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

Revision 0
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Commonwealth Edison Company

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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. REQUIREMENTS 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 MTT 111	MTT111	12/3/95 / POST TEST
Pressure Gage Downstream Side	ASHCROFT MTT 111	MTT 111	12/3/95 / POST TEST
Pressure Gage Bonnet	MTT8008	MTT8008	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	274460BR	8/95 / 2/96
Stem Thrust	Teledyne Quick Stem Sensor	NONE	DURING TEST
Stem Thrust (Verification)	Liberty, C-Clamp	278981BR	
Motor Power	Liberty, MPM	I004076	1/96
Motor Current	Liberty, MPM	I004076	1/96
Motor Voltage	Liberty, MPM	I004076	1/96

TABLE 2
TESTING SEQUENCE AND NUMBERING

NOTES TEST # Procedure Section	Test Title
1 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.: 278951BR

VOTES SYSTEM QA NO.: 278951BR

CAL DUE DATE: [illegible]/96

CALIBRATOR LOCATION: THREADED UN-THREADED SLOTTED TRANSITION

DESCRIPTION: VOTES SYSTEM WITH QSS. QSS CALIBRATED WITH C-CLAMP #1C005 QA # 278981BR. BFSL USED FOR CALIBRATION ONLY

NEW EFFECTIVE STEM DIA. 1.184

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 % CHG	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

Low FLOW METER 444947BR CAL 2/95 DUE 2/96
HI FLOW METER 109952BR CAL 2/95 DUE 2/96
PRESSURE GAGE 033201BR CAL 8/95 DUE 8/96

LLRT RESULTS DATA SHEET

VOTES Test #	TSS	C14, lbf	C!6, 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

DIFFERENTIAL PRESSURE TEST RESULTS DATA SHEET

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	25431	8858	≈ 100 ~~200~~	0	1543	617		DP TEST AT TSS 2.0 @ 200PSI
20	25825	7063	≈ 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	26959	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 12/4/95

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

RCB 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
30	28550	14722	540	0	15767	435	.359	
31	29395	15966	245	0	7311	482	.360	
32	29446	14126	285	0	8257	500	.345	
33	29843	11291	455	0	13529	426	.364	
34	29245	11539	475	0	14573	448	.375	
35	29794	13927	450	0	13828	528	.373	
36	29344	10494	550	550	6863	499	.159	
37	29344	9102	0	505	9599	439	.239	CONDITIONING STROKES PERFORMED PRIOR TO THIS TEST (DP)

LCB 12/4/95

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

LCB 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	~~51~~0	510	17553	350	.423	
66	31722	22474	0 ~~208~~ RCB 12/4/95	208 ~~0~~ RCB 12/4/95	6165	525	.34~~4~~7	
67	31772	22126	0	198	6066	653	.347	
68	31922	24513	0	370	11834	614	.382	
69	31873	24414	0	413	13922	623	.405	
70	32069	25506	0	5~~7~~85	18346	557	.390	

RCB 12/4/95

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

RCB 12/4/95

DIFFERENTIAL PRESSURE TEST RESULTS DATA SHEET

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	20683	638	.413	
99	19164	21022	0	610	20177 ~~217~~ LCB 12/4/95			TEST NO GOOD
100	16101	19729	0	578	20325	748	.425	

LCB 12/4/95

[1] Valve Factor =

$$\frac{\text{O10} - \text{Run Load} + \left[\text{Upstream Pressure} \times \frac{\pi}{4}\left(1.\overset{5}{\cancel{2}}5\right)^{2}\right]}{\text{Upstream Pressure} \times \frac{\pi}{4}\left(\underset{10.586}{\cancel{3.445}}\right)^{2}}$$

LCB 12/4/95

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BONNET PRESSURE RESPONSE RESULTS DATA SHEET Appendix A4
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 ~~ee~~ remained dry during test

BONNET PRESSURE RESPONSE RESULTS DATA SHEET Appendix A4

VOTES Test #: ____________ C16 Thrust: ______________

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

BONNET PRESSURE RESPONSE RESULTS DATA SHEET

Appendix A4

VOTES Test #: ____________ C16 Thrust: ______________

Time	Bonnet Pressure, Psig

BONNET PRESSURE RESPONSE RESULTS DATA SHEET

VOTES Test #: ____________ C16 Thrust: ______________

Time	Bonnet Pressure, Psig

11/28/95PRESSURE LOCK TEST RESULTS DATA SHEET

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	0 ELB 12/6/95 ~~208~~	—	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 PM	16,859	7907	0	1.569	77.0	TSS = 1
PRESSURE LOCK TEST	48	PRESS LOCK LOW TSS 200 psi	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 400 PSI	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 UNW 700 PSI	16958	26705	630	4.35	262.9	TSS = 1
Static Test	53	Static test 1:20 pm Lower TSS	16460	8105	0	1.53	79.1	TSS = 1
PRESSURE LOCK TEST	54	PRESS LOCK LOW TSS 1000 PSI	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 TSS	16956	7658	0	1.58	74.9	
PRESS LOCK TEST	56	PRES LOCK LOWER TSS 1000 PSI	16709	41872	919	9.77	427.3	
STATIC TEST w/1000 PSI	58	STATIC LOW TSS 1000	15665	5023	950	1.24	49.3	
STATIC TEST AFTER DP	72	STATIC HIGH TSS	31521	16705	0	2.57	168.0	
STATIC REPEAT TEST AFTER DP	73	STATIC HIGH TSS	31670	17202	0	2.55	164.4	
PRESS LOCK TEST	74	PRESS LOCK UNW HIGH TS 200 PSIG	31670	27643	208	4.19	271.2	
Press Lock Test	75	PRESS LOCK HIGH TSS 200 PSIG	31920	28241	213	4.86	277.5	
Static	76	11:53am	31822	17751 ~~[illegible]~~ 11/4	0	2.70	171.3	
Pres Lock Test	77	PRESS LOCK HIGH TSS 400 PSIG	32017	33906	391	6.36	343.3	
PRESS Lock TEST	78	PRESS LOCK HIGH TSS 400 PSIG	32168	34604	402	6.37	344.0	
STATIC TEST	79	STATIC HIGH TSS	31671	17949	0	2.78	169.9	
PRESS LOCK TEST	80	PRESS LOCK HIGH TSS 400 PSIG	31868	40121	467	7.91	410.6	PRESS WHOLE VALVE AND CLOSED
PRESS LOCK TEST	81	PRESS LOCK HIGH TSS 200 PSI	31971	28540	219	4.82	278.8	"

11/28/95PRESSURE LOCK TEST RESULTS DATA SHEET

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	4.76	246.9	
PRESSURE LOCK	84	PRESS LOCK HIGH TSS 50 PSIG	31820	22871	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, 0 psi Low TSS	17244	8547	0	1.84	83.2	TSS=1 CHECK OF MEMORY ← air in bonnet
~~Static (Memory Effect)~~ ~~Fe~~ Static Mem Effect Test	95	"	17443	11132	0	1.92	106.1	" ← bonnet water-solid
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	

Appendix A5

11/28/95PRESSURE LOCK TEST RESULTS DATA SHEET

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	98	STATIC LOW PSS	17393	8547	0	1.71	82.5	
D								

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 60 C16 Thrust: 31,327

O9 Thrust: 16,609

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	

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PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 60

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				

PRESSURE RESPONSE TO TEMPERATURE DATA SHEET

VOTES Test #: 88 C16 Thrust: 32267

O9 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

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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 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 #: 88 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 TH
BONNET GA

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
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 PRES
THROUGH GAU

DECREASED
BONNET PRE

Pg 8

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
4:00:30	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	218.6	258
4:15:30	232	251	260
4:18:00	282	252.4	262
4:20:30	348	253.2	264
4:23:60	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

pg 7

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

O9 Thrust: N/A   INITIAL WTR TEMP 103 °F

Time	Bonnet Pressure, Psig	Bonnet Temperature, °F FLUID TEMP	UPSTREAM TEMP	V/v Body disk	V/v Body Dwst 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	74.4 ~~86.4~~	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	78.0
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
11 30:00	198	93.5	210.8	88.0 ~~210.8~~	84
1:35:00	242	95.8	213.2	89.4	86.
1:40:00	361	98.4	215.6	92.6	88.
1:45:00	395	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	92. ~~95.~~
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	102.0 ~~102.8~~	96
2:30:00	643	117.2	229.6	100.0	97.
2:37:00	673	119.8	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					

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		Post Cooling test data	
Votes Test #	63	Votes Test #	~~90~~ 64
O9	16008	O9	18995
C16	32264	C16	~~2597~~ 31973

Bonnet Temperature	203 °F	75 °F
Valve Body Temperature	287 °F	72 °F

~~Pre~~ heating test data		Post Cooling test data	
Votes Test #	89, 90, ~~91~~ K15 14/8/AC	Votes Test #	91
O9	24052	O9	24244
C16	25942	C16	31348

DATA SUSPECT DUE TO
HEATING OF SENSOR
SEE TEST #92

Bonnet Temperature ____________
Valve Body Temperature ____________

Pre heating test data		Post Cooling test data	
Votes Test #		Votes Test #	
O9		O9	
C16		C16	

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/N 3A6606A
Serial No	261003
OAR	31.11
Spring Pack No.	017
Motor	
Type	RY 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 Differential pressure testing
12/06/95

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.

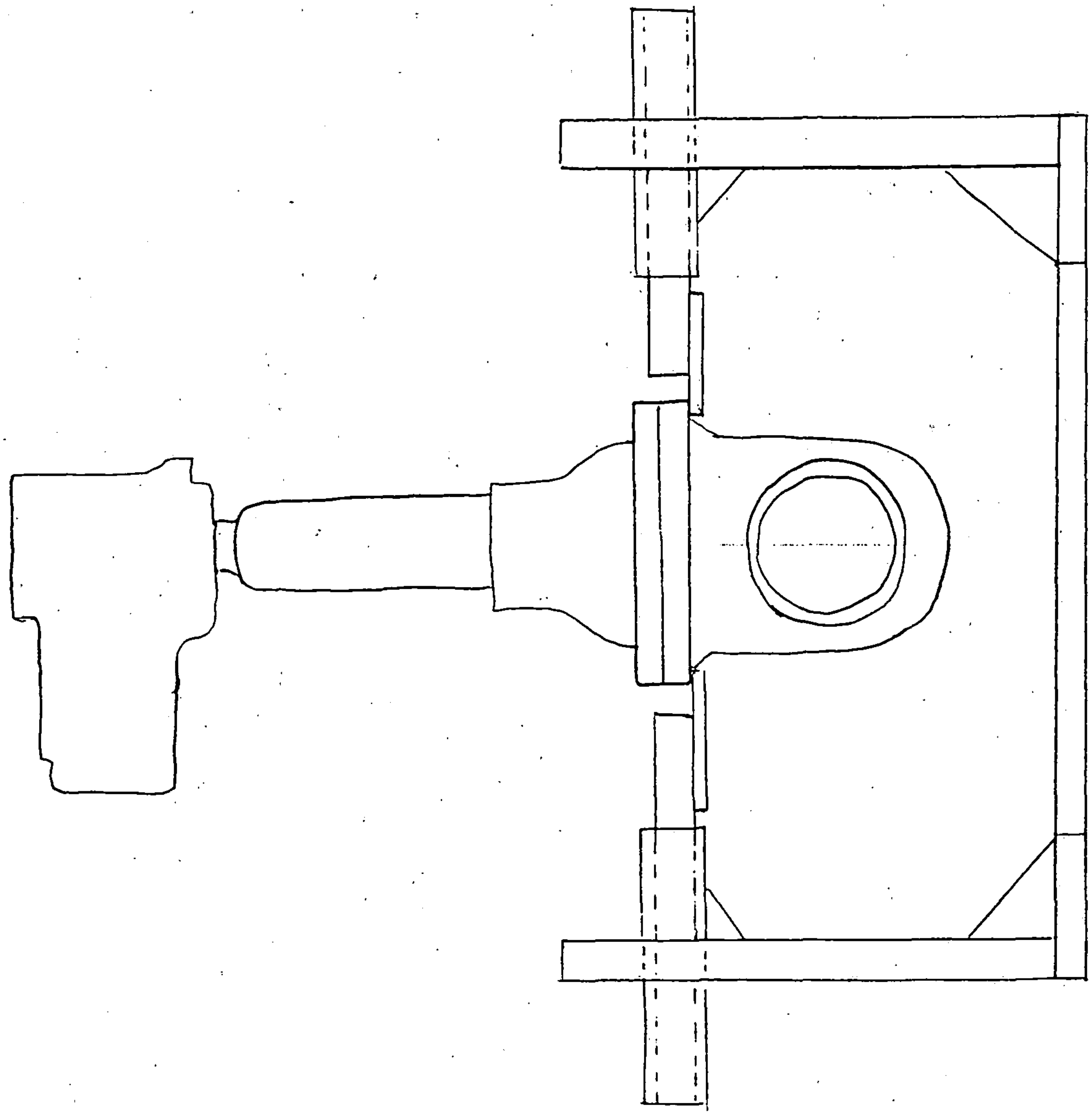
Thermal binding test

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.

