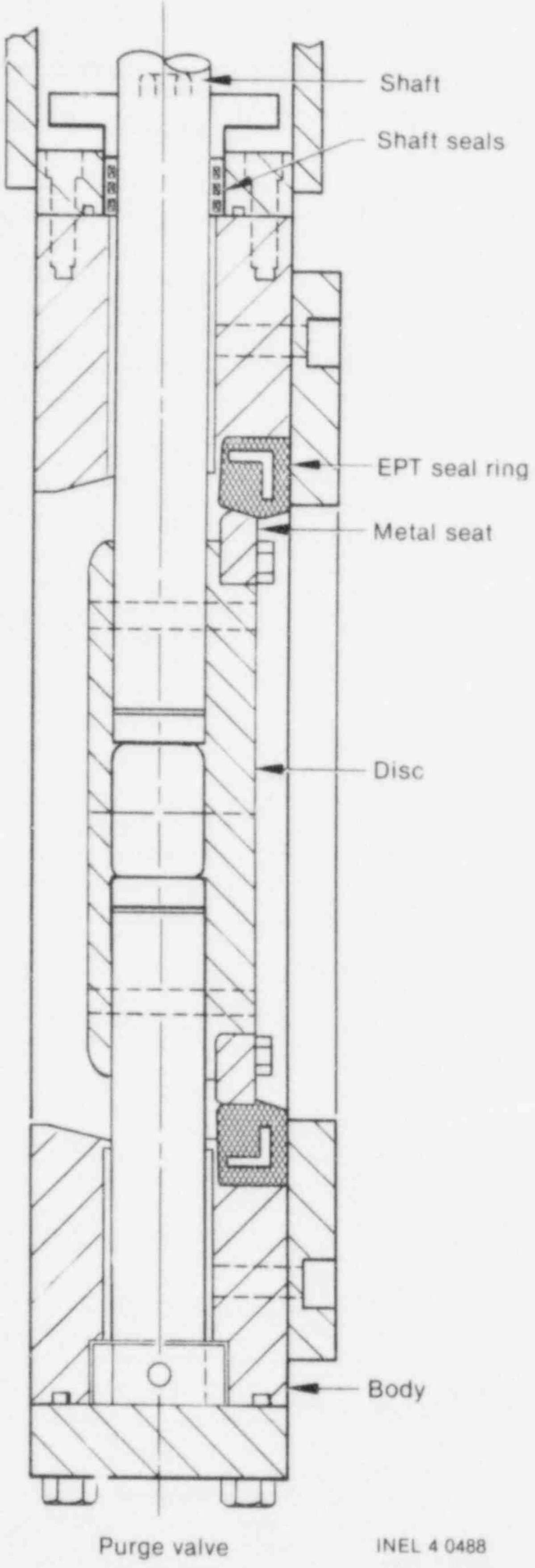
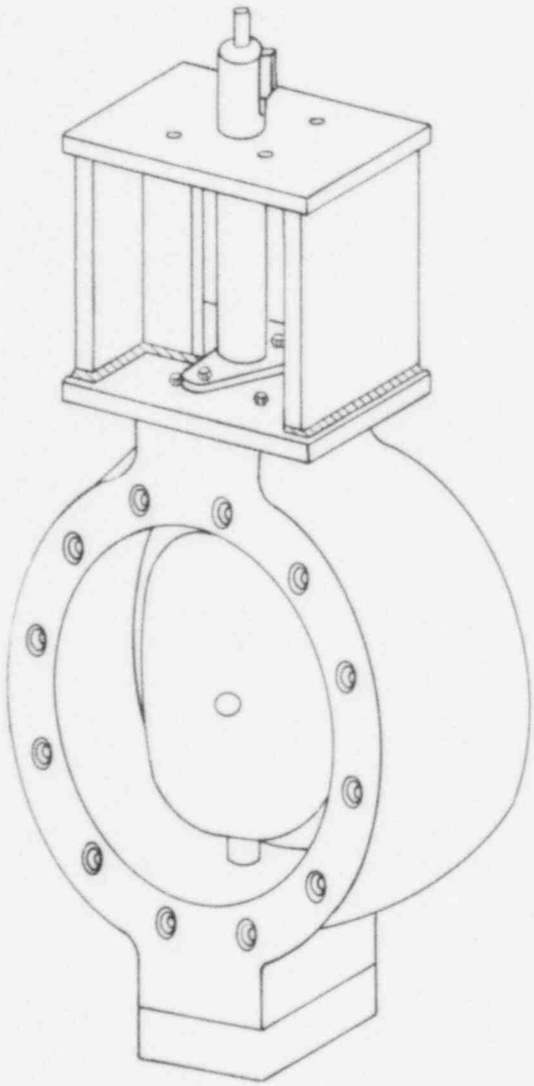


Figure 1. Cross section purge valve No. 1.



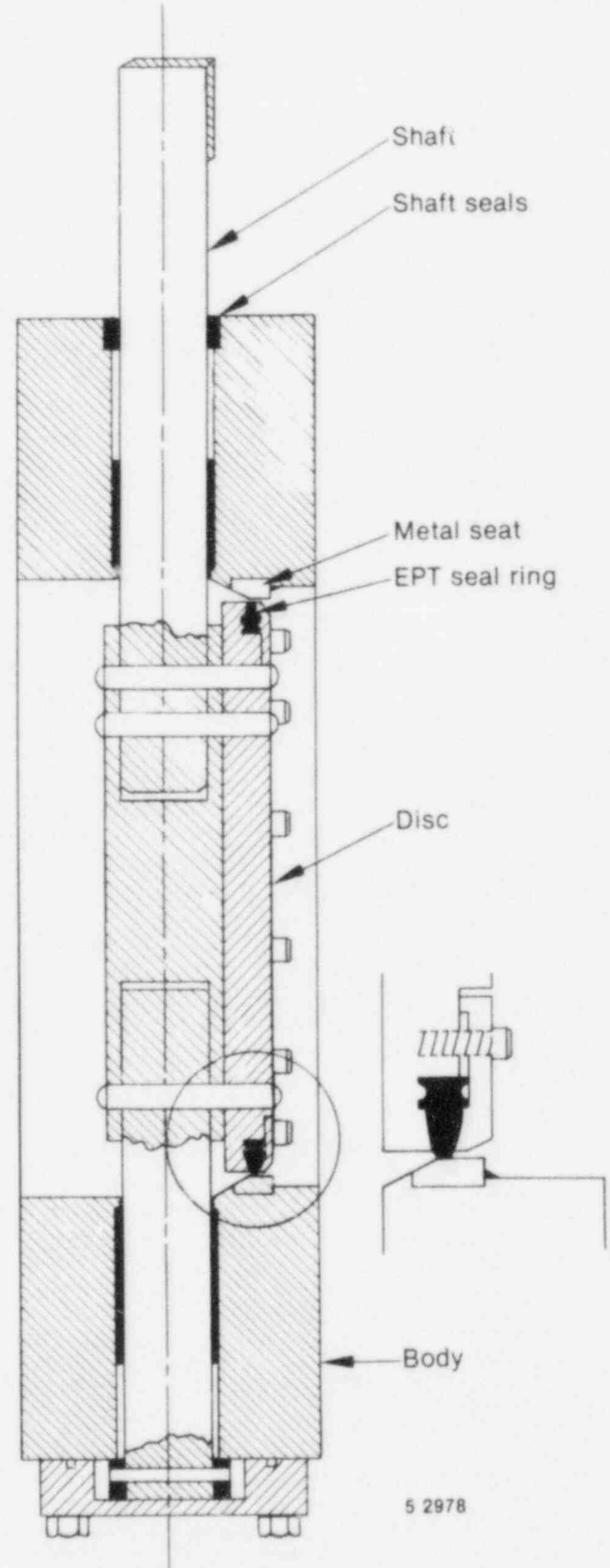


Figure 2. Cross section purge valve Nos. 2 and 3.

disc thickness divided by the disc diameter. The NASA-Langley work was very good as far as it went. However, it did not address maximum flow rates in the first 20 degrees of valve closure, or address a larger valve size to verify the extrapolation theory. Additionally, the work was accomplished for a specific vendor and did not address comparisons to other vendor designs.

The purge valve dynamic flow test program performed for EDQP was designed to address response similarity by comparing two eight inch nominal pipe size valves with differing internal designs. For extrapolation insights, a 24 inch nominal pipe size valve was also tested.

The valve leak integrity evaluation investigated purge valve elastomer seal integrity when exposed to the temperature and pressure environments predicted for a DB-LOCA and for severe accident environments.

TEST HARDWARE SELECTION

The selection of purge and vent valves for testing which were representative of the types used in nuclear power plants was accomplished using the following selection criteria:

1. Brookhaven National Laboratory (BNL) made a partial survey of commercial nuclear containment purge and vent valves. This survey was used to establish predominant manufacturers, types of valves used, and the size of the valves used in the field, however it did not include valve operational status.

2. A literature search was made to determine what previous work had been done by others with respect to the program issues. The most significant published work was accomplished by NASA-Langley for Allis Chalmers. This work involved a six inch valve with three different disc configurations.

3. From the review in Item 1 above, it was concluded that the dominant purge and vent valve manufacturers were: Fisher Controls, Henry Pratt Company and Allis Chalmers.

4. From the review in Item 1 above, it was estimated that the generic butterfly valve is the most predominant purge and vent valve installed in the field. Two valve manufacturing standards, AWWA (American Water Works Association) and ANSI (American National Standards Institute) are the predominant valve standards. AWWA valves were phased out with Class 2 and 3 piping being incorporated into the ASME Code. The primary difference, other than materials, occurs in valves under 24 inches in size. AWWA valves are limited to 75 psi cold working pressure, while ANSI valves under 24 inches in size are part of the 150 pound class limited to 280 psi cold working pressure. ANSI purge valves greater than 24 inches are limited to 75 psi cold working pressure but designed and analyzed for plant design pressure and temperature conditions. The principal difference between containment purge valves, with respect to this program's objectives, is internal. Disc shapes and seal configurations are the major internal differences. Disc shapes run from symmetrical to the high aspect ratio offset disc ANSI 150 pound class valves. The higher pressure rating of the ANSI valves normally requires larger shafts which dictate thicker discs. The major difference in seal designs is that some valves have the elastomer seal in the body, while others have the seal in the disc.

5. The final valve selection was determined by the following:

    a. The test facility flow capability limited the largest size valve to 24 inches.

    b. Information from previous tests using five and six inch valves could be used to supplement this program.

    c. The NASA-Langley work had determined that higher aspect ratio valves have the highest dynamic torque.

    d. ASME Section III, eight inch butterfly valves with the seal in the body were available from WPPSS-4.

e. Nuclear designed valves with the seal in the disc could be obtained from a valve manufacturer in time to meet test schedules.

f. The valves would be representative of two of the three largest manufacturers in the field.

g. The two valve seat designs represent most of the valve types in the field.

h. Offset disc ANSI 150 pound class valves probably would result in the worse case closing torque responses.

i. The earlier Langley work with the six inch valve could be directly compared to one of the eight inch valves. The second eight inch valve could be compared to the first eight inch valve for a comparison of response, and then to the 24 inch valve for extrapolation insights.

TEST FACILITY DESCRIPTION

Energy Technology Engineering Center (ETEC) was selected to perform the purge valve dynamic flow tests. The test facility required very few modifications to perform the testing required. Nitrogen gas was available to test up to 24 inch valves over the full DB-LOCA test pressure range.

ETEC Test Facility Description

The Thermal Transient Facility (TTF) is designed to enable accelerated life tests, thermal transient tests, and thermal creep tests under mechanical loading using gaseous nitrogen as the heat transfer medium.

Structural steel members embedded in the floor are designed to react loads through interaction with test article support members bolted to these floor beams. This technique provides flexibility in the test article configurations that can be accommodated. The mechanical loads are normally provided by load struts powered by hydraulic load cylinders with load cells for load measurement. The facility maintains an inventory of different sized load cylinders. The hydraulic system is dedicated and includes a load maintainer which enables precise pressure control to 20 different supply lines, thus accommodating requirements to apply bending moments, torsional loads and tensile or compressive loads to the desired level. Gaseous nitrogen is supplied from a 1080 ft^3 (16,000 lb) bottle bank at 3200 psig.

The basic piping, with control valves and safety features in both bays of the facility, is ready for connection to any test article. The exhaust stacks and associated piping are also in place and blast shields are available for equipment and personnel protection during high pressure test programs. Electric power is available for heating elements when required to provide controlled temperature distribution across a test article. The heating elements can be zoned and each zone maintained at the proper level by temperature controllers.

Both bays in the facility have patch panels which are connected to the Digital Data Acquisition System (DDAS). Instrumentation for a test program is connected to the patch panel for monitoring and recording in the control room. Control signals are also connected through the patch panel to enable remote control of all high pressure tests.

One reason TTF was selected for this valve program was on the basis of their ability to provide the necessary gas flow at the required pressures. The flexible feature of the support beams enabled suitable tie-down for restraint of the piping configuration during high pressure blowdowns.

The piping system for the eight inch butterfly valve tests was installed in the high bay and was connected to the facility four inch nitrogen supply line through a flow meter and a four inch ball-type regulating valve. From the control valve, the line expanded into an eight inch vertical U-bend arrangement with a rupture disc connection at the top of the U-bend. The horizontal test section of pipe was connected to the return leg of the U-bend through a 90 degree elbow. The outlet end of the test section was flared and exhausted to atmosphere through a horizontal 24 inch pipe duct. The test piping system was supported and restrained using the existing facility structural steel support members. The piping system was fully instrumented with thermocouples and pressure transducers. All parameters required for each test were recorded by

the data acquisition system and quick-look printouts and plots were available from the line printer in the control room. The ball-type pressure regulating valve was hydraulically actuated under computer control. The valve was ramped open in the prescribed time by the computer until the desired upstream pressure was achieved and then controlled by the computer while the test valve was being cycled.

Vertical support stands were used to support the valve outside of the test loop for valve cycling and leak testing. The leak tests were performed using a portable rig which includes provisions for accurate control of the applied gas pressure, for reading low leak rates by means of positive water displacement, and for reading larger leak rates by means of calibrated flow meters of various capacities.

For the 24 inch butterfly valve test, the test loop was located adjacent to the nitrogen bottle bank area in order to minimize line losses. The test loop was connected to a 600 ft^3, 3200 psig nitrogen storage bottle through a six inch block valve. From this valve, the line was reduced to match the four inch ball-type control valve. From the outlet of this control valve, the line expanded to the 24 inch pipe which was welded to a 90 degree elbow. The straight section of pipe was fitted with a 16 inch, 150 psi rupture disk. The 24 inch test section was then bolted to the outlet of the 90 degree elbow. Instrumentation and controls were similar to those used for the eight inch valve tests and the signal cables were routed to the control room to provide the necessary control and data recording. Cycling and leak testing were performed in a vertical support stand in the facility high bay. All tests were controlled remotely from the control room with visual observation of the control valve, the test valve, and the valve exhaust provided by TV cameras with TV monitors located in the control room.

Instrumentation

The Thermal Transient Facility (TTF) Containment Purge Valve Test Instrumentation System consisted of pressure transducers, thermocouples, RVDTs for valve angular position, and a torque sensor. Each of these measurements employs standard electronics and signal conditioning components. All parameters are ultimately recorded on the TTF computer-based Digital Data Acquisition System (DDAS). Test data are temporarily recorded in computer memory, transferred to disk, and permanently recorded on magnetic tape. A DDAS recording rate of 155 samples per second was available for these highly transient tests. Data could be retrieved from disc storage shortly after the actual tests or from magnetic tape at any time in the future.

Data Acquisition System. The TTF DDAS is based on a Hewlett Packard Model 21MX E series computer. This system interfaces the facility data channels with a Hewlett Packard Model HP 2313B multiplexer.

While this system has inherent capacity for hundreds of measurement channels, the requirements of this test program were satisfied with 48 channels. These channels were input to either a high-level card or a programmable low-level card, depending on their signal requirements. Data could be monitored at two facility CRTs, and plots or tabulations could be made on an HP 2608A printer/plotter.

Pressure Transducers. The program utilized several static, total and differential pressure transducers. The transducers utilized strain gage transducing techniques and were of both amplified and nonamplified configurations, and are summarized in Table 1.

Temperature Measurements. All temperature measurements were made with Type K (Chromel-Alumel) thermocouples used with 130°F (54°C) heated reference junctions. The thermocouples were premium grade 1/4 inch OD stainless steel sheathed units manufactured to RDT Standard C7-6T.

Valve Position Measurement. Both the facility control valve and the test valve shaft position measurements were made with Schaerritz Model R30D rotary variable differential transformer (RVDT) transducers.

Torque Measurement. The test valve shaft torque measurement was made with a LeBow Model 2112-100K, a 100,000 in.-lb torque sensor, for the 24 inch valve and a LeBow Model 2110-5K, a 5,000 in.-lb torque sensor, for the eight inch valves.

Accuracy. The accuracies of all measurements were equal to or better than the INEL requirements except for the torque measurement, where the resolution was ± 108 in.-lb and the accuracy was ± 300 in.-lb, and the nitrogen flow rate, where the

accuracy was ±2 lb/s when the flow rate was 20 lb/s or larger. Table 2 lists the instrument accuracies.

Quality Control

The ETEC Quality Assurance Department ensured that the requirements of RDT Standard F2-2, including Amendments 1 through 7, are met. Quality Assurance Program Index QADD No. 9, relates ETEC procedures and directives to RDT Standard F2-2.

The ETEC Quality Assurance Department participated in the program through document reviews, shop and facility surveillance, and inspections. All documents related to the program, such as drawings, specifications, purchase orders and procedures were reviewed for compliance with RDT Standard F2-2, the Test Request, and all Industry codes. Surveillance of suppliers, shop facilities, contractor activities, and the facility operations and maintenance ensured that quality requirements were met. All verifications required by inspection plans, construction inspection records, and procedures were verified by Quality Assurance inspection.

Table 1. Pressure transducer summary

Tag Number	Model Transducer	Range
PT-TA-A	CEC-1000-02	100 psig
PT-TA-B	CEC-1000-02	100 psig
PT-TA-C	STATHAM PA497-100-3	100 psia
PT-TA-D	STATHAM PA418-100-7	100 psia
PT-TA-E	STATHAM PA497-100-6	100 psia
PT-TA-F	STATHAM PA497-100-6	100 psia
PT-TA-G	STATHAM PA418-100-6	100 psia
PT-TA-H	STATHAM PA418-100-6	100 psia
PT-TA-J	STATHAM PA418-100-7	100 psia
PT-TA-K	STATHAM PA418-100-7	100 psia
PDT-TA	STATHAM PM8142-100	100 psid
FE-102A	STATHAM PM8142-300	300 psid

Table 2. Instrumentation accuracy

Parameter	Range	Required Accuracy
Pressure	0-100 psig	±2 psi
Differential pressure	0-100 psid	±4 psi
Flow rate	—	±20 cfm
Temperature	0-1000°F	±5°F
8 inch valve torque	0-5000 in.-lb	±24 in.-lb
24 inch valve torque	0-100,000 in.-lb	±24 in.-lb

DYNAMIC FLOW TEST PROCEDURE AND RESULTS

The purpose of the nuclear containment purge and vent valve flow testing was to determine if the containment isolation valves will close in the rising pressure environment of a Design Basis (DB) Loss-of-Coolant Accident (LOCA). The size of many purge and vent valves prevent full scale testing due to the pressure and gas flow rates required to duplicate internal containment accident predictions. Consequently, the industry predicts the response of larger valves from small scale model test valves. The methodology used by the industry was developed from incompressible flow scaling techniques and applied to a compressible flow media. The INEL's mission was to develop an experimental base to assist the NRC in the evaluation of the current analytical methods and to determine the influence of inlet pressure, inlet duct geometry, and valve orientation to the flow media on valve torque requirements, along with any resulting limitations to the extrapolation methods. Valve disc position (angle), valve shaft torque, mass flow rate, pressure and temperature were identified as the important parameters.

Scope

Three nuclear designed butterfly valves typical of those used in domestic nuclear power plant containment purge and vent applications were tested. For a comparison of response, two eight inch nominal pipe size valves with differing internal designs were tested. For extrapolation insights, a 24 inch nominal pipe size valve from the same manufacturer as one of the eight inch valves was also tested. Figures 1 and 2 provide cross-sectional views of the valves which were American National Standards Institute (ANSI) 150 pound class, offset disc, elastomer sealed, high aspect ratio units typical of designs up to 24 inch nominal diameter. Figure 3 is a composite cross-sectional view of all three discs with the 24 inch disc reduced by a factor of 3.

The valve experiments were performed with various piping configurations and valve disc orientations to the flow to simulate various installation options in field applications. As a standard for comparing the effects of the installation options, testing was also performed in a standard ANSI Test Section. Figure 4 shows this nominal inlet flow ANSI Test Section and Figure 5 identifies valve test positions for this configuration. Position 1 is the shaft downstream orientation and position 2 is the shaft upstream orientation. Figure 6 identifies the nonuniform inlet flow test configuration and Figure 7 identifies valve shaft orientations for that flow configuration. The odd numbered positions identify shaft downstream orientations and the even numbered positions identify shaft upstream orientations.

