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SUBJECT: Provides info that was requested in response to GL 95-07, "Pressure Locking & Thermal Binding of Safety-Related Power-Operated Valves."

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APS

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U.S. Nuclear Regulatory Commission
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Dear Sirs:

Subject: Palo Verde Nuclear Generating Station (PVNGS)
Units 1, 2, and 3
Docket Nos. STN 50-528/529/530
Reponse to Generic Letter 95-07, Request for Additional Information, dated June 11, 1999
(TAC NOS. M93497, M93498, M93499)

By letter dated June 11, 1999, the NRC requested that Arizona Public Service Company (APS) provide additional information for their review of APS' response to Generic Letter 95-07, "Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves." The requested information is provided in Enclosure 1. Additional supporting documentation is provided in the accompanying enclosures.

No commitments are being made to the NRC by this letter. If you have any questions, please contact Scott A. Bauer at (623) 393-5978.

Sincerely,

David Mauldin

CDM/SAB/JAP/kg

Enclosures

cc: E. W. Merschoff (w/ enclosure 1 only)
N. Kalyanam
J. H. Moorman (w/ enclosure 1 only)

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50-528 PALO VERDE 1 APSCO

ENCLOSURE 1 RESPONSE TO GL 95-07 PRESSURE LOCKING AND THERMAL BINDING OF SAFETY-RELATED POWER-OPERATED GATE VALVES RAI

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ENCLOSURE 1

RESPONSE TO GENERIC LETTER 95-07, "PRESSURE LOCKING AND THERMAL BINDING OF SAFETY-RELATED POWER-OPERATED GATE VALVES," REQUEST FOR ADDITIONAL INFORMATION

Each of the questions from the RAI is repeated in whole or in part below, directly followed by the APS response.

NRC Statement:

In the February 21, 1996, response to Generic Letter (GL) 95-07 it states that you used a pressure locking thrust prediction methodology to calculate the opening stem thrust required to overcome pressure locking. This analytical method was used as a long-term corrective action to demonstrate the valves would operate during pressure locking conditions. GL 95-07 states that the use of a pressure locking thrust prediction methodology is an acceptable corrective action to demonstrate that valves are capable of operating during pressure locking conditions provided that the methodology is validated by a test program. During a phone call conducted on May 20, 1999, you stated that your pressure locking thrust prediction methodology was based on assumptions similar to the assumptions used in the pressure locking thrust prediction methodology developed by Entergy Operations, Inc. (EOI).

APS RESPONSE:

PVNGS PRESSURE LOCKING MODEL BACKGROUND

The Palo Verde Nuclear Generating Station (PVNGS) pressure locking model was initially developed in the 1994-1995 time frame. The Entergy Operations, Inc. (EOI) pressure locking model was presented in February 1994 at the Workshop on Gate Valve Pressure Locking and Thermal Binding (NUREG/CP-0146 1994). The EOI model's use of the Roark equations for thin flat circular homogeneous plates of uniform thickness is the core of many of the pressure locking models in use today. Although this EOI model is at the core of the PVNGS model, the PVNGS model has been updated as additional information, test data and evaluations have become available over the last four years. The PVNGS pressure locking model utilizes five component loading terms to determine the required gate valve thrust to overcome the worst case postulated design basis pressure locking condition. PVNGS model validation was accomplished utilizing testing performed in cooperation with Commonwealth Edison and the Westinghouse Owners Group on a Borg Warner gate valve supplied by PVNGS. The details of the PVNGS model along with the model validation test results are presented in PVNGS calculation 13-MC-ZZ-217, "Gate Valve Open Thrust Required During Potential Pressure Locking Conditions" (Enclosure 3). Further, the PVNGS pressure locking model was not solely relied upon for valves that were identified as being potentially subjected to significant thermal pressurization. Significant thermal pressurization to susceptible valves was identified where valve bonnet fluid was being subjected to temperature increases above 30°F prior to or during design basis conditions. These valves have been modified to include bonnet pressure relief devices to preclude the possibility of excessive thermal pressurization-induced pressure locking.

NRC REQUEST:

In order for the NRC to review your pressure locking thrust prediction methodology, please provide the following information:

NRC QUESTION (1a):

Describe the pressure locking thrust prediction methodology and provide the test procedure/results that validate the methodology. Include any information that will help evaluate if your valves are similar to test valves as applicable.

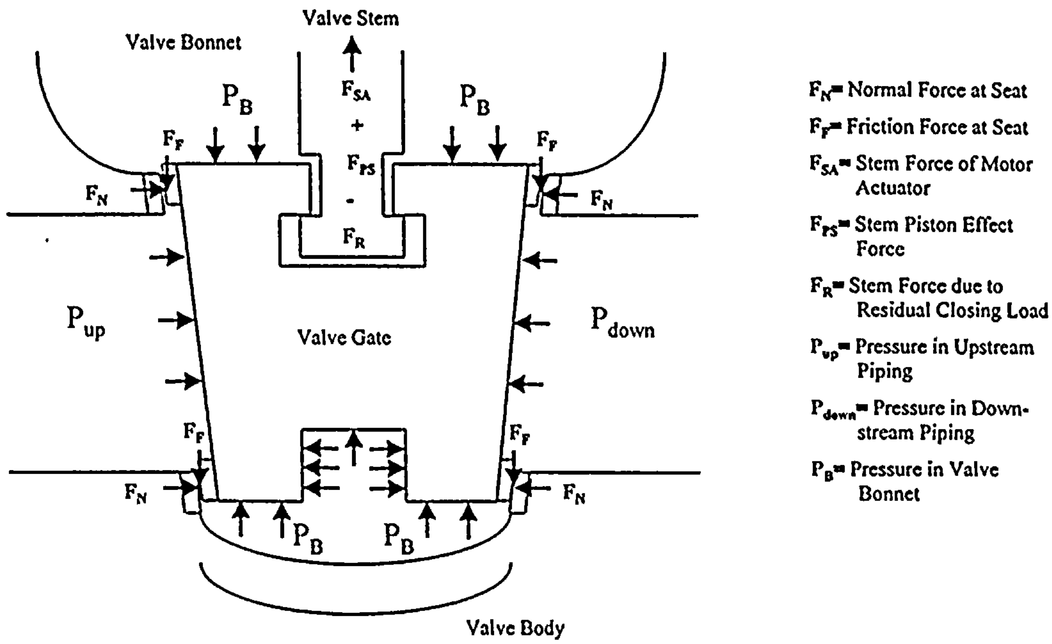

Figure 1: Simplified Valve Gate, Bonnet, and Stem Pressure Locking Forces

APS RESPONSE (1a):
PVNGS PRESSURE LOCKING MODEL OVERVIEW
The PVNGS pressure locking thrust prediction methodology involves the superposition of five terms to determine the postulated state of pressure locking loading. Figure 1 represents a simplified pressure locking force diagram on the valve disk and stem. The resulting equation is:

Required Pressure Locking Stem Thrust (F_{total}) = Disk Load (F_{disk}) + Hub Load (F_{hub}) + Vertical Load (F_{vert}) + Residual Load (F_{resid}) – Stem Piston Load (F_{piston}).

A simplified equation for each load is presented in the following discussion.