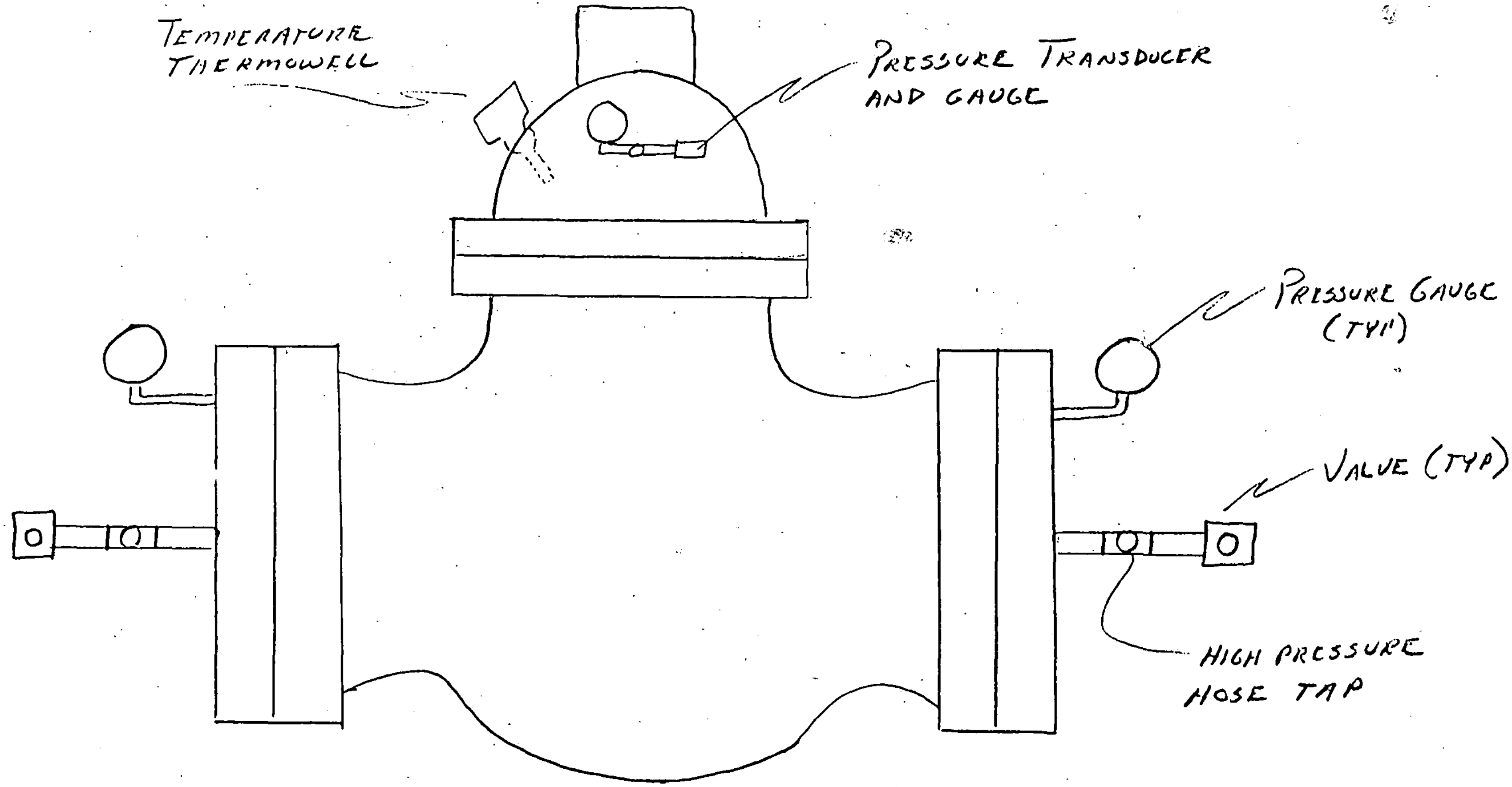
12/08/95 Pressure response to temperature test

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



FIGURE


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

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	$theta := 5 \cdot deg$	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)

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

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

Geometry Factors: (Reference 1, Table 24)

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

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

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

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

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

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

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

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

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

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

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

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

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

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)

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

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

$F_p = 600$

$q = 5.168$

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

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

$$= 31400 / 2(.4667)$$

$$= 31400 / .9334$$

$$= 33640$$

$$P = \frac{F_N \times Y_\omega}{\pi \times a} * \frac{1}{Y_q + (q/2) * Y_\omega}$$

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

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

$$= 1094.6 * .524$$

$$= 574.6 \text{ LBS}$$

REFERENCES:

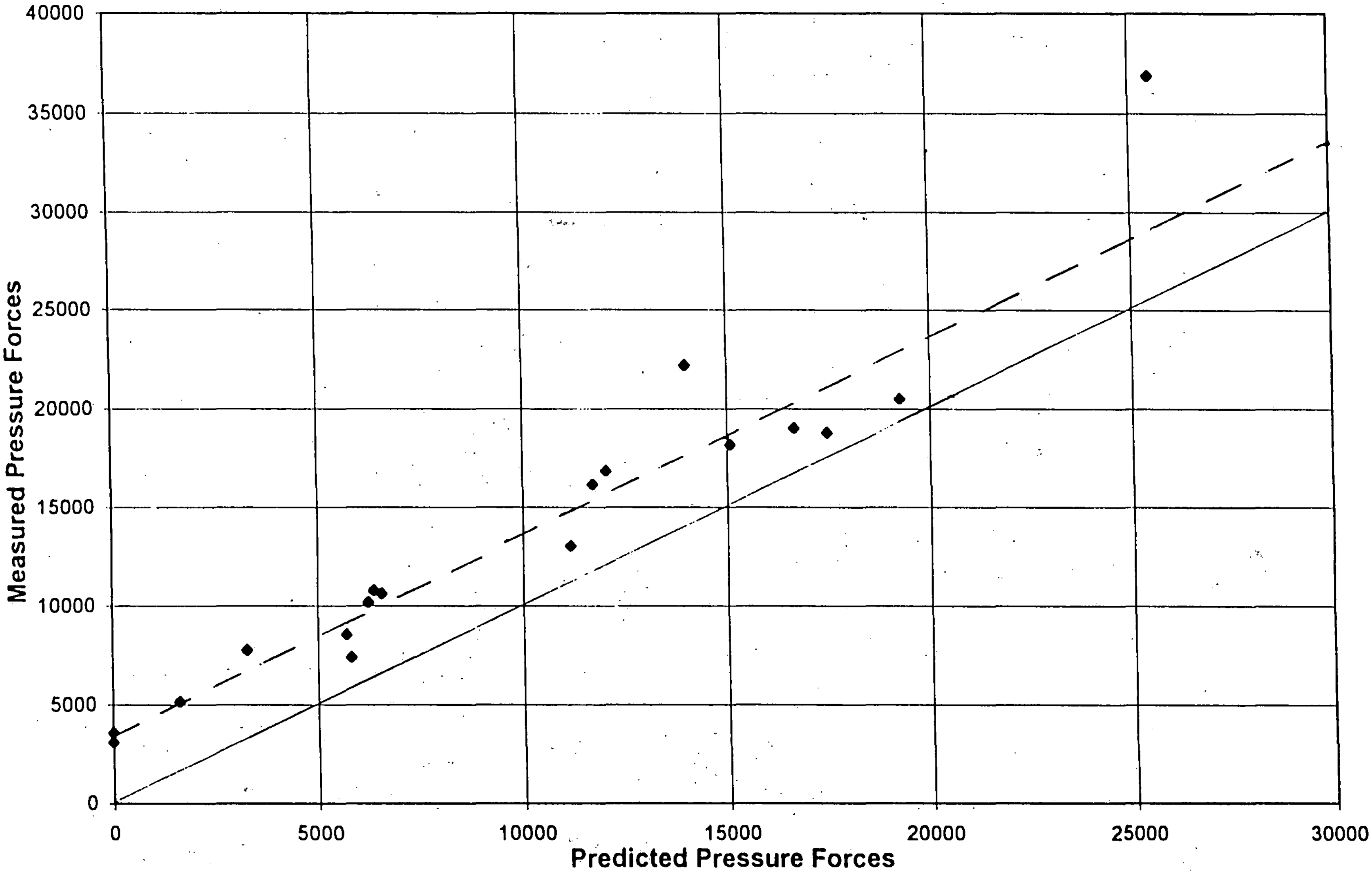
1. SIXTH EDITION OF ROARKS FORMULAS FOR STRESS & STRN.