Each test was performed with the valve inlet pressure controlled at a relatively constant pressure

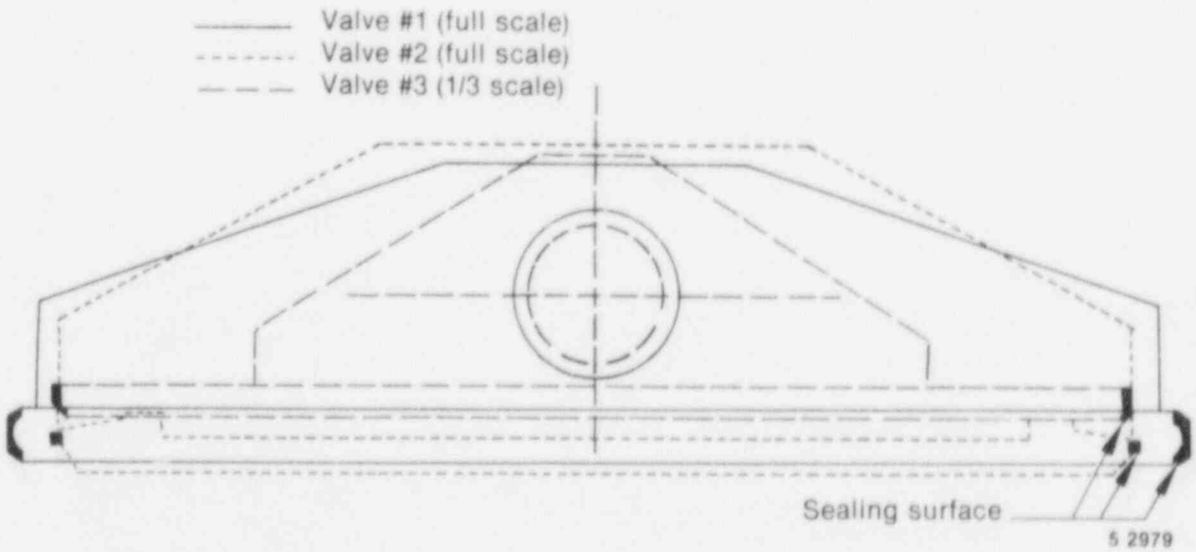


Figure 3. Containment valve disc overlay

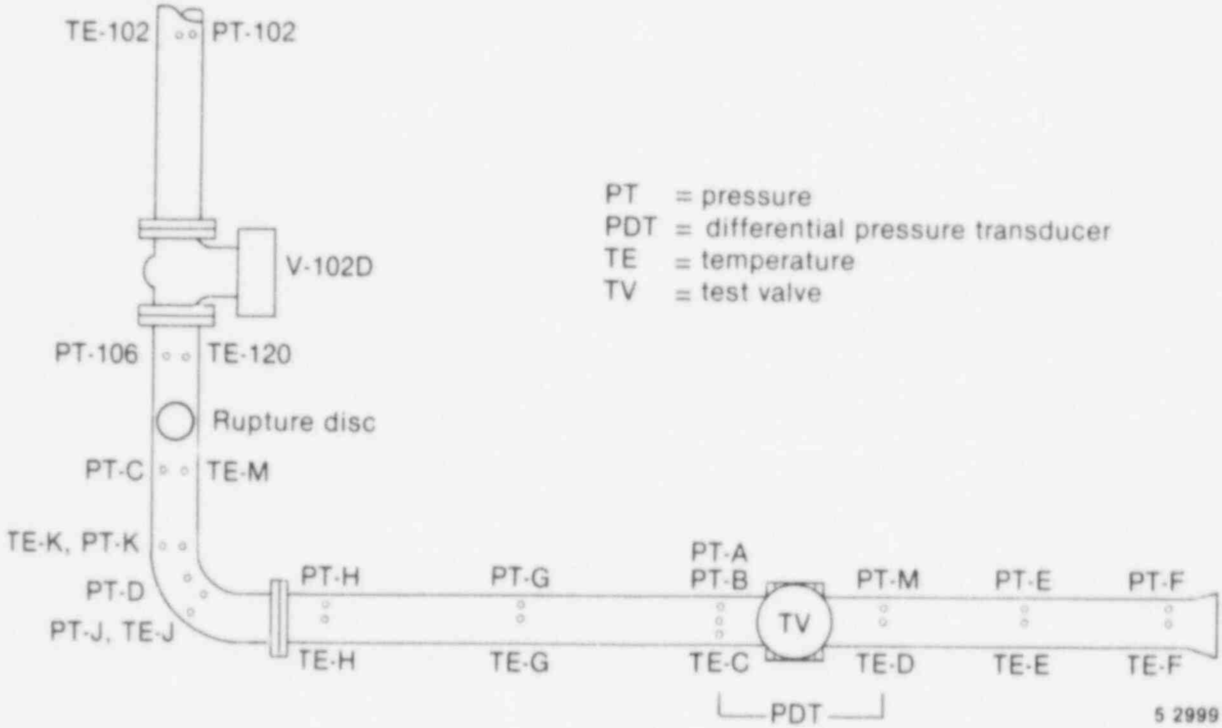


Figure 4. Typical installation—nominal inlet flow test section.

Figure 5. Nominal inlet flow valve positions.

throughout the valve closure cycle. Each cycle consisted of stabilizing the valve inlet pressure with the valve in the fully open (90°) position. The valve was then closed at 18° per second to the fully closed (0°) position. The valve was reopened at 45° per second after a 250 millisecond delay. Test cycles were performed at inlet pressures of 5 to 60 psig while monitoring numerous test parameters, such as the valve disc position, valve shaft torque, mass flow rate, and the pressure and temperature at multiple locations throughout the test system. Test measurements were monitored and recorded through 48 separate instrument channels by a Hewlett Packard model 21MX E computer (see Figures 4 and 6). The computer was used to control the test as well as record the instrument outputs at a sampling rate of 155 data points per second.

Immediately following the initial testing, the recorded data received a limited evaluation to insure that information for a complete analysis was being obtained.

Experimental Results

The test results were reduced and entered into a computer data base (see Appendix A). This data base was used to establish a common base for presentation, comparison, analysis and plotting. The initial analytical effort consisted of preparing typical industry torque coefficient (C_T) versus valve position plots from the test results of the two eight inch valves. C_T plots derived from scale model valves are typically the method industry uses to predict larger valve torque requirements.

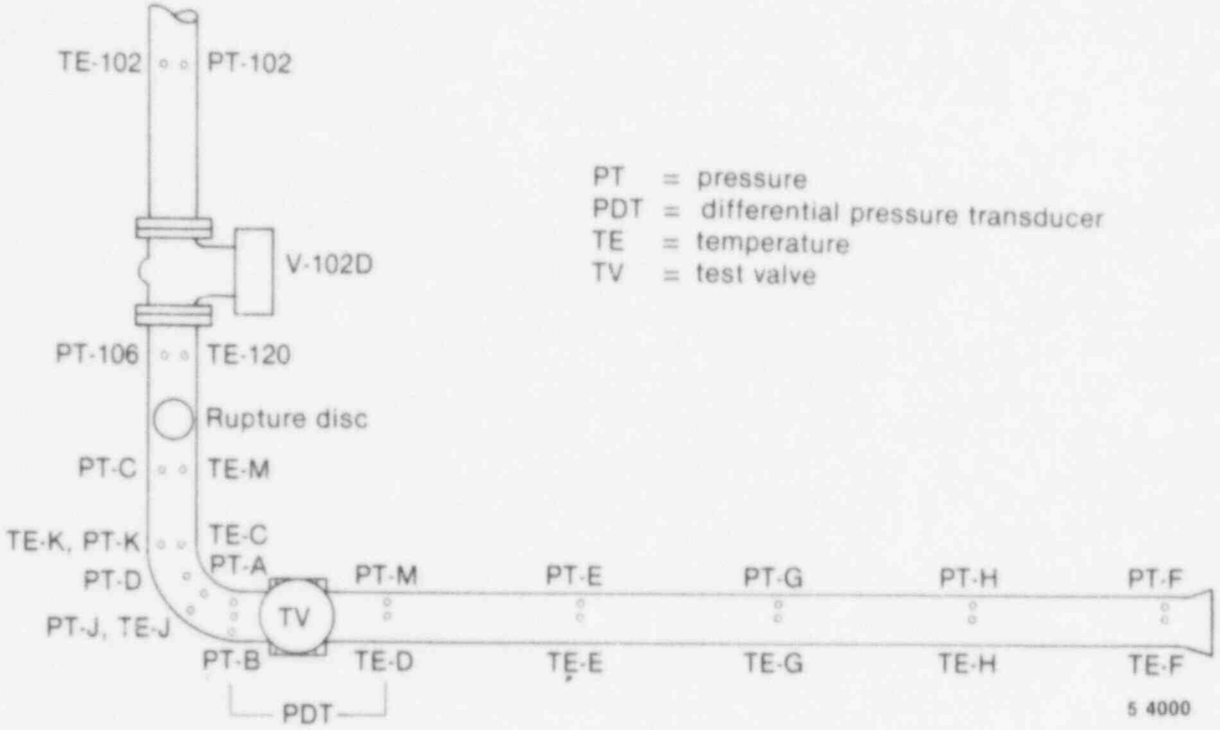


Figure 6. Typical installation—nonuniform inlet flow configuration.

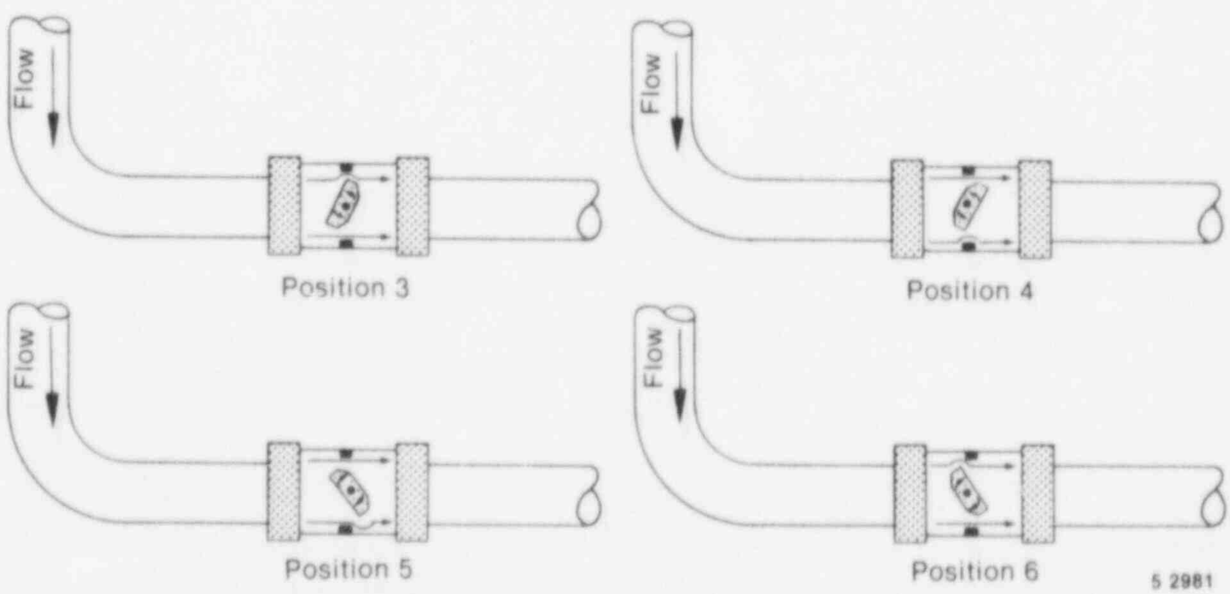


Figure 7. Nonuniform inlet flow valve positions.

Valve torque coefficients were calculated as

$$C_T = \frac{SVT_d}{SVD^3 \Delta P} \qquad (1)$$

where

C_T = torque coefficient

SVT_d = small valve dynamic torque

SVD = small valve diameter

ΔP = pressure drop across the valve.

Plots of C_T versus valve position were developed using the test results for inlet pressures of 15, 30, 45 and 60 psig for larger valve predictions. The larger valve torque was then calculated as

$$LVT_d = C_T \, LVD^3 \, \Delta P \qquad (2)$$

where

LVT_d = large valve dynamic torque

LVD = large valve diameter.

These industrial torque calculations are based on the theoretical assumption that in geometrically scaled systems, when all other conditions are the same, the flow characteristics and the pressure drop across valves which have been scaled to each other will be the same. Note that if the ΔP of the smaller and larger valve is the same, the formula for calculating the larger valve torque reduces to

$$LVT_d = \frac{LVD^3}{SVD^3} SVT_d \, . \qquad (3)$$

To evaluate the validity of predicting the larger valve torque, only the nominal or straight inlet test results for each eight inch valve were used, precluding any effects of nonuniform flow at this time. Small valve C_T plots were then used to predict the larger valve torque, which was in turn compared to actual larger valve test results. (A conservative comparison being a prediction which exceeds the actual larger valve test results.) An approximate comparison was found with the valve in the shaft upstream or shaft side of the valve disc closing toward the flow orientation. However, the results in the shaft downstream orientation were nonconservative. Note that the valves used for containment purge and vent applications are not sized for the flow rates resulting from inlet pressures greater than 15 psig. Consequently, for pressures above 15 psig, choked flow is generally established for these high aspect ratio valves. The ratio of valve ΔP to upstream pressure versus valve disc angle was plotted at pressures of 15, 30, 45, and 60 psig for one of the valve orientations tested.

The results, Figure 8, indicate an initially different response for the 15 psig test relative to the higher pressure tests. Beyond the 40° position, however, the slopes look very similar. This initial difference is indicative of choked flow at the higher test pressures and for valve open angles of 40° or less at an upstream pressure of 15 psig. These choked flow conditions result in a supersonic flow region downstream of the valve. This supersonic flow region changes length as the valve closes, resulting in a ΔP variation during each closure cycle, (Figure 9) which is very different than that experienced in incompressible flow. Specifically, the downstream pressure, as measured 15 diameters downstream of the test valves, had not always recovered from the flow perturbation during certain portions of the valve travel and that the measurement location was in a supersonic region which extends beyond the downstream instrument location. Note also that the ΔP variation between the valves, Figure 10, is considered to be greater than their geometric dissimilarities.

The variations presented ultimately raise the concern that the torque extrapolation theory developed for incompressible flow should contain a nonlinear extrapolation component for the higher Mach Numbers experienced during a design basis compressible flow application.

Consequently, the generic ΔP torque relationship developed from modified water technology does not appear to be adequate to model the downstream supersonic conditions, and the resulting effect on valve differential pressure, resulting from compressible flows.

Based on the preceding results, a study was conducted into the physics of a butterfly valve disc in a compressible flow application. The results of the study are presented in the following hypothesis: The butterfly disc will respond as an airfoil from the full open position to the position where maximum lift occurs (peak torque). The disc orientation

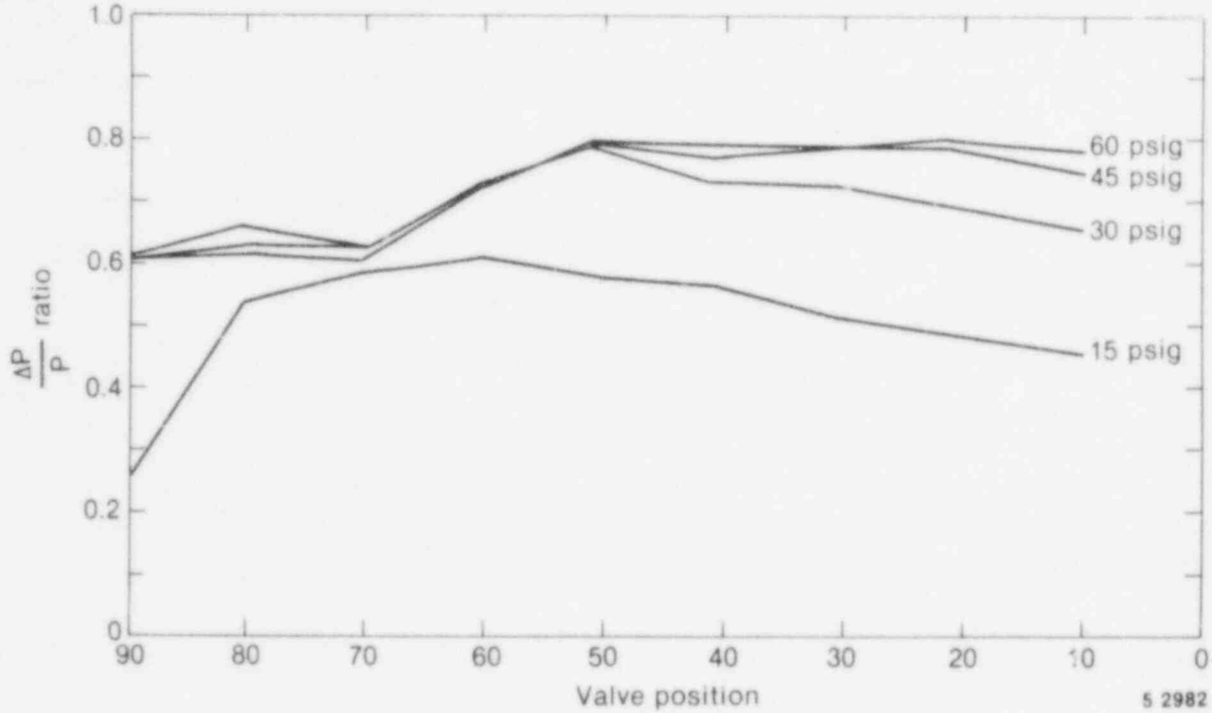


Figure 8. Valve differential pressure/upstream pressure ratio vs valve position.

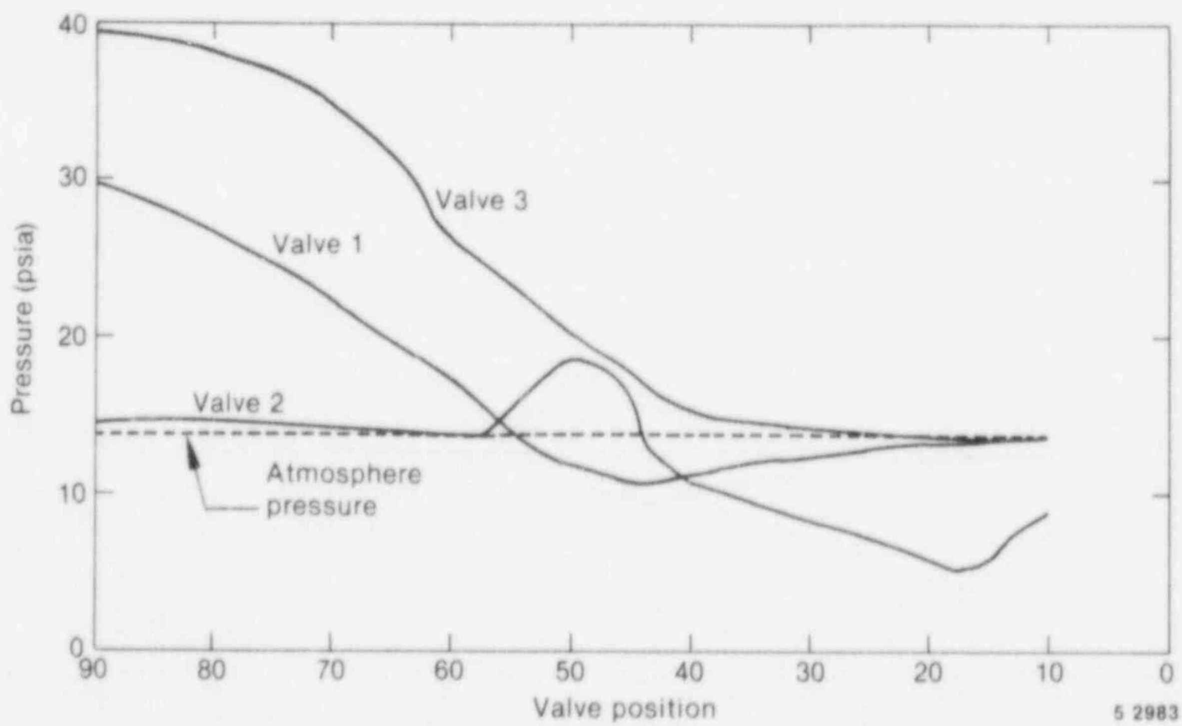


Figure 9. Static pressure at 15 diameters downstream of valve vs valve position.

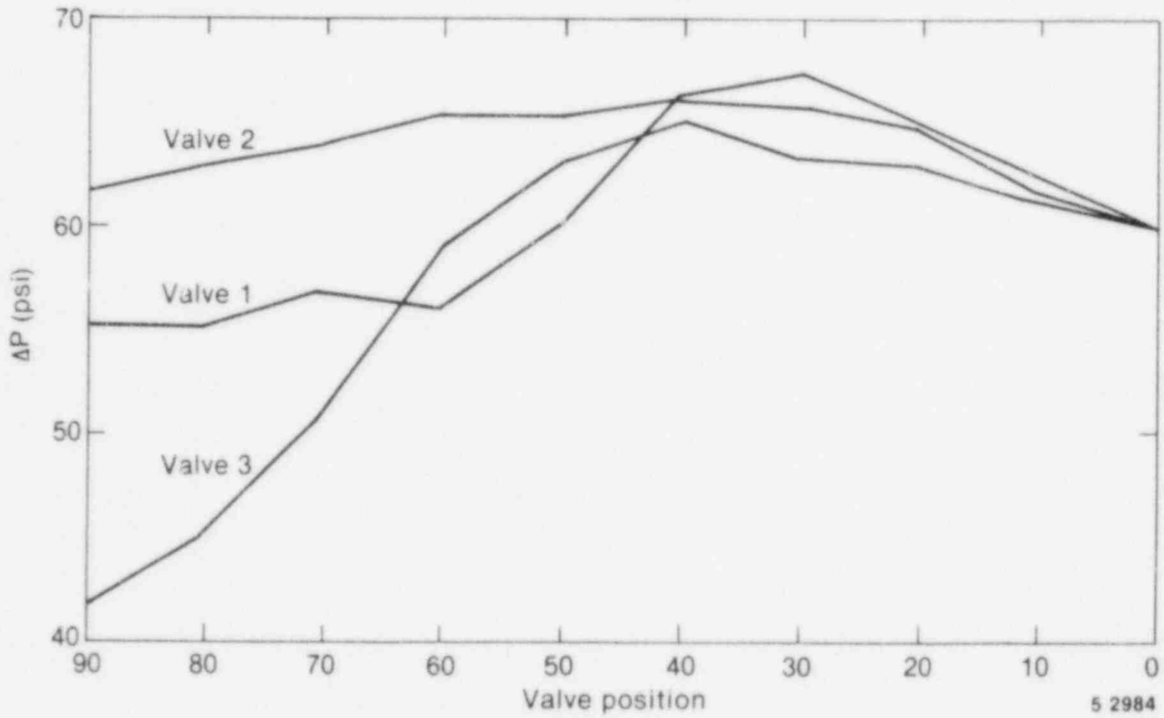


Figure 10. Valve differential pressure at 60 psig inlet pressure vs valve position.

to the flow stream determines whether a positive or negative torque occurs. The shaft upstream orientation provides a positive response and assists in valve closure. The shaft downstream orientation provides a negative response and resists valve closure. Immediately after peak torque occurs, the airfoil stalls and torque decreases. The disc then becomes an increasingly larger flow obstruction as the valve completes its closing cycle. Based on this hypothesis and the inability of the C_T methodology to model the supersonic flow downstream of the test valve, the work with the C_T technique was discontinued. The C_T method could have been improved by the substitution of inlet pressure in place of ΔP, which is the key to the method developed during the program. However, the additional calculations required with the C_T method were felt to be unnecessary and added the possibility of error. To reduce the variables to the maximum extent possible in the development of a generic valve torque extrapolation equation which would not be dependent on the choked flow effects of the valve, it was decided to use the containment pressure in the development of a substitute method. Thus, valve response plots were developed relating valve upstream pressure, torque and disc angle in a single graphic presentation. Figures 11 through 16 are the response plots for valves 1, 2, and 3 in the nominal piping configuration. Position 1 is the shaft downstream orientation and position 2 is the shaft upstream orientation.

Upon analyzing the results of the response plots, it was determined that the absolute magnitude of the positive response characteristics upper bounded the absolute magnitude of the negative response characteristics of the valves, when only dynamic torque was considered in the extrapolation technique. The similarity in the positive response characteristics of the three valves as reflected in Figures 14 through 16 and allowing for small shifts in the angle of peak torque and the magnitude of the response expected for each valve size, provides the assurance that limited extrapolation is possible.