DISK LOAD

The disk load (F_{disk}) is the load at the valve stem due to a component of the friction force (F_F') at the interface of the valve gate and the valve body seat. The disk load equation is a function of a component of the normal force (F_N') to the seat, the angle between the plane of the valve seat (θ) and the valve stem axis, and the coefficient of friction (μ) at the valve seat. The normal force (F_N') at the valve seat is a function of the valve bonnet pressure (P_B), the piping upstream pressure (P_{up}) and downstream pressure (P_{down}) of the valve, as well as the cross-sectional areas upon which the pressures are applied. Many of the forces on the disk of the gate are balanced by forces equal and opposite. Only the unbalanced forces on the disk contribute to the normal load (F_N') on the seat.

The disk load (F_{disk}) can be expressed as:

$$(F_{disk}) = 2 * Q_a * P_L * \mu$$

where:

Q_a is the equivalent force/inch due to the unbalanced bonnet pressure (P_B) exerted at the perimeter of the valve disks. This term is developed from Roark's model of a thin flat circular homogeneous plate with the outer edge simply supported and the inner edge fixed (Roark's Formulas for Stress and Strain 1989). This has been determined to conservatively model the dominant force component at the disk seat due to bending primarily induced by the bonnet pressure (P_B). This term is proportional to the differential pressure between the bonnet pressure (P_B) and the average between the upstream pressure (P_{up}) and the downstream pressure (P_{down}).

P_L is the circumference of the disk seat. This term is proportional to twice the value of Pi (π) and the mean radius of the valve seat (a).

μ is the coefficient of friction at the valve seat. This term is proportional to the valve factor (VF) and the cosine of the seat angle (θ) and inversely proportional to 1 minus the valve factor (VF) times the sine of the seat angle (θ). The valve factor (VF) utilized was develop from the equations for the differential pressure presented in EPRI's Application Guide for Motor-Operated Valves in Nuclear Power Plants (EPRI NP-6660-D 1990).

HUB LOAD

The hub load is the additional load at the valve stem due to increased friction at the interface of the valve gate and valve body seat as a result of the differential pressure between the upstream and downstream piping pressure acting on the area of the disk hub.

The hub load (F_{hub}) can be expressed as:

$$(F_{hub}) = Q_a' * P_L * \mu$$

where:

Q_a' is the equivalent force/inch due to the unbalanced piping pressure exerted at the perimeter of the valve disks. The unbalanced piping pressure is the differential pressure between the upstream pressure (P_{up}) and the downstream pressure (P_{down}). This bending force is conservatively modeled at the valve seat of the low pressure disk. This term is developed from Roark's model of a thin flat circular homogeneous plate with the outer edge simply supported and the inner edge guided (Roark's Formulas for Stress and Strain 1989). This term is proportional to the differential pressure between the upstream pressure (P_{up}) and the downstream pressure (P_{down}).

P_L – same as for Disk Load

μ – same as for Disk Load

<u>VERTICAL LOAD</u>

The vertical load (F_{vert}) is the force due to bonnet pressure (P_B) driving the gate into the seat. The differential pressure between the bonnet (P_B) and the average of the upstream pressure (P_{up}) and downstream pressure (P_{down}) directed into the valve seat drive this vertical unbalanced load across the valve disk. The vertical unbalanced load is calculated by multiplying the average differential pressure between the valve bonnet pressure (P_B) and the connecting piping upstream pressure (P_{up}) and downstream pressure (P_{down}) by the horizontal projected area of the gate disks. The horizontal projected area is a sum of the two ellipses projected on to the horizontal plane whose perimeter is bounded by the seat inside perimeter. The force down on the disk is due to the horizontal projection of the circular geometry of the seat, which the unbalanced differential pressure is applied across. The net effective cross-sectional area of each gate disk seat, which the net pressure acts upon, is the resulting ellipse.

The vertical load (F_{vert}) can be expressed as:

$$(F_{vert}) = 2 * A_e * (P_B - ((P_{up} + P_{down})/2)$$

where:

A_e is the elliptical area, which is the single seat inside diameter area projection on to the horizontal plane. This term is proportional to the value of Pi (π), the sine of the seat angle (θ) and the square of the mean radius of the valve seat (a).

<u>RESIDUAL LOAD</u>

The residual load (F_{resid}) is the load opposing valve opening caused by wedging the valve disk into the seat by the closing thrust of the prior valve stroke. This empirically derived load includes the running loads. The residual load (F_{resid}) accounts for the relaxation in the wedging load which occurs when stem motion is initiated in the open

direction and is substituted to some degree by the bonnet pressure induced load that has been determined, from a review of Commonwealth Edison test results, to replace increasing proportions of the residual load as bonnet pressure (P_B) increases. The residual load is calculated by taking the established static peak cracking load and dividing by 0.67 to determine the effective closing thrust based on 33% wedging load relaxation similar to the unwedging load coefficient utilized in the EPRI MOV Performance Prediction Program (EPRI TR-103237 1994). This value is then multiplied by a residual load coefficient (C_{resid}) which is developed from an experimentally derived correlation which indicates that as the bonnet pressure increases the residual load percentage of the effective closing thrust is reduced in a linear manner.

The residual load (F_{resid}) can be expressed as:

$$(F_{resid}) = F_{eff.closing} * C_{resid}$$

where:

$F_{eff.closing}$ is the prior effective closing force that is proportional to the error adjusted static peak cracking limit divided by an EPRI established constant of 0.67 that is a function of the valve seat angle (θ) and the coefficient of friction of the valve seat (μ) to account for relaxation. The static peak cracking is the required opening force with zero bonnet pressure ($P_B = 0$). The static peak cracking is sometimes identified as static unwedging thrust or static unseating force.

C_{resid} is the coefficient of residual load and is an empirically derived coefficient that accounts for an observed reduction in the measured residual load due to a proportional replacement by the effect of the bonnet pressure (P_B) induced force.

<u>STEM PISTON LOAD</u>

The stem piston load is the load in the open direction created by application of the differential pressure between valve internals and the ambient pressure on the net cross-sectional area of the valve stem. For simplification, atmospheric pressure can be neglected since the effect is not significant for the calculation of pressure locking loads. The net effect of this load is to drive the stem in the open direction, like a piston, reducing the required opening thrust.

The stem piston load (F_{piston}) can be expressed as:

$$(F_{piston}) = A_{stem} * P_B$$

where:

A_{stem} is the stem cross section area and is proportional to the value of Pi (π), and the square of the stem diameter divided by 4.

PVNGS MODEL VALIDATION TESTING

Commonwealth Edison, in partnership with the Westinghouse Users Group and Arizona Public Service, performed pressure locking testing and evaluation of a PVNGS Borg Warner 10", 300 lb class gate valve. These special tests involved determining the stem thrust required to open the valve with the fluid pressure in the valve bonnet greater than the fluid pressure in the upstream and downstream piping. The test methodology, instrumentation, and the final results are presented in Attachment 5 of the PVNGS calculation 13-MC-ZZ-217, "Gate Valve Open Thrust Required During Potential Pressure Locking Conditions" (Enclosure 3).

NRC QUESTION (1b):

Results from pressure locking testing sponsored by the NRC performed by INEEL on a flexible wedge gate valve have been placed in the Public Document Room (NUREG/CR-6611, "Results of Pressure Locking and Thermal Binding Tests of Gate Valves"). Discuss if your pressure locking thrust prediction methodology accurately calculates the results of these pressure locking tests.

