ENCLOSURE 2

PVNGS ENGINEERING CALCULATION 13-MC-ZZ217, Rev. 3, "GATE VALVE OPEN THRUST REQUIRED DURING POTENTIAL PRESSURE LOCKING CONDITIONS"

Palo Verde Nuclear Generating Station

CALCULATION REVISION/TITLE SHEET

CALCULATION NO.	REV.	CLASS:	AFFECTED SHEET NO(S)
13-MC-ZZ-217	3	Q ☒ QAG ☐ NQR ☐	Indicated sheets

CALCULATION TITLE	ISSUED
Gate Valve Open Thrust Required During Potential Pressure Locking Condition per G.L. 95-07	2/18/00

PLANT CHANGE DOCUMENT	REFERENCE(S)
N/A	Generic Letter 95-07 Engineering Study 13-MS-A96, CRDR 9-5-0836 & 9-8-1207 Generic Letter 95-07 RAI NRC Letter Dated June 11, 1999 Generic Letter 95-07 RAI APS Letter Dated October 08, 1999

REASON FOR CHANGE

NRC Review and subsequent discussions of APS response letter dated 10-08-99 (102-04355-CDM/SAB/JAP) to Generic Letter 95-07 RAI NRC Letter dated 06-11-99 required adjustment to valve residual and piping pressure load components, validation, and documentation of additional test data.

DESCRIPTION OF CHANGE

1. Revised calculation body and attachments to reflect adjustment and validation of PVNGS pressure locking model. Model adjustment shifted pressure locking analysis loading bias from the line pressure component (hub load) to the peak cracking component (residual load). These adjustments result in model consistency with industry test results that indicate that measured pressure locking loads are proportional to differential pressure between the valve bonnet pressure and the average connecting line pressure.

2. Revised calculation body and attachments to reflect the use of a more conservative constant thermal pressurization rate through the full range of conditions subject to valve bonnet thermal pressurization. This more conservative model is consistent with the calculated theoretical thermal pressurization rates and the steady state conditions indicated from INEEL test results.

3. Revised calculation to update body and attachments to reflect the current status of pressure locking modification implementation and correct miscellaneous typo's and text grammar.

4. Revised calculation body and attachments to reflect reformatting of attachments to include renumbering of the pages of each attachment separately to facilitate future calculation maintenance.

5. Revised Attachment 6 to include comparison of PVNGS pressure locking model with the Commonwealth Edison pressure locking test results for 10" 900 lb Crane Flexible Wedge Gate Valve. This comparison was added to demonstrate PVNGS Pressure locking model validity for flexible gate valves with relatively rigid disks.

50.59 Screening/Evaluation Required/Attached: YES ☒ NO ☐

EDCs Incorporation ☐

Direct Revision ☒

Electronically Available? Yes ☐ No ☒

	Preparer	RE	Second Party Verification	Mech.	Civil	Elec.	I & C	Independent Verification	Other (Specify Org.)	Section Leader
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Date	2-10-2000	2-10-2000						02/10/00		2-18-2000

CROSS DISCIPLINE REVIEW (Mech., Civil, Elec., I & C)

IMPACT REVIEW FORM

PART A - INITIATING DEPARTMENT AND DOCUMENT

1.

Doc. type: Calculation

Doc. No.: 13-MC-ZZ-217 R/3

PCO: ☐ YES ☒ NO

2.

Resp. Ind.: Steven A. Lopez

Ext.: 82-1943

Dept.: NED Valve Design Engineering

Unit: 9722

Date: 02/11/00

PART B - IMPACTED DEPARTMENTS AND DOCUMENTS

1.

Impacts Identified: ☒ YES ☐ NO

2. Resp. Unit	3. Impacted Documents	4. M	5. Cyc	6. Sch. Comp.	7. Act. Comp.	8. Sign/Date	9. Comments
9722	13-JC-ZZ-201 R/11	O	N/A	08/31/00			685/686/688/693/694/696/651/652
9722	01-JC-ZZ-223 R/0	O	N/A	08/31/00			685/686/688/693/694/696/651/652
9722	01-J-ZZI-004 R/20	O	N/A	08/31/01			685/686/688/693/694/696/651/652
9722	02-JC-ZZ-223 R/1	O	N/A	08/31/01			685/686/688/693/694/696/651/652
9722	02-J-ZZI-004 R/17	O	N/A	03/31/01			685/686/688/693/694/696/651/652
9722	03-JC-ZZ-223 R/1	O	N/A	03/31/01			685/686/688/693/694/696/651/652
9722	03-J-ZZI-004 R/20	O	N/A	03/31/01			685/686/688/693/694/696/651/652

PART C - 1. REMARKS AND JUSTIFICATION

Static Peak cracking design limits were adjusted for selected SI valves identified in the comments column above based on an updated PVNGS pressure locking design model in response to NRC G.L. 95-07 Request for Additional Information to provide adequate margin.

SIHV685, 688, 693, 694 design static peak cracking was reduced. (Reference 11,500). SIHV686 & 696 design peak cracking was reduced. (Reference 17,500). SIHV651 & 652 design peak cracking was increased. (Reference 61,500).

Review of the adjusted field as-left static peak cracking values for these affected valves, accounting for appropriate instrument error and uncertainity, did not result in existing field conditions that would result in inoperable conditions. Any field as left conditions outside of established setpoint values in 1,2,3-J-ZZI-004 would be evaluated and documented in accordance with existing plant procedures.

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 2

REV	ORIGINATOR	DATE	INDEPENDENT VERIFICATION	DATE	REV	ORIGINATOR	DATE	INDEPENDENT VERIFICATION	DATE	Rev. Indicator ↓
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1.0 PURPOSE:
Determine the level of pressure locking susceptibility of the identified PVNGS power-operated gate valves, having an active open safety function.

2.0 BACKGROUND/SUMMARY:

2.1 BACKGROUND:
Pressure locking occurs when the valve bonnet is pressurized from high process fluid pressure and the line pressure subsequently is reduced and/or when a bonnet is pressurized cold and subsequent heatup increases the pressure of fluid trapped in the bonnet above line pressure. The resultant bonnet pressure and accompanying seating forces may require an opening stem thrust above an actuator or valve thrust/ torque limit, and in some cases prevent opening of the valve.

The industry has reported events involving the failure of power-operated gate valves to open due to pressure locking and thermal binding. The NRC has issued a number of reports/notices (e.g., GL 95-07, NUREG 1275, GL 89-10 Supplement 6, and various AEOD and operating experience reports) describing these events and requesting Licensees to perform susceptibility analyses and take appropriate corrective actions. Because the gate valve pressure locking and thermal binding failure rate was determined to not have sufficiently decreased, the NRC decided to issue Generic Letter 95-07 (Reference 16) to formally require Licensees to take appropriate actions to analyze and eliminate the potential for gate valve pressure locking and thermal binding events. |

2.2 SUMMARY:
This calculation presents the PVNGS Motor Operated Valve (MOV) Pressure Locking Analytical Model developed to predict the maximum required open thrust utilizing conservative potential pressure locking conditions based on design basis information. Those gate valves identified, in the "Gate Valve Pressure Locking and Thermal Binding Evaluation" (Reference 9), as being normally closed and having an active safety function to open are reviewed in this calculation for potential susceptibility to pressure locking . The sample results of the application of this model are then validated by comparison to representative test data.

All the identified valves evaluated in this calculation except CH-536 were initially found to be susceptible to pressure locking. Required G.L. 95-07 (Reference 16) susceptibility and operability of these valves was established in CRDR 9-5-0836 (Reference 15). This evaluation was updated to account for Limitorque Technical Update 98-01 (Reference 32) CRDR 9-8-1207 (Reference 33). The relative level of susceptibility/nonsusceptibility was established in this calculation based on the PVNGS pressure locking model and the associated modifications implemented between outages Unit 3 R5 (Fall 95) and Unit 3 R8 (Spring 2000) using the presented analytical model. |

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 3

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Table 1 shows the numerical results from the Attachment 1 Excel spreadsheet for the safety-related power-operated gate valves that were identified as potentially susceptible to pressure locking (Reference 9). This table shows the results after implementation of the recommended pressure locking modifications for the Work Auhtorization (WA) projects 950018, 950019, & 950020 (Phase I-Units 1, 2, & 3) and WA projects 960079, 960078, & 960070 (Phase II- Units 1, 2, & 3). |

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 4

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Table 1: Calculation Post Modification Results

Valve ID	Valve Size (inches-rating)	Valve Vendor	Predicted Bonnet Pressure (psig)	**Total Stem Thrust Req'd/ PL (lbf)**	**Min. Avail. or Limiting Thrust (lbf)**	Rev. Indicator
AF-34/35	6-900#	Anchor/ Darling	1,880	45,486	50,000	|
AF-36/37	6-900#	Anchor/ Darling	1,880	45,486	50,000	|
SG-134/138	6-900#	Anchor/ Darling	1,383	36,346	46,270	|
CH-536	3-1500#	Borg-Warner	97	5,428	6,940	|
SI-604/609	3-1500#	Borg-Warner	2,760	9,753	12,097	|
SI-651/652	12-1500#	Borg-Warner	2,936	163,266	179,786	|
SI-653/654	12-1500#	Borg-Warner	465	30,708	51,548	|
SI-655/656	12-300#	Borg-Warner	465	30,932	53,235	|
SI-671/672	8-300#	Borg-Warner	326	19,318	24,983	|
SI-685/694	10-330#	Borg-Warner	458	28,986	31,909	|
SI-686/696	20-300#	Borg-Warner	458	70,325	77,499	|
SI-688/693	10-330#	Borg-Warner	458	28,956	31,909	|

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3.0 CRITERIA/ASSUMPTIONS

The following conservative assumptions (1-8) are made to ensure that the estimated maximum required stem thrust to open the identified valves in this calculation during potential pressure locking conditions are conservatively high.

1. In cases involving bonnet pressure increases due to increased bonnet fluid temperatures, the pressure in the line downstream of the valve is normally assumed to be zero (0) psig. The pressure in the line upstream is either assumed to be zero (0) psig or conservatively low based on design basis calculations.The line pressure reduces the differential pressure across the disk, reducing the stem thrust required to open the valve, therefore; utilizing the low design basis values for line pressure is conservative.

2. The "unwedging effect" is assumed to be zero (0). The unwedging effect theoretically aids in opening the valve, hence, assuming the unwedging effect to be zero (0) is a conservative assumption.

3. The seating friction factor mu (μ) is derived as a function of the Valve Factor (VF) and Seating Angle theta (θ). This derivation is developed from the equations for the Differential Pressure presented in Reference 11 (Sections 5.1.2.4 and 5.1.3). The resulting equation is:

$$\mu = [VF * \cos(\theta)] / [1 - (VF * \sin(\theta))].$$

Utilizing a representative valve factor of 0.6 results in a seating friction factor of 0.6307 for θ of 5^{o}and 0.6322 for θ of 5.25^o. These values are conservative with respect to the coefficient of friction for sliding presented by EPRI (Reference 25).

4. The valve body is conservatively modelled as a rigid structure when analyzing the load transferred from the perimeter of the valve gate disks to the valve body seats. Actual elastic deformation of the valve body seat when loaded by the valve gate disk results in a lower seat load than that obtained by modelling the seats as rigid structure. A reduction in the normal load results in a reduction in the "Seat Friction Load" and the resultant actuator thrust.

The valve gate disk is modelled as a semi-rigid structure in determining the effects of differential pressure across the valve on seat loads. Differential pressure across the gate valve, applied to the high pressure side gate disk and proportionally transmitted through the gate hub to the low pressure side gate disk, causes a transfer of a portion of the normal force from one seat to the other (Ref. 14). The valve gate is modelled to maximize the seat friction load during "pressure locking" conditions in accordance with available test results. The model is described in more detail in Criteria/Assumption #7.

5. Conservative values for the valve factor (VF) are used throughout this calculation. These values are from the specific open valve factors for the individual valves found in Reference 1 and/or Reference 28. Conservative specific VF test values per Reference 28 are utilized for evaluation of SI-604/609, SI-651/652, SI-653/654, SI-655/656, SI-672/671, AF-34/35, AF-36/37, SI-685/694, SI-686/696, & SI-688/693.

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 6

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6. When the stem moves upward in the bonnet to engage the lugs of the T-slot of the gate, the bonnet volume is increased slightly reducing the fluid density and significantly reducing the bonnet pressure. The drop in pressure due to stem movement out of the valve bonnet is conservatively neglected in this calculation.

7. The model used to establish the normal force on the valve seat (see Fig. 2) assumes (a) the disks are flat, uniform in thickness, and of homogeneous isotropic material; (b) the thickness is not more than about one-quarter of the least transverse dimension, and the maximum deflection is not more than about one-half the thickness; (c) all forces, loads and reactions are normal to the plane of the plate; and (d) the plate is nowhere stressed beyond its elastic limit. Although the valve gates do not strictly meet assumption (b), use of this "thin plate" model conservatively estimates the disk perimeter line load, and therefore conservatively estimates the normal force in the seat. The use of this model is consistent with the methodology employed by Borg-Warner in the original design report (Ref. 10). A thin plate model is expected to predict greater flex in the disk, and a corresponding higher load in the seat, than would actually be present for the relatively thick disks of these gate valves. Therefore, use of the thin plate model results in additional conservatism in prediction of the stem thrust required to open the valve.

8. Many of the gate valve dimensions/tolerances are considered proprietary information by the vendors, Anchor Darling and Borg-Warner. The gate dimensions of similar spare gate valves were measured in the PVNGS Warehouse and verified and compared with vendor supplied information. Dimensions were confirmed to be conservative for this calculation. The disk hub and seat angle dimensions are recorded in Attachment 3 for use in this calculation. The valve Seat Radius dimensions were taken from Reference 1.

Other significant assumptions/criteria, not identified explicitly in the body of the calculation, are identified below:

9. The mean diameter of the seat is used to establish the portion of the valve gate disk susceptible to internal valve pressure. This assumption is consistent with the methodology used in the initial Borg-Warner design report (Ref. 10) and that recommended by EPRI (Ref.11) in their design guidelines.

10. The initial load in the valve seat, the seating load, is developed during valve closure by compression of the gate hub and bending the perimeter of the valve disks inward. This hub compression is partially relieved as the stem begins to travel upward, however, the majority of the compressive load remains in the hub due to the flex remaining in the perimeter of the disks. As pressurization of the bonnet takes place, the perimeter of the disks is forced outward by the bonnet pressure relieving a portion of the initial compression on the hub and the initial bending in the disks. A further increase in the bonnet pressure bends the perimeter of the disks outward loading the seats beyond the initial seating load and begins to place the gate hub in tension. This outward flex in the disks creates the "friction load" identified in Section 5.1.2.

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11. The weight of the valve stem and disk assembly is negligible (Ref. 1).

12. Conservative values for the stem/stem-nut coefficient are used throughout this calculation. These values are taken from Reference 1 and/or Reference 28.

13. A nomimal seat angle value of 5^o is used throughout this calculation unless otherwise specified. This value is found to be consistent with available vendor information, various field observations and Ref 10.

14. An average value for Poisson's ratio of 0.3 is used in this calculation to evaluate the value of the constants used in Roark's equation for perimeter load (Reference 12, Table 24, Case 2d) used to determine the disk load. The results of Roark's flat circular plate equations with loading constants are not sensitive to the specific value used for Poisson's ratio. This value is established as representative based on evaluation of Table 5.1.3, Elastic Constants of metals in Mark's Standard Handbook (Reference 17). Mark's Standard Handbook lists a Poisson's ratio for Stainless Steel of 0.305 and a Poisson's ratio for steels, including high-carbon, heat treated, in the range of 0.283 to 0.292.

15. The original Actuator Rated Thrust Limit is increased 140% for normal conditions for SMB-000, SMB-00, SMB-0, SMB-1 actuators. The total number of cycles under this increased thrust limit is limited to 2000 cycles. This increase of the original published Actuator Rated Thrust Limit supported by Reference 18, is endorsed by Limitorque in Reference 22.

16. Limitorque Engineering considers any size SMB actuator capable of withstanding a one-time allowable overload of up to 2 1/2 times the thrust load and up to 2 times the published torque load rating without damage or sacrifice to the actuator qualification per Reference 30. This one-time actuator allowable is utilized for the Shutdown Cooling System isolation valve modifications to SI-651/652, SI-653/654, & SI-655/656.

17. Pullout efficiencies identified in Calculation 13-JC-ZZ-201 (Reference 1) are typically used in actuator/thrust output determinations.

18. The minimum voltage used in this calculation is the available percentage of the motor rated voltage. These minimum voltages are developed from 01, 02, 03-EC-MA-221 (Ref. 35) and 01, 02, 03-EC-PK-207 (Ref. 36) for AC and DC MOV's respectively. In some cases the specific available minimum voltages are based on running unseating voltage and specific motor characteristics. Running currents after starting can be assumed when determining the worse case degraded voltage condition for MOV's with hammerblow or spring compensator pack since these devices allow the motor to reach running conditions prior to valve unseating. (Ref. 1, Section 4.2.3 and Ref. 34, Section 4.3)]

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 8

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19. Thermal Pressurization rates of 50 psig/^{o}F are modelled for the temperature increase above the highest normal design bases ambient temperature. This is more conservative than both the associated Commonwealth Edison Test (Attachment 5) and the INEEL Test (Reference 31). Based on discussions with the NRC, no credit is taken for the initial lower pressurization rates found in the initial heatup during testing that is attributed to the effect of the entrained air.

20. The hub load is a component load due to the piping differential pressure. It is modelled such that the load increase is transferred in accordance with the established EPRI test results that indicate a 40%/60% distribution reaction load between the high pressure and the low pressure seats (Reference 14). Based on discussions with the NRC, this adjustment was made to account for the INEEL, Crane and other test results that indicate that the pressure locking loads increase as the pressure difference between the bonnet and average line pressure goes up.

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4.0 INPUT DATA

The input data is included in the "Pressure Locking Susceptibility Evaluation" spreadsheet (Attachment 1). Table 2 below includes the values along with the references from which these values were obtained. Additional definition of terms along with common reference sources for the balance of the input data is included in the listing which follows this table.

Table 2: **System Inputs**

Valve ID	Tinitial (°F)	Tfinal (°F)	Pinitial (psig)	Pup (psig)	Pdown (psig)
AF-34/35	104 (Ref. 2)	123 (Ref. 2)	1801 (Ref. 26)	0 (Asmpt. 1)	0 (Asmpt. 1)
AF-36/37	104 (Ref. 2)	125 (Ref. 2)	1816 (Ref. 26)	0 (Asmpt. 1)	0 (Asmpt. 1)
SG-134/138	587 (Note 1)	587 (Note 1)	1383 (Ref. 4)	650 (Ref. 29)	0 (Asmpt. 1)
CH-536	104 (Ref. 2)	104 (Ref. 2)	97 (Ref. 8)	0 (Asmpt. 1)	0 (Asmpt. 1)
SI-604/609	104 (Ref. 2)	120 (Ref. 19)	1960 (Note 4)	660 (Note 2)	0 (Asmpt. 1)
SI-651/652	120 (Ref. 3)	160 (Ref. 20)	2561 (Ref. 6)	465 (Ref 6)	5 (Note 5)
SI-653/654	120 (Ref. 3)	160 (Ref. 20)	465 (Ref. 6)	465 (Ref 6)	5 (Note 5)
SI-655/656	104 (Ref. 2)	120 (Ref. 20)	470 (Ref. 6)	465 (Ref 6)	12 (Note 5)
SI-671/672	104 (Ref. 2)	104 (Ref. 2)	326 (Ref. 6)	5 (Note 5)	0 (Asmpt. 1)
SI-685/694	104 (Ref. 2)	104 (Ref. 2)	458 (Ref. 6)	12 (Note 5)	12 (Note 5)
SI-686/696	104 (Ref. 2)	104 (Ref. 2)	458 (Ref. 6)	12 (Note 5)	12 (Note 5)
SI-688/693	104 (Ref. 2)	104 (Ref. 2)	458 (Ref. 6)	13 (Note 5)	13 (Note 5)

NOTES:

1. Temperature is based on saturation temperature of steam at maximum pressure of 1383 psig (1398 psia) from Reference 4.
2. Pressure is based on lowest available total dynamic head at maximum flow of HPSI Pumps (Ref 23).
3. DELETED
4. Pressure is based on maximum upstream pressure at valves due to HPSI Pump total dynamic head (Ref. 5).
5. Piping Pressure (P_{up} & P_{down}) is conservatively based on Minimum RWT Level (Ref 6).

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SYSTEM INPUTS: (Table 2)

$T_{initial}$ = Initial Bonnet Temperature
T_{final} = Final Bonnet Temperature
$P_{initial}$ = Initial Bonnet Pressure
P_{up}= Upstream Piping Pressure
P_{down} = Downstream Piping Pressure

VALVE INPUTS

a = Mean Seating Radius = Mean Seating Diameter/2 (Attachment 3)
b = Hub Radius = Hub Diameter/2 (Attachment 3)
θ = theta = Seat Angle (Attachment 3)
ν = nu = Poisson's Ratio (Assumption 14)
VF = Valve Factor (Assumption 5)

VALVE STRUCTURAL LIMIT

Thrust = Valve Thrust (Ref. 1)
Torque = Valve Torque (Ref. 1)

MOV ACTUATOR/STEM INPUTS

OAR = Overall (Gear) Ratio (Ref. 1)
P.O. Ef = Pullout Efficiency (Ref 1)
COF = Stem Coefficient of Friction (Assumption 12)
Dstem = Diameter of Stem (Ref 1)
Pstem = Stem Thread Pitch (Ref. 1)
Lstem = Stem Thread Lead (Ref. 1)

ACTUATOR STRUCTURAL LIMITS

Thrust = Actuator Thrust (Ref. 1)
Torque = Actuator Torque (Ref. 1)

MOTOR INPUTS

Vfull = Motor Rated Voltage (Ref. 1)
Vmin = Minimum Voltage (Assumption 18)
VDF = Voltage Degradation Factor (Section 5.1.9.2)
M_{torq} = Rated Motor Torque (Ref. 1)
n = Voltage Degradation Factor Exponent, n = 1 for DC & n = 2 AC motors (Ref. 1)
TDF = Temperature Degradation Factor (Ref. 1)

MOV MISC INPUTS

Max Close Load = Maximum Closure Thrust (Ref. 1)
% Residual Load = Coefficient of Residual Maximum Closure Thrust (Assumption 10)

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5.0 CALCULATIONS/RESULTS

The term "Pressure Locking" is applied to a condition in which pressurization of the bonnet of a gate valve beyond the adjacent line pressure results in a higher stem thrust than the actuator is capable of delivering, preventing opening of the valve.

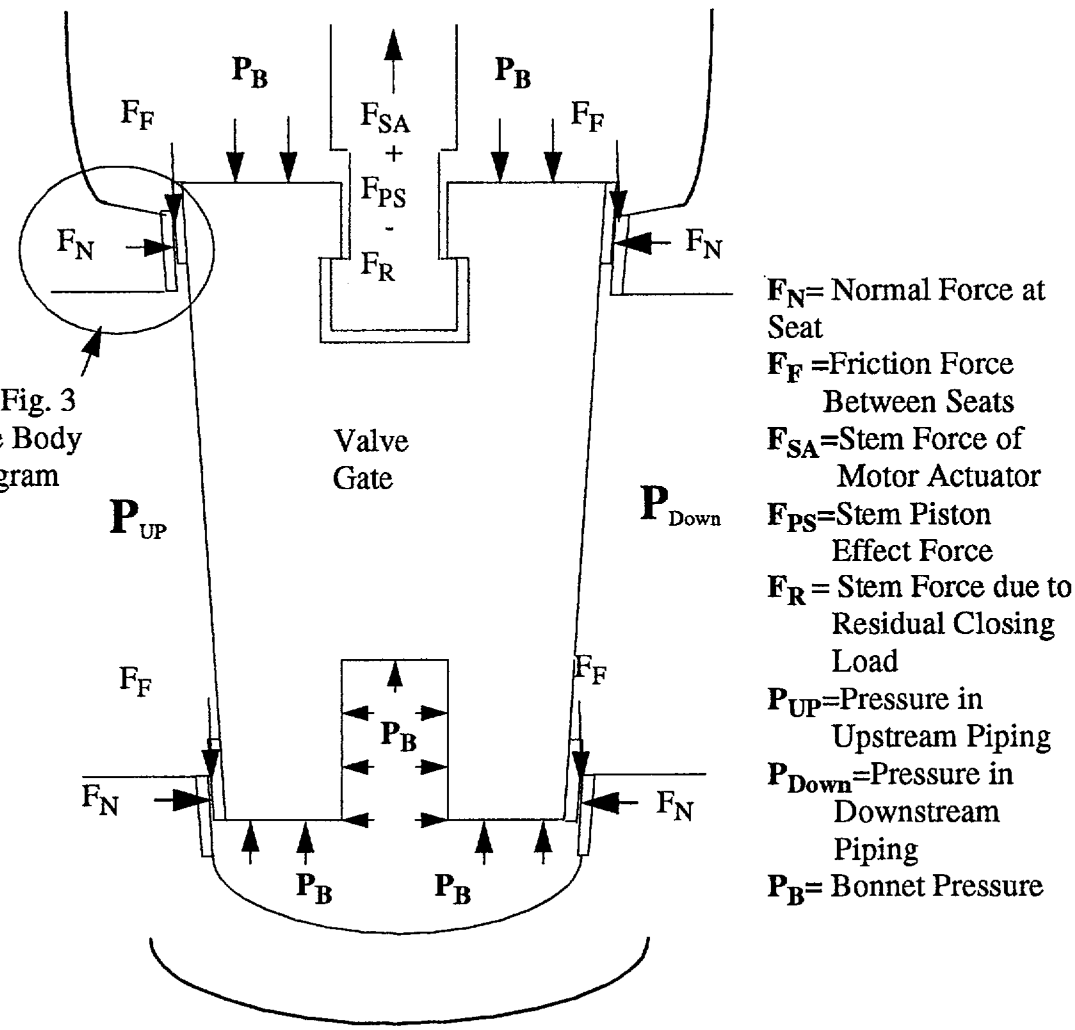

Figure 1:
Valve Gate/Body/Bonnet Interface

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5.1 Calculation Methodology

If potential "Pressure Locking (PL)" condition occurs, the following forces may be affecting the stem thrust required of the actuator to open the valve (see Figure 1):

Packing Load (Pkgld)- The load (opposed to valve motion) due to friction between the stem and the packing. This load is included in the value used for the Residual Load.

Disk Load (F_{disk})- The load (opposed to valve motion) transmitted to the valve stem due to friction between the seating surface of the gate and the seat of the valve body created by application of a differential pressure between the internals of the valve and the piping across the disks of the gate.

Hub Load (F_{hub}) The additional load transmitted to the valve stem due to friction between the seating surface of the gate and the seat of the valve body created by the upstream and downstream piping differential pressure acting on the gate disk and proportionally transmitted through the hub.

Residual Load (F_{resid})- The Load opposing valve opening caused by wedging the valve gate into the seat. This load includes running loads.

Vertical Load (F_{vert})- The vertical unbalanced load forcing the gate into the seat created by the bonnet pressure on the valve gate.

Stem Piston Load (F_{piston})- A load in the open direction created by application of the differential pressure between the valve internals and the ambient pressure on the net cross-sectional area of the valve stem. The net affect is to drive the stem, like a piston, out of the valve.

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 13

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5.1.1 Packing Load-
The packing load is conservatively approximated in "MOV Thrust and Actuator Sizing Calculation" (Ref. 1) by using the empirical equation of:

$$\textbf{Packing Load (Pkgld)} = D_{stem} \times 1000 \text{ lbf}$$

This is consistent with EPRI recommended methodologies for calculation of Packing Load (Ref.11). This load is included in the value used for the Residual load (F_{resid}).

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5.1.2 Disk and Hub Load

5.1.2.1 Disk Load-

The Disk Load (F_{disk}), the load at the valve stem due to friction at the interface of the valve gate and valve body seat, is a function of the force normal to the seat, the angle between the plane of the valve seat and the valve stem axis, and the coefficient of friction at the valve seat. The normal force at the seat is a function of the valve internal (bonnet) pressure, the pressure in the piping upstream and downstream of the valve, as well as the cross-sectional areas upon which the pressures are applied. Many of the forces on the disk of the gate are balanced by forces of equal magnitude but opposite in direction (Reference Figure 1). Only the unbalanced forces on the disk contribute to the normal load on the seat.

For the purpose of determining the Seat Friction Load, the unbalanced load applied on each seat can be conservatively estimated by modelling the flex-wedge gate valve as a parallel disk gate valve. The hub connecting the two disks of the gate is modelled as a rigid, fixed structure. The force applied across the disk due to the difference in bonnet pressure and line pressure results in a deflection of the outer perimeter of the disk seat and resultant normal load on the seat (see Figure 2). |

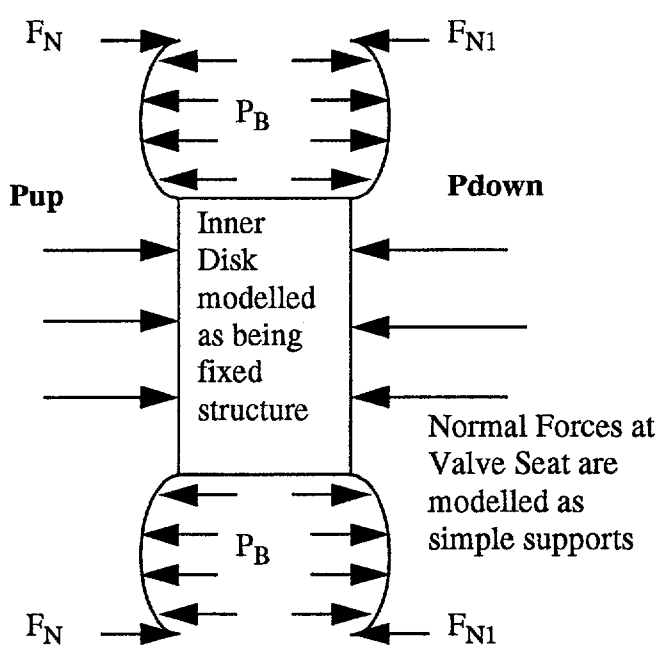

Figure 2: Model Utilized in Calculating the Forces on the Disk in the Axis of the pipe

The force on the seat at the perimeter of the disks, due to disk deflection, (F_N in Figure 3) will be conservatively assumed to be the net unbalanced horizontal force on the gate due to Bonnet Pressure |

(F_{BG} in Figure 3). The friction force (F_F in Figure 3) lies in the plane of the valve seats and places a load on the stem (F_F (cos 5^o)). The full friction force will be conservatively assumed to be transmitted to the valve stem.

F_{BW}= Net Vertical Force on Gate due to Bonnet Pressure
F_{BG}= Net Horizontal Force on Gate due to Bonnet Pressure
F_F= Friction Force between Gate Seat & Valve Body Seat
F_{LP}= Force on Gate due to Line Pressure on one side of Gate
F_N= Normal Force of Seat (opposing disk deflection)
F_S= Net Stem Force required at Stem/Gate interface to unseat Gate

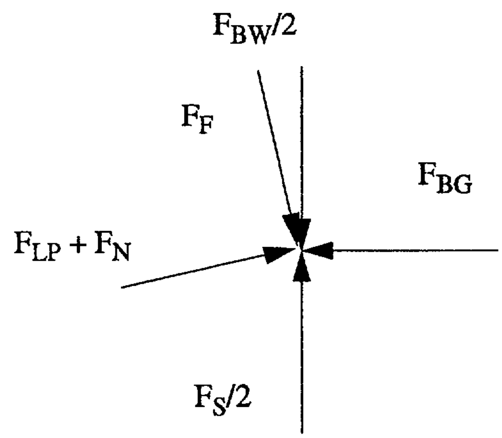

Figure 3: Free Body Diagram of the Valve Seat

The Disk Load conservatively taken to be the horizontal disk load caused by the differential pressure between the average line pressure and the bonnet pressure at both of the seats is given by:

Disk Load (F_{disk}) = $2(Q_a)P_L(\mu)$
with,
P_L= length of Disk mean seat perimeter= $2\pi a$
μ= Coefficient of Friction at Valve Seat = $[VF*\cos\theta]/[1-(VF*\sin\theta)]$ (Assumption 3)
Q_a = Force/inch exerted at the gate disk seat

where,

$Q_a = -[Q_b(b/a)-((P_b-P_{ave})/2a)(a^2-r^2)]$ (Ref. 12, Table 24, Case 2d)
$Q_b = (P_b-P_{ave})(a)[C_2(L_{17})-C_8(L_{11})]/[C_2(C_9)-C_3(C_8)]$ Note: $q = (P_b - P_{ave})$
$C_2= 0.25\{1-(b/a)^2[1+2\ln(a/b)]\}$
$C_3= (b/4a)\{[(b/a)^2+1]\ln(a/b)+(b/a)^2-1\}$
$C_8= 0.5[1+\nu+(1-\nu)(b/a)^2]$
$C_9= (b/a)\{[(1+\nu)/2]\ln(a/b)+[(1-\nu)/4][1-(b/a)^2]\}$
$L_{11}= 0.015625\{1+4(r/a)^2-5(r/a)^4-4(r/a)^2[2+(r/a)^2]\ln(a/r)\}$ (Note: r = b)

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$L_{17} = 0.25\{1-[(1-\nu)/4][1-(r/a)^4]-(r/a)^2[1+(1+\nu)\ln(a/r)]$

and,

$P_b = P_B$ = Valve Bonnet (Valve Internal) Final Pressure

P_{ave} = Average Line Pressure $(P_{up} + P_{down})/2$

P_{up} = Line pressure upstream of the Valve Gate

$P_{down} = P_{DP}$ = Line pressure downstream of the Valve Gate

b= Radius of Hub between Valve Gate Disks

a= Mean Radius of Disk Seat

r= Minimum Radius of Disk subjected to bonnet pressure

ν= Poisson's ratio

5.1.2.2 Hub Load

The Hub Load (F_{hub}) accounts for the additional load at the valve stem due to friction at the interface of the valve gate and valve body seats as a result of the differential pressure between the upstream and downstream piping pressure acting on the gate disk and proportionally transmitted through the hub. This load is added as a component due to piping differential pressure in accordance with the established 40%/60% split in load reaction between the high pressure and low pressure seats.(Criteria/Assumption 4 & 20)

Hub Load (F_{hub}) = $(Q_{ad} + Q_{au})P_L(\mu)$

with,

P_L = length of Disk mean seat perimeter= $2\pi a$

μ = Coefficient of Friction at Valve Seat = $[VF^*\cos\theta]/[1-(VF^*\sin\theta)]$ (Assumption 3)

Q_{ad} = Force per inch on the downstream disk at the seat due to proportioned transfer of differential line pressure (difference between upstream and downstream piping pressure)

Q_{au} = Force per inch on the upstream disk at the seat due to proportioned transfer of differential line pressure (difference between upstream and downstream piping pressure)

where,

On the downstream side of gate,

$Q_{ad} = w(b/a) = [(0.6P_{up} - 0.4P_{down})(\pi a^2)/(2\pi b)](b/a)$ (Ref. 12, Table 24, Case 1b)

$= (0.6P_{up} - 0.4P_{down})(a/2)$

On the upstream side of gate,

$Q_{au} = w(b/a) = [(0.6P_{down} - 0.4P_{up})(\pi a^2)/(2\pi b)](b/a)$ (Ref. 12, Table 24, Case 1b)

$= (0.6P_{down} - 0.4P_{up})(a/2)$

therefore,

$(F_{hub}) = (0.6P_{up} - 0.4P_{down} + 0.6P_{down} - 0.4P_{up})(a/2)[P_L(\mu)]$

$= (0.2P_{up} + 0.2P_{down})(a/2)(2\pi a)(\mu)$

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 17

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5.1.3 **Residual Load**

The residual load is the load opposing valve opening caused by wedging the valve into the seat during the prior closing stroke. This load is adjusted to compensate for the relaxation in the wedging load which occurs when stem motion is initiated in the open direction and the substitution of this load with the bonnet pressure induced load. The bonnet pressure load has been determined to replace increasing proportions of the residual load as the bonnet pressure increases (Criteria/Assumption 10).

The residual load is calculated by taking the established design static peak cracking load (Reference 1), inclusive of inertia and instrument uncertainty, and multiplying it by an empirically derived fractional residual load factor developed from the experimentally derived correlation presented in Attachment 4. It is based on the correlation with the ratio of the bonnet pressure loads and the prior closing force. It has been established that at Static Peak cracking conditions that the fractional residual load factor is 0.67 of the prior closing force (Ref. 14). This correlation was established based on analysis of test results (Attachment 5) and indicates that as the bonnet pressure increases the residual load percentage of the effective closing thrust is reduced. The following resulting relationships for the Residual Load are used:

Residual Load (F_{resid}) = (SPC) (F_{rspc})

SPC = Static Peak Cracking

F_{rspc} = Fractional Residual Load of Static Peak Cracking Factor (Attachment 4, Chart 3)

$= 1 - 0.15(DC_{resid})$

DC_{resid} = Dimensional Correlation = $P_b[\pi(a^2 - b^2)]\cos(\theta)/F_{eff.\ closing}$

$F_{eff.\ closing}$ = Effective Closing Force = Static Peak Cracking/0.67

Coefficient of Residual load = 0.67

The Coefficient of Residual Load is the empirically derived coefficient (0.67) that based on an observed 33% relaxation in load between closure and when the open stem motion is initiated under static conditions (with zero bonnet pressure) and a reduction in the residual load due to a proportional replacement by the effect of the bonnet pressure load. The static peak cracking is the value of the unwedging load (opening force) with zero bonnet and line pressure.

The Static Peak Cracking is divided by 0.67 to determine the effective closing force using 33% relaxation in the prior closing load. This is similar to the coefficient utilized in the EPRI MOV Performance Prediction Program Topical Report (Ref 14) for correlating test data to develop a simplified unwedging thrust equation.

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5.1.4 Vertical Load

The vertical load is the force due to bonnet pressure (P_b) driving the gate into the seat. This vertical unbalanced load across the valve disk is driven by the differential pressure between the bonnet and average of the upstream and downstream piping pressure directed into the valve seat ($Pb - P_{ave}$). The vertical load is conservatively calculated by multiplying the average differential pressure between the valve bonnet pressure and the average of the upstream and downstream pressures by the unbalanced horizontal area of the gate disks. The unbalanced horizontal area is a sum of the two ellipses projected on to the horizontal plane whose perimeter is bounded by the seat inside perimeter. The actual force down on the disk is due to the horizontal projection of the circular geometry of the seat which the unbalance differential pressure (P_b-P_{ave}) is applied across. The net cross-sectional area of each gate disk seat which the pressure acts upon is an ellipse (see Figure 4).

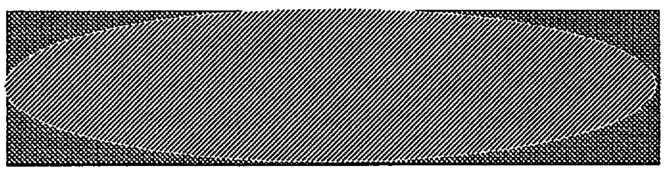

Figure 4: Plan View of Net Cross-Sectional Area on which the Bonnet Pressure may be Applied for a Single Disk of a Valve Gate
(Elliptical Area is the Effective Area which DP is applied across)

The Vertical Load is then:

$$\textbf{Vertical Load } (\mathbf{F_{vert}}) = (A_e)(P_b - P_{up}) + (A_e)(P_b - P_{down})$$
$$= 2(A_e)\ (P_b - (P_{up} + P_{down})$$

let,

$$P_{ave} = (P_{up} + P_{down})/2$$
$$F_{vert} = 2(A_e)(P_b - P_{ave})$$
$$= 2(\pi(\mathrm{Sin}(\theta))a^2(P_b - P_{ave})$$

where,

A_e = Elliptical Area, Effective Single Seat Area projected on to the horizontal plane susceptible to differential pressure.

$A_e = \pi(a)d = \pi(\mathrm{Sin}(\theta))a^2$

- a = Ellipse major Radius = $D_{seat}/2$
  - D_{seat}= Diameter of Seat (inches)
- d = Ellipse minor Radius = $(\sin(\theta)(D_{seat}))/2$
- θ = theta = Seat Angle (degrees)

and,

P_b = Bonnet Presure (psig)

P_{up} = Upstream Piping Pressure (psig)

P_{down} = Downstream Piping Pressure (psig)

$P_{ave} = (P_{up}+P_{down})/2$ (psig)

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5.1.5 Unwedging Effect

The unwedging effect is the upward component of the upstream and downstream line pressure load acting on the gate due to the gate taper. It is conservatively neglected.

Unwedging Load= $[(P_{up} + P_{down}) / 2]\,[\pi a^2]\,[\sin\theta]$

5.1.6 Stem Piston Load

The Stem Piston Load is conservatively determined by calculating the product of the bonnet pressure and the stem cross-sectional area (Ref. 11):

Stem Piston Load $(F_{piston}) = (\pi/4)(D_{stem}^2)P_B$

5.1.7 The Total Required Stem Thrust

The total required stem thrust is the sum of these various forces acting on the stem. If the "unwedging load" is neglected the total required stem thrust can be calculated as:

Required Stem Thrust = Disk load + Hub Load + Residual Load + Vertical Load - Stem Piston Load

$$(F_{total}) = (F_{disk}) + (F_{hub}) + (F_{resid}) + (F_{vert}) - (F_{piston})$$

5.1.8 Bonnet Pressure and Average Differential Pressure

5.1.8.1 Bonnet Thermal Pressurization Model

A conservative relationship consistent with the steady state rate between bonnet pressure and temperature implied by NUREG/CE-6611 (Ref. 31) and the theoretical saturated liquid conditions is utilized. This implied pressurization is 50 psig/°F. No credit for the potential initial lower pressurization rates observed during testing is taken in accordance with agreement during discussions with the NRC since these initial lower thermal pressurization rates are attributed to the effect of entrained air. The resulting equation for final bonnet pressure utilized in this model is therefore:

$$P_b = P_0 + [50\ \text{psig}/^{o}\text{F} * (T_2 - T_1)]$$

Where:

P_b = Final Bonnet Pressure
P_0 = Inital Bonnet Pressure at time 0
T_2 = Final Temperature
T_1 = Inital Temperature

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 20

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5.1.8.2 Bonnet Thermal Pressurization Tests

This evaluation is presented to document the initial review of the Commonwealth Edison Borg Warner thermal pressurization test results presented in Attachment 5. The resulting equations are not utilized for design basis purposes. This evaluation developed a relationship between bonnet pressure and temperature due to the effects of bonnet water temperature increases on bonnet pressure based on testing of a PVNGS spare 10" Borg-Warner gate valve at Commonwealth Edison's Braidwood Station test facility. The practically water solid valve assembly was heated in separate tests at different heat rates and the internal bonnet fluid temperature and pressure were recorded at various time intervals. This test data is compared to theoretical pressurization and the model presented below and in Attachment 2 to identify the relative apparent conservatisms.