2. MOV WHITE PAPER WP-134 REV 0

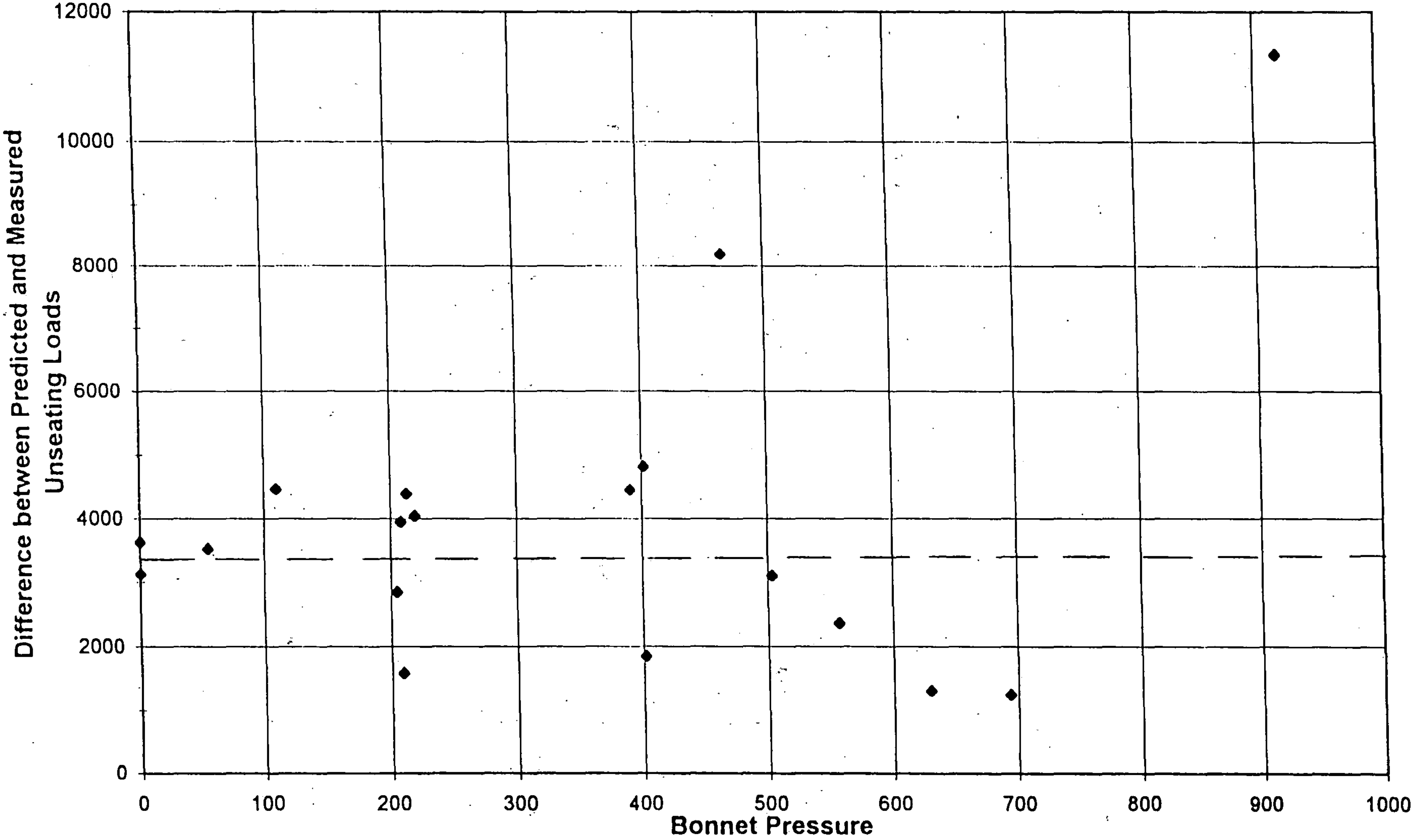
3. MECHANICAL ENGINEERING DESIGN FOURTH EDITION, SHIGLEY AND MITCHELL

THIS METHOLOGY AND CALC FOLLOWS CALCULATION 95-158 AT BRAIDWOOD

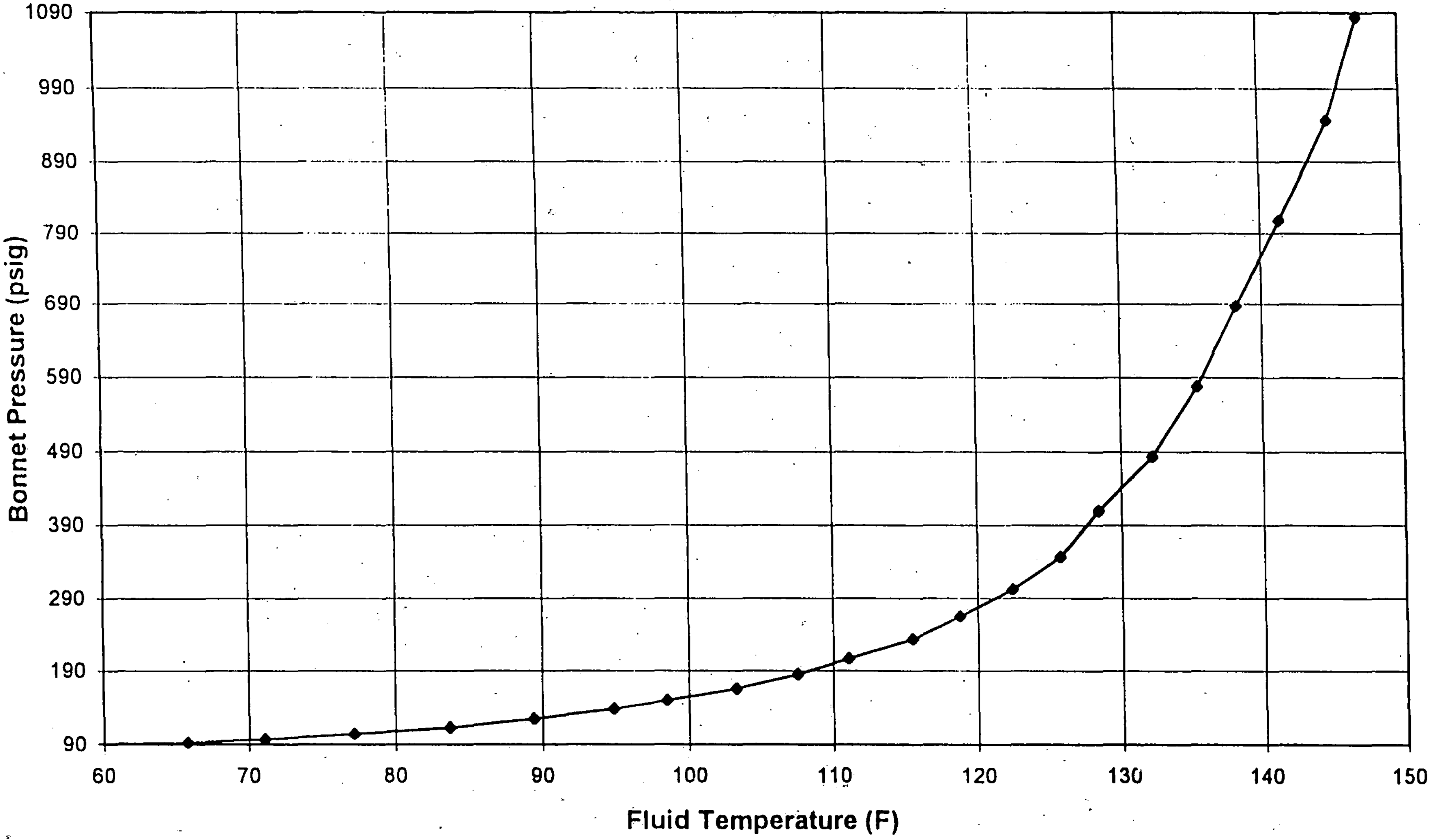
Borg-Warner 10" 300# Class Gate Valve
Measured vs Predicted Pressure Forces



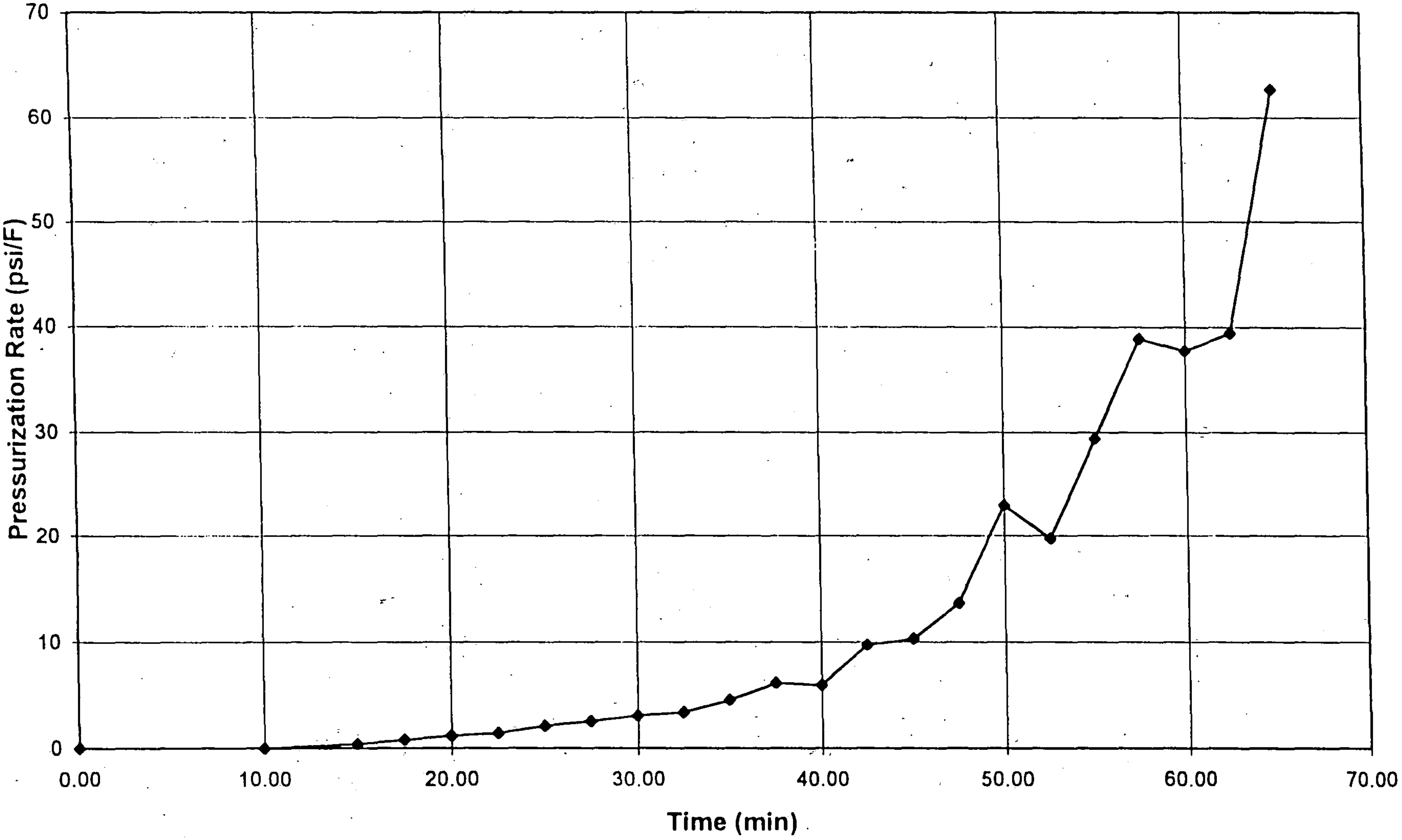
Borg-Warner 10" 300# Class Gate Valve
Deviation in Unseating Load vs Bonnet Pressure