APS RESPONSE (1b):

Review and comparison of the applicable NRC sponsored Idaho National Engineering and Environmental Laboratory (INEEL) pressure locking test results presented in NUREG/CR-6611 is documented in PVNGS calculation 13-MC-ZZ-217, "Gate Valve Open Thrust Required During Potential Pressure Locking Conditions" (Enclosure 3). This INEEL pressure locking testing included pressure locking testing of a 6" Walworth 600 lb class flexible wedge gate valve and a 6" Anchor Darling 900 lb class double disk gate valve. APS has compared the Walworth flexible wedge gate valve pressure locking test results to the PVNGS pressure locking model that was used to evaluate the identified potentially susceptible PVNGS Anchor Darling and Borg Warner flexible wedge gate valves. Since PVNGS does not have any pressure locking susceptible double disk gate valves, the tested Anchor Darling double disk valves were not applicable to the evaluated PVNGS valves which are all flexible wedge gate valves. In general, the least square linear regression comparison of the PVNGS pressure locking model with the INEEL pressure locking test results shows a conservative divergent correlation. Although there appears to be some scatter of the test results that may be partially attributed to the effect of varying upstream and down stream pressures, there was a good correlation of the PVNGS model to conservatively predict the INEEL thermal pressure locking measured opening thrust test results for specific data points. However, the PVNGS model was less conservative in predicting the cold pressure locking measured opening thrust test results. The margin between the INEEL Walworth gate valve thermally-induced pressure locking test results measured peak unwedging and the PVNGS model's predicted pressure locking thrust data ranged from a conservative positive margin of 77% to a minimum margin of (negative) –10.5%. Note that the conservative margin was found for the measured pressure locking load of 10,429 lbf. with a bonnet pressure of 922 psig and 916 psig downstream pressure at

187°F (Test 310) and the minimum margin of (negative) –10.5% was found for the measured pressure locking load of 19,501 lbf. with a bonnet pressure of 1050 psig and essentially no upstream or down stream pressure at 65 °F (Test 343). Refer to PVNGS calculation 13-MC-ZZ-217, Enclosure 3, Attachment 6.

There appears to be some inconsistency between the INEEL test results for the 6" Walworth 900 lb valve and the Commonwealth Edison test results for the 10" Borg Warner 300 lb valve. This inconsistency could be attributed to the characteristics of the tested flexible Walworth gate valve disk with its typically thinner disk and smaller hub dimensions and an apparent instability in the friction factors under cold temperature conditions. Therefore, it is difficult to conclude that the PVNGS pressure locking analysis model is accurate in predicting the indicated INEEL measured pressure locking loads. However, when the INEEL test data and PVNGS model results for the required opening thrust versus the bonnet pressure were fit with least square linear regression, accounting for inherent errors, the Palo Verde model reasonably approaches conservatively predicting the trends of the INEEL test results (See Charts 1 & 2 of PVNGS calculation 13-MC-ZZ-217, Enclosure 3, Appendix 6). Further, the results of this INEEL pressure locking test data do not invalidate the PVNGS pressure locking model that was developed for the relatively more rigid disk of the Borg Warner 300 lb class flexible wedge gate valve based on the Commonwealth Edison pressure locking test data documented in PVNGS calculation 13-MC-ZZ-217, Enclosure 3, Attachment 5. It is apparent that the more flexible the gate valve disk is, the more sensitive the valve is to pressure locking conditions.

NRC QUESTION (1c):
Discuss the recommended margin between actuator capability and the calculated thrust value when using your pressure locking thrust prediction methodology, and limitations associated with the use of your methodology and any diagnostic test equipment accuracy requirements. Commonwealth Edison provided this type of information to the NRC in a letter dated May 29, 1998. This letter is in the Public Document Room (Accession Number: 9806040184).

APS RESPONSE (1c):
Commonwealth Edison, in partnership with Arizona Public Service and the Westinghouse Owners Group, performed testing of a PVNGS Borg Warner 10", 300 lb class flexible wedge gate valve to determine the stem thrust required to open these type of flexible wedge gate valves with the fluid pressure in the valve bonnet greater than the fluid pressure in the upstream and downstream piping. The test methodology instrumentation, and final results are identified in Attachment 5 of the PVNGS calculation 13-MC-ZZ-217, "Gate Valve Open Thrust Required During Potential Pressure Locking Conditions" (Enclosure 3).

The measured data and predicted values from selected Commonwealth Edison tests were plotted and fit with best fitting least square linear regression. In general a good correlation between the regression for the measured data and for the predicted values was demonstrated by the similarity in slope between the plotted lines. The margin between the measured data and predicted data for relatively low values of prior closing thrust (less than 17,000 lbf.), were found to be from a conservative 30.9% for the measured pressure locking load of 26,705 lbf. with a bonnet pressure of 630 psig (Test #52) to a minimum margin of 8.9% between the measured and predicted values of the pressure locking load of 41,872 lbf. with a bonnet pressure of 919 psig (Test #56). However, the measured data presented tracks the predicted values calculated utilizing the methodology of PVNGS calculation 13-MC-ZZ-217 (Enclosure 3). There is one set of data for the relatively high values of closing thrust (greater than 31,000 lbf.) (Test #80), where the measured pressure locking load exceeds the calculated stem thrust required to open by 3.1%. Therefore, for applications of the PVNGS pressure locking model presented in calculation 13-MC-ZZ-217 with postulated bonnet pressure of above 200 psig, at least an additional 10% margin to account for PVNGS Model uncertainty is maintained between the minimum actuator capability or load limit and the calculated required pressure locking load unless otherwise justified. In addition, instrument errors that are a function of overall diagnostic test equipment accuracy and percent of full scale error that varies from 10% to 25% is factored into the peak cracking limit for each valve based on the established pressure locking static peak cracking limit used in the PVNGS pressure locking calculation, 13-MC-ZZ-217 (Enclosure 3). These established peak cracking limits with their associated errors are controlled by PVNGS utilizing a design setpoint document for each unit; 01-J-ZZI-004, 02-J-ZZI-004, and 03-J-ZZI-004; Controlled Motor Operator Data Base (CMODB).

NRC QUESTION (1d):
Pressure locking test results conducted by INEEL on a flexible wedge gate valve discussed in NUREG/CR-6611 indicated that, as differential pressure between the bonnet and the downstream (or upstream) side of the valve increased, the stem thrust required to open the pressure-locked valve increases. The EOI pressure locking methodology predicted that the opposite would occur in that, as differential pressure between the bonnet and downstream (or upstream) side of the valve increased, the stem thrust predicted to open the pressure-locked valve decreased. Discuss how your pressure locking thrust prediction methodology trends as differential pressure between the bonnet and the downstream (or upstream) side of the valve increases. If applicable, discuss any differential pressure restrictions or other conditions associated with the use of your pressure locking thrust prediction methodology.