The heat-up testing indicates two distinctive pressurization regions. The first region [Region I] which indicates the initial 60 °F bonnet temperature increase can be conservatively modeled using a pressurization rate of 3 psig/ °F, the maximum dP/dT identified in Region I. Although the first region spans the first 60 °F bonnet fluid temperature increase, additional conservatism was added by assuming this gradual pressurization rate (3 psig/ °F) through only the first 30 °F of the thermal transient. Then for Region I,

$dP_I/dT = 3$ psig/°F [Region I, first 30 °F temperature change only]

$P_I = P_0 + 3$ psig/ °F$(T_2 - T_1)$

where P_0 is the initial bonnet pressure and P_I is the bonnet pressure increase in Region I. If $T_2 - T_1$ is greater than 30 °F,

$P_I = P_0 + 3(30) = P_0 + 90$ °F [Region I]

The second region [Region II] which includes the bonnet temperature increase greater than 30 °F can be conservatively modelled using the highest two applicable pressurization rates: 42 psig/ °F at 150 °F and 65 psig/ °F at 290 °F. For Region II ($T_2 - T_1$ must be greater than 30 °F),

$dP_{II}/dT = mT + b$ [Region II, after first 30 °F temperature change only]

where:

m= (65 psig/ °F - 42 psig/ °F)/(290 °F - 150 °F) = 0.16429 psig/°F^2

b = 42 psig/ °F - (0.16429 psig/°F^2)(150 °F) = 17.3565 psig/°F

Thus, dP/dT becomes:

dP_{II}/dT = (0.16429 psig/°F^2)T + 17.3565 psig/°F

Integrating the Region II dP/dT equation from an initial Region II temperature (T_1 + 30 °F) to a final Region II temperature (T_2) yields the following equation:

P_{II} = 0.08215 psig/ °F^2($T_2^2 - (T_1 + 30)^2$) + 17.3565 psig/°F($T_2 - (T_1 + 30)$) [Region II]

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 21

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The Region I and Region II pressure equations can be added together to determine the total pressure increase due to a bonnet fluid temperature increase from T_1 to T_2. This equation can be expressed in two forms depending on the magnitude of the bonnet temperature increase.

This first equation applies to temperature increases less than or equal to 30 °F ($T_2 - T_1 <= 30$ °F):

$$P_I = P_b = P_0 + 3 \text{ psig/ }^oF(T_2 - T_1)$$

This second equation applies to temperature increases greater than 30 °F ($T_2 - T_1 > 30$ °F):

$$P_{TOTAL} = P_b = P_0 + 90 \text{ psig} + 0.08215 \text{ psig/ }^oF^2(T_2{}^2 - (T_1 + 30)^2) + 17.3565 \text{ psig/}^oF(T_2 - (T_1 + 30))$$

This equation is pressented for evaluation purposes only. See Section 5.1.8.1 of this calculation for the thermal pressurization equation utilized for design basis purposes.

5.1.8.3 Average Differential Pressure

The Average Diffential Pressure is determined by the equation:

$$DP_{avg} = P_b - ((P_{up} + P_{down})/2)$$

Where:

P_b = Final Bonnet Pressure

P_{up} = Piping Upstream Pressure

P_{down} = Piping Downstream Pressure

5.1.9 Available Torque and Thrust Limits

This section of the methodology is taken from the "MOV Thrust and Actuator Sizing Calculation", Reference 1. The available Motor Torque is derived utilizing the rated motor torque, overall gear ratio, Pullout efficiency, voltage degradation factor, temperature degradation factor and the stem factor similar to Reference 1. The minimum limiting Thrusts and Torques for the valve and actuator are identified. The torque values are converted to thrust values utilizing an updated derived stem factor similar to that in Reference 1 utilizing stem/stem-nut coefficient of friction based on available test results (Assumption 12 & Reference 28).

5.1.9.1 Stem Factor

$$FS = (D * ((0.96815 * \tan \alpha) + COF))/(24 * (0.96815 - (COF * \tan \alpha)))$$ (Reference 1)

FS = Stem Factor

D = Active Thread Diameter (inches) = $D_{stem} - (0.5 * P_{stem})$

D_{stem} = Stem Diameter (inches)
P_{stem} = Stem Pitch (inches/thread)

COF = Stem/Stem Nut Coefficient of Friction (Assumption 12)

Tan α = Tangent of thread helix angle = $L_{stem} / (\pi * D)$
L_{stem} = Stem Lead (inches/revolution)
π = Ratio of circumference to diameter = 3.141592654...

5.1.9.2 Available Torque

$A_{torq} = M_{torq} * OAR * P.O.\ Ef * VDF * TDF$ (Reference 1)

A_{torq} = Available Torque

OAR = Overall (Gear) Ratio

M_{torq} = Rated Motor Torque

P.O. Ef = Pullout Efficiency (Reference 1)

5.1.9.2.1 VDF = Voltage Degradation Factor (Reference 24)
V_{min} = Minimum Voltage
V_{full} = Motor Rated Voltage

5.1.9.2.1.1 VDF and related Factors for AC Motors (Reference 33)
If $V_{min}/V_{full} >= 0.9$ Then use 0.9

If $V_{min}/V_{full} < 0.9$ Then use 0.9 and $(V_{min}/V_{full})^2$ Factors

1.9.2.1.1 VDF for DC Motors (Reference 34)
Use 1.0 and $(V_{min}/V_{full})^1$ Factors

5.1.9.2.2TDF = Temperature Degradation Factor (Reference 1 App. M)

5.1.9.3 Available Thrust

$A_{thrust} = A_{torq} / FS$ (Reference 1)
A_{thrust} = Available Thrust

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5.1.9.4 MOV Minimum Available Thrust or Torque Limit

Thrust Limits

A = Valve Structural Thrust Limit (Reference 1)

B = Actuator Structural Thrust Limit (Reference 1)

C = Available Thrus (Section 5.1.9.3)

Torque Limits (Converted to Equivalent Thrust)

D = Actuator Structural Torque Limit / Stem Factor (Ref. 1 & Section 5.1.9.1)

E = Valve Structural Torque Limit / Stem Factor (Ref. 1 & Section 5.1.9.1)

The mimimum limiting case, F_{min}, from the above listed parameters A, B, C, D or E is controlling.

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 24

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5.1.10 <u>Pressure Lock Susceptibility</u>

Pressure Lock susceptibility is checked by comparing the minimum limiting value of the available thrust, allowable torque and thrust limits for the valve and actuator (Section 5.1.9) to the "Total Required Stem Thrust" for potential pressure locking conditions (Section 5.1.7). A valve is identified as susceptible to pressure locking when the conservatively calculated "Total Required Stem Thrust" exceeds the identified minimum limiting value of torque or thrust.

If (Total Required Stem Thrust) > (MOV Minimum Thrust or Torque Limit)

$$\text{If } F_{total} > F_{min}$$

then the MOV is susceptible to pressure locking

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5.2 Manual Verification Calculation

The following hand calculation is applicable to the 3" Borg Warner 1500# gate valve 1SI-604 and is presented as a representative check to validate the results of the Excel computer spread sheet calculations in Attachment 1. A calculator with 10 digit floating point significant figures with standard rounding is used for this hand calculation. Efforts were taken to maintain as much precision as reasonable when working through each equation to minimize the effects of rounding. The maximum available Excel spreadsheet full precision was utilized in the calculation of loads and determination of coefficients and factors presented in Attachment 1.

5.2.1 Bonnet Pressure

Input Data

$T_1 = T_{initial} = 104\ ^oF$

$T_2 = T_{final} = 120\ ^oF$

$P_o = P_{initial} = 1{,}960$ psig

Output Data

$T_2 - T_1 = 120\ ^oF - 104\ ^oF = 16\ ^oF$ (Use Equation for P_b, Section 5.1.8.1)

$P_b = P_{final} = P_I = P_o + [50\ psig/^oF * (T_2 - T_1)^oF] = [1{,}960 + 50(16)] = 2{,}760$ psig

5.2.2 Average Differential Pressure

Input Data

$P_{up} = 660$ psig

$P_{down} = 0$ psig

Output Data

$DP_{avg} = P_b - ((P_{up} + P_{down})/2) = 2760 - ((660 + 0)/2) = 2{,}430$ psig

5.2.3 Stem Factor

Input Data

$D_{stem} =$ 0.875 (in.)

$P_{stem} =$ 0.16667 (in./thread)

COF = 0.20

$L_{stem} =$ 0.33333 (in./rev)

Output Data

$D = D_{stem} - (0.5 * P_{stem}) = 0.875 - (0.16667/2) = 0.79166$ (in.)

$\text{Tan}\ \alpha = L_{stem} / (\pi * D) = 0.33333/(\pi * 0.79166) = 0.13402$

$FS = (D * ((0.96815 * \text{Tan}\ \alpha) + COF))/(24 * (0.96815 - (COF * \text{Tan}\ \alpha)))$

$= (0.79166((0.96815*0.13402)+0.2))/(24*(0.96815-(0.20*0.13402) = 0.011555$

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 26

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5.2.4 Available Torque

Input Data

M_{torq} = 15 ft-lbs

OAR = 36.2

P.O. Ef = 0.4

V_{min} = 414 volts

V_{full} = 460 volts

n = 2 (for AC motors)

TDF = 0.97

Output Data

V_{min}/V_{full} = (414/460) = 0.9; Then use VDF = 0.9

$A_{torq} = M_{torq}$ * OAR * P.O. Ef * VDF * TDF

= 15(36.2)(0.4)(0.9)(0.97) = 189.62 ft-lbf

5.2.5 Available Thrust

Output Data

$A_{thrust} = A_{torq}$ /FS = 189.62/.011555 = 16,410 lbf

5.2.6 Disk Load & Hub Load

Input data

b = r = 1.11 (in.) (Attachment 3)

a = 1.375 (in.) (Attachment 3)

ν = nu = 0.3 (Assumption 14)

θ = theta = 5.25° (Attachment 3)

μ = mu = [VF*Cos θ]/[1-(VF*Sin θ)]

[0.5*cos(5.25°))/(1-(0.5*sin(5.25°))] = 0.5218

Output Data

Perimeter Load

$C_2 = 0.25\{1-(b/a)^2[1+2\ln(a/b)]\} = 0.25\{1-(1.11/1.375)^2[1+2\ln(a/b)]\} = 0.0173$

$C_3 = (b/4a)\{[(b/a)^2+1]\ln(a/b)+(b/a)^2-1\}$

$= (1.11/(4(1.375))\{[(1.11/1.375)^2+1]\ln(1.375/1.11)+(1.11/1.375)^2-1\} = 0.00107$

$C_8 = 0.5[1+\nu+(1-\nu)(b/a)^2] = 0.5[1+0.3+(1-0.3)(1.11/1.375)^2] = 0.8781$

$C_9 = (b/a)\{[(1+\nu)/2]\ln(a/b)+[(1-\nu)/4][1-(b/a)^2]\}$

$= (1.11/1.375)\{[(1+0.3)/2]\ln(1.375/1.11)+[(1-0.3)/4][1-(1.11/1.375)^2]\} = 0.1616$

$L_{11}= (0.015625)\{1+4(r/a)^2-5(r/a)^4-4(r/a)^2[2+(r/a)^2]\ln(a/r)\}$

$= (0.015625)\{1+4(1.11/1.375)^2-5(1.11/1.375)^4-4(1.11/1.375)^2[2+(1.11/1.375)^2*$

$n(1.375/1.11)\} = 0.0000528$

$L_{17}= 0.25\{1-[(1-\nu)/4][1-(r/a)^4]-(r/a)^2[1+(1+\nu)\ln(a/r)]$

$= 0.25\{1-((1-0.3)/4)[1-(1.11/1.375)^4]-(1.11/1.375)^2[1+(1+0.3)\ln(1.375/1.11)]\} =0.0166$

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3	[signature]	2-10-2000	[signature]	02/10/00						↓

$Q_b = (DP_{avg})(a)[C_2(L_{17})\text{-}C_8(L_{11})]/[C_2(C_9)\text{-}C_3(C_8)]$

$= (2430)(1.375)[0.0173(0.0166)\text{-}0.8781(0.0000528)]/[0.0173(0.1616)\text{-}0.00107(0.8781)]=433$

$Q_a = \text{-}[Q_b(b/a)\text{-}(((P_b\text{-}P_{ave})/2a)(a^2\text{-}r^2))]$

$= \text{-}[433(1.11/1.375)\text{-}(2430/(2(1.375))(1.375^2\text{-}1.11^2))] = \text{-}232$

5.2.6.1 Disk Load

$(F_{disk}) = -4(\pi)a(Q_a)(\mu) = -4(\pi)1.375(-232)(0.5218) = 2{,}092$ lbf

5.2.6.2 Hub Load

$(F_{hub}) = [0.2(P_{up} + P_{down})\ (a/2)\ (2\pi a)\ (\mu)]$

$= [0.2(660\text{-}0)(1.375/2)(2(\pi)1.375)(0.5218) = 409$ lbf

5.2.7 Residual Load

Input Data

SPC (Static Peak Cracking) = 6836 lbf (Ref. 38 & 39)

P_{final} (Bonnet Pressure) = 2760 psig (Sect. 5.2.1)

Output Data

$F_{eff.\ closing} = SPC/0.67 = 6836/0.67 = 10{,}203$ lbf

DC (Dimensional Correlation) = Ratio of pressure bonnet forces to closing forces

$DC_{resid} = P_b[\pi(a^2 - b^2)]\cos(\theta)/F_{eff.\ closing}$

$= 2760[\pi(1.375^2 - 1.11^2)]\cos(5.25)/10{,}203 = 0.557$

F_{rspc}(Fractional Residual Load of Static Peak Cracking) = Experimentally derived fractional factor for Static peak cracking remaining at pressure locking conditions (See Attachment 4)

$F_{rspc} = 1 - 0.15(DC_{resid}) = 1 - 0.15\ (0.557) = 0.916$

F_{resid} (Residual Force) = SPC * F_{rspc} = 6836 * 0.916 = 6262 lbf

5.2.8 Vertical Load

Input Data

θ = theta = 5.25° (Attachment 3)

a = 1.375 in. (Attachment 3)

Output Data

$F_{vert} = 2(\pi(\sin(\theta))a^2(P_b - P_{avg}) = 2(\pi)(\sin(5.25))(1.375)^2(2430) = 2{,}641$ lbf

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3	[signature]	2-10-2000	[signature]	02/10/00						

5.2.9 Stem Piston Load

Input Data

$D_{stem} = 0.875$

Output Data

$F_{piston} = (\pi/4)(D_{stem}{}^2)P_b = (\pi/4)(0.875^2)(2{,}760) = 1{,}660$ lbf

5.2.10 The Total Required Stem Thrust (to overcome pressure locking conditions)

Output Data

$F_{total} = F_{disk} + F_{hub} + F_{vert} + F_{resid} - F_{piston} = 2{,}092 + 409 + 2{,}641 + 6262 - 1{,}660 = 9{,}744$ lbf

5.2.11 The Total Required Stem Torque (to overcome pressure locking conditions)

Output Data

$T_{required} = F_{total}$ * FS (Stem Factor) = 9,744 * 0.011555 = 112 ft-lbf

5.2.12 MOV Minimum Trust or Torque Limit

Thrust Limits

A = Valve Structural Thrust Limit = 12,097 lbf (Reference 1)

B = Actuator Structural Thrust Limit = 19,600 lbf (Reference 1)

C = Available Thrust = 16,410 lbf (Section 5.1.9.3)

Torque Limits

D = Actuator Structural Torque Limit / Stem Factor (Ref. 1 & Section 5.2.3)
= 275/0.011555 = 23,799 lbf

E = Valve Structural Torque Limit / Stem Factor (Ref. 1 & Section 5.2.3)
= 140/0.011555 = 12,116 lbf

Note: the valve structural torque limit was increased by 13% (124 * 1.13 = 140) based on study 13-JS-A41 (Reference 37) which increased the allowable stress by approximately 13% based on an acceptable lower temperature limit of 225 ^oF.

The mimimum limiting value for Valve 1SI-604 from the above listed parameters is the Thrust associated with the Valve Structural Thrust Limit of 12097 lbf.

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potential CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L 95-07 SHEET NO. 29

REV	ORIGINATOR	DATE	INDEPENDENT VERIFICATION	DATE	REV	ORIGINATOR	DATE	INDEPENDENT VERIFICATION	DATE	Rev. Indi-cator ↓
3	[signature]	2-10-2000	[signature]	02/10/00						

5.2.13 Pressure Lock Susceptibility

If the Total Required Stem Thrust for potential pressure locking conditions from Section 5.1.7 is less than the MOV Minimum Thrust or Torque Limit from Section 5.1.9.4 then the MOV is not susceptible to pressure locking

Total Required Trust < Valve/Actuator Limiting Thrust

9,744 lbf < 12,097 lbf (Section 5.2)

therefore; MOV 1SI-604 is not susceptible to pressure locking

5.3 Comparison of Calculation Results

Comparison of the hand calculation numerical results in Section 5.2 above are in agreement with the computer Excel spreadsheet calculation. The small difference in the Total Required Thrust (or Torque) Limit is in the order of 0.1% and due to rounding. Therefore, the Excel spreadsheet results are validated by this representative sample hand calculation.

REV	ORIGINATOR	DATE	INDEPENDENT VERIFICATION	DATE	REV	ORIGINATOR	DATE	INDEPENDENT VERIFICATION	DATE	Rev. Indicator
3	[signature]	2-10-2000	[signature]	02/10/00						

6.0 References

1. 13-JC-ZZ-201, Rev. 11, "MOV Thrust, Torque and Actuator Sizing Calculation".

2. 13-NC-ZA-212, Rev 1, "Auxiliary Building Pressure/Temperature Analysis for Letdown Line Break".

3. 13-NC-ZC-211, Rev 4, "Safety Related Equipment Thermal Qualification Analysis".

4. 13-MC-SG-811, Rev 1, "Maximum Differential Pressures Across MOV's SG-134/138 and AF-54".

5. 13-MC-SI-222, Rev 0, "HPSI Hot Leg Injection MOV's-Maximum Differential Pressure, Line Pressure, Temp, Flow".

6. 13-MC-SI-226, Rev 0, "Maximum Operating Pressures for Low Pressure SIS, SCS, and CS MOVs".

7. 13-NC-ZC-206, Rev 1, "Containment Pressure/Temperature Transient Analysis, Loss of Coolant Accident".

8. N001-07.01-174-2, Maximum Line/DP Cases for CVCS.

9. 13-MS-A96, Rev 0, "Gate Valve Pressure Locking and Thermal Binding Evaluation".

10. N001-01.01-0262, "Design Report of 16 x 12 x 16 Inch 1512 lbs Stainless Steel Gate Valve.

11. MPR Associates, "Application Guide for Motor-Operated Valves in Nuclear Power Plants", EPRI NP-6660-D, Research Project 2814-2 (January 1990).

12. Young, Warren C.,Roark's Formulas for Stress & Strain, 6th ed., New York: McGraw-Hill, 1989.

13. BATTEL, "EPRI MOV Performance Prediction Program- Friction Separate Effects TesReport", EPRI TR-103119, Project 3433-13 (November 1993).

14. MPR Associates, "EPRI MOV Performance Prediction Program, Topical Report", EPRI TR-103237, Research Project 3433 (November 1994).

15. CRDR 9-5-0836, Generic Letter 95-07 PVNGS MOV Operability Evaluation.

16. Generic letter 95-07, Pressure Locking and Thermal Binding of safety-Related Power-Operated Gate Valves.

CALCULATION SHEET

CALC. TITLE Gate Valve Open Thrust Required during Potental — CALC. NO 13-MC-ZZ-217

SUBJECT Pressure Locking Conditions per G.L. 95-07 — SHEET NO. 31

REV	ORIGINATOR	DATE	INDEPENDENT VERIFICATION	DATE	REV	ORIGINATOR	DATE	INDEPENDENT VERIFICATION	DATE
3	[signature]	2-10-2000	[signature]	02/10/00					

Rev. Indicator ↓

17. Avallone & Baumeister, Mark's Standard Handbook for Mechanical Engineers, Ninth Edition (1987).

18. 13-JN-021-A044-1, Kalsi Report No. 1707C, "Thrust Rating increase of Limitorque SMB-000, SMB-00, SMB-0, and SMB-1 Actuators".

19. 13-MC-SI-330 R/0, Calculation of Bonnet Fluid Temperature for MOV SI-604/609.

20. 13-MC-SI-331 R/0, MOV Bonnet Temperature (MOV's SI-651/652/653/654/655/656).

21. EPRI MOV PPP Program Staff, "EPRI MOV Stem/Stem-Nut Lubrication Test Report, EPRI TR-102135, Projects 3433-04,-10,-26 Topical Report (August 1993).

22 Limitorque Technical Update 92-02, Kalsi Engineering Document #1707-C, Rev 0 (11-25-91) Thrust Rating increase.

23. VTM I075-001-3, Ingersol Rand Pumps and Associated Components.

24. Limitorque Technical Update 93-03, Reliance 3-Phase Limitorque Corporation Actuator Motors.

25. Battelle, "EPRI MOV PPP Friction Separate Effects Test Reports, EPRI TR-103119, Poject 3433-13 Topical Report (November 1993) .

26. 13-MC-AF-401, Rev 2, "AFW System MOV Maximum Differential Pressure".

27. ASME Steam Tables, Fifth Edition (1983).

28. 13-MS-B07, Rev 3, "Evaluation of Dynamic Performance Parameters for Generic Letter 89-10 MOV's".

29. 13-N001-1900-550-1, CE Calculation Number V-FS-C-008 Rev. 00, "Analysis of Steam Line Break Events for Palo Verde for License Condition 21" (August 1985).

30. Limitorque Maintenance Update 92-01, 4. Allowable Overloads of Limitorque SMB Actuator.

31. NUREG/CR-6611 INEEL/EXT-98/00161, Results of Pressure Locking and Thermal Binding Tests of Gate Valves (May 1998).

32. Limitorque Technical Update 98-01 and Supplement 1, "Actuator Output Torque Calculation; SMB/SB/SBD Actuators" (July 1998).

33. CRDR 9-8-1207, Limitorque Technical Update 98-01 PVNGS MOV Operability Evaluation.

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REV	ORIGINATOR	DATE	INDEPENDENT VERIFICATION	DATE	REV	ORIGINATOR	DATE	INDEPENDENT VERIFICATION	DATE	Rev. Indi- cator ↓
3	[signature]	2-10-2000	[signature]	02/10/00						

34. IEEE 1290-1996, IEEE Guide for Motor Operated Valve (MOV) Motor Application, Protection, Control, and Testing in Nuclear Power Generating Stations.

35. 01, 02, 03-EC-MA-221; Rev 4, 5, 4; AC Distribution (Minimum Voltage Calculation).

36. 01, 02, 03-EC-PK-207; Rev 0, 2, 0; DC Battery Sizing and Minimum Voltage Calculation.

37. 13-JS-A41, Rev 0, Technical Study to Support G.L. 89-10 MOV Program.

38. 32MT-9ZZ56, Rev 20, Motor Operator Testing Using MOVATS 3500 System.

39. 39DP-9ZZ05, Rev 0, Trending Performance Monitoring and Failure Data Trending.

40. 13-MC-SI-229, Rev 2, PRV Sizing Calculation for SI System Valve Bonnets.

I.V. [signature] 02/10/00

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Steven A. Lopez [signature] 2-10-2000												
2	Rafael Rios & Joe Daza____		PRESSURE LOCKING										
3	Revision 13		CALCULATIONS										
4													
5	**Valve Tag (size)**	**SYSTEM INPUTS**					**VALVE INPUTS**						
6		Tinitial	Tfinal	Pinitial	Pup	Pdown	a	b	theta	nu	VF	***Valve Structural Limit***	
7		(degf)	(degf)	(psig)	(psig)	(psig)	(in.)	(in.)	(deg.)			***Thrust (lbf)***	***Torque (ft-lbf)***
8	**A/D Gate Valves:**												
9	1AF-34 (6")/Modification	104	123	1,801	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
10	2AF-34 (6")/Modification	104	123	1,801	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
11	3AF-34 (6")/Modification	104	123	1,801	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
12	1AF-35 (6")/Modification	104	123	1,801	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
13	2AF-35 (6")/Modification	104	123	1,801	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
14	3AF-35 (6")/Modification	104	123	1,801	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
15													
16													
17	1AF-36 (6")/Modification	104	125	1,816	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
18	2AF-36 (6")/Modification	104	125	1,816	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
19	3AF-36 (6")/Modification	104	125	1,816	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
20	1AF-37 (6")/Modification	104	125	1,816	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
21	2AF-37 (6")/Modification	104	125	1,816	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
22	3AF-37 (6")/Modification	104	125	1,816	0	0	2.63	0.88	5	0.3	0.55	*50,000*	*802*
23													
24													
25	1SG-134 (6")/Modification	587	587	1,383	650	0	2.63	0.88	5	0.3	0.6	*50,000*	*802*
26	2SG-134 (6")/Modification	587	587	1,383	650	0	2.63	0.88	5	0.3	0.6	*50,000*	*802*
27	3SG-134 (6")/Modification	587	587	1,383	650	0	2.63	0.88	5	0.3	0.6	*50,000*	*802*
28	1SG-138 (6")/Modification	587	587	1,383	650	0	2.63	0.88	5	0.3	0.6	*50,000*	*802*
29	2SG-138 (6")/Modification	587	587	1,383	650	0	2.63	0.88	5	0.3	0.6	*50,000*	*802*
30	3SG-138 (6")/Modification	587	587	1,383	650	0	2.63	0.88	5	0.3	0.6	*50,000*	*802*
31													
32													
33													

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Steven A. Lopez ________________												
2	Rafael Rios & Joe Daza_____	PRESSURE LOCKING											
3	Revision 13		CALCULATIONS										
4													
5	**Valve Tag (size)**	**SYSTEM INPUTS**					**VALVE INPUTS**						
6		Tinitial	Tfinal	Pinitial	Pup	Pdown	a	b	theta	nu	VF	***Valve Structural Limit***	
7		(degf)	(degf)	(psig)	(psig)	(psig)	(in.)	(in.)	(deg.)			***Thrust (lbf)***	***Torque (ft-lbf)***
34	**BW/IP Gate Valves:**												
35	1CH-536 (3")/Evaluation	104	104	97	0	0	1.50	1.11	5.25	0.3	0.6	*10,705*	*124*
36	2CH-536 (3")/Evaluation	104	104	97	0	0	1.50	1.11	5.25	0.3	0.6	*10,705*	*124*
37	3CH-536 (3")/Evaluation	104	104	97	0	0	1.50	1.11	5.25	0.3	0.6	*10,705*	*124*
38													
39													
40	1SI-604 (3")/Modification	104	120	1,960	660	0	1.38	1.11	5.25	0.3	0.5	*12,097*	*140*
41	2SI-604 (3")/Modification	104	120	1,960	660	0	1.38	1.11	5.25	0.3	0.5	*12,097*	*140*
42	3SI-604 (3")/Modification	104	120	1,960	660	0	1.38	1.11	5.25	0.3	0.5	*12,097*	*140*
43	1SI-609 (3")/Modification	104	120	1,960	660	0	1.38	1.11	5.25	0.3	0.5	*12,097*	*140*
44	2SI-609 (3")/Modification	104	120	1,960	660	0	1.38	1.11	5.25	0.3	0.5	*12,097*	*140*
45	3SI-609 (3")/Modification	104	120	1,960	660	0	1.38	1.11	5.25	0.3	0.5	*12,097*	*140*
46													
47													
48	1SI-651 (12")/Modification	120	160	2,561	465	5	5.25	2.97	5.25	0.3	0.6	*179,786*	*5,009*
49	2SI-651 (12")/Modification	120	160	2,561	465	5	5.25	2.97	5.25	0.3	0.6	*179,786*	*5,009*
50	3SI-651 (12")/Modification	120	160	2,561	465	5	5.25	2.97	5.25	0.3	0.6	*179,786*	*5,009*
51	1SI-652 (12")/Modification	120	160	2,561	465	5	5.25	2.97	5.25	0.3	0.6	*179,786*	*5,009*
52	2SI-652 (12")/Modification	120	160	2,561	465	5	5.25	2.97	5.25	0.3	0.6	*179,786*	*5,009*
53	3SI-652 (12")/Modification	120	160	2,561	465	5	5.25	2.97	5.25	0.3	0.6	*179,786*	*5,009*
54													
55													
56													
57													
58													
59													

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Steven A. Lopez ____________												
2	Rafael Rios & Joe Daza_____	**PRESSURE LOCKING**											
3	Revision 13	**CALCULATIONS**											
4													
5	**Valve Tag (size)**	**SYSTEM INPUTS**					**VALVE INPUTS**						
6		Tinitial	Tfinal	Pinitial	Pup	Pdown	a	b	theta	nu	VF	***Valve Structural Limit***	
7		(degf)	(degf)	(psig)	(psig)	(psig)	(in.)	(in.)	(deg.)			***Thrust (lbf)***	***Torque (ft-lbf)***
60	1SI-653 (12")/Modification	120	160	465	465	5	5.25	2.97	5.25	0.3	0.65	*74,133*	*2,342*
61	2SI-653 (12")/Modification	120	160	465	465	5	5.25	2.97	5.25	0.3	0.65	*74,133*	*2,342*
62	3SI-653 (12")/Modification	120	160	465	465	5	5.25	2.97	5.25	0.3	0.65	*74,133*	*2,342*
63	1SI-654 (12")/Modification	120	160	465	465	5	5.25	2.97	5.25	0.3	0.65	*74,133*	*2,342*
64	2SI-654 (12")/Modification	120	160	465	465	5	5.25	2.97	5.25	0.3	0.65	*74,133*	*2,342*
65	3SI-654 (12")/Modification	120	160	465	465	5	5.25	2.97	5.25	0.3	0.65	*74,133*	*2,342*
66													
67													
68	1SI-655 (12")/Modification	104	120	465	465	12	5.25	2.97	5.25	0.3	0.55	*80,000*	*2,300*
69	2SI-655 (12")/Modification	104	120	465	465	12	5.25	2.97	5.25	0.3	0.55	*80,000*	*2,300*
70	3SI-655 (12")/Modification	104	120	465	465	12	5.25	2.97	5.25	0.3	0.55	*80,000*	*2,300*
71	1SI-656 (12")/Modification	104	120	465	465	12	5.25	2.97	5.25	0.3	0.55	*80,000*	*2,300*
72	2SI-656 (12")/Modification	104	120	465	465	12	5.25	2.97	5.25	0.3	0.55	*80,000*	*2,300*
73	3SI-656 (12")/Mod (Note 3)	104	120	465	465	12	5.25	2.97	5.25	0.3	0.55	*80,000*	*2,300*
74													
75													
76													
77	1SI-672 (8")/Modification	104	104	326	5	0	4.07	2.29	5.25	0.3	0.55	*30,248*	*478*
78	2SI-672 (8")/Modification	104	104	326	5	0	4.07	2.29	5.25	0.3	0.55	*30,248*	*478*
79	3SI-672 (8")/Modification	104	104	326	5	0	4.07	2.29	5.25	0.3	0.55	*30,248*	*478*
80	1SI-671 (8")/Modification	104	104	326	5	0	4.07	2.29	5.25	0.3	0.55	*30,248*	*478*
81	2SI-671 (8")/Modification	104	104	326	5	0	4.07	2.29	5.25	0.3	0.55	*30,248*	*478*
82	3SI-671 (8")/Modification	104	104	326	5	0	4.07	2.29	5.25	0.3	0.55	*30,248*	*478*
83													
84													
85													

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Steven A. Lopez ____________												
2	Rafael Rios & Joe Daza_____	**PRESSURE LOCKING**											
3	Revision 13		**CALCULATIONS**										
4													
5	**Valve Tag (size)**	**SYSTEM INPUTS**					**VALVE INPUTS**						
6		Tinitial	Tfinal	Pinitial	Pup	Pdown	a	b	theta	nu	VF	***Valve Structural Limit***	
7		(degf)	(degf)	(psig)	(psig)	(psig)	(in.)	(in.)	(deg.)			***Thrust (lbf)***	***Torque (ft-lbf)***
86	1SI-685 (10")/Modification	104	104	458	12	12	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
87	2SI-685 (10")/Modification	104	104	458	12	12	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
88	3SI-685 (10")/Modification	104	104	458	12	12	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
89	1SI-694 (10")/Modification	104	104	458	12	12	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
90	2SI-694 (10")/Modification	104	104	458	12	12	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
91	3SI-694 (10")/Mod (Note 1)	104	104	458	12	12	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
92													
93													
94	1SI-686 (20")/Modification	104	104	458	12	12	9.52	5.25	5	0.3	0.5	*128,368*	*2,805*
95	2SI-686 (20")/Modification	104	104	458	12	12	9.52	5.25	5	0.3	0.5	*128,368*	*2,805*
96	3SI-686 (20")/Modification	104	104	458	12	12	9.52	5.25	5	0.3	0.5	*128,368*	*2,805*
97	1SI-696 (20")/Modification	104	104	458	12	12	9.52	5.25	5	0.3	0.5	*128,368*	*2,805*
98	2SI-696 (20")/Modification	104	104	458	12	12	9.52	5.25	5	0.3	0.5	*128,368*	*2,805*
99	3SI-696 (20")/Modification	104	104	458	12	12	9.52	5.25	5	0.3	0.5	*128,368*	*2,805*
100													
101													
102	1SI-688 (10")/Modification	104	104	458	13	13	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
103	2SI-688 (10")/Modification	104	104	458	13	13	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
104	3SI-688 (10")/Modification	104	104	458	13	13	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
105	1SI-693 (10")/Modification	104	104	458	13	13	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
106	2SI-693 (10")/Modification	104	104	458	13	13	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*
107	3SI-693 (10")/Mod (Note 1)	104	104	458	13	13	5.13	2.63	5.25	0.3	0.55	*37,835*	*597*

	A	O	P	Q	R	S	T	U	V	X	Y	Z	AA
1	Steven A. Lopez ________												
2	Rafael Rios & Joe Daza______												
3	Revision 13												
4													
5	**Valve Tag (size)**	**MOV ACTUATOR/STEM INPUTS**								**MOTOR INPUTS**			
6		OAR	P.O. Ef	COF	Dstem	Pstem	Lstem	***Actuator Structural Limit***		Vfull	Vmin	MTorq	n
7					(in.)	(in./th.)	(in./rev.)	***Thrust (lbf***	***Torque (ft-lbf)***	(volts)	(volts)	(ft-lbf)	
8	**A/D Gate Valves:**												
9	1AF-34 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	460	414	60	2
10	2AF-34 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	460	414	60	2
11	3AF-34 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	460	414	60	2
12	1AF-35 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	460	414	60	2
13	2AF-35 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	460	414	60	2
14	3AF-35 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	460	414	60	2
15													
16													
17	1AF-36 (6")/Modification	60.15	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	98.4	40	1
18	2AF-36 (6")/Modification	60.15	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	98.4	40	1
19	3AF-36 (6")/Modification	60.15	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	98.4	40	1
20	1AF-37 (6")/Modification	60.15	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	98.4	40	1
21	2AF-37 (6")/Modification	60.15	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	98.4	40	1
22	3AF-37 (6")/Modification	60.15	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	98.4	40	1
23													
24													
25	1SG-134 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	93	60	1
26	2SG-134 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	93	60	1
27	3SG-134 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	93	60	1
28	1SG-138 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	93	60	1
29	2SG-138 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	93	60	1
30	3SG-138 (6")/Modification	42.5	0.4	0.12	1.5	0.333	0.667	*63,000*	*935*	115	93	60	1
31													
32													
33													

	A	O	P	Q	R	S	T	U	V	X	Y	Z	AA
1	Steven A. Lopez ___________												
2	Rafael Rios & Joe Daza_____												
3	Revision 13												
4													
5	**Valve Tag (size)**	**MOV ACTUATOR/STEM INPUTS**								**MOTOR INPUTS**			
6		OAR	P.O. Ef	COF	Dstem	Pstem	Lstem	***Actuator Structural Limit***		Vfull	Vmin	MTorq	n
7					(in.)	(in./th.)	(in./rev.)	***Thrust (lbf***	***Torque (ft-lbf)***	(volts)	(volts)	(ft-lbf)	
34	**BW/IP Gate Valves:**												
35	1CH-536 (3")/Evaluation	30	0.4	0.2	0.875	0.167	0.333	*19,600*	*275*	460	414	7.5	2
36	2CH-536 (3")/Evaluation	30	0.4	0.2	0.875	0.167	0.333	*19,600*	*275*	460	414	7.5	2
37	3CH-536 (3")/Evaluation	30	0.4	0.2	0.875	0.167	0.333	*19,600*	*275*	460	414	7.5	2
38													
39													
40	1SI-604 (3")/Modification	36.2	0.4	0.2	0.875	0.167	0.333	*19,600*	*275*	460	414	15	2
41	2SI-604 (3")/Modification	36.2	0.4	0.2	0.875	0.167	0.333	*19,600*	*275*	460	414	15	2
42	3SI-604 (3")/Modification	36.2	0.4	0.2	0.875	0.167	0.333	*19,600*	*275*	460	414	15	2
43	1SI-609 (3")/Modification	36.2	0.4	0.2	0.875	0.167	0.333	*19,600*	*275*	460	414	15	2
44	2SI-609 (3")/Modification	36.2	0.4	0.2	0.875	0.167	0.333	*19,600*	*275*	460	414	15	2
45	3SI-609 (3")/Modification	36.2	0.4	0.2	0.875	0.167	0.333	*19,600*	*275*	460	414	15	2
46													
47													
48	1SI-651 (12")/Modification	132.81	0.38	0.12	2.75	0.333	0.667	*350,000*	*6,600*	460	414	100	2
49	2SI-651 (12")/Modification	132.81	0.38	0.12	2.75	0.333	0.667	*350,000*	*6,600*	460	414	100	2
50	3SI-651 (12")/Modification	132.81	0.38	0.12	2.75	0.333	0.667	*350,000*	*6,600*	460	414	100	2
51	1SI-652 (12")/Modification	132.81	0.38	0.12	2.75	0.333	0.667	*350,000*	*6,600*	460	414	100	2
52	2SI-652 (12")/Modification	132.81	0.38	0.12	2.75	0.333	0.667	*350,000*	*6,600*	460	414	100	2
53	3SI-652 (12")/Modification	132.81	0.38	0.12	2.75	0.333	0.667	*350,000*	*6,600*	460	414	100	2
54													
55													
56													
57													
58													
59													

	A	O	P	Q	R	S	T	U	V	X	Y	Z	AA
1	Steven A. Lopez ____________												
2	Rafael Rios & Joe Daza_____												
3	Revision 13												
4													
5	**Valve Tag (size)**	**MOV ACTUATOR/STEM INPUTS**								**MOTOR INPUTS**			
6		OAR	P.O. Ef	COF	Dstem	Pstem	Lstem	***Actuator Structural Limit***		Vfull	Vmin	MTorq	n
7					(in.)	(in./th.)	(in./rev.)	***Thrust (lbf***	***Torque (ft-lbf)***	(volts)	(volts)	(ft-lbf)	
60	1SI-653 (12")/Modification	124.1	0.35	0.16	2.75	0.333	0.667	*112,500*	*1,700*	460	456	40	2
61	2SI-653 (12")/Modification	124.1	0.35	0.16	2.75	0.333	0.667	*112,500*	*1,700*	460	456	40	2
62	3SI-653 (12")/Modification	124.1	0.35	0.16	2.75	0.333	0.667	*112,500*	*1,700*	460	456	40	2
63	1SI-654 (12")/Modification	124.1	0.35	0.16	2.75	0.333	0.667	*112,500*	*1,700*	460	456	40	2
64	2SI-654 (12")/Modification	124.1	0.35	0.16	2.75	0.333	0.667	*112,500*	*1,700*	460	456	40	2
65	3SI-654 (12")/Modification	124.1	0.35	0.16	2.75	0.333	0.667	*112,500*	*1,700*	460	456	40	2
66													
67													
68	1SI-655 (12")/Modification	124.1	0.35	0.15	2.75	0.333	0.667	*112,500*	*1,700*	460	414	40	2
69	2SI-655 (12")/Modification	124.1	0.35	0.15	2.75	0.333	0.667	*112,500*	*1,700*	460	414	40	2
70	3SI-655 (12")/Modification	124.1	0.35	0.15	2.75	0.333	0.667	*112,500*	*1,700*	460	414	40	2
71	1SI-656 (12")/Modification	124.1	0.35	0.15	2.75	0.333	0.667	*112,500*	*1,700*	460	414	40	2
72	2SI-656 (12")/Modification	124.1	0.35	0.15	2.75	0.333	0.667	*112,500*	*1,700*	460	414	40	2
73	3SI-656 (12")/Mod (Note 3)	124.1	0.35	0.15	2.75	0.333	0.667	*112,500*	*1,700*	460	414	40	2
74													
75													
76													
77	1SI-672 (8")/Modification	27.2	0.45	0.19	1.375	0.250	0.500	*63,000*	*935*	460	414	40	2
78	2SI-672 (8")/Modification	27.2	0.45	0.19	1.375	0.250	0.500	*63,000*	*935*	460	414	40	2
79	3SI-672 (8")/Modification	27.2	0.45	0.19	1.375	0.250	0.500	*63,000*	*935*	460	414	40	2
80	1SI-671 (8")/Modification	27.2	0.45	0.19	1.375	0.250	0.500	*63,000*	*935*	460	414	40	2
81	2SI-671 (8")/Modification	27.2	0.45	0.19	1.375	0.250	0.500	*63,000*	*935*	460	414	40	2
82	3SI-671 (8")/Modification	27.2	0.45	0.19	1.375	0.250	0.500	*63,000*	*935*	460	414	40	2
83													
84													
85													

	A	O	P	Q	R	S	T	U	V	X	Y	Z	AA
1	Steven A. Lopez ________												
2	Rafael Rios & Joe Daza_____												
3	Revision 13												
4													
5	**Valve Tag (size)**	**MOV ACTUATOR/STEM INPUTS**								**MOTOR INPUTS**			
6		OAR	P.O. Ef	COF	Dstem	Pstem	Lstem	***Actuator Structural Limit***		Vfull	Vmin	MTorq	n
7					(in.)	(in./th.)	(in./rev.)	***Thrust (lbf***	***Torque (ft-lbf)***	(volts)	(volts)	(ft-lbf)	
86	1SI-685 (10")/Modification	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
87	2SI-685 (10")/Modification	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
88	3SI-685 (10")/Modification	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
89	1SI-694 (10")/Modification	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
90	2SI-694 (10")/Modification	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
91	3SI-694 (10")/Mod (Note 1)	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
92													
93													
94	1SI-686 (20")/Modification	80	0.4	0.15	2.125	0.333	0.667	*98,000*	*1,980*	460	414	60	2
95	2SI-686 (20")/Modification	80	0.4	0.15	2.125	0.333	0.667	*98,000*	*1,980*	460	414	60	2
96	3SI-686 (20")/Modification	80	0.4	0.15	2.125	0.333	0.667	*98,000*	*1,980*	460	414	60	2
97	1SI-696 (20")/Modification	80	0.4	0.15	2.125	0.333	0.667	*98,000*	*1,980*	460	414	60	2
98	2SI-696 (20")/Modification	80	0.4	0.15	2.125	0.333	0.667	*98,000*	*1,980*	460	414	60	2
99	3SI-696 (20")/Modification	80	0.4	0.15	2.125	0.333	0.667	*98,000*	*1,980*	460	414	60	2
100													
101													
102	1SI-688 (10")/Modification	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
103	2SI-688 (10")/Modification	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
104	3SI-688 (10")/Modification	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
105	1SI-693 (10")/Modification	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
106	2SI-693 (10")/Modification	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2
107	3SI-693 (10")/Mod (Note 1)	61.64	0.4	0.17	1.5	0.250	0.500	*33,600*	*550*	460	414	25	2