The peak torque for each of the three valves was also plotted against upstream pressure in the nominal piping configuration, Figures 17 through 19. The results indicate a linear relationship between the two parameters. The peak torque angle varies with pressure, however, the torque response remains linear. The higher the inlet pressure the higher the torque relationship is not unexpected; the fact that the response is linear reinforces the confidence of extrapolating the response of a valve between test pressures.

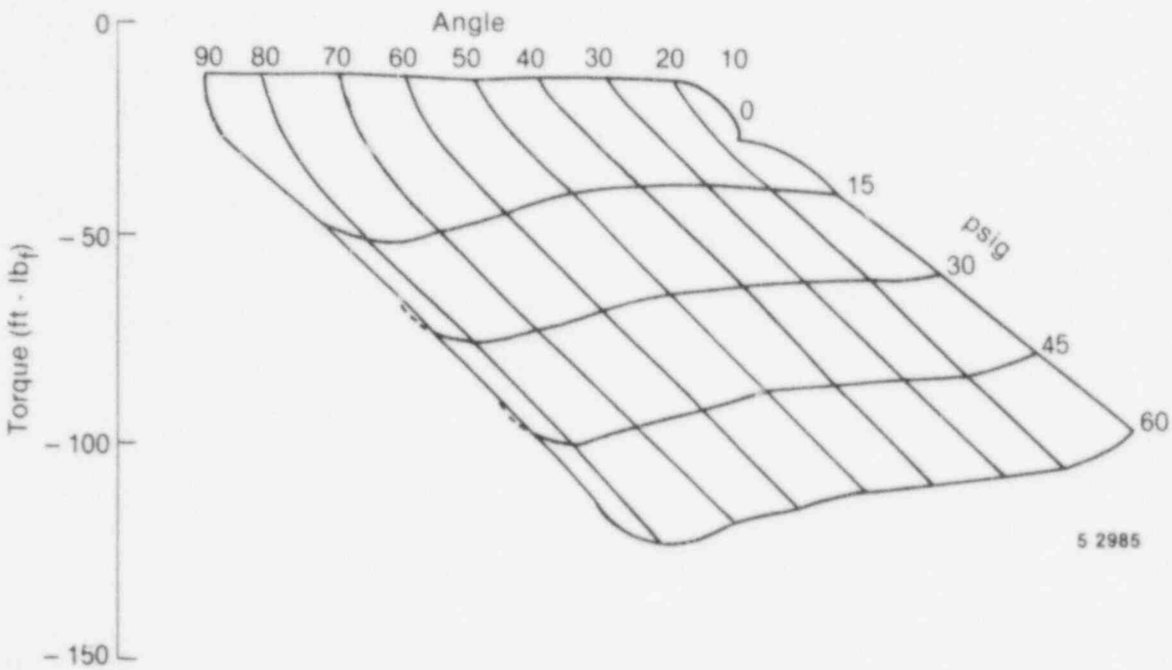


Figure 11. Valve 1, position 1, torque vs upstream pressure, angle.

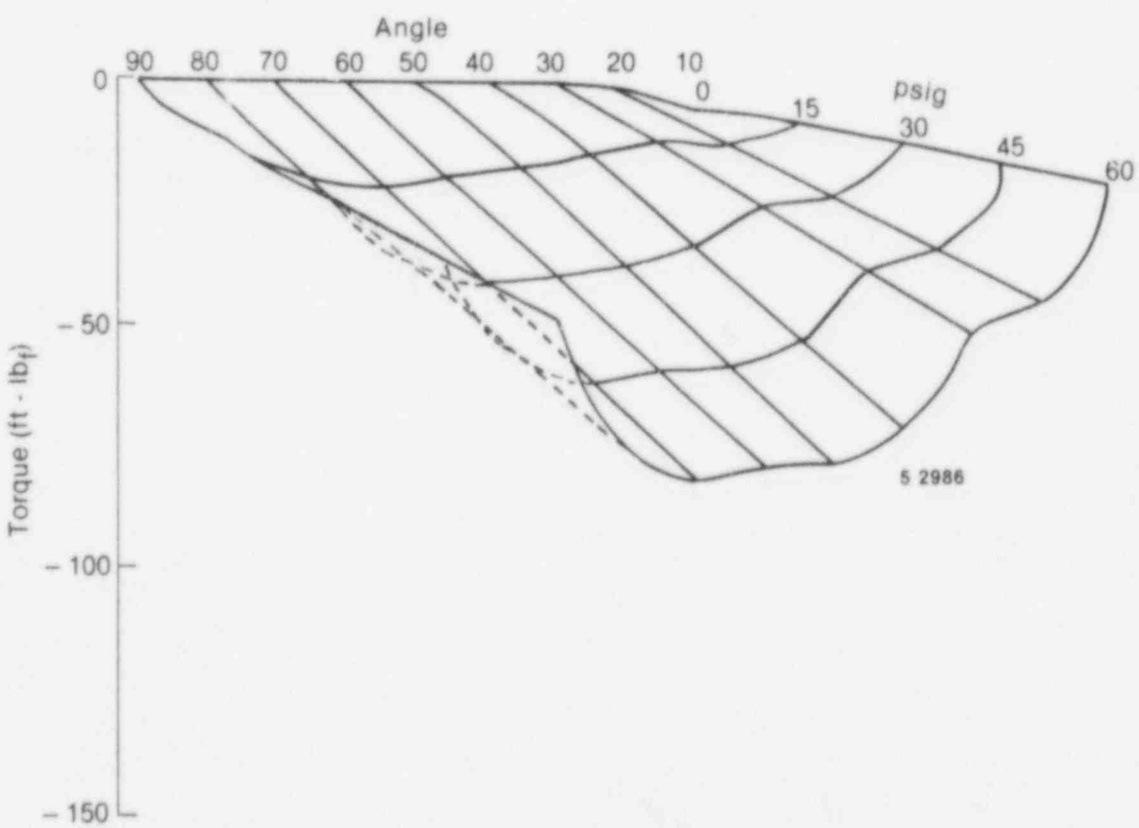


Figure 12. Valve 2, position 1, torque vs upstream pressure, angle.

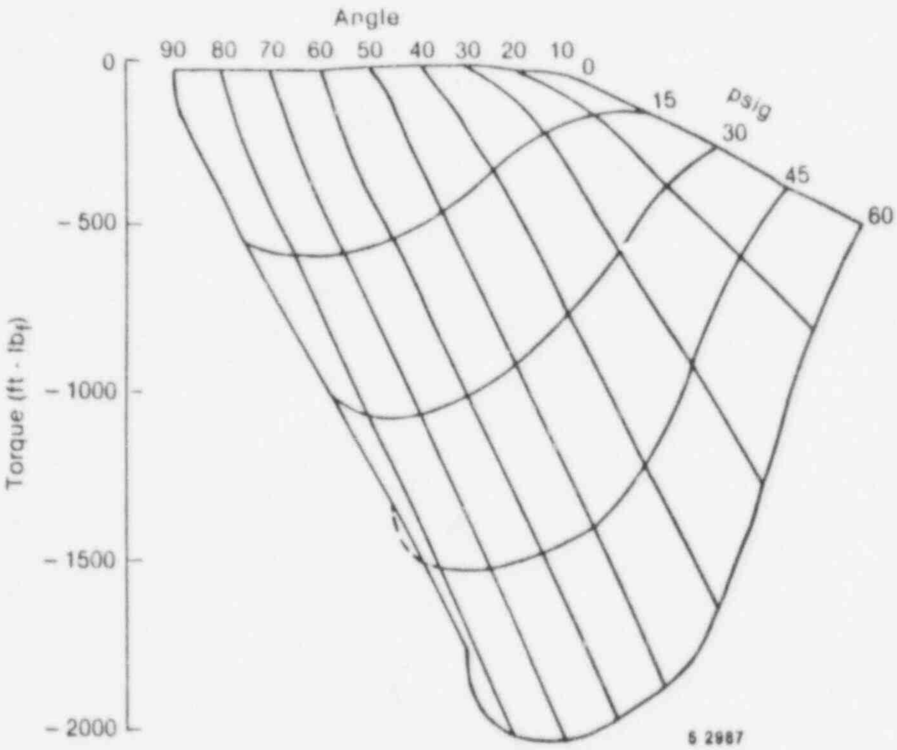


Figure 13. Valve 3, position 1, torque vs upstream pressure, angle.

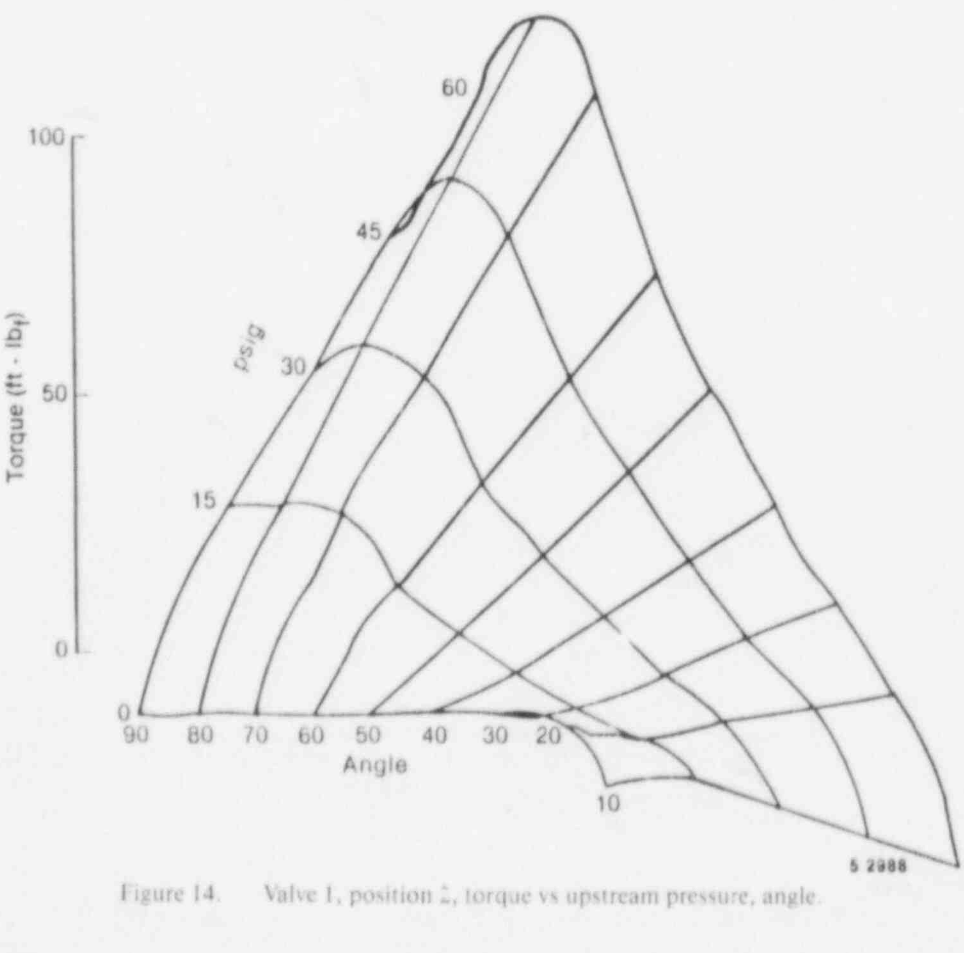


Figure 14. Valve 1, position 2, torque vs upstream pressure, angle.

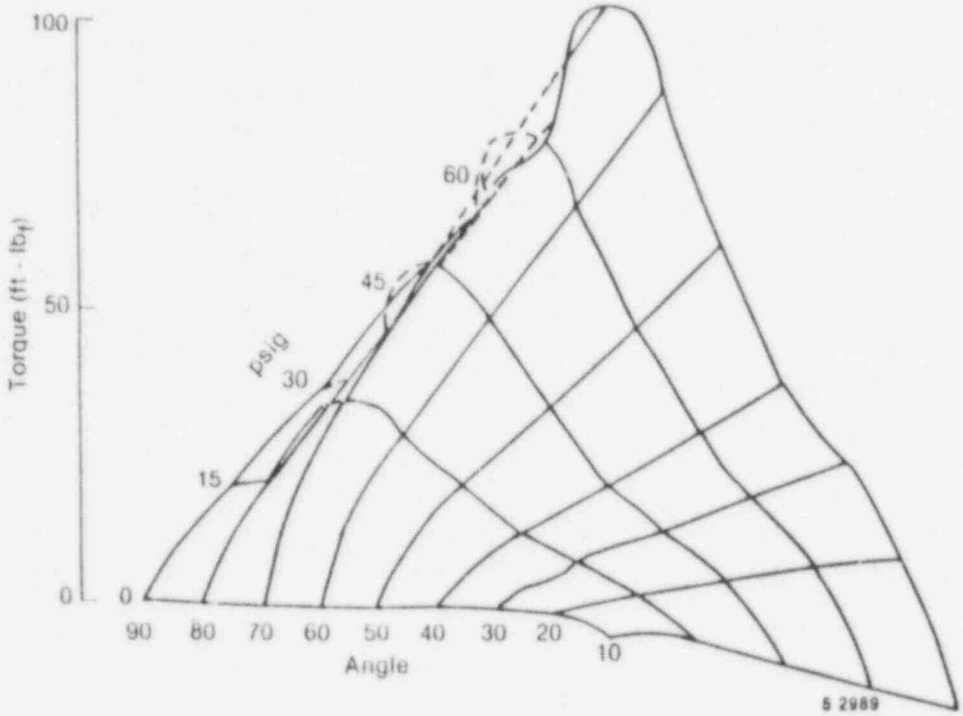


Figure 15. Valve 2, position 2, torque vs upstream pressure, angle.

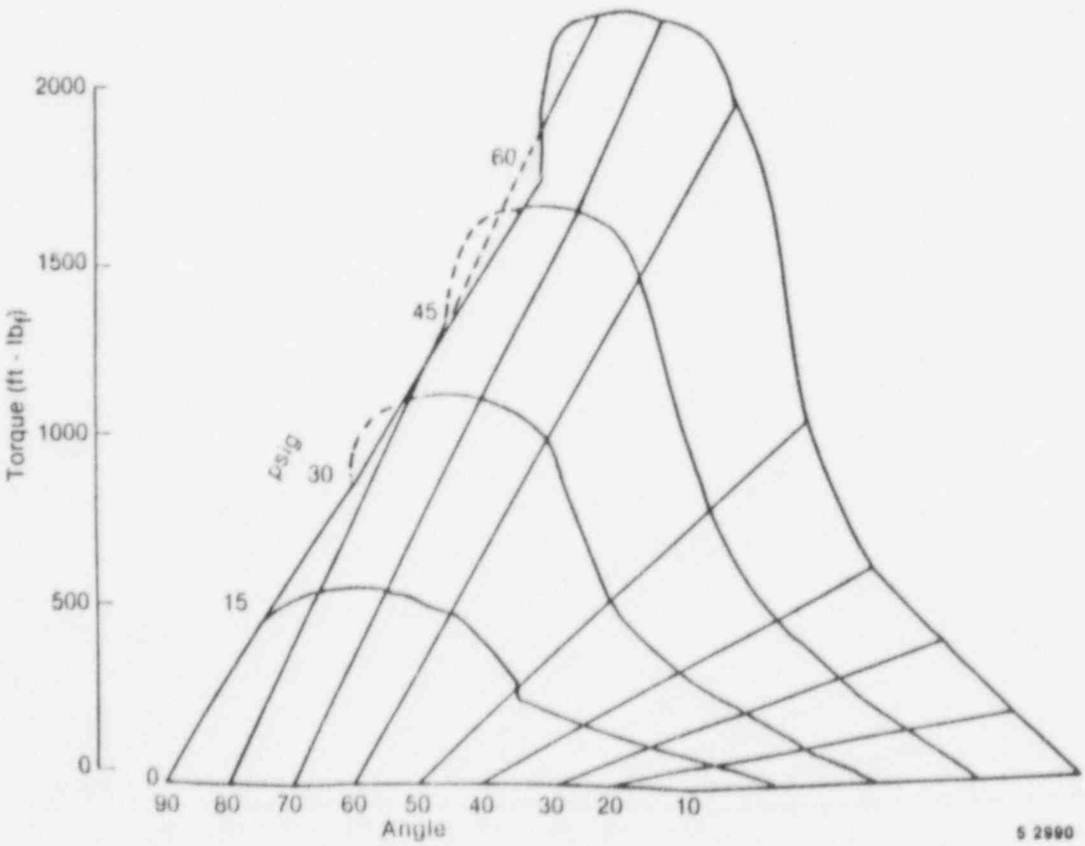


Figure 16. Valve 3, position 2, torque vs upstream pressure, angle.

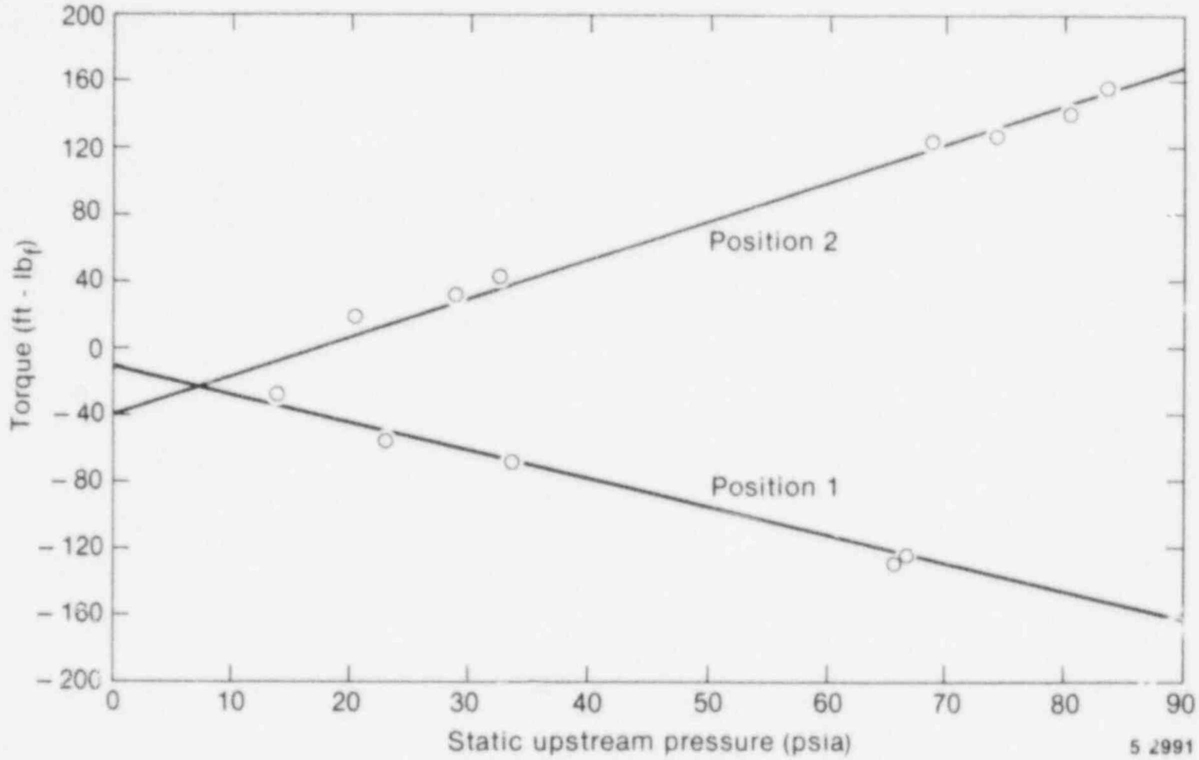


Figure 17. Valve 1, peak torque vs static inlet pressure.

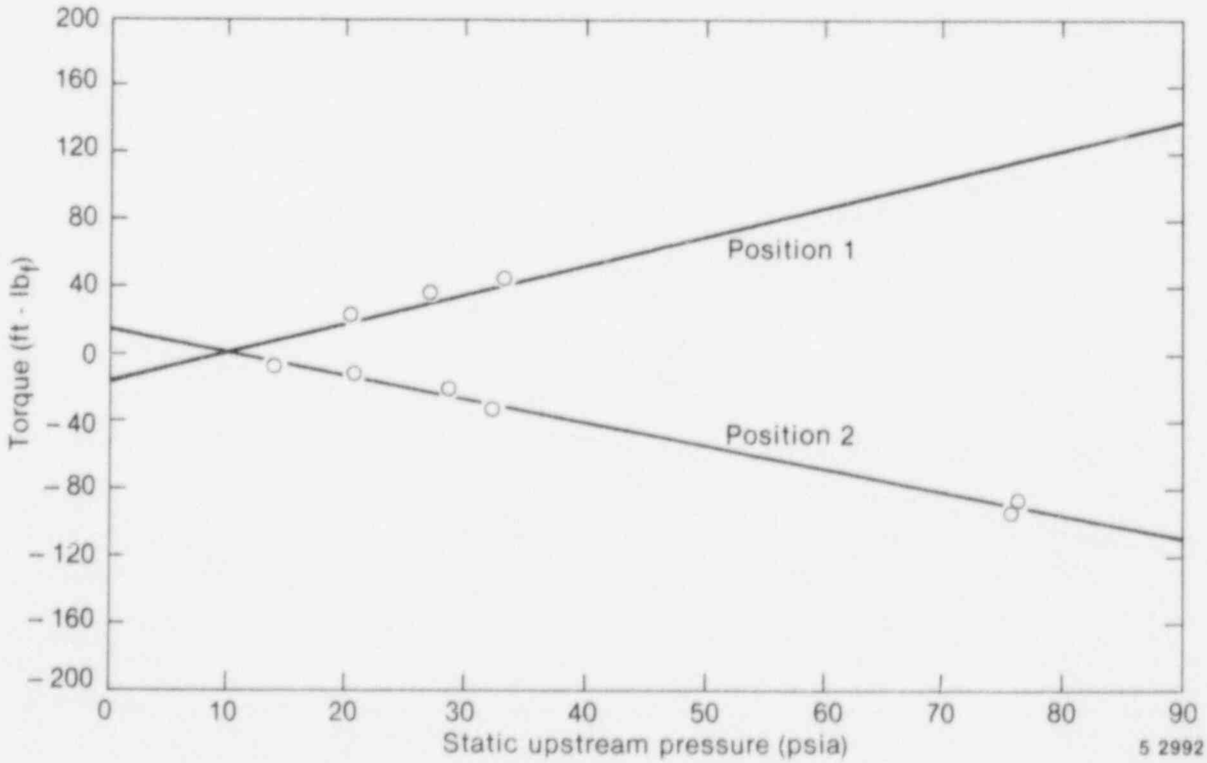


Figure 18. Valve 2, peak torque vs static inlet pressure.