APS RESPONSE (1d):
The PVNGS pressure locking methodology deviates from the Entergy Operations, Incorporated (EOI) model. The PVNGS model includes three terms that account for the effects of the variation of differential pressure between the bonnet and the upstream and downstream side of the valve. These terms are the disk load, vertical load, and

hub load. The disk load accounts for the friction load due to the normal forces caused by the difference between the bonnet pressure and the average of the upstream and downstream pressures. The vertical load accounts for the increased load due to the effect of the unbalanced load across the valve disk caused by the differential pressure between the bonnet and the average of the upstream and downstream pressures. This vertical load term is not included in the EOI model but is included in the Commonwealth Edison model. The hub load accounts for the increased loading at the low pressure seat caused by the differential pressure between the upstream and downstream side of the valve such that this load is proportional to this differential pressure. The hub load increases due to increased friction load caused by the additional normal forces at the low pressure valve seat. Therefore, the PVNGS pressure locking model indicates that, as differential pressure between the bonnet and the valve downstream and/or upstream sides increases, the predicted pressure locking stem thrust also increases. Conversely, decreases in differential pressure between the bonnet and valve upstream and/or downstream sides result in a commensurate decrease in the predicted pressure locking stem thrust. The disk load and the hub loads are similar to the bonnet pressure and differential pressure terms in the EOI model.

NRC QUESTION (1e):
Identify the valves for which your pressure locking thrust prediction methodology was used to demonstrate that the valves would operate during pressure locking conditions.

APS RESPONSE (1e):
Valves utilizing PVNGS Pressure model without a bonnet pressure relief modification:

CHE-HV-536, RWT Gravity Feed Line to Charging Pumps Isolation Valve
APS found CHEHV536 to be the only potential pressure locking susceptible gate valve in each unit that did not require any modification or corrective action based on an evaluation utilizing the PVNGS pressure locking model. This valve is located at the 70-foot elevation of the Auxiliary Building in the Reactor Makeup Water and Boric Acid Makeup Pump Room. This valve is a 3" Borg Warner 1500 lb class flexible wedge gate valve with relatively low potential bonnet pressures and not susceptible to thermal pressurization. Consequently, the valve is subject to relatively low postulated pressure locking loads. The postulated pressure locking loads based on the PVNGS pressure locking thrust prediction model were factored into the existing setpoints and an established peak cracking limit was added.

SIA-HV-604 & SIB-HV-609, High Pressure Safety Injection (HPSI) Long Term Recirculation Isolation Valves
Corrective action for an additional pair of potential pressure locking susceptible gate valves in each unit, SIAUV604 & SIBUV609, only required establishment and resetting to a lower limit for the allowable peak cracking in order to control the postulated pressure locking loads. These valves are located at the 40-foot elevation of the Auxiliary Building in their respective train High Pressure Safety Injection Pump Rooms.

These are 3" Borg Warner 1500 lb class flexible wedge gate valves with relatively high potential bonnet pressures and susceptible to slight thermal pressurization and upstream minimum system pressure. Consequently, these valves are subject to relatively moderate postulated pressure locking loads. A heat transfer and fluid flow evaluation was performed and documented (13-MC-SI-330, Calculation of Bonnet Fluid Temperature for MOV SI-604/609, Enclosure 4) to determine the maximum steady state bonnet fluid temperature.

SGA-UV-134/138, Steam Generator Steam Supply to Auxiliary Feedwater Pump Turbine Isolation Valves

Modification to a pair of potential pressure locking susceptible gate valves in each unit, SGAUV134 & SGBUV138, involved an upgrade in the actuator and valve weaklink as described in APS response to question 4 below to provide additional actuator capacity and component strength to overcome postulated pressure locking loads. These valves are located in the 120-foot elevation of the Main Steam Support Structure (MSSS) building in the Main Steam Isolation and Dump Valve Area. These are 6" Anchor Darling 900 lb class flexible wedge gate valves with relatively high potential bonnet pressures and are not susceptible to additional thermal pressurization. Consequently, these valves are subject to relatively moderate postulated pressure locking loads.

SIB-UV-671 & SIA-UV-672, Containment Spray Control Valves

Modification to a pair of potential pressure locking susceptible gate valves in each unit, SIBUV671 & SIAUV672, involved an upgrade in the actuator as described in APS response to question 4 below to provide additional actuator capacity and component strength to overcome postulated pressure locking loads. These valves are located in the 87-foot elevation of the Auxiliary building in their respective train Piping Penetration Rooms. These are 8" Borg Warner 300 lb class flexible wedge gate valves with relatively moderate potential bonnet pressures and are not susceptible to thermal pressurization. Consequently, these valves are subject to relatively moderate postulated pressure locking loads.

SIA-HV-686 & SIB-HV-696, Shutdown Heat Exchanger to Low Pressure Safety Injection Header Crossover Valve

Modification to a pair of potential pressure locking susceptible gate valves in each unit, SIAHV686 & SIBHV696, involved an upgrade in the actuator as described in APS response to question 4 below to provide additional actuator capacity to overcome postulated pressure locking loads. These valves are located in the 70-foot elevation of the Auxiliary building in their respective train Shutdown Cooling Heat Exchanger and Valve Gallery Rooms. These are 20" Borg Warner 300 lb class flexible wedge gate valves with relatively moderate potential bonnet pressures and are not susceptible to thermal pressurization. Consequently, these valves are subject to relatively moderate postulated pressure locking loads.

SIA-HV-688 & SIB-HV-693, Containment Spray Bypass Valves

Modification to a pair of potential pressure locking susceptible gate valves in each unit, SIAHV688 & SIBHV693, involved an increase in the actuator overall gear ratio as described in APS response to question 4 below to provide additional actuator capacity to overcome postulated pressure locking loads. These valves are located in the 70-foot elevation of the Auxiliary building in their respective train Shutdown Cooling Heat Exchanger and Valve Gallery Rooms. These are 10" Borg Warner 330 lb class flexible wedge gate valves with relatively moderate potential bonnet pressures and are not susceptible to thermal pressurization. Consequently, these valves are subject to relatively moderate postulated pressure locking loads.

SIA-HV-685 & SIB-HV-694, Low Pressure Safety Injection to Shutdown Cooling Heat Exchanger Cross Connect Valves

Modification to a pair of potential pressure locking susceptible gate valves in each unit, SIAHV685 & SIBHV694, involved an increase in the actuator overall gear ratio as described in APS' response to question 4 below to provide additional actuator capacity to overcome postulated pressure locking loads. These valves are located in the 70-foot elevation of the Auxiliary Building in their respective train Shutdown Cooling Heat Exchanger and Valve Gallery Rooms. These are 10" Borg Warner 330 lb class flexible wedge gate valves with relatively moderate potential bonnet pressures and are not susceptible to thermal pressurization. Consequently, these valves are subject to relatively moderate postulated pressure locking loads.

NRC QUESTION (2a):

The February 21, 1996, submittal states that an algorithm was used to calculate thermally induced bonnet pressure increase in determining the maximum bonnet pressure in your pressure locking thrust prediction methodology.

Describe the algorithm and the basis for the algorithm.

APS RESPONSE (2a):

The thermal pressurization algorithm developed for the PVNGS pressure locking model utilizes an empirical relationship between pressure and temperature to evaluate the effects of bonnet water temperature increases on valve bonnet pressure. This relationship was developed based on testing of a PVNGS spare 10" Borg Warner 300 lb flexible wedge gate valve at Commonwealth Edison's Braidwood Station test facility. The valve assembly was vented, filled with water and then heated utilizing strategically placed heating coils wrapped in thermal blankets in separate tests at different heat rates. The internal bonnet fluid temperature and pressure was recorded at various time intervals.