	A	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1	Steven A. Lopez ___________									
2	Rafael Rios & Joe Daza_____									
3	Revision 13									
4					***Calculation of Minimum Available***				**CALCULATION**	
5	**Valve Tag (size)**		**MOV MISC INPUTS**		***Torque and Thrust at Motor Stall***				**DP X DISKS**	
6		TDF	Max Close	% Residual	Stem Factor	***Avail Torque***	***Avail Thrust***	VDF	Pfinal	DPavg
7			Load (lbf)	Load		(ft-lbf)	(lbf)		(psig)	(psig)
8	**A/D Gate Valves:**									
9	1AF-34 (6")/Modification	0.96	36,963	57%	0.0160	881	54,927	0.900	1,880	1880
10	2AF-34 (6")/Modification	0.96	36,963	57%	0.0160	881	54,927	0.900	1,880	1880
11	3AF-34 (6")/Modification	0.96	36,963	57%	0.0160	881	54,927	0.900	1,880	1880
12	1AF-35 (6")/Modification	0.96	36,963	57%	0.0160	881	54,927	0.900	1,880	1880
13	2AF-35 (6")/Modification	0.96	36,963	57%	0.0160	881	54,927	0.900	1,880	1880
14	3AF-35 (6")/Modification	0.96	36,963	57%	0.0160	881	54,927	0.900	1,880	1880
15										
16										
17	1AF-36 (6")/Modification	0.98	36,963	57%	0.0160	807	50,298	0.856	1,880	1880
18	2AF-36 (6")/Modification	0.98	36,963	57%	0.0160	807	50,298	0.856	1,880	1880
19	3AF-36 (6")/Modification	0.98	36,963	57%	0.0160	807	50,298	0.856	1,880	1880
20	1AF-37 (6")/Modification	0.98	36,963	57%	0.0160	807	50,298	0.856	1,880	1880
21	2AF-37 (6")/Modification	0.98	36,963	57%	0.0160	807	50,298	0.856	1,880	1880
22	3AF-37 (6")/Modification	0.98	36,963	57%	0.0160	807	50,298	0.856	1,880	1880
23										
24										
25	1SG-134 (6")/Modification	0.9	34,328	59%	0.0160	*742*	*46,270*	0.809	1,383	1058
26	2SG-134 (6")/Modification	0.9	34,328	59%	0.0160	*742*	*46,270*	0.809	1,383	1058
27	3SG-134 (6")/Modification	0.9	34,328	59%	0.0160	*742*	*46,270*	0.809	1,383	1058
28	1SG-138 (6")/Modification	0.9	34,328	59%	0.0160	*742*	*46,270*	0.809	1,383	1058
29	2SG-138 (6")/Modification	0.9	34,328	59%	0.0160	*742*	*46,270*	0.809	1,383	1058
30	3SG-138 (6")/Modification	0.9	34,328	59%	0.0160	*742*	*46,270*	0.809	1,383	1058
31										
32										
33										

	A	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1	Steven A. Lopez ______									
2	Rafael Rios & Joe Daza_____									
3	Revision 13									
4					***Calculation of Minimum Available***				**CALCULATION**	
5	**Valve Tag (size)**		**MOV MISC INPUTS**		***Torque and Thrust at Motor Stall***				**DP X DISKS**	
6		TDF	Max Close	% Residual	Stem Factor	***Avail Torque***	***Avail Thrust***	VDF	Pfinal	DPavg
7			Load (lbf)	Load		(ft-lbf)	(lbf)		(psig)	(psig)
34	**BW/IP Gate Valves:**									
35	1CH-536 (3")/Evaluation	0.99	7,810	67%	0.0116	*80*	*6,940*	0.900	97	97
36	2CH-536 (3")/Evaluation	0.99	7,810	67%	0.0116	*80*	*6,940*	0.900	97	97
37	3CH-536 (3")/Evaluation	0.99	7,810	67%	0.0116	*80*	*6,940*	0.900	97	97
38										
39										
40	1SI-604 (3")/Modification	0.97	10,203	61%	0.0116	*190*	*16,410*	0.900	2,760	2430
41	2SI-604 (3")/Modification	0.97	10,203	61%	0.0116	*190*	*16,410*	0.900	2,760	2430
42	3SI-604 (3")/Modification	0.97	10,203	61%	0.0116	*190*	*16,410*	0.900	2,760	2430
43	1SI-609 (3")/Modification	0.97	10,203	61%	0.0116	*190*	*16,410*	0.900	2,760	2430
44	2SI-609 (3")/Modification	0.97	10,203	61%	0.0116	*190*	*16,410*	0.900	2,760	2430
45	3SI-609 (3")/Modification	0.97	10,203	61%	0.0116	*190*	*16,410*	0.900	2,760	2430
46										
47										
48	1SI-651 (12")/Modification	0.95	91,791	48%	0.0224	*4,315*	*192,533*	0.900	2,936	2701
49	2SI-651 (12")/Modification	0.95	91,791	48%	0.0224	*4,315*	*192,533*	0.900	2,936	2701
50	3SI-651 (12")/Modification	0.95	91,791	48%	0.0224	*4,315*	*192,533*	0.900	2,936	2701
51	1SI-652 (12")/Modification	0.95	91,791	48%	0.0224	*4,315*	*192,533*	0.900	2,936	2701
52	2SI-652 (12")/Modification	0.95	91,791	48%	0.0224	*4,315*	*192,533*	0.900	2,936	2701
53	3SI-652 (12")/Modification	0.95	91,791	48%	0.0224	*4,315*	*192,533*	0.900	2,936	2701
54										
55										
56										
57										
58										
59										

	A	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1	Steven A. Lopez ___________									
2	Rafael Rios & Joe Daza______									
3	Revision 13									
4					***Calculation of Minimum Available***				**CALCULATION**	
5	**Valve Tag (size)**		**MOV MISC INPUTS**		***Torque and Thrust at Motor Stall***				**DP X DISKS**	
6		TDF	Max Close	% Residual	Stem Factor	***Avail Torque***	***Avail Thrust***	VDF	Pfinal	DPavg
7			Load (lbf)	Load		(ft-lbf)	(lbf)		(psig)	(psig)
60	1SI-653 (12")/Modification	0.89	27,985	57%	0.0270	*1,392*	*51,548*	0.900	465	230
61	2SI-653 (12")/Modification	0.89	27,985	57%	0.0270	*1,392*	*51,548*	0.900	465	230
62	3SI-653 (12")/Modification	0.89	27,985	57%	0.0270	*1,392*	*51,548*	0.900	465	230
63	1SI-654 (12")/Modification	0.89	27,985	57%	0.0270	*1,392*	*51,548*	0.900	465	230
64	2SI-654 (12")/Modification	0.89	27,985	57%	0.0270	*1,392*	*51,548*	0.900	465	230
65	3SI-654 (12")/Modification	0.89	27,985	57%	0.0270	*1,392*	*51,548*	0.900	465	230
66										
67										
68	1SI-655 (12")/Modification	0.88	31,791	58%	0.0258	*1,376*	*53,235*	0.900	465	227
69	2SI-655 (12")/Modification	0.88	31,791	58%	0.0258	*1,376*	*53,235*	0.900	465	227
70	3SI-655 (12")/Modification	0.88	31,791	58%	0.0258	*1,376*	*53,235*	0.900	465	227
71	1SI-656 (12")/Modification	0.88	31,791	58%	0.0258	*1,376*	*53,235*	0.900	465	227
72	2SI-656 (12")/Modification	0.88	31,791	58%	0.0258	*1,376*	*53,235*	0.900	465	227
73	3SI-656 (12")/Mod (Note 3)	0.88	31,791	58%	0.0258	*1,376*	*53,235*	0.900	465	227
74										
75										
76										
77	1SI-672 (8")/Modification	0.98	15,672	60%	0.0173	*432*	*24,983*	0.900	326	323
78	2SI-672 (8")/Modification	0.98	15,672	60%	0.0173	*432*	*24,983*	0.900	326	323
79	3SI-672 (8")/Modification	0.98	17,910	61%	0.0173	*432*	*24,983*	0.900	326	323
80	1SI-671 (8")/Modification	0.98	15,672	60%	0.0173	*432*	*24,983*	0.900	326	323
81	2SI-671 (8")/Modification	0.98	15,672	60%	0.0173	*432*	*24,983*	0.900	326	323
82	3SI-671 (8")/Modification	0.98	15,672	60%	0.0173	*432*	*24,983*	0.900	326	323
83										
84										
85										

	A	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1	Steven A. Lopez ___________									
2	Rafael Rios & Joe Daza_____									
3	Revision 13									
4					***Calculation of Minimum Available***				**CALCULATION**	
5	**Valve Tag (size)**		**MOV MISC INPUTS**		***Torque and Thrust at Motor Stall***				**DP X DISKS**	
6		TDF	Max Close	% Residual	Stem Factor	***Avail Torque***	***Avail Thrust***	VDF	Pfinal	DPavg
7			Load (lbf)	Load		(ft-lbf)	(lbf)		(psig)	(psig)
86	1SI-685 (10")/Modification	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	446
87	2SI-685 (10")/Modification	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	446
88	3SI-685 (10")/Modification	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	446
89	1SI-694 (10")/Modification	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	446
90	2SI-694 (10")/Modification	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	446
91	3SI-694 (10")/Mod (Note 1)	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	446
92										
93										
94	1SI-686 (20")/Modification	0.98	26,119	32%	0.0219	*1,693*	*77,499*	0.900	458	446
95	2SI-686 (20")/Modification	0.98	26,119	32%	0.0219	*1,693*	*77,499*	0.900	458	446
96	3SI-686 (20")/Modification	0.98	26,119	32%	0.0219	*1,693*	*77,499*	0.900	458	446
97	1SI-696 (20")/Modification	0.98	26,119	32%	0.0219	*1,693*	*77,499*	0.900	458	446
98	2SI-696 (20")/Modification	0.98	26,119	32%	0.0219	*1,693*	*77,499*	0.900	458	446
99	3SI-696 (20")/Modification	0.98	26,119	32%	0.0219	*1,693*	*77,499*	0.900	458	446
100										
101										
102	1SI-688 (10")/Modification	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	445
103	2SI-688 (10")/Modification	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	445
104	3SI-688 (10")/Modification	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	445
105	1SI-693 (10")/Modification	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	445
106	2SI-693 (10")/Modification	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	445
107	3SI-693 (10")/Mod (Note 1)	0.98	17,164	51%	0.0170	*544*	*31,909*	0.900	458	445

	A	AK	AL	AM	AN	AO	AP	AQ	AR	AS
1	Steven A. Lopez ___________									
2	Rafael Rios & Joe Daza_____									
3	Revision 13									
4										
5	**Valve Tag (size)**	**Calculation of Disk Load Perpendicular to the Seat/Roak Thin Plate Theory**								
6		C2	C3	C8	C9	L11	L17	mu	Qb	Qa
7										
8	**A/D Gate Valves:**									
9	1AF-34 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
10	2AF-34 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
11	3AF-34 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
12	1AF-35 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
13	2AF-35 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
14	3AF-35 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
15										
16										
17	1AF-36 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
18	2AF-36 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
19	3AF-36 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
20	1AF-37 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
21	2AF-37 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
22	3AF-37 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.5755	3,329	-1,084
23										
24										
25	1SG-134 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.6307	1,874	-610
26	2SG-134 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.6307	1,874	-610
27	3SG-134 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.6307	1,874	-610
28	1SG-138 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.6307	1,874	-610
29	2SG-138 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.6307	1,874	-610
30	3SG-138 (6")/Modification	0.1612	0.0276	0.6889	0.2899	0.00550	0.1393	0.6307	1,874	-610
31										
32										
33										

	A	AK	AL	AM	AN	AO	AP	AQ	AR	AS
1	Steven A. Lopez ___________									
2	Rafael Rios & Joe Daza_____									
3	Revision 13									
4										
5	**Valve Tag (size)**	**Calculation of Disk Load Perpendicular to the Seat/Roak Thin Plate Theory**								
6		C2	C3	C8	C9	L11	L17	mu	Qb	Qa
7										
34	**BW/IP Gate Valves:**									
35	1CH-536 (3")/Evaluation	0.0304	0.0025	0.8423	0.2027	0.00017	0.0286	0.6322	26	-13
36	2CH-536 (3")/Evaluation	0.0304	0.0025	0.8423	0.2027	0.00017	0.0286	0.6322	26	-13
37	3CH-536 (3")/Evaluation	0.0304	0.0025	0.8423	0.2027	0.00017	0.0286	0.6322	26	-13
38										
39										
40	1SI-604 (3")/Modification	0.0173	0.0011	0.8781	0.1615	0.00005	0.0166	0.5218	433	-233
41	2SI-604 (3")/Modification	0.0173	0.0011	0.8781	0.1615	0.00005	0.0166	0.5218	433	-233
42	3SI-604 (3")/Modification	0.0173	0.0011	0.8781	0.1615	0.00005	0.0166	0.5218	433	-233
43	1SI-609 (3")/Modification	0.0173	0.0011	0.8781	0.1615	0.00005	0.0166	0.5218	433	-233
44	2SI-609 (3")/Modification	0.0173	0.0011	0.8781	0.1615	0.00005	0.0166	0.5218	433	-233
45	3SI-609 (3")/Modification	0.0173	0.0011	0.8781	0.1615	0.00005	0.0166	0.5218	433	-233
46										
47										
48	1SI-651 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6322	4,767	-2,123
49	2SI-651 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6322	4,767	-2,123
50	3SI-651 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6322	4,767	-2,123
51	1SI-652 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6322	4,767	-2,123
52	2SI-652 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6322	4,767	-2,123
53	3SI-652 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6322	4,767	-2,123
54										
55										
56										
57										
58										
59										

	A	AK	AL	AM	AN	AO	AP	AQ	AR	AS
1	Steven A. Lopez ____________									
2	Rafael Rios & Joe Daza______									
3	Revision 13									
4										
5	**Valve Tag (size)**	**Calculation of Disk Load Perpendicular to the Seat/Roak Thin Plate Theory**								
6		C2	C3	C8	C9	L11	L17	mu	Qb	Qa
7										
60	1SI-653 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6882	406	-181
61	2SI-653 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6882	406	-181
62	3SI-653 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6882	406	-181
63	1SI-654 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6882	406	-181
64	2SI-654 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6882	406	-181
65	3SI-654 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.6882	406	-181
66										
67										
68	1SI-655 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.5767	400	-178
69	2SI-655 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.5767	400	-178
70	3SI-655 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.5767	400	-178
71	1SI-656 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.5767	400	-178
72	2SI-656 (12")/Modification	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.5767	400	-178
73	3SI-656 (12")/Mod (Note 3)	0.0788	0.0102	0.7620	0.2768	0.00119	0.0715	0.5767	400	-178
74										
75										
76										
77	1SI-672 (8")/Modification	0.0798	0.0104	0.7608	0.2776	0.00122	0.0723	0.5767	447	-198
78	2SI-672 (8")/Modification	0.0798	0.0104	0.7608	0.2776	0.00122	0.0723	0.5767	447	-198
79	3SI-672 (8")/Modification	0.0798	0.0104	0.7608	0.2776	0.00122	0.0723	0.5767	447	-198
80	1SI-671 (8")/Modification	0.0798	0.0104	0.7608	0.2776	0.00122	0.0723	0.5767	447	-198
81	2SI-671 (8")/Modification	0.0798	0.0104	0.7608	0.2776	0.00122	0.0723	0.5767	447	-198
82	3SI-671 (8")/Modification	0.0798	0.0104	0.7608	0.2776	0.00122	0.0723	0.5767	447	-198
83										
84										
85										

	A	AK	AL	AM	AN	AO	AP	AQ	AR	AS
1	Steven A. Lopez ____________									
2	Rafael Rios & Joe Daza_____									
3	Revision 13									
4										
5	**Valve Tag (size)**	**Calculation of Disk Load Perpendicular to the Seat/Roak Thin Plate Theory**								
6		C2	C3	C8	C9	L11	L17	mu	Qb	Qa
7										
86	1SI-685 (10")/Modification	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	901	-380
87	2SI-685 (10")/Modification	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	901	-380
88	3SI-685 (10")/Modification	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	901	-380
89	1SI-694 (10")/Modification	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	901	-380
90	2SI-694 (10")/Modification	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	901	-380
91	3SI-694 (10")/Mod (Note 1)	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	901	-380
92										
93										
94	1SI-686 (20")/Modification	0.0834	0.0111	0.7566	0.2804	0.00134	0.0754	0.5208	1,488	-653
95	2SI-686 (20")/Modification	0.0834	0.0111	0.7566	0.2804	0.00134	0.0754	0.5208	1,488	-653
96	3SI-686 (20")/Modification	0.0834	0.0111	0.7566	0.2804	0.00134	0.0754	0.5208	1,488	-653
97	1SI-696 (20")/Modification	0.0834	0.0111	0.7566	0.2804	0.00134	0.0754	0.5208	1,488	-653
98	2SI-696 (20")/Modification	0.0834	0.0111	0.7566	0.2804	0.00134	0.0754	0.5208	1,488	-653
99	3SI-696 (20")/Modification	0.0834	0.0111	0.7566	0.2804	0.00134	0.0754	0.5208	1,488	-653
100										
101										
102	1SI-688 (10")/Modification	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	899	-379
103	2SI-688 (10")/Modification	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	899	-379
104	3SI-688 (10")/Modification	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	899	-379
105	1SI-693 (10")/Modification	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	899	-379
106	2SI-693 (10")/Modification	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	899	-379
107	3SI-693 (10")/Mod (Note 1)	0.0963	0.0136	0.7422	0.2887	0.00181	0.0863	0.5767	899	-379

	A	AT	AU	AV	AW	AX	AY
1	Steven A. Lopez ___________						
2	Rafael Rios & Joe Daza_____						
3	Revision 13						
4				Static	**Residual Closing**	**Vertical Load**	**Stem piston**
5	**Valve Tag (size)**	**Disk Load**	**Hub Load**	Peak	**Load at Cracking**	**On Disks**	**Load**
6		w/DPavg	Pup-Pdown	Cracking	Residual Load	Fvert	Fpiston
7		(lbf)	(lbf)	(lbf)	(lbf)	(lbf)	(lbf)
8	**A/D Gate Valves:**						
9	1AF-34 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
10	2AF-34 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
11	3AF-34 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
12	1AF-35 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
13	2AF-35 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
14	3AF-35 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
15							
16							
17	1AF-36 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
18	2AF-36 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
19	3AF-36 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
20	1AF-37 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
21	2AF-37 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
22	3AF-37 (6")/Modification	20,571	-	24,765	21,143	7,094	3,322
23							
24							
25	1SG-134 (6")/Modification	12,687	1,775	23,000	20,336	3,992	2,444
26	2SG-134 (6")/Modification	12,687	1,775	23,000	20,336	3,992	2,444
27	3SG-134 (6")/Modification	12,687	1,775	23,000	20,336	3,992	2,444
28	1SG-138 (6")/Modification	12,687	1,775	23,000	20,336	3,992	2,444
29	2SG-138 (6")/Modification	12,687	1,775	23,000	20,336	3,992	2,444
30	3SG-138 (6")/Modification	12,687	1,775	23,000	20,336	3,992	2,444
31							
32							
33							

	A	AT	AU	AV	AW	AX	AY
1	Steven A. Lopez ________						
2	Rafael Rios & Joe Daza_____						
3	Revision 13						
4				Static	**Residual Closing**	**Vertical Load**	**Stem piston**
5	**Valve Tag (size)**	**Disk Load**	**Hub Load**	Peak	**Load at Cracking**	**On Disks**	**Load**
6		w/DPavg	Pup-Pdown	Cracking	Residual Load	Fvert	Fpiston
7		(lbf)	(lbf)	(lbf)	(lbf)	(lbf)	(lbf)
34	**BW/IP Gate Valves:**						
35	1CH-536 (3")/Evaluation	160	-	5,233	5,202	125	58
36	2CH-536 (3")/Evaluation	160	-	5,233	5,202	125	58
37	3CH-536 (3")/Evaluation	160	-	5,233	5,202	125	58
38							
39							
40	1SI-604 (3")/Modification	2,098	409	6,836	6,265	2,641	1,660
41	2SI-604 (3")/Modification	2,098	409	6,836	6,265	2,641	1,660
42	3SI-604 (3")/Modification	2,098	409	6,836	6,265	2,641	1,660
43	1SI-609 (3")/Modification	2,098	409	6,836	6,265	2,641	1,660
44	2SI-609 (3")/Modification	2,098	409	6,836	6,265	2,641	1,660
45	3SI-609 (3")/Modification	2,098	409	6,836	6,265	2,641	1,660
46							
47							
48	1SI-651 (12")/Modification	88,561	5,143	61,500	44,203	42,795	17,436
49	2SI-651 (12")/Modification	88,561	5,143	61,500	44,203	42,795	17,436
50	3SI-651 (12")/Modification	88,561	5,143	61,500	44,203	42,795	17,436
51	1SI-652 (12")/Modification	88,561	5,143	61,500	44,203	42,795	17,436
52	2SI-652 (12")/Modification	88,561	5,143	61,500	44,203	42,795	17,436
53	3SI-652 (12")/Modification	88,561	5,143	61,500	44,203	42,795	17,436
54							
55							
56							
57							
58							
59							

	A	AT	AU	AV	AW	AX	AY
1	Steven A. Lopez ___________						
2	Rafael Rios & Joe Daza_____						
3	Revision 13						
4				Static	**Residual Closing**	**Vertical Load**	**Stem piston**
5	**Valve Tag (size)**	**Disk Load**	**Hub Load**	Peak	**Load at Cracking**	**On Disks**	**Load**
6		w/DPavg	Pup-Pdown	Cracking	Residual Load	Fvert	Fpiston
7		(lbf)	(lbf)	(lbf)	(lbf)	(lbf)	(lbf)
60	1SI-653 (12")/Modification	8,215	5,599	18,750	16,010	3,647	2,762
61	2SI-653 (12")/Modification	8,215	5,599	18,750	16,010	3,647	2,762
62	3SI-653 (12")/Modification	8,215	5,599	18,750	16,010	3,647	2,762
63	1SI-654 (12")/Modification	8,215	5,599	18,750	16,010	3,647	2,762
64	2SI-654 (12")/Modification	8,215	5,599	18,750	16,010	3,647	2,762
65	3SI-654 (12")/Modification	8,215	5,599	18,750	16,010	3,647	2,762
66							
67							
68	1SI-655 (12")/Modification	6,782	4,760	21,300	18,560	3,592	2,762
69	2SI-655 (12")/Modification	6,782	4,760	21,300	18,560	3,592	2,762
70	3SI-655 (12")/Modification	6,782	4,760	21,300	18,560	3,592	2,762
71	1SI-656 (12")/Modification	6,782	4,760	21,300	18,560	3,592	2,762
72	2SI-656 (12")/Modification	6,782	4,760	21,300	18,560	3,592	2,762
73	3SI-656 (12")/Mod (Note 3)	6,782	4,760	21,300	18,560	3,592	2,762
74							
75							
76							
77	1SI-672 (8")/Modification	5,851	32	10,500	9,340	3,079	484
78	2SI-672 (8")/Modification	5,851	32	10,500	9,340	3,079	484
79	3SI-672 (8")/Modification	5,851	32	12,000	10,840	3,079	484
80	1SI-671 (8")/Modification	5,851	32	10,500	9,340	3,079	484
81	2SI-671 (8")/Modification	5,851	32	10,500	9,340	3,079	484
82	3SI-671 (8")/Modification	5,851	32	10,500	9,340	3,079	484
83							
84							
85							

	A	AT	AU	AV	AW	AX	AY
1	Steven A. Lopez ____________						
2	Rafael Rios & Joe Daza_____						
3	Revision 13						
4				Static	**Residual Closing**	**Vertical Load**	**Stem piston**
5	**Valve Tag (size)**	**Disk Load**	**Hub Load**	Peak	**Load at Cracking**	**On Disks**	**Load**
6		w/DPavg	Pup-Pdown	Cracking	Residual Load	Fvert	Fpiston
7		(lbf)	(lbf)	(lbf)	(lbf)	(lbf)	(lbf)
86	1SI-685 (10")/Modification	14,120	221	11,500	8,714	6,741	809
87	2SI-685 (10")/Modification	14,120	221	11,500	8,714	6,741	809
88	3SI-685 (10")/Modification	14,120	221	11,500	8,714	6,741	809
89	1SI-694 (10")/Modification	14,120	221	11,500	8,714	6,741	809
90	2SI-694 (10")/Modification	14,120	221	11,500	8,714	6,741	809
91	3SI-694 (10")/Mod (Note 1)	14,120	221	11,500	8,714	6,741	809
92							
93							
94	1SI-686 (20")/Modification	40,694	739	17,500	8,429	22,089	1,624
95	2SI-686 (20")/Modification	40,694	739	17,500	8,429	22,089	1,624
96	3SI-686 (20")/Modification	40,694	739	17,500	8,429	22,089	1,624
97	1SI-696 (20")/Modification	40,694	739	17,500	8,429	22,089	1,624
98	2SI-696 (20")/Modification	40,694	739	17,500	8,429	22,089	1,624
99	3SI-696 (20")/Modification	40,694	739	17,500	8,429	22,089	1,624
100							
101							
102	1SI-688 (10")/Modification	14,086	241	11,500	8,714	6,725	809
103	2SI-688 (10")/Modification	14,086	241	11,500	8,714	6,725	809
104	3SI-688 (10")/Modification	14,086	241	11,500	8,714	6,725	809
105	1SI-693 (10")/Modification	14,086	241	11,500	8,714	6,725	809
106	2SI-693 (10")/Modification	14,086	241	11,500	8,714	6,725	809
107	3SI-693 (10")/Mod (Note 1)	14,086	241	11,500	8,714	6,725	809

	A	AZ	BA	BB	BF
1	Steven A. Lopez ___________				
2	Rafael Rios & Joe Daza_____			**MOV Min Avail**	
3	Revision 13	**Total Stem Thrust**	**Total Torque Required**	**Thrust due to**	**MARGIN**
4		**Req'd to Overcome**	**to Overcome Pressure**	**Structural Limit or**	LIMITING THRUST
5	**Valve Tag (size)**	**Press Locking**	**Locking**	**Motor Torque Limit**	subtract
6		Ftotal	Required Torque	Limiting Thrust	REQUIRED THRUST
7		(lbf)	(ft-lbf)	(lbf)	(lbf)
8	**A/D Gate Valves:**				
9	1AF-34 (6")/Modification	45,486	730	50,000	4,514
10	2AF-34 (6")/Modification	45,486	730	50,000	4,514
11	3AF-34 (6")/Modification	45,486	730	50,000	4,514
12	1AF-35 (6")/Modification	45,486	730	50,000	4,514
13	2AF-35 (6")/Modification	45,486	730	50,000	4,514
14	3AF-35 (6")/Modification	45,486	730	50,000	4,514
15					
16					
17	1AF-36 (6")/Modification	45,486	730	50,000	4,514
18	2AF-36 (6")/Modification	45,486	730	50,000	4,514
19	3AF-36 (6")/Modification	45,486	730	50,000	4,514
20	1AF-37 (6")/Modification	45,486	730	50,000	4,514
21	2AF-37 (6")/Modification	45,486	730	50,000	4,514
22	3AF-37 (6")/Modification	45,486	730	50,000	4,514
23					
24					
25	1SG-134 (6")/Modification	36,346	583	46,270	9,924
26	2SG-134 (6")/Modification	36,346	583	46,270	9,924
27	3SG-134 (6")/Modification	36,346	583	46,270	9,924
28	1SG-138 (6")/Modification	36,346	583	46,270	9,924
29	2SG-138 (6")/Modification	36,346	583	46,270	9,924
30	3SG-138 (6")/Modification	36,346	583	46,270	9,924
31					
32					
33					

	A	AZ	BA	BB	BF
1	Steven A. Lopez ___________				
2	Rafael Rios & Joe Daza_____			**MOV Min Avail**	
3	Revision 13	**Total Stem Thrust**	**Total Torque Required**	**Thrust due to**	**MARGIN**
4		**Req'd to Overcome**	**to Overcome Pressure**	**Structural Limit or**	LIMITING THRUST
5	**Valve Tag (size)**	**Press Locking**	**Locking**	**Motor Torque Limit**	subtract
6		Ftotal	Required Torque	Limiting Thrust	REQUIRED THRUST
7		(lbf)	(ft-lbf)	(lbf)	(lbf)
34	**BW/IP Gate Valves:**				
35	1CH-536 (3")/Evaluation	5,428	63	6,940	1,511
36	2CH-536 (3")/Evaluation	5,428	63	6,940	1,511
37	3CH-536 (3")/Evaluation	5,428	63	6,940	1,511
38					
39					
40	1SI-604 (3")/Modification	9,753	113	12,097	2,344
41	2SI-604 (3")/Modification	9,753	113	12,097	2,344
42	3SI-604 (3")/Modification	9,753	113	12,097	2,344
43	1SI-609 (3")/Modification	9,753	113	12,097	2,344
44	2SI-609 (3")/Modification	9,753	113	12,097	2,344
45	3SI-609 (3")/Modification	9,753	113	12,097	2,344
46					
47					
48	1SI-651 (12")/Modification	163,266	3,659	179,786	16,520
49	2SI-651 (12")/Modification	163,266	3,659	179,786	16,520
50	3SI-651 (12")/Modification	163,266	3,659	179,786	16,520
51	1SI-652 (12")/Modification	163,266	3,659	179,786	16,520
52	2SI-652 (12")/Modification	163,266	3,659	179,786	16,520
53	3SI-652 (12")/Modification	163,266	3,659	179,786	16,520
54					
55					
56					
57					
58					
59					

	A	AZ	BA	BB	BF
1	Steven A. Lopez ____________				
2	Rafael Rios & Joe Daza_____			MOV Min Avail	
3	Revision 13	**Total Stem Thrust**	**Total Torque Required**	**Thrust due to**	**MARGIN**
4		**Req'd to Overcome**	**to Overcome Pressure**	**Structural Limit or**	LIMITING THRUST
5	**Valve Tag (size)**	**Press Locking**	**Locking**	**Motor Torque Limit**	subtract
6		Ftotal	Required Torque	Limiting Thrust	REQUIRED THRUST
7		(lbf)	(ft-lbf)	(lbf)	(lbf)
60	1SI-653 (12")/Modification	30,708	829	51,548	20,840
61	2SI-653 (12")/Modification	30,708	829	51,548	20,840
62	3SI-653 (12")/Modification	30,708	829	51,548	20,840
63	1SI-654 (12")/Modification	30,708	829	51,548	20,840
64	2SI-654 (12")/Modification	30,708	829	51,548	20,840
65	3SI-654 (12")/Modification	30,708	829	51,548	20,840
66					
67					
68	1SI-655 (12")/Modification	30,932	800	53,235	22,303
69	2SI-655 (12")/Modification	30,932	800	53,235	22,303
70	3SI-655 (12")/Modification	30,932	800	53,235	22,303
71	1SI-656 (12")/Modification	30,932	800	53,235	22,303
72	2SI-656 (12")/Modification	30,932	800	53,235	22,303
73	3SI-656 (12")/Mod (Note 3)	30,932	800	53,235	22,303
74					
75					
76					
77	1SI-672 (8")/Modification	17,818	308	24,983	7,166
78	2SI-672 (8")/Modification	17,818	308	24,983	7,166
79	3SI-672 (8")/Modification	19,318	334	24,983	5,666
80	1SI-671 (8")/Modification	17,818	308	24,983	7,166
81	2SI-671 (8")/Modification	17,818	308	24,983	7,166
82	3SI-671 (8")/Modification	17,818	308	24,983	7,166
83					
84					
85					

	A	AZ	BA	BB	BF
1	Steven A. Lopez ___________				
2	Rafael Rios & Joe Daza_____			**MOV Min Avail**	
3	Revision 13	**Total Stem Thrust**	**Total Torque Required**	**Thrust due to**	**MARGIN**
4		**Req'd to Overcome**	**to Overcome Pressure**	**Structural Limit or**	LIMITING THRUST
5	**Valve Tag (size)**	**Press Locking**	**Locking**	**Motor Torque Limit**	subtract
6		Ftotal	Required Torque	Limiting Thrust	REQUIRED THRUST
7		(lbf)	(ft-lbf)	(lbf)	(lbf)
86	1SI-685 (10")/Modification	28,986	494	31,909	2,923
87	2SI-685 (10")/Modification	28,986	494	31,909	2,923
88	3SI-685 (10")/Modification	28,986	494	31,909	2,923
89	1SI-694 (10")/Modification	28,986	494	31,909	2,923
90	2SI-694 (10")/Modification	28,986	494	31,909	2,923
91	3SI-694 (10")/Mod (Note 1)	28,986	494	31,909	2,923
92					
93					
94	1SI-686 (20")/Modification	70,325	1,537	77,499	7,174
95	2SI-686 (20")/Modification	70,325	1,537	77,499	7,174
96	3SI-686 (20")/Modification	70,325	1,537	77,499	7,174
97	1SI-696 (20")/Modification	70,325	1,537	77,499	7,174
98	2SI-696 (20")/Modification	70,325	1,537	77,499	7,174
99	3SI-696 (20")/Modification	70,325	1,537	77,499	7,174
100					
101					
102	1SI-688 (10")/Modification	28,956	493	31,909	2,953
103	2SI-688 (10")/Modification	28,956	493	31,909	2,953
104	3SI-688 (10")/Modification	28,956	493	31,909	2,953
105	1SI-693 (10")/Modification	28,956	493	31,909	2,953
106	2SI-693 (10")/Modification	28,956	493	31,909	2,953
107	3SI-693 (10")/Mod (Note 1)	28,956	493	31,909	2,953

	A	BG	BH	BI	BJ	BK	BL
1	Steven A. Lopez ___________						
2	Rafael Rios & Joe Daza_____			Additional			**CHAPTER 15 EVENT RESULTING**
3	Revision 13			PL		**FRACTION**	**IN THE MAXIMUM INCREASE IN**
4				Load	**DIMEN.**	**RESIDUAL**	**BONNET TEMPERATURE PRIOR TO**
5	**Valve Tag (size)**	**MARGIN**		"(PL Load	**CORR.**	**OF STATIC**	**REQ'D ACTIVE OPEN FUNCTION**
6		DESIGN	Suscept?	-Res. Load)"		**PEAK**	Reqd by GL 95-07
7		(%)		(lbf)		**CRACKING**	
8	**A/D Gate Valves:**						
9	1AF-34 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
10	2AF-34 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
11	3AF-34 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
12	1AF-35 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
13	2AF-35 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
14	3AF-35 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
15							
16							
17	1AF-36 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
18	2AF-36 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
19	3AF-36 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
20	1AF-37 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
21	2AF-37 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
22	3AF-37 (6")/Modification	9.9	No	24,343	0.975	0.854	HELB
23							
24							
25	1SG-134 (6")/Modification	27.3	No	16,010	0.772	0.884	ALL (Normal Conditions)
26	2SG-134 (6")/Modification	27.3	No	16,010	0.772	0.884	ALL (Normal Conditions)
27	3SG-134 (6")/Modification	27.3	No	16,010	0.772	0.884	ALL (Normal Conditions)
28	1SG-138 (6")/Modification	27.3	No	16,010	0.772	0.884	ALL (Normal Conditions)
29	2SG-138 (6")/Modification	27.3	No	16,010	0.772	0.884	ALL (Normal Conditions)
30	3SG-138 (6")/Modification	27.3	No	16,010	0.772	0.884	ALL (Normal Conditions)
31							
32							
33							

	A	BG	BH	BI	BJ	BK	BL
1	Steven A. Lopez ____________						
2	Rafael Rios & Joe Daza_____			Additional			**CHAPTER 15 EVENT RESULTING**
3	Revision 13			PL		**FRACTION**	**IN THE MAXIMUM INCREASE IN**
4				Load	**DIMEN.**	**RESIDUAL**	**BONNET TEMPERATURE PRIOR TO**
5	**Valve Tag (size)**	**MARGIN**		"(PL Load	**CORR.**	**OF STATIC**	**REQ'D ACTIVE OPEN FUNCTION**
6		DESIGN	Suscept?	-Res. Load)"		**PEAK**	Reqd by GL 95-07
7		(%)		(lbf)		**CRACKING**	
34	**BW/IP Gate Valves:**						
35	1CH-536 (3")/Evaluation	27.8	No	226	0.039	0.994	ALL (Normal Conditions)
36	2CH-536 (3")/Evaluation	27.8	No	226	0.039	0.994	ALL (Normal Conditions)
37	3CH-536 (3")/Evaluation	27.8	No	226	0.039	0.994	ALL (Normal Conditions)
38							
39							
40	1SI-604 (3")/Modification	24.0	No	3,489	0.557	0.916	LOCA
41	2SI-604 (3")/Modification	24.0	No	3,489	0.557	0.916	LOCA
42	3SI-604 (3")/Modification	24.0	No	3,489	0.557	0.916	LOCA
43	1SI-609 (3")/Modification	24.0	No	3,489	0.557	0.916	LOCA
44	2SI-609 (3")/Modification	24.0	No	3,489	0.557	0.916	LOCA
45	3SI-609 (3")/Modification	24.0	No	3,489	0.557	0.916	LOCA
46							
47							
48	1SI-651 (12")/Modification	10.1	No	119,063	1.875	0.719	LOCA
49	2SI-651 (12")/Modification	10.1	No	119,063	1.875	0.719	LOCA
50	3SI-651 (12")/Modification	10.1	No	119,063	1.875	0.719	LOCA
51	1SI-652 (12")/Modification	10.1	No	119,063	1.875	0.719	LOCA
52	2SI-652 (12")/Modification	10.1	No	119,063	1.875	0.719	LOCA
53	3SI-652 (12")/Modification	10.1	No	119,063	1.875	0.719	LOCA
54							
55							
56							
57							
58							
59							

	A	BG	BH	BI	BJ	BK	BL
1	Steven A. Lopez ___________						
2	Rafael Rios & Joe Daza_____			Additional			CHAPTER 15 EVENT RESULTING
3	Revision 13			PL		FRACTION	IN THE MAXIMUM INCREASE IN
4				Load	DIMEN.	RESIDUAL	BONNET TEMPERATURE PRIOR TO
5	Valve Tag (size)	MARGIN		"(PL Load	CORR.	OF STATIC	REQ'D ACTIVE OPEN FUNCTION
6		DESIGN	Suscept?	-Res. Load)"		PEAK	Reqd by GL 95-07
7		(%)		(lbf)		CRACKING	
60	1SI-653 (12")/Modification	67.9	No	14,698	0.974	0.854	LOCA
61	2SI-653 (12")/Modification	67.9	No	14,698	0.974	0.854	LOCA
62	3SI-653 (12")/Modification	67.9	No	14,698	0.974	0.854	LOCA
63	1SI-654 (12")/Modification	67.9	No	14,698	0.974	0.854	LOCA
64	2SI-654 (12")/Modification	67.9	No	14,698	0.974	0.854	LOCA
65	3SI-654 (12")/Modification	67.9	No	14,698	0.974	0.854	LOCA
66							
67							
68	1SI-655 (12")/Modification	72.1	No	12,372	0.858	0.871	HELB
69	2SI-655 (12")/Modification	72.1	No	12,372	0.858	0.871	HELB
70	3SI-655 (12")/Modification	72.1	No	12,372	0.858	0.871	HELB
71	1SI-656 (12")/Modification	72.1	No	12,372	0.858	0.871	HELB
72	2SI-656 (12")/Modification	72.1	No	12,372	0.858	0.871	HELB
73	3SI-656 (12")/Mod (Note 3)	72.1	No	12,372	0.858	0.871	HELB
74							
75							
76							
77	1SI-672 (8")/Modification	40.2	No	8,478	0.737	0.889	LOCA
78	2SI-672 (8")/Modification	40.2	No	8,478	0.737	0.889	LOCA
79	3SI-672 (8")/Modification	29.3	No	8,478	0.645	0.903	LOCA
80	1SI-671 (8")/Modification	40.2	No	8,478	0.737	0.889	LOCA
81	2SI-671 (8")/Modification	40.2	No	8,478	0.737	0.889	LOCA
82	3SI-671 (8")/Modification	40.2	No	8,478	0.737	0.889	LOCA
83							
84							
85							

	A	BG	BH	BI	BJ	BK	BL
1	Steven A. Lopez ________						
2	Rafael Rios & Joe Daza_____			Additional			**CHAPTER 15 EVENT RESULTING**
3	Revision 13			PL		**FRACTION**	**IN THE MAXIMUM INCREASE IN**
4				Load	**DIMEN.**	**RESIDUAL**	**BONNET TEMPERATURE PRIOR TO**
5	**Valve Tag (size)**	**MARGIN**		"(PL Load	**CORR.**	**OF STATIC**	**REQ'D ACTIVE OPEN FUNCTION**
6		DESIGN	Suscept?	-Res. Load)"		**PEAK**	Reqd by GL 95-07
7		(%)		(lbf)		**CRACKING**	
86	1SI-685 (10")/Modification	10.1	No	20,272	1.615	0.758	ALL (Normal Conditions)
87	2SI-685 (10")/Modification	10.1	No	20,272	1.615	0.758	ALL (Normal Conditions)
88	3SI-685 (10")/Modification	10.1	No	20,272	1.615	0.758	ALL (Normal Conditions)
89	1SI-694 (10")/Modification	10.1	No	20,272	1.615	0.758	ALL (Normal Conditions)
90	2SI-694 (10")/Modification	10.1	No	20,272	1.615	0.758	ALL (Normal Conditions)
91	3SI-694 (10")/Mod (Note 1)	10.1	No	20,272	1.615	0.758	ALL (Normal Conditions)
92							
93							
94	1SI-686 (20")/Modification	10.2	No	61,897	3.456	0.482	ALL (Normal Conditions)
95	2SI-686 (20")/Modification	10.2	No	61,897	3.456	0.482	ALL (Normal Conditions)
96	3SI-686 (20")/Modification	10.2	No	61,897	3.456	0.482	ALL (Normal Conditions)
97	1SI-696 (20")/Modification	10.2	No	61,897	3.456	0.482	ALL (Normal Conditions)
98	2SI-696 (20")/Modification	10.2	No	61,897	3.456	0.482	ALL (Normal Conditions)
99	3SI-696 (20")/Modification	10.2	No	61,897	3.456	0.482	ALL (Normal Conditions)
100							
101							
102	1SI-688 (10")/Modification	10.2	No	20,242	1.615	0.758	ALL (Normal Conditions)
103	2SI-688 (10")/Modification	10.2	No	20,242	1.615	0.758	ALL (Normal Conditions)
104	3SI-688 (10")/Modification	10.2	No	20,242	1.615	0.758	ALL (Normal Conditions)
105	1SI-693 (10")/Modification	10.2	No	20,242	1.615	0.758	ALL (Normal Conditions)
106	2SI-693 (10")/Modification	10.2	No	20,242	1.615	0.758	ALL (Normal Conditions)
107	3SI-693 (10")/Mod (Note 1)	10.2	No	20,242	1.615	0.758	ALL (Normal Conditions)

NOTES:

13JAFBUV0034/0035

1) Electrical voltage is based on a conservatively interpolated available 414 volts @ 44 amps at unseating. (Curve M5204)

13JSGAUV0134/138

1) Electrical voltage is based on a conservatively interpolated available 93 volts @ 165 amps at unseating. (Curve K11350)

13JAFC(A)UV0036/(0037)

1) Electrical voltage is based on a conservatively interpolated available 98.44 volts @ 104 amps at unseating. (Curve 5013)

13JCHEHV0536

1) Electrical voltage is based on a conservatively interpolated available 414 volts @ 44 amps at unseating. (Curve M1468)

13JSIA(B)UV0604(609)

1) The valve structural limits for thrust and torque reflect the re-evalation based on design basis temperature of 225 DEGF. This re-evaluation of BW/IP weaklink analysis (Valve Part No. 77910/13-N001-2101-94-8) is documented in study 13-JS-A41.