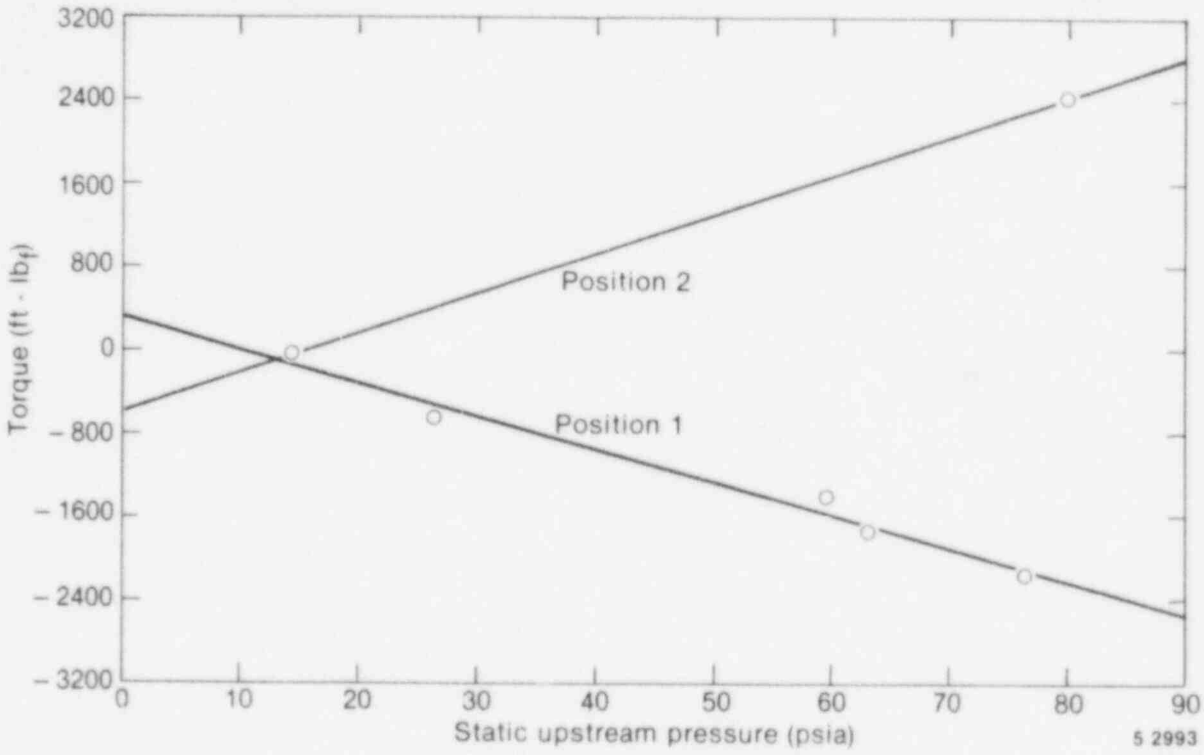


Figure 19. Valve 3, peak torque vs static inlet pressure.

To assist in developing a calculational technique, the validity of a D^3 ratio as used in Equations (1), (2) or (3) was evaluated. The dynamic torque of the 24 inch valve, valve 3, was divided by the dynamic torque of the similar eight inch valve, valve 2. The resulting ratio was plotted against valve position for inlet pressures of 15, 30, 45, and 60 psig, Figure 20. The actual diameter cubed relationship for the valves used in developing this figure was $(24/8)^3 = 27$. Twenty-seven upper bounds all but one point at 60 psig where the excursion was considered to be less than the scaling differences between the compared valves and is thus considered to provide a bounded extrapolation coefficient for predicting the larger valve torque. Consequently, a D^3 formulation appears justified. The following equations are presented to envelop the response of larger valves based on smaller scale model test valves. "Shaft upstream" torques must be used to provide conservative results.

$$LVT_T = \frac{LVD^3}{SVD^3} SVT_d - LVT_b \quad (4)$$

$$LVT_T = \frac{LVD^3}{SVD^3} (SVT_T + SVT_b) - LVT_b \quad (5)$$

where

SVD = small valve diameter

LVD = large valve diameter

SVT = small valve torque

LVT = large valve torque

b = bearing

d = dynamic

T = total (bearing + dynamic).

It should be noted that the small valve dynamic torque was established using the predicted pressure of the containment at the valve inlet while the downstream was exhausted to atmospheric conditions within a reasonable distance. The downstream test configuration was modeled to be typical of field installations where the stiff piping terminates and the flexible ducting starts. Since accident pressure loads on flexible ducting may cause structural damage, modeling the Containment Isolation System (CIS) portion of the downstream piping

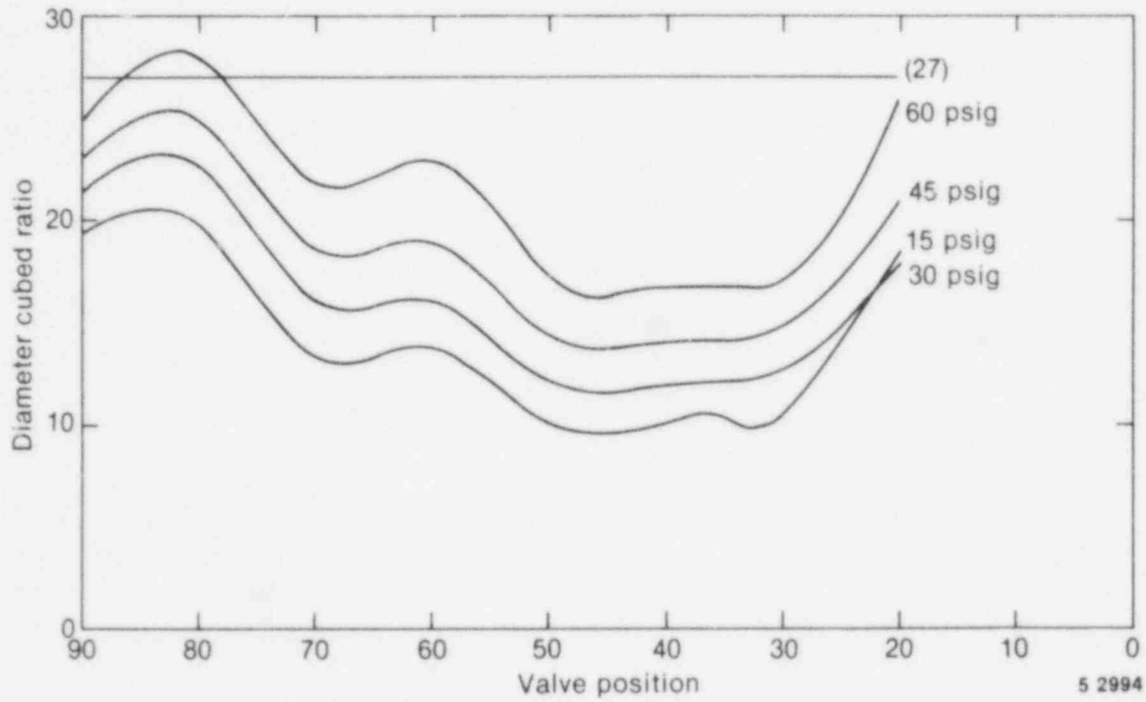


Figure 20. Diameter cubed ratio as a function of upstream pressure vs valve position.

only provides the worst case effects on valve torque response. Test measurements indicate that the pressure had not always recovered within the 15 pipe diameter region downstream of the valve. This downstream influence on ΔP, as discussed earlier, is the reason for considering only the upstream pressure in establishing the small valve torque response. Additionally, the experimental torque measurements recorded for each valve disc orientation includes valve internal torques (bearing, seating and packing). In the shaft downstream orientation, the recorded torque is the result of the dynamic torque plus the valve internal torques. In the shaft upstream orientation, the recorded torque is the result of the dynamic torque less the valve internal torques.

Laboratory torque measurements would normally be the result of well lubricated bearings, properly adjusted packing, and resilient seats. Predictions made from dynamic torque obtained under these conditions will be conservative, or overpredict the actual dynamic torque of the larger valve. However, if for any reason the resistive forces were greater, the conservatism would be reduced. It is suggested that to reduce the impact of error, if the torque of the larger valve is being predicted directly from the torque of a scale model valve recorded with a moving disc, (without attempting to separate the dynamic torque of the disc from other sources of torque) the large valve torque prediction include a bearing torque value as defined in the American Water Works Association Standard (AWWA).

The proposed technique as reflected in Equation (5) was then used to predict the response of a 48 inch valve using both the eight inch and the 24 inch valves as the scale model test valves. The results, Figure 21, indicate a large variation between the two 48 inch valve predictions. This variation questions whether a limit exists to the scalability of a test valve. ANSI B16.41 Annex J, Guidance for Qualification of Candidate Valve Assemblies, establishes a limit for valve scalability of 50% to 200% of the test valve. Based on the large variations noted, this limit cannot be disputed to date. It should be noted, however, that the smaller eight inch valve yielded higher torque predictions than the larger 24 inch valve.

Upstream Elbow Effects. The effects of system upstream geometry were also studied. The test results for valve orientations downstream of an elbow (see Figure 7) were compared to the nominal configuration results. Comparisons were made for

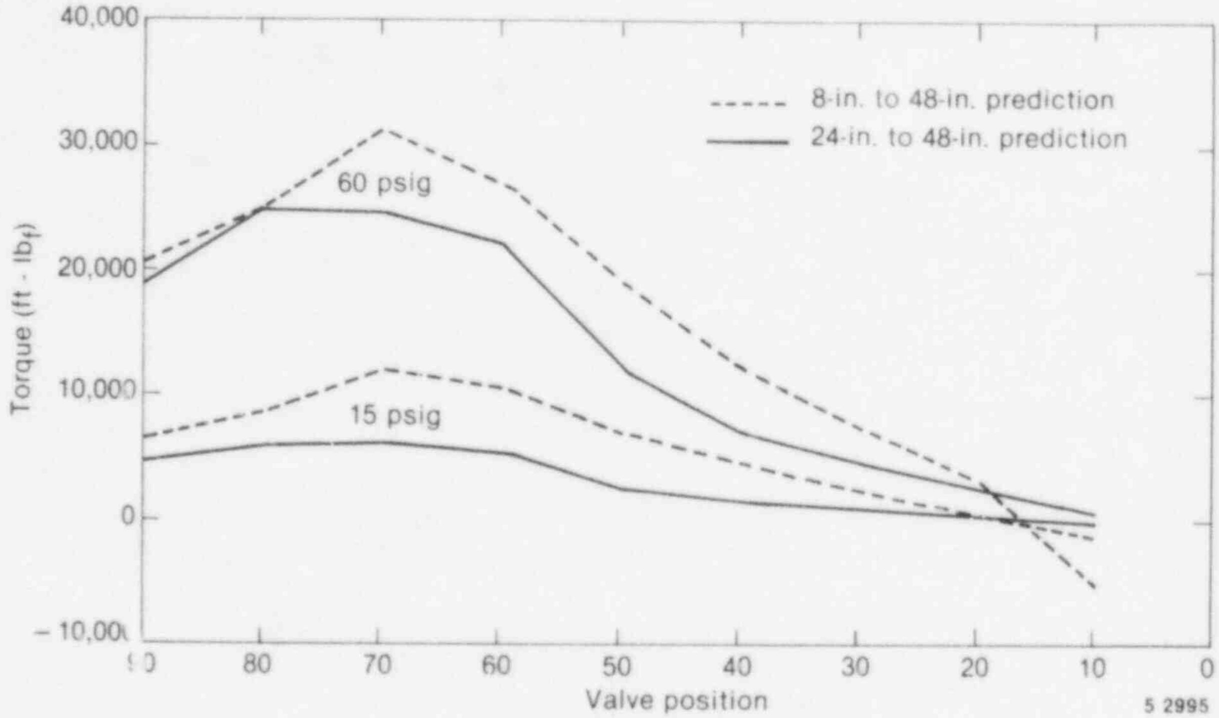


Figure 21. Predictions for a 48 inch valve based on extrapola 'ng the torques of an 8 inch and a 24 inch valve at upstream pressures of 15 and 60 psig.

worst case valve orientation, torque response variation, response similarity and peak torque versus pressure linearity. Peak torque at an adjusted pressure of 60 psig was tabulated for all three valves in each of the six positions tested, Table 3a. The effect of valve orientation and nonuniform inlet flow were evaluated, results of which are contained in Tables 3b and 3c. Table 3b ranks the absolute value of torque from highest to lowest for each valve, and also presents an overall ranking which is the average of the ranking of all three valves. The shaft upstream orientations result in the highest absolute torques, which supports the conclusion that the shaft upstream orientation upper bou ds the valve response. Next, the effect of nonuniform inlet flow relative to uniform inlet flow was evaluated. The peak torque for each orientation was divided by the torque at the cor es nding nominal inlet orientation, r ults of are contained in Table 3c. Valve positions 3 and 4 cor stently produced the highest results. The worst case elbow effect was noted for valve 3 position 3, 1.42 times the nominal inlet torque. Based on these tests, the maximum torque variation produced by nonuniform inlet flow configurations can be bounded by multiplying the nominal configuration (position 2, shaft upstream) torque by 1.5.

A valve response plot was developed for valve 3 position 4, the valve disc being in the shaft upstream orientation and the shaft of the valve being in the same plane as the elbow. This position is comparable to the nominal configuration position 2. The similarity of the shape of this response plot (see Figure 22) to valve 3 in the nominal configuration (see Figure 16) is clear. This comparison adds confidence that the torques produced in some nonuniform inlet flow configurations may be higher, but extrapolation of results can be made due to the similarity of response.

Figure 23 compares the peak torque response linearity versus inlet pressure of the nonuniform inlet flow case as described above, valve 3 position 4 with valve 3 position 2. Overall, the torque is higher but the response is linear. This comparison provides added confidence in extrapolation within limits for the nonuniform inlet flow configuration.

Density Effects. The internal containment atmosphere during a DB-LOCA will be a mixture of gases and steam. The density of this mixture was studied for effect on valve torque. The results of this study determined that the densities are very similar and that density will not be a factor if the scale model valve is tested at the expected containment pressure of the large valve. Testing with either nitrogen or air will provide conservative results (Reference Figure 24).

Table 3. Purge valve peak torque analysis (See Figures 5 and 7 for valve position identification)

TABLE 3a. VALVE TORQUES AT A NOMINAL 60 PSIG

Valve Position	Valve 1	Valve 2	Valve 3
1	-137.3	-86.8	-2064.1
2	129.9	107.6	2189.1
3	-117.4	-89.5	-2920.6
4	166.9	107.7	2280.7
5	-132.8	-90.1	-1896.1
6	148.4	102.1	2003.9

TABLE 3b. VALVE POSITION RANKING BY VALVE TORQUE

Ranking	Valve 1	Valve 2	Valve 3	Overall
1	4	4	3	4[a]
2	6	2	4	2[a]
3	1	6	2	6[a]
4	5	5	1	3[b]
5	2	3	6	1[b]
6	3	1	5	5[b]

a. Shaft upstream orientation.

b. Shaft downstream orientation.

TABLE 3c. VALVE INLET GEOMETRY INFLUENCE FACTOR

Valve Position	Valve 1	Valve 2	Valve 3
1	1.00	1.00	1.00
2	1.00	1.00	1.00
3	0.86	1.03	1.42
4	1.29	1.00	1.04
5	0.97	1.04	0.92
6	1.14	0.95	0.92

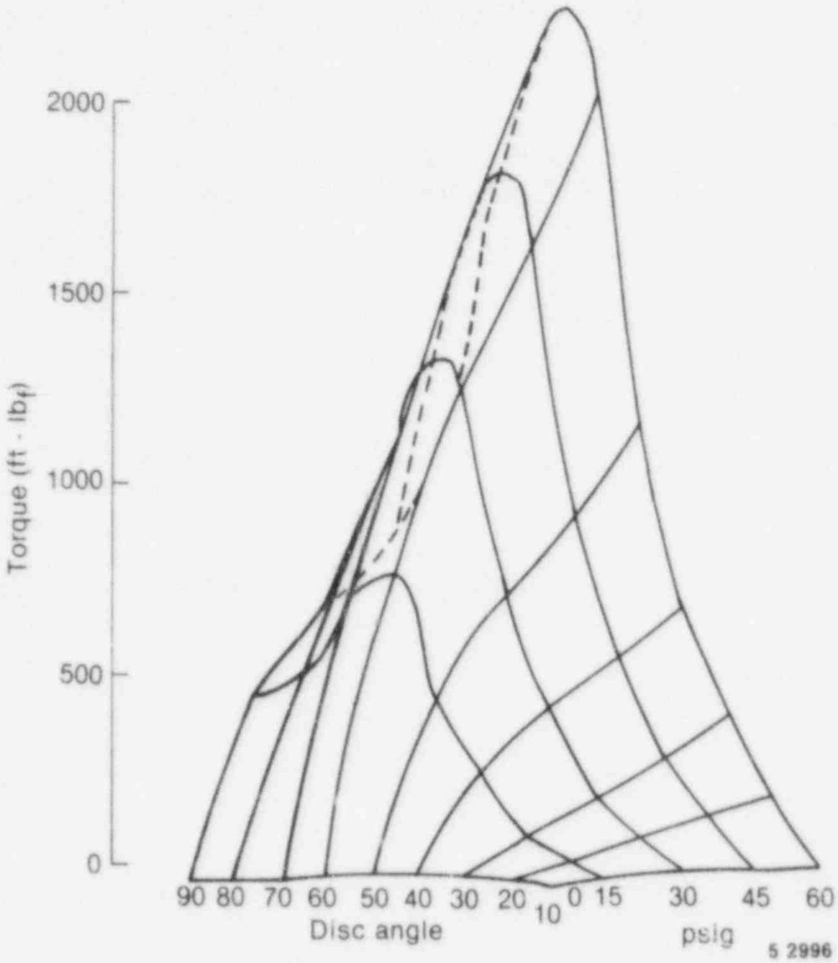


Figure 22. Valve 3, position 4, torque vs upstream pressure, angle.

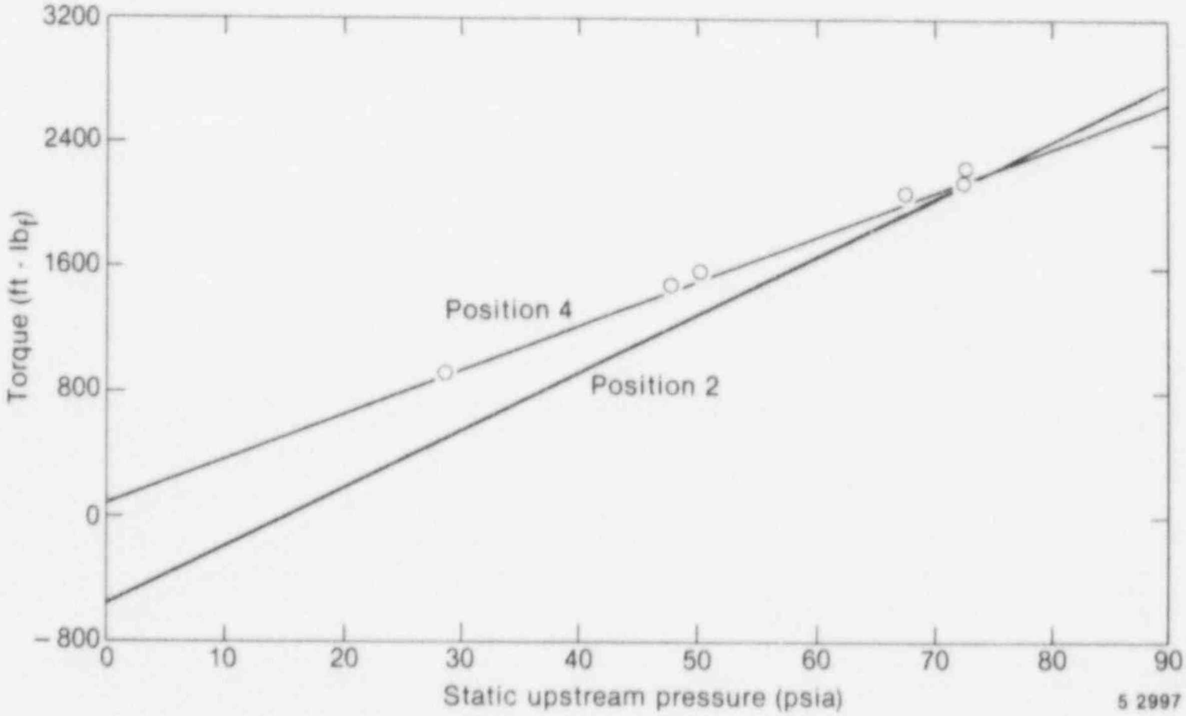


Figure 23. Valve 3 peak torque vs static inlet pressure comparing response at valve positions 2 and 4.

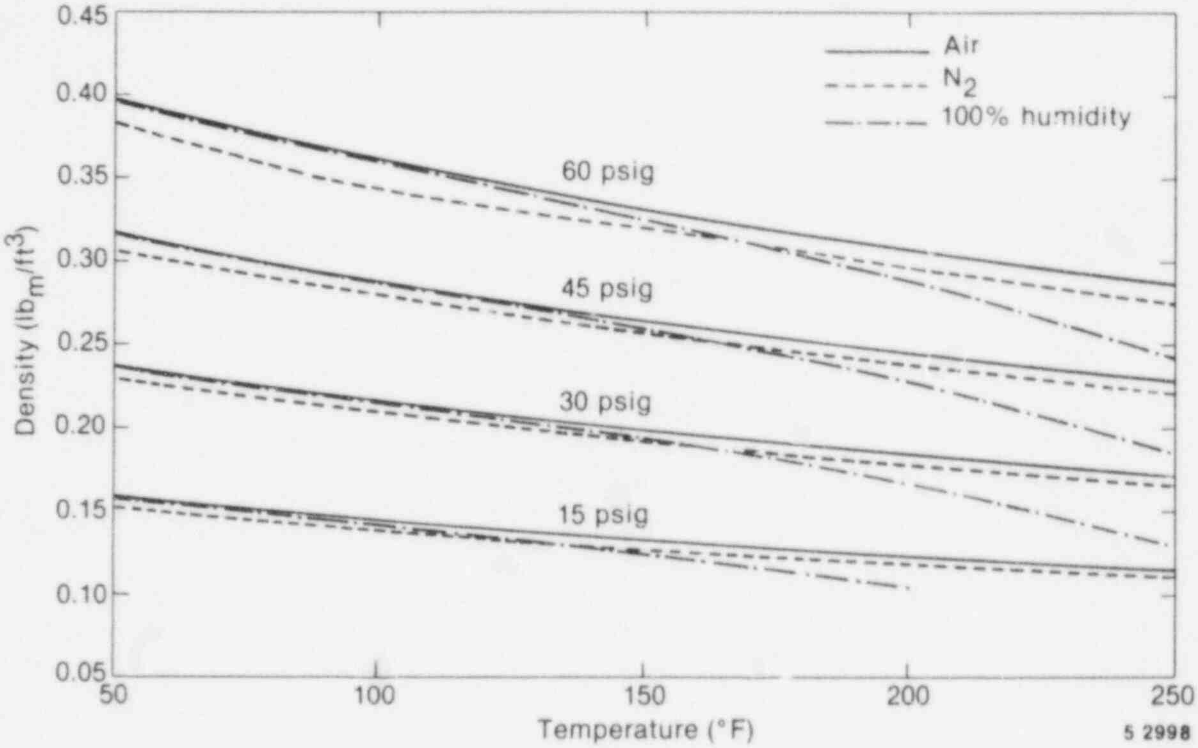


Figure 24. Gas density vs pressure and temperature.