The thermal testing heat-up test results indicated two distinctive pressurization regions. The first pressurization region which included the initial 60 °F bonnet temperature increase could be modeled using a pressurization rate of 3 psig/°F. However, this gradual 3 psig/°F was modeled for only the first 30 °F temperature increase. The second pressurization region, which includes the bonnet temperature increase greater than 60 °F, was modeled starting at increases greater than 30°F using the two highest observed applicable pressurization rates of 42 psig/°F at 150 °F and 65 psig/°F at 290 °F. These rates were normalized by developing a differential linear expression averaging these rates over the applicable temperatures ranges and integrating the expression over the modeled temperature range. These expressions for region one and region two were then added together to determine the total pressure increase. The resulting average pressurization rates after the first 30°F temperature increase are in the range of 35 psig/°F to 45 psig/°F in the 100 °F to 160°F temperature range of interest. The resulting postulated bonnet pressure increase is compared with the test data and a theoretical pressurization model as is shown in Attachment 2 of the PVNGS calculation 13-MC-ZZ-217, "Gate Valve Open Thrust Required During Potential Pressure Locking Conditions" (Enclosure 3). The PVNGS pressurization model is representative of the field conditions of the PVNGS valves including the moderate temperature increases that the applicable PVNGS valves would be subjected to based on review of test results, design basis temperature calculations, heat transfer analysis, and applicable normal and accident scenario evaluations.

NRC QUESTION (2b):
Discuss if your algorithm accurately predicted the pressure/temperature relationship test results sponsored by the NRC and conducted by INEEL that are documented in NUREG/CR-6111(6611). Testing conducted by INEEL identified thermal-induced pressurization rates of up to 50 psi/°F.

APS RESPONSE (2b):
Review and comparison of the applicable NRC sponsored Idaho National Engineering and Environmental Laboratory (INEEL) thermal pressurization test results presented in NUREG/CR-6611 with attachment 2 of PVNGS calculation 13-MC-ZZ-217, "Gate Valve Open Thrust Required During Potential Pressure Locking Conditions" (Enclosure 3) indicated that in the temperature region of interest that the PVNGS thermal pressurization model rates approach those of the INEEL test results. Although no specific thermal pressurization rate was found stated in NUREG/CR-6611 the rates implied by the linear pressurization rates depicted in the graphical presentation indicate that the thermal pressurization rate approaches 50 psig/°F. This does not appear inconsistent with the Commonwealth Edison PVNGS Borg Warner valve high temperature test results. However, the Commonwealth Edison test results of the PVNGS Borg Warner valve indicated that there was an initial approximately 60°F temperature heatup region before significant thermal pressurization rates were observed. After this first 60°F temperature increase these thermal pressurization rates

were then found to vary up to a high temperature region maximum rate of around 60 psig/°F as temperature continued to increase. The appropriate thermal pressurization rates of significant interest to PVNGS were modeled based on these test results for the temperature region of interest for potential PVNGS pressure locking conditions. These do not appear to be directly comparable to the INEEL test results although they approach the predicted pressure/temperature relationship for the 2% air volume in the region of 150°F. However, it is difficult to conclude that the PVNGS thermal pressurization model is accurate in predicting the indicated INEEL measured test results. Review of additional detailed INEEL test data in the PVNGS temperature range of interest, 100°F to 160°F, would be required.

NRC QUESTION (2c):
Assuming zero leakage through the valve seats and stem packing, zero entrapped air and negligible pressure expansion of the valve bonnet, the theoretical increase in bonnet pressure due to temperature increase is greater than 50 psi/°F. If the results of your algorithm are less conservative than the INEEL pressurize/temperature relationship test results, explain why it is acceptable to use the results of your algorithm.

APS RESPONSE (2c):
The PVNGS thermal pressurization algorithm was developed based on the 1995 Commonwealth Edison test results of a representative 10" 300 lb class Borg Warner flexible wedge gate valve. The INEEL thermal pressurization test data is not inconsistent with the available data for the PVNGS temperature range of interest (100°F to 160°F) for the PVNGS flexible wedge gate valves that were identified as being susceptible to thermal pressurization due to design basis event system and environmental exposure temperature increases. This temperature range of interest is based on review of design basis heat transfer and fluid flow calculations and is documented in PVNGS CRDR 9-5-0836 (Enclosure 2) and PVNGS calculation 13-MC-ZZ-217 (Enclosure 3). Further, PVNGS valves that were identified as being potentially subjected to significant thermal pressurization have been modified to include bonnet relief devices to preclude the possibility of excessive thermal pressurization induced pressure locking. Significant thermal pressurization was identified as bonnet fluid subject to temperature increases above 30°F prior to or during design basis conditions requiring the opening of a closed pressure locking susceptible valve.

NRC QUESTION (3a):
The February 21, 1996, submittal states that thermal binding test results from a 10-inch Borg Warner valve were used to determine the additional thrust required for valves to operate during thermal binding conditions. During a phone call conducted on May 20, 1999, you stated that there are no solid wedge gate valves in the scope of GL 95-07 and that flexible wedge gate valves in the scope of GL 95-07 were evaluated for thermal binding.

The NRC staff considers that thermal binding occurs as a result of valve design characteristics such as wedge and valve body configuration, flexibility (pressure rating), and material thermal coefficients. The NRC staff has approved the use of thermal binding test results to demonstrate that valves will operate during thermal binding conditions as acceptable corrective action for GL 95-07. However, the thermal binding test results were used for valves with very similar design characteristics.

Identify the instances where the test results from the Borg Warner valve were used to determine that valves are capable of operating during thermal binding conditions.

APS RESPONSE (3a):
Engineering Study 13-MS-A96 Revision 0, "Gate Valve Pressure Locking and Thermal Binding (TB) Evaluations", identified safety-related motor operated gate valves with a safety function to open. The identified Motor Operated Valves (MOVs) are: AF-34/35, AF-36/37, CH-536, SG-134/138, SI-604/609, SI-651/652, SI-653/654, SI-655/656, SI-671/672, SI-686/696, SI-685/694, SI-688/693.

PVNGS' criteria to determine if a gate valve is susceptible to thermal binding is a delta temperature decrease of at least 200°F from the time the valve is closed to when the valve is required to open. This criteria is based upon actual operating experience, which includes over twenty plant cool downs between the three PVNGS Units. During these plant cool downs many gate valves have undergone large temperature decreases (around 200°F) and none of the identified valves have failed to open due to thermal binding during outage maintenance or unit start ups.

A review of the motor operated gate valves with a safety function to open was performed to identify MOVs that experience a temperature decrease of 200°F or more from the time they close to the time they are required to reopen. Only the Shutdown Cooling suction inboard /outboard isolation MOVs (13JSIAUV0651, 13JSIBUV0652, 13JSICUV0653, 13JSIDUV0654) were identified as matching these criteria, and are considered susceptible to thermal binding.

However, the open capability of all the safety related gate valves with a safety function to open was evaluated and compared to the test results, but the testing was not used as the determination of the MOV's capability to open during thermal binding conditions. Since PVNGS evaluations have shown that all other safety related gate valves with a safety function to open are not subjected to a temperature decrease of 200°F, they are not considered susceptible to thermal binding based on operating experience.

NRC QUESTION (3b):
Discuss the Borg Warner thermal binding test results that were used in determining if valves were susceptible to thermal binding.