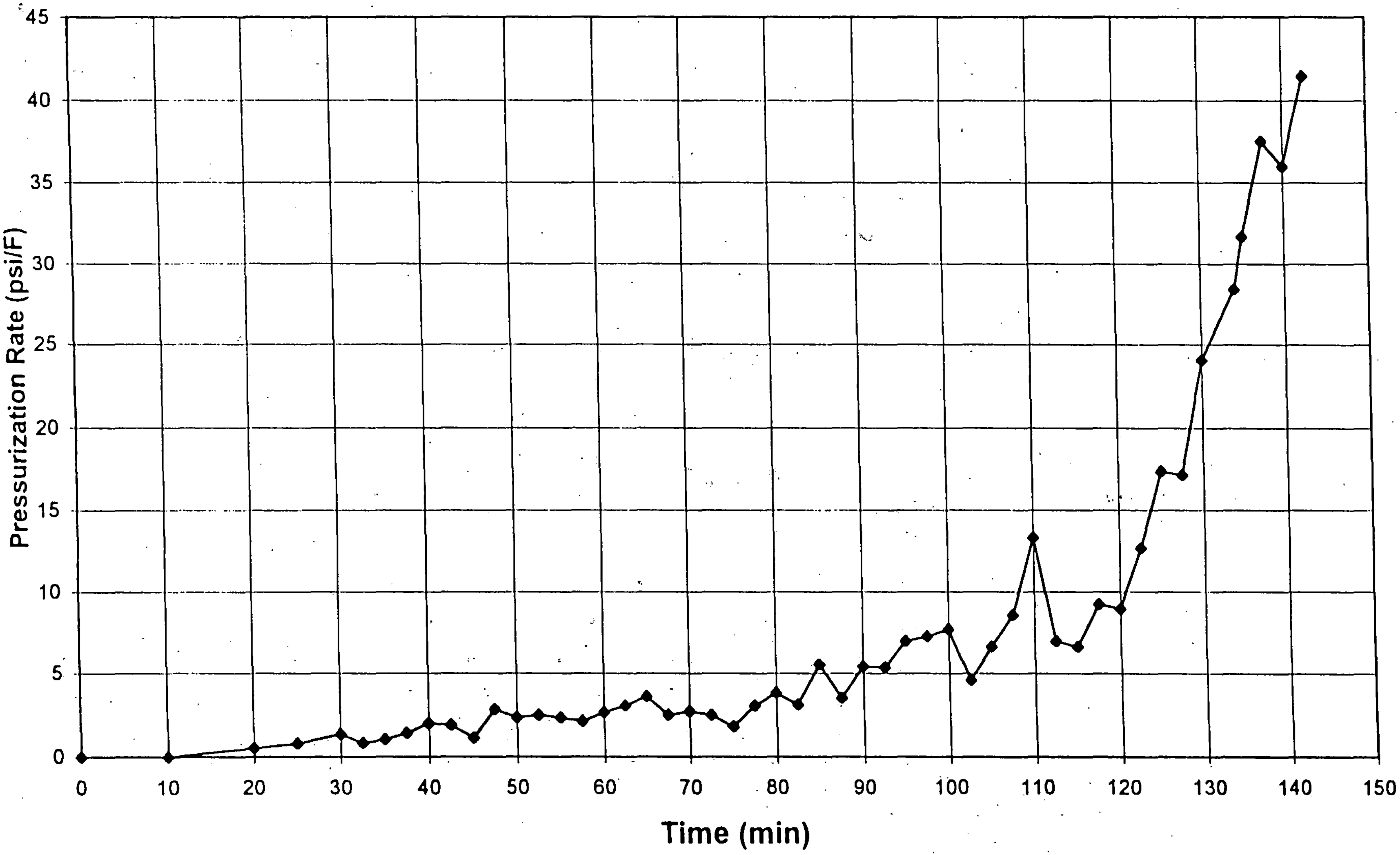
Borg-Warner 10" 300# Class Gate Valve
Bonnet Pressure vs. Temperature (High Heat Input Rate)

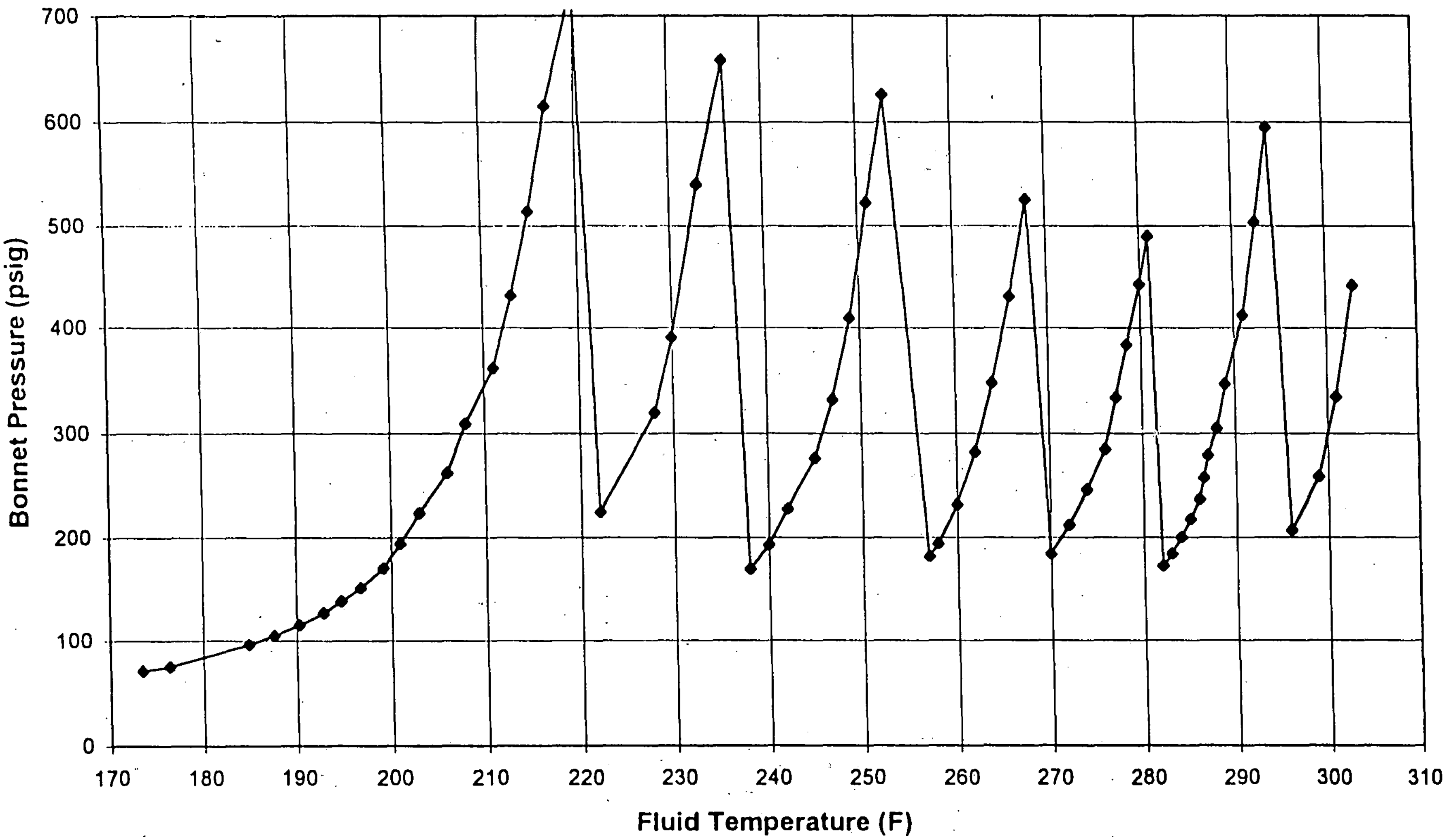


Borg-Warner 10" 300# Class Gate Valve
Pressurization Rate vs. Time (High Heat Input Rate)



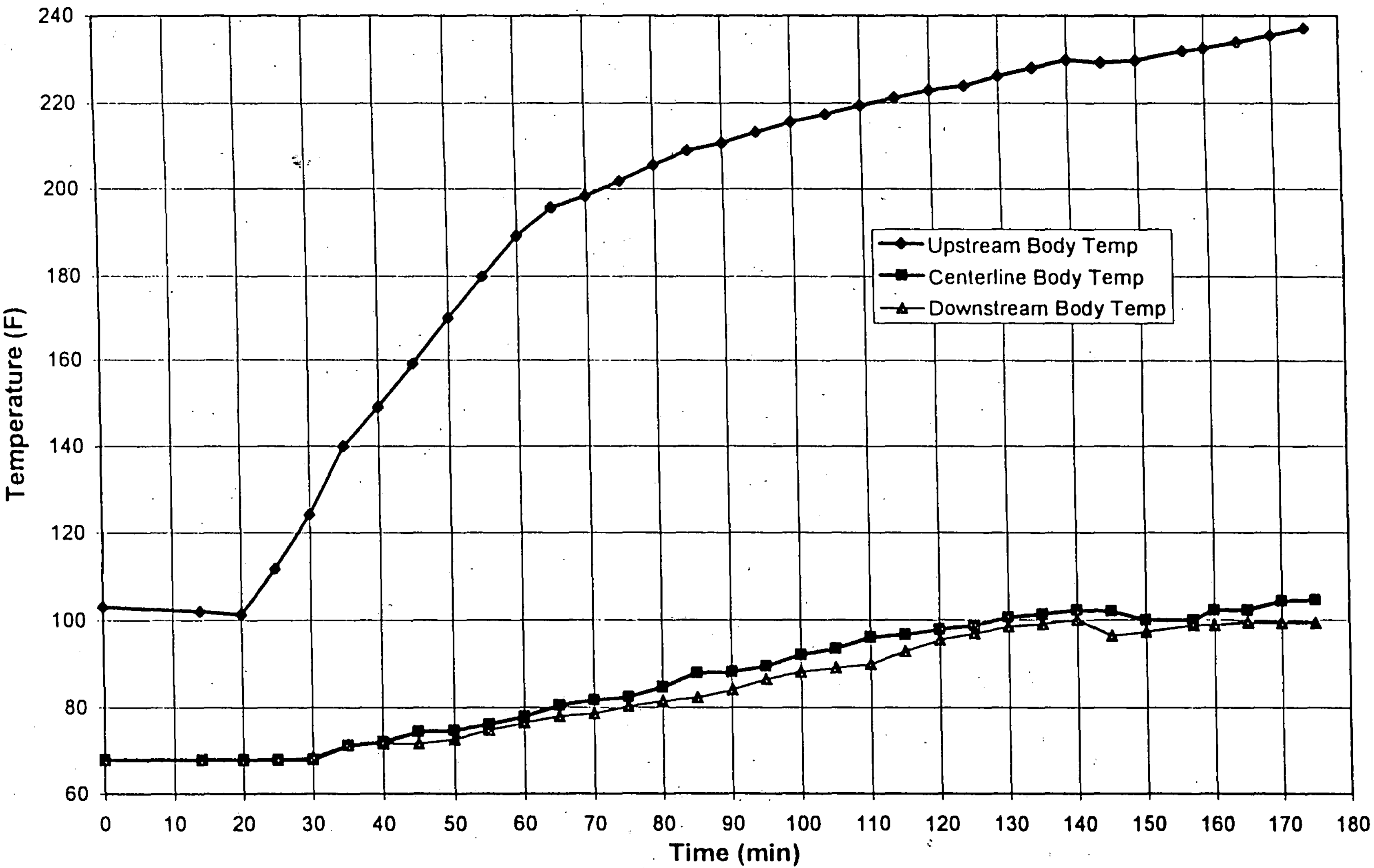
Borg-Warner 10" 300# Class Gate Valve
Pressurization Rate vs. Time (Low Heat Input Rate)