PURGE VALVE SEAL INTEGRITY

The object of this part of the test program was to evaluate the ability of the containment purge and vent valve elastomer seals to remain bubble tight when exposed to accident environments.

Test Parameters Determination

The following questions were considered applicable in determining test parameters:

1. What are the typical containment environmental loads with respect to DB LOCA and severe accident scenarios which challenge the ultimate containment capacity?

2. What are the upper limits of a typical manufacturers valve specification with respect to anticipated accident environment loads?

The results of the investigations to determine the answers to these questions are as follows.

A companion project, the Containment Isolation System (CIS) Valve Integrity Test Program, also being performed as part of the Environmental Qualification of Mechanical and Dynamic (including seismic) Qualification of Mechanical and Electrical Equipment Program (EDQP), FIN A6322, performed an indepth study of loads resulting from DB-LOCA and severe accident scenarios which challenge the containment pressure boundary. The results of that study were used to characterize the containment environments which are applicable to purge valve leak integrity. Loads considered potentially the most damaging to elastomer seals were temperature, pressure, and radiation. [Radiation loads are the subject of other work and were not incorporated into this program. It should also be recognized that the allowables for radiation exposure levels for the elastomers used in purge valves is very high (1×10^8 rad). This is not considered as potentially damaging in most containment designs as temperature and pressure.] Table 4, obtained from the CIS valve integrity study, indicates the typical containment upper design pressure would be 60 psig. Due to the scatter in design temperatures, a typical design temperature of [280°F (138°C)] was selected as being most applicable.

Table 4. Composite, accident, design, and capacity predictions

Plant	Design			Predicted Ultimate Capacity		
	Pressure (psig)	Temperature [°F (°C)]		Pressure (psig)	Temperature [°F (°C)]	
BWR-Mark I						
Dresden 2	62	281	(138)			
Oyster Creek	62	281	(138)			
Millstone	62	281	(138)			
Arnold	56	281	(138)			
E. Fermi 2	56	281	(138)			
Browns Ferry	56	281	(138)	117	375	(191)
BWR-Mark II		Drywell Sup.Cham.				
Zimmer	45	340	(171)			
LaSalle	45	340	(171)			
WPPSS 2	—	—	—	133		
BWR-Mark III						
Perry 1				100		
Grand Gulf				52		
MK III Standard	15			56		
PWR-Ice Condenser						
Sequoyah	10.8	220	(104)	60	250	(121)
McGuire	15	190	(88)	84	250	(121)
Watts Bar	13.5	220	(104)	120	350	(177)
PWR-Subatmosphere						
North Anna	45	280	(138)			
PWR-Large Dry						
R.E. Ginna						
Palisades	55	283	(139)			
Diablo Canyon	47	246	(119)			
St. Lucie	39.6	274	(134)	95		
Midland	70	120	(49)			
Rancho Seco	59	286	(141)			
Zion	47	271	(133)	125	325	(163)
J. M. Farley	54	220	(104)			
Songs 2&3	60	300	(149)			
ANO 2	54	300	(149)			
Summer	57	283	(139)			
Comanche Peak	50	280	(138)			
Cherokee				116		
Indian Point				118	350	(177)
Bellefonte				130	350	(177)
Maine Yankee				96		
Byron/Braidwood				99		

Review of Severe Accident Sequence Analysis (SASA) predictions show there are accident scenarios which challenge the ultimate capacity of all the containments studied. Using Table 4, the ultimate pressure capacity of a typical containment was selected to be 120 psig. Due to the limited temperature predictions available, the approximate saturation temperature for 120 psig [350°F (177°C)] was used to bound the severe accident.

Valve manufacturers' published specifications were reviewed for elastomers used for sealing their nuclear application valves and for material property limits with respect to temperature and pressure for those elastomers. The review determined ethylene propylene terpolymer (EPT) to be the most common elastomer used in nuclear purge valves. EPT is a generic material designation. Exact compounding for final properties is determined by the seal manufacturer. Typically, valve manufacturers specified a normal maximum temperature of 300°F (149°C) and one manufacturer specified a faulted temperature of 350°F (177°C). Maximum pressure varied from 100 to 200 psig.

From these investigations, it appears that DBA parameters of 60 psig at 280°F (138°C) are well within the manufacturer's specified limits, and severe accident parameters of 120 psig at 350°F (177°C) are at or slightly above manufacturers' specified limits. A further review of the EPT seal literature determined that the material is not moisture sensitive; however, it is sensitive to compression set. A dry heated gas was then chosen over steam for the test media as it would provide the most sensitive leakage measurement.

A combined test was the initial test specified, (see Appendix B, B-3). The design basis and severe accident leak tests were combined into a single test. Temperatures and pressures were increased from ambient to design basis levels with a hold period, and then increased to severe accident levels with a second hold period. Valve No. 1 was exposed to this test. The valve leaked a small amount during the test (see leak integrity history for Valve No. 1 in this section for results). After cooldown, an ambient temperature leak test was performed and the valve exhibited gross leakage. Posttest discussion with valve manufacturers revealed this leakage after cooldown was not a surprise. The probable cause was compression set of the EPT seal material due to thermal expansion during the test. The combined design basis-severe accident elevated temperature leak test did not establish the temperature threshold where thermal expansion was great enough to cause a permanent compression set (that temperature where the elastomer seal is permanently reshaped, thus reducing the interference fit between the metal and elastomer seal when cooldown starts to take place). Following this first test, the test scenario was divided into two separate tests (see Appendix B, B-4 and B-5). A new seal was installed in the first valve and subjected to the design basis elevated temperature leak test conditions only. The remaining two valves in the program were exposed to the two separate test scenarios.

Valve leak integrity was monitored throughout the test program. The valves were leak tested as a part of the receiving inspection procedure at the test laboratory, and after each significant part of the dynamic testing. These tests were performed at ambient temperature with three test pressure levels (3-5, 50, and 125 psig) applied to each side of the disc face. The alternate side of the disc was monitored for leakage. To ensure the disc was centered (fully closed), a physical measurement was taken from the valve flange to the disc face from both sides of the disc. The valve shaft was locked to prevent rotation of the disc when pressure was applied. The following is the leak integrity history of the three test valves.

Leak Integrity History, Test Valve No. 1

Valve Description

Eight inch nominal pipe size, ANSI 150 pound class, in-line flanged, offset disc butterfly valve. EPT elastomer seals with the elastomer seat located in the body. Originally purchased by the Washington Public Power Supply System for CIS application in WPPSS-4. ASME Code Class II "N" stamped.

History

Valve was designed in 1977, manufactured in 1979, and delivered to WPPSS in late 1979 or early 1980. The valve was purchased from WPPSS-4 in 1983 for the purge valve test program.

Receiving Inspection

The valve was visually inspected for damage. No damage was noted. The valve was received from

WPPSS in the fully-closed position. The valve operator was removed and the valve operated manually to check for smoothness of operation. The valve functioned normally.

The valve disc was closed, the shaft locked to prevent rotation, and the valve subjected to a standard ambient temperature leak test the results of this test are presented in Table 5.

Due to the excessive leakage, the test was suspended at 100 psig. The downstream flange was removed, 5 psig reapplied to the nonshaft side of the disc and a leak test solution applied to the shaft side of the disc. A visual inspection revealed that the valve was leaking around the disc-seat seal in an area from about 9 to 12 o'clock (as viewed from the shaft side of the disc with the actuator vertical) around the circumference. The upstream flange was removed and a strong light shone on the leakage area. Light could be seen on the other side of the disc. The valve seal was replaced with a new seal, manufactured in 1983. The valve was releak tested using the standard ambient temperature leak test procedure. The valve had zero leakage at all pressures and disc sides, except the shaft side leaked two small bubbles after five minutes when pressurized to 125 psig.

Functional Leak Test Results. The valve was then moved to the dynamic test area for initial cycling and flow testing. Several times during dynamic testing, the valve was leak tested with no leakage noted at any pressure or disc face. At the completion of dynamic flow testing, the valve was moved to the elevated temperature leak test area.

With Valve No. 1 only, the design basis and the severe accident elevated temperature leak tests were combined without a cooldown in between. The original review of the seal material specifications indicated the temperatures and pressures were within the allowable limits for the seal material. After the first test, where leakage values increased after cooldown, the tests were separated. The results of the combined elevated temperature leak test and the postelevated temperature ambient temperature leak test are presented in Tables 6 and 7 respectively.

At the completion of the postelevated temperature ambient temperature leak test, the elastomer seal was measured for roundness while still installed in the valve. Figure 25 shows the resulting out-of-round condition, which is assumed to be due to permanent set of the elastomer.

The seal was replaced with a new seal manufactured in 1983. The valve was set up for a standard ambient temperature leak test. The flange was installed on the nonshaft side of the disc and pressurized. A leak-test solution was used to check the new seal prior to performing the complete leak test. Leakage was found to be coming from around the metal seat next to the disc and through the pins which attach the disc to the shafts. Both the metal seat to the disc and the pin to the shaft joints have EPT O-rings and all were leaking. The three O-rings were replaced after which the valve passed the standard ambient temperature leak test with zero leakage noted.

The valve was then subjected to a design basis elevated temperature leak test and a postdesign

Table 5. Standard ambient temperature leak test, test valve No. 1

Pressure Applied (psig)	Side of Valve Disk Pressurized	Leak Rate
3-5	Nonshaft side	41.5 SCFH[a]
50	Nonshaft side	210 SCFH
100	Nonshaft side	505 SCFH

a. SCFH (standard cubic feet per hour)

Table 6. Combined elevated temperature leak test, test valve No. 1

Pressure Applied (psig)	Side of Valve Disk Pressurized	Valve Temperature [°F (°C)]		Leak Rate
60	Shaft side	285	(141)	0
60	Nonshaft side	285	(141)	58 cm^3/min
60	Nonshaft side	310	(154)	84 cm^3/min
90	Nonshaft side	310	(154)	32 cm^3/min
90	Shaft side	310	(154)	0
90	Shaft side	350	(177)	0
120	Shaft side	350	(177)	0
120	Shaft side	—	—	—[a]

a. This step omitted in error.

Table 7. Postelevated temperature ambient temperature leak test, test valve No. 1

Pressure Applied (psig)	Side of Valve Disk Pressurized	Leak Rate
3-5	Nonshaft side	0
3-5	Shaft side	0
50	Nonshaft side	52 SCFH
50	Shaft side	90 cm^3/5 min
125	Nonshaft side	36 SCFH
125	Shaft side	100 cm^3/5 min

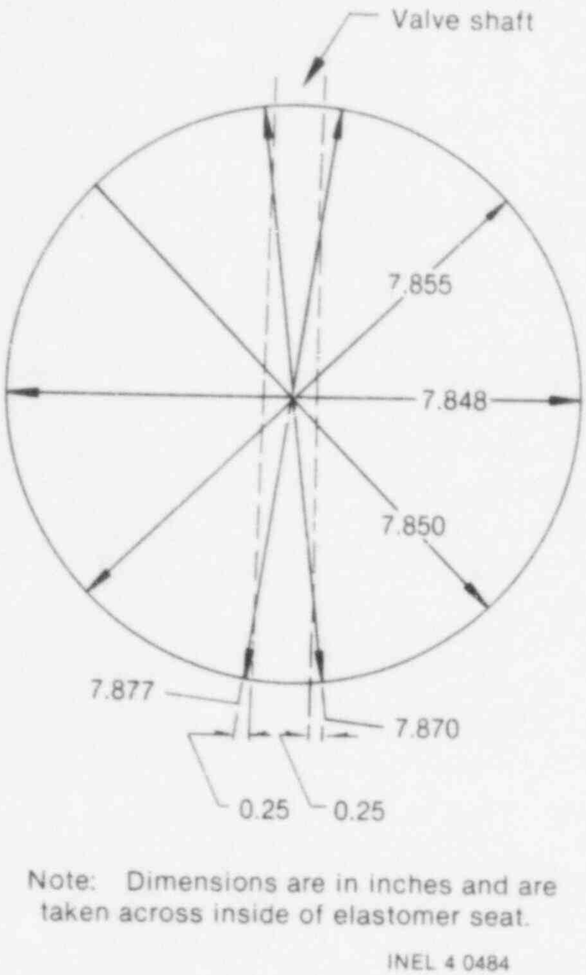


Figure 25. Out-of-roundness of valve seat.

basis ambient temperature leak test following cooldown. The results of these tests are presented in Tables 8 and 9 respectively.

Leak Integrity History, Test Valve No. 2

Valve Description

Eight inch nominal pipe size, ANSI 150 pound class, in-line flanged, offset disc butterfly valve. EPT elastomer seals with the elastomer seat located in the disc. The valve is of nuclear design, originally purchased for this test series.

History

The valve was manufactured in 1983 for testing without a valve operator.

Receiving Inspection

The valve was visually inspected for damage. No damage was noted. The valve was found to have been shipped with the disc 3 to 5 degrees open which is per manufacturer's recommendations. No operator was ordered with the valve. The dynamic flow tests required a special operator for measuring closing torques. The valve was manually operated to check for smoothness of operation. The valve functioned normally. The valve was set up for a standard ambient temperature leak test. No leakage was noted.

Functional Leak Test Results. The valve was leak tested several times during dynamic testing with no leakage noted.

Table 8. Design basis elevated temperature leak test, test valve No. 1

Pressure Applied (psig)	Side of Valve Disk Pressurized	Valve Temperature [°F (°C)]	Leak Rate
60	Shaft side	280 (138)	1 cm^3/min^a
60	Nonshaft side	280 (138)	1 cm^3/min^a

a. Leakage was detected in the last 30 minutes.

Table 9. Postdesign basis ambient temperature leak test, test valve No. 1

Pressure Applied (psig)	Side of Valve Disk Pressurized	Leak Rate
3-5	Nonshaft side	0
3-5	Shaft side	0
50	Nonshaft side	0
50	Shaft side	70 SCFH
125	Nonshaft side	0
125	Shaft side	470 SCFH

NOTE: The valve was refurbished after this test for additional flow testing.

The valve was given a standard ambient temperature leak test prior to design basis elevated temperature leak testing. No leakage was noted. The valve was then subjected to the design basis elevated temperature leak test, which resulted in zero leakage at all test temperatures and pressures. The postdesign basis ambient temperature leak test was performed which resulted in zero leakage at all test pressures or valve orientations. Without changing the elastomer seal, the valve was subjected to the severe accident elevated temperature leak test. The valve completed the severe accident elevated temperature leak test as well as the post severe accident ambient temperature leak test with zero leakage noted at all test temperatures, pressures and valve orientations.

Leak Integrity History, Test Valve No. 3

Valve Description

24 inch nominal pipe size, ANSI 150 pound class, in-line flanged, offset disc butterfly valve. EPT elastomer seals with the elastomer seat located in the disc. The valve is of nuclear design originally purchased for this test series.

History

The valve was manufactured in 1983 for testing without a valve operator.

Receiving Inspection

The valve was visually inspected for damage. No damage was noted. The valve was shipped with the disc 3 to 5 degrees open which is per manufacturer's recommendations. The valve was liberally coated with what appeared to be a zinc primer. Several areas of the sealing surface required that the primer be cleaned off. No operator was purchased with the valve. The dynamic flow tests required a special operator for measuring closing torques. The valve was operated manually to check for smoothness of operation. The valve functioned normally.

The valve was set up for a standard ambient temperature leak test. The results are shown in Table 10.

This type of valve has a ring which retains the seal on the disc (see Figure 2). The proper seal load is attained by tightening the screws holding the retaining ring. The seal was adjusted per manufacturer's recommendations without improvement in leakage. A representative from the manufacturer inspected the valve and determined the disc was shimmed incorrectly. The disc was reshimmed, after which it passed the leak test with zero leakage at all pressures and disc sides. The valve had a certified leak test from the vendor prior to shipment. The leak and disc shimming were discussed with the vendor. From these discussions, it appears that the

Table 10. Standard ambient temperature leak test, test valve No. 3

Pressure Applied (psig)	Side of Valve Disk Pressurized	Leak Rate
3-5	Nonshaft side	0
3-5	Shaft side	0
50	Nonshaft side	0
50	Shaft side	0
125	Nonshaft side	0
125	Shaft side	25.5 SCFH

disc was very close to having been in the proper position as leakage occurred only at the highest pressure. The vendor leak test was performed with the valve shaft horizontal and the leak tests in this program were performed with the valve shaft vertical. The weight of the 24 inch disc on the lower shims was sufficient to relax the seal tension on the top of the disc and there was not enough adjustment in the seal to make up for it. Leak tests performed during the dynamic flow test resulted in no leakage at all pressures and valve orientations.

Functional Leak Test Results. At the conclusion of the dynamic flow tests, a standard ambient temperature leak test was performed with no leakage noted.

The design basis elevated temperature leak test and the postelevated temperature ambient temperature leak test were performed with no leakage noted.

The severe accident elevated temperature leak test was performed without changing the elastomer seal. The results are shown in Table 11.

The ambient temperature leak test was performed after cooldown. The results are shown in Table 12.

Table 11. Severe accident elevated temperature leak test, test valve No. 3

Pressure Applied (psig)	Side of Valve Disk Pressurized	Valve Temperature [°F (°C)]		Leak Rate
60	Nonshaft side	285	(141)	0
60	Nonshaft side	310	(154)	0
90	Nonshaft side	310	(154)	0
90	Shaft side	310	(154)	0
90	Shaft side	350	(177)	0
120-90[a]	Shaft side	350	(177)	2 cm^3/min
120	Nonshaft side	350	(177)	Sporadic

Pressurization of the nonshaft side of the disc did not result in continuous leakage, the leakage was on an intermittent basis.

a. When the 350°F (177°C) temperature was reached and the pressure increased from 90 to 120 psig on the shaft side of the disc, the valve stem packing leakage was excessive. The pressure was reduced to 90 psig to finish the 350°F (177°C) hold period on the shaft disc face. At 90 psig and 350°F (177°C) the packing leak was minimal.

Table 12. Postelevated temperature ambient temperature leak test, test valve No. 3

Pressure Applied (psig)	Side of Valve Disk Pressurized	Leak Rate
3-5	Nonshaft side	0
3-5	Shaft side	0
50	Nonshaft side	0
50	Shaft side	38 SCFH
125	Nonshaft side	0
125	Shaft side	320 SCFH

CONCLUSIONS

The conclusions from the containment purge and vent valve testing are presented as follows:

Conclusions for the Dynamic Flow Tests

Two eight inch and one 24 inch ANSI 150 pound class, offset disc, elastomer seated, high aspect ratio butterfly valves were tested. Three valves were initially selected to provide insights into how the valves respond. The three valves initially selected to provide butterfly response understanding were 150 lb ANSI design. This design was selected to provide the highest magnitude torque response. The worst case response would provide a bounding technology or a means for a conservative assessment of the mostly completed utility valve submittals. The response of the three valves was found to be the same in the positive torque orientation, including worst case geometric effects. Consequently, three valves were felt to provide a sufficient sample size from which to draw conclusions relative to their response and relative to extrapolability of the performance of a scale model test valve to a larger valve.

In order to reasonably extrapolate the response of a larger valve from a scale model test valve, a geometric similarity must exist between the two valves with respect to disc shapes, aspect ratios and disc size to normal bore size ratios. The failure to insure this basic level of similarity could effectively render any extrapolation meaningless.

When a valve is in service, it could be installed in either orientation, i.e., shaft upstream or shaft downstream. The response of the valve is dependent on the orientation, however the absolute torque requirements are always larger when the valve is installed in the shaft upstream orientation. Consequently, torque measurements from a scale model test valve should be obtained with the valve in the shaft upstream orientation. This data, when extrapolated by the methods contained within this report, will overpredict the torque requirements of the larger valve, irrespective of its orientation in the system.

Scale model valve testing for use in a gaseous service will usually be performed with the most readily available gas, such as air, nitrogen or steam, irrespective of the gas which will exist in the actual installation. The effect of density variations between the various gases has been evaluated and the resultant variation in torque has been shown to be insignificant provided each gas is at the same pressure and temperature. Consequently, to insure that the effect of density does not affect the test results, valve testing should be performed at or above the maximum anticipated large valve inlet pressure and at or below the maximum anticipated large valve inlet temperature.

Subsequent to scale model valve testing in accordance with the above guidelines, the total torque requirements of the larger valve can be estimated by multiplying the scale model valve dynamic torque at the pressure, temperature and valve position in question, by the cube of the larger valve diameter to smaller valve diameter ratio. From this value, an approximation of the larger valve bearing torque at the same pressure, temperature and position is subtracted. The result will overestimate the larger valve torque requirements and can be used to insure that the valve actuator is adequately sized. An acceptable alternative to the above method is to use the scale model valve total torque plus the scale model valve bearing torque instead of the scale model valve dynamic torque.

Either of the above methods has been shown to overestimate the total torque for a larger valve provided the system geometry upstream of either valve does not contain any bends. If the actual system contains an upstream elbow, either of the above methods can be used to overestimate the total torque for a larger valve provided the estimate is multiplied by 1.5. This accounts for the potential increase in total valve torque resulting from nonuniform flow entering the valve.

Finally, the results of both the eight inch and the 24 inch valves were used to estimate the maximum torque requirements of a 48 inch valve using the above methods. Using the eight inch valve results as the scale model test valve implies a 600% extrapolation whereas using the 24 inch valve results as the scale model test valve implies a 200% extrapolation. The results of both extrapolations were compared and found to be extremely different, not so much in shape but in magnitude. The results of this extrapolation comparison implies that a limit to extrapolability may exist. ANSI B16.41-1983

addresses the issue of an extrapolation limit when qualifying a valve from a scale model test valve. This standard limits qualification of a valve unless it is within 50 to 200% of the test valve.

The other standards applicable to valve qualification which were reviewed do not address this issue. Consequently, since a limit to extrapolability appears to be necessary and since the limits of B16.41-1983 cannot be refuted, the above method for estimating the response of a larger butterfly valve from the response of a scale model test valve should be limited to valves which do not exceed 50 to 200% of the scale model test valve size.

Conclusions for the Leak Integrity Testing

The sample of valve sealing material in this program was small: two manufacturers, two designs, and four seals. Seal material of ethylene propylene terpolymer (EPT) is used by most butterfly valve manufacturers in elastomer sealed purge valve applications and is very close to its material properties limits when subjected to elevated temperatures as experienced in these tests at severe accident conditions [350°F (177°C), 120 psig].

A review of the properties for EPT reveals the material is susceptible to compression set. The material specification allows up to 20% compression set. Thermal expansion experienced at elevated temperature can increase the compression the seal is experiencing in the closed position for sealing purposes. This additional compression can exceed material limits. The seal design can also be an influence in the amount of compression experienced. The smaller the cross section, the less the seal will be compressed during thermal expansion. Any compression set will reduce the interference fit between metal and EPT seal, lowering the leak threshold. Leakage after cooldown from design basis accident exposure was experienced by one valve type and by two valves after severe accident exposure. Longer exposure to the temperature loading than experienced in these tests may cause all EPT seals to leak.