APS RESPONSE (3b):
The thermal binding test results used by PVNGS were developed with a Borg Warner 10" 300 lb class flex wedge gate valve during thermal binding effects testing performed by the Commonwealth Edison Company. As documented in the Borg Warner 10" valve test procedure, the valve body was heated externally with the valve in the open position. Then the valve was closed and allowed to cool with the disk seated. After the valve cooled, the valve was unseated and the unwedging force was recorded. The delta temperature unwedging force result was then compared to the unwedging force measured with no thermal binding conditions (no thermal cool down) at the same control switch setting. The test result used by PVNGS to determine thermal binding susceptibility is documented in the test procedure as a 38 % increase in the gate valve's required unseating thrust after experiencing a decrease in temperature of approximately 215°F, reference PVNGS CRDR 9-5-0836, Attachment 4 (Enclosure 2). Therefore, to demonstrate the valves susceptible to thermal binding have adequate open ability, the actuator's worst case design basis open capability was evaluated to ensure it is greater than the valves measured unwedging static thrust plus 40% additional thrust for thermal binding effects. In addition, to ensure capability of these safety related gate MOVs, a static as-left unwedging thrust has been established as a controlled limit and is compared to the valve's actual unwedging thrust, measured during diagnostic testing, to ensure the measured value is below the evaluated limit.

NRC QUESTION (3c):
Discuss the valve design characteristics (wedge and valve body configuration, flexibility (pressure rating), and material thermal coefficients) of the Borg Warner test valve and the valves that utilized the Borg Warner valve test results to demonstrate that the valves would operate during thermal binding conditions.

APS RESPONSE (3c):
The Shutdown Cooling suction inboard/outboard isolation MOVs that utilized the Borg Warner valve test results to demonstrate they would operate during thermal binding conditions are similar type gate valves. The comparison between the Borg Warner test valve and the PVNGS susceptible valves are shown below:

Valve design characteristics	Test Valve	PVNGS susceptible Valves
Vendor	Borg Warner	Borg Warner
Type	flex-wedge gate	flex-wedge gate
Size	10"	12"
Class	300 lb	1500 lb
Disk material	ASME SA 351 GR CF8M	ASME SA 351 GR CF8M
Disk thermal coefficients*	9.11×10^{-6} in/in/°F	9.11×10^{-6} in/in/°F
Valve Body material	ASME SA 351 GR CF8M	ASME SA182 F316
Body thermal coefficients*	9.11×10^{-6} in/in/°F	9.10×10^{-6} in/in/°F
Seat Ring material	ASTM A296 GR CF3M	ASTM A276 TYPE 316L
Seat Ring thermal coefficients*	9.10×10^{-6} in/in/°F	9.10×10^{-6} in/in/°F

*Reference ASME B&PV Code, Sec. II, Materials Part D - Properties, July 95 Addenda; Tables TE-1, Nominal Coefficients of Thermal Expansion for Ferrous Materials, Mean Coefficients of Thermal Expansion.

The material thermal coefficients of the test valve and the susceptible valves are very similar. However, the susceptible valves have a larger class rating and, therefore, the disk of the valve is stiffer than the test valve, which may make the susceptible valves more prone to thermal binding. PVNGS evaluation concluded this is a benefit. Since the susceptible MOVs have a large actuator open capability, and the higher class valve disk "T" slot has a much larger weaklink limit (179,986 lbs.) than the test valve (64,230 lbs.), no valve damage would occur in a thermal binding event. The susceptible valves have a worst case open margin capability of 55% above the expected thermal binding event unwedging thrust, as shown below.

13JSIAUV0651, 13JSIBUV0652
PVNGS static unwedging control limit = 55,000 lbs.
Expected thermal binding unwedging load = 55,000 lbs. x 1.4 = 77,000 lbs.
Actuator open capability = (start torque x temp. factor x OAR x pull out eff. x low voltage % x APFR)/(stem factor)
= [100 ft-lbs x 0.95 x 132.81 x 38% x $(414/460)^2$ x 0.9]/(0.02931 @ 0.18 stem friction)
= 119,248 lbs.
Margin of open capability = [(119,248 – 77,000)/77,000] x 100% = 55%

13JSICUV0653, 13JSIDUV0654

PVNGS static unwedging control limit = 18,750 lbs.
Expected thermal binding unwedging load = 18,750 lbs x 1.4 = 26,250 lbs.
Actuator open capability = (start torque x temp. factor x OAR x pull out eff. x low voltage % x APFR)/(stem factor)
= [40 ft-lbs x 0.816 x 124.1 x 35% x $(456/460)^2$ x 0.9]/(0.02931 @ 0.18 stem friction)
= 42,779 lbs.
Margin of open capability = [(42,779 – 26,250)/26,250] x 100% = 63%

NRC QUESTION (3d):
If the design characteristics are not similar, discuss long-term corrective action, and any short-term corrective action, if applicable, to ensure valves susceptible to thermal binding are operable.

APS RESPONSE (3d):
The following corrective actions have been implemented and completed to resolve the plant condition which may cause thermal binding for the valves having a possible temperature decrease of over 200°F after valve closure.

- Procedure 40OP-9ZZ01 "Cold Shutdown To Hot Standby Mode 5 To Mode 3" was revised to ensure the administrative controls are sufficient for the removal of the Shutdown Cooling loop from service before the Reactor Coolant System (RCS) temperature exceeds 310°F, to avoid possible thermal binding of the Shutdown Cooling/Safety Injection (SI) MOVs. This procedure change resolves the possible plant condition which may cause thermal binding of the Shutdown Cooling suction inboard/outboard isolation MOVs since the identified worst case open temperature for these MOVs is 110°F.
- During diagnostic testing the as-left unwedging thrust is measured and compared to a controlled design unwedging limit to ensure the measure thrust value is not over the evaluated limit.

In addition, actual operating experience at PVNGS has shown that these valves have undergone large temperature decreases after closure, approximately 200°F, and have not thermally bound. Therefore, no additional corrective actions are required.

NRC QUESTION (4):
Briefly explain the modifications that have been implemented or are scheduled to be implemented to eliminate the potential for pressure locking. If the modification involves the installation of a bonnet relief valve, discuss relief valve setpoint and how it is verified that the valve will open when pressure in the bonnet is higher than upstream and downstream pressure but below the relief valve setpoint.

APS RESPONSE (4):
Pressure Locking modification descriptions:

SIA-HV-604 & SIB-HV-609, High Pressure Safety Injection (HPSI) Long Term Recirculation Isolation Valves
LOCATION: These valves are 3" Borg Warner 1500 lb class gate valves on the HPSI injection lines to the Reactor Coolant System (RCS) hot legs. These valves are located near the 50-foot level of the HPSI pump rooms.
FUNCTION: Required to open to allow HPSI hot leg injection under various accident conditions.
MODIFICATION: In order to ensure that the motor and actuator combination is capable of overcoming the postulated pressure locking loads, the valve unwedging forces are controlled as a safety related setpoint in the Controlled Motor Operator Database (CMODB), drawing 01-, 02-, 03-J-ZZI-004. This setpoint is verified on a 2 refueling cycle basis through the use of MOV static diagnostic testing.
SCHEDULE: The setpoint control for these valves has been implemented in all 3 units.