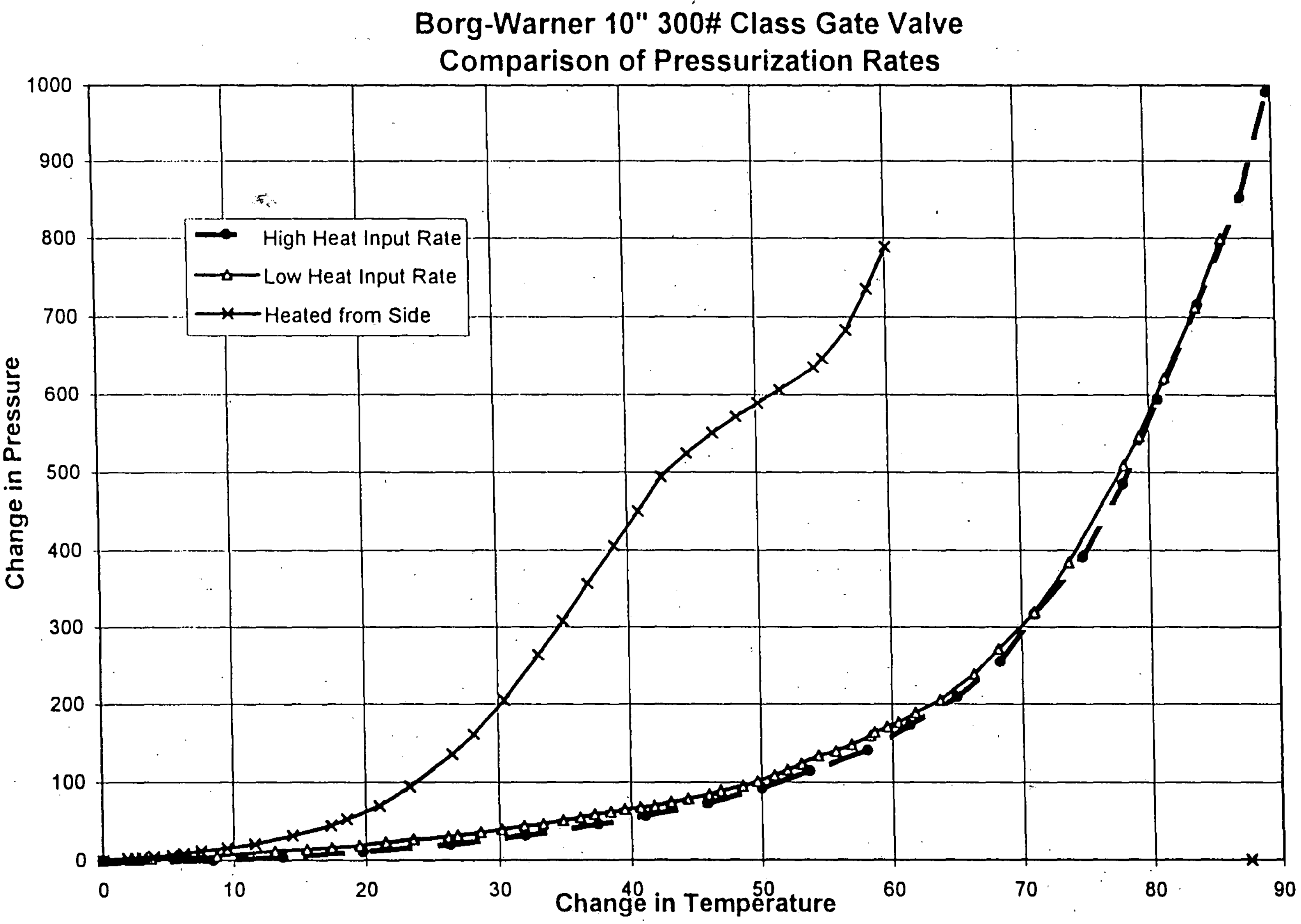




Borg-Warner 10" 300# Class Gate Valve
Bonnet Pressure vs. Temperature
(Valve Bonnet Periodically Vented)

Borg-Warner 10" 300# Class Gate Valve
Body Temperature vs Time (Heat Input from Side)




Borg-Warner 10" 300# Class Gate Valve
Comparison of Pressurization Rates
High Heat Input Rate
Low Heat Input Rate
Heated from Side
Change in Pressure
Change in Temperature
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90

Memorandum

In Reference
Refer to DOC ID # DG96-000078

ComEd

Date: January 16, 1996

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

Brian D. Bunte
MOV Program Lead
Commonwealth Edison Company

Attachments

A Unicom Company

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

ATTACHMENT 2

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

Page:

Revision 2

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	PH 12-3-95 ~~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#	AF/AL	MODEL#	RANGE	RATE	CERT DUE
031	AF/AL	Mansfield + Green	0-1000 PSIG	N/A	3-96

DOCUMENT REVIEW

SUPERVISOR:

DATE REVIEWED: 12-3-95

DATE ENTRY:

SYS ID:

NWR#: 950003824-03

(Final)

APPROVED
AUG 27 1992
BRAIDWOOD
ON-SITE REVIEW

Date:

Revision 2

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 2.2*
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		REQUIRED	AS FOUND	AS LEFT
%	PSIG	PSIG	PSIG	PSIG
0	0	0	0	0
25	250	250	250	250
50	500	500	500	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	
SETPOINT		A	
RESET			

REMARKS:
Pre cal for Special Test ON VALVE Pressure LOCKING

TEST EQUIPMENT

ID#	AF/AL	MODEL#	RANGE	RATE	CERT DUE
031	AF/AL	Mansfield + Green	0-1000 PSIG	N/A	3-96

DOCUMENT REVIEW
SUPERVISOR:
DATE REVIEWED: 12-3-95
DATE ENTRY:
SYS ID:
NWR#: 950007824-03

(Final)

APPROVED

AUG 27 1992
BRAIDWOOD
ON-SITE REVIEW

Date:

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	AS FOUND	AS LEFT
	%	°F	°F	°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	RATE	CERT DUE
BR751	AF/AL	Gordon	E		10-96

DOCUMENT REVIEW

SUPERVISOR:

DATE REVIEWED: 12-3-95

DATE ENTRY:

SYS ID:

NWR#: 950003824-03

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ON-SITE REVIEW

Revision 2

MULTIPLE USE

Date:

CALIBRATION TEST REPORT FORM

Instr. No/Type

Location

Instrument Name OMEGA

Tolerance 2% = 20 psi

Instr.Model Mfr.

References

Instr.Serial No.

Procecure No.

Head Correction

Setpoint

Technician Santa Arenas

Date Calibrated 12-3-95

Range

INPUT TEST POINT		OUTPUT TEST POINT		
INPUT		REQUIRED	AS FOUND	AS LEFT
12-3-95 ~~PSI~~ %	PSI	PSI	PSI	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:

DATE REVIEWED: 12-3-95

DATE ENTRY:

SYS ID:

NWR#: 950003824-03

(Final)

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AUG 27 1992
BRAIDWOOD
ON-SITE REVIEW

Source Document:
Revision: N/A
Date:

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

REMARKS:

Post Cal
950003824-09

TEST EQUIPMENT

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

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

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APPROVED
AUG 27 1992
BRAIDWOOD
ON-SITE REVIEW

Source Document: N/A
Revision:
Date:

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 1-12-96
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			ACTUATION
	AS FOUND	AS LEFT	INC/DEC
SETPOINT			
RESET		N/A	
SETPOINT			
RESET			

REMARKS:

POST CAL
950003824.09

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

DOCUMENT REVIEW
SUPERVISOR:
DATE REVIEWED: 2-5-96
DATE ENTRY:
SYS ID:
NWR#: 950003824.03

(Final)

APPROVED
AUG 27 1992
BRAIDWOOD
ON-SITE REVIEW

Source Document: ______ ______
Revision: ______ ______
Date: ______ ______

BwIP 2000-TO
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. ______ Procecure No. ______

Head Correction ______ Setpoint ______

Technician Santo Arenas

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	~~0~~ 3 SA 1-17	3 ~~0~~ SA 1-17

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
BR1053	AF/AL	CMM	0-1000	NA	2-2-96

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

(Final)
1

92(082092)
ZWBWIP

APPROVEL
AUG 27 1992
BRAIDWOOD
ON-SITE REVIEW

Source Document: N/A
Revision:
Date:

BwIP 2000-T0
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	Procecure No.	
Head Correction		Setpoint	
Technician	M Bond		
Date Calibrated	1-12-96	Range	0-200 °F T T/C

INPUT TEST POINT — OUTPUT TEST POINT

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

SWITCH OPERATION — ACTUATION

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

REMARKS:

PostCal
9500038240 9

for Chris Bedford
x2440

TEST EQUIPMENT

ID#	AF/AL	MODEL#	RANGE	RATE	CERT DUE
BR 750	AF/	Gordon TULO	Type K T/C	N/A	4-96

DOCUMENT REVIEW

SUPERVISOR:
DATE REVIEWED: 2-5-96
DATE ENTRY:
SYS ID:
NWR#: 95003824-03

(Final)

1

-92(082092)
ZWBWIP

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AUG 27 1992
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ON-SITE REVIEW

Attachment 5

ComEd Response to NRC Request for Additional Information on ComEd Pressure Locking Testing

Pressure Locking Test Valve (10" Crane Valve)

This Mathcad Program is designed to calculate the estimated openning force under pressure locking scenarios for flex-wedge gate valves using a calculational methodology that accounts for wedge stiffness resisting pressure locking forces.

INPUTS:

Bonnet Pressure	$P_{bonnet} := 1775 \cdot psi$
Upstream Pressure	$P_{up} := 0 \cdot psi$
Downstream Pressure	$P_{down} := 0 \cdot psi$
Disk Thickness	$t := 2.1875 \cdot in$
Seat Radius	$a := 4.36 \cdot in$
Hub Radius	$b := 1.25 \cdot in$
Hub Length	$L := 1.625 \cdot in$
Seat Angle	$theta := 5 \cdot deg$
Poisson's Ratio (disk)	$v := .3$
Mod. of Elast. (disk)	$E := 27.6 \cdot 10^{6} \cdot psi$
Static Pullout Force (Test 37)	$F_{po} := 35000 \cdot lbf$
Disk/Seat Friction Coef.	$mu := .28$
Stem Diameter	$D_{stem} := 1.875 \cdot in$

PRESSURE FORCE CALCULATIONS

Average DP across disks:

$$DPavg := P_{bonnet} - \frac{P_{up} + P_{down}}{2}$$

$$DPavg = 1.775 \cdot 10^{3} \cdot psi$$

Disk Stiffness Constants (Reference 1, Table 24)

$$D := \frac{E \cdot (t)^{3}}{12 \cdot \left(1 - v^{2}\right)}$$

$$D = 2.646 \cdot 10^{7} \cdot lbf \cdot in$$

$$G := \frac{E}{2 \cdot (1 + v)}$$

$$G = 1.062 \cdot 10^{7} \cdot psi$$

Geometry Factors: **(Reference 1, Table 24)**

$$C_2 := \frac{1}{4} \cdot \left[1 - \left(\frac{b}{a} \right)^2 \cdot \left(1 + 2 \cdot \ln\left(\frac{a}{b} \right) \right) \right] \qquad C_2 = 0.178$$

$$C_3 := \frac{b}{4 \cdot a} \cdot \left[\left[\left(\frac{b}{a} \right)^2 + 1 \right] \cdot \ln\left(\frac{a}{b} \right) + \left(\frac{b}{a} \right)^2 - 1 \right] \qquad C_3 = 0.031$$

$$C_8 := \frac{1}{2} \cdot \left[1 + \nu + (1 - \nu) \cdot \left(\frac{b}{a} \right)^2 \right] \qquad C_8 = 0.679$$

$$C_9 := \frac{b}{a} \cdot \left[\frac{1 + \nu}{2} \cdot \ln\left(\frac{a}{b} \right) + \frac{1 - \nu}{4} \cdot \left[1 - \left(\frac{b}{a} \right)^2 \right] \right] \qquad C_9 = 0.279$$