RECOMMENDATIONS

The following recommendations are offered as a result of the containment purge and vent valve test program.

Dynamic Flow Test Recommendations

The results of testing efforts to date partially answer the question of: Will all nuclear plant containment purge and vent valves close as required during a design basis loss-of-coolant accident? The testing program was designed, with limitations, to bound the question into the area of greatest interest and most usefulness. The program succeeded in generating test data useful in answering concerns regarding plant safety but restricted in application in accordance with testing limitations. It uncovered a number of technical questions which have not been answered but which may not require answers based on the standpoint of plant safety. The best way to determine if these technical questions should be answered and if there are other unanswered safety questions is to complete an accurate survey of existing operational nuclear plant containment vent and purge valves. This survey should include the following information for all valves and operators:

manufacturer
model number
size
disc style
valve orientation to flow
seal design and material
operational status (open, closed, blocked, etc.)

This tabulation is essential in determining if further testing of different valve sizes and kinds is warranted. Efforts resulting from all other recommendations described in this section are dependent upon the completion of this survey.

If further effort is needed, the following recommendations will provide answers to technical and safety questions identified by testing to date. These recommendations are influenced by the following significant considerations.

The valves tested in this program were modern nuclear designed, 150 pound class ANSI valves. The valves are representative by manufacturer and

sealing configuration of most of the elastomer seal valves installed in nuclear containments. They are not representative of all of the valve internal designs with respect to aspect ratio and disc offset. They do however represent the worst case aspect ratio with respect to dynamic torque response and they do represent the style of elastomer seal replacement valves.

The ratio of the inside diameters of the valves tested in this program (eight to 24 inch) are outside of the extrapolation proportionality limits suggested by ANSI B16.41 Annex J which are 50 to 200% of nominal piping diameter plus other similarity of construction requirements. These requirements, however, are waived for flow interruption testing by Annex G. This Annex allows infinite extrapolation if the known valve response is 8 inches or greater. The results of this program indicate that for butterfly valve response this exception may be marginal.

In summary, the following recommendations will expand the application of data and close any of the gaps identified by the testing performed in this program to date. However, a valve survey must first be completed to determine the extent of further research and to assure that additional testing will answer any remaining safety issues.

1. The results obtained in this report are based in part on the assumption that two of the valves tested, one of the eight inch valves and the 24 inch valve (valves 2 and 3, respectively), which were manufactured by the same company and are of the same class type, are scale models of each other. The internals of these valves are similar but not identical to each other. Consequently, the differences in response observed between these valves may be due in part to the internal differences in geometry. This is believed to be a second order effect but these types of differences would be most important in projecting the response of a larger valve from a small model test valve. One of the results of this work was that the performance of a scale model test valve can only be used to extrapolate the performance of larger valves provided the size of the larger valve does not exceed the size of the scale model test valve by more than 200%. Additional testing with specially manufactured scale model test valves would provide additional insight into the above extrapolation limit issue.

2. The conclusions concerning extrapolation arrived at in this report are the result of, in part, estimating the effect of bearings, packings, and seats on the torque requirements of a valve in accordance with industrial standards. A more accurate accounting of these effects could extend or reduce the extrapolation limits recommended in this report, as contained in ANSI B16.41-1983, "Functional Qualification Requirements for Power Operated Active Valve Assemblies for Nuclear Power Plants."

3. The results of this program have presented an extrapolation technique for predicting the response of a large valve from a scale model test valve. The results also indicate that extrapolation of torque requirements may not be possible if the actual valve is more than twice the size of the test valve. The extrapolation theory should be improved to cover a larger extrapolation range provided a survey of the valves in service indicates the need for a larger extrapolation range.

4. While evaluating the techniques various manufacturers use to obtain scale model test data, it was observed that some manufacturers obtained data with a stationary disc whereas others obtained data with a moving disc. Since the effect of disc movement or movement at different rates could influence the resultant flow field and hence the resultant data, the effect of a stationary disc versus a disc moving at various rates should be evaluated.

5. During our review of published data on valve performance extrapolation techniques prior to initiating the testing discussed in this report, the work done by Allis Chalmers at NASA-Langley was evaluated and the results factored into our test program. The results of this work are also used by the industry in general, when applicable. One result which influenced our testing of ANSI high aspect ratio valves was the conclusion that the higher

the aspect ratio, the higher the torque. Our testing program included two eight inch valves, admittedly manufactured by different vendors. However, the valve which produced the higher torque was not the valve with the highest aspect ratio. Since the conclusion arrived at by the Allis Chalmers work cannot be verified to date, and may impact bounding torque calculations, the influence of aspect ratio on the torque for various valve sizes and types of designs should be investigated.

6. The valves flow tested to date have been ANSI 150 pound class, offset disc, elastomer sealed, high aspect ratio butterfly valves. A substantial number of valves are in service in containment vent and purge systems which fall outside this category. These include symmetric disc valves, low aspect ratio valves and the tricentric valves manufactured by the Clow Corporation. The response characteristics of these valves are not well known and the torque extrapolation techniques for these lower aspect ratio or offset disc valves have not been evaluated.

7. Commercial nuclear power plants are required to establish double isolation in the event of a potential accident. Consequently, there are typically two butterfly valves in series for every containment vent and purge penetration. During a suspected accident, both valves would be activated simultaneously. The effect of valves in series on the torque requirements of either butterfly valve are not known. Since the influence of a valve in series could act much like an upstream elbow and increase the torque requirements of the valve to close, additional testing should be performed to better understand and evaluate this phenomena.

8 The results of the test program to date have been obtained when the butterfly valve was, for the most part, choked. The results do indicate that unchoked flow through the valve results in different flow characteristics although the peak torque appears to remain linear. An undetermined number of utilities are taking credit for early CIS valve closure which will occur at low containment pressures with unchoked flow conditions through the valve. The general response characteristics of an unchoked valve have not been obtained. Since the actual performance of a valve could be underpredicted or overpredicted when using choked flow test results, the phenomena of unchoked valve performance and torque requirements should be investigated further.

9. In the event of a severe accident after the isolation valves have successfully closed, it could become necessary to open a valve under high containment temperature and pressure conditions in order to perform a controlled depressurization of the containment. Opening the valves under these conditions would necessitate cycling the valves under high stress conditions which could cause the valve to bind. The ability of a valve to operate under these conditions should be investigated.

Leak Integrity Test Recommendations

1. The survey of industrial valve status as proposed in this report, will provide insights to valve designs and seal material options which were not tested in this program or in other research work. Testing of these other designs should be performed to determine leakage susceptibility in accident environments.

2. EPT as compounded for the various valve manufacturers should be studied for qualified life. From a very limited sample, a valve which had remained closed for several years caused permanent set of the seal and resulted in valve leakage.

3. Leakage models should be developed from the test results and extrapolated for all valves to determine the impact of purge and vent valve leakage in accident and postaccident environments.

APPENDIX A

TABULATED TEST RESULTS

DATA FOR VALVE NUMBER 1 POSITION NUMBER 1 FLAT FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.875 PIPE DIA. (IN) 7.981 ASPECT RATIO .2550

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			60 PSIG TEST NUMBER 1-1-1A							
90.	-85.06	63.58	71.46	39.33	24.21	44.22	53.57	49.73	33.17	.00
80.	-109.43	66.88	74.38	37.78	29.09	45.78	53.68	48.83	32.09	.00
70.	-125.27	77.42	83.63	50.79	26.63	44.10	52.58	48.29	31.73	.00
60.	-125.27	76.10	79.97	59.91	16.29	33.76	41.14	48.11	31.37	.00
50.	-123.45	75.88	78.13	69.43	6.45	31.90	31.28	48.29	30.29	.00
40.	-122.23	74.35	75.46	64.86	9.49	17.89	21.85	48.65	28.13	.00
30.	-110.65	73.03	73.53	61.24	11.79	14.78	14.53	49.01	27.59	.00
20.	-109.43	73.24	73.44	60.47	12.78	13.83	8.97	49.55	28.67	.00
10.	-103.34	72.37	72.38	59.65	12.72	12.76	1.76	49.91	31.19	.00
61.3	-129.54	76.19		56.56						
			10 PSIG TEST NUMBER 1-1-5							
90.	-45.13	23.16	25.59	14.37	8.79	19.68	17.77	61.07	.00	10.88
80.	-50.29	22.35	25.00	11.30	11.25	15.69	17.59	60.89	.00	10.95
70.	-51.58	25.18	27.21	13.08	12.10	14.32	16.95	60.71	.00	11.18
60.	-44.92	26.80	28.19	15.71	11.14	13.72	14.22	60.53	.00	12.07
50.	-40.62	28.31	29.05	16.68	11.63	13.68	10.87	60.53	.00	12.86
40.	-40.62	29.47	29.79	16.92	12.65	13.68	7.23	60.35	.00	13.37
30.	-42.13	30.25	30.35	16.69	13.58	13.68	4.06	60.53	.00	13.65
20.	-45.99	31.59	31.69	18.52	13.07	13.68	.00	60.53	.00	13.78
10.	-37.19	29.92	30.02	17.19	12.73	13.68	.00	60.71	.00	13.88
87.4	-54.80	22.80		14.00						
			15 PSIG TEST NUMBER 1-1-4							
90.	-39.83	27.31	30.30	19.04	8.27	23.76	21.72	45.59	.00	.00
80.	-58.49	26.88	29.88	14.78	12.10	18.51	21.61	45.41	.00	.00
70.	-65.42	31.75	34.29	16.80	14.95	17.40	21.54	45.05	.00	.00
60.	-54.20	29.98	31.59	19.36	10.62	13.72	16.73	45.05	.00	.00
50.	-43.26	29.75	30.58	18.91	10.83	13.63	11.99	44.87	.00	.00
40.	-39.83	29.53	29.84	17.58	11.95	13.63	7.30	44.87	.00	.00
30.	-41.97	29.98	30.06	16.66	13.31	13.76	3.81	44.87	.00	.00
20.	-43.69	30.20	30.28	17.54	12.66	13.76	.00	44.87	.00	.00
10.	-33.18	28.60	28.68	15.29	13.31	13.68	.00	44.87	.00	.00
68.1	-68.77	33.52		18.16						
			60 PSIG TEST NUMBER 1-1-1J							
90.	-111.61	66.60	74.12	46.72	19.88	57.44	53.40	52.97	.00	27.95
80.	-109.78	64.57	72.25	36.40	28.17	44.76	53.15	52.61	.00	27.67
70.	-117.10	75.81	82.28	39.91	35.90	41.67	52.89	52.25	.00	26.83
60.	-126.23	85.02	90.03	52.62	32.40	36.51	49.27	52.07	.00	21.93
50.	-120.29	84.83	87.85	65.88	18.95	26.79	38.21	52.07	.00	16.48
40.	-113.44	82.44	83.95	70.30	12.14	18.09	26.63	52.07	.00	11.02
30.	-111.61	79.67	80.37	71.03	8.64	14.11	17.88	52.07	.00	11.63
20.	-107.49	78.57	78.89	67.34	11.23	14.40	11.97	52.07	.00	12.81
10.	-98.81	80.05	80.17	67.91	12.14	14.11	7.47	52.25	.00	13.42
88.2	-132.14	66.24		46.35						

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
0 PSIG TEST NUMBER 1-1-0										
90.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-12.75	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-26.92	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 1 POSITION NUMBER 2 CURVED FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.875 PIPE DIA. (IN) 7.981 ASPECT RATIO .2550

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
60 PSIG TEST NUMBER 1-2-1										
90.	89.46	63.96	71.90	47.70	16.26	46.82	54.43	40.55	29.93	26.86
80.	115.05	68.63	75.74	51.07	17.56	44.74	53.40	40.01	29.03	24.34
70.	108.35	70.44	75.75	54.97	15.48	38.95	45.72	40.01	25.33	20.45
60.	79.71	72.91	76.43	55.48	17.43	31.71	38.74	40.01	24.53	16.17
50.	57.16	73.82	75.95	60.67	13.15	24.66	30.25	40.37	23.09	11.44
40.	35.83	73.17	74.28	66.63	6.54	18.46	21.74	40.91	21.83	11.33
30.	16.33	71.75	72.34	65.34	6.41	12.73	15.70	41.45	20.57	12.57
20.	-2.56	71.36	71.68	62.35	9.01	11.45	11.57	41.81	19.67	13.08
10.	-37.90	71.36	71.49	60.02	11.34	12.12	7.34	42.17	19.49	13.13
78.9	124.19	68.79		52.50						
60 PSIG TEST NUMBER 1-2-1A										
90.	101.68	72.36	81.16	54.07	18.29	52.17	61.00	40.19	26.51	29.99
80.	142.97	81.82	87.90	60.74	21.07	44.00	53.95	39.83	25.07	28.35
70.	123.09	83.74	87.64	65.04	18.71	35.57	43.67	39.65	23.27	23.89
60.	85.62	84.04	86.32	64.60	19.44	28.98	33.53	39.83	22.19	18.12
50.	60.40	83.74	84.89	70.66	13.08	20.11	23.63	40.01	20.93	12.40
40.	35.69	82.41	83.03	76.29	6.12	14.09	17.22	40.37	20.39	10.75
30.	11.47	80.19	80.52	74.81	5.38	10.02	12.32	40.73	19.67	12.27
20.	-9.18	80.05	80.18	72.00	8.05	9.34	7.96	41.27	19.31	13.26
10.	-45.11	79.02	79.03	68.44	10.57	10.70	2.82	41.81	19.31	13.74
75.2	155.96	83.74		65.63						
60 PSIG TEST NUMBER 1-2-1B										
90.	105.51	73.39	82.50	54.81	18.58	52.94	62.68	37.13	14.81	30.50
80.	135.32	80.34	87.63	60.89	19.45	48.20	58.71	36.59	13.91	27.85
70.	115.44	80.50	85.69	63.11	17.39	40.33	49.60	36.23	13.73	23.57
60.	81.80	80.93	84.11	61.34	19.59	32.12	38.89	36.23	14.27	17.67
50.	59.11	80.64	82.57	66.82	13.82	24.58	30.25	36.77	14.63	12.11
40.	30.58	80.05	80.96	72.45	7.60	16.77	20.70	37.13	15.17	11.39
30.	7.65	79.45	79.95	73.19	6.27	12.31	15.26	37.49	14.99	12.75
20.	-9.18	79.02	79.31	70.66	8.35	10.97	11.60	38.03	14.63	13.26
10.	-43.58	79.02	79.08	67.41	11.60	12.04	5.58	38.57	14.81	13.59
77.9	139.91	80.50		63.11						
60 PSIG TEST NUMBER 1-2-1C										
90.	108.26	74.54	83.73	55.71	18.83	53.69	63.67	34.07	13.01	30.99
80.	116.82	74.24	81.58	55.71	18.54	46.62	56.77	33.53	11.93	26.05
70.	107.65	74.69	79.92	56.45	18.25	38.69	48.08	33.17	11.21	21.55
60.	67.89	76.03	79.40	57.78	18.25	31.67	38.96	33.35	11.57	16.69
50.	47.09	76.46	78.29	62.53	13.94	23.54	28.77	33.53	12.11	11.73
40.	26.91	75.72	76.58	67.85	7.88	15.78	19.62	34.07	12.47	11.52
30.	9.18	74.54	75.09	68.30	6.24	12.53	15.59	34.43	12.11	12.49
20.	-11.62	74.54	74.73	66.22	8.31	9.94	9.15	34.97	12.11	13.24
10.	-42.20	75.87	75.91	63.35	12.02	12.26	4.19	35.51	12.11	13.53
76.7	127.21	74.27		56.00						

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
				5 PSIG TEST NUMBER 1-2-6						
90.	10.82	18.35	20.45	6.19	12.15	16.68	14.99	41.45	.00	11.78
80.	11.33	18.99	21.02	6.77	12.21	17.97	14.99	41.27	.00	11.59
70.	15.24	20.00	21.51	9.54	10.46	13.92	13.27	41.09	.00	12.21
60.	2.64	20.22	21.13	9.64	11.57	13.95	10.63	41.09	.00	12.79
50.	-6.48	20.58	21.05	7.98	12.60	14.10	7.54	40.91	.00	13.24
40.	-12.57	20.75	20.94	7.73	13.02	14.01	4.67	40.91	.00	13.52
30.	-15.83	20.97	21.02	7.86	13.11	13.94	2.34	40.91	.00	13.62
20.	-17.57	20.09	20.09	7.44	12.65	13.85	.66	40.91	.00	13.68
10.	-22.56	19.39	19.40	5.87	13.50	13.82	.00	41.09	.00	13.71
75.5	13.71	20.23		9.05						
				10 PSIG TEST NUMBER 1-2-5						
90.	26.67	23.00	25.81	10.67	12.33	16.37	19.09	58.19	.00	10.41
80.	23.95	25.12	27.69	13.62	11.50	19.15	19.09	57.65	.00	10.52
70.	29.13	28.51	30.50	18.39	10.12	14.21	17.86	57.47	.00	10.75
60.	10.37	25.90	27.03	14.62	11.28	14.53	12.83	57.29	.00	12.20
50.	-.99	25.12	25.72	12.88	12.24	14.16	9.22	57.11	.00	13.15
40.	-8.89	25.63	25.86	12.79	12.84	13.91	5.82	57.11	.00	13.49
30.	-14.82	24.95	24.91	12.60	12.24	13.85	2.95	57.11	.00	13.62
20.	-17.53	24.38	24.39	11.55	12.84	13.85	.82	57.11	.00	13.72
10.	-25.43	24.34	24.34	10.53	13.81	13.85	.00	57.11	.00	13.74
71.7	31.54	28.89		17.61						
				15 PSIG TEST NUMBER 1-2-4						
90.	32.32	27.21	30.38	13.02	14.18	19.12	22.13	54.59	.00	11.86
80.	33.35	28.31	31.36	15.72	12.59	20.99	22.13	54.23	.00	11.60
70.	38.68	32.42	34.80	22.93	9.49	15.74	20.97	53.87	.00	10.76
60.	23.83	33.56	35.23	23.00	10.57	15.30	17.75	53.69	.00	10.85
50.	12.48	35.19	36.14	23.51	11.68	14.90	13.78	53.69	.00	12.21
40.	2.35	36.03	36.48	24.54	11.49	14.34	9.59	53.69	.00	13.11
30.	-6.86	35.95	36.13	24.67	11.28	14.05	5.97	53.69	.00	13.40
20.	-14.53	38.28	38.31	25.76	12.52	13.79	2.82	53.69	.00	13.60
10.	-24.35	33.97	33.97	22.74	11.23	13.75	.71	53.87	.00	13.71
68.6	42.47	32.46		23.05						
				0 PSIG TEST NUMBER 1-2-0						
90.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-12.75	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-26.92	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 1 POSITION NUMBER 3 FLAT FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.875 PIPE DIA. (IN) 7.981 ASPECT RATIO .2550

60 PSIG TEST NUMBER 1-3-1

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
90.	-101.05	73.03	85.77	40.29	32.74	60.53	74.21	33.53	22.73	35.71
80.	-96.22	75.52	87.17	43.55	31.97	58.97	72.20	32.99	22.01	32.46
70.	-101.57	77.51	85.60	51.40	26.11	49.56	60.96	32.81	21.47	26.11
60.	-107.11	78.35	83.48	58.07	20.28	39.61	48.81	32.53	20.75	19.30
50.	-113.16	78.51	81.31	62.82	15.69	29.31	36.09	32.81	19.13	14.13
40.	-116.79	77.02	78.51	65.18	11.84	21.27	26.15	32.99	16.97	10.12
30.	-112.55	75.68	76.34	65.34	10.34	14.95	17.13	33.35	14.99	12.20
20.	-106.50	74.52	74.84	63.41	11.11	13.15	11.79	33.53	15.17	13.17
10.	-90.17	75.66	75.78	62.82	12.86	13.42	6.64	33.89	16.97	13.60
38.6	-122.83	76.86		65.63						

0 PSIG TEST NUMBER 1-3-0

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
90.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-12.75	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-26.92	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 1 POSITION NUMBER 4 CURVED FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.875 PIPE DIA. (IN) 7.981 ASPECT RATIO .2550

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			60 PSIG TEST NUMBER 1-4-1							
90.	111.17	73.46	85.52	38.52	34.94	59.77	71.89	40.73	30.29	34.88
80.	170.27	77.80	88.08	52.14	25.66	56.18	68.37	40.01	29.57	29.96
70.	140.25	78.31	85.04	57.78	20.52	45.64	55.53	39.65	28.31	22.76
60.	87.71	78.31	82.46	59.55	19.75	35.67	43.61	39.47	27.23	17.39
50.	59.57	78.13	80.41	63.56	14.58	26.45	32.28	39.47	25.43	11.88
40.	35.18	76.64	77.83	68.44	8.19	18.99	23.13	39.65	22.73	11.43
30.	15.42	75.13	75.74	69.63	5.50	13.50	16.36	39.83	20.21	12.34
20.	-3.28	74.80	75.05	63.11	11.69	13.27	10.60	40.37	18.95	13.26
10.	-30.49	77.46	77.54	63.70	13.76	14.16	5.75	41.09	18.23	13.52
82.7	177.77	77.46		48.95						
			0 PSIG TEST NUMBER 1-4-0							
90.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-12.75	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-26.92	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 1 POSITION NUMBER 5 FLAT FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.875 PIPE DIA. (IN) 7.981 ASPECT RATIO .2550

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			60 PSIG TEST NUMBER 1-5-1							
90.	-115.74	72.91	85.23	42.08	30.84	58.67	71.47	53.51	30.83	34.81
80.	-104.63	74.24	86.13	37.19	37.06	59.81	70.88	53.15	30.29	33.62
70.	-107.71	77.20	85.55	43.13	34.07	52.15	60.58	52.61	30.29	26.14
60.	-110.80	78.25	83.40	51.40	26.95	41.23	47.95	52.25	30.65	19.30
50.	-118.21	78.39	81.15	59.55	18.84	29.86	35.14	51.71	31.19	13.53
40.	-120.68	77.80	79.20	63.41	14.39	21.70	25.00	50.99	31.91	10.31
30.	-112.66	75.67	76.53	64.30	11.57	15.74	16.91	50.27	33.17	12.21
20.	-104.01	74.39	74.77	63.41	10.98	13.50	12.79	49.91	30.89	13.00
10.	-102.78	73.95	74.03	61.63	12.33	12.76	5.58	49.19	34.79	13.59
89.6	-131.29	73.06		41.84						
			0 PSIG TEST NUMBER 1-5-0							
90.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-12.75	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-26.92	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 1 POSITION NUMBER 6 CURVED FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.875 PIPE DIA. (IN) 7.981 ASPECT RATIO .2550