AFB-UV-34, AFB-UV-35, AFC-UV-36, & AFA-UV-37, Auxiliary Feedwater (AF) Pump Steam Generator Supply Valves
LOCATION: These valves are 6" Anchor Darling 900 lb class gate valves on the discharge side of the Auxiliary Feedwater pumps. These valves are located in the Auxiliary Feedwater pump room in the 80-foot level of the Main Steam Support Structure (MSSS) building.
FUNCTION: Required to open to allow Auxiliary Feedwater flow to operable Steam Generators under certain accident conditions.
MODIFICATION: A pressure relief valve is installed off of the valve bonnet with its discharge routed to the Auxiliary Feedwater Pump Turbine discharge line downstream of the pressure reducing orifice to the condensate storage tank. The valve disk to valve stem interface was strengthened to increase valve weaklink limits. The stem to stem nut interface machine tolerances were tightly controlled to improve the valve stem factor. The relief valve setpoint (reference PVNGS calculation 13-MC-AF-309) was selected to be adequately above normal system operating pressures but below actuator capabilities. The PVNGS pressure locking model was used to ensure that the resulting actuator capability was above resulting bonnet pressure loads.
SCHEDULE: These modifications have been installed in all 3 units.

SGA-UV-134/138, Steam Generator Steam Supply to Auxiliary Feedwater (AF) Pump Turbine Isolation Valves
LOCATION: These valves are 6" Anchor Darling 900 lb class gate valves on the steam supply headers to the AF pump turbine. These valves are located in the 120-foot elevation in the Main Steam Isolation and Dump Valves Area of the MSSS.
FUNCTION: The valves are required to open automatically on an Auxiliary Feedwater Actuation Signal to provide steam admission to the turbine driven AF pump.

MODIFICATION: The motor operator combination was changed from a Limitorque SB-0-40 to a SB-1-60. The MOV thermal overload settings and breaker settings were re-sized. The valve disk to valve stem interface was strengthened to increase valve weaklink limits. The stem to stem nut interface machine tolerances were tightly controlled to improve the valve stem factor.
SCHEDULE: This modification has been installed in Units 2 and 3. Unit 1 is scheduled for the 1R8 refueling outage, which began October 2, 1999.

SIA-UV-651 & SIB-UV-652, Shutdown Cooling Suction Inboard Isolation Valves
LOCATION: These valves are 12" Borg Warner 1500 lb class gate valves on the shutdown cooling suction lines from the Reactor Coolant System (RCS) hot legs. These valves are located in the containment building outside the bio-shield at approximately the 90-foot elevation.
FUNCTION: The function of these valves is to provide shutdown cooling suction from the RCS hot legs. The valves are opened to provide Shutdown Cooling and are the inboard RCS pressure boundary between the Reactor Coolant (RC) and Safety Injection (SI) system.
MODIFICATION: A pressure relief valve is installed off of the valve bonnet with its discharge routed to the Reactor Drain Tank. The relief valve setpoint (reference PVNGS calculation 13-MC-SI-229) was selected to be adequately above normal system operating pressures but below actuator capabilities. The PVNGS pressure locking model was used to ensure that the resulting actuator capability was above resulting bonnet pressure loads.
SCHEDULE: This modification has been installed in all 3 units.

SIC-UV-653 & SID-UV-654, Shutdown Cooling Suction Outboard and Inboard Containment Isolation Valves
LOCATION: These valves are 12" Borg Warner 1500 lb class gate valves on the shutdown cooling suction lines from the Reactor Coolant System (RCS) hot legs. These valves are located in the containment building outside the bio-shield at approximately the 90-foot elevation.
FUNCTION: The function of these valves is to provide shutdown cooling suction from the RCS hot legs. The valves are opened after opening of inboard isolation valves to provide Shutdown Cooling and they also provide the outboard RCS pressure boundary isolation between the RC and SI system. These valves are also inboard containment isolation valves.
MODIFICATION: A spring check valve is installed off of the bonnet with its discharge routed to the piping upstream of the subject gate valve. The check valve setting (reference calculation 13-MC-SI-229) was selected to be adequately above normal system operating pressures but below actuator capabilities. The PVNGS pressure locking model was used to ensure that the resulting actuator capability was above resulting bonnet pressure loads.
SCHEDULE: This modification has been installed in all 3 units.

SIA-UV-655 & SIB-UV-656, Shutdown Cooling Outboard Containment Isolation Valves

LOCATION: These valves are 12 " Borg Warner 300 lb class gate valves on the shutdown cooling suction lines from the Reactor Coolant System (RCS) hot legs. These valves are located in the pipe penetration rooms at the 80-foot elevation of the Auxiliary building.

FUNCTION: The function of these valves is to provide shutdown cooling suction from the RCS hot legs. The valves are opened to establish shutdown cooling. These valves are also outboard containment isolation valves.

MODIFICATION: A spring check valve is installed off of the bonnet with its discharge routed to the piping upstream of the subject gate valve. The check valve setting (reference calculation 13-MC-SI-229) was selected to be adequately above normal system operating pressures but below actuator capabilities. The PVNGS pressure locking model was used to ensure that the resulting actuator capability was above resulting bonnet pressure loads.

SCHEDULE: The modification has been installed for SIBUV656 in all 3 units. The modification for SIAUV655 has been installed in Units 2 and 3. The modification to Unit 1 SIAUV655 is scheduled for 1R8 which began on October 2, 1999.

SIA-HV-688 & SIB-HV-693, Containment Spray Bypass Valves

LOCATION: These valves are 10" 300 lb class Borg Warner gate valves. These valves are located on the shutdown cooling heat exchanger bypass header from the containment spray pump discharge. The valves are on the 70-foot elevation of the Shutdown Heat Exchanger rooms in the Auxiliary Building.

FUNCTION: These valves provide a flowpath for Containment Spray to be used when the plant is on shutdown cooling.

MODIFICATION: The actuator internal gearing of these valves has been changed from an overall ratio of 38.11:1 to 81.64:1. This ensures that the thrust delivered by the motor actuator is capable of overcoming the calculated bonnet pressure loads under design basis conditions.

SCHEDULE: The modification to SIAHV688 has been completed in all 3 units. The modification for SIBHV693 has been installed in Units 1 and 2. The modification to Unit 3 SIBHV693 is scheduled for the 3R8 refueling outage which is scheduled to begin on April 2, 2000.

SIA-HV-685 & SIB-HV-694, LPSI to Shutdown Cooling Heat Exchanger Cross Connect Valves

LOCATION: The valves are 10" Borg Warner 300 lb class gate valves. These valves are located on the inlet lines to the shutdown heat exchangers. The valves are located on the 70-foot elevation in the Shutdown Cooling Heat Exchanger rooms.

FUNCTION: These valves are opened to establish shutdown cooling flow through the inlet to the Shutdown Cooling Heat Exchangers and are closed to isolate shutdown cooling flow.

MODIFICATION: The actuator internal gearing of these valves has been changed from an overall ratio of 38.11:1 to 81.64:1. This ensures that the thrust delivered by the motor actuator is capable of overcoming the calculated bonnet pressure loads under design basis conditions.
SCHEDULE: The modification to SIAHV685 has been completed in Units 2 and 3. The modification to Unit 1 SIAHV685 is scheduled for the 1R8 refueling outage which began October 2, 1999. The modification to SIBHV694 has been installed in Units 1 and 2. The modification to Unit 3 SIBHV694 is scheduled for the 3R8 refueling outage which is scheduled to begin on April 2, 2000.