13JSIA(B)UV0651/(652)

1) Electrical voltage is based on a conservatively interpolated available 414 volts @ 118 amps at unseating. (Curve SK-34176)

13JSIA(B)UV0653/(654)

1) Electrical voltage is based on 95% of nominal inverter AC output voltage of 480 volts & manual operation time requirements. (13--JC-ZZ-210)

13JSIA(B)UV0655/(656)

1) Bounding Coefficient Of Friction (COF) for applicable 13-MS-B07 R/3, Evaluation of Dynamic Performance Parameters for Generic Letter 89-10 MOVs, valve group 19, Borg-Warner 12 inch 300 lb & 1500 lb Class Flex Wedge Gate Valves is 0.18. Specific Open COF for this valve based on dynamic testing is recorded as 0.10. A COF value of 0.15 is used to consevatively estimate maximum COF for this valve.

2) Electrical voltage is based on a conservatively interpolated 414 volts @ 30.8 amps at unseating. (Curve M1488)

3) 3JSIBUV0656 is scheduled for OAR change in U3 R8 (Spring 2000).

13JSIBUV0671

1) Electrical voltage is based on a conservatively interpolated available 414 volts @ 47.3 amps at unseating. (Curve M-4635)

13JSIAUV0672

1) The lowest voltage that may occur during the actuation of this MOV is 405 VAC: however, this voltage ony occurs for a duration of approximately 1.44 seconds @ 5 seconds after SIAS/CSAS. Available voltage is at time 0 is 425 VAC, at approximately 6.5 seconds the available voltage increases to 414 VAC. 414 VAC is conservatively used as the effective available voltage during unseating since the actuator motor is rated for 10 seconds stall without permanent damage and the short duration of the 405 min voltage does not impact the ability of the actuator to unseat given the postulated pressure locking loads.
Limitorque motors can go to a locked rotor condition for 10 seconds without sustaining damage per Limitorque fax date 9-30-94 and review of the motor thermal limit curve.

13JSIA(B)HV685(694)

1) 3JSIBUV0694 is scheduled for OAR change in U3 R8 (Spring 2000).

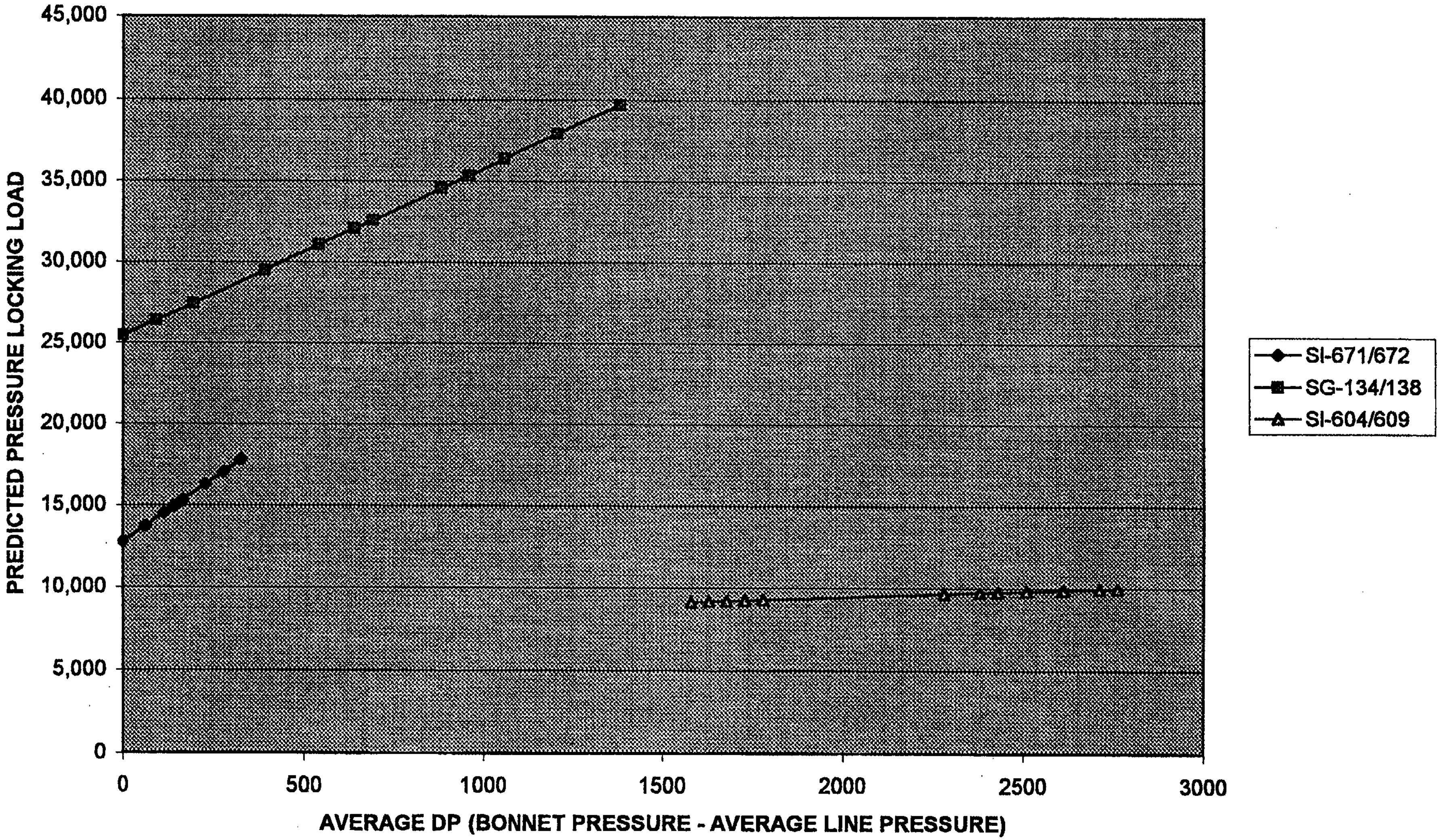
13JSIA(B)HV686(696)

1) Electrical voltage is based on a conservatively interpolated available 414 volts @ 33 amps at unseating. (Curve E2272A-A-001)

13JSIA(B)HV688(693)

1) 3JSIBUV0693 is scheduled for OAR change in U3 R8 (Spring 2000).

COMPARISON OF PRESSURE LOCKING LOAD WITH BONNET TO PIPING DP



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Attachment 2 – Bonnet Pressure/Temperature Relationship

Calculation of the Theoretical Increases in Bonnet Pressure in Gate Valves

The theoretical curve for pressure vs. temperature plotted in this attachment is based on the following theory. A significant increase in valve temperature is accompanied with an increase in bonnet fluid pressure and temperature. The valve body will expand as the fluid temperature and pressure increases. A coarse calculation of the increase in bonnet fluid pressure with an increase in room temperature will be performed conservatively neglecting the expansion of the valve body and the bonnet.

The increase in bonnet fluid pressure can be calculated by modeling the isolated valve bonnet as a closed system with constant mass (dM/dt = 0). The specific volume at initial temperature and pressure is assumed to be maintained constant throughout since the bonnet cavity volume is constant and zero leakage is assumed (dM/dt = 0). The final pressure is calculated using the following algorithms with the final temperature and the initial specific volume as inputs [Ref. 27, ASME Steam Tables (subregion 1, compressed water region)].

These algorithms were taken from Appendix 1 of Reference 27 where they were presented for use with digital computers for the calculation of the associated thermodynamic properties. These algorithms were programmed and the associated thermodynamic properties were calculated utilizing T-K Solver. This approach is similar to that used in Reference 5. The resulting Pressure-Temperature correlation is plotted on the attached graph and has been validated by correlation with the tabular values for these thermodynamic properties in Table 3 of Reference 27. The attached graph also includes the adjusted experimental correlation, pressurization model used in the PVNGS model, and the high heatup and low heatup test data from the Commonwealth Edison thermal pressurization tests. The pressurization model used in the PVNGS model utilizes conservative pressurization rates consistent with this calculated theoretical and the maximum INEEL pressurization test rates (Ref. 31).

$v = v_r(0.00317)(16.018)$

$T_r = (T+459.67)/[(647.3)(9/5)]$

$P_r = P/(3207)$

$v_r = C1+C2-C3-C4+C5+C6$

where,

v = Specific Volume (ft^3/lbm)

v_r = Reduced Specific Volume

T = Temperature (°F)

T_r = Reduced Temperature

P = Pressure (psia)

P_r = Reduced Pressure

and,

$C1 = A11(B5)(Z)^{-5/17}$

$C2 = A12+A13(T_r)+A14(T_r)^2+A15(B6T_r)^{10}+A16(B7+T_r^{19})^{-1}$

$C3 = (B8+T_r^{11})^{-1}[A17+2(A18)(P_r)+3(A19)(P_r)^2]$
$C4 = A20(T_r)^{18}(B9+T_r^2)[-3(B10+P_r)^{-4}+B11]$
$C5 = 3(A21)(B12-T_r)(P_r)^2$
$C6 = 4(A22)(T_r^{-20})(P_r)^3$

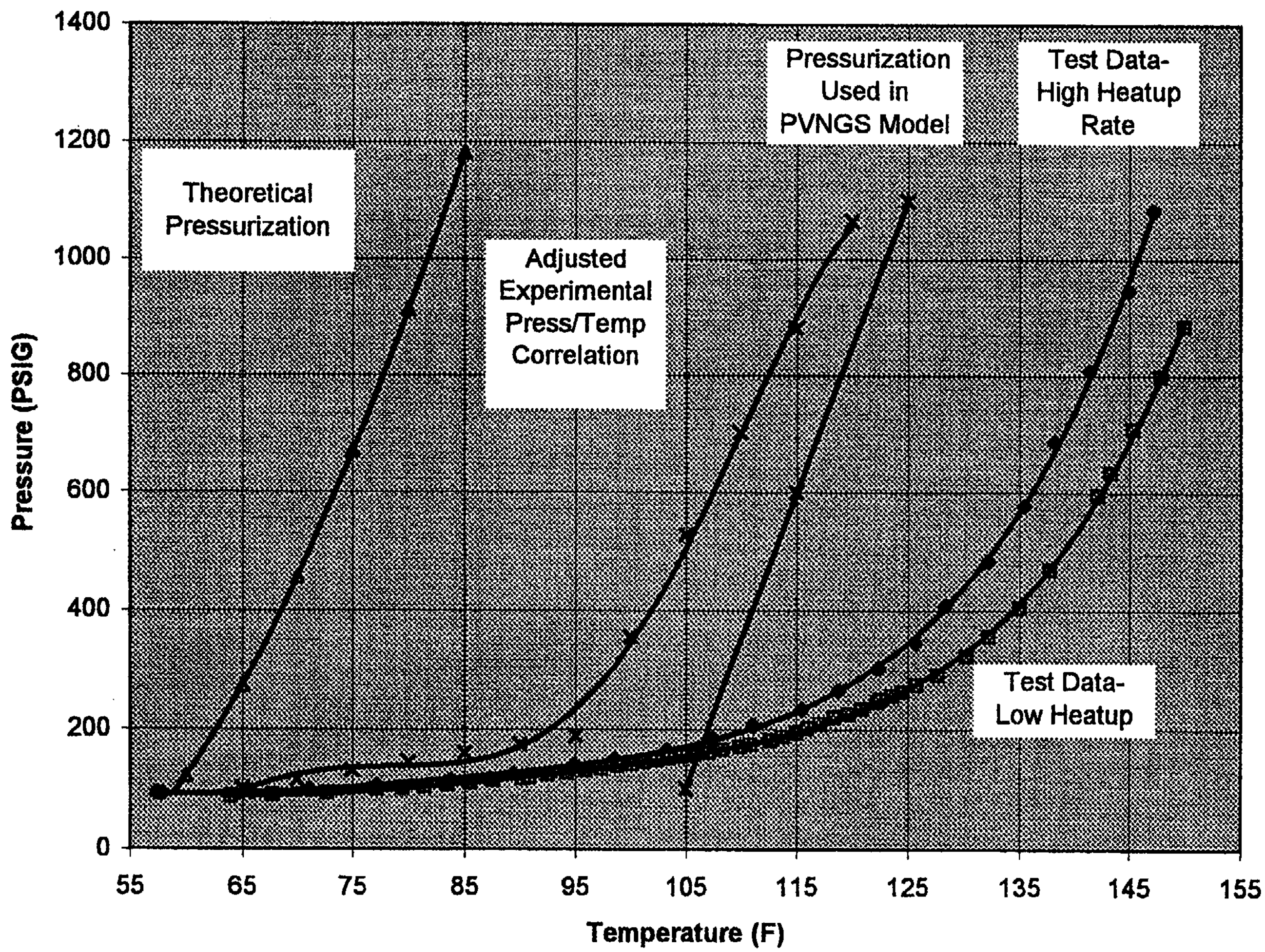
when,

$Z = Y+[(B3)(Y^2)-2(B4)(T_r)+2(B5)(P_r)]^{0.5}$
$Y = 1-(B1)(T_r)^2-(B2)(T_r)^{-6}$

<u>Constants</u> (Ref. ASME Steam Tables)

A11= 7.982692717
A12= 2.616571843E-2
A13= 1.522411790E-3
A14= 2.284279054E-2
A15= 2.421647003E2
A16= 1.269716088E-10
A17= 2.074838328E-7
A18= 2.1740020350E-8
A19= 1.105710498E-9
A20= 1.293441934E1
A21= 1.308119072E-5
A22= 6.047626338E-14
B1 = 8.438375405E-1
B2 = 5.362162162E-4
B3 = 1.720000000
B4 = 7.342278489E-2
B5 = 4.975858870E-2
B6 = 6.537154300E-1
B7 = 1.150000000E-6
B8 = 1.510800000E-5
B9 = 1.418800000E-1
B10= 7.002753165
B11= 2.995284926E-4
B12= 2.040000000E-1

Bonnet Fluid Pressure vs Bonnet Fluid Temperature



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	PVNGS PRESSURE LOCKING SUSCEPTIBILTY EVALUATION				
	VALVE FIELD DIMENSIONAL DATA				
			2a	2b	theta
VALVE	PVNGS	VENDOR	MEAN SEAT	MIN. DISK	SEAT ANGLE
SIZE (IN.)	TAG	MODEL #	DIA. (IN.)	HUB DIA. (IN.)	(DEG.,MIN.)
6	21-AF-34	A/D 3897-3	5.25	1.75	5
6	03-AF-34	A/D W8321892	5.25	1.75	5
6	21-AF-35	A/D 3897-3	5.25	1.75	5
6	03-AF-35	A/D W8321892	5.25	1.75	5
6	13-AF-36	A/D 3896-3	5.25	1.75	5
6	13-AF-37	A/D 3897-3	5.25	1.75	5
6	13-SG-134	A/D 3994-3	5.25	1.75	5
6	13-SG-138	A/D 3994-3	5.25	1.75	5
3	13-SI-604	B/W 77910	2.75	2.22	5 ,15
3	13-SI-609	B/W 77910	2.75	2.22	5 ,15
3	13-CH-536	B/W 77910	2.995	2.22	5 ,15
8	13-SI-671	B/W 79510	8.14	4.58	5 ,15
8	13-SI-672	B/W 79510	8.14	4.58	5 ,15
10	13-SI-685	B/W 77780	10.25	5.26	5 ,15
10	13-SI-688	B/W 77780	10.25	5.26	5 ,15
10	13-SI-693	B/W 77780	10.25	5.26	5 ,15
10	13-SI-694	B/W 77780	10.25	5.26	5 ,15
12	13-SI-651	B/W 77850	10.505	5.94	5 ,15
12	13-SI-652	B/W 77850	10.505	5.94	5 ,15
12	13-SI-653	B/W 77850-1	10.505	5.94	5 ,15
12	13-SI-654	B/W 77850-1	10.505	5.94	5 ,15
12	13-SI-655	B/W 77850-2	10.505	5.94	5 ,15
12	13-SI-656	B/W 77850-2	10.505	5.94	5 ,15
20	13-SI-686	B/W 77890-2	19.03	10.5	5
20	13-SI-696	B/W 77890-2	19.03	10.5	5

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Attachment 4- Validation of Pressure Locking Thrust vs Bonnet Pressure Model

Arizona Public Service, in partnership with Commonwealth Edison and the Westinghouse Users Group, performed testing of a Borg Warner 10", 300# class flexible wedge gate valve to determine the stem thrust required to open a flexible wedge gate valve with the fluid pressure in the valve bonnet greater than the fluid pressure in the upstream and downstream piping. The test methodology instrumentation, and final results are identified in Attachment 5 of 13-MC-ZZ-217.

Testing performed to measure the stem thrust at several different bonnet pressures was performed with two different closed torque switch settings. A plot of the peak stem thrust required to open the valve as a function of the bonnet pressure has been generated for both of these torque switch settings (see charts 1 & 2 of this attachment). For comparison, the predicted stem pullout thrust, calculated using the methodology of 13-MC-ZZ-217, is plotted as a function of bonnet pressure.

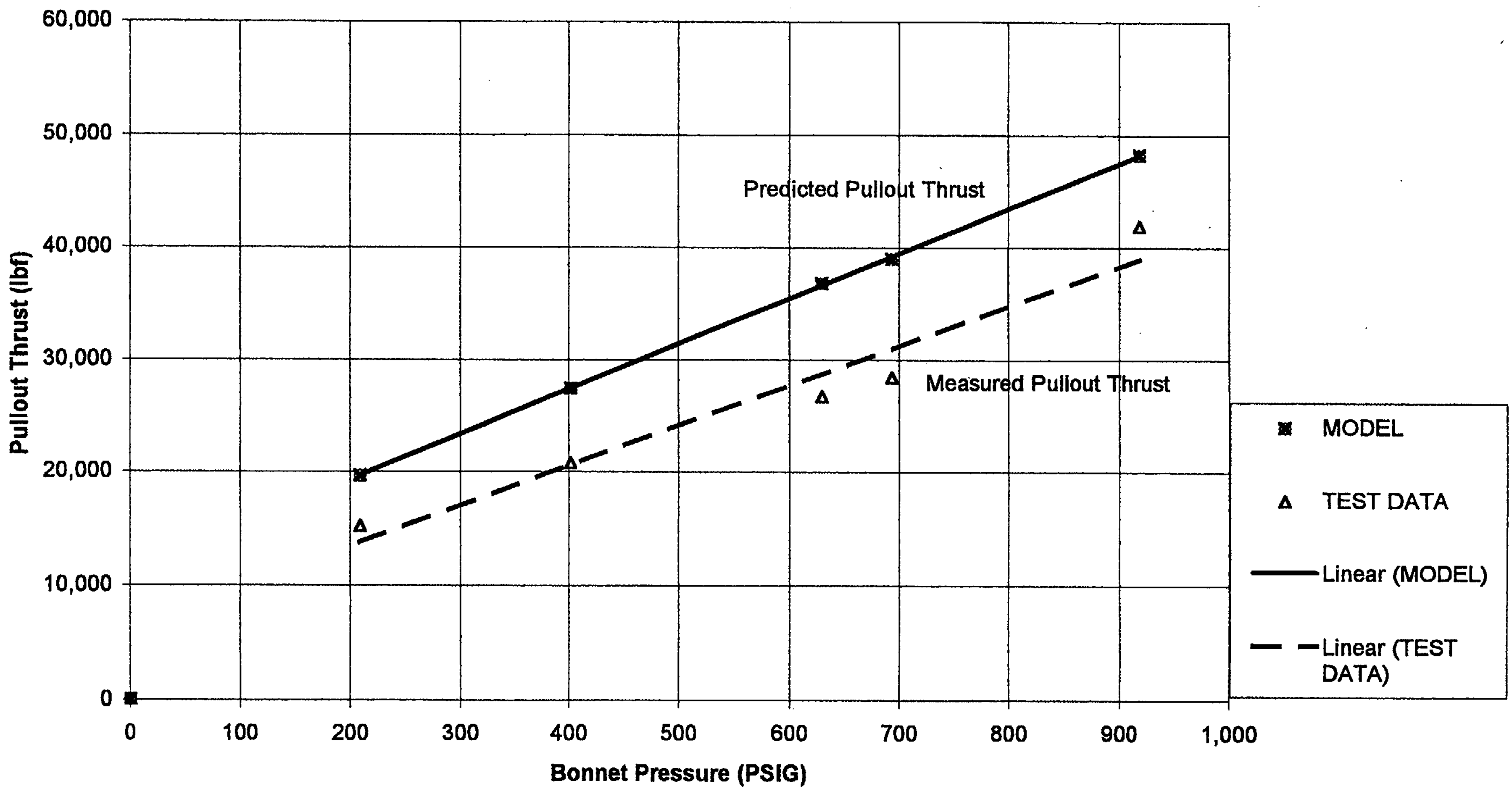
The inputs required to calculate the predicted stem pullout thrust are provided in Attachment 5. Analysis of the data resulted in the development of an experimental dimensional correlation to determine the percentage of residual load as a function of the bonnet pressure induced load. This correlation was established based on the test results in Attachment 5 and is represented in chart 3 of this attachment. The correlation indicates that as the bonnet pressure increases the residual load percentage of the effective closing thrust is reduced. The test value for the residual closing load at opening, peak cracking, is obtained by substracting the calculated pressure locking load components, without residual load, from the total measured load. This value is then divided by the measured test value of the prior closing thrust to determine the measured residual percentage of closing force.

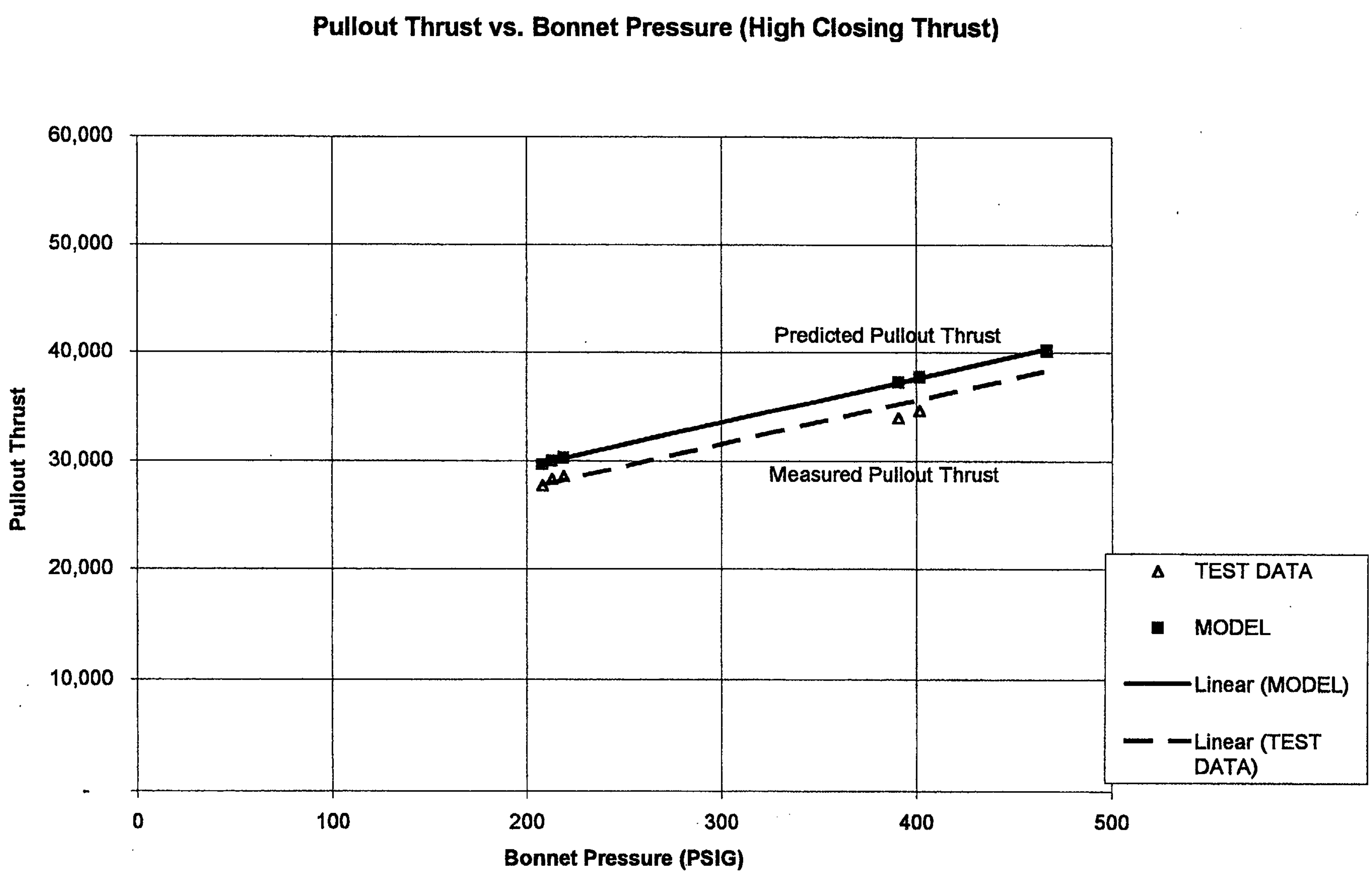
The measured data and predicted values from selected tests are plotted and fit with linear regressions on charts 1 & 2 of this attachment. Chart 1 includes selected tests with a measured bonnet pressure greater than 200 psig and prior closing thrust less than 17,000 lbs (Low closing Thrust). Chart 2 includes selected tests with a measured bonnet pressure greater than 200 psig and prior closing thrust greater than 31,000 lbs (High closing Thrust). In general a good correlation between the regression for the measured data and for the predicted values is demonstrated by the similarity in slope between the plotted lines on chart 1. The margin between the measured data and predicted data presented in chart 1 ranges from a high of 37.8% for the measured pressure locking load of 26,705 lbf with a bonnet pressure of 630 psig (Test #52) to a minimum margin of 15.3% between the measured and predicted values of the pressure locking load of 41,872 lbf with a bonnet pressure of 919 psig (Test #56). However, the measured data presented in chart 2 tracks the predicted values calculated utilizing the methodology of 13-MC-ZZ-217. There is one set of data (Test #80) where the calculated pressure locking load exceeds the measured open pressure locking load by less than 1%. Therefore, for applications of this 13-MC-ZZ-217 model with postulated bonnet pressure of above 200 psig an additional minimum 10% margin is maintained between the minimum actuator load limit and the calculated required pressure locking load unless otherwise specified.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1		BORG WARNER 10" 300# TEST GATE VALVE																									
2														MOV MISC INPUTS													
3		TEST PRESSURES						VALVE INPUTS						Max Clos	% Residual		Calculation of Disk Load Perpindicular to the Seat Using Roark Thin Plate Theory										
4	TEST	Pinitial	Pup	Pdown	DPavg		a	b	theta	nu	VF	Dstem		Load	Load		C2	C3	C8	C9	L11	L17	mu	Qb	Qa	Disk Load	
5	Test #42	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		31,783	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
6	Test #43	205	0	0	205		5.13	2.7	5	0.3	0.6	1.5		32,032	63%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	397	-170	6,911	
7	Test #44	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		31,731	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
8	Test #45	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		16,162	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
9	Test #46	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		16,669	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
10	Test #47	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		16,859	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
11	Test #48	209	0	0	209		5.13	2.7	5	0.3	0.6	1.5		16,809	60%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	405	-173	7,046	
12	Test #49	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		16,659	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
13	Test #50	402	0	0	402		5.13	2.7	5	0.3	0.6	1.5		16,708	53%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	779	-334	13,552	
14	Test #51	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		16,807	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
15	Test #52	630	0	0	630		5.13	2.7	5	0.3	0.6	1.5		16,958	45%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	1,221	-523	21,238	
16	Test #53	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		16,460	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
17	Test #54	694	0	0	694		5.13	2.7	5	0.3	0.6	1.5		16,361	42%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	1,345	-576	23,395	
18	Test #55	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		16,956	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
19	Test #56	919	0	0	919		5.13	2.7	5	0.3	0.6	1.5		16,709	34%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	1,782	-763	30,980	
20																											
21	Test #58	950	0	0	950		5.13	2.7	5	0.3	0.6	1.5		15,665	31%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	1,842	-788	32,025	
22																											
23																											
24	Test #72	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		31,521	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
25	Test #73	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		31,670	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
26	Test #74	208	0	0	208		5.13	2.7	5	0.3	0.6	1.5		31,670	63%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	403	-173	7,012	
27	Test #75	213	0	0	213		5.13	2.7	5	0.3	0.6	1.5		31,920	63%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	413	-177	7,180	
28	Test #76	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		31,822	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
29	Test #77	391	0	0	391		5.13	2.7	5	0.3	0.6	1.5		32,017	60%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	758	-325	13,181	
30	Test #78	402	0	0	402		5.13	2.7	5	0.3	0.6	1.5		32,168	60%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	779	-334	13,552	
31	Test #79	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		31,671	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
32	Test #80	467	0	0	467		5.13	2.7	5	0.3	0.6	1.5		31,868	58%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	905	-388	15,743	
33	Test #81	219	0	0	219		5.13	2.7	5	0.3	0.6	1.5		31,971	63%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	425	-182	7,383	
34	Test #82	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		32,417	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
35	Test #83	110	0	0	110		5.13	2.7	5	0.3	0.6	1.5		32,318	65%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	213	-91	3,708	
36	Test #84	54	0	0	54		5.13	2.7	5	0.3	0.6	1.5		31,820	66%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	105	-45	1,820	
37	Test #85	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		31,722	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
38	Test #86	1	0	0	1		5.13	2.7	5	0.3	0.6	1.5		32,464	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	2	-1	34	
39	Test #87	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		32,413	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
40	Test #88	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		32,267	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
41																											
42	Test #92	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		31,951	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
43	Test #93	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		17,392	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
44	Test #94	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		17,244	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
45	Test #95	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		17,443	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	
46	Test #96	557	0	0	557		5.13	2.7	5	0.3	0.6	1.5		17,394	48%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	1,080	-462	18,777	
47	Test #97	504	0	0	504		5.13	2.7	5	0.3	0.6	1.5		17,691	50%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	977	-418	16,990	
48	Test #98	0	0	0	0		5.13	2.7	5	0.3	0.6	1.5		17,393	67%		0.0917	0.0127	0.7471	0.2861	0.00163	0.0824	0.6307	0	0	0	

	A	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1														
2		**Residual Closing**	**Vertical Load**	**Stem Piston**		**Calculated Stem Thrust**	**Measured**	**Margin %**		**Residual Closing**	**% Residual Load**	**Exp.Dimensional**	**Meas. Residual %**	Model Residual %
3		**Load at Cracking**	**On Disks**	**Load**		**Req'd to Open**	**PL Load**		Bonnet	**Load at Opening**	**of Total Load**	**Corrolation**	**of Closing Thrust**	of Closing Thrust
4	TEST	Residual Load	Fvert	Fpiston		Ftotal			Pressure	(Measured Load-PL Loads)		(BP*SA/Closing)		
5	Test #42	21,295	0	0		21,295	16,513	29.0	0	16,513	100%	0.000	52%	67%
6	Test #43	20,238	2,949	362		29,735	25,467	16.8	205	15,970	63%	0.255	50%	63%
7	Test #44	21,260	0	0		21,260	17,357	22.5	0	17,357	100%	0.000	55%	67%
8	Test #45	10,829	0	0		10,829	7,261	49.1	0	7,261	100%	0.000	45%	67%
9	Test #46	11,162	0	0		11,162	7,509	48.6	0	7,509	100%	0.000	45%	67%
10	Test #47	11,296	0	0		11,296	7,907	42.9	0	7,907	100%	0.000	47%	67%
11	Test #48	10,015	3,006	369		19,697	15,268	29.0	209	5,586	37%	0.495	33%	60%
12	Test #49	11,162	0	0		11,162	7,857	42.1	0	7,857	100%	0.000	47%	67%
13	Test #50	8,795	5,782	710		27,419	20,786	31.9	402	2,163	10%	0.957	13%	53%
14	Test #51	11,261	0	0		11,261	7,707	46.1	0	7,707	100%	0.000	46%	67%
15	Test #52	7,602	9,062	1,113		36,788	26,705	37.8	630	-2,481	-9%	1.478	-15%	45%
16	Test #53	11,028	0	0		11,028	8,105	36.1	0	8,105	100%	0.000	49%	67%
17	Test #54	6,820	9,982	1,226		38,971	28,395	37.2	694	-3,756	-13%	1.688	-23%	42%
18	Test #55	11,361	0	0		11,361	7,658	48.3	0	7,658	100%	0.000	45%	67%
19	Test #56	5,710	13,218	1,624		48,285	41,872	15.3	919	-703	-2%	2.188	-4%	34%
20														
21	Test #58	4,826	13,664	1,679		48,836	5,023	872.3	950	-38,988	-776%	2.413	-249%	31%
22														
23														
24	Test #72	21,119	0	0		21,119	16,705	26.4	0	16,705	100%	0.000	53%	67%
25	Test #73	21,219	0	0		21,219	17,202	23.4	0	17,202	100%	0.000	54%	67%
26	Test #74	19,977	2,992	368		29,614	27,643	7.1	208	18,007	65%	0.261	57%	63%
27	Test #75	20,115	3,064	376		29,983	28,241	6.2	213	18,373	65%	0.266	58%	63%
28	Test #76	21,321	0	0		21,321	17,751	20.1	0	17,751	100%	0.000	56%	67%
29	Test #77	19,118	5,624	691		37,232	33,906	9.8	391	15,792	47%	0.486	49%	60%
30	Test #78	19,153	5,782	710		37,777	34,604	9.2	402	15,981	46%	0.497	50%	60%
31	Test #79	21,220	0	0		21,220	17,949	18.2	0	17,949	100%	0.000	57%	67%
32	Test #80	18,564	6,717	825		40,199	40,121	0.2	467	18,486	46%	0.583	58%	58%
33	Test #81	20,113	3,150	387		30,259	28,540	6.0	219	18,394	64%	0.273	58%	63%
34	Test #82	21,719	0	0		21,719	17,700	22.7	0	17,700	100%	0.000	55%	67%
35	Test #83	20,997	1,582	194		26,093	25,457	2.5	110	20,361	80%	0.135	63%	65%
36	Test #84	20,997	777	95		23,499	22,871	2.7	54	20,369	89%	0.068	64%	66%
37	Test #85	21,254	0	0		21,254	17,352	22.5	0	17,352	100%	0.000	55%	67%
38	Test #86	21,745	14	2		21,791	20,980	3.9	1	20,934	100%	0.001	64%	67%
39	Test #87	21,717	0	0		21,717	18,494	17.4	0	18,494	100%	0.000	57%	67%
40	Test #88	21,619	0	0		21,619	18,197	18.8	0	18,197	100%	0.000	56%	67%
41														
42	Test #92	21,407	0	0		21,407	17,541	22.0	0	17,541	100%	0.000	55%	67%
43	Test #93	11,653	0	0		11,653	8,000	45.7	0	8,000	100%	0.000	46%	67%
44	Test #94	11,653	0	0		11,553	8,547	35.2	0	8,547	100%	0.000	50%	67%
45	Test #95	11,687	0	0		11,687	11,132	5.0	0	11,132	100%	0.000	64%	67%
46	Test #96	8,330	8,012	984		34,134	27,035	26.3	657	1,231	5%	1.274	7%	48%
47	Test #97	8,845	7,249	891		32,194	26,189	22.9	504	2,840	11%	1.134	16%	50%
48	Test #98	11,653	0	0		11,653	8,547	36.3	0	8,547	100%	0.000	49%	67%

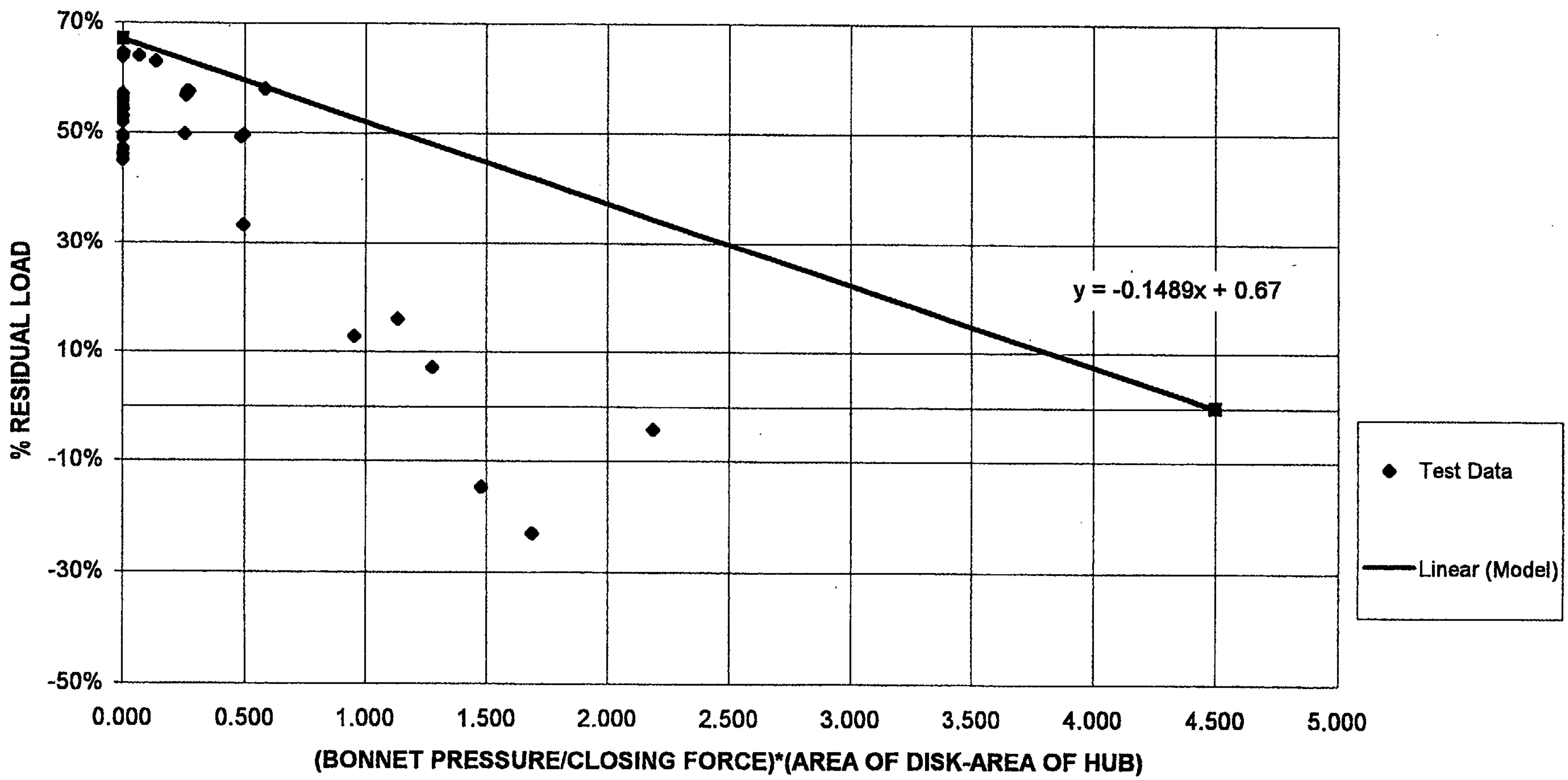
Pullout Thrust vs. Bonnet Pressure (Low Closing Thrust)





Pullout Thrust vs. Bonnet Pressure (High Closing Thrust)
60,000
50,000
40,000
30,000
20,000
10,000
Pullout Thrust
0
100
200
300
400
500
Bonnet Pressure (PSIG)
Predicted Pullout Thrust
Measured Pullout Thrust
TEST DATA
MODEL
Linear (MODEL)
Linear (TEST DATA)

RESIDUAL LOAD PRESSURE BONNET RELATIONSHIP



R.E. [signature] 2-10-2000 I.V. [signature] 02/10/00

PRESSURE LOCKING SPECIAL TEST PROCEDURE
BORG WARNER VALVE
COMMONWEALTH EDISON COMPANY PROCEDURE PL/TB-2

PRESSURE LOCKING SPECIAL TEST PROCEDURE

BORG WARNER VALVE

PROCEDURE PL/TB-2

Revision 0

November 28, 1995

Commonwealth Edison Company

Prepared by: Robert C.Bedford, Program Support

Approved by: Dan Christiana, Programs Supv. 12/4/95

Test Results

Prepared by:

Approved by: 3/6/96

TABLE OF CONTENTS

SPECIAL TEST PROCEDURE
PRESSURE LOCKING

A. PURPOSE

The purpose of this special test is to validate the proposed model and input assumptions for quantifying capability margin for valves susceptible to pressure locking. Specifically, testing will be performed on a Borg Warner valve to verify:

- the model for estimating MOV presssure lock pullout forces
- bonnet ability to retain pressure when upstream presssure source is removed
- bonnet pressure response to temperature changes

The MOV for this special test is a Borg Warner valve. This procedure provides the test requirements, procedures, and equipment to be used.

B. REFERENCES

1. Generic Letter 95-07, Pressure Locking and Thermal Binding
2. ComEd Quality Assurance Program

C. TEST EQUIPMENT AND INSTRUMENTATION

1. All instrumentation, measuring, and test equipment used in the performance of this test program should be calibrated in accordance with ComEd's Quality Assurance Program
2. Measurement Equipment is listed in Table 1
3. Thrust, torque, motor power, and motor current shall be monitored
4. Upstream, downstream, and bonnet pressure and temperature should be recorded as specified herein
5. Teledyne Quick Stem Sensor
6. Hydro-pump capable of generating 2000 psi
7. Miscellaneous valves and fittings

D. PRECAUTIONS

1. Standard safe work practices shall be followed when working around high pressure and electrical test equipment.

E. REQUIRFMENTS AND PROCEDURES

Table 2 specifies the testing to be performed and the test sequence. This test sequence and requriements may be modified during the special test. Sections may be added or omitted based on testing results at the discretion of the test engineer. New or revised test sequences should be added to Table 2.

1. Pre-Test Preparation
   a. Record valve and actuator nameplate data into the test datasheets (Appendix A-8)
   b. The required measurements and associated instruments to be installed are listed in Table 1
   c. The data acquisition method will consist of the VOTES system, motor power monitor (if required), associated support equipment and cables.
   d. Pressures and temperatures will be recorded manually or electronically.
   e. Prior to any testing or stroking of the valve, actuator switches shall be set as follows:
      1) The open limit switch shall be set to prevent back-seating of the valve
      2) The open torque switch should be bypassed a minimum of 25% of the open travel distance.
   f. Calibration of the VOTES Force Sensor and/or Teledyne Quick Stem Sensor shall be documented on Appendix A1.