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			60 PSIG TEST NUMBER 1-6-1							
90.	112.91	73.65	84.83	44.29	29.36	56.82	68.98	45.59	34.97	33.76
80.	147.69	78.10	87.76	50.66	27.44	54.34	66.05	44.87	34.25	29.31
70.	120.02	78.10	64.42	59.41	18.70	44.53	53.44	44.33	34.07	23.28
60.	75.74	78.39	82.27	61.63	16.77	34.56	41.98	43.97	34.61	17.13
50.	49.65	78.39	80.57	68.15	10.24	26.55	31.42	44.15	34.43	12.01
40.	21.19	77.20	78.23	71.11	6.09	18.81	21.43	44.69	32.81	11.36
30.	1.42	75.72	76.34	71.11	4.61	14.49	16.45	44.87	31.91	12.21
20.	-13.60	74.98	75.23	63.41	11.57	13.11	10.27	45.23	32.09	13.20
10.	-47.59	76.77	76.83	63.85	12.92	13.29	5.29	45.95	33.35	13.52
57.0	160.35	78.28		62.41						
			0 PSIG TEST NUMBER 1-6-0							
90.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-11.84	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-12.30	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-12.75	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-26.92	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 2 POSITION NUMBER 1 FLAT FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.250 PIPE DIA. (IN) 7.981 ASPECT RATIO .3280

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			60 PSIG TEST NUMBER 2-1-1							
90.	-56.00	79.79	83.96	71.18	8.60	45.04	43.39	56.39	26.33	14.14
80.	-79.43	77.19	81.03	67.53	9.66	38.44	40.98	55.13	23.45	18.16
70.	-85.00	76.41	79.39	67.37	9.04	32.68	36.02	53.87	20.93	11.17
60.	-87.43	76.03	77.92	68.28	7.75	25.03	28.59	53.15	18.23	7.75
50.	-84.00	76.03	77.19	70.27	5.76	20.00	22.42	52.61	16.61	5.53
40.	-77.72	76.54	77.10	70.88	5.66	12.76	15.72	52.43	15.35	11.63
30.	-60.57	78.22	78.47	69.36	8.86	10.91	10.56	52.61	16.07	12.75
20.	-51.43	79.65	79.70	67.53	12.13	12.39	4.41	52.79	18.77	13.33
10.	-22.29	69.15	69.19	61.44	7.72	7.88	.00	53.15	22.19	10.31
60.4	-92.02	76.03		68.28						
			60 PSIG TEST NUMBER 2-1-1A							
90.	-53.18	81.08	85.15	72.37	8.70	44.35	43.48	50.09	19.49	14.65
80.	-77.40	76.41	80.01	66.28	10.12	35.60	39.75	48.65	16.79	18.48
70.	-83.74	76.41	79.25	67.05	9.35	31.06	35.36	47.57	14.27	10.57
60.	-77.65	76.28	78.19	68.41	7.86	25.06	28.92	46.67	12.11	7.63
50.	-79.18	76.14	77.21	70.10	6.05	18.52	21.65	46.49	10.31	6.61
40.	-71.81	76.03	76.56	70.55	5.48	12.34	15.30	46.49	9.41	11.89
30.	-53.78	79.00	79.25	69.63	9.37	11.28	10.54	46.49	9.77	12.82
20.	-48.19	79.65	79.71	69.79	9.86	10.30	5.14	46.67	12.65	13.39
10.	-19.24	70.44	70.45	60.50	9.95	9.98	1.30	46.85	16.07	13.69
72.6	-88.32	76.29		67.96						
			5 PSIG TEST NUMBER 2-1-6							
90.	-8.08	18.[illegible]7	19.10	6.67	11.60	15.10	9.22	61.43	.00	12.97
80.	-4.98	18.11	19.52	5.27	12.44	14.32	9.22	61.25	.00	12.95
70.	-5.62	19.56	20.20	6.67	12.91	14.04	8.22	61.25	.00	13.10
60.	-6.15	19.97	20.34	5.89	13.08	14.00	6.39	61.25	.00	13.39
50.	-5.83	20.25	20.42	6.89	13.36	14.00	4.43	61.25	.00	13.59
40.	-5.52	20.81	20.87	7.09	13.72	14.00	2.62	61.25	.00	13.69
30.	-6.48	21.22	21.23	7.60	13.62	14.00	1.06	61.25	.00	13.75
20.	-6.37	19.15	19.15	5.96	13.19	14.00	.18	61.25	.00	13.78
10.	-6.69	19.30	19.30	5.66	13.65	14.00	.00	61.25	.00	13.78
68.0	-11.32	20.41		4.53						
			10 PSIG TEST NUMBER 2-1-5							
90.	-12.04	22.45	23.59	12.27	10.18	15.45	11.99	56.93	.00	12.39
80.	-13.26	23.51	24.58	11.79	11.72	14.08	11.95	56.75	.00	12.42
70.	-20.08	27.44	28.36	14.30	13.14	14.26	11.93	56.57	.00	12.46
60.	-15.33	24.95	25.53	14.26	10.69	13.79	9.26	56.57	.00	13.08
50.	-11.68	24.76	25.07	12.79	11.97	13.94	6.57	56.39	.00	13.37
40.	-9.01	25.16	25.26	12.01	13.15	13.84	3.75	56.39	.00	13.59
30.	-9.74	25.98	26.01	12.56	13.42	13.79	2.07	56.57	.00	13.69
20.	-9.85	24.21	24.21	11.62	12.59	13.79	.26	56.57	.00	13.78
10.	-6.93	23.89	23.89	10.28	13.60	13.79	.00	56.57	.00	13.79
67.4	-21.48	28.38		15.62						

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			15 PSIG TEST NUMBER 2-1-4							
90.	-14.41	27.53	28.87	18.84	8.69	16.58	14.31	68.45	.00	11.70
80.	-25.62	28.08	29.40	17.84	10.24	14.36	14.31	68.27	.00	11.60
70.	-31.84	32.08	33.24	19.83	12.26	14.18	14.31	68.09	.00	11.70
60.	-23.68	29.67	30.43	18.72	10.95	13.98	11.13	67.91	.00	12.76
50.	-19.53	29.28	29.67	17.90	11.39	13.85	7.96	67.91	.00	13.23
40.	-14.66	29.83	30.32	17.07	12.76	13.85	5.58	67.91	.00	13.46
30.	-14.04	30.76	30.82	16.58	14.18	13.85	3.02	67.91	.00	13.60
20.	-14.29	30.05	30.06	15.85	13.20	13.35	1.10	67.91	.00	13.66
10.	-8.92	27.35	27.36	14.00	13.36	13.85	.00	67.91	.00	13.71
69.7	-31.93	32.23		20.03						
			0 PSIG TEST NUMBER 2-1-0							
90.	-.33	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-.55	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-1.62	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-3.11	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-6.95	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 2 POSITION NUMBER 2 CURVED FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.250 PIPE DIA. (IN) 7.981 ASPECT RATIO .3280

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			60 PSIG TEST NUMBER 2-2-1							
90.	74.60	79.39	83.94	65.67	13.72	38.65	45.30	54.05	26.87	14.40
80.	83.73	76.94	80.84	65.67	11.27	36.43	41.36	52.61	24.35	14.37
70.	104.37	76.29	79.38	66.28	10.01	32.18	36.66	51.53	22.17	14.24
60.	88.09	76.04	78.12	66.89	9.15	25.41	30.05	50.63	21.29	13.76
50.	61.11	76.04	77.17	67.66	8.38	18.01	22.16	50.27	20.21	18.67
40.	37.30	76.42	77.00	69.18	7.24	13.04	15.98	50.27	19.85	10.59
30.	23.41	77.46	77.71	70.10	7.37	9.77	10.38	50.27	19.13	8.43
20.	7.54	77.97	78.00	69.79	8.18	8.47	3.77	50.45	19.85	5.87
10.	-20.24	72.81	72.84	60.96	11.85	12.26	.00	50.81	21.29	8.96
73.8	112.30	76.42		65.88						
			15 PSIG TEST NUMBER 2-2-4							
90.	18.99	27.04	28.48	16.30	10.73	15.00	14.73	66.29	.00	12.92
80.	23.58	27.31	28.73	15.85	11.46	15.23	14.66	66.11	.00	12.84
70.	42.48	31.71	32.92	20.44	11.27	14.84	14.62	65.93	.00	13.10
60.	34.22	29.47	30.30	21.29	8.18	13.75	11.66	65.75	.00	13.36
50.	23.21	29.37	29.86	18.78	10.59	13.92	8.93	65.57	.00	13.52
40.	14.04	29.75	30.01	17.72	12.02	13.97	6.59	65.57	.00	13.62
30.	7.80	30.34	30.43	17.55	12.79	13.98	3.79	65.57	.00	13.71
20.	2.11	31.57	31.59	18.27	13.30	13.98	1.50	65.57	.00	13.76
10.	-5.41	27.63	27.63	13.84	13.79	13.98	.26	65.57	.00	13.78
67.8	44.85	33.23		22.31						
			10 PSIG TEST NUMBER 2-2-5							
90.	12.63	22.60	23.80	11.88	10.72	15.81	12.28	66.47	.00	12.30
80.	18.13	22.89	24.07	11.52	11.37	14.90	12.24	66.29	.00	12.34
70.	35.90	25.98	27.01	14.04	11.94	15.84	12.21	66.29	.00	12.37
60.	27.84	24.73	25.42	14.97	9.76	13.71	9.74	66.11	.00	12.97
50.	19.05	24.73	25.11	13.39	11.34	13.85	7.23	66.11	.00	13.39
40.	10.62	25.09	25.27	12.62	12.47	13.91	4.96	66.11	.00	13.56
30.	5.86	26.01	26.06	12.86	13.14	13.95	2.76	66.11	.00	13.66
20.	.37	26.12	26.12	13.34	12.78	13.97	.68	66.11	.00	13.74
10.	-5.31	22.81	22.82	10.12	12.69	13.97	.00	66.11	.00	13.76
68.1	37.18	27.18		15.48						
			5 PSIG TEST NUMBER 2-2-6							
90.	7.18	18.25	19.15	5.64	12.60	15.49	9.57	66.83	.00	11.72
80.	12.21	18.38	19.28	6.58	11.79	15.40	9.59	66.65	.00	11.89
70.	24.42	20.28	21.09	8.06	12.21	16.58	9.57	66.65	.00	11.62
60.	17.55	19.83	20.66	8.02	11.81	13.69	9.57	66.65	.00	12.71
50.	12.21	20.13	20.70	7.67	12.46	14.04	8.00	66.65	.00	13.17
40.	7.02	20.73	21.03	7.51	13.21	13.98	5.86	66.65	.00	13.40
30.	3.51	22.10	22.21	8.30	13.81	13.98	3.59	66.65	.00	13.62
20.	-.91	19.41	19.42	6.82	12.59	13.98	1.32	66.65	.00	13.69
10.	-4.88	19.38	19.38	5.77	13.60	13.98	.1[illegible]	66.65	.00	13.74
7[illegible].6	25.06	20.28		8.06						

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
0 PSIG TEST NUMBER 2-2-0										
90.	-.33	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-.55	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-1.62	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-3.11	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-6.95	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 2 POSITION NUMBER 3 FLAT FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.250 PIPE DIA. (IN) 7.981 ASPECT RATIO .3280

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
				60 PSIG TEST NUMBER 2-3-1						
90.	-59.51	79.00	83.59	64.79	14.21	39.43	45.77	45.77	39.83	23.34
80.	-85.17	78.87	85.36	62.05	16.82	37.58	45.30	44.15	36.95	22.29
70.	-92.59	77.64	81.23	61.15	16.69	32.21	39.15	42.89	33.71	17.90
60.	-93.44	77.32	79.52	64.03	13.29	25.81	31.44	42.17	31.73	14.26
50.	-88.02	76.67	77.95	67.07	9.60	19.59	23.90	41.63	30.47	10.53
40.	-77.47	76.54	77.16	69.20	7.34	13.74	16.73	41.63	30.29	11.75
30.	-60.65	78.35	74.58	69.20	9.15	11.10	10.30	41.81	30.47	12.86
20.	-48.10	78.10	78.17	67.67	10.43	10.89	5.34	42.53	31.19	13.34
10.	-20.15	78.61	78.67	64.95	13.66	14.26	.00	43.07	32.09	13.55
60.8	-94.87	77.45		63.73						
				0 PSIG TEST NUMBER 2-3-0						
90.	-.33	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-.55	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-1.62	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-3.11	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-6.95	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 2 POSITION NUMBER 4 CURVED FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.250 PIPE DIA. (IN) 7.981 ASPECT RATIO .3280

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			60 PSIG TEST NUMBER 2-4-1							
90.	78.34	79.92	84.59	54.65	25.27	39.95	46.78	39.11	35.51	24.32
80.	98.29	79.13	83.38	53.90	25.24	38.43	44.40	37.67	33.53	21.81
70.	105.87	77.84	80.84	61.53	16.32	30.50	37.06	36.41	32.27	16.97
60.	83.01	76.67	78.50	65.19	11.47	23.65	28.81	35.51	31.55	13.30
50.	57.25	76.28	77.39	67.94	8.34	18.42	22.38	35.33	30.65	10.01
40.	38.17	76.93	77.54	69.45	7.47	13.65	15.60	35.51	29.75	11.40
30.	20.99	77.84	78.05	70.53	7.31	9.47	9.72	35.69	28.49	12.39
20.	4.77	74.85	74.91	68.85	6.00	6.74	5.14	36.05	27.23	13.39
10.	-22.42	69.55	69.55	58.17	11.37	11.39	1.19	37.13	27.05	13.60
75.0	115.95	78.36		57.29						
			0 PSIG TEST NUMBER 2-4-0							
90.	-.33	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-.55	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-1.62	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-3.11	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-6.95	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 2 POSITION NUMBER 5 FLAT FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.250 PIPE DIA. (IN) 7.981 ASPECT RATIO .3280

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
60 PSIG TEST NUMBER 2-5-1										
90.	-55.43	80.05	84.39	65.34	14.71	38.19	44.97	41.63	38.75	23.51
80.	-79.96	77.19	81.12	65.34	11.85	37.29	42.11	39.83	36.77	21.34
70.	-88.26	76.54	79.54	65.04	11.50	31.39	36.71	38.57	35.87	17.93
60.	-92.27	76.41	78.26	67.49	8.92	24.73	28.81	37.85	36.05	14.01
50.	-89.98	76.14	77.15	70.23	5.92	18.30	21.19	37.49	36.23	10.57
40.	-82.25	76.28	76.75	71.14	5.13	12.09	14.51	37.49	35.69	11.44
30.	-65.36	78.61	73.82	70.39	8.22	10.26	9.94	37.49	35.33	12.69
20.	-51.91	78.87	78.93	69.15	9.72	10.19	5.20	38.21	34.97	13.34
10.	-24.43	73.43	73.44	63.82	9.62	9.64	1.12	38.75	34.79	13.60
56.7	-94.00	76.41		68.72						
0 PSIG TEST NUMBER 2-5-0										
90.	-.33	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-.55	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-1.62	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-3.11	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-6.95	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 2 POSITION NUMBER 6 CURVED FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 8.000 SEAT DIA. (IN) 7.250 PIPE DIA. (IN) 7.981 ASPECT RATIO .3280

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
60 PSIG TEST NUMBER 2-6-1										
90.	78.48	79.26	83.82	58.78	20.48	38.01	45.86	41.45	38.75	23.95
80.	107.51	80.55	84.93	59.70	20.86	37.67	45.39	39.65	37.13	22.52
70.	109.10	79.13	82.01	64.43	14.71	30.12	36.55	38.57	35.51	17.22
60.	84.44	77.58	79.41	67.63	9.95	24.11	28.86	37.85	34.07	13.95
50.	59.00	77.06	78.09	68.40	8.65	17.78	21.63	37.49	33.35	10.30
40.	37.93	77.32	77.79	69.62	7.70	12.35	14.57	37.49	32.99	11.89
30.	20.84	79.65	79.85	59.92	9.73	11.30	9.50	37.67	33.35	12.94
20.	5.72	79.65	79.71	66.88	12.78	13.12	5.07	38.39	33.89	13.40
10.	-16.54	76.93	76.93	61.93	15.10	15.11	1.21	38.93	34.43	13.60
78.1	113.49	80.42		60.34						
0 PSIG TEST NUMBER 2-6-0										
90.	-.33	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
80.	-.55	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
70.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
60.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
50.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
40.	-1.19	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
30.	-1.62	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
20.	-3.11	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00
10.	-6.95	13.79	13.79	.00	.00	13.79	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 3 POSITION NUMBER 1 FLAT FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 24.000 SEAT DIA. (IN) 21.781 PIPE DIA. (IN) 22.624 ASPECT RATIO .2580

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			15 PSIG	TEST NUMBER	3-1-4					
90.	-419.86	20.10	.00	5.09	15.01	.00	.00	97.25	.00	.00
80.	-602.68	26.05	.00	13.97	12.08	.00	.00	92.93	.00	.00
70.	-535.04	26.05	.00	15.10	10.95	.00	.00	87.53	.00	.00
60.	-483.85	27.30	.00	16.59	10.70	.00	.00	82.31	.00	.00
50.	-326.63	27.69	.00	15.94	11.75	.00	.00	77.99	.00	.00
40.	-121.87	26.99	.00	15.13	11.86	.00	.00	75.11	.00	.00
30.	-78.00	27.04	.00	13.78	13.26	.00	.00	72.59	.00	.00
20.	-134.67	26.56	.00	12.76	13.79	.00	.00	71.51	.00	.00
10.	-147.47	26.24	.00	11.88	14.36	.00	.00	71.33	.00	.00
77.0	-648.38	26.31		14.43						
			30 PSIG	TEST NUMBER	3-1-3					
90.	-1386.26	59.41	.00	36.16	23.25	.00	.00	89.51	92.03	29.31
80.	-1237.98	46.88	.00	30.99	15.88	.00	.00	81.05	84.11	23.89
70.	-1272.20	46.99	.00	29.23	17.77	.00	.00	72.59	75.83	20.96
60.	-1131.54	43.37	.00	31.31	12.05	.00	.00	66.47	68.27	16.94
50.	-922.45	41.16	.00	32.20	8.96	.00	.00	61.79	61.79	14.76
40.	-713.35	43.47	.00	31.65	11.82	.00	.00	58.73	57.11	14.17
30.	-462.44	44.45	.00	32.20	12.26	.00	.00	56.93	53.15	13.85
20.	-253.35	43.80	.00	29.99	13.81	.00	.00	56.75	50.45	13.58
10.	-234.34	43.13	.00	28.24	14.90	.00	.00	56.75	48.65	13.52
90.0	-1386.26	59.41		36.15						
			45 PSIG	TEST NUMBER	3-1-2					
90.	-1399.94	60.77	.00	36.62	24.15	.00	.00	85.91	74.39	31.34
80.	-1696.47	64.35	.00	40.58	23.77	.00	.00	78.35	68.63	32.49
70.	-1655.41	60.51	.00	37.65	22.86	.00	.00	70.61	61.43	27.96
60.	-1495.74	57.71	.00	41.86	15.85	.00	.00	62.87	54.05	21.44
50.	-1349.75	55.40	.00	43.77	11.63	.00	.00	57.47	48.29	17.72
40.	-1185.52	56.68	.00	43.40	13.29	.00	.00	53.69	43.25	15.17
30.	-980.23	59.49	.00	46.59	12.91	.00	.00	51.71	40.01	13.87
20.	-578.77	59.12	.00	46.46	12.66	.00	.00	50.99	37.67	13.75
10.	-373.48	58.60	.00	43.77	14.82	.00	.00	51.53	35.87	13.53
78.0	-1760.47	62.96		39.09						
			60 PSIG	TEST NUMBER	3-1-1A					
90.	-1634.43	68.91	.00	41.54	27.37	.00	.00	86.27	88.25	36.69
80.	-2113.44	77.38	.00	47.51	29.86	.00	.00	75.83	79.43	39.93
70.	-2065.54	77.52	.00	46.64	30.88	.00	.00	65.03	69.53	34.59
60.	-1826.03	71.98	.00	51.46	20.52	.00	.00	55.95	59.45	26.70
50.	-1634.43	67.44	.00	53.65	13.79	.00	.00	48.65	50.63	19.70
40.	-1426.86	64.82	.00	51.02	13.79	.00	.00	44.15	43.97	15.64
30.	-1277.83	70.52	.00	55.11	15.40	.00	.00	41.81	38.75	14.21
20.	-889.29	73.58	.00	58.90	14.68	.00	.00	41.45	35.87	13.84
10.	-538.01	76.20	.00	59.64	16.56	.00	.00	41.99	33.89	13.62
76.3	-2161.35	76.67		45.66						

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			0 PSIG TEST NUMBER 3-1-0							
90.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
80.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
70.	-30.09	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
60.	-22.53	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
50.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
40.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
30.	-26.85	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
20.	-32.25	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
10.	-48.46	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 3   POSITION NUMBER 2   CURVED FACE OF DISK INTO FLOW   GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 24.000   SEAT DIA. (IN) 21.781   PIPE DIA. (IN) 22.624   ASPECT RATIO .2580

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			60 PSIG TEST NUMBER 3-2-1							
90.	1570.69	67.63	.00	37.54	30.10	.00	.00	83.57	72.23	39.31
80.	2271.48	74.19	.00	45.37	28.82	.00	.00	73.31	64.31	38.03
70.	2385.74	77.46	.00	53.94	23.53	.00	.00	63.41	55.13	34.71
60.	1928.70	72.00	.00	57.22	14.78	.00	.00	54.95	46.85	26.66
50.	900.36	65.44	.00	54.48	10.96	.00	.00	48.11	40.73	20.41
40.	534.73	65.66	.00	56.30	9.35	.00	.00	43.97	34.79	15.36
30.	397.62	74.40	.00	63.95	10.46	.00	.00	42.71	29.03	14.00
20.	222.43	80.96	.00	70.50	10.46	.00	.00	43.07	23.99	13.62
10.	16.76	85.11	.00	72.88	12.23	.00	.00	43.97	21.83	13.62
73.3	2416.21	79.94		53.75						
			0 PSIG TEST NUMBER 3-2-0							
90.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
80.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
70.	-30.09	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
60.	-22.53	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
50.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
40.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
30.	-26.85	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
20.	-32.25	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
10.	-48.46	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 3 POSITION NUMBER 3 FLAT FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 24.000 SEAT DIA. (IN) 21.781 PIPE DIA. (IN) 22.624 ASPECT RATIO .2580