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

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

$$L_{11} := \frac{1}{64} \cdot \left[1 + 4 \cdot \left(\frac{b}{a} \right)^2 - 5 \cdot \left(\frac{b}{a} \right)^4 - 4 \cdot \left(\frac{b}{a} \right)^2 \cdot \left[2 + \left(\frac{b}{a} \right)^2 \right] \cdot \ln\left(\frac{a}{b} \right) \right] \qquad L_{11} = 0.007$$

$$L_{17} := \frac{1}{4} \cdot \left[1 - \frac{1 - \nu}{4} \cdot \left[1 - \left(\frac{b}{a} \right)^4 \right] - \left(\frac{b}{a} \right)^2 \cdot \left[1 + (1 + \nu) \cdot \ln\left(\frac{a}{b} \right) \right] \right] \qquad L_{17} = 0.153$$

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

$$M_{rb} := \frac{-DPavg \cdot a^2}{C_8} \cdot \left[\frac{C_9}{2 \cdot a \cdot b} \cdot \left(a^2 - b^2 \right) - L_{17} \right] \qquad M_{rb} = -1.46 \cdot 10^4 \cdot lbf$$

$$Q_b := \frac{DPavg}{2 \cdot b} \cdot \left(a^2 - b^2 \right) \qquad Q_b = 1.239 \cdot 10^4 \cdot \frac{lbf}{in}$$

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

$$y_{bq} := M_{rb} \cdot \frac{a^2}{D} \cdot C_2 + Q_b \cdot \frac{a^3}{D} \cdot C_3 - \frac{DPavg \cdot a^4}{D} \cdot L_{11} \qquad y_{bq} = -8.275 \cdot 10^{-4} \cdot in$$

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

$$K_{sa} := -0.3\cdot\left[2\cdot\ln\left(\frac{a}{b}\right) - 1 + \left(\frac{b}{a}\right)^2\right] \qquad K_{sa} = -0.474$$

$$y_{sq} := \frac{K_{sa}\cdot DPavg\cdot a^2}{t\cdot G} \qquad y_{sq} = -6.891\cdot 10^{-4}\cdot in$$

Deflection due to hub stretch (from center of hub to disk):

$$P_{force} := 3.1416\cdot\left(a^2 - b^2\right)\cdot DPavg \qquad P_{force} = 9.729\cdot 10^{4}\cdot lbf$$

$$y_{stretch} := \frac{P_{force}}{3.1416\cdot b^2}\cdot\frac{L}{(2\cdot E)} \qquad y_{stretch} = 5.835\cdot 10^{-4}\cdot in$$

Total Deflection due to pressure forces:

$$y_q := y_{bq} + y_{sq} - y_{stretch} \qquad y_q = -0.002\cdot in$$

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

$$y_{sw} := -\left[\frac{1.2\cdot\left(\frac{a}{a}\right)\cdot\ln\left(\frac{a}{b}\right)\cdot a}{t\cdot G}\right] \qquad y_{sw} = -2.815\cdot 10^{-7}\cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

(per lbf/in)

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

$$y_{bw} := -\left(\frac{a^3}{D}\right)\cdot\left[\left(\frac{C_2}{C_8}\right)\cdot\left[\left(\frac{a\cdot C_9}{b}\right) - L_9\right] - \left[\left(\frac{a}{b}\right)\cdot C_3\right] + L_3\right] \qquad y_{bw} = -4.595\cdot 10^{-7}\cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

(per lbf/in)

Deflection due to hub compression (per lbf/in), (from center of hub to disk):

$$y_{compr} := \frac{2\cdot a\cdot\pi}{3.1416\cdot b^2}\cdot\frac{L}{(2\cdot E)} \qquad y_{compr} = 1.643\cdot 10^{-7}\cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

(per lbf/in)

Total deflection due to seat contact force (per lbf//in.):

$$y_w := y_{bw} + y_{sw} - y_{compr} \qquad y_w = -9.053\cdot 10^{-7}\cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

(per lbf/in)

Seat Contact Force for which deflection is equal previously calculated deflection from pressure forces:

$$F_s := 2\cdot\pi\cdot a\cdot\frac{y_q}{y_w} \qquad F_s = 6.355\cdot 10^{4}\cdot lbf$$

UNSEATING FORCES

$F_{packing}$ is included in measured static pullout Force

$F_{piston} := \frac{\pi}{4} \cdot D_{stem}{}^2 \cdot P_{bonnet}$ $\quad$ $F_{piston} = 4.901 \cdot 10^3 \cdot lbf$

$F_{vert} := \pi \cdot a^2 \cdot \sin(theta) \cdot \left(2 \cdot P_{bonnet} - P_{up} - P_{down}\right)$ $\quad$ $F_{vert} = 1.848 \cdot 10^4 \cdot lbf$

$F_{preslock} := 2 \cdot F_s \cdot (mu \cdot \cos(theta) - \sin(theta))$ $\quad$ $F_{preslock} = 2.438 \cdot 10^4 \cdot lbf$

$F_{total} := -F_{piston} + F_{vert} + F_{preslock} + F_{po}$ $\quad$ $F_{po} = 3.5 \cdot 10^4 \cdot lbf$

$F_{total} = 7.295 \cdot 10^4 \cdot lbf$

$F_{pressure} := F_{total} - F_{po}$ $\quad$ $F_{pressure} = 3.795 \cdot 10^4 \cdot lbf$

Attachment 6

ComEd Response to NRC Request for Additional Information on ComEd Pressure Locking Testing

Pressure Locking Test Valve (4" Westinghouse Valve)

This Mathcad Program is designed to calculate the estimated openning force under pressure locking scenarios for flex-wedge gate valves using a calculational methodology that accounts for wedge stiffness resisting pressure locking forces.

INPUTS:

Bonnet Pressure	$P_{bonnet} := 1000 \cdot psi$
Upstream Pressure	$P_{up} := 0 \cdot psi$
Downstream Pressure	$P_{down} := 0 \cdot psi$
Disk Thickness	$t := 1.02 \cdot in$
Seat Radius	$a := 1.986 \cdot in$
Hub Radius	$b := 1.056 \cdot in$
Hub Length	$L := .6 \cdot in$
Seat Angle	$theta := 7 \cdot deg$
Poisson's Ratio (disk)	$\nu := .3$
Mod. of Elast. (disk)	$E := 27.6 \cdot 10^6 \cdot psi$
Static Pullout Force (Test 37)	$F_{po} := 0 \cdot lbf$
Disk/Seat Friction Coef.	$mu := .13$
Stem Diameter	$D_{stem} := 1.25 \cdot in$

PRESSURE FORCE CALCULATIONS

Average DP across disks:

$$DPavg := P_{bonnet} - \frac{P_{up} + P_{down}}{2} \qquad DPavg = 1 \cdot 10^3 \cdot psi$$

Disk Stiffness Constants (Reference 1, Table 24)

$$D := \frac{E \cdot (t)^3}{12 \cdot \left(1 - \nu^2\right)} \qquad D = 2.682 \cdot 10^6 \cdot lbf \cdot in$$

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

Geometry Factors: (Reference 1, Table 24)

$$C_2 := \frac{1}{4}\cdot\left[1-\left(\frac{b}{a}\right)^2\cdot\left(1+2\cdot\ln\left(\frac{a}{b}\right)\right)\right] \qquad C_2 = 0.09$$

$$C_3 := \frac{b}{4\cdot a}\cdot\left[\left[\left(\frac{b}{a}\right)^2+1\right]\cdot\ln\left(\frac{a}{b}\right)+\left(\frac{b}{a}\right)^2-1\right] \qquad C_3 = 0.012$$

$$C_8 := \frac{1}{2}\cdot\left[1+\nu+(1-\nu)\cdot\left(\frac{b}{a}\right)^2\right] \qquad C_8 = 0.749$$

$$C_9 := \frac{b}{a}\cdot\left[\frac{1+\nu}{2}\cdot\ln\left(\frac{a}{b}\right)+\frac{1-\nu}{4}\cdot\left[1-\left(\frac{b}{a}\right)^2\right]\right] \qquad C_9 = 0.285$$

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

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

$$L_{11} := \frac{1}{64}\cdot\left[1+4\cdot\left(\frac{b}{a}\right)^2-5\cdot\left(\frac{b}{a}\right)^4-4\cdot\left(\frac{b}{a}\right)^2\cdot\left[2+\left(\frac{b}{a}\right)^2\right]\cdot\ln\left(\frac{a}{b}\right)\right] \qquad L_{11} = 0.002$$

$$L_{17} := \frac{1}{4}\cdot\left[1-\frac{1-\nu}{4}\cdot\left[1-\left(\frac{b}{a}\right)^4\right]-\left(\frac{b}{a}\right)^2\cdot\left[1+(1+\nu)\cdot\ln\left(\frac{a}{b}\right)\right]\right] \qquad L_{17} = 0.081$$

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

$$M_{rb} := \frac{-DPavg\cdot a^2}{C_8}\cdot\left[\frac{C_9}{2\cdot a\cdot b}\cdot\left(a^2-b^2\right)-L_{17}\right] \qquad M_{rb} = -585.782\cdot\mathrm{lbf}$$

$$Q_b := \frac{DPavg}{2\cdot b}\cdot\left(a^2-b^2\right) \qquad Q_b = 1.34\cdot 10^3\cdot\frac{\mathrm{lbf}}{\mathrm{in}}$$

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

$$y_{bq} := M_{rb}\cdot\frac{a^2}{D}\cdot C_2+Q_b\cdot\frac{a^3}{D}\cdot C_3-\frac{DPavg\cdot a^4}{D}\cdot L_{11} \qquad y_{bq} = -3.834\cdot 10^{-5}\cdot\mathrm{in}$$

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

$K_{sa} := -0.3 \cdot \left[2 \cdot \ln\left(\frac{a}{b}\right) - 1 + \left(\frac{b}{a}\right)^2 \right]$ $K_{sa} = -0.164$

$y_{sq} := \frac{K_{sa} \cdot DPavg \cdot a^2}{t \cdot G}$ $y_{sq} = -5.967 \cdot 10^{-5} \cdot in$

Deflection due to hub stretch (from center of hub to disk):

$P_{force} := 3.1416 \cdot \left(a^2 - b^2\right) \cdot DPavg$ $P_{force} = 8.888 \cdot 10^3 \cdot lbf$

$y_{stretch} := \frac{P_{force}}{3.1416 \cdot b^2} \cdot \frac{L}{(2 \cdot E)}$ $y_{stretch} = 2.758 \cdot 10^{-5} \cdot in$

Total Deflection due to pressure forces:

$y_q := y_{bq} + y_{sq} - y_{stretch}$ $y_q = -1.256 \cdot 10^{-4} \cdot in$

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

$y_{sw} := -\left[\frac{1.2 \cdot \left(\frac{a}{a}\right) \cdot \ln\left(\frac{a}{b}\right) \cdot a}{t \cdot G} \right]$ $y_{sw} = -1.39 \cdot 10^{-7} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$

(per lbf/in)

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

$y_{bw} := -\left(\frac{a^3}{D}\right) \cdot \left[\left(\frac{C_2}{C_8}\right) \cdot \left[\left(\frac{a \cdot C_9}{b}\right) - L_9 \right] - \left[\left(\frac{a}{b}\right) \cdot C_3 \right] + L_3 \right]$ $y_{bw} = -1.203 \cdot 10^{-7} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$

(per lbf/in)