2. Static Break-in Test

Verify that the valve has been stroked a minimum of 15 strokes open and 15 strokes closed. If not, cycle valve until the specified strokes are achieved.

3. LLRT Test

An LLRT Leakage Rate Test shall be performed at specified torque switch settings in both directions to verify seat leakage requirements in accordance with approved station procedures. This testing will be documented in Appendix A2.

4. Differential Pressure Test to Determine Valve Factor

   a. With the valve open fill the specimen with water .
   b. With the valve unpressurized, stroke test specimen open and then closed at the lower torque switch setting and record test data.
   c. Pressurize upstream disk side per Table 2.
   d. Vent downstream disk side to atmosphere.
   e. Open the valve , record diagnostic test data, and record upstream pressure.
   f. With the valve unpressurized, stroke test specimen closed and record test data in Appendix A3.
   g. Perform valve factor calculation as described in Appendix A3 and record results.

5. Bonnet Pressure Response

   a. With the valve open fill the specimen with water.
   b. With the valve unpressurized and setup per Table 2, stroke test specimen open and then closed and record test data.
   c. With downstream disk side vented to atmosphere pressurize upstream disk side to the pressure indicated in Table 2 for this test.
   d. Vent upstream disk side to atmosphere and record bonnet pressure as a function of time in Appendix A4.

6. Pressure Lock Test

   a. With the valve open fill the specimen with water such that all air pockets are vented and bonnet is filled solid with water.
   b. With the valve unpressurized and setup per Table 2, stroke test specimen open and then closed and record test data.
   c. Pressurize bonnet to the pressure indicated in Table 2 for this test
   d. Vent downstream and upstream disk side to atmosphere.
   e. Record bonnet pressure and open/close the valve while recording diagnostic test data in Appendix A5.

7. Bonnet Pressure Response to Temperature Changes

   a. With the valve open fill the specimen with water such that all air pockets are vented and bonnet is filled solid with water.
   b. With the valve unpressurized and setup per Table 2, stroke test specimen open and then closed and record test data.
   c. Pressurize bonnet to the pressure indicated in Table 2 for this test.
   d. Heat bonnet to maximum achievable temperature.
   e. Monitor and record fluid temperature and bonnet pressure until stable. Record results in Appendix A6.

8. Thermal Binding Response to Temperature Changes

   a. With the valve open fill the specimen with water.
   b. With the valve unpressurized, stroke test specimen open, closed and open at the lower torque switch setting and record test data.
   c. With the upstream and downstream disk sides vented to atmosphere heat valve body and bonnet to temperature indicated in Table 2 for this test.
   d. Close valve and record test and temperature data. Temperatures will be recorded at various locations on the valve body to establish overall temperature.
   e. When valve has cooled to room temperature open valve and record diagnostic test and temperature data in Appendix A7.

F. RESULTS/ACCEPTANCE CRITERIA

The results of this test will be used as technical input for evaluations and calculations to resolve/assess the pressure locking issue. This test has no acceptance criteria.

G. DATA SHEETS

Appendix A provides Data Sheets for recording the results of the testing.

TABLE 1
MEASUREMENT EQUIPMENT AND TOLERANCES

Measurement Parameter	Device Name	QA/Serial #	Calibration Date/Due Date
Pressure Gage Upstream Disk Side	ASHCROFT MIT 111	MIT 111	12/3/95 / POST TEST
Pressure Gage Downstream Side	ASHCROFT MIT 111	MIT 111	12/3/95 / POST TEST
Pressure Gage Bonnet	MIT8003	MIT8003	12/3/95 / POST TEST
Temperature Gage Bonnet	OMEGA	–	12/3/95 / POST TEST
Stem Torque	Teledyne Quick Stem Sensor	NONE	DURING TEST
Stem Torque	Liberty , VTC	27896OBR	5/95 / 2/96
Stem Thrust	Teledyne Quick Stem Sensor	NONE	DURING TEST
Stem Thrust (Verification)	Liberty, C-Clamp	27898IBR	
Motor Power	Liberty, MPM	ICO4076	1/96
Motor Current	Liberty, MPM	ICO4076	1/96
Motor Voltage	Liberty, MPM	ICO4076	1/96

TABLE 2
TESTING SEQUENCE AND NUMBERING

Procedure Section (NOTES TEST #)	Test Title
F 18	STATIC, HIGHER TSS (2.0)
F.4 19/20/21	Differential pressure test to quantify disk friction factor at 200 psi (BONNET 72)
F.4 22	Differential pressure test to quantify disk friction factor at 500 psi
F.4 23	Differential pressure test to quantify disk friction factor at 800 psi
F.5	Bonnet Pressure Response at 500 psi and lower torque switch setting
F.5	Bonnet Pressure Response at 1000 psi and lower torque switch setting
F.5 26	Bonnet Pressure Response at 500 psi and higher torque switch setting
F.5	Bonnet Pressure Response at 1000 psi and higher torque switch setting
F.6 43/48	Pressure Lock Un-wedging at 200 psi and lower torque switch setting
F.6 50	Pressure Lock Un-wedging at 400 psi and lower torque switch setting
F.6 52	Pressure Lock Un-wedging at 700 psi and lower torque switch setting
F.6 54	Pressure Lock Un-wedging at 1000 psi and lower torque switch setting
F.7	Bonnet pressure start at 0 psig. Temperature start at ambient. Torque switch at higher setting
F.7	Bonnet pressure start at 50 psig. Temperature start at ambient. Torque switch at higher setting
F.7	Bonnet pressure start at 100 psig. Temperature start at ambient. Torque switch at higher setting
F.8	Valve body temperature maximum approximately 212 °F
F.8	Valve body temperature maximum approximately 350 °F

VFS CALIBRATION FEILD DATA SHEET

VALVE TAG NUMBER: BORGW1	VOTES SYSTEM SERIAL NO.: 278951BK
VOTES SYSTEM QA NO.: 278951BR	CAL DUE DATE: 8/96

CALIBRATOR LOCATION: THREADED UN-THREADED SLOTTED TRANSITION

DESCRIPTION: VOTES SYSTEM WITH QSS. QSS CALIBRATED WITH C-CLAMP #K005 QA # 278981BR. BFSL USED FOR CALIBRATION ONLY

NEW EFFECTIVE STEM DIA. 1.154	CB3-100 LENGTH: 31 ft	AMP PROBE SETTING: 2V 20A
ANTI-ROTATION DEVICE: yes (no)		

CALIBRATION TABLE

RUN #	Test Number	VOTES SENS NO.	CAL DEV. NO.	CLAMP PRE-TENSION READING	TSS	MAX THRUST	RSQ	CFA	BFSL SENS	BFSL % CH(	STEM TEMP (F)	GAIN
1	-	N/A	N/A		2.0	32940	1.0	N/A	4.10 E-2		-	2
2	-	N/A	N/A			32919	1.0	N/A	4.09 E-2	0.24	-	2

Attachment 5

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LOW FLOW METER ~~444447BR~~ CAL 2/95 DUE 2/96
HI FLOW METER 104952BR CAL 2/95 DUE 2/96
PRESSURE GAGE 033201BR CAL 8/95 DUE 8/96

LLRT RESULTS DATA SHEET

VOTES Test #	TSS	C14, lbf	CI6, lbf	Pullout, lbf	Leakage, scf~~m~~h	Comments, Note upstream or downstream test.
18	2.0	20902	23241	7863	11.5 SCFH	Upstream, 45.6 psid
24	1.0	7662	12638	3781	10.5 SCFH	Upstream, 45.6 psid
24	1.0	7662	12638	3781	<0.4 SCFH	Downstream, 45.6 psid
25	2.0	22438	24826	7612	<0.4 SCFH	Downstream, 45.6 psid
25	2.0	22438	24826	7612	3.5 SCFH	Upstream, 45.6

Test #	C16 Thrust, lbf	Pullout Thrust, lbf	Upstream Disk Side Pressure, psi	Downstream Disk Side Pressure, psi	O10 Thrust, lbf	Open Run Thrust, lbf	Open Valve Factor[1]	Comments
18	23241	7863	–	–	–	669	–	STATIC AT TSS 2.0
19	25430	8858	≈ 100 ~~200~~	0	1543	617		DP TEST AT TSS 2.0 @ 200PSI
20	25825	7663	≈ 100 ~~200~~	0	1841			REPEAT TEST 19
21	26172	11096	200	0	2587	540	0.143	
22	25477	13535	450	0	5424	535	0.151	
23	23436	16420	730	0	9902	555	0.174	
28	26459	13330	760	0	14475	605 ~~597~~	0.24	FOR CONDITIONING TEST AFTER NUMEROUS DP TESTS
29	28945	18799	530	0	14025	406	0.327	

RCB 12/1/95

[1] Valve Factor = $\dfrac{O10 - \text{Run Load} + \left[\text{Upstream Pressure} \times \frac{\pi}{4}\left(1.\cancel{25}\,5\right)^2\right]}{\text{Upstream Pressure} \times \frac{\pi}{4}\left(\cancel{3.445}\ 10.336\right)^2}$ RCB 12/1/95

Pullout Thrust, lbf	Upstream Disk Side Pressure, psi	Downstream Disk Side Pressure, psi	O10 Thrust, lbf	Open Run Thrust, lbf	Open Valve Factor[1]	Comments
4722	540	0	15767	435	.359	
5966	245	0	7311	482	.360	
4126	285	0	8257	500	.345	
1291	455	0	13529	426	.364	
1539	475	0	14573	448	.375	
13927	450	0	13828	528	.373	
0494	550	550	6863	499	.159	
9102	0	505	9599	439	.239	CONDITIONING STROKES PERFORMED PRIOR TO THIS TEST (DP)

DEB 12/4/95

$$O10 - \text{Run Load} + \left[\text{Upstream Pressure} \times \frac{\pi}{4}(1.\cancel{26}\;5)^2\right]$$

$$\text{Upstream Pressure} \times \frac{\pi}{4}(\cancel{3.445}\;10.386)^2$$

DEB 12/4/95

Test #	C16 Thrust, lbf	Pullout Thrust, lbf	Upstream Disk Side Pressure, psi	Downstream Disk Side Pressure, psi	O10 Thrust, lbf	Open Run Thrust, lbf	Open Valve Factor[1]	Comments
38	28966	9549	0	550	14821	479	.332	
39	29096	12683	0	520	15269	447	.361	
59	9845	16757	~~510~~	510	17553	350	.423	
66	31722	22474	0 ~~208~~	208 ~~0~~	6165	525	.344	
67	31722	22126	0	198	6066	653	.347	
68	31922	24513	0	370	11834	614	.382	
69	31873	24414	0	413	13922	623	.405	
70	32069	25306	0	575	18346	557	.390	

$$^{1}\text{Valve Factor} = \frac{\text{O10} - \text{Run Load} + \left[\text{Upstream Pressure} \times \frac{\pi}{4}\left(1.\overset{5}{\cancel{25}}\right)^2\right]}{\text{Upstream Pressure} \times \frac{\pi}{4}\left(\underset{10.386}{\cancel{3.445}}\right)^2}$$

12/4/95

12/4/95

Test #	C16 Thrust, lbf	Pullout Thrust, lbf	Upstream Disk Side Pressure, psi	Downstream Disk Side Pressure, psi	O10 Thrust, lbf	Open Run Thrust, lbf	Open Valve Factor[1]	Comments
71	31721	27545	0	610	20633	638	.413	
99	19164	21022	0	610	20177 ~~21710~~ 11/1/05			TEST NO GOOD
100	16101	19729	0	578	20325	748	.425	

$$^{1}\text{Valve Factor} = \frac{\text{O10} - \text{Run Load} + \left[\text{Upstream Pressure} \times \frac{\pi}{4}\left(\overset{5}{\cancel{1.25}}\right)^2\right]}{\text{Upstream Pressure} \times \frac{\pi}{4}\left(\underset{10.536}{\cancel{3.445}}\right)^2}$$

12/1/05

PRESSURE LOCKING SPECIAL TEST PROCEDURE
Revision 0
BONNET PRESSURE RESPONSE RESULTS DATA SHEET
VOTES Test #: 25 C16 Thrust: 24826

Time	Bonnet Pressure, Psig
0	504
1:00	503
2:00	502
3:00	501
4:00	500
5:00	500
6:00	499
7:00	498
0	938
1:00	928
2:00	918
3:00	910
4:00	900
5:00	892
6:00	883
7:00	875
8:00	867
9:00	858
10:00	850

Note: Packing region and all external seals remained dry during test

PRESSURE LOCKING SPECIAL TEST PROCEDURE
Revision 0
BONNET PRESSURE RESPONSE RESULTS DATA SHEET
VOTES Test #: ________ C16 Thrust: ________

Time	Bonnet Pressure, Psig
11:00	842
12:00	835
13:00	827
14:00	820
15:00	812

PRESSURE LOCKING SPECIAL TEST PROCEDURE 11/28/95
Revision 0 Page 12 of 16
BONNET PRESSURE RESPONSE RESULTS DATA SHEET Appendix A4
VOTES Test #: ____________ C16 Thrust: ____________

Time	Bonnet Pressure, Psig

PRESSURE LOCKING SPECIAL TEST PROCEDURE
Revision 0
BONNET PRESSURE RESPONSE RESULTS DATA SHEET
VOTES Test #: ____________ C16 Thrust: ____________

Time	Bonnet Pressure, Psig

Test Description	VOTES Test #	MPM Title	C16 Thrust, lbf	09 Thrust, lbf	Bonnet Pressure, psi	Pullout Motor Power, kW	Pullout Torque, lbf	Comments
STATIC TEST	42	—	31,783	16,513	~~200~~ 0	—	162.4	
PRESSURE LOCK TEST	43	12-6-95 11:26 AM	32,032	25,467	205	4.197	251.9	TSS = 2
STATIC TEST	44	11:41 AM	31,731	17,357	0	2.61	166.5 ~~294.2~~	
STATIC TEST	45	11:51 AM	16,162	7,261	0	1.48	70.8	LOWER TS TO 1
Static Test	46	12:10 P.M	16,659	7509	0	1.63	73.5	TSS = 1
Static Test	47	12:14 P.M	16,859	7907	0	1.569	77.0	TSS = 1
PRESSURE LOCK TEST	48	PRESS LOCK LOW TSS 200psi	16809	15268	209	2.56	148.5	TSS = 1
STATIC TEST	49	STATIC LOW TSS	16659	7857	0	1.61	76.3	TSS = 1
PRESSURE LOCK TEST	50	LOW TSS PL AT 400psi	16708	20786	402	3.08	202.6	TSS = 1
STATIC TEST	51	STATIC TEST 1:12 LOWER TSS	16807	7707	0	1.55	75.6	TSS = 1
PRESSURE LOCK TEST	52	PRESS LOCK LOW TSS [illegible] 700psi	16958	26705	630	4.35	262.9	TSS = 1
Static Test	53	Static test 1:20pm Lower TSS	16460	8105	0	1.53	79.1	TSS = 1
PRESSURE LOCK TEST	54	PRESS LOCK LOW TSS 700psi	16361	28395	694	4.77	279.6	

Test Description	VOTES Test #	MPM Title	C16 Thrust, lbf	09 Thrust, lbf	Bonnet Pressure, psi	Pullout Motor Power, kW	Pullout Torque, lbf	Comments
STATIC TEST	55	STATIC TEST LOWER PSS	16956	7658	0	1.58	74.9	
PRESS LOCK TEST	56	PRES LOCK LOWER PSS 1000 psi	16109	41872	919	9.77	427.3	
STATIC TEST w/1000 PSI	58	STATIC LOW PSS 1000	15665	5023	950	1.24	49.7	
STATIC TEST AFTER DP	72	STATIC HIGH PSS	31521	16705	0	2.57	168.0	
REPEAT STATIC TEST AFTER DP	73	STATIC HIGH PSS	31670	17202	0	2.55	164.4	
PRESS LOCK TEST	74	PRESS LOCK UNW HEATS 200 PSIG	31670	27613	208	4.79	271.2	
Press Lock Test	75	PRESS LOCK HIGH PSS 200 PSIG	31920	28241	213	4.86	277.5	
Static	76	11:53am	31822	17751	0	2.70	171.3	
Pres Lock Test	77	PRESS LOCK HIGH PSS 400 PSIG	32017	33906	391	6.36	343.3	
PRESS Lock TEST	78	PRESS LOCK HIGH PSS 400 PSIG	32168	34604	402	6.37	344.0	
STATIC TEST	79	STATIC HIGH PSS	31671	17949	0	2.78	169.9	
PRESS LOCK TEST	80	PRESS LOCK HIGH PSS 400 PSIG	31868	40121	467	7.41	410.6	PRESS WHOLE VALVE AND CLOSED
PRESS LOCK TEST	81	PRESS LOCK HIGH PSS 200 psi	31971	28540	219	4.82	278.8	"

Test Description	VOTES Test #	MPM Title	C16 Thrust, lbf	09 Thrust, lbf	Bonnet Pressure, psi	Pullout Motor Power, kW	Pullout Torque, lbf	Comments
STATIC TEST	82	STATIC HIGH TSS	32417	17700	0	2.69	170.6	
PRESSURE LOCK	83	PRESS LOCK HIGH TSS 100 PSIG	32318	25457	110	4.26	246.9	
PRESSURE LOCK	84	PRESS LOCK HIGH TSS 50 PSIG	31820	22571	54	3.45	222.0	
STATIC TEST	85	STATIC HIGH TSS	31722	17352	0	2.54	167.8	
STATIC TEST	86	STATIC HIGH TSS	32464	20980	1	3.09	205.3	PRESSURIZED DOWNSTREAM TO 500 AND DEPRESSURIZED
STATIC TEST	87	STATIC HIGH TSS	32413	18494	0	2.85	177.6 ~~157.1~~	" 200 PSID
Static test	88	Static High TSS	32267	18197	0	2.67	175.5	
STATIC TEST	92	STATIC HIGH TSS	31951	17541	0	2.78	167.8	POST ~~PRESS~~ THERMAL BINDING
STATIC TEST	93	STATIC LOW TSS	17392	8000	0	1.67	77.0	TSS = 1 PRE-MEMORY-STATIC
STATIC TEST (Memory Effect)	94	Memory Effect Orig Low TSS	17244	8547	0	1.84	83.2	TSS = 1 CHECK OF MEMORY
~~Static (Memory Effect)~~ Re Static Mem Effect Test	95	"	17413	11132	0	1.92	106.1	"
PRESSURE LOCK	96	PRESS LOCK LOW TSS 500 psig	17394	27035	557	4.44	269.0	
PRESSURE LOCK	97	"	17691	26189	504	3.95	259.3	

E – air in bonnet
E – bonnet water ...

Attachment 5

Test Description	VOTES Test #	MPM Title	C16 Thrust, lbf	09 Thrust, bf	Bonnet Pressure, psi	Pullout Motor Power, kW	Pullout Torque, lbf	Comments
STATIC TEST	98	STATIC [illegible]	17393	8547	0	1.71	82.5	
D								

PRESSURE LOCKING SPECIAL TEST PROCEDURE
Revision 0

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 60 C16 Thrust: 31,327

O9 Thrust: 16,609

HIGH HEAT RATE

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F Outside top	Internal fluid	
0	93	61.2	57.4	
10:00	90	62.2	59.7	
15:00	93	63.4	65.8	
17:30	97	65.4	71.1	
20:00	104	68.0	77.2	
22:30	113	70.4	83.7	
25:00	125	73.6	89.4	
27:30	139	77.4	94.9	
30:00	150	80.2	98.5	
32:30	166	84.0	103.3	
35:00	185	87.6	107.5	
37:30	207	90.4	111.1	
40:00	233	93.8	115.5	
42:30	265	97.4	118.9	
45:00	302	99.8	122.4	
47:30	347	103.2	125.7	

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 30 C16 Thrust: 31327

O9 Thrust: 16609

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F OUTSIDE TOP	INTERNAL FLUID	
50:00	409	105.4	128.4	
52:30	484	108.0	132.2	
55:00	578	110.0	135.4	
57:30	687	112.0	138.2	
60:00	808	115.4	141.4	
62:30	946	119.2	144.9	
65:00	1084	122.0	147.1	
67:30				
70:00				
72:30				
75:00				
77:30				
80:00				
82:30				
85:00				
87:30				

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PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 88 C16 Thrust: 32267

09 Thrust: 18197

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F OUTSIDE TOP	INTERNAL FLUID
~~90:00~~			
00:00	86	65.0	64.0
10:00	86	76.0*	64
20:00	88	73	67.7
25:00	92	75.4	72.7
30:00	96	78.2	77.1
32:30	100	80.0	79.5
35:00	102	80.8	81.4
37:30	105	82.4	83.5
40:00	109	83.8	85.5
42:30	113	85.8	87.6
45:00	116	88	90.2
47:30	118	88.8	90.9
50:00	122	90.2	92.6
52:30	126	92	94.2
55:00	130	93.2	95.9

* PICKED UP HEAT FROM HEATERS / DISCARD POINT

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 78 C16 Thrust: 32267

O9 Thrust: 18197

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F Outside Body Top	Internal Fluid
57:30	133	94.4	97.3
60:00	137	95.6	98.8
1:02:30	140	96.8	100.1
1:05:00	145	97.6	101.2
1:07:30	148	97.8	102.4
1:10:00	151	98.2	103.5
1:12:30	154	98.8	104.7
1:15:00	156	99.4	105.8
1:17:30	160	100.2	107.1
1:20:00	165	101.0	108.4
1:22:30	170	102.0	110.0
1:25:00	175	103.0	110.9
1:27:50	181	104.2	112.6
1:30:00	187	105.2	113.7
1:32:50	194	106.4	115.0
1:35:00	201	107.4	116.0
1:37:30	209	108.6	117.1
1:40:00	219	110.0	118.4
1:42:30	225	111.0	119.7

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 88 C16 Thrust: 32267

O9 Thrust: 18197

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F OUTSIDE	INSIDE
1:45:00	233	112.0	120.9
1:48:30 ← Really 1:48:30	245	113.4	122.3
1:50:00	249	114.0	122.6
1:52:30	256	115.0	123.6
1:55:00	262	116.0	124.5
1:57:30	274	117.0	125.8
2:00:00	291	118.2	127.7
2:02:30	324	119.7	130.3
2:05:00	357	121.2	132.2
2:07:30	405	123	135
2:10:00	470	125	137.7
2:14 (2:12:30 missed)	595	128.6	142.1
2:15	633	129.6	143.3
2:17:30	708	131.4	145.3
2:20	798	133.8	147.8
2:22:30	885	136.0	149.9

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 58   C16 Thrust: 32267

O9 Thrust: 18197

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F BODY TEMP	FLUID TEMP
2:44:00	71	177.0	173.4
2:46:30	75	171.8	176.4
2:49:00	MISSED	—	—
2:51:30	MISSED	—	—
2:54:00	96	179.2	184.9
2:56:30	105	182.8	187.6
2:59:00	115	184.6	190.3
3:01:30	127	184.6	192.9
3:03:00	138	186.4	194.8
3:05:30	151	187.6	196.8
3:08:00	170	189.8	199.2
3:10:30	194	193.0	201.0
3:13:00	224	196.6	203.0
3:15:30	262	196.4	206.0
3:18:00	309	197.6	208.0
3:20:30	362	202.2	211.0

DECREASED PRESSURE THE BONNET GAU

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 88 C16 Thrust: 32267

09 Thrust: 18197

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F BONNET TEMP	FLUID TEMP
3:23:00	431	202.6	213
3:25:30	514	201.8	215
3:28:00	615	203.8	217
3:30:30	729	206.2	220
3:34:00	225	212.4	222
3:36:30	MISSED	—	—
3:39:00	320	216.8	228
3:41:30	391	216.4	230
3:43:00	MISSED	—	—
3:45:30	540	218.8	233
3:48:00	659	221.4	236
3:50:30	169	221.4	238
3:53:00	193	228.2	240
3:55:30	228	230.4	242
3:58:00	276	233	245

DECREASED BONNET PRESS THROUGH GATE

DECREASED BONNET PRES.

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 85 C16 Thrust: 32267

O9 Thrust: 18197

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F BONNET TEMP	FLUID TEMP
4:00:30	332	235	247
4:03:00	409	237.2	249
4:05:30	523	239.2	252
4:08:00	626	241.4	253
4:10:30	181	247	257
4:13:00	194	248.6	258
4:15:30	232	251	260
4:18:00	282	252.4	262
4:20:30	348	253.2	264
4:23:00	430	254.4	266
4:25:30	526	256.4	268
4:28:00	184	262.6	270
4:30:30	212	266.2	272
4:33:00	246	270 6	274
4:35:30	285	273.4	276
4:38:00	339	275	277

DEPRESS

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PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 88 C16 Thrust: 32267

O9 Thrust: 18197

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F	
		BONNET TEMP	FLUID TEMP
4:40:30	384	277	278
4:43:00	442	269.4	280
4:45:30	490	268.8	281
4:48:00	172	271	281
4:50:30	184	272	283
4:53:00	200	272	284
4:55:30	218	272.6	285
4:58:00	237	273.2	286
5:00:30	258	273.6	286
5:03:00	279	274.4	287
5:05:30	305	275.6	288
5:08:00	347	276.6	290
5:10:30	412	277.4	291
5:13:00	504	278.8	293
5:15:30	595	279.6	294

DEPRESS

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: Low TSS C16 Thrust: N/A

09 Thrust: N/A INITIAL WTR TEMP 103 °F

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F FLUID TEMP	UPSTREAM TEMP	Vlv Body disk	Vlv Body Dust upside
00:00	37	65.3	103°F		
14:00	40	67.2	102		
20:00	40	67.8	101.2		
25:00	41	68.3	111.8		
30:00	42	69.2	124.2	68.0	68.6
35:00	44	70.6	140	71.2	7[illegible].4
40:00	46	71.5	149	72	71.6
45:00	49	72.8	159.2	~~86.4~~ 74.4	71.6
50:00	53	74.8	170	74.6	72.6
55:00	58	76.9	179.8	76.0	74.8
60:00	69	79.8	189.4	77.8	76.4
1:05:00	82 Late	82.7	195.8	80.4	78.c
1:10:00	90	83.9	198.4	81.6	78.6
1:15:00	107	86.4	201.8	82.4	80.2
1:20:00	131	88.7	205.6	84.6	81.4
1:25:00	172 late	91.9	209.0	87.8	82.2

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: Low TSS C16 Thrust: N/A

O9 Thrust: N/A

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F FLUID TEMP	UPSTR TEMP	V/v Body disk	V/v Rest
1:30:00	198	93.5	210.8	~~210.8~~ 88.0	84
1:35:00	242	95.8	213.2	89.4	86.4
1:40:00	301	98.4	215.6	92.0	88
1:45:00	345	100.3	217.4	93.4	89.
1:50:00	394	102.2	219.4	96.0	89.
1:55:00	443	104.3	221.2	96.6	~~95.~~ 92.
2:00:00	488	106.2	223.0	97.8	95.
2:05:00	531	108.0	224.0	98.6	96.8
2:10:00	562	110.0	226.2	100.6	98.
2:15:00	588	112.0	228.0	101.2	99.
2:20:00	609	113.8	229.8	102.2	~~100.~~ 100
2:25:00	626	115.5	229.2	~~102.8~~ 102.0	96
2:30:00	643	117.2	229.6	100.0	97.
2:35:00	673	119.6	231.8	100.0	98
2:40:00	684	120.5	232.4	102.2	98
2:45:00	720	122.3	233.8	102.2	99.
2:50:00	772	123.9	235.4	104.4	99.
2:55:00	826	125.4	237.0	104.6	
3:00:00					

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THERMAL BINDING TEST RESULTS DATA SHEET

	HIGH TEMP	COOL
Bonnet Temperature	152 °F	77 °F
Valve Body Temperature	160 °F	72 °F

~~Pre~~ heating test data

Votes Test # 63
O9 16008
C16 32264

Post Cooling test data

Votes Test # ~~90~~ 64
O9 18995
C16 ~~2594~~ 31973

Bonnet Temperature	203 °F	75 °F
Valve Body Temperature	237 °F	72 °F

~~Pre~~ heating test data

Votes Test # ~~89,~~ 90 ~~91~~ (initialed, 12/14/95)
O9 24052
C16 25942

DATA SUSPECT DUE TO
HEATING OF SENSOR
SEE TEST #92

Post Cooling test data

Votes Test # 91
O9 24244
C16 31348

Bonnet Temperature ________
Valve Body Temperature ________

Pre heating test data

Votes Test # ________
O9 ________
C16 ________

Post Cooling test data

Votes Test # ________
O9 ________
C16 ________

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VALVE DATA SHEET

Valve	
Type	GATE (FLEX WEDGE)
Vendor	BORG WARNER
Size	10 INCH
Model No.	77780
Mean Seat Diameter	10.199 INNER SEAT DIA 10.473 OUTER
Stem Diameter	1.5 INCH
Actuator	
Type	SMB
Vendor	LIMITORQUE
Size	0
Model No.	O/W 3A6606A
Serial No	261003
OAR	31.11
Spring Pack No.	017
Motor	
Type	RH INSULATION CLASS B, FRAME P56
Vendor	RELIANCE
Motor Rating	25 FT LB START 5 RUN
Model No.	—
RPM	1700
Voltage	460
Motor Power (AC/DC)	AC

Borg Warner Valve
Pressure Locking Thermal Binding Test Notes

12/04/95 Test Setup

The Borg Warner valve was received from the stand fabricator and is shown in figure 1. The stand was designed such that the valve could be rotated about the center of gravity to remove air from the valve bonnet. The instrument maintenance department calibrated and installed the test equipment as shown in figure 2. Two holes were drilled and tapped into the bonnet to accept a thermowell/temperature meter and a pressure transducer/indicator. This pressure transducer was input into the VOTES system spare channel to obtain bonnet pressure traces.

A high pressure air/water accumulator was used to pump high pressure water into either the upstream or downstream side of the valve. The accumulator would supply a constant water pressure during unseating of the valve.

Data Acquisition

The VOTES and MPM systems were used as data acquisition devices for the test. The VOTES system was used to monitor stem thrust, switch actuation, spare channel bonnet pressure and motor current. The MPM system was used to monitor motor voltage parameters. The Borg Warner valve stem (threads) were machined to the minor diameter for approximately 3 inches in stem length. In this area a Teledyne QSS was mounted and connected to the VOTES system. This QSS was then calibrated using a Liberty C-Clamp on the machined section of stem. Because the QSS is a linear device a best fit straight line was used to fit the calibration data.

A calibration was performed at a high valve torque switch setting of 2.0. Two calibrations were performed which were within 0.24 percent of each other.

Conditioning strokes

After performance of the calibration the valve was stroked approximately 15 times in accordance with the procedure. These strokes were performed without data acquisition.

12/05/95 Local leak rate testing

A Local Leak Rate Test (LLRT) was performed in accordance with procedural step E.3 after initial differential pressure testing. This LLRT testing was performed in accordance with plant procedures with a test pressure of 45.6 psig. Initial results on the upstream side of the valve indicated leakage rates of 11.5 scfh at a TSS of 2.0 and 10.5 scfh at a TSS of 1.0. On the downstream side of the valve the indicated leakage rates were zero or the test equipment accuracy of 0.4 scfh. Based on these results the upstream side of the valve was retested at a TSS of 2.0 and leakage rates were 3.5 scfh. It is believed that leakage path existed outside the valve during the original upstream leakrate tests.

Bonnet Pressure Response

In accordance with test section E.5 a bonnet depressurization test was performed. The valve was set at a TSS of 2.0 to run this test. The bonnet was pressurized through the upstream seat to a pressure of approximately 500 psig and the upstream and downstream sides of the valve were depressurized. The bonnet depressurization rate at approximately 500 psig was approximately 1 psi per minute and at approximately 940 psi the depressurization rate was approximately 10 psi per minute decreasing to 7 psi per minute at approximately 820 psig. It should be noted that the packing area remained dry during this test. It should also be noted that the packing leak off line was capped during all of the testing.

12/05/95
12/06/95 Differential pressure testing

Differential pressure tests were started on the upstream side of the valve at a TSS of 2.0. Tests 19 through 23 were performed at differential pressures of 100, 200, 450, and 730 with valve factors ranging from 0.143 to 0.174. It was decided to run some conditioning differential pressure tests and approximately eight unmonitored tests were performed at a differential pressure of approximately 600 psig. Differential pressure test 28 and 29 were performed with valve factors of 0.24 and 0.32. Differential pressure tests 30 through 35 were performed at various pressures between 200 and 500 psid and valve factors ranged between 0.34 and 0.37. Based on this it was believed that the valve factor had stabilized. Differential pressure test 36 was performed by pressurizing on the downstream side of the valve and at a dp of 550 a valve factor of 0.16 was achieved. Based on this low valve factor numerous unmonitored conditioning dp tests were performed. This raised the valve factor to 0.361 on test 39. It was believed that the valve factor had stabilized on both seats of the valve.

Pressure locking testing

Pressure locking data acquisition started with static test 42 and pressure lock test 43 at a TSS of 2.0. After this test the TSS was lowered to 1.0 and static tests 45 through 47 were run. Tests 48 through 56 were performed alternating between static and pressure lock with bonnet pressures ranging between 200 and 900 psig.

Pressure response to temperature

During this test the valve was set up with high temperature heating coils placed around the center of the valve body around where the disk seats are such that the center of the valve could be heated. During this test the temperature was monitored and recorded both on the outside of the bonnet and the inside water temperature. The bonnet internal pressure was also recorded. The valve was tipped to remove all the air from the bonnet as water was run into the valve. VOTES test 60 was run at a TSS of 2.0 prior to this test. The bonnet pressure started at 93 psig prior to the heating coils being energized. During this test each of the heating coils were fully energized and remained energized throughout the heatup process (labeled high heat input test). After cooling of the valve a similar test was run with the same setup and VOTES test 88. The only difference with this test is that the heatup was slower. The heating coils were cycled on and off while constantly increasing the heat setpoint. The results of these two tests matched very closely relative to pressure increase versus temperature. During this second test, the pressure was bleed off as it approached approximately 900 psig. After bleed off the heatup continued. As can be seen by later testing it is believed that not all the air was removed from the bonnet during both of these tests.

Test Summary and Conclusions

Differential Pressure Testing

The first set of DP tests were run at 100 to 700 psid on the upstream side of the valve and indicated a valve factor in the range of 0.13 to 0.17. In an effort to increase the valve factor an unmonitored set of ten dp tests were performed at approximately 600 psid. The valve factor slowly increased to approximately 0.37. Differential pressure tests were then run on the downstream side of the valve and initial testing indicated a valve factor of 0.16. In an effort to increase the valve factor an unmonitored set of ten dp tests were performed at approximately 600 psid. The valve factor slowly increased to approximately 0.40. This testing indicates that static testing does not increase the initially very low valve factor but rather high load differential pressure testing was needed to increase the valve factor. The valve factor appeared to become stable in the range of 0.37 to 0.41.

Pressure Locking Test

Initial pressure locking tests at a TSS of 1 and bonnet pressures between 200 and 700 psid indicated that the model for prediction of pullout thrust was under predicting by approximately 3100 lbs. Pressure locking tests at a TSS of 2 indicated that the model for prediction of pullout thrust was under predicting by approximately 3500 lbs. In an effort to resolve this discrepancy a test was performed in which the downstream side of the valve was pressurized to approximately 500 psid and then vented and a pressure lock test was performed with 0 pressure in the bonnet. This test indicated that there was an increase in the pullout thrust of 3628 lbs at a TSS of 2 and 3132 lbs at a TSS of 1. Therefore, it appeared that when the bonnet was pressurized through the upstream or downstream side of the valve a set in the disk was created which added to the pullout thrust. This set was measured in two subsequent tests to be 3628 lbs at a TSS of 2 and 3132 lbs at a TSS of 1. During the last two pressure lock tests at a TSS of 1 and bonnet pressures of 557 and 504 the pullout thrust was under predicted by 2667 and 3377 lbs which are both very close to the set at a TSS of 1. The comparison of testing results (pressure locking forces) to model predictions is summarized in DOC ID#DG96-000078.

Bonnet Pressure Response Test

The valve was closed with a static seating thrust of approximately 30000 lbs. The bonnet was pressurized through the upstream seat to approximately 500 psig and the upstream and downstream sides of the valve were vented. The bonnet depressurization rate at this pressure was approximately 1 psig per minute. The valve was then opened and pressurized to approximately 1000 psig and the valve was closed with a similar seating thrust. Bonnet pressure after seating was 940 psig where this test was started. The depressurization rate started at 10 psig per minute decreasing to 7-8 psig per minute at 820 psig.

Bonnet Pressure Response to Temperature

During the first two temperature tests, pressure vs temperature results were identical with the only difference between the two tests being the rate of heat input. The setup for this test consisted of utilizing three large heating coils which were wrapped around the lower center section of the valve body. These coils could be set to achieve a saturated metal temperature or could be constantly energized. The valve was then wrapped in thermal blankets and these were tie wrapped to the valve body. The first test was run with all the heating coils energized (high heat input) and the pressurization rate is shown in the attached charts. This test was run for approximately 65 minutes with a pressure increase from 90 to 1000 psig and a pressurization rate of 0.5 to 40 psig/degree F. The second test was run with the heating coils cycling on and off (low heat rate input) and the pressurization rate is shown in the attached charts. This test was run for approximately 140 minutes with a pressure increase from 90 to 800 psig with a similar pressurization rate.

The last pressure response to temperature test was performed by heating up only one side of the valve. The only other difference during this test is the valve was shook while trying to remove air from the bonnet. Based on the pressurization rate shown in the attached charts, it is believed that all the air was not removed from the previous two tests. This test was run for approximately 175 minutes with a pressure increase from approximately 40 to 800 psig and pressurization rate of 1 to 23 psig/degree F.

Thermal Binding Test

The setup for this test consisted of utilizing three large heating coils which were wrapped around the lower center section of the valve body. These coils could be set to achieve a saturated metal temperature or could be constantly energized. The valve was then wrapped in thermal blankets and these were tie wrapped to the valve body. Temperatures were measured on the valve body in the bonnet area using a temperature probe and the internal water temperature was measured using the bonnet temperature thermowell. After heating of the valve body to an average temperature of 156 F a static VOTES test was performed which indicated a final seating thrust of 32264 lbs and a pullout thrust of 16008 lbs. After overnight cooling of the valve to an average valve body temperature of 74.5 F another VOTES test was performed. This test indicated a static pullout thrust of 18995 lbs with static seating thrust remaining constant within 0.9 percent. Therefore, there was approximately a 19 percent in pullout thrust with a delta temperature of approximately 80 F.

The second test was performed similar to the first, however, the valve body was heated to an average temperature of 295 F. A VOTES test was performed at this point but the results were discarded due to heat up of the thrust sensor. The valve was cooled to an average body temperature of 73.5 F. A VOTES test was performed and the pullout thrust was 24244 lbs. A subsequent static VOTES test was performed as a baseline and the pullout thrust was 17541 with a static seating thrust of 31951 lbs. Between these two tests static seating remained within 1.9 percent. Therefore, there was approximately a 38 percent increase in pullout thrust with a delta temperature of approximately 220 F.

Flex of Valve Disk

This test was performed (although not part of the procedure) to determine at what pressure the disk would deflect and allow pressure to enter the bonnet. The valve was closed with a TSS of 2.0. With the bonnet pressure at zero psig, the upstream side of the disk was pumped up slowly until an increase in bonnet pressure was observed. An increase in bonnet pressure was observed slightly above 550 psid and pressure did not increase rapidly until above approximately 600 psig.

During the test the downstream side of the valve was pumped up to pressurize the bonnet. It was found that the bonnet could not be pressuized to greater than approximately 620 psig. If the bonnet was pressurized to 1000 psig through the downstream side disk, when the downstream side was depressurized the bonnet followed until approximately 620 at which point the downstream side disk sealed and held pressure. This information indicates that there is a maximum pressure which could be trapped in the bonnet under a sudden depressurization event. A calculation was performed utilizing a flat plate model to determine the point at which the disk would flex or rather at what point the seating force would become zero. This calculation indicated a force of 574 psig indicating a good correlation between the calculational model and the test. This calculation is attached.

Thermal binding test

The first thermal binding test was performed at the end of this day such that the valve could cool overnight. The valve was wrapped in thermal blankets such that the temperature of the whole valve was fairly constant. Static test 63 was performed after the valve was heated to an internal bonnet temperature of 152 F and an external valve body temperature of 160 F. After cooling the valve to an internal bonnet temperature of 77 F and valve body temperature of 72 F another static test 64 was run. During this test the static pullout thrust increased from 16008 lbs to 18995 lbs with static seating remaining constant within 0.9 percent. Results of this test indicate that static pullout increased approximately 19 percent with a delta temperature of approximately 80 F.

12/07/95 Additional differential pressure tests were performed during VOTES tests 66 through 71 where the valve was pressurized from the downstream side. The differential pressures ranged from approximately 200 to 600 psid and valve factors range from 0.34 to 0.41.

Additional pressure locking and associated static tests were performed during VOTES tests 72 through 85 where the bonnet pressure ranged between 50 and 500 psid at a TSS of 2.0.

The pressure locking test results to this point have been indicating that the measured pressure locking force is approximately 2000 lbs above the predicted value at a TSS of 1.0 and approximately 4000 lbs above the predicted value at a TSS of 2.0. Because of this VOTES tests 86 through 94 were run to check what was believed to be a memory effect. So a static test was performed with the valve completely depressurized. Next with a bonnet pressure of zero the downstream side of the valve was pressurized to 500 psid and then depressurized. Another static test was performed and this test indicated an increase in static pullout forces approximately equal to the increase in actual pullout forces versus the predicted values.

Disk deflection test

This test was performed to determine at what pressure the disk would deflect and allow pressure to enter the bonnet. The valve was closed with a TSS of 2.0. With the bonnet pressure at zero psig the upstream side of the disk was pumped up slowly until an increase in bonnet pressure was observed. An increase in bonnet pressure was observed slightly above 550 psid and pressure did not increase rapidly until above approximately 600 psig.

During the test the downstream side of the valve was pressurized to pressurize the bonnet. It was found that the bonnet could not be pressurized to greater than approximately 620 psig. If the bonnet was pressurized to 1000 psig when the downstream side was depressurized the bonnet followed until approximately 620 at which point the downstream side disk sealed and held pressure. This test was performed again, however, the downstream side of the valve was depressurized very rapidly. The results were the same regardless of depressurization rate.