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
60 PSIG TEST NUMBER 3-3-1										
90.	-1257.60	41.25	.00	30.62	10.63	.00	.00	.00	67.91	25.25
80.	-2131.58	60.51	.00	45.37	15.14	.00	.00	.00	63.59	34.20
70.	-2679.44	74.09	.00	57.75	16.33	.00	.00	.00	59.81	35.45
60.	-2055.96	73.43	.00	59.94	13.49	.00	.00	.00	55.31	27.69
50.	-1774.63	70.81	.00	60.90	10.31	.00	.00	.00	51.71	20.84
40.	-1569.34	68.84	.00	57.58	11.25	.00	.00	.00	47.75	16.43
30.	-1516.12	76.51	.00	63.41	13.10	.00	.00	.00	43.43	14.65
20.	-1151.16	81.32	.00	69.42	11.91	.00	.00	.00	40.19	13.79
10.	-573.30	89.63	.00	73.80	15.84	.00	.00	.00	38.03	13.60
70.3	-2946.27	73.80		56.72						
60 PSIG TEST NUMBER 3-3-18										
90.	-1995.45	77.46	.00	55.40	22.06	.00	.00	.00	68.09	37.97
80.	-2304.54	76.14	.00	60.07	16.07	.00	.00	.00	61.97	38.73
70.	-2637.88	73.97	.00	58.90	15.07	.00	.00	.00	55.67	34.07
60.	-1831.82	72.00	.00	58.90	13.10	.00	.00	.00	50.45	27.60
50.	-1716.67	72.21	.00	57.74	14.47	.00	.00	.00	46.49	21.23
40.	-1522.73	71.34	.00	57.16	14.18	.00	.00	.00	42.53	16.39
30.	-1274.24	72.65	.00	57.88	14.76	.00	.00	.00	38.57	14.52
20.	-783.34	72.87	.00	58.90	13.97	.00	.00	.00	34.97	13.69
10.	-419.69	67.63	.00	53.65	13.98	.00	.00	.00	32.09	13.62
75.5	-2892.38	73.75		58.20						
0 PSIG TEST NUMBER 3-3-0										
90.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
80.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
70.	-30.39	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
60.	-22.53	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
50.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
40.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
30.	-26.85	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
20.	-32.25	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
10.	-48.46	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 3 POSITION NUMBER 4 CURVED FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 24.000 SEAT DIA. (IN) 21.781 PIPE DIA. (IN) 22.624 ASPECT RATIO .2580

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			15 PSIG TEST NUMBER 3-4-4							
90.	279.76	21.22	.00	9.15	12.07	.00	.00	.00	74.75	15.21
80.	641.73	25.47	.00	15.91	9.56	.00	.00	.00	71.87	15.39
70.	942.83	28.34	.00	19.84	8.50	.00	.00	.00	67.91	15.16
60.	736.01	27.25	.00	20.39	6.86	.00	.00	.00	63.95	14.55
50.	422.75	26.75	.00	18.61	8.14	.00	.00	.00	60.17	14.17
40.	189.57	26.24	.00	17.33	8.91	.00	.00	.00	57.65	13.75
30.	76.04	26.79	.00	16.65	10.14	.00	.00	.00	56.03	13.68
20.	9.12	25.70	.00	15.04	10.66	.00	.00	.00	54.23	13.69
10.	-45.62	25.43	.00	12.40	13.02	.00	.00	.00	52.33	13.69
70.0	942.83	28.34		19.84						
			30 PSIG TEST NUMBER 3-4-3							
90.	555.96	41.31	.00	24.66	16.65	.00	.00	.00	69.17	23.84
80.	733.88	40.10	.00	30.69	9.41	.00	.00	.00	64.49	24.64
70.	1304.14	46.47	.00	35.30	11.17	.00	.00	.00	59.27	22.23
60.	1263.07	45.15	.00	36.84	8.31	.00	.00	.00	54.23	17.49
50.	743.01	45.48	.00	36.29	9.20	.00	.00	.00	50.45	15.79
40.	501.22	50.53	.00	40.45	10.08	.00	.00	.00	47.57	14.47
30.	259.43	53.71	.00	44.19	9.51	.00	.00	.00	45.77	13.98
20.	108.88	52.17	.00	42.54	9.63	.00	.00	.00	44.69	13.79
10.	-23.42	48.33	.00	37.61	10.72	.00	.00	.00	43.43	13.79
68.5	1495.74	47.57		35.85						
			30 PSIG TEST NUMBER 3-4-3A							
90.	614.05	40.87	.00	24.00	16.87	.00	.00	.00	59.81	21.84
80.	860.40	42.53	.00	30.81	11.72	.00	.00	.00	55.13	23.58
70.	1499.09	48.78	.00	36.94	11.84	.00	.00	.00	50.63	22.23
60.	1252.73	46.14	.00	37.61	8.53	.00	.00	.00	47.75	17.68
50.	700.73	46.25	.00	37.61	8.64	.00	.00	.00	45.59	15.32
40.	440.69	48.44	.00	39.46	8.98	.00	.00	.00	44.33	14.59
30.	217.15	51.52	.00	41.77	9.75	.00	.00	.00	43.07	14.01
20.	98.54	51.52	.00	40.90	10.62	.00	.00	.00	41.99	13.97
10.	-24.63	50.42	.00	38.48	11.94	.00	.00	.00	41.45	13.87
72.0	1590.62	49.98		36.17						
			45 PSIG TEST NUMBER 3-4-2							
90.	520.68	36.49	.00	22.32	14.17	.00	.00	.00	66.47	21.34
80.	1420.93	57.33	.00	36.94	20.39	.00	.00	.00	62.33	32.08
70.	2193.43	72.24	.00	53.48	18.77	.00	.00	.00	57.65	30.91
60.	1871.05	67.20	.00	54.49	12.71	.00	.00	.00	52.43	23.53
50.	946.47	63.69	.00	53.77	9.92	.00	.00	.00	47.39	17.38
40.	618.00	68.30	.00	57.42	10.88	.00	.00	.00	44.15	14.90
30.	374.70	74.88	.00	65.47	9.41	.00	.00	.00	41.81	14.16
20.	192.22	76.64	.00	67.08	9.56	.00	.00	.00	40.37	13.76
10.	-2.43	75.75	.00	64.59	11.17	.00	.00	.00	39.11	13.65
72.1	2278.59	72.39		50.84						

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
60 PSIG TEST NUMBER 3-4-1										
90.	778.59	40.81	.00	23.82	17.00	.00	.00	.00	64.67	23.67
80.	1709.25	62.70	.00	40.28	22.42	.00	.00	.00	60.89	34.85
70.	2658.15	85.25	.00	60.02	25.24	.00	.00	.00	56.21	36.69
60.	2229.32	79.13	.00	63.86	15.27	.00	.00	.00	50.45	28.86
50.	1207.42	77.60	.00	64.22	13.37	.00	.00	.00	45.23	22.42
40.	778.59	82.41	.00	70.26	12.15	.00	.00	.00	41.27	16.64
30.	495.74	89.42	.00	77.39	12.02	.00	.00	.00	38.57	14.72
20.	231.14	92.71	.00	82.50	10.21	.00	.00	.00	36.77	13.87
10.	-6.08	87.44	.00	78.12	9.33	.00	.00	.00	35.51	13.66
70.0	2658.15	85.25		60.02						
60 PSIG TEST NUMBER 3-4-1A										
90.	983.76	64.93	.00	42.51	22.42	.00	.00	.00	65.21	34.59
80.	1244.84	59.96	.00	42.21	17.75	.00	.00	.00	58.19	31.95
70.	1864.14	66.40	.00	48.36	18.04	.00	.00	.00	51.89	28.99
60.	1815.58	66.11	.00	49.68	16.43	.00	.00	.00	46.31	23.28
50.	1026.26	66.98	.00	51.29	15.69	.00	.00	.00	41.81	19.99
40.	668.03	73.13	.00	58.74	14.39	.00	.00	.00	38.57	16.43
30.	449.46	76.93	.00	64.15	12.78	.00	.00	.00	36.59	14.33
20.	206.59	77.94	.00	66.05	11.89	.00	.00	.00	35.51	13.94
10.	18.37	70.34	.00	56.55	13.79	.00	.00	.00	34.43	13.66
73.9	2100.94	67.44		45.32						
60 PSIG TEST NUMBER 3-4-1B										
90.	885.13	58.64	.00	33.53	25.11	.00	.00	.00	68.27	32.55
80.	1640.77	65.77	.00	43.00	22.77	.00	.00	.00	63.23	33.87
70.	2042.96	70.89	.00	50.66	20.23	.00	.00	.00	56.75	30.57
60.	1902.80	69.62	.00	53.39	16.23	.00	.00	.00	51.17	24.79
50.	1165.45	70.34	.00	54.66	15.68	.00	.00	.00	46.31	20.25
40.	708.41	75.74	.00	62.31	14.43	.00	.00	.00	42.89	15.84
30.	464.66	83.14	.00	69.24	13.89	.00	.00	.00	40.55	14.39
20.	220.90	82.05	.00	70.14	11.91	.00	.00	.00	39.29	14.07
10.	32.00	71.62	.00	60.67	10.95	.00	.00	.00	37.85	13.66
69.1	2189.22	71.92		51.02						
0 PSIG TEST NUMBER 3-4-0										
90.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
80.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
70.	-30.09	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
60.	-22.53	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
50.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
40.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
30.	-26.85	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
20.	-32.25	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
10.	-48.46	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 3 POSITION NUMBER 5 FLAT FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 24.000 SEAT DIA. (IN) 21.781 PIPE DIA. (IN) 22.624 ASPECT RATIO .2580

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
				60 PSIG TEST NUMBER 3-5-1						
90.	-756.24	58.31	.00	40.42	17.88	.00	.00	.00	74.03	31.95
80.	-1581.21	73.45	.00	47.99	25.45	.00	.00	.00	69.53	38.58
70.	-1937.80	78.12	.00	54.69	23.42	.00	.00	.00	63.77	36.46
60.	-1842.00	74.33	.00	61.70	12.63	.00	.00	.00	56.93	27.89
50.	-1783.78	73.01	.00	63.15	9.86	.00	.00	.00	52.07	21.13
40.	-1607.82	72.00	.00	62.86	9.14	.00	.00	.00	48.47	17.07
30.	-1405.55	74.33	.00	64.61	9.72	.00	.00	.00	45.59	14.81
20.	-820.10	71.56	.00	61.10	10.46	.00	.00	.00	42.35	13.98
10.	-426.24	65.59	.00	53.10	12.49	.00	.00	.00	39.29	13.84
69.1	-2145.38	80.02		56.74						
				60 PSIG TEST NUMBER 3-5-1A						
90.	-731.75	56.26	.00	40.13	16.13	.00	.00	.00	65.75	31.36
80.	-1315.69	72.21	.00	47.56	24.66	.00	.00	.00	61.43	38.35
70.	-1762.77	78.34	.00	54.69	23.64	.00	.00	.00	56.03	35.64
60.	-1817.52	75.49	.00	61.70	13.79	.00	.00	.00	49.37	28.27
50.	-1730.84	72.00	.00	62.42	9.57	.00	.00	.00	43.79	21.58
40.	-1562.05	70.91	.00	61.26	9.65	.00	.00	.00	40.19	16.77
30.	-1343.06	73.75	.00	63.44	10.31	.00	.00	.00	36.95	14.59
20.	-781.93	69.81	.00	59.07	10.73	.00	.00	.00	34.25	13.91
10.	-398.73	62.38	.00	50.47	11.91	.00	.00	.00	31.37	13.62
64.4	-1949.91	77.25		59.51						
				0 PSIG TEST NUMBER 3-5-0						
90.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
80.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
70.	-30.09	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
60.	-22.53	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
50.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
40.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
30.	-26.85	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
20.	-32.25	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
10.	-48.46	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00

DATA FOR VALVE NUMBER 3 POSITION NUMBER 6 CURVED FACE OF DISK INTO FLOW GAS TYPE: NITROGEN

NOMINAL DIA. (IN) 24.000 SEAT DIA. (IN) 21.781 PIPE DIA. (IN) 22.624 ASPECT RATIO .2580

DISK ANGLE (DEG)	TORQUE DYNAMIC + BEARING (FT*LB)	STATIC UP STREAM PRESS. (PSIA)	TOTAL UP STREAM PRESS. (PSIA)	STATIC DELTA PRESS. (PSIA)	STATIC DOWN STREAM PRESS. (PSIA)	TOTAL DOWN STREAM PRESS. (PSIA)	MASS FLOW (LB/S)	UP STREAM TEMP. (F)	DOWN STREAM TEMP. (F)	STATIC DOWN STREAM RECOVERY PRESS. (PSIA)
			60 PSIG	TEST NUMBER 3-6-1						
90.	1396.60	55.80	.00	36.36	19.44	.00	.00	64.31	64.49	29.59
80.	1804.14	71.62	.00	47.92	23.70	.00	.00	54.23	58.19	34.93
70.	2017.03	73.98	.00	50.11	23.87	.00	.00	43.43	49.73	31.17
60.	1560.83	69.62	.00	41.48	28.14	.00	.00	33.71	40.55	25.64
50.	879.56	66.70	.00	42.80	23.90	.00	.00	26.51	34.25	20.12
40.	532.84	67.25	.00	49.23	18.03	.00	.00	21.47	30.47	15.84
30.	332.12	74.16	.00	60.79	13.37	.00	.00	18.95	28.13	14.20
20.	131.39	72.34	.00	65.02	7.32	.00	.00	17.51	26.51	13.60
10.	-45.01	66.53	.00	55.09	11.44	.00	.00	17.51	25.79	13.66
70.0	2017.03	73.98		50.11						
			60 PSIG	TEST NUMBER 3-6-1A						
90.	1434.91	56.26	.00	37.17	19.09	.00	.00	90.23	78.17	32.29
80.	1860.71	71.13	.00	46.28	24.85	.00	.00	77.45	70.97	33.92
70.	1799.88	71.78	.00	48.83	22.95	.00	.00	64.67	61.97	29.59
60.	1580.90	73.08	.00	43.00	30.08	.00	.00	53.69	53.69	25.31
50.	917.88	75.27	.00	46.47	28.80	.00	.00	45.41	47.75	20.38
40.	625.91	80.53	.00	58.86	21.67	.00	.00	39.83	44.33	15.84
30.	413.02	86.21	.00	70.33	15.98	.00	.00	36.23	42.17	14.72
20.	181.88	84.02	.00	73.61	10.41	.00	.00	34.79	40.37	13.94
10.	-37.11	75.49	.00	64.50	10.99	.00	.00	34.25	39.11	13.60
64.4	1982.36	73.37		43.00						
			0 PSIG	TEST NUMBER 3-6-0						
90.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
80.	-31.17	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
70.	-30.09	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
60.	-22.53	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
50.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
40.	-21.45	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
30.	-26.85	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
20.	-32.25	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00
10.	-48.46	13.79	.00	.00	.00	.00	.00	40.73	40.73	.00

APPENDIX B

LEAK TEST PROCEDURES

APPENDIX B

LEAK TEST PROCEDURES

B-1. General Leak Test Guidelines

Definition of Valve Orientation. Most butterfly valve designs do not have a defined inlet or outlet. Typically, field installations have one face or the other as the inlet, depending on the load response characteristic desired (see Section 5 for additional information). For complete understanding of the response characteristics of the test valves in this study, both sides of the valve discs were subjected to the load alternately. (Dynamic load response valve orientation is detailed in Section 5 of the main report). For leak test purposes, the disc face for which the action (pressure applied or leakage measured) was to apply was identified by its physical characteristics. The shaft side of the disc is curved in physical appearance and was identified by "shaft side." The opposite side of the disc is flat and was identified as the "nonshaft side."

Standard Ambient Temperature Leak Test. The following test procedure was used whenever an ambient temperature leak test was required:

1. Valve disc centered closed.
2. Shaft locked to prevent rotation.
3. Leak test flanges and gaskets installed on valve flanges.
4. Nitrogen gas (0-125 psig source) installed on one side of valve.
5. Leak detection system installed on opposite side of valve. The system starts with positive water displacement sensitive to 1 cm^3 and progresses through eight succeedingly larger flow meters manifolded and individually isolable.
6. Leak testing is performed by pressurizing one side of the valve disc and measuring leakage on the other.
7. Test pressures are 3-5, 50, and 120 psig. Hold periods at each pressure are five minutes minimum or until leakage stabilizes.
8. After testing one side of the valve, test connections are reversed and the other side tested.

   NOTE: Both sides of the valve are tested because in some designs, pressurizing the disc from one side will move the disc away from the seat, while pressurizing the other will move it into the seat. Valves are typically installed in containment CIS systems both ways.

B-2. Elevated Temperature Leak Test General Requirements

The following procedure shall be used in elevated temperature leak tests.

1. At any time during the test, should valve leakage reach the point where internal valve temperature cannot be maintained, the test shall be stopped.
2. The difference between the valve external temperature and internal temperature shall not be greater than 30°F during heatup. The difference shall not exceed 15°F during the hold periods. The difference between the external temperature readings shall not exceed 15°F at any time.
3. The valve shall have a minimum of two externally mounted thermocouples and one internally mounted thermocouple. The external thermocouple shall be mounted 180 degrees apart and on the largest body masses.
4. The valve shall be heat traced and insulated as required to meet the test conditions.
5. Pressure tolerances shall be ± 5 psig. Temperature tolerances shall be ± 5°F. Leakage measurements shall be made within ± 5% of full scale accuracy.
6. The valve shall be mounted with the butterfly disc parallel to the body flanges and

the shaft locked to keep the valve closed throughout the test.

7. Test flange, gaskets, and pressurizing and leak detection systems shall be installed and checked for leaks.

8. The pressurizing media shall be gaseous nitrogen.

9. Once the test has started, it shall not be stopped unless equipment failure occurs.

10. Leak rates should be recorded every 30 minutes and whenever there is a significant change. Leakage measurements shall include valve test conditions, times, temperatures, and pressures.

B-3. Combined Design Basis—Severe Accident Elevated Temperature Leak Test Procedure

(This test was performed only on one valve. The separate tests were performed on all other valves including a retest for design basis temperatures on Valve No. 1.)

1. Perform a standard ambient temperature leak test (in both directions) on the valve, prior to test.

   NOTE: Temperature increase durations are minimumns: longer durations are acceptable.

2. Apply 60 psig to the shaft side of the valve. Increase temperature of the valve at 50°F (28°C) per hour to 250°F (121°C). (Monitor pressure closely while increasing temperature. Pressure will increase through gas expansion.) Continue to increase the valve temperature to 280°F (138°C) at 30°F per hour.

3. Hold valve at 280°F (138°C) and 60 psig for two hours monitoring leakage.

4. Vent shaft side of valve.

5. Apply 60 psig to nonshaft side of valve.

6. Monitor leakage on the shaft side of the valve for 30 minutes.

7. Maintain 60 psig on the nonshaft side of valve while continuing to monitor leakage on the shaft side of valve, and increase the valve temperature to 310°F (154°C) at 30°F per hour.

8. When 310°F (154°C) is reached, increase the pressure on the nonshaft side of the valve to 90 psig. Hold for 30 minutes, monitoring leakage on the shaft side of valve.

9. Vent the nonshaft side of the valve. Apply 90 psig to the shaft side of valve. Hold for 30 minutes, monitoring leakage on the nonshaft side of valve.

10. Maintain 90 psig on the shaft side of valve, monitoring leakage on the nonshaft side of valve. Increase the valve temperature to 350°F (177°C) at 30°F per hour.

11. Increase the pressure on the shaft side of valve to 120 + 10 - 0 psig, monitoring leakage on the nonshaft side of the valve. Hold for three hours.

12. Vent the shaft side of the valve. Apply 120 + 10 - 0 psig to the nonshaft side of the valve. Monitor leakage on the shaft side of the valve. Holding 350°F (177°C), monitor leakage for three hours.

13. Vent pressure from valve. Terminate valve heat source.

14. This ends the nonstop portion of the test.

15. When the valve returns to room temperature, without moving the valve disc, perform a standard ambient temperature base line leak test in both directions. Record results.

B-4. Design Base Elevated Temperature Leak Test Procedure

1. Perform a standard ambient temperature leak test (in both directions) on the valves, prior to test.

NOTE: Temperature increase durations are minimums: longer durations are acceptable.

2. Apply 60 psig to the shaft side of the valve. Increase temperature of the valve at 50°F per hour to 250°F (121°C). (Monitor pressure closely while increasing temperature. Pressure will increase through gas expansion.) Continue to increase temperature of valve to 280°F (138°C) at 30°F per hour.

3. Hold valve at 280°F (138°C) and 60 psig for two hours monitoring leakage.

4. Vent shaft side of valve.

5. Apply 60 psig to the nonshaft side of valve.

6. Monitor leakage on the shaft side of the valve for one hour.

7. Vent pressure from valve. Terminate valve heat source.

8. This ends the nonstop portion of the test.

9. When the valve returns to room temperature, without moving the valve disc, perform a standard ambient temperature leak test in both valve flow directions. Record results.

B-5. Severe Accident Elevated Temperature Leak Test Procedure

1. Perform a standard ambient temperature leak test on the valve in both directions prior to test. This test may be omitted providing the valve disc has not been moved after Step 9 of the DBA test.

   NOTE: Temperature increase durations are minimums: longer durations are acceptable.

2. Apply 60 psig to the nonshaft side of the valve. Increase temperature of the valve at 50°F per hour to 280°F (138°C). (Watch monitor pressure closely while increasing temperature. Pressure will increase through gas expansion.) Continue to increase temperature of valve to 310°F (154°C) at 30°F per hour.

3. When 310°F (154°C) is reached, increase the pressure on the nonshaft side of the valve to 90 psig. Hold for 30 minutes, monitoring leakage on the shaft side of valve.

4. Vent the nonshaft side of the valve. Apply 90 psig to the shaft side of the valve. Hold for 30 minutes, monitoring leakage on the nonshaft side of the valve.

5. Maintain 90 psig on the shaft side of valve, while continuing to monitor leakage on the nonshaft side of valve. Increase the temperature of the valve to 350°F (154°C) at 30°F per hour.

6. Increase the pressure on the shaft side of valve to 120 + 10 - 0 psig, while monitoring leakage on the nonshaft side of the valve. Hold for three hours.

7. Vent the shaft side of the valve. Apply 120 + 10 - 0 psig to the nonshaft side of the valve. Monitor leakage on the shaft side of the valve. Holding 350°F (154°C), monitor leakage for three hours.

8. Vent pressure from valve. Terminate valve heat source.

9. This ends the nonstop portion of the test.

10. When the valve returns to room temperature, without moving the valve disc, perform a standard ambient temperature leak test in both valve flow directions.

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13. ABSTRACT (200 words or less)

This report presents the results of the containment purge and vent valve test program, conducted under the sponsorship of the United States Nuclear Regulatory Commission, Office of Nuclear Regulatory Research. The test program investigated valve functionality and leak integrity.

Three nuclear designed butterfly valves typical of those used in domestic nuclear power plant containment purge and vent applications were tested. For a comparison of response, two valves of the same size with differing internal designs were tested. For extrapolation insights, a larger sized valve was also tested.

The valve experiments were performed with various piping configurations and valve disc orientations to the flow to simulate various installation options in field applications. As a standard for comparing the effects of the installation options, testing was also performed in a standard ANSI test section. Dynamic flow tests were performed over the range of a design basis accident. Leak integrity testing was also performed and extended into severe accident conditions.

Analysis of the test results produced a technical basis to assess industry purge and vent valve closing torque extrapolation methodology and quantified the influence of worst case piping geometry on valve torque response. It was also determined that some valve designs will leak in single isolation when exposed to design basis and severe accident environments.

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