Deflection due to hub compression (per lbf/in), (from center of hub to disk):

$y_{compr} := \frac{2 \cdot a \cdot \pi}{3.1416 \cdot b^2} \cdot \frac{L}{(2 \cdot E)}$ $y_{compr} = 3.872 \cdot 10^{-8} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$

(per lbf/in)

Total deflection due to seat contact force (per lbf//in.):

$y_w := y_{bw} + y_{sw} - y_{compr}$ $y_w = -2.981 \cdot 10^{-7} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$

(per lbf/in)

Seat Contact Force for which deflection is equal previously calculated deflection from pressure forces:

$F_s := 2 \cdot \pi \cdot a \cdot \frac{y_q}{y_w}$ $F_s = 5.257 \cdot 10^3 \cdot lbf$

UNSEATING FORCES

$F_{packing}$ is included in measured static pullout Force

$F_{piston} := \frac{\pi}{4} \cdot D_{stem}^{2} \cdot P_{bonnet}$ $F_{piston} = 1.227 \cdot 10^{3} \cdot lbf$

$F_{vert} := \pi \cdot a^{2} \cdot \sin(theta) \cdot \left(2 \cdot P_{bonnet} - P_{up} - P_{down}\right)$ $F_{vert} = 3.02 \cdot 10^{3} \cdot lbf$

$F_{preslock} := 2 \cdot F_{s} \cdot (mu \cdot \cos(theta) - \sin(theta))$ $F_{preslock} = 75.3 \cdot lbf$

$F_{total} := -F_{piston} + F_{vert} + F_{preslock} + F_{po}$ $F_{po} = 0 \cdot lbf$

$F_{total} = 1.868 \cdot 10^{3} \cdot lbf$

$F_{pressure} := F_{total} - F_{po}$ $F_{pressure} = 1.868 \cdot 10^{3} \cdot lbf$

Attachment 7

ComEd Response to NRC Request for Additional Information on ComEd Pressure Locking Testing

Pressure Locking Test Valve (10" Borg-Warner Valve)

This Mathcad Program is designed to calculate the estimated openning force under pressure locking scenarios for flex-wedge gate valves using a calculational methodology that accounts for wedge stiffness resisting pressure locking forces.

INPUTS:

Bonnet Pressure	$P_{bonnet} := 100 \cdot psi$
Upstream Pressure	$P_{up} := 0 \cdot psi$
Downstream Pressure	$P_{down} := 0 \cdot psi$
Disk Thickness	$t := 1.5 \cdot in$
Seat Radius	$a := 5.168 \cdot in$
Hub Radius	$b := 3.158 \cdot in$
Hub Length	$L := .156 \cdot in$
Seat Angle	$theta := 5 \cdot deg$
Poisson's Ratio (disk)	$\nu := .3$
Mod. of Elast. (disk)	$E := 27.6 \cdot 10^{6} \cdot psi$
Static Pullout Force (Test 37)	$F_{po} := 9948 \cdot lbf$
Open Valve Factor	$VF := .41$
Stem Diameter	$D_{stem} := 1.5 \cdot in$

PRESSURE FORCE CALCULATIONS

Coefficient of friction between disk and seat: (Reference 3)

$$mu := VF \cdot \frac{\cos(theta)}{1 - VF \cdot \sin(theta)} \qquad mu = 0.424$$

Average DP across disks:

$$DPavg := P_{bonnet} - \frac{P_{up} + P_{down}}{2} \qquad DPavg = 100 \cdot psi$$

Disk Stiffness Constants (Reference 1, Table 24)

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

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

Geometry Factors: (Reference 1, Table 24)

$$C_2 := \frac{1}{4}\cdot\left[1-\left(\frac{b}{a}\right)^2\cdot\left(1+2\cdot\ln\left(\frac{a}{b}\right)\right)\right] \qquad C_2 = 0.065$$

$$C_3 := \frac{b}{4\cdot a}\cdot\left[\left[\left(\frac{b}{a}\right)^2+1\right]\cdot\ln\left(\frac{a}{b}\right)+\left(\frac{b}{a}\right)^2-1\right] \qquad C_3 = 0.008$$

$$C_8 := \frac{1}{2}\cdot\left[1+v+(1-v)\cdot\left(\frac{b}{a}\right)^2\right] \qquad C_8 = 0.781$$

$$C_9 := \frac{b}{a}\cdot\left[\frac{1+v}{2}\cdot\ln\left(\frac{a}{b}\right)+\frac{1-v}{4}\cdot\left[1-\left(\frac{b}{a}\right)^2\right]\right] \qquad C_9 = 0.263$$

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

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

$$L_{11} := \frac{1}{64}\cdot\left[1+4\cdot\left(\frac{b}{a}\right)^2-5\cdot\left(\frac{b}{a}\right)^4-4\cdot\left(\frac{b}{a}\right)^2\cdot\left[2+\left(\frac{b}{a}\right)^2\right]\cdot\ln\left(\frac{a}{b}\right)\right] \qquad L_{11} = 7.876\cdot 10^{-4}$$

$$L_{17} := \frac{1}{4}\cdot\left[1-\frac{1-v}{4}\cdot\left[1-\left(\frac{b}{a}\right)^4\right]-\left(\frac{b}{a}\right)^2\cdot\left[1+(1+v)\cdot\ln\left(\frac{a}{b}\right)\right]\right] \qquad L_{17} = 0.059$$

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

$$M_{rb} := \frac{-DPavg\cdot a^2}{C_8}\cdot\left[\frac{C_9}{2\cdot a\cdot b}\cdot\left(a^2-b^2\right)-L_{17}\right] \qquad M_{rb} = -258.064\cdot lbf$$

$$Q_b := \frac{DPavg}{2\cdot b}\cdot\left(a^2-b^2\right) \qquad Q_b = 264.966\cdot\frac{lbf}{in}$$

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

$$y_{bq} := M_{rb}\cdot\frac{a^2}{D}\cdot C_2+Q_b\cdot\frac{a^3}{D}\cdot C_3-\frac{DPavg\cdot a^4}{D}\cdot L_{11} \qquad y_{bq} = -2.619\cdot 10^{-5}\cdot in$$

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

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

$$K_{sa} = -0.108$$

$$y_{sq} := \frac{K_{sa}\cdot DPavg\cdot a^2}{t\cdot G}$$

$$y_{sq} = -1.804\cdot 10^{-5}\ \cdot in$$

Deflection due to hub stretch (from center of hub to disk):

$$P_{force} := 3.1416\cdot\left(a^2 - b^2\right)\cdot DPavg$$

$$P_{force} = 5.258\cdot 10^{3}\ \cdot lbf$$

$$y_{stretch} := \frac{P_{force}}{3.1416\cdot b^2}\cdot\frac{L}{(2\cdot E)}$$

$$y_{stretch} = 4.742\cdot 10^{-7}\ \cdot in$$

Total Deflection due to pressure forces:

$$y_q := y_{bq} + y_{sq} - y_{stretch}$$

$$y_q = -4.471\cdot 10^{-5}\ \cdot in$$

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

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

(per lbf/in)

$$y_{sw} = -1.918\cdot 10^{-7}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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

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

(per lbf/in)

$$y_{bw} = -3.745\cdot 10^{-7}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

Deflection due to hub compression (per lbf/in), (from center of hub to disk):

$$y_{compr} := \frac{2\cdot a\cdot\pi}{3.1416\cdot b^2}\cdot\frac{L}{(2\cdot E)}$$

(per lbf/in)

$$y_{compr} = 2.929\cdot 10^{-9}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

Total deflection due to seat contact force (per lbf//in.):

$$y_w := y_{bw} + y_{sw} - y_{compr}$$

(per lbf/in)

$$y_w = -5.693\cdot 10^{-7}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

Seat Contact Force for which deflection is equal previously calculated deflection from pressure forces:

$$F_s := 2\cdot\pi\cdot a\cdot\frac{y_q}{y_w}$$

$$F_s = 2.55\cdot 10^{3}\ \cdot lbf$$

UNSEATING FORCES

$F_{packing}$ **is included in measured static pullout Force**

$F_{piston} := \frac{\pi}{4} \cdot D_{stem}{}^{2} \cdot P_{bonnet}$ $F_{piston} = 176.715 \cdot lbf$

$F_{vert} := \pi \cdot a^{2} \cdot \sin(theta) \cdot \left(2 \cdot P_{bonnet} - P_{up} - P_{down}\right)$ $F_{vert} = 1.463 \cdot 10^{3} \cdot lbf$

$F_{preslock} := 2 \cdot F_{s} \cdot (mu \cdot \cos(theta) - \sin(theta))$ $F_{preslock} = 1.707 \cdot 10^{3} \cdot lbf$

$F_{total} := -F_{piston} + F_{vert} + F_{preslock} + F_{po}$ $F_{po} = 9.948 \cdot 10^{3} \cdot lbf$

$F_{total} = 1.294 \cdot 10^{4} \cdot lbf$

$F_{pressure} := F_{total} - F_{po}$ $F_{pressure} = 2.993 \cdot 10^{3} \cdot lbf$

Attachment 8

ComEd Response to NRC Request for Additional Information on ComEd Pressure Locking Testing

Crane Pressure Locking Test Data

			Pressures				Thrust Measurements			
Test #	Test Type	TSS	Pump	Reactor	Bonnet	Final	O9 thrust	O10 thrust	Run thrust	Corr Stat O9 thrust
1	Static	1	0	0	0	0	24680			
2	Static	1	0	0	0	0	24584			
3	Static	1	0	0	0	0	24888			
4	Static	1	350	350	350	350	23583			
5	Static	1	350	350	350	350	24383			
6	PL	1	350	355	650	400	30103			25000
7	PL	1	360	350	850	400	32213			25000
8	Static	1	325	440	335	400	25288			
9	Static	1	390	340	1040	430	35421			26000
10	PL	1	330	340	1040	400	35922			26000
11	PL	1	330	340	345	340	26090			
12	Static	1	0	0	0	0	27791			
13	PL	1	0	0	1195	0	47462			28000
14	PL	1	0	0	1375	0	50974			28000
15	PL	1	0	0	1375	0	51126			28000
16	Hydro DP	1	1440	0	1425	0	33512	17359	1102	
17	Hydro DP	1	1470	0	1475	0	31107	18362	905	
18	Hydro DP	1	1015	0	1000	0	30103	13246	1003	
19	Hydro DP	1	990	0	995	0	30905	12651	1102	
20	Hydro DP	1	1030	0	1015	0	32209	14950	1606	
21	Hydro DP	1	1010	0	975	0	31707	14549	1003	
22	Static	1	0	0	0	0	28696			
23	Static	1	0	0	0	0	28893			
24	Static	2.5	0	0	0	0	29199			
25	Static	2.5	0	0	0	0	35520			
26	Hydro DP	2.5	1010	0	995	0		15050	1204	
27	Hydro DP	2.5	980	0	965	0		15051	1204	
28	Hydro DP	2.5	1480	0	1485	0		22455	1104	
29	Hydro DP	2.5	1490	0	1465	0		22374	1104	
30	Static	2.5	0	0	0	0	39229		1405	
31	Static	2.5	0	0	0	0	36821		301	
32	Static	2.5	335	340	345	350	37223		301	
33	Static	2.5	360	340	335	350	38528		201	
34	PL	2.5	330	350	655	340	44243		401	38000
35	PL	2.5	330	340	655	370	43142		401	38000
36	Static	2.5	340	360	345	400	36819		301	
37	Static	2.5	330	340	315	350	37923		301	
38	PL	2.5	350	370	1055	380	50664		201	37500
39	PL	2.5	370	350	1055	380	50565		602	37500
40	Static	2.5	330	330	335	340	37323		401	
41	Static	2.5	0	0	0	0	40834		1304	
42	PL	2.5	0	0	1365	0	70028		3813	40000
43	PL	2.5	0	0	1165	0	70428		502	40000
44	Static	2.5	0	0	0	0	39627		502	
45	Static	2.5	0	0	0	0	40130		1404	
46	PL	2.5	0	0	1575	0	72231		1304	40000
47	PL	2.5	0	0	1575	0	71931		1003	40000
48	Static	2.5	0	0	0	0	40128		401	
49	Static	2.5	0	0	0	0	40831			
50	PL	2.5	0	0	1775	0	77749			40000