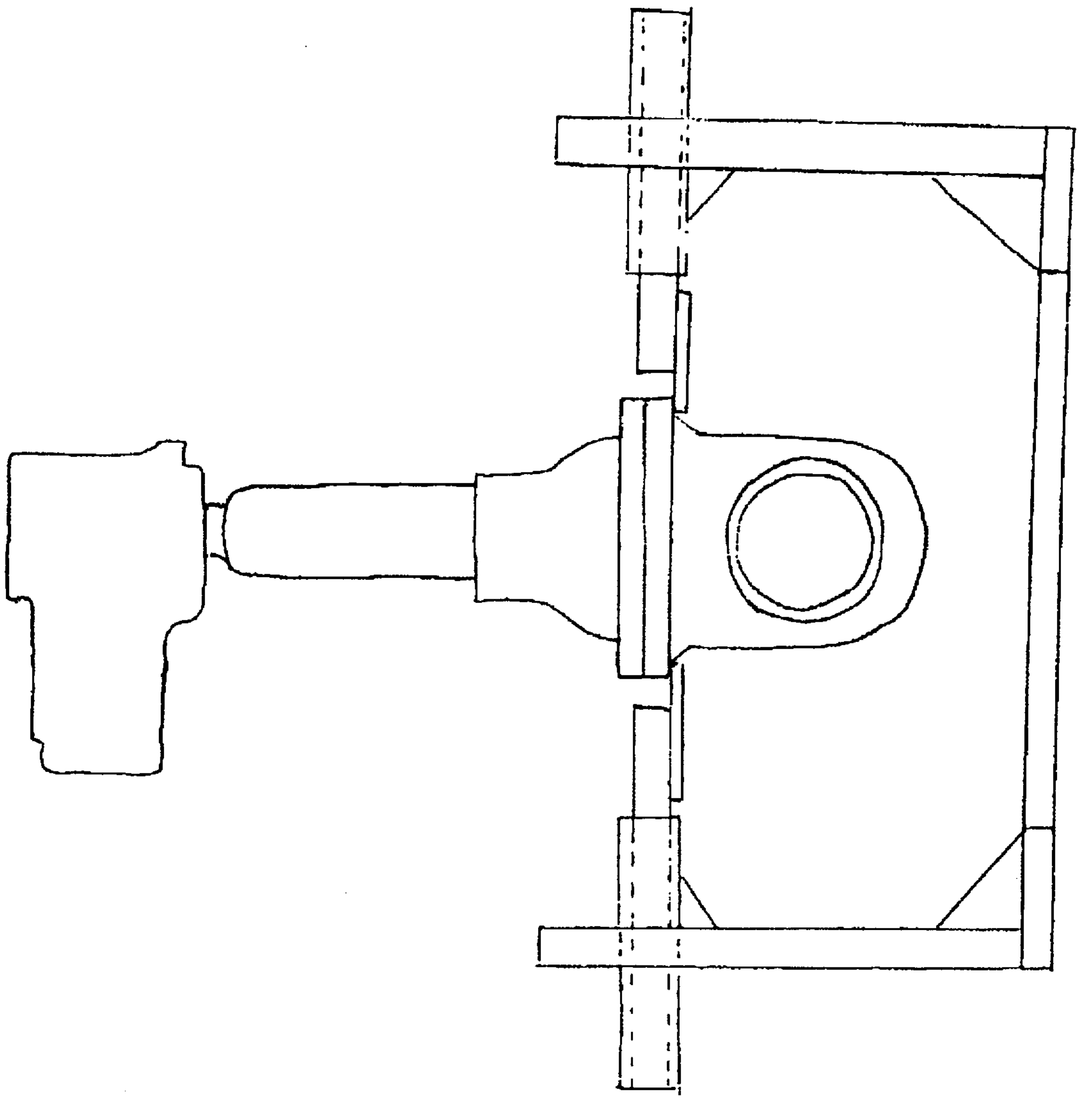
Thermal binding test

The second thermal binding test was performed similar to the first with the exception of a higher temperature. Static test 89 and 90 were performed after the valve was heated to an internal bonnet temperature of 303 F and an external valve body temperature of 287 F. After cooling the valve to an internal bonnet temperature of 75 F and valve body temperature of 72 F another static test 91 was run. Review of tests 89 and 90 indicated that the thrust values were affected by the high temperature of the valve which heated the stem and affected the sensor thrust output. Therefore, after test 91 was performed static test 92 was performed to compare data. Between tests 91 and 92 the static pullout thrust increased from 17541 lbs to 24244 lbs with static seating remaining constant within 1.9 percent. Results of this test indicate that static pullout increased approximately 38 percent with a delta temperature of approximately 220 F.

12/08/95 Pressure response to temperature test

A final test was performed in which the heating coils were moved to the downstream side of the valve (independent of which side) and placed around the pipe flanges. Only the downstream flanges were insulated to prevent heat loss. During this test the valve was closed at a TSS of 1.0 and a water solid condition in the bonnet at a starting pressure of 37 psig. The difference between this test and the previous two pressure response to temperature tests is that the valve was shook while tipped on its side and during this process of shaking, air could be seen exiting the discharge hose. This shaking was continued until no air could be seen exiting the discharge hose. Water at a temperature of approximately 100 F was injected into the downstream side of the valve and the heating coils were turned on. Temperature and pressure were monitored and recorded in the bonnet and temperatures were recorded on the downstream flange, center bottom and upstream side of the valve body. During this test two heating coils were operating and after approximately 20 minutes into the test one of the remaining two coils stopped functioning.

FIGURE 1



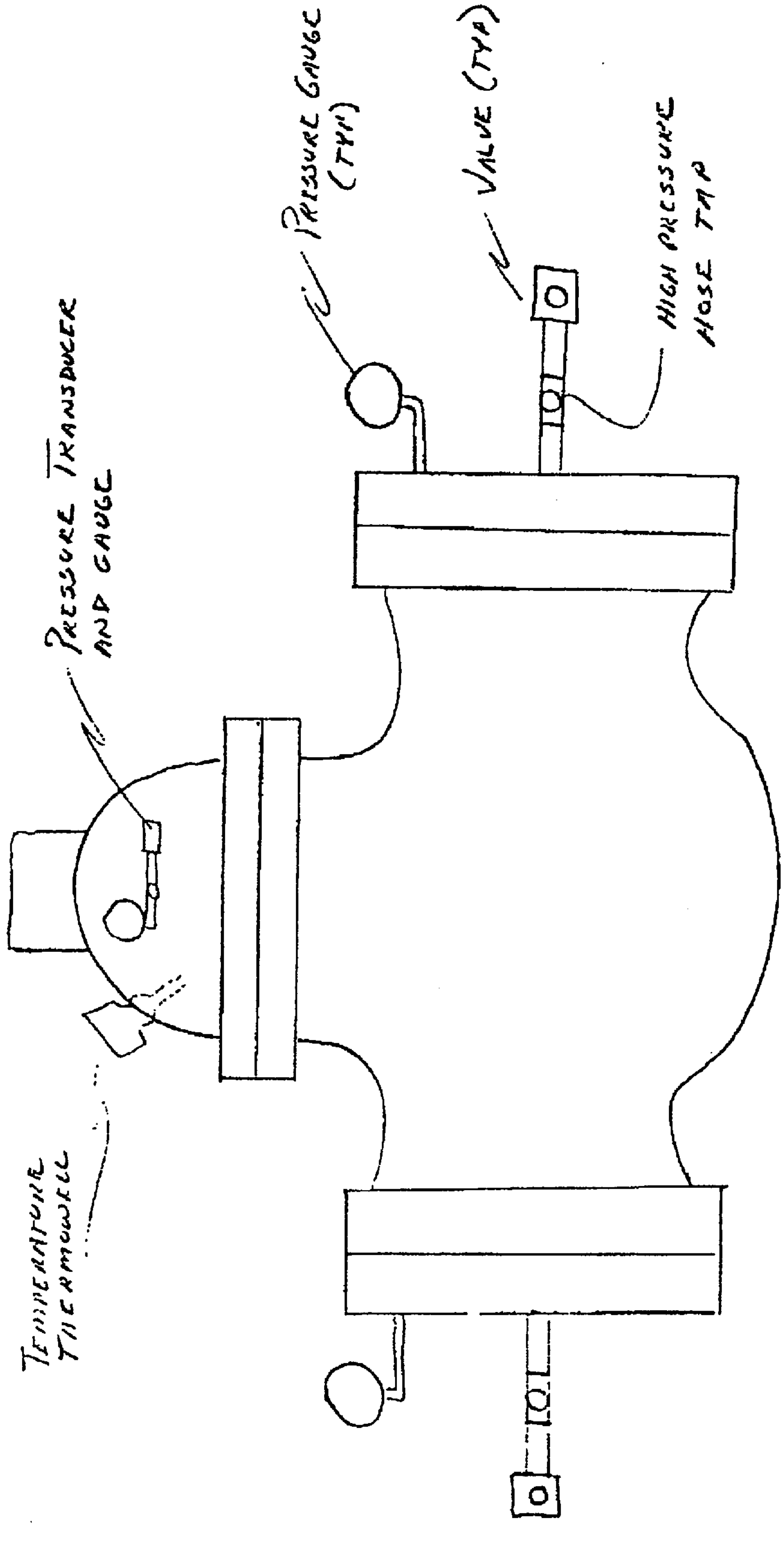

PRESSURE GAUGE (TYP)
VALVE (TYP)
HIGH PRESSURE HOSE TAP
PRESSURE TRANSDUCER AND GAUGE
TEMPERATURE THERMOWELL

FIGURE 1

Borg Warner valve, Point at which disk flexes

This Mathcad Program is designed to calculate the estimated flexing point for a valve disk. This calculational methodology accounts for wedge stiffness. This calculation methodology was prepared similar to Braidwood Calculation 95-158. References numbers are changed.

INPUTS:

Load Value	$q := 1000000 \cdot psi$	
Load Value	$w := 1000000 \cdot \frac{lbf}{in}$	
Disk Thickness	$t := 1.5 \cdot in$	Valve Data Sheet
Seat Radius	$a := 5.168 \cdot in$	Valve Data Sheet
Hub Radius	$b := 3.158 \cdot in$	Valve Data Sheet
Hub Length	$L := 0.156 \cdot in$	Valve Data Sheet
Seat Angle	$theta := 5\ deg$	Valve Data Sheet
Poisson's Ratio (disk)	$v := .3$	Typical of Stainless Steel
Mod. of Elast. (disk)	$E := 27.6 \cdot 10^6 \cdot psi$	Attachment
Force of Packing	$Fp := 600 \cdot lbf$	
Static Seating Force	$Fs := 32000 \cdot lbf$	Avg of Seating High TSS
Open Valve Factor	$VF := .37$	Valve Testing Avg.
Stem Diameter	$D_{stem} := 1.5 \cdot in$	Valve Data Sheet

PRESSURE FORCE CALCULATIONS

Coefficient of friction between disk and seat: (Reference 2)

$$mu := VF \cdot \frac{\cos(theta)}{1 - VF \cdot \sin(theta)} \qquad mu = 0.381$$

Disk Stiffness Constants (Reference 1 Table 24, Reference 3)

$$D := \frac{E \cdot (t)^3}{12 \cdot (1 - v^2)} \qquad D = 8.53 \cdot 10^6 \cdot lbf \cdot in$$

$$G := \frac{E}{2 \cdot (1 - v)} \qquad G = 1.062 \cdot 10^7 \cdot psi$$

Geometry Factors: (Reference 1, Table 24)

$C_2 := \frac{1}{4}\cdot\left[1 - \left(\frac{b}{a}\right)^2\cdot\left(1 + 2\cdot\ln\left(\frac{a}{b}\right)\right)\right]$ $C_2 = 0.06469$

$C_3 := \frac{b}{4\cdot a}\cdot\left[\left[\left(\frac{b}{a}\right)^2 + 1\right]\cdot\ln\left(\frac{a}{b}\right) + \left(\frac{b}{a}\right)^2 - 1\right]$ $C_3 = 0.00762$

$C_8 := \frac{1}{2}\cdot\left[1 + \nu + (1 - \nu)\cdot\left(\frac{b}{a}\right)^2\right]$ $C_8 = 0.78069$

$C_9 := \frac{b}{a}\cdot\left[\frac{1+\nu}{2}\cdot\ln\left(\frac{a}{b}\right) + \frac{1-\nu}{4}\cdot\left[1 - \left(\frac{b}{a}\right)^2\right]\right]$ $C_9 = 0.26264$

$L_3 := \frac{a}{4\cdot a}\cdot\left[\left[\left(\frac{a}{a}\right)^2 + 1\right]\cdot\ln\left(\frac{a}{a}\right) + \left(\frac{a}{a}\right)^2 - 1\right]$ $L_3 = 0$

$L_9 := \frac{a}{a}\cdot\left[\frac{1+\nu}{2}\cdot\ln\left(\frac{a}{a}\right) + \frac{1-\nu}{4}\cdot\left[1 - \left(\frac{a}{a}\right)^2\right]\right]$ $L_9 = 0$

$L_{11} := \frac{1}{64}\cdot\left[1 + 4\cdot\left(\frac{b}{a}\right)^2 - 5\cdot\left(\frac{b}{a}\right)^4 - 4\cdot\left(\frac{b}{a}\right)^2\cdot\left[2 + \left(\frac{b}{a}\right)^2\right]\cdot\ln\left(\frac{a}{b}\right)\right]$ $L_{11} = 0.00079$

$L_{17} := \frac{1}{4}\cdot\left[1 - \frac{1-\nu}{4}\cdot\left[1 - \left(\frac{b}{a}\right)^4\right] - \left(\frac{b}{a}\right)^2\cdot\left[1 + (1 + \nu)\cdot\ln\left(\frac{a}{b}\right)\right]\right]$ $L_{17} = 0.05923$

Moment (Reference 1, Table 24, Case 2L)

$M_{rb} := \frac{q\cdot a^2}{C_8}\cdot\left[\frac{C_9}{2\cdot a\cdot b}\cdot\left(a^2 - b^2\right) - L_{17}\right]$ $M_{rb} = -2.581\cdot 10^6 \cdot \mathrm{lbf}$

$Q_b := \frac{q}{2\cdot b}\cdot\left(a^2 - b^2\right)$ $Q_b = 2.65\cdot 10^6 \cdot \frac{\mathrm{lbf}}{\mathrm{in}}$

Deflection due to pressure and bending: (Reference 1, Table 24, Case 2L)

$y_{bq} := M_{rb}\cdot\frac{a^2}{D}\cdot C_2 + Q_b\cdot\frac{a^3}{D}\cdot C_3 - \left(q\cdot\frac{a^4}{D}\right)\cdot L_{11}$ $y_{bq} = 0.2619 \cdot \mathrm{in}$

Deflection due to pressure and shear stress: (Reference 1, Table 25, Case 2L)

$$K_{sa} := 0.3\cdot\left[2\cdot\ln\left(\frac{a}{b}\right) - 1 + \left(\frac{b}{a}\right)^2\right] \qquad K_{sa} = -0.10755$$

$$y_{sq} := \frac{K_{sa}\cdot q\cdot a^2}{t\cdot G} \qquad y_{sq} = -0.1804\cdot in$$

Total Deflection due to pressure forces:

$$y_q := y_{bq} + y_{sq} \qquad y_q = -0.4423\cdot in$$

Deflection due to seat contact force and shear stress (per lbf/in.): (Reference 1, Table 25, Case 1L)

$$y_{sw} := -\left[\frac{1.2\cdot\left(\frac{a}{a}\right)\cdot\ln\left(\frac{a}{b}\right)\cdot w\cdot a}{t\cdot G}\right] \qquad y_{sw} = -0.1918\cdot in$$

Deflection due to seat contact force and bending (per lbf/in.): (Reference 1, Table 24, Case 1L)

$$y_{bw} := -\left[\frac{(w\cdot a^3)}{D}\right]\cdot\left[\left(\frac{C_2}{C_8}\right)\cdot\left[\left(\frac{a\cdot C_9}{b}\right) - L_9\right] - \left[\frac{a}{b}\cdot C_3\right] + L_3\right] \qquad y_{bw} = -0.375\cdot in$$

Total deflection due to seat contact force :

$$y_w := y_{bw} + y_{sw} \qquad y_w = -0.566\cdot in$$

POINT OF DISK FLEX BW VALUE

$y_\omega = -0.566$

$y_q = -0.4423$

$F_s = 32000$ } AVG OF TESTING

$F_p = 600$

$a = 5.168$

$F_N = (F_s - F_p)/2(\sin\theta + \mu\cos\theta)$

$= (32000 - 600)/2(\sin 5° + .381\cos 5°)$

$= 31400 / 2(.4667)$

$= 31400 / .9334$

$= 33640$

$$P = \frac{F_N \times y_\omega}{\pi \times a} \times \frac{1}{y_q + (a/2) \times y_\omega}$$

$$= \frac{31400 \cdot (-0.566)}{3.14159 \cdot 5.168} \times \frac{1}{(-0.4423 + (2.584 \cdot -0.566)}$$

$$= \frac{17772}{16.23} \times .524$$

$= 1094.6 \times .524$

$= 574.6$ LBS

REFERENCES:

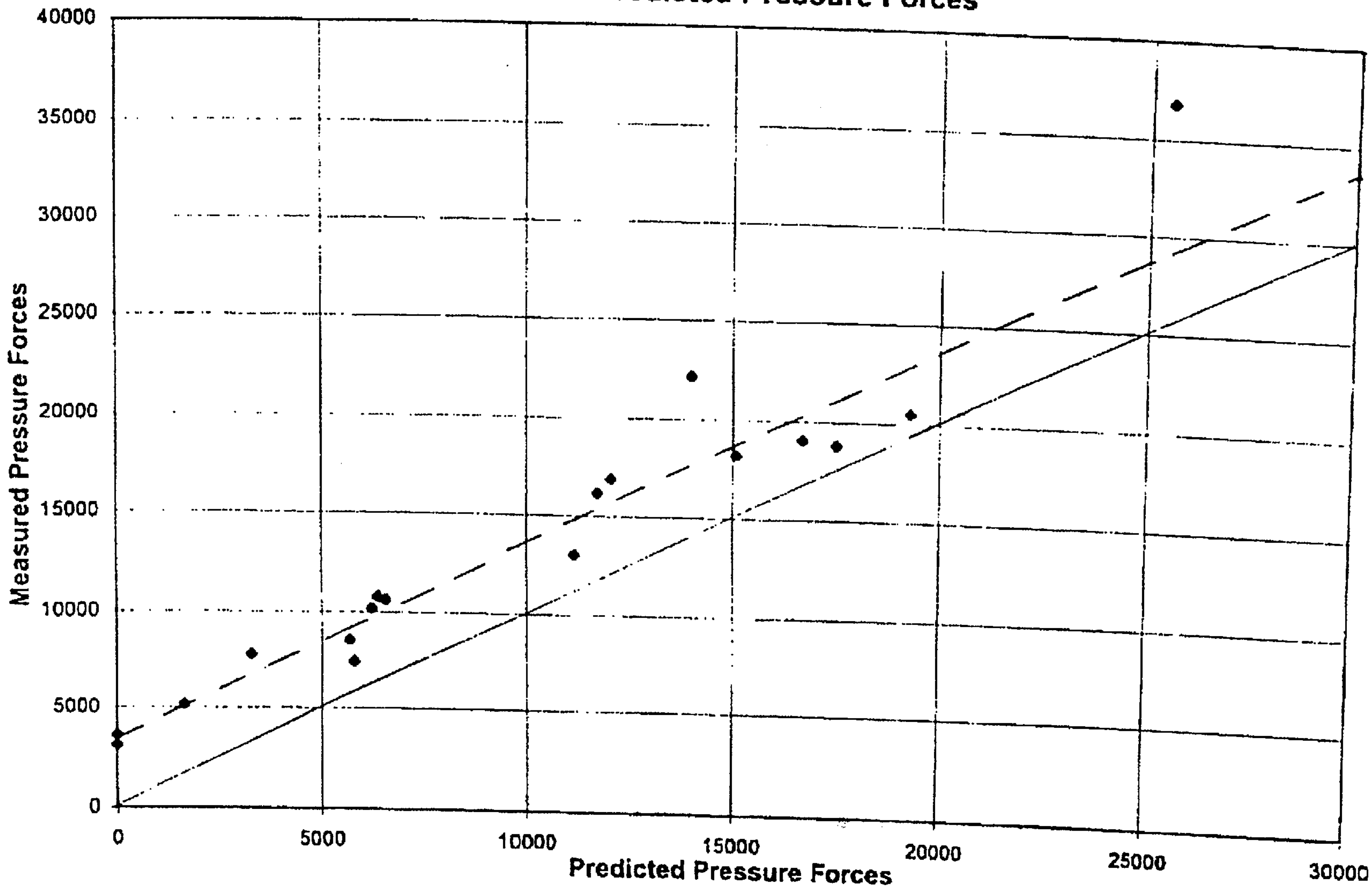
1. SIXTH EDITION OF ROARKS FORMULAS FOR STRESS & STRAIN

2. MOV WHITE PAPER WP-134 REV O

3. MECHANICAL ENGINEERING DESIGN FOURTH EDITION, SHIGLEY AND MITCHELL

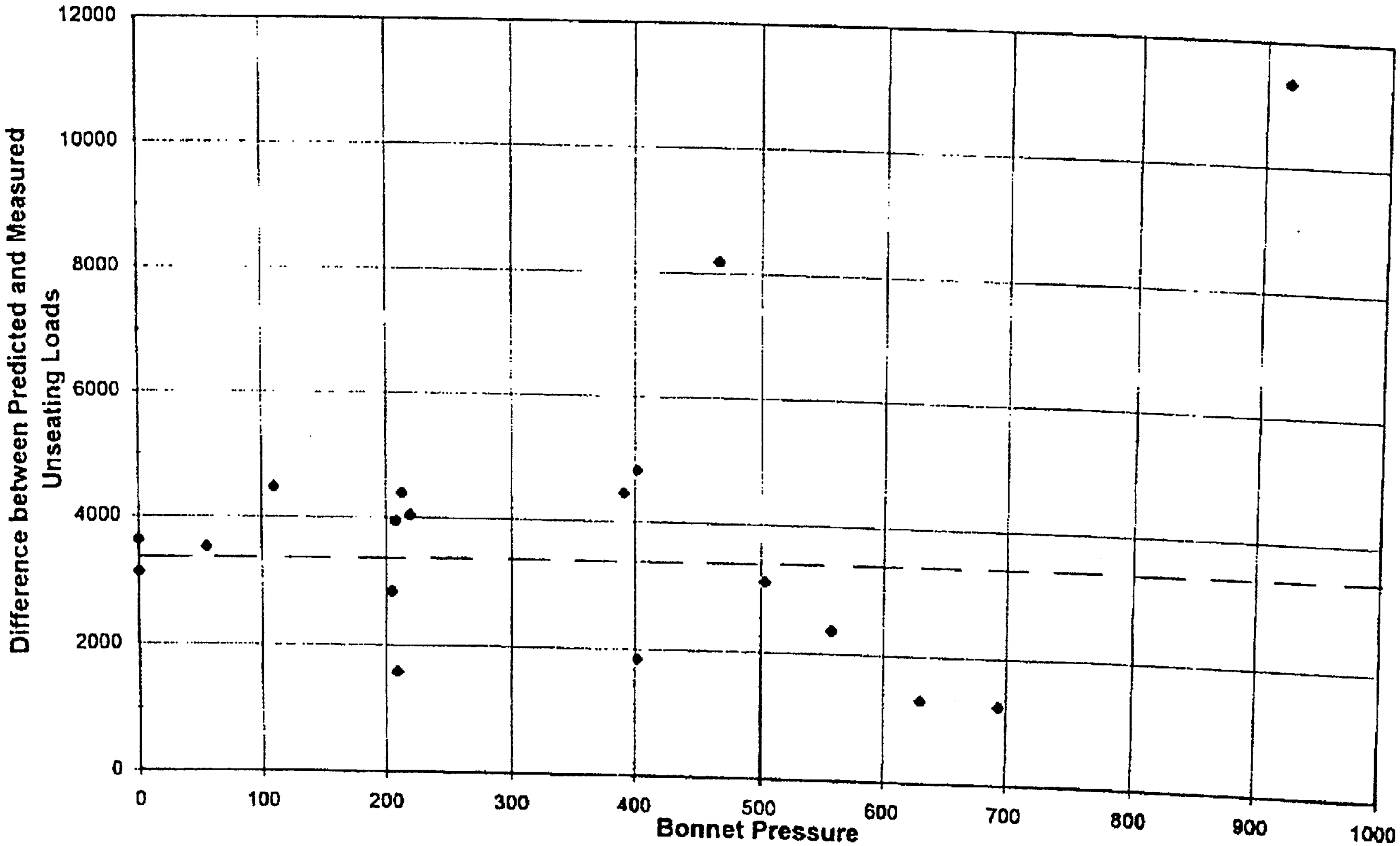
THIS METHODOLOGY AND CALC FOLLOWS CALCULATION 95-158 AT BRAIDWOOD

Borg-Warner 10" 300# Class Gate Valve
Measured vs Predicted Pressure Forces

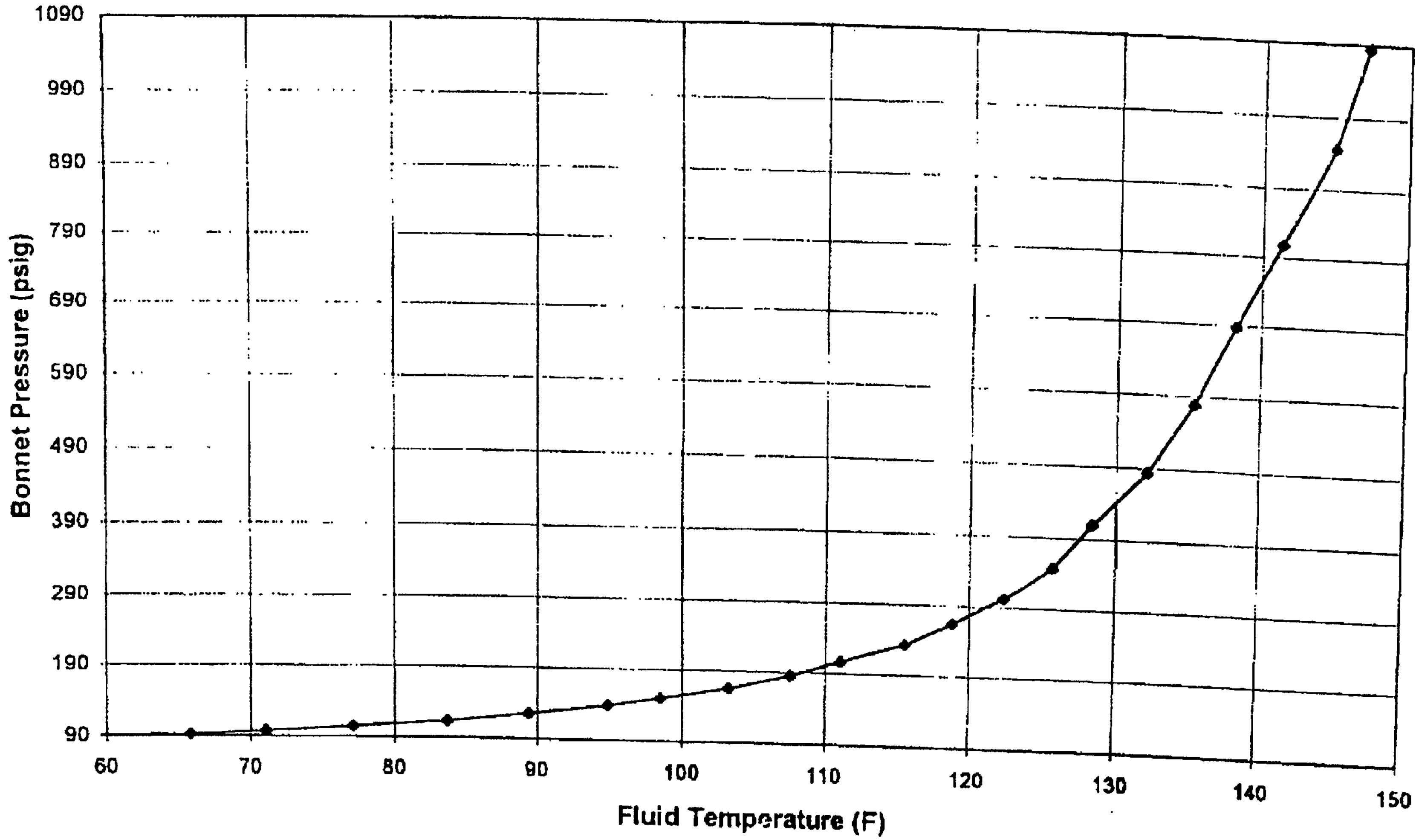


Attachment 5

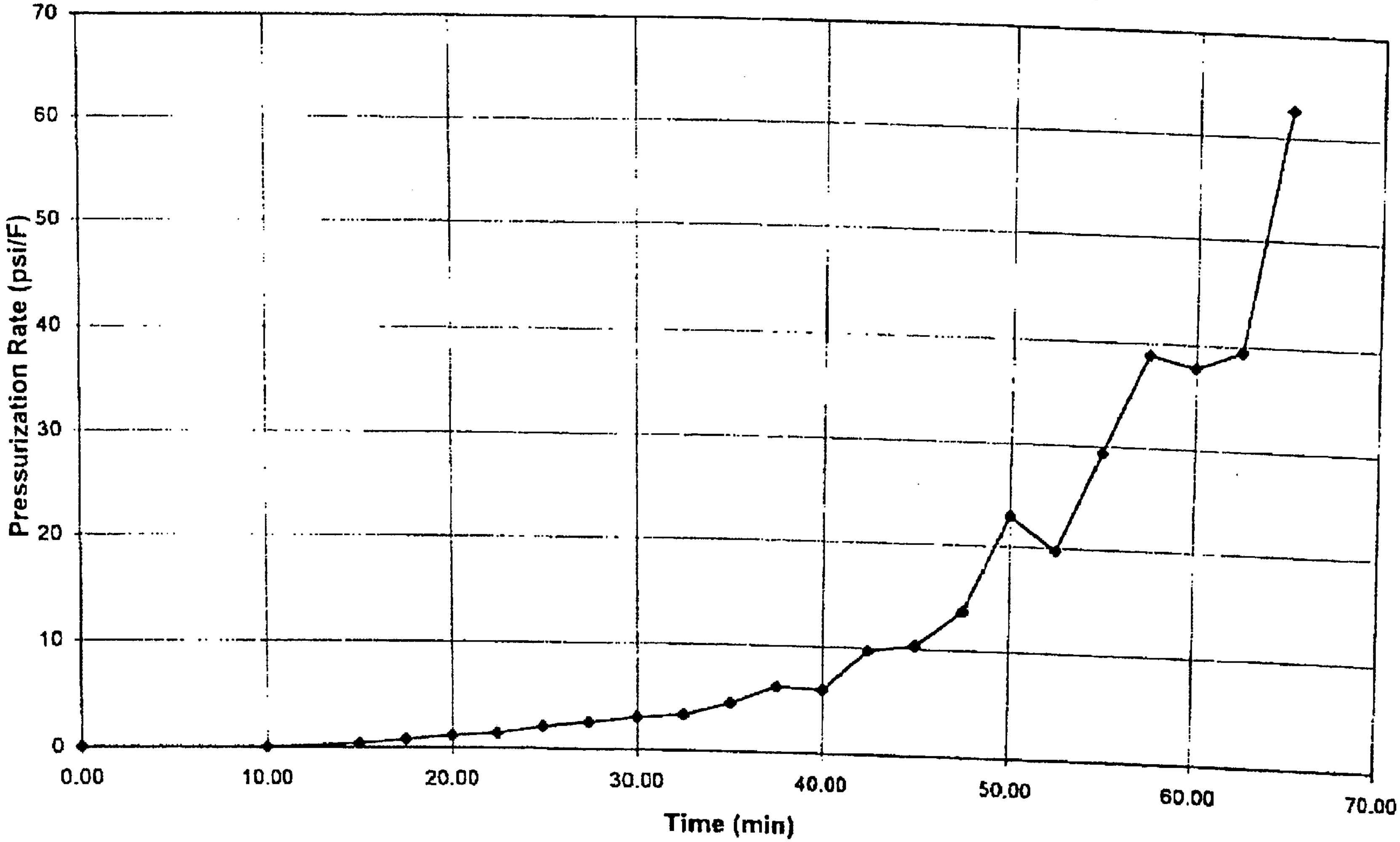
Borg-Warner 10" 300# Class Gate Valve
Deviation in Unseating Load vs Bonnet Pressure

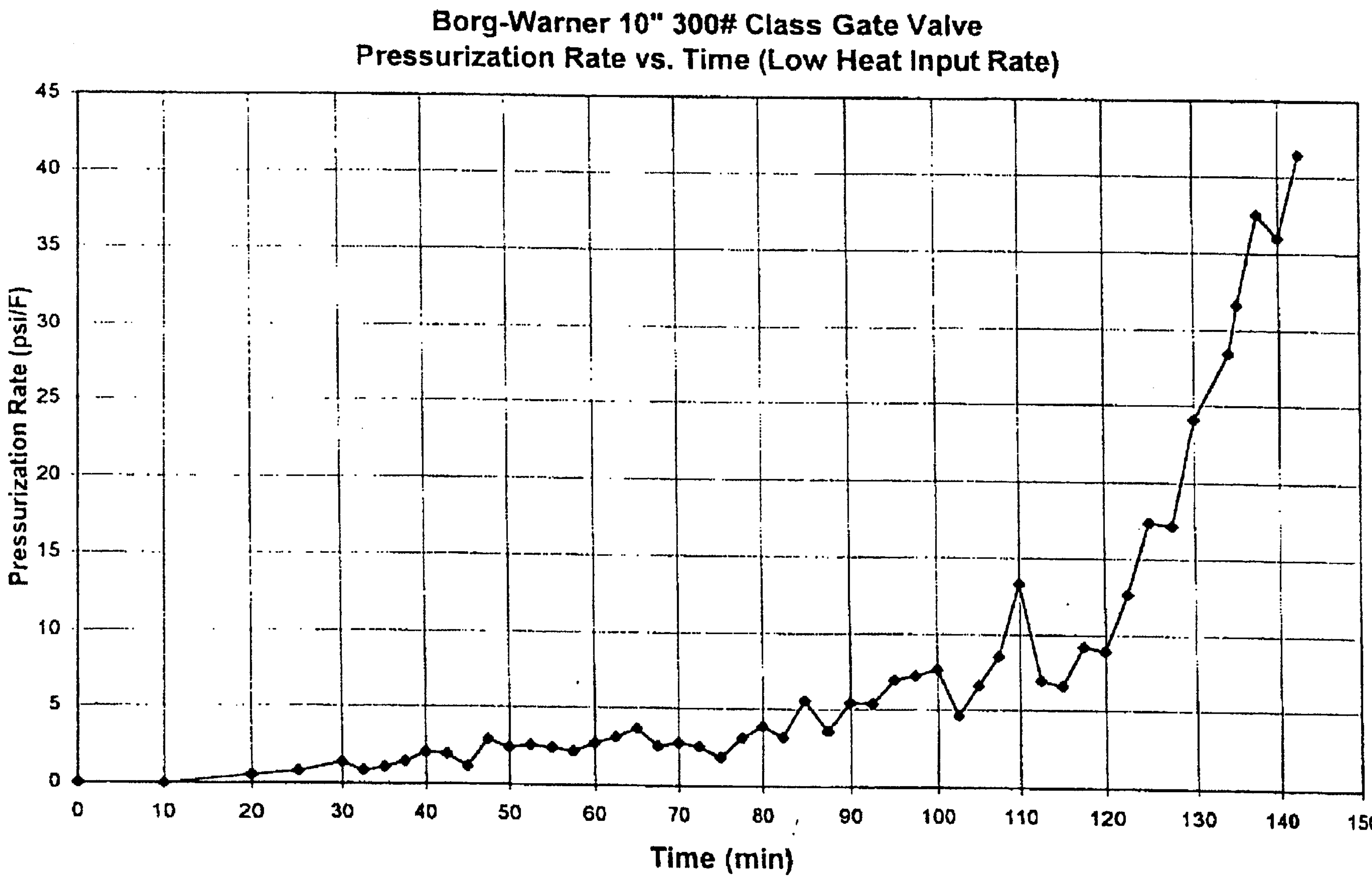


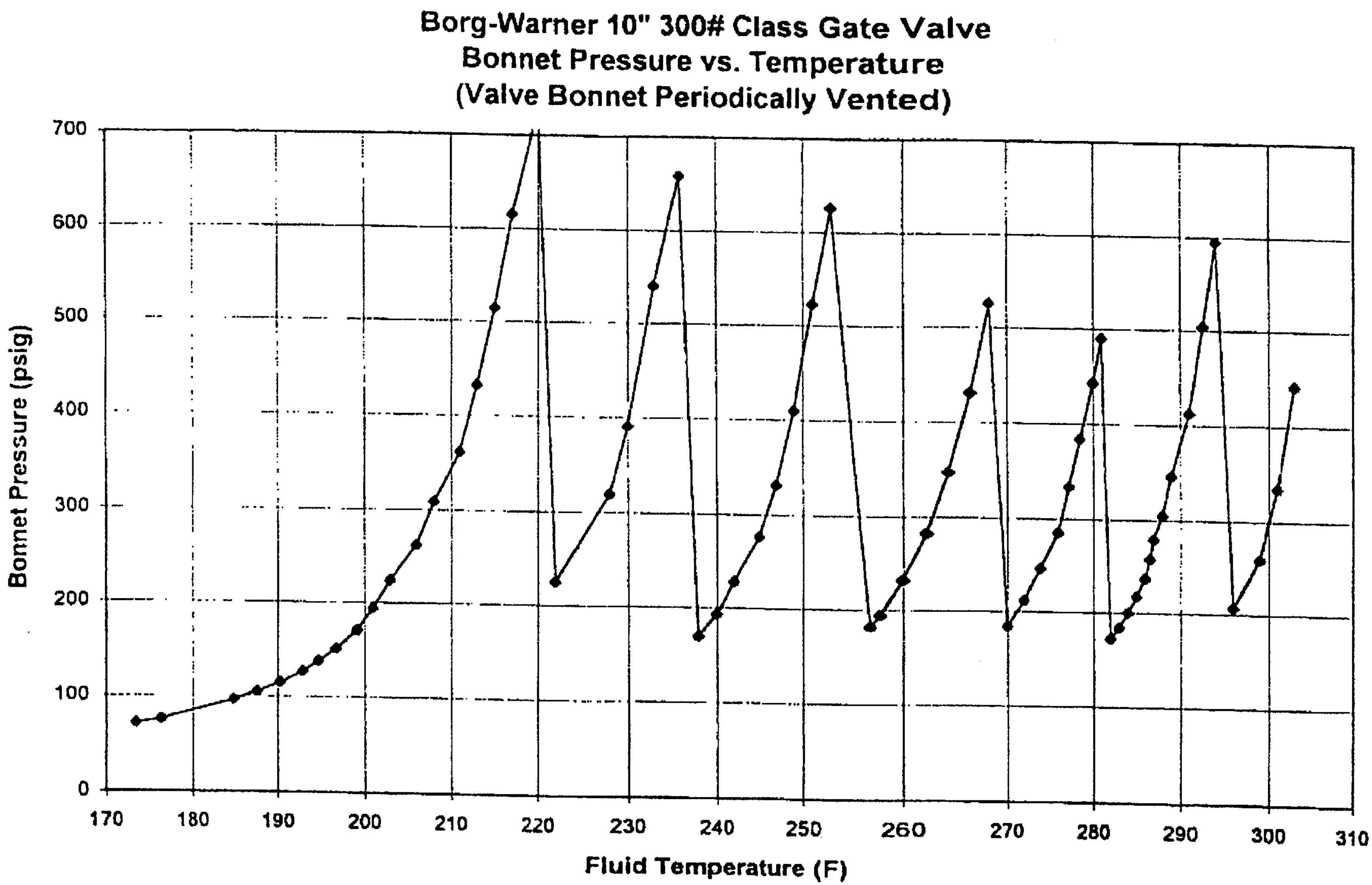
Borg-Warner 10" 300# Class Gate Valve
Bonnet Pressure vs. Temperature (High Heat Input Rate)

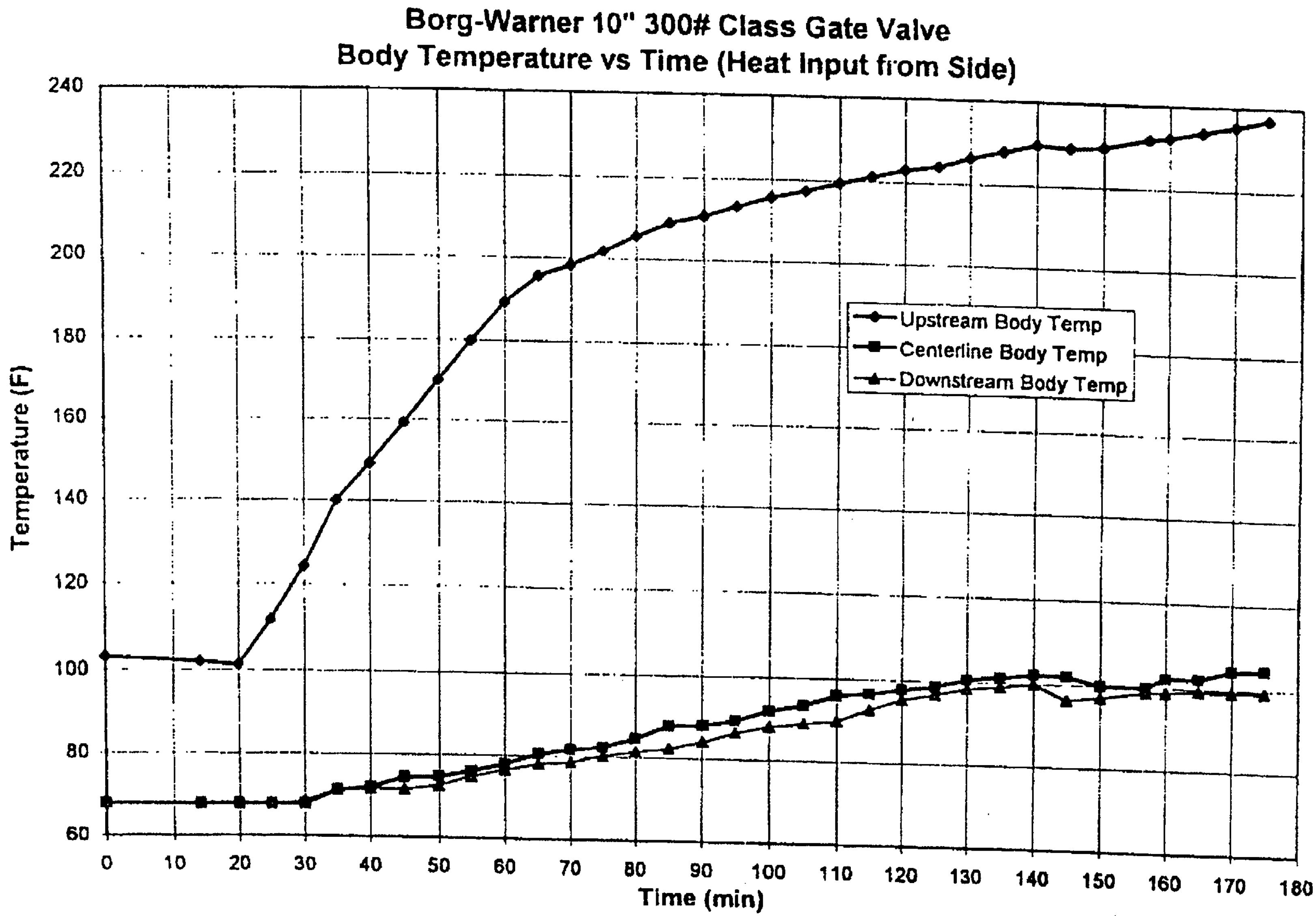


Borg-Warner 10" 300# Class Gate Valve
Pressurization Rate vs. Time (High Heat Input Rate)

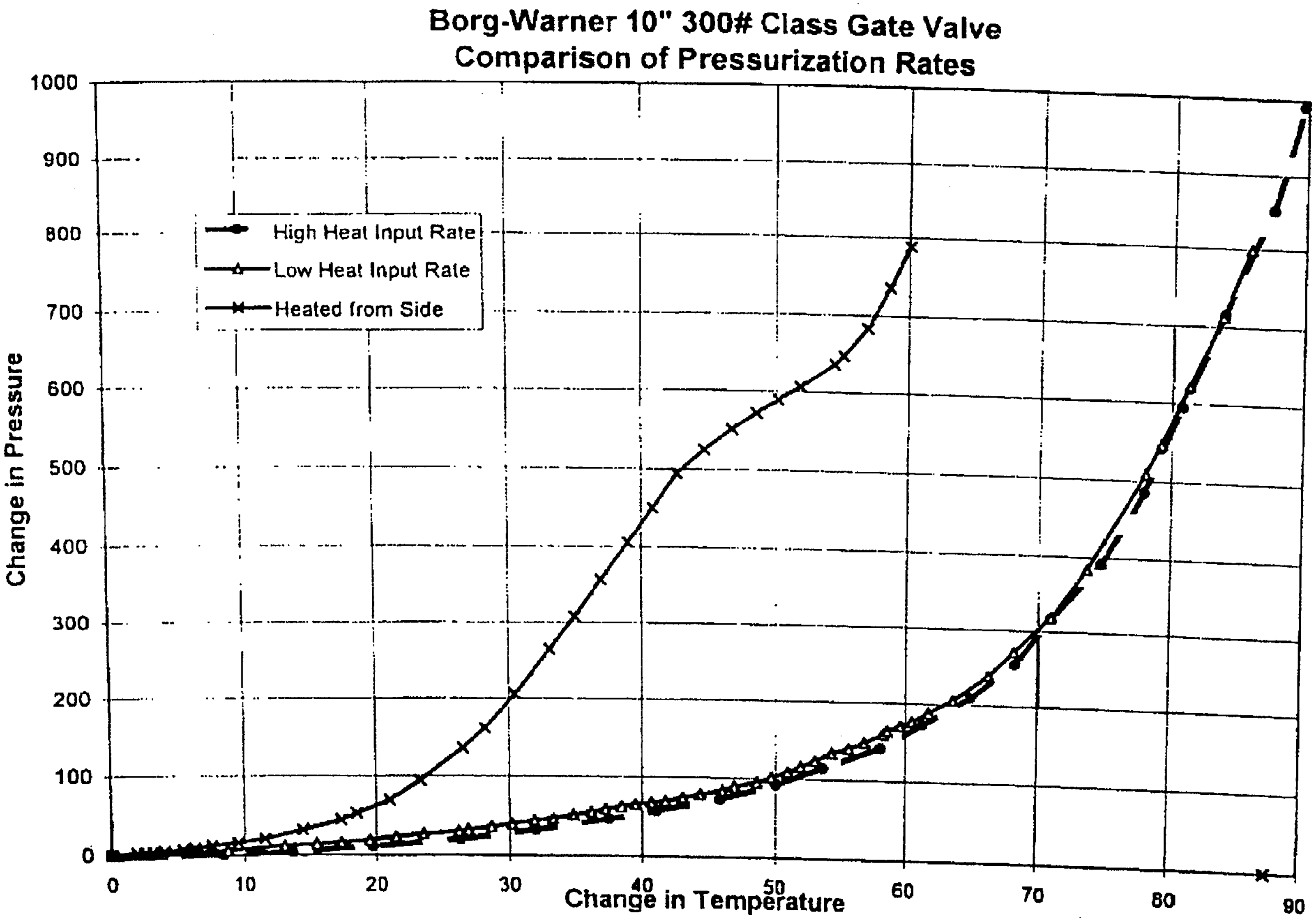



Borg-Warner 10" 300# Class Gate Valve
Pressurization Rate vs. Time (Low Heat Input Rate)
Pressurization Rate (psi/F)
0
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Time (min)


Borg-Warner 10" 300# Class Gate Valve
Bonnet Pressure vs. Temperature
(Valve Bonnet Periodically Vented)
Bonnet Pressure (psig)
700
600
500
400
300
200
100
0
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
Fluid Temperature (F)


Borg-Warner 10" 300# Class Gate Valve
Body Temperature vs Time (Heat Input from Side)
Temperature (F)
Time (min)
Upstream Body Temp
Centerline Body Temp
Downstream Body Temp
240
220
200
180
160
140
120
100
80
60
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180

Sheet1 Chart 13



Attachment 5

6d of 74

Memorandum

ComEd

In Reference
Refer to DOC ID # DG96-000078

Date: January 16, 1996

To: R. C. Bedford (Braidwood) W. R. Cote (Braidwood) N. B. Stremmel (Byron)
B. K. Smith (Byron) H. L. Mulderink (Dresden) J. G. O'Neill (Dresden)
B. S. Westphal (LaSalle) L. D. Pool (LaSalle) J. R. Arnold (Quad Cities)
B. Gebhardt (Quad Cities) R. Mika (Zion) G. C. Lauber (Zion)
S. Raborn (Zion) S. A. Korn I. Garza

Subject: Pressure Locking / Thermal Binding Test Data

The purpose of this memorandum is to provide a summary of the initial results from pressure locking and thermal binding testing that has been performed at ComEd Stations. A formal report documenting the final test results and analyzing test valve performance against pressure locking and thermal binding model predictions will be issued early in 1996.

This testing was performed on a 10" Crane 900# Class gate valve, a 4" Westinghouse 2500# Class gate valve, and a 10" Borg-Warner 300# Class gate valve. The Crane valve was tested at the Quad Cities Station training building; the Westinghouse and Borg-Warner valves were tested at the Braidwood Station training building and warehouse facilities.

Attachment 1 provides the bonnet depressurization test results for the subject valves. Attachment 2 compares the measured pressure locking loads to the ComEd MathCad model for predicting pressure locking unseating load. The MathCad pressure locking calculation models and Excel spreadsheets with test results for these valves are available on the NODWORLD/SYS network drive in the PRESLOCK directory. Attachment 3 provides the thermally-induced, bonnet pressurization rates for the test valves. Excel spreadsheets containing this data are also contained in the PRESLOCK directory. Attachment 4 provides the results of thermal binding tests.

If you have any questions concerning this memorandum or its attachments, please call me at Downers Grove extension 3824.

Brian D. Bunte
MOV Program Lead
Commonwealth Edison Company

Attachments

ATTACHMENT 1

BONNET DEPRESSURIZATION RATE DATA

Valve	Torque Switch Setting	Initial Pressure	Maximum Closing Thrust	Initial Depressurization Rate (psi/min)
Crane 10"	1	1040 psig	63805 lbf	45 psi/min
Westinghouse 4"	1	2000 psig	13816 lbf	400 psi/min
Westinghouse 4"	1	900 psig	13804 lbf	200 psi/min
Westinghouse 4"	2	1980 psig	19869 lbf	40 psi/min
Borg-Warner 10"	2	504 psig	24826 lbf	1 psi/min
Borg-Warner 10"	2	938 psig	24826 lbf	10 psi/min

MathCad Model Predictions versus Pressure Locking Unseating Loads

Valve	Test #	TSS	Static Unseating Thrust	Bonnet Pressure	Predicted Increase	Measured Increase	Percent Conservatism (Non-Cons.)	Notes
Crane 10"	6	1	25000	650	5103	4539	-2%	6
Crane 10"	7	1	25000	850	7213	8191	4%	6
Crane 10"	9	1	26000	1040	9421	11500	8%	6
Crane 10"	10	1	26000	1040	9922	12140	9%	6
Crane 10"	13	1	28000	1195	19462	22140	10%	
Crane 10"	14	1	28000	1375	22974	25480	9%	
Crane 10"	15	1	28000	1375	23126	25480	8%	
Crane 10"	34	2.5	38000	655	6243	5796	-1%	6
Crane 10"	35	2.5	38000	655	5142	5796	2%	6
Crane 10"	38	2.5	37500	1055	13164	13870	2%	6
Crane 10"	39	2.5	37500	1055	13065	13870	2%	6
Crane 10"	42	2.5	40000	1365	30028	29190	-2%	
Crane 10"	43	2.5	40000	1165	30428	24913	-14%	5
Crane 10"	46	2.5	40000	1575	32231	33680	4%	
Crane 10"	47	2.5	40000	1575	31931	33680	4%	
Crane 10"	50	2.5	40000	1775	37749	37950	1%	3,4
West. 4"	30	2	1450	496	1537.6	1555	-1%	
West. 4"	31	2	1450	514	1593.4	1538	2%	
West. 4"	33	2	900	1000	3100	3007	2%	
West. 4"	35	2	900	1000	3100	2990	3%	
West. 4"	37	2	50	1500	4650	4775	-3%	
West. 4"	39	2	50	1500	4650	4672	0%	
West. 4"	42	2	-400	2000	6200	5989	4%	
West. 4"	44	2	-400	2000	6200	6126	1%	
Borg-W. 10"	43	2	16935	205	5691	8532	4%	1
Borg-W. 10"	48	1	7882	209	5802	7386	19%	1
Borg-W. 10"	50	1	7782	402	11160	13004	16%	1
Borg-W. 10"	52	1	7906	630	17489	18799	23%	1
Borg-W. 10"	54	1	7882	694	19265	20514	23%	1
Borg-W. 10"	56	1	5023	919	25511	36849	-164%	1,2
Borg-W. 10"	74	2	17477	208	6225	10167	-2%	1
Borg-W. 10"	75	2	17477	213	6375	10765	-5%	1
Borg-W. 10"	77	2	17751	391	11703	16155	-5%	1
Borg-W. 10"	78	2	17751	402	12032	16853	-7%	1
Borg-W. 10"	80	2	17949	467	13977	22172	-26%	1,2
Borg-W. 10"	81	2	17949	219	6555	10591	2%	1
Borg-W. 10"	83	2	17700	110	3292	7757	-5%	1
Borg-W. 10"	84	2	17700	55	1646	5171	0%	1
Borg-W. 10"	86	2	17352	0	0	3628	0%	3
Borg-W. 10"	95	1	8000	0	0	3132	0%	3
Borg-W. 10"	96	1	8000	557	16671	19035	9%	1
Borg-W. 10"	97	1	8000	504	15085	18189	0%	1

ATTACHMENT 2 (continued)

NOTES:

1. The percent conservatism values are calculated after a "memory effect" of 3100 lbf (at TSS=1) or 3500 lbf (at TSS=2) is added to the calculated pressure locking increase. Testing indicated that the process of applying and then relieving pressure against one side of the closed valve was sufficient to cause the unseating force to increase by these amounts, even when no pressure was captured in the valve bonnet. This effect was only noted for the Borg-Warner test valve.

2. When bonnet pressure significantly exceeds the pressure class rating of the test valve, the pressure locking calculation methodology appears to become non-conservative.

3. Tests 86 and 95 were performed to quantify the "memory effect" for the Borg-Warner valve. These tests were performed like a pressure locking test in that high pressure (~ 600 psig) was put against one side of the valve disk and then bled off. However, any pressure that entered the valve bonnet was relieved prior to the opening stroke.

4. The AC motor for the test valve stalled during this test and the valve did not fully unseat. Test data suggests that open valve motion was initiated prior to the stall. Consequently, the measured increase due to pressure locking is believed to be correct.

5. The pressure data for this test is questionable and is being evaluated at this time.

6. The upstream and downstream pressure during these tests was approximately 350 psig. This was done to approximate the LPCI and LPCS injection valve pressure conditions which could exist in the event of a LOCA.

ATTACHMENT 3

BONNET PRESSURIZATION RATE DUE TO BONNET TEMPERATURE RISE

Valve	Torque Switch Setting	Initial Pres. & Temp.	Maximum Closing Thrust	Initial Pressurization Rate (psi / °F)	Final Pressurization Rate (psi / °F)	Final Pres. & Temp.
Westinghouse 4"	2	102 psig 78.5 °F	20041 lbf	0.5 psi / °F	2.0 psi / °F	201.7 psig 263 °F
Borg-Warner 10"	2	93 psig 61 °F	31327 lbf	0.5 psi / °F	50 psi / °F	1084 psig 147 °F
Borg-Warner 10"	2	86 psig 64 °F	32267 lbf	0.75 psi / °F	40 psi / °F	885 psig 150 °F
Borg-Warner 10"	2	37 psig 65 °F	32267 lbf	1.0 psi / °F	37 psi / °F	826 psig 125 °F

ATTACHMENT 4

THERMAL BINDING TEST RESULTS

Valve	Torque Switch Setting	Static Unseating Load	Temperature Decrease (°F)	Measured Increase in Unseating Load Due to Thermal Binding
Westinghouse 4"	2	1909 lbf	100 °F	330 lbf
Borg-Warner 10"	2	16008 lbf	88 °F	2987 lbf
Borg-Warner 10"	2	17541 lbf	215 °F	6703 lbf

MULTIPLE USE

CALIBRATION TEST REPORT FORM

Instr. No/Type ______ Location ______

Instrument Name Gauge Tolerance ±2% of span or ±20 PSIG

Instr.Model Mfr. ______ References BWIP 2400-026 Rev. 2.1

Instr.Serial No. MTI 8008 Procedure No. BWIP 2400-026 Rev. 2.1

Head Correction N/A Setpoint N/A

Technician Speed

Date Calibrated 12-3-95 Range 0-1000 PSIG

INPUT TEST POINT		OUTPUT TEST POINT		
INPUT		REQUIRED	AS FOUND	AS LEFT
%	PSIG	PSIG	PSIG	PSIG
0	0	0	0	0
25	250	250	252	251
50	500	500	502	501
75	750	750	752	751
100	1000	1000	1005	1003
75	750	750	755	752
50	500	500	504	502
25	250	250	~~250~~ 253	251
0	0	0	0	0

SWITCH OPERATION	AS FOUND	AS LEFT	ACTUATION INC/DEC
SETPOINT			
RESET		N/A	
SETPOINT			
RESET			

REMARKS: Pre cal for Special Test on Valve Pressure Locking

TEST EQUIPMENT					
ID#	AT/AL	MODEL#	RANGE	RATE	CERT DUE
031	PE/AL	Gauge	0-1000 PSIG	N/A	3-96

DOCUMENT REVIEW

SUPERVISOR: [signature]

DATE REVIEWED: 12-3-95

DATE ENTRY:

SYS ID:

WR#: 950003824-03

APPROVED
AUG 27 1992
BRAIDWOOD ON-SITE REVIEW

MULTIPLE USE

CALIBRATION TEST REPORT FORM

Instr. No/Type		Location	
Instrument Name	Gauge	Tolerance	±2% of span or ±20 PSIG
Instr.Model Mfr.	Ashcroft	References	BwIP 2400-026 Rev 2.1
Instr.Serial No.	MTT 111	Procedure No.	BwIP 2400-026 Rev 2.1
Head Correction	N/A	Setpoint	N/A
Technician	Speed		
Date Calibrated	12-3-95	Range	0-1000 PSIG

INPUT TEST POINT		OUTPUT TEST POINT		
INPUT %	INPUT PSIG	REQUIRED PSIG	AS FOUND PSIG	AS LEFT PSIG
0	0	0	0	0
25	250	250	250	250
50	500	500	510	500
75	750	750	750	750
100	1000	1000	998	998
75	750	750	752	752
50	500	500	502	502
25	250	250	250	250
0	0	0	0	0

SWITCH OPERATION	AS FOUND	AS LEFT	ACTUATION INC/DEC
SETPOINT			
RESET		N/A	
SETPOINT			
RESET			

REMARKS: Pre cal for Special Test on Valve Pressure Locking

TEST EQUIPMENT

ID#	AF/AL	MODEL#	RANGE	RATE	CERT DUE
031	AF/AL	[illegible]	0-1000 PSIG	N/A	3-96

DOCUMENT REVIEW

SUPERVISOR: [signature]

DATE REVIEWED: 12-3-95

DATE ENTRY:

SYS ID:

WR#: 950007824-02

.93(082092)
DRBWIP

(Final)

APPROVED
AUG 27 1992
BRAIDWOOD ONSITE REVIEW

Date:

13-MC-ZZ-217 R/3

Attachment 5

MULTIPLE USE

CALIBRATION TEST REPORT FORM

Instr. No/Type		Location	
Instrument Name	FLUKE	Tolerance	2% = 2.8°F
Instr.Model Mfr.		References	
Instr.Serial No.		Procedure No.	
Head Correction		Setpoint	
Technician	J. Harvey		
Date Calibrated	12-3-95	Range	

INPUT TEST POINT / OUTPUT TEST POINT

	INPUT %	REQUIRED °F	AS FOUND °F	AS LEFT °F
	0	70	69.8	69.8
	50	141	139.6	139.6
	100	212	210.8	210.8

SWITCH OPERATION

	AS FOUND	AS LEFT	ACTUATION INC/DEC
SETPOINT		N	
RESET			
SETPOINT		A	
RESET			

REMARKS:

As Found
For Test
950003824-09

TEST EQUIPMENT

ID#	AF/AL	MODEL#	RANGE	DATE	CERT DUE
BR751	AF/AL	Gordon	E		10-96

DOCUMENT REVIEW

SUPERVISOR: [signature]

DATE REVIEWED: 12-3-95

DATE ENTRY:

SYS ID:

NWR#: 950003824-03

.92(082092)
CWBWIP

(Final)

APPROVED
AUG 27 1992
BRAIDWOOD
ON-SITE REVIEW

Date:

13-MC-ZZ-217 R/3

Attachment 5 Revision 2

MULTIPLE USE

CALIBRATION TEST REPORT FORM

Instr. No/Type		Location	
Instrument Name	OMEGA	Tolerance	2% = 20 psi
Instr.Model Mfr.		References	
Instr.Serial No.		Procedure No.	
Head Correction		Setpoint	
Technician	Santa Arenas		
Date Calibrated	12-3-95	Range	

INPUT TEST POINT		OUTPUT TEST POINT		
~~PSI~~ % (12-3-95)	INPUT PSI	REQUIRED PSI	AS FOUND PSI	AS LEFT PSI
0	0	0	0	0
25	250	250	246	246
50	500	500	496	496
75	750	750	744	744
100	1000	1000	993	993
75	750	750	744	744
50	500	500	495	495
25	250	250	246	246
0	0	0	0	0

SWITCH OPERATION	AS FOUND	AS LEFT	ACTUATION INC/DEC
SETPOINT			
RESET			
SETPOINT			
RESET			

REMARKS:

As Found
For Test:
950003824.09

TEST EQUIPMENT

ID#	AF/AL	MODEL#	RANGE	RATE	CERT DUE
BR 266	AF/AL		0/1000 psi	NA	12-30-95

DOCUMENT REVIEW

SUPERVISOR: [signature]

DATE REVIEWED: 12-3-95

DATE ENTRY:

SYS ID:

NWR#: 950003824.03

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BRAIDWOOD
ON-SITE REVIEW

Source Document: 13-MC-ZZ-217 R08:
Date: N/A

Attachment 5

BwIP 2000-T0
Revision 2

MULTIPLE USE

CALIBRATION TEST REPORT FORM

Instr. No/Type	MTT 8008	Location	
Instrument Name	test Gauge	Tolerance	2% = 20 PSI
Instr.Model Mfr.	Ashcroft 1082	References	
Instr.Serial No.		Procecure No.	BwIP 2400-00
Head Correction	N/A	Setpoint	
Technician	M Bord		
Date Calibrated	1-12-96	Range	0-1000 psi

INPUT TEST POINT / OUTPUT TEST POINT

INPUT	Psi	REQUIRED Psi	AS FOUND Psi	AS LEFT Psi
	0	0	0	0
	250	250	252	250
	500	500	505	500
	750	750	760	746
	1000	1000	1015	996
	750	750	760	750
	500	500	510	500
	250	250	255	250
	0	0	0	0

SWITCH OPERATION

	AS FOUND	AS LEFT	ACTUATION INC/DEC
SETPOINT	N/A		
RESET			
SETPOINT			
RESET			

REMARKS:

Post Cal
950003824·09

TEST EQUIPMENT

ID#	AF/AL	MODEL#	RANGE	RATE	CERT DUE
SR 266	AF / AL	Ashcroft 1082	0-1000psi	N/A	1-26-96

DOCUMENT REVIEW
SUPERVISOR: [signature]
DATE REVIEWED: 2-5-96
DATE ENTRY:
SYS ID:
NWR#: 950003824·09

(Final)
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.92(082092)
ZWBWIP

APPROVED
AUG 27 1992
BRAIDWOOD
ON-SITE REVIEW

13-MC-ZZ-217 R/3

Source Document: N/A
Revision:
Date:

Attachment 5

BwIP 2000-T0
Revision 2

MULTIPLE USE

CALIBRATION TEST REPORT FORM

Instr. No/Type	MTT 111	Location	
Instrument Name	test gauge	Tolerance	2% = 20 PSI
Instr. Model Mfr.	Ashcroft 1279	References	
Instr. Serial No.	N/A	Procecure No.	
Head Correction		Setpoint	
Technician	M Bond		
Date Calibrated	1-16-96	Range	0-1000 psi

INPUT TEST POINT / OUTPUT TEST POINT

INPUT		REQUIRED	AS FOUND	AS LEFT
	Psi	Psi	Psi	Psi
	0	0	0	0
	250	250	250	250
	500	500	500	500
	750	750	750	750
	1000	1000	1000	1000
	750	750	750	750
	500	500	500	500
	250	250	250	250
	0	0	0	0

SWITCH OPERATION	AS FOUND	AS LEFT	ACTUATION INC/DEC
SETPOINT			
RESET		N/A	
SETPOINT			
RESET			

REMARKS:

Post Cal

950003824.09

TEST EQUIPMENT

ID#	AF/AL	MODEL#	RANGE	RATE	CERT DUE
31 266	AF/AL	Ashcroft 1082	0-1000 psi	N/A	1-5-96

DOCUMENT REVIEW

SUPERVISOR: [signature]

DATE REVIEWED: 2-5-96

DATE ENTRY:

SYS ID:

NWR#: 950003824.03

(Final)

.92(082092)
ZWBWIP

APPROVEL
AUG 27 1992
BRAIDWOOD
ON-SITE REVIEW

Source Document: 13-MC-22-015 R/3
Date:

Attachment 5

BWIP 2000-T5
Revision 2

MULTIPLE USE

CALIBRATION TEST REPORT FORM

Instr. No/Type

Location

Instrument Name OMEGA

Tolerance 2% = 20 PSI

Instr.Model Mfr.

References

Instr.Serial No.

Procedure No.

Head Correction

Setpoint

Technician [signature]

Date Calibrated 1-17-96

Range

INPUT TEST POINT		OUTPUT TEST POINT		
INPUT		REQUIRED	AS FOUND	AS LEFT
%	PSI	PSI	PSI	PSI
0	0	0	0	0
25	250	250	247	247
50	500	500	499	499
75	750	750	747	747
100	1000	1000	995	995
75	750	750	747	747
50	500	500	499	499
25	250	250	250	250
0	0	0	~~8~~ 3	3 ~~8~~

SWITCH OPERATION	AS FOUND	AS LEFT	ACTUATION INC/DEC
SETPOINT			
RESET			
SETPOINT			
RESET			

REMARKS:

POST CAL
950003824-09

TEST EQUIPMENT

ID#	AF/AL	MODEL#	RANGE	RATE	CERT DUE
BR 1053	AF/AL	CMM	0-1000	NA	2-2-96

DOCUMENT REVIEW

SUPERVISOR: [signature]

DATE REVIEWED: 2-5-96

DATE ENTRY:

SYS ID:

NWR#: 950003824-03

(Final)

.92(082092)
ZWBWIP

APPROVED
AUG 27 1992
BRAIDWOOD
ON-SITE REVIEW

Source Document: 13-MC-ZZ-217 R/3
Revision:
Date:

Attachment 5

BWIP 2000-10
Revision 2

MULTIPLE USE

CALIBRATION TEST REPORT FORM

Instr. No/Type		Location	
Instrument Name	test meter	Tolerance	2%
Instr.Model Mfr.	Omega HH 25TF	References	
Instr.Serial No.	N/A	Procedure No.	
Head Correction		Setpoint	
Technician	[signature]		
Date Calibrated	1-12-96	Range	0-200 °F T T/C

INPUT TEST POINT	OUTPUT TEST POINT		
INPUT °F	REQUIRED °F	AS FOUND °F	AS LEFT °F
75	75	75.2	75.2
125	125	124.3	124.3
175	175	173.6	173.6

SWITCH OPERATION	AS FOUND	AS LEFT	ACTUATION INC/DEC
SETPOINT			
RESET			
SETPOINT			
RESET			

REMARKS:

Post Cal
950003824 09

for Chris Bedford
x2440

TEST EQUIPMENT					
ID#	AF/AL	MODEL#	RANGE	RATE	CERT DUE
32750	AF/	Gordon Tube	type K T/C	5.4	4-96

DOCUMENT REVIEW
SUPERVISOR: [signature]
DATE REVIEWED: 2-5-96
DATE ENTRY:
SYS ID:
NWR#: 950003824-03

.92(082092)
ZWBWIP

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APPROVED
AUG 27 1992
BRAIDWOOD ON-SITE REVIEW

R.E. [signature] 2-10-2000 I.V. [signature] 02/10/00

Attachment 6- PVNGS PL Model Comparison to Other Test Data

BACKGROUND

This attachment was added to the PVNGS 13-MC-ZZ-217, Gate Valve Open Thrust Required during Pressure Locking Conditions per G. L. 95-07, calculation to document comparison of the PVNGS pressure locking model with other selected Test Data in response to NRC Request for Additional Information (Generic Letter 95-07 RAI NRC Letter dated June 11, 1999). INEEL pressure locking test results were published under NUREG/CR-6611 in May 1998. The US Nuclear Regulatory Commission (NRC), Office of Nuclear Regulatory Research funded the Idaho National Engineering and Environmental Laboratory (INEEL) pressure locking testing of a Walworth flexible gate and a Anchor Darling double disk gate valve. PVNGS has compared the Walworth flexible gate pressure locking test results to the PVNGS pressure locking model that was used to evaluate the identified potentially susceptible PVNGS Anchor Darling and Borg Warner flexible wedge gate valves. The results of this comparison are presented in the first part of this attachment (pages 3-18). In addition Commonwealth Edison had also tested a Crane Valve under varying pressure locking conditions including line pressures. A summary of these test results were included in the Commonwealth Edison report in attachment 5 of this Calculation. The results of this comparison are presented in the second part of this attachment (pages 20-26).

INEEL 6" 600 LB. WALWORTH FLEX WEDGE PL TEST RESULTS

The applicable INEEL 6", 600 lb class flexible wedge Walworth test valve parameters and test inputs included bonnet pressure, up and down stream pressures, and peak unwedging from NUREG/CR-6611. These test values from NUREG/CR-6611, Appendix A, Table 5; Walworth Gate Valve, Cold Pressure Locking Test Results; and Table 7; Walworth Gate Valve, Thermally Induced Pressure Locking Test Results; were input into a spreadsheet similar to that used in Attachment 1 of this calculation, 13-MC-ZZ-217. Reasonable assumptions for parameters not available in NUREG/CR-6611 were made for inputs that were not sensitive to the comparison of these results and these assumptions were checked by conversations with one of the principal INEEL testers.

The comparison of these INEEL measured opening thrust pressure locking test results to the PVNGS pressure locking model predicted opening thrust for the 6" 600# Walworth flexible wedge gate valves is shown in the first attached Excel spreadsheet and represented in the two subsequent charts. These charts present a least square linear regression of the PVNGS Pressure Locking model with the corresponding INEEL Pressure locking test results. These charts present a plot of the peak stem thrust required to open the valve as a function of the bonnet pressure.

Attachment 6 chart 1 shows the comparison of the PVNGS pressure locking analysis model to the INEEL cold pressure locking test results (Tests 226 thru 235 and 237). All these test cases were identified as restricted to pressure locking at temperatures near around 75 °F. In general the least square linear regression comparisons shown in chart 1 of the PVNGS pressure locking model with the INEEL pressure locking test results indicate a nonconservative correlation. However, the overall scatter of the test results indicate some inconsistency in these results which could be partially attributed to the effect of varying upstream and down steam pressures. There were also a number of specific data points, most notably tests 227 thru 232, where the PVNGS model under predicted the INEEL test results. This consistent under prediction may be attributed to the characteristics of this more flexibleWalworth flexible gate valve with its typically thinner disk and smaller hub dimensions and the reported instability in the friction factors under ambient temperature conditions.

Attachment 6 chart 2 shows the comparison of the PVNGS pressure locking analysis model to the INEEL thermal pressure locking test results (Tests 307 to 343). These test cases were identified as occurring subsequent or during heating of the valve both internally and externally causing bonnet thermal pressurization. The final temperatures were recorded in the range 65 °F to 217 °F. In general the least square linear regression comparisons shown in chart 2 of the PVNGS pressure locking model with the INEEL pressure locking test results indicate a close correlation. However, there is also some overall scatter of the test results indicating some inconsistency which could also be partially attributed to the effect of varying upstream and down steam pressures. Attachment 6 chart 3 shows the correlation between Pressure Locking Load and Average DP (Bonnet Pressure – Average Line Pressure). This correlation also shows some scatter of the test results but also indicates the relationship of increasing pressure locking with increasing DP and the close correlation between the INEEL thermal pressure locking test results and the PVNGS model. There were also a number of specific data points, most notably tests 326, 327, 331, 332, & 341, where the PVNGS model under predicted the INEEL test results. There were no discernible differences with the parameters of these tests and those of the corresponding tests 309, 310, 313, 314, 316, 318, & 319 results that reflected correspondingly conservative results. This apparent variation of measured results may be attributed to inherit test errors and the characteristics of this more flexibleWalworth flexible gate valve with its typically thinner disk and smaller hub dimensions.

It is difficult to conclude that the PVNGS pressure locking analysis model is accurate in predicting the indicated INEEL measured pressure locking loads. There was some apparent inconsistency in the INEEL data that could be attributed to the characteristics of this apparently more flexible Walworth gate valve disk with its typically thinner disk and smaller hub dimensions and the reported instability in the friction factors under ambient temperature conditions. However, when the INEEL thermal pressure locking test and PVNGS model results for the required opening thrust versus the bonnet pressure and average DP were fit with least square linear regression accounting for inherent errors it appears that the Palo Verde model does reasonably approach conservatively predicting the trends of this data (see charts 2 & 3). Further it is apparent that the results of this INEEL pressure locking test data does not invalidate the PVNGS model that was developed for the relatively more rigid disk of the Borg-Warner 300 # class flexible wedge gate valve based on the APS/Commonwealth pressure locking test data documented in Attachment 5. It is apparent that the more flexible the gate valve is the more sensitive the valve is to pressure locking conditions.

COMED 10" 900 LB. CRANE FLEX WEDGE PL TEST RESULTS

A follow-up discussions with the NRC based on APS Generic Letter 95-07 RAI Response Letter dated October 8, 1999 resulted in further PVNGS pressure locking model adjustment and review and documentation of additional test results. These additional test results were needed to reflect the response of flexible wedge gate valves with relatively rigid gates, thicker disk and larger hub diameter dimensions, than the 6" 600 lb. Walworth, more comparable to the relatively rigid and stout PVNGS Borg-Warner and Anchor-Darling gates. The additional Commonwealth Edison pressure locking test results for a 4" 2500 lb Westinghouse flexible wedge gate valve and a 10" 900 lb Crane flexible wedge gate valve were reviewed and compared with the predicted PVNGS model pressure locking loads. The results from the 10" 900 lb Crane pressure locking test are presented in the second part of this attachment. These test results are more representative since they more closely reflect the size and pressure rating of the PVNGS Borg-Warner valves evaluated, were tested with line pressure, and were representative of the trends seen in the Westinghouse valve test results. Comparison of the PVNGS pressure locking model results with the measured Crane test results indicate a conservative divergent trend with increasing bonnet pressures (Chart 4). All the Crane (Chart 5) and Westinghouse test cases of the PVNGS pressure locking model conservatively calculated the associated measured pressure locking load. This analysis indicates that the PVNGS pressure locking model use should be restricted to the PVNGS Borg-Warner and Anchor-Darling Flexible Wedge gate valves since the model is sensitive to the relative gate dimensions and stiffness in the PVNGS design basis pressure and temperature ranges.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Steven A. Lopez____________													
2	Rafael Rios & Joe Daza ______________													
3	Revision 13													
4		PRESSURE LOCKING CALCULATION												
5	**Walworth 600#**	SYSTEM INPUTS						VALVE INPUTS						
6	**Gate Valve**	Tinitial	Tfinal	Pinitial	Pup	Pdown	Pnet	a	b	theta	nu	VF	***Valve Structural Limit***	
7		(degf)	(degf)	(psig)	(psig)	(psig)	(psig)	(in.)	(in.)	(deg.)			***Thrust (lbf)***	***Torque (ft-lbf)***
8	PL COLD TEST													
9	Test 226	74	74	3	1	1	3	2.7575	1.29	5	0.3	0.6	30000	475
10	Test 227	72	72	1075	1072	-4	-1	2.7575	1.29	5	0.3	0.6	30000	475
11	Test 228	77	77	1039	-3	1031	5	2.7575	1.29	5	0.3	0.6	30000	475
12	Test 229	73	73	495	-3	-1	493	2.7575	1.29	5	0.3	0.6	30000	475
13	Test 230	69	69	1065	-3	-3	1065	2.7575	1.29	5	0.3	0.6	30000	475
14	Test 231	72	72	1127	-3	363	761	2.7575	1.29	5	0.3	0.6	30000	475
15	Test 232	73	73	1056	318	-3	735	2.7575	1.29	5	0.3	0.6	30000	475
16	Test 233	70	70	1	-1	-2	0	2.7575	1.29	5	0.3	0.6	30000	475
17	Test 234	71	71	1012	1009	-2	1	2.7575	1.29	5	0.3	0.6	30000	475
18	Test 235	71	71	1041	-3	1034	4	2.7575	1.29	5	0.3	0.6	30000	475
19	Test 237	70	70	-2	-3	-4	-3	2.7575	1.29	5	0.3	0.6	30000	475
20														
21	PL HOT TEST													
22	Test 307	203	203	1073	34	-2	1037	2.7575	1.29	5	0.3	0.6	30000	475
23	Test 308	217	217	16	14	12	14	2.7575	1.29	5	0.3	0.6	30000	475
24	Test 309	190	190	1024	1022	-2	0	2.7575	1.29	5	0.3	0.6	30000	475
25	Test 310	187	187	922	0	916	6	2.7575	1.29	5	0.3	0.6	30000	475
26	Test 312	71	71	207	200	196	203	2.7575	1.29	5	0.3	0.6	30000	475
27	Test 313	69	69	1056	1053	5	8	2.7575	1.29	5	0.3	0.6	30000	475
28	Test 314	67	67	1062	6	1055	13	2.7575	1.29	5	0.3	0.6	30000	475
29	Test 316	205	205	1141	-1	-3	1139	2.7575	1.29	5	0.3	0.6	30000	475
30	Test 317	179	179	9	9	8	8	2.7575	1.29	5	0.3	0.6	30000	475
31	Test 318	181	181	1061	1059	-4	-2	2.7575	1.29	5	0.3	0.6	30000	475
32	Test 319	182	182	1010	-3	1003	4	2.7575	1.29	5	0.3	0.6	30000	475
33	Test 322	69	69	44	41	57	28	2.7575	1.29	5	0.3	0.6	30000	475

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Steven A. Lopez													
2	Rafael Rios & Joe Daza													
3	Revision 13													
4		**PRESSURE LOCKING CALCULATION**												
5	**Walworth 600#**	**SYSTEM INPUTS**						**VALVE INPUTS**						
6	**Gate Valve**	Tinitial	Tfinal	Pinitial	Pup	Pdown	Pnet	a	b	theta	nu	VF	***Valve Structural Limit***	
7		(degf)	(degf)	(psig)	(psig)	(psig)	(psig)	(in.)	(in.)	(deg.)			***Thrust (lbf)***	***Torque (ft-lbf)***
34	Test 323	67	67	1007	1004	44	47	2.7575	1.29	5	0.3	0.6	30000	475
35	Test 324	76	76	1015	39	1009	45	2.7575	1.29	5	0.3	0.6	30000	475
36	Test 325	71	71	49	46	44	47	2.7575	1.29	5	0.3	0.6	30000	475
37	Test 326	66	66	1100	1097	-4	-1	2.7575	1.29	5	0.3	0.6	30000	475
38	Test 327	70	70	1073	-3	1066	4	2.7575	1.29	5	0.3	0.6	30000	475
39	Test 329	125	125	1105	35	-3	1067	2.7575	1.29	5	0.3	0.6	30000	475
40	Test 330	148	148	42	67	55	30	2.7575	1.29	5	0.3	0.6	30000	475
41	Test 331	136	136	1083	1080	-4	-1	2.7575	1.29	5	0.3	0.6	30000	475
42	Test 332	133	133	1047	-2	1040	5	2.7575	1.29	5	0.3	0.6	30000	475
43	Test 341	66	66	1119	-1	1114	4	2.7575	1.29	5	0.3	0.6	30000	475
44	Test 342	70	70	2	1	2	1	2.7575	1.29	5	0.3	0.6	30000	475
45	Test 343	65	65	1050	2	3	1049	2.7575	1.29	5	0.3	0.6	30000	475

	A	P	Q	R	S	T	U	V	W	Y	Z	AA	AB	AC
1	Steven A. Lopez__													
2	Rafael Rios & Joe													
3	Revision 13													
4														
5	**Walworth 600#**	**MOV ACTUATOR/STEM INPUTS**								**MOTOR INPUTS**				
6	**Gate Valve**	OAR	P.O. Eff	COF	Dstem	Pstem	Lstem	***Actuator Structural Limit***		Vfull	Vmin	MTorq	n	TDF
7					(in.)	(in./th.)	(in./rev.)	***Thrust (lbf)***	***Torque (ft-lbf)***	(volts)	(volts)	(ft-lbf)		
8	PL COLD TEST													
9	Test 226	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
10	Test 227	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
11	Test 228	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
12	Test 229	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
13	Test 230	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
14	Test 231	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
15	Test 232	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
16	Test 233	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
17	Test 234	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
18	Test 235	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
19	Test 237	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
20														
21	PL HOT TEST													
22	Test 307	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
23	Test 308	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
24	Test 309	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
25	Test 310	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
26	Test 312	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
27	Test 313	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
28	Test 314	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
29	Test 316	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
30	Test 317	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
31	Test 318	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
32	Test 319	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
33	Test 322	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98

	A	P	Q	R	S	T	U	V	W	Y	Z	AA	AB	AC
1	Steven A. Lopez__													
2	Rafael Rios & Joe													
3	Revision 13													
4														
5	**Walworth 600#**	**MOV ACTUATOR/STEM INPUTS**								**MOTOR INPUTS**				
6	**Gate Valve**	OAR	P.O. Eff	COF	Dstem	Pstem	Lstem	***Actuator Structural Limit***		Vfull	Vmin	MTorq	n	TDF
7					(in.)	(in./th.)	(in./rev.)	***Thrust (lbf)***	***Torque (ft-lbf)***	(volts)	(volts)	(ft-lbf)		
34	Test 323	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
35	Test 324	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
36	Test 325	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
37	Test 326	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
38	Test 327	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
39	Test 329	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
40	Test 330	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
41	Test 331	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
42	Test 332	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
43	Test 341	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
44	Test 342	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98
45	Test 343	48.95	0.4	0.12	1.25	0.250	0.500	*24,000*	*500*	460	415	25	2	0.98

	A	AD	AE	AF	AG	AH	AI	AJ	AK
1	Steven A. Lopez__								
2	Rafael Rios & Joe								
3	Revision 13								
4					***Calculation of Minimum Available***			**CALCULATION**	
5	**Walworth 600#**	**MOV MISC INPUTS**			***Torque and Thrust at Motor Stall***			**DP X DISKS**	
6	**Gate Valve**	Max Close	% Residual	Stem Factor	***Avail Torque***	***Avail Thrust***	VDF	Pfinal	DPavg
7		Load (lbf)	Load		(ft-lbf)	(lbf)		(psig)	(psig)
8	PL COLD TEST								
9	Test 226	6,200	100%	0.0127	*432*	*34,093*	0.900	3	2
10	Test 227	6,200	54%	0.0127	*432*	*34,093*	0.900	1,075	541
11	Test 228	6,200	55%	0.0127	*432*	*34,093*	0.900	1,039	525
12	Test 229	6,200	79%	0.0127	*432*	*34,093*	0.900	495	497
13	Test 230	6,200	54%	0.0127	*432*	*34,093*	0.900	1,065	1068
14	Test 231	6,200	52%	0.0127	*432*	*34,093*	0.900	1,127	947
15	Test 232	6,200	55%	0.0127	*432*	*34,093*	0.900	1,056	899
16	Test 233	6,200	100%	0.0127	*432*	*34,093*	0.900	1	3
17	Test 234	6,200	69%	0.0127	*432*	*34,093*	0.900	1,012	509
18	Test 235	6,200	68%	0.0127	*432*	*34,093*	0.900	1,041	526
19	Test 237	6,200	100%	0.0127	*432*	*34,093*	0.900	-2	2
20									
21	PL HOT TEST								
22	Test 307	6,200	68%	0.0127	*432*	*34,093*	0.900	1,073	1057
23	Test 308	6,200	100%	0.0127	*432*	*34,093*	0.900	16	3
24	Test 309	6,200	70%	0.0127	*432*	*34,093*	0.900	1,024	514
25	Test 310	6,200	73%	0.0127	*432*	*34,093*	0.900	922	464
26	Test 312	6,200	93%	0.0127	*432*	*34,093*	0.900	207	9
27	Test 313	6,200	66%	0.0127	*432*	*34,093*	0.900	1,056	527
28	Test 314	6,200	66%	0.0127	*432*	*34,093*	0.900	1,062	532
29	Test 316	6,200	64%	0.0127	*432*	*34,093*	0.900	1,141	1143
30	Test 317	6,200	100%	0.0127	*432*	*34,093*	0.900	9	1
31	Test 318	6,200	69%	0.0127	*432*	*34,093*	0.900	1,061	534
32	Test 319	6,200	71%	0.0127	*432*	*34,093*	0.900	1,010	510
33	Test 322	6,200	98%	0.0127	*432*	*34,093*	0.900	44	-5

	A	AD	AE	AF	AG	AH	AI	AJ	AK
1	Steven A. Lopez__								
2	Rafael Rios & Joe								
3	Revision 13								
4				***Calculation of Minimum Available***				**CALCULATION**	
5	**Walworth 600#**	**MOV MISC INPUTS**		***Torque and Thrust at Motor Stall***				**DP X DISKS**	
6	**Gate Valve**	Max Close	% Residual	Stem Factor	***Avail Torque***	***Avail Thrust***	VDF	Pfinal	DPavg
7		Load (lbf)	Load		(ft-lbf)	(lbf)		(psig)	(psig)
34	Test 323	6,200	63%	0.0127	*432*	*34,093*	0.900	1,007	483
35	Test 324	6,200	63%	0.0127	*432*	*34,093*	0.900	1,015	491
36	Test 325	6,200	98%	0.0127	*432*	*34,093*	0.900	49	4
37	Test 326	6,200	48%	0.0127	*432*	*34,093*	0.900	1,100	554
38	Test 327	6,200	49%	0.0127	*432*	*34,093*	0.900	1,073	542
39	Test 329	6,200	48%	0.0127	*432*	*34,093*	0.900	1,105	1089
40	Test 330	6,200	98%	0.0127	*432*	*34,093*	0.900	42	-19
41	Test 331	6,200	60%	0.0127	*432*	*34,093*	0.900	1,083	545
42	Test 332	6,200	61%	0.0127	*432*	*34,093*	0.900	1,047	528
43	Test 341	6,200	58%	0.0127	*432*	*34,093*	0.900	1,119	563
44	Test 342	6,200	100%	0.0127	*432*	*34,093*	0.900	2	1
45	Test 343	6,200	67%	0.0127	*432*	*34,093*	0.900	1,050	1048