Crane Pressure Locking Test Data

	meas PL	calc PL	calc O9	
Test #	thrust	thrust	thrust	VF
	(PE+vert+PL)			
1				
2				
3				
4				
5				
6	5103	4539	29539	
7	7213	8191	33191	
8				
9	9421	11500	37500	
10	9922	12140	38140	
11				
12				
13	19462	22140	50140	
14	22974	25480	53480	
15	23126	25480	53480	
16				0.24
17				0.24
18				0.25
19				0.24
20				0.27
21				0.28
22				
23				
24				
25				
26				0.28
27				0.29
28				0.29
29				0.29
30				
31				
32				
33				
34	6243	5796	43796	
35	5142	5796	43796	
36				
37				
38	13164	13870	51370	
39	13065	13870	51370	
40				
41				
42	30028	29190	69190	
43	30428			
44				
45				
46	32231	33680	73680	
47	31931	33680	73680	
48				
49				
50	37749	37950	77950	

Attachment 9

ComEd Response to NRC Request for Additional Information on ComEd Pressure Locking Testing

Westinghouse Pressure Locking Test Data

Test #	Test	TSS	Pressures				Measured Thrust Values				
	Type		Pump	Reactor	Bonnet	Final	C16	O9	O10	Run	Corr Sta
											O9
1	Static	1.5	0	0	0	0					
2	Static	1.5	0	0	0	0					
3	Static	1.5	0	0	0	0					
4	Static	1.5	0	0	0	0					
5	Static	1.5	0	0	0	0					
6	DP	1.5	460	0	460	0	15050	3167	2430	1517	
7	DP	1.5	480	0	480	0	15665	2904	2359	1508	
8	DP	1.5	980	0	980	0	15699	3378	2640	1482	
9	DP	1.5	1590	0	1590	0	15548	3501	2675	1590	
10	Static	1.5	0	0	0	0	15497				
11	Static	1	0	0	0	0	13820				
12	DP	1	1590	0	1590	0	15548	3501	2552	1590	
13	DP	2	1880	0	1880	0	13751	3500	2429	1581	
14	Static	2	0	0	0	0					
15	Static	2	0	0	0	0					
16	PL	2	0	0	0	0					
17	Static	2	0	0	0	0					
18	Static	2	0	0	0	0	20101	1952			
19	DP	2	505	0	505	0	19717	2751	2189	1582	
20	DP	2	1020	0	1020	0	19914	2870	2342	1650	
21	DP	2	1496	0	1496	0	19900	3091	2428	1604	
22	DP	2	1944	0	1944	0	19949	3125	2377	1634	
23	DP	2	1880	0	1880	0	20047	3108	2529	1694	
24	DP	2	1596	0	1596	0	20112	2852	2359	1694	
25	DP	2	1068	0	1068	0	19946	2410	2070	1670	
26	Static	2	0	0	0	0	20031	1900			
27	Static	2	0	0	0	0	20129	1866			
28	Static	2	500	500	500	500	20179	1441			
29	Static	2	500	500	500	500	20080	1458			
30	PL	2	0	0	496	0	20096	3005			1450
31	PL	2	0	0	514	0	19879	2988			1450
32	Static	2	1000	1000	1000	1000	19962	896			
33	PL	2	0	0	1000	0	20029	3907			900
34	Static	2	998	998	998	998	19962	930			
35	PL	2	0	0	1000	0	19984	3890			900
36	Static	2	1500	1500	1500	1500	19697	104			
37	PL	2	0	0	1500	0	20077	4825			50
38	Static	2	1500	1500	1500	1500	20094	17			
39	PL	2	0	0	1500	0	20059	4722			50
40	Static	2	2000	2000	2000	2000	na	na	na	na	na
41	Static	2	2000	2000	2000	2000	19677	-346			
42	PL	2	0	0	2000	0	20323	5589			-400
43	Static	2	2000	2000	2000	2000	19976	-536			
44	PL	2	0	0	2000	0	20158	5726			-400
45	Static	2	1500	1500	1500	1500	20041	17			
46	DP	2	1515	0	1515	0	20058	2699	2019	1742	
47	DP	2	1564	0	1564	0	20291	3192	2240	1756	

Westinghouse Pressure Locking Test Data

Test #	meas PL	calc PL	calc O9		
	thrust	thrust	thrust	VF	
		(vert+PL)			
1					
2					
3					
4					
5					
6				thrust data questionable	
7				thrust data questionable	
8				thrust data questionable	
9				thrust data questionable	
10					
11					
12				0.148015	
13				0.135577	
14					
15					
16					
17					
18					
19				0.196239	
20				0.153944	
21				0.143634	
22				0.130014	
23				0.135018	
24				0.132798	
25				0.129394	
26					
27					
28					
29					
30	1555	1537.6	2987.6		
31	1538	1593.4	3043.4		
32					
33	3007	3100	4000		
34					
35	2990	3100	4000		
36					
37	4775	4650	4700		
38					
39	4672	4650	4700		
40					
41					
42	5989	6200	5800		
43					
44	6126	6200	5800		
45					
46				0.113908	
47				0.124138	

Attachment 10

ComEd Response to NRC Request for Additional Information on ComEd Pressure Locking Testing

Borg-Warner Pressure Locking Test Data

Test #	Test	TSS	Pressures				Thrust Measurements				
	Type		Pump	Reactor	Bonnet	Final	C16	O9	O10	Open	Corr Sta
										Run	O9
18	Static	2					23241	7863			
19	DP	2	100		100		25430	7863	1543	617	
20	DP	2	100		100		25825	7663	1841	600	
21	DP	2	200	0	200	0			2587	540	
22	DP	2	450	0	450	0			5424	535	
23	DP	2	730	0	730	0			9902	555	
24	Static	1					12638	3781			
25	Static	2					24826	7612			
28	DP	2	760	0	760	0			14475	605	
29	DP	2	530		530		28945	18799	14025	406	
30	DP	2	540		540		28550	14722	15767	435	
31	DP	2	245		245		29395	15966	7311	482	
32	DP	2	285		285		29446	14126	8257	500	
33	DP	2	455		455		29843	11291	13529	426	
34	DP	2	475		475		29245	11539	14573	448	
35	DP	2	450		450		29794	13927	13828	528	
36	DP	2	550		550		29344	10494	6863	499	
37	DP	2	505		505		29344	9102	9599	439	
38	DP	2	550		550		28966	9549	14821	479	
39	DP	2	520		520		29096	12683	15269	447	
42	Static	2					31783	16513			
43	PL	2			205		32032	25467			16935
44	Static	2					31731	17357			
45	Static	1					16162	7261			
46	Static	1					16659	7509			
47	Static	1					16859	7907			
48	PL	1			209		16809	15268			7882
49	Static	1					16659	7857			
50	PL	1			402		16708	20786			7782
51	Static	1					16807	7707			
52	PL	1			630		16958	26705			7906
53	Static	1					16460	8105			
54	PL	1			694		16361	28395			7881.5
55	Static	1					16956	7658			
56	PL	1			919		16709	41872			5023
58	Static	1					15665	5023			
59	DP	2	510		510		9845	16757	17553	350	
63	Static	2									16008
64	TB	2									18995
65	Static	2									17402
66	DP	2	208		208				6165	525	
67	DP	2	198		198				6066	653	
68	DP	2	370		370				11834	627	
69	DP	2	413		413				13922	623	
70	DP	2	575		575		32069	25506	18346	557	
71	DP	2	610		610		31721	27545	20683	638	
73	Static	2						17202			
74	PL	2			208			27643			17477
75	PL	2			213			28241			17477
76	Static	2						17751			
77	PL	2			391			33906			17751

Borg-Warner Pressure Locking Test Data

Test #	Test	TSS	Pressures				Thrust Measurements				
	Type		Pump	Reactor	Bonnet	Final	C16	O9	O10	Open	Corr Sta
										Run	O9
78	PL	2			402			34604			17751
79	Static	2						17949			
80	PL	2			467			40121			17949
81	PL	2			219			28540			17949
82	Static	2						17700	17700	17700	
83	PL	2			110			25457			17700
84	PL	2			55			22871			17700
85	Static	2						17352			
86	PL	2			0			20980			17352
87	Static	2						18494			
88	Static	2						18197			
91	TB	2						24244			17541
92	Static	2						17541			
93	Static	1						8000			
95	PL	1			0			11132			8000
96	PL	1			557			27035			8000
97	PL	1			504			26189			8000
99	DP	1			607				20177	35	
100	DP	1			578				20325	740	

Borg-Warner Pressure Locking Test Data

Test #	PL thrust	calc PL thrust (PE+vert+PL)	meas O thrust	calc O9 thrust	VF	Comments
18						
19					0.131	
20					0.169	
21					0.143	
22					0.151	
23					0.174	
24						
25						
28					0.239	
29					0.327	
30					0.359	
31					0.353	
32					0.345	
33					0.364	
34					0.375	
35					0.373	
36					0.159	INITIAL REVERSE FLOW DP TEST
37					0.237	DP TEST AFTER 6 PRECONDITIONING STROKES
38					0.332	DP TEST AFTER 12 PRECONDITIONING STROKES
39					0.361	
42						
43	8532	5690.8	25467	22625.8		
44						
45						
46						
47						
48	7386	5801.8	15268	13683.8		
49						
50	13004	11160	20786	18941.5		
51						
52	18799	17489	26705	25394.8		
53						
54	20514	19265	28395	27146.9		
55						
56	36849	25511	41872	30534.4		
58						
59					0.423	
63						
64	16008					Delta T of 75 F
65						
66					0.344	
67					0.347	
68					0.382	
69					0.405	
70					0.390	
71					0.413	
73						
74	10167	6225.4	27643	23701.9		
75	10765	6375.1	28241	23851.6		
76						
77	16155	11703	33906	29453.6		

Borg-Warner Pressure Locking Test Data

Test #	PL	calc PL	meas O	calc O9		
	thrust	thrust	thrust	thrust	VF	Comments
		(PE+vert+PL)				
78	16853	12032	34604	29782.9		
79						
80	22172	13977	40121	31926.3		Test performed by pressurizing open valve
81	10591	6554.7	28540	24503.7		Test performed by pressurizing open valve
82						
83	7757	3292.3	25457	20992.3		
84	5171	1646.2	22871	19346.2		
85						
86	3628	0	20980	17352		Test demonstrates "Memory Effect" for 500 psi side load
87						Test demonstrates "Memory Effect" is much smaller for 200 ps
88						
91						Delta T of 230 F
92						
93						
95	3132	0	11132	8000		
96	19035	16671	27035	24671		
97	18189	15085	26189	23084.7		
99					0.417	data suspect, not all line pressure gone
100					0.425	