	A	AL	AM	AN	AO	AP	AQ	AR	AS	AT
1	Steven A. Lopez__									
2	Rafael Rios & Joe									
3	Revision 13									
4										
5	**Walworth 600#**	**Calculation of Disk Load Perpendicular to the Seat/Roak Thin Plate Theory**								
6	**Gate Valve**	C2	C3	C8	C9	L11	L17	mu	Qb	Qa
7										
8	PL COLD TEST									
9	Test 226	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	2	-1
10	Test 227	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	671	-269
11	Test 228	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	652	-261
12	Test 229	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	617	-247
13	Test 230	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	1,325	-530
14	Test 231	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	1,175	-470
15	Test 232	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	1,115	-446
16	Test 233	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	3	-1
17	Test 234	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	631	-252
18	Test 235	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	652	-261
19	Test 237	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	2	-1
20										
21	PL HOT TEST									
22	Test 307	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	1,312	-525
23	Test 308	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	4	-1
24	Test 309	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	638	-255
25	Test 310	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	576	-230
26	Test 312	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	11	-4
27	Test 313	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	654	-262
28	Test 314	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	660	-264
29	Test 316	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	1,418	-567
30	Test 317	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	1	0
31	Test 318	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	662	-265
32	Test 319	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	633	-253
33	Test 322	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	-6	2

	A	AL	AM	AN	AO	AP	AQ	AR	AS	AT
1	Steven A. Lopez__									
2	Rafael Rios & Joe									
3	Revision 13									
4										
5	**Walworth 600#**	**Calculation of Disk Load Perpendicular to the Seat/Roak Thin Plate Theory**								
6	**Gate Valve**	C2	C3	C8	C9	L11	L17	mu	Qb	Qa
7										
34	Test 323	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	599	-240
35	Test 324	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	609	-244
36	Test 325	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	5	-2
37	Test 326	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	687	-275
38	Test 327	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	672	-269
39	Test 329	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	1,351	-541
40	Test 330	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	-24	9
41	Test 331	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	676	-271
42	Test 332	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	655	-262
43	Test 341	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	698	-279
44	Test 342	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	1	0
45	Test 343	0.1122	0.0169	0.7266	0.2950	0.00251	0.0996	0.6307	1,300	-520

	A	AU	AV	AW	AX	AY	AZ	BA
1	Steven A. Lopez__							
2	Rafael Rios & Joe							
3	Revision 13							**Total Stem Thrust**
4				Static	**Residual Closing**	**Vertical Load**	**Stem piston**	**Req'd to Overcome**
5	**Walworth 600#**	**Disk Load**	**Hub Load**	Peak	**Load at Cracking**	**On Disks**	**Load**	**Press Locking**
6	**Gate Valve**	w/DPavg	Pup-Pdown	Cracking	Residual Load	Fvert	Fpiston	Ftotal
7		(lbf)	(lbf)	(lbf)	(lbf)	(lbf)	(lbf)	(lbf)
8	PL COLD TEST							
9	Test 226	22	6	4,353	4,347	8	4	4,380
10	Test 227	5,870	3,218	4,353	2,345	2,253	1,319	12,366
11	Test 228	5,696	3,098	4,353	2,412	2,186	1,275	12,117
12	Test 229	5,392	12	4,353	3,428	2,069	607	10,295
13	Test 230	11,588	18	4,353	2,363	4,447	1,307	17,110
14	Test 231	10,275	1,085	4,353	2,248	3,943	1,383	16,168
15	Test 232	9,749	949	4,353	2,380	3,741	1,296	15,524
16	Test 233	27	9	6,065	6,063	10	1	6,108
17	Test 234	5,517	3,034	6,065	4,174	2,117	1,242	13,601
18	Test 235	5,702	3,107	6,065	4,120	2,188	1,277	13,839
19	Test 237	16	21	10,612	10,608	6	-2	10,654
20								
21	PL HOT TEST							
22	Test 307	11,469	96	6,354	4,349	4,401	1,317	18,999
23	Test 308	33	78	6,354	6,324	12	20	6,428
24	Test 309	5,577	3,073	6,354	4,441	2,140	1,257	13,975
25	Test 310	5,034	2,760	6,354	4,632	1,932	1,131	13,227
26	Test 312	98	1,193	5,866	5,479	37	254	6,554
27	Test 313	5,718	3,188	5,866	3,893	2,194	1,296	13,698
28	Test 314	5,767	3,197	5,866	3,882	2,213	1,303	13,756
29	Test 316	12,402	12	5,866	3,734	4,759	1,400	19,507
30	Test 317	5	51	6,404	6,387	2	11	6,435
31	Test 318	5,789	3,179	6,404	4,422	2,221	1,302	14,309
32	Test 319	5,534	3,013	6,404	4,517	2,124	1,239	13,948
33	Test 322	-54	295	5,102	5,020	-21	54	5,186

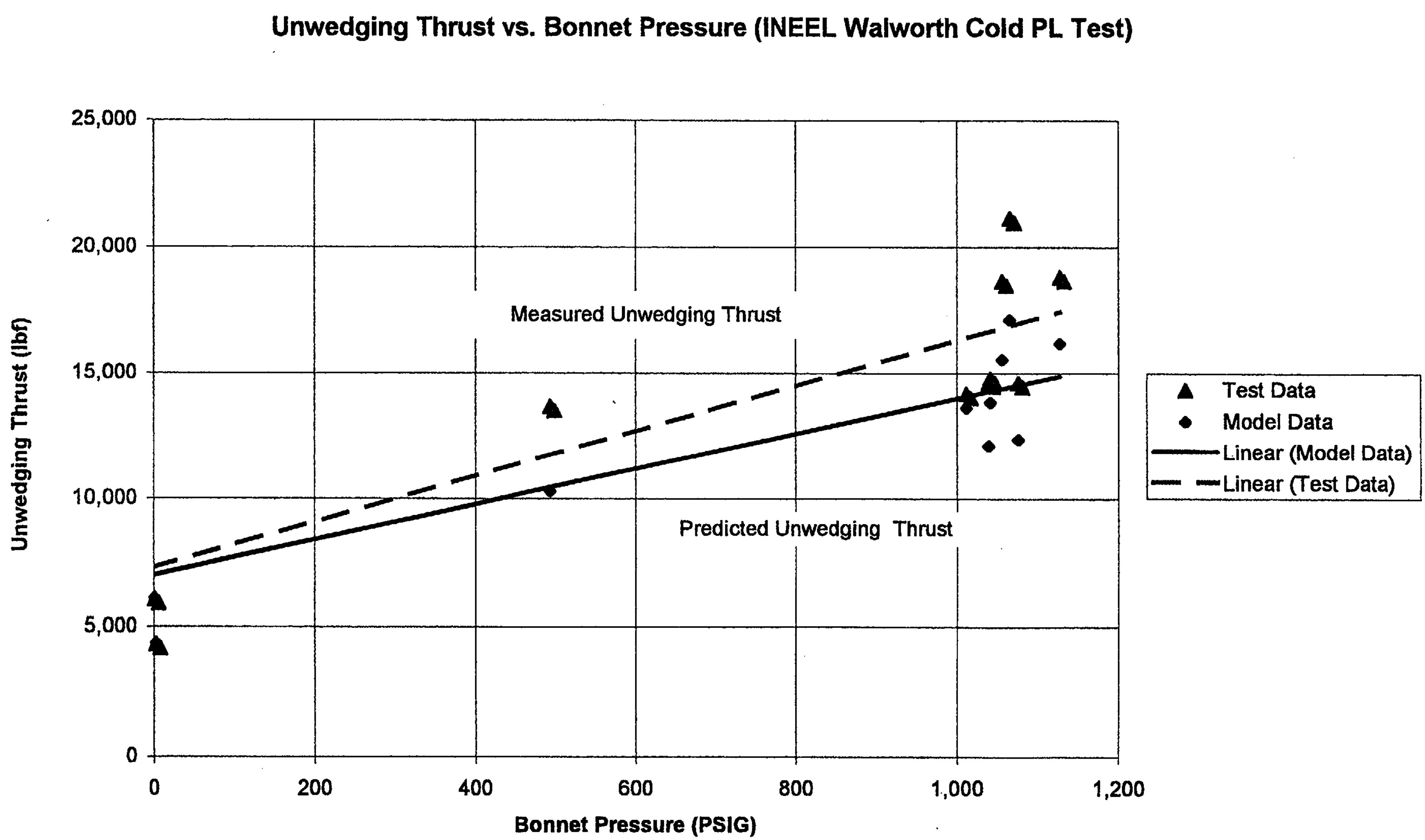
	A	AU	AV	AW	AX	AY	AZ	BA
1	Steven A. Lopez__							
2	Rafael Rios & Joe							
3	Revision 13							**Total Stem Thrust**
4				Static	**Residual Closing**	**Vertical Load**	**Stem piston**	**Req'd to Overcome**
5	**Walworth 600#**	**Disk Load**	**Hub Load**	Peak	**Load at Cracking**	**On Disks**	**Load**	**Press Locking**
6	**Gate Valve**	w/DPavg	Pup-Pdown	Cracking	Residual Load	Fvert	Fpiston	Ftotal
7		(lbf)	(lbf)	(lbf)	(lbf)	(lbf)	(lbf)	(lbf)
34	Test 323	5,241	3,158	5,102	3,221	2,011	1,236	12,395
35	Test 324	5,327	3,158	5,102	3,206	2,045	1,246	12,490
36	Test 325	43	271	3,944	3,852	17	60	4,124
37	Test 326	6,006	3,293	3,944	1,889	2,305	1,350	12,143
38	Test 327	5,875	3,203	3,944	1,939	2,255	1,317	11,956
39	Test 329	11,816	96	3,944	1,880	4,535	1,356	16,970
40	Test 330	-206	368	5,022	4,944	-79	52	4,974
41	Test 331	5,913	3,242	5,022	2,999	2,269	1,329	13,095
42	Test 332	5,729	3,128	5,022	3,066	2,199	1,285	12,836
43	Test 341	6,103	3,354	5,022	2,931	2,342	1,373	13,357
44	Test 342	5	9	5,924	5,920	2	2	5,934
45	Test 343	11,365	15	5,924	3,962	4,362	1,289	18,416

	A	BB	BC	BG	BH	BI
1	Steven A. Lopez__					
2	Rafael Rios & Joe		**MOV Min Avail**			
3	Revision 13	**Total Torque Required**	**Thrust due to**	**MARGIN**		
4		**to Overcome Pressure**	**Structural Limit or**	LIMITING THRUST		
5	**Walworth 600#**	**Locking**	**Motor Torque Limit**	subtract	**MARGIN**	
6	**Gate Valve**	Required Torque	Limiting Thrust	REQUIRED THRUST	DESIGN	Suscept?
7		(ft-lbf)	(lbf)	(lbf)	(%)	
8	PL COLD TEST					
9	Test 226	55	24,000	19,620	448.0	No
10	Test 227	157	24,000	11,634	94.1	No
11	Test 228	153	24,000	11,883	98.1	No
12	Test 229	130	24,000	13,705	133.1	No
13	Test 230	217	24,000	6,890	40.3	No
14	Test 231	205	24,000	7,832	48.4	No
15	Test 232	197	24,000	8,476	54.6	No
16	Test 233	77	24,000	17,892	292.9	No
17	Test 234	172	24,000	10,399	76.5	No
18	Test 235	175	24,000	10,161	73.4	No
19	Test 237	135	24,000	13,346	125.3	No
20						
21	PL HOT TEST					
22	Test 307	241	24,000	5,001	26.3	No
23	Test 308	81	24,000	17,572	273.4	No
24	Test 309	177	24,000	10,025	71.7	No
25	Test 310	167	24,000	10,773	81.5	No
26	Test 312	83	24,000	17,446	266.2	No
27	Test 313	173	24,000	10,302	75.2	No
28	Test 314	174	24,000	10,244	74.5	No
29	Test 316	247	24,000	4,493	23.0	No
30	Test 317	81	24,000	17,565	273.0	No
31	Test 318	181	24,000	9,691	67.7	No
32	Test 319	177	24,000	10,052	72.1	No
33	Test 322	66	24,000	18,814	362.8	No

	A	BB	BC	BG	BH	BI
1	Steven A. Lopez__					
2	Rafael Rios & Joe		**MOV Min Avail**			
3	Revision 13	**Total Torque Required**	**Thrust due to**	**MARGIN**		
4		**to Overcome Pressure**	**Structural Limit or**	LIMITING THRUST		
5	**Walworth 600#**	**Locking**	**Motor Torque Limit**	subtract	**MARGIN**	
6	**Gate Valve**	Required Torque	Limiting Thrust	REQUIRED THRUST	DESIGN	Suscept?
7		(ft-lbf)	(lbf)	(lbf)	(%)	
34	Test 323	157	24,000	11,605	93.6	No
35	Test 324	158	24,000	11,510	92.2	No
36	Test 325	52	24,000	19,876	482.0	No
37	Test 326	154	24,000	11,857	97.6	No
38	Test 327	151	24,000	12,044	100.7	No
39	Test 329	215	24,000	7,030	41.4	No
40	Test 330	63	24,000	19,026	382.5	No
41	Test 331	166	24,000	10,905	83.3	No
42	Test 332	163	24,000	11,164	87.0	No
43	Test 341	169	24,000	10,643	79.7	No
44	Test 342	75	24,000	18,066	304.4	No
45	Test 343	233	24,000	5,584	30.3	No

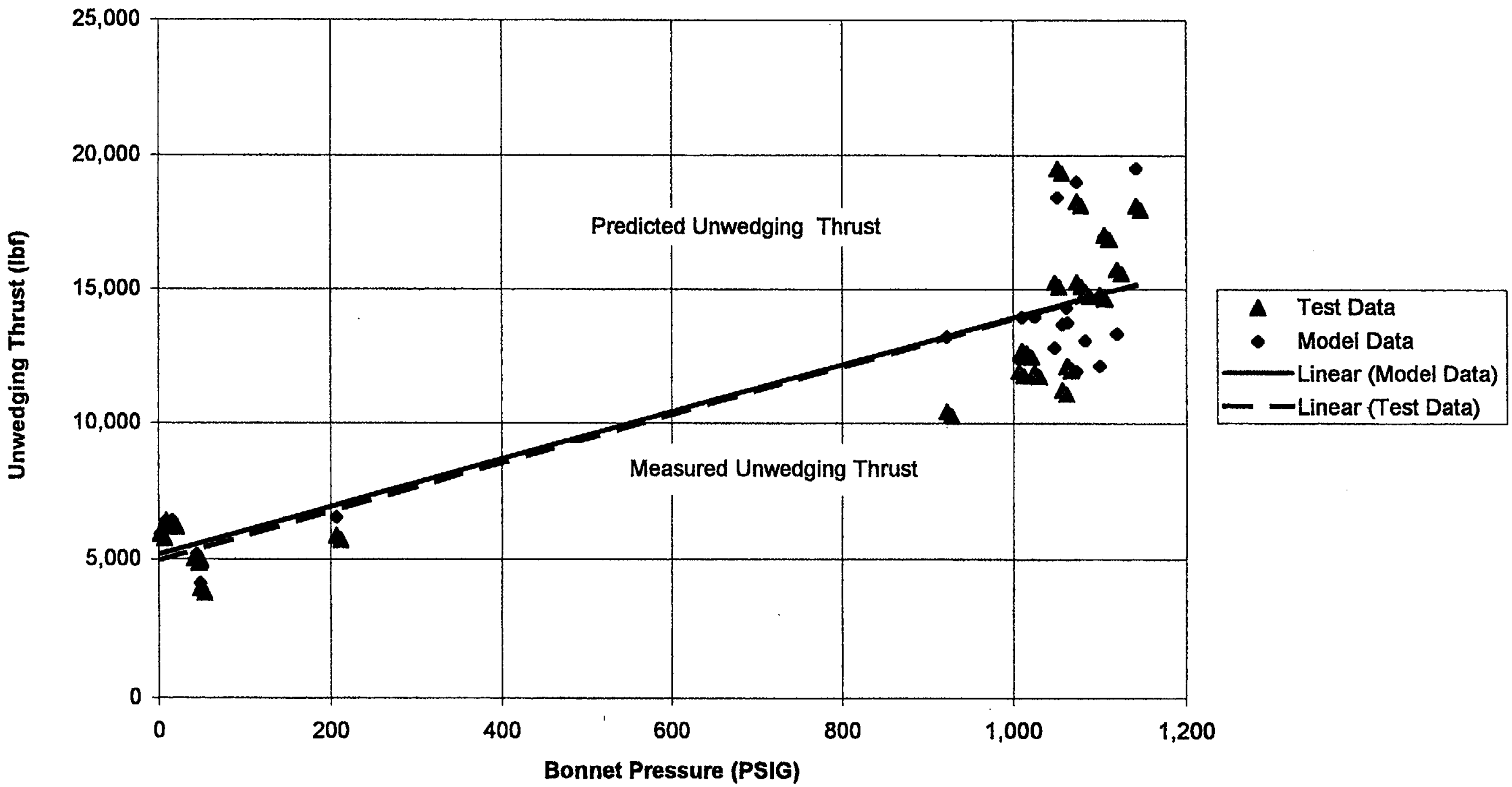
	A	BJ	BK	BL	BM	BN	BO
1	Steven A. Lopez__						
2	Rafael Rios & Joe	Additional					
3	Revision 13	PL		**FRACTION**	**MEASURED**	**MARGIN**	**LOADING**
4		Load	**DIMEN.**	**RESIDUAL**	**PEAK**	**(P-M/M)**	**TYPE**
5	**Walworth 600#**	"(PL Load	**CORR.**	**OF CLOSING**	**UNWEDGING**	***100**	
6	**Gate Valve**	-Res. Load)"				**%**	
7		(lbf)					
8	PL COLD TEST						
9	Test 226	32	0.009	0.999	4,353	0.6	S
10	Test 227	10,022	3.076	0.539	14,590	-15.2	HD
11	Test 228	9,705	2.973	0.554	14,612	-17.1	HU
12	Test 229	6,867	1.416	0.788	13,652	-24.6	PL
13	Test 230	14,746	3.047	0.543	21,132	-19.0	PL
14	Test 231	13,920	3.225	0.516	18,798	-14.0	PL
15	Test 232	13,143	3.021	0.547	18,634	-16.7	PL
16	Test 233	45	0.002	1.000	6,065	0.7	S
17	Test 234	9,427	2.078	0.688	14,177	-4.1	HD
18	Test 235	9,719	2.138	0.679	14,778	-6.4	HU
19	Test 237	46	0.002	1.000	10,612	0.4	S
20							
21	PL HOT TEST						
22	Test 307	14,650	2.103	0.685	18,251	4.1	PL
23	Test 308	104	0.031	0.995	6,354	1.2	S
24	Test 309	9,534	2.007	0.699	11,895	17.5	HD
25	Test 310	8,595	1.807	0.729	10,429	26.8	HU
26	Test 312	1,074	0.440	0.934	5,866	11.7	S
27	Test 313	9,805	2.242	0.664	11,226	22.0	HD
28	Test 314	9,874	2.255	0.662	12,142	13.3	HU
29	Test 316	15,773	2.423	0.637	18,096	7.8	PL
30	Test 317	48	0.018	0.997	6,404	0.5	S
31	Test 318	9,887	2.063	0.690	12,108	18.2	HD
32	Test 319	9,431	1.964	0.705	12,703	9.8	HU
33	Test 322	166	0.107	0.984	5,102	1.6	S

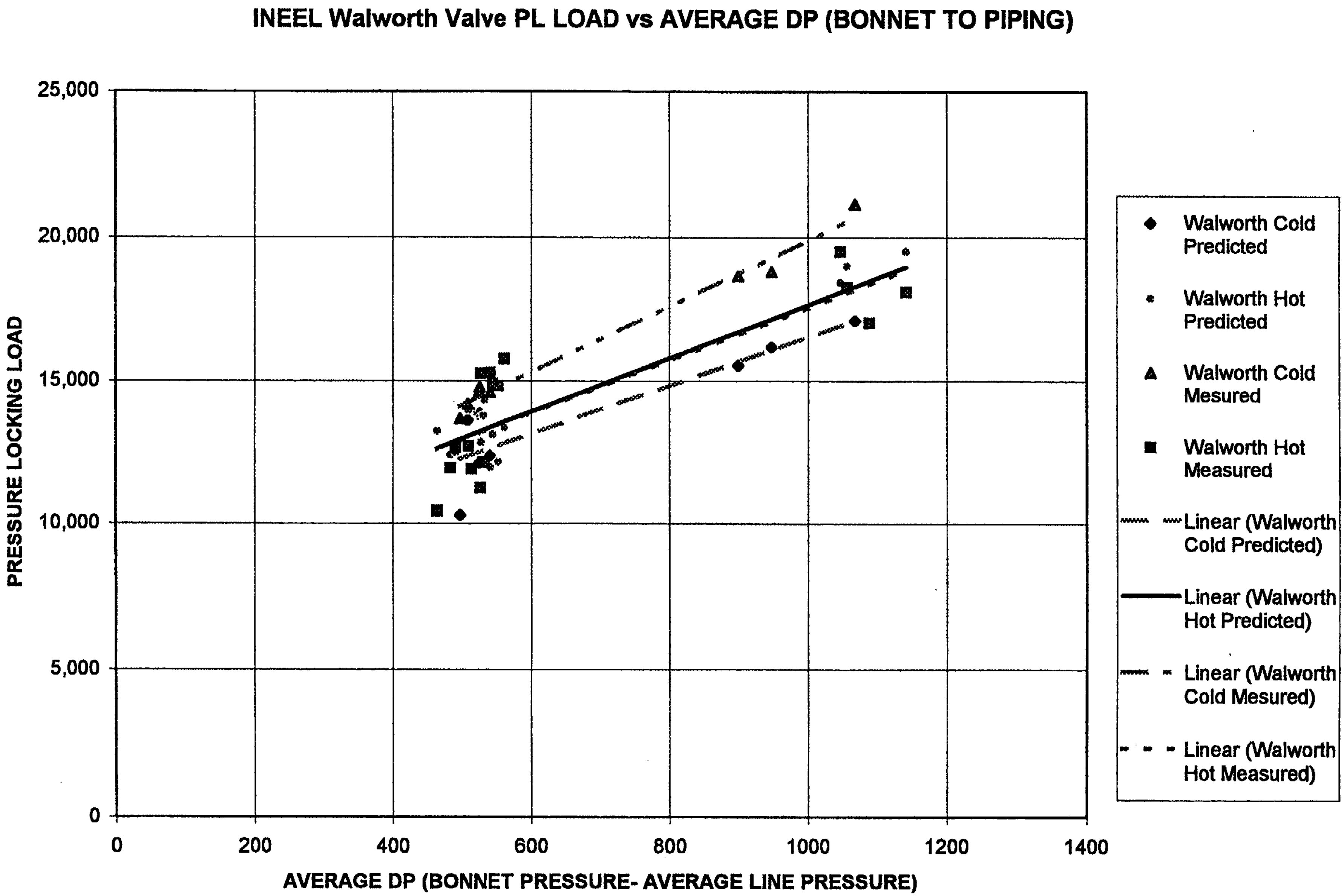
	A	BJ	BK	BL	BM	BN	BO
1	Steven A. Lopez__						
2	Rafael Rios & Joe	Additional					
3	Revision 13	PL		**FRACTION**	**MEASURED**	**MARGIN**	**LOADING**
4		Load	**DIMEN.**	**RESIDUAL**	**PEAK**	**(P-M/M)**	**TYPE**
5	**Walworth 600#**	"(PL Load	**CORR.**	**OF CLOSING**	**UNWEDGING**	***100**	
6	**Gate Valve**	-Res. Load)"				**%**	
7		(lbf)					
34	Test 323	9,174	2.458	0.631	11,936	3.8	HD
35	Test 324	9,284	2.478	0.628	12,636	-1.2	HU
36	Test 325	271	0.155	0.977	3,944	4.6	S
37	Test 326	10,254	3.474	0.479	14,801	-18.0	HD
38	Test 327	10,016	3.388	0.492	15,256	-21.6	HU
39	Test 329	15,091	3.489	0.477	17,010	-0.2	PL
40	Test 330	31	0.104	0.984	5,022	-0.9	S
41	Test 331	10,096	2.686	0.597	14,893	-12.1	HD
42	Test 332	9,770	2.597	0.611	15,242	-15.8	HU
43	Test 341	10,426	2.775	0.584	15,742	-15.1	HU
44	Test 342	14	0.004	0.999	5,924	0.2	S
45	Test 343	14,454	2.208	0.669	19,501	-5.6	PL



Unwedging Thrust vs. Bonnet Pressure (INEEL Walworth Cold PL Test)
25,000
20,000
15,000
10,000
5,000
0
Unwedging Thrust (lbf)
Measured Unwedging Thrust
Predicted Unwedging Thrust
0
200
400
600
800
1,000
1,200
Bonnet Pressure (PSIG)
Test Data
Model Data
Linear (Model Data)
Linear (Test Data)

Unwedging Thrust vs. Bonnet Pressure (INEEL Walworth Thermal PL Test)




INEEL Walworth Valve PL LOAD vs AVERAGE DP (BONNET TO PIPING)
PRESSURE LOCKING LOAD
25,000
20,000
15,000
10,000
5,000
0
0
200
400
600
800
1000
1200
1400
AVERAGE DP (BONNET PRESSURE- AVERAGE LINE PRESSURE)
Walworth Cold Predicted
Walworth Hot Predicted
Walworth Cold Mesured
Walworth Hot Measured
Linear (Walworth Cold Predicted)
Linear (Walworth Hot Predicted)
Linear (Walworth Cold Mesured)
Linear (Walworth Hot Measured)

Pete Knaggs & Steven A. Lopez														
Rafael Rios & Joe Daza														
Revision 13														
	PRESSURE LOCKING CALCULATION													
10"Crane 900 # Gate Valve	**SYSTEM INPUTS**						**VALVE INPUTS**							
	Tinitial	Tfinal	Pinitial	Pup	Pdown	Pini-Pav	a	b	theta	nu	VF		COF	Dstem
	(degf)	(degf)	(psig)	(psig)	(psig)	(psig)	(in.)	(in.)	(deg.)					(in.)
PRESSURE LOCKING TEST														
CRANE (10") test# 6	104	104	650	350	350	300.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 7	104	104	850	350	350	500.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 9	104	104	1,000	350	350	650.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 10	104	104	1,040	350	350	690.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 13	104	104	1,195	0	0	1195.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 14	104	104	1,375	0	0	1375.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 15	104	104	1,375	0	0	1375.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 34	104	104	655	350	350	305.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 35	104	104	655	350	350	305.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 38	104	104	1,000	350	350	650.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 39	104	104	1,040	350	350	690.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 42	104	104	1,365	0	0	1365.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 43	104	104	1,165	0	0	1165.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 46	104	104	1,575	0	0	1575.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 47	104	104	1,575	0	0	1575.00	4.36	1.25	5	0.3	0.45		0.12	1.25
CRANE (10") test# 50	104	104	1,775	0	0	1775.00	4.36	1.25	5	0.3	0.45		0.12	1.25

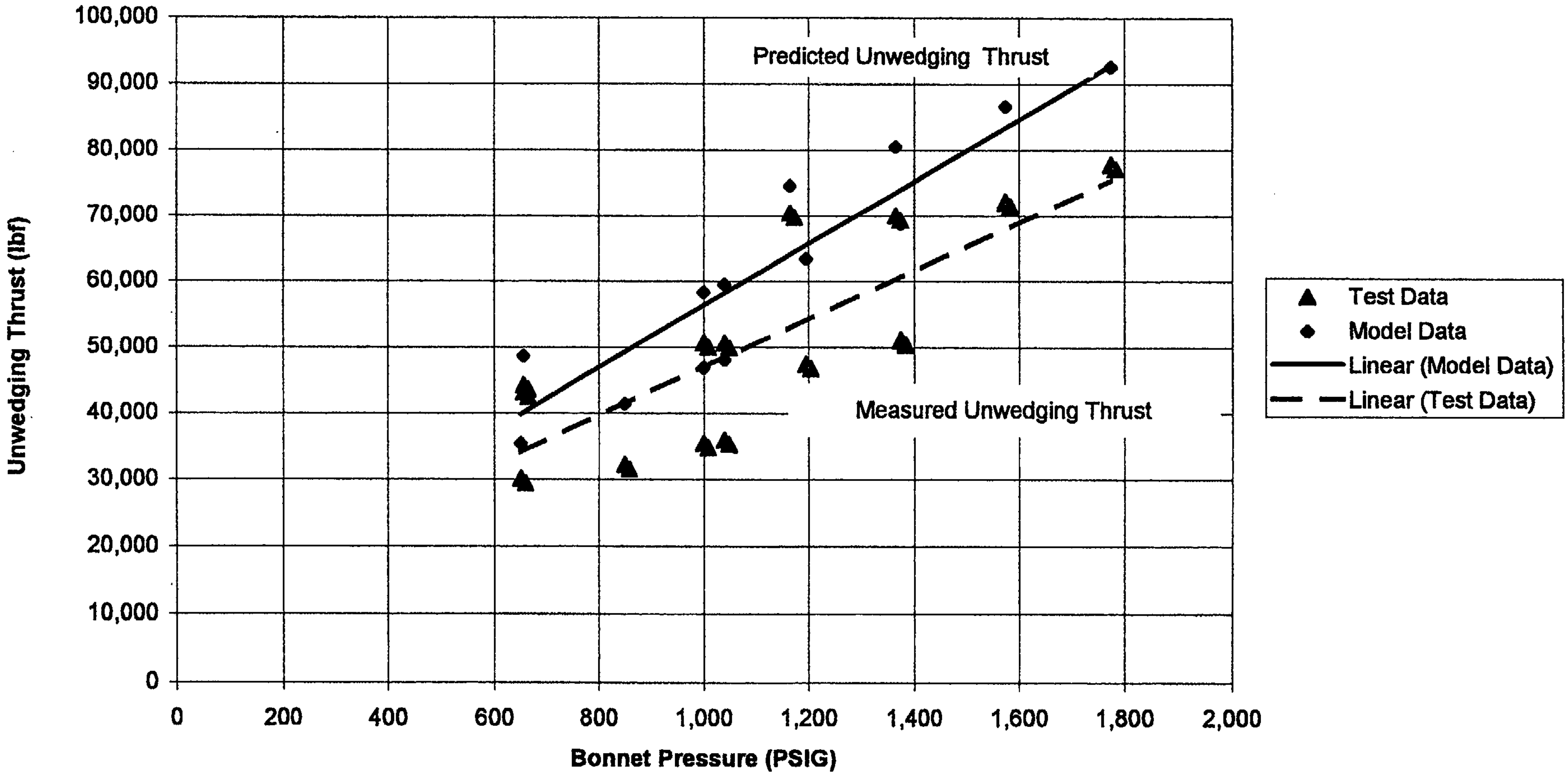
Pete Knaggs & Steven A. Lopez									
Rafael Rios & Joe Daza______									
Revision 13									
									BONNET
10"Crane 900 # Gate Valve					**MOV MISC INPUTS**				**PRESS.**
	Pstem	Lstem		TDF	Max Close	% Residual	Stem Factor	VDF	Pfinal
	(in./th.)	(in./rev.)			Load (lbf)	Load			(psig)
PRESSURE LOCKING TEST									
CRANE (10") test# 6	0.250	0.500		0.98	6,200	86%	0.0127	0.900	650
CRANE (10") test# 7	0.250	0.500		0.98	6,200	81%	0.0127	0.900	850
CRANE (10") test# 9	0.250	0.500		0.98	6,200	79%	0.0127	0.900	1,000
CRANE (10") test# 10	0.250	0.500		0.98	6,200	78%	0.0127	0.900	1,040
CRANE (10") test# 13	0.250	0.500		0.98	6,200	77%	0.0127	0.900	1,195
CRANE (10") test# 14	0.250	0.500		0.98	6,200	73%	0.0127	0.900	1,375
CRANE (10") test# 15	0.250	0.500		0.98	6,200	73%	0.0127	0.900	1,375
CRANE (10") test# 34	0.250	0.500		0.98	6,200	91%	0.0127	0.900	655
CRANE (10") test# 35	0.250	0.500		0.98	6,200	91%	0.0127	0.900	655
CRANE (10") test# 38	0.250	0.500		0.98	6,200	85%	0.0127	0.900	1,000
CRANE (10") test# 39	0.250	0.500		0.98	6,200	85%	0.0127	0.900	1,040
CRANE (10") test# 42	0.250	0.500		0.98	6,200	81%	0.0127	0.900	1,365
CRANE (10") test# 43	0.250	0.500		0.98	6,200	84%	0.0127	0.900	1,165
CRANE (10") test# 46	0.250	0.500		0.98	6,200	78%	0.0127	0.900	1,575
CRANE (10") test# 47	0.250	0.500		0.98	6,200	78%	0.0127	0.900	1,575
CRANE (10") test# 50	0.250	0.500		0.98	6,200	76%	0.0127	0.900	1,775

Pete Knaggs & Steven A. Lopez								
Rafael Rios & Joe Daza______								
Revision 13								
	CALC DP							Static
10"Crane 900 # Gate Valve	**X DISK**					**Disk Load**	**Hub Load**	Peak
	DPavg	L17	mu	Qb	Qa	w/DPavg	Pup-Pdown	Cracking
	(psig)					(lbf)	(lbf / in)	(lbf)
PRESSURE LOCKING TEST								
CRANE (10") test# 6	300	0.1526	0.4666	1,032	-304	7,781	3,901	25,000
CRANE (10") test# 7	500	0.1526	0.4666	1,720	-507	12,969	3,901	25,000
CRANE (10") test# 9	650	0.1526	0.4666	2,236	-659	16,859	3,901	26,000
CRANE (10") test# 10	690	0.1526	0.4666	2,374	-700	17,897	3,901	26,000
CRANE (10") test# 13	1195	0.1526	0.4666	4,111	-1,212	30,995	-	28,000
CRANE (10") test# 14	1375	0.1526	0.4666	4,730	-1,395	35,664	-	28,000
CRANE (10") test# 15	1375	0.1526	0.4666	4,730	-1,395	35,664	-	28,000
CRANE (10") test# 34	305	0.1526	0.4666	1,049	-309	7,911	3,901	38,000
CRANE (10") test# 35	305	0.1526	0.4666	1,049	-309	7,911	3,901	38,000
CRANE (10") test# 38	650	0.1526	0.4666	2,236	-659	16,859	3,901	37,500
CRANE (10") test# 39	690	0.1526	0.4666	2,374	-700	17,897	3,901	37,500
CRANE (10") test# 42	1365	0.1526	0.4666	4,695	-1,385	35,405	-	40,000
CRANE (10") test# 43	1165	0.1526	0.4666	4,007	-1,182	30,217	-	40,000
CRANE (10") test# 46	1575	0.1526	0.4666	5,418	-1,598	40,851	-	40,000
CRANE (10") test# 47	1575	0.1526	0.4666	5,418	-1,598	40,851	-	40,000
CRANE (10") test# 50	1775	0.1526	0.4666	6,106	-1,801	46,039	-	40,000

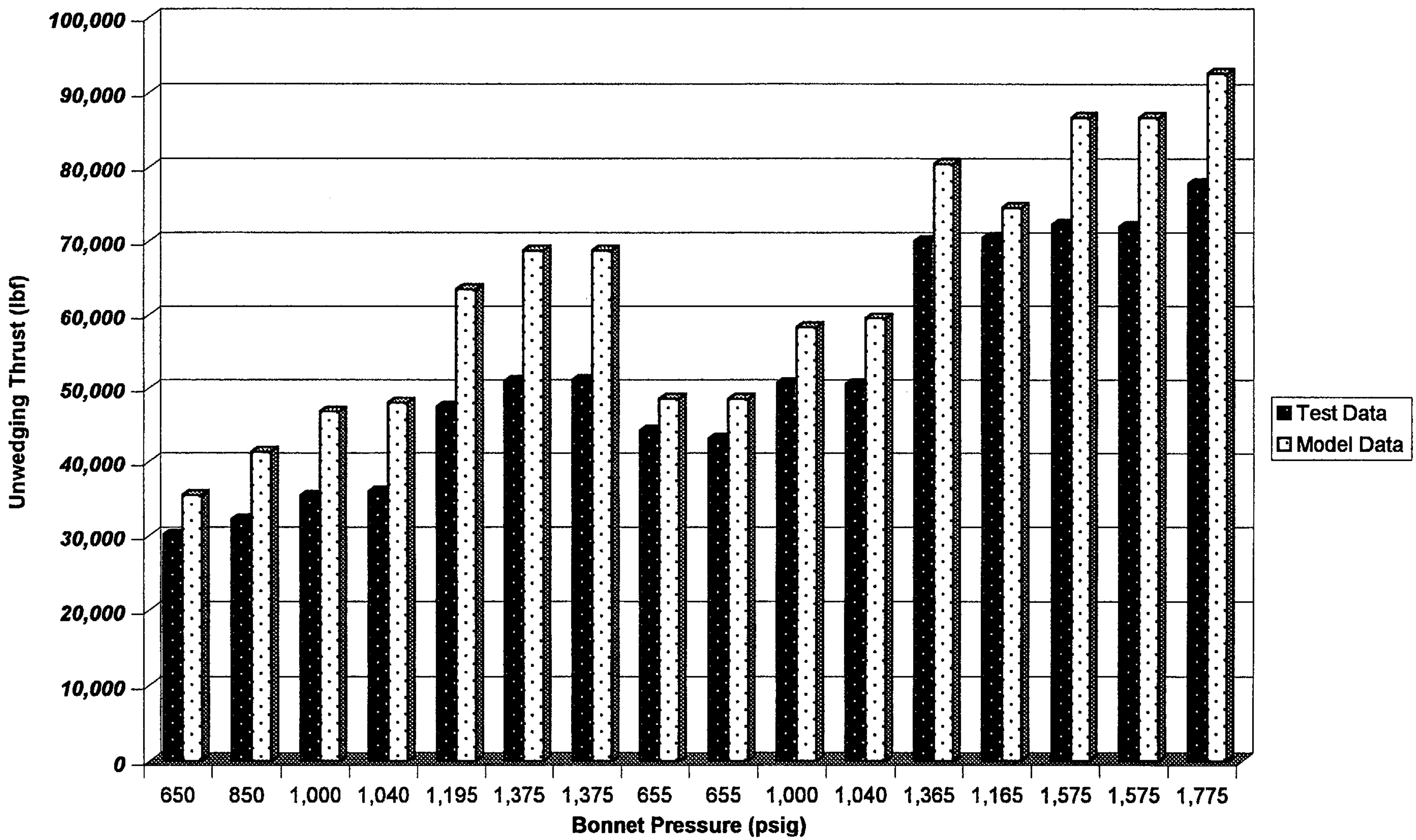
Pete Knaggs & Steven A. Lopez					
Rafael Rios & Joe Daza______					
Revision 13				**Total Stem Thrust**	**Total Torque Required**
	Residual Closing	**Vertical Load**	**Stem piston**	**Req'd to Overcome**	**to Overcome Pressure**
10"Crane 900 # Gate Valve	**Load at Cracking**	**On Disks**	**Load**	**Press Locking**	**Locking**
	Residual Load	Fvert	Fpiston	Ftotal	Required Torque
	(lbf)	(lbf)	(lbf)	(lbf)	(ft-lbf)
PRESSURE LOCKING TEST					
CRANE (10") test# 6	21,433	3,123	798	35,441	449
CRANE (10") test# 7	20,336	5,205	1,043	41,367	524
CRANE (10") test# 9	20,512	6,766	1,227	46,812	593
CRANE (10") test# 10	20,293	7,183	1,276	47,997	608
CRANE (10") test# 13	21,442	12,440	1,466	63,411	803
CRANE (10") test# 14	20,455	14,314	1,687	68,745	871
CRANE (10") test# 15	20,455	14,314	1,687	68,745	871
CRANE (10") test# 34	34,406	3,175	804	48,589	615
CRANE (10") test# 35	34,406	3,175	804	48,589	615
CRANE (10") test# 38	32,012	6,766	1,227	58,312	738
CRANE (10") test# 39	31,793	7,183	1,276	59,497	753
CRANE (10") test# 42	32,509	14,210	1,675	80,448	1,019
CRANE (10") test# 43	33,607	12,128	1,430	74,522	944
CRANE (10") test# 46	31,357	16,396	1,933	86,671	1,098
CRANE (10") test# 47	31,357	16,396	1,933	86,671	1,098
CRANE (10") test# 50	30,259	18,478	2,178	92,598	1,173

Pete Knaggs & Steven A. Lopez						
Rafael Rios & Joe Daza______	Additional					
Revision 13	PL		**FRACTION**	**MEASURED**	**MARGIN**	**MEASURED**
	Load	**DIMEN.**	**RESIDUAL**	**PEAK**	**(P-M/M)**	**PL**
10"Crane 900 # Gate Valve	"(PL Load	**CORR.**	**OF CLOSING**	**UNWEDGING**	***100**	**INCREASE**
	-Res. Load)"				**%**	
	(lbf)					
PRESSURE LOCKING TEST						
CRANE (10") test# 6	14,008	0.951	0.857	30,103	17.7	5103
CRANE (10") test# 7	21,032	1.244	0.813	32,213	28.4	7213
CRANE (10") test# 9	26,300	1.407	0.789	35,421	32.2	9421
CRANE (10") test# 10	27,704	1.463	0.780	35,922	33.6	9922
CRANE (10") test# 13	41,969	1.561	0.766	47,462	33.6	19462
CRANE (10") test# 14	48,290	1.797	0.731	50,974	34.9	22974
CRANE (10") test# 15	48,290	1.797	0.731	51,126	34.5	23126
CRANE (10") test# 34	14,183	0.631	0.905	44,243	9.8	6243
CRANE (10") test# 35	14,183	0.631	0.905	43,142	12.6	5142
CRANE (10") test# 38	26,300	0.976	0.854	50,664	15.1	13164
CRANE (10") test# 39	27,704	1.015	0.848	50,565	17.7	13065
CRANE (10") test# 42	47,939	1.248	0.813	70,028	14.9	30028
CRANE (10") test# 43	40,915	1.066	0.840	70,428	5.8	30428
CRANE (10") test# 46	55,314	1.440	0.784	72,231	20.0	32231
CRANE (10") test# 47	55,314	1.440	0.784	71,931	20.5	31931
CRANE (10") test# 50	62,338	1.623	0.756	77,749	19.1	37749

Unwedging Thrust vs. Bonnet Pressure (CRANE PL Test/PVNGS PL Model)



Unwedging Thrust vs Bonnet Pressure (Crane Test Data/PVNGS Model Data)



Unwedging Thrust vs Average DP (Bonnet to Piping)