SIA-HV-686 & SIB-HV-696, Shutdown Cooling Heat Exchanger to LPSI Header Crossover Valve
LOCATION: These valves are 20" Borg Warner 300 lb class gate valves. The subject valves are located in the Shutdown Cooling Heat Exchanger valve gallery on the 80-foot elevation of the Auxiliary Building.
FUNCTION: These valves are remotely opened to establish shutdown cooling flow through the heat exchanger.
MODIFICATION: The motor operator combination has been changed from an SMB-1-60 to an SMB-2-60. The MOV thermal overload settings and breaker settings have been re-sized. This modification ensures the motor operator is capable of overcoming bonnet pressure loads under all design basis conditions.
SCHEDULE: The modification to SIAHV686 has been completed in all 3 Units. The modification to SIBHV696 has been installed in Units 1 and 2. The modification to Unit 3 SIBHV696 is scheduled for the 3R8 refueling outage which begins April 2, 2000.

SIB-UV-671 & SIA-UV-672, Containment Spray Control Valve
LOCATION: These valves are 8" Borg Warner 300 lb class gate valves. The subject valves are located on the 90-foot elevation of the Auxiliary Building in the Pipe Penetration Rooms.
FUNCTION: These valves are on the discharge header to the containment spray nozzles and are opened on a Containment Spray Actuation Signal (CSAS). These valves are also outboard containment isolation valves.
MODIFICATION: The motor operator combination has been changed from a SB-0-25 to a SB-1-40. The MOV thermal overload settings and breaker settings were re-sized. This modification ensures the motor operator is capable of overcoming bonnet pressure loads under all design basis conditions.
SCHEDULE: The modification to SIBUV671 has been completed in all 3 Units. The modification to SIAUV672 has been installed in Units 2 and 3. The modification to Unit 1 SIAUV672 is scheduled for the 1R8 refueling outage which began October 2, 1999.

ENCLOSURE 2

PVNGS CONDITION REPORT/DISPOSITION REQUEST (CRDR) 9-5-0836, GENERIC LETTER 95-07 180 DAY RESPONSE EVALUATION

CONDITION REPORT/DISPOSITION REQUEST

CRDR 9-5-0836

(PLEASE PRINT, SEE BACK OF FORM FOR INSTRUCTIONS)

ORIGINATOR

1) DESCRIPTION OF CONDITION:
See Attached Pages

REFERENCES (ATTACH IF AVAILABLE):
(1) Calculation 13-MC-ZZ-215, Revision 0 (Issued 8-1-95), "Pressure Locking Calculations" (2) CATS 930561.12 (3) Engineering Study 13-MS-A96 (4) CRDR 9-3-0561

[X] CONTINUATION PAGES/ATTACHMENT

2) REQUIREMENT VIOLATED (Describe how or why the Condition is a problem):
See Attached Pages

3) LOCATION (BLDG./ELEV./ROOM):	4) AFFECTED EQUIPMENT (TAG NO.):	5) UNIT NO:
70' Aux Bldg / SDCHX A & B; Other	1,2,3-J-SIA-HV0686; 1,2,3-J-SIB-HV0696; Other	1,2,3

6) DISCOVERY DATE:	TIME:	7) CONDITION DATE:	TIME:
August 9, 1995	11:00 AM	August 9, 1995	11:00 AM

8) ORIGINATOR (PLEASE PRINT):	9) DEPARTMENT:	10) EXT.:	11) STA:
Jeff Kriner	NED/MOV	1916	7153

12) SUGGESTED DISPOSITION (INCLUDING NOTIFICATIONS MADE):
See Attached Pages

[ ] NO ACTION RECOMMENDED - CLOSE CRDR [ ] ACTION TAKEN/COMPLETED - CLOSE CRDR [X] ACTION RECOMMENDED

13) ORIGINATOR'S SIGNATURE:	DATE:	TIME:
Jeff K[signature]	8-9-95	11:00 AM

LEADER

14) LEADER'S REVIEW, INCLUDING ACTIONS TAKEN/RECOMMENDED:
SEE ATTACHED RECOMMENDED DISPOSITION.

[ ] CONTINUATION PAGES/ATTACHMENT

[ ] NO ACTION REQUIRED CLOSE CRDR [ ] ACTION TAKEN/COMPLETED - CLOSE CRDR [X] ACTION REQUIRED - FURTHER EVALUATE

15) LEADER'S SIGNATURE:	DATE:	TIME:	DELIVER TO
Michael T. R[signature]	8-9-95	1100	[ ] NAS [X] CONTROL ROOM

SHIFT SUPERVISOR (For CRDRs Delivered to Control Room)

16) ACTIONS TAKEN/COMMENTS:
NOTIFIED CONTROL ROOMS, NO IMMEDIATE ACTIONS REQUIRED DUE TO ON-GOING INVESTIGATION AND PREVIOUS CRDRS IN PROGRESS NOTED IN THIS CRDR. [signature] SSM 8-9-95.

17) TECH SPEC ACTION ENTERED? NO [X] YES [ ] SECTIONS:

[X] CONTINUATION PAGES/ATTACHMENT

18) UNITS/ORGANIZATIONS NOTIFIED? NO [ ] YES [X]
NOTIFICATIONS MADE: U-1,2,3 CONTROL ROOM VIA PHONE+FAX
IMMEDIATE REPORTABILITY REQUIRED: [ ] YES [X] NO

19) NOTIFICATIONS REQUIRED? [X] NO [ ] YES
NOTIFICATIONS MADE: / (DATE/TIME)

SHIFT SUPERVISOR SIGNATURE:	DATE:	TIME:
[signature]	8-9-95	1540

PV419-04EM (6-95) 90AC-0IP04

CRDR CONTINUATION SHEET

CRDR 9-5-0836

CONDITION REPORT/DISPOSITION REQUEST

BACKGROUND

Pressure locking occurs when a closed gate valve bonnet is pressurized from high process fluid pressure and the line pressure subsequently reduces, or when the bonnet is hydraulically heated to increase the pressure of fluid trapped in the bonnet above line pressure. The resultant bonnet pressure and accompanying seating forces on the gate may require an opening stem thrust above an actuator or valve thrust/torque limit, and in some cases prevent opening the valve.

The NRC recently published Federal Register Notice (3-27-95, Vol 60 No 58), "Proposed Generic Letter; Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves," which will require all nuclear power plant Licensees to perform pressure locking and thermal binding susceptibility evaluations and take appropriate actions to ensure those gate valves deemed susceptible will perform their required safety functions. Engineering is currently evaluating pressure locking and thermal binding of gate valves per CRDR 9-3-0561. As part of this work effort, NED/MOV developed a methodology to evaluate safety-related power-operated (motor, air, hydraulic and solenoid) gate valves per Calculation 13-MC-ZZ-215, Revision 0.

(1) DESCRIPTION OF CONDITION

Based on a technical review of Calculation 13-MC-ZA-215, Revision 0 and the latest information pertaining to Engineering Study 13-MS-A96 (*draft*), the following issues have been identified:

(1) MOVs AF-34/35/36/37, SI-651/652, SI-653/654, SI-655/656, SI-671/672, SI-686/696, SI-685/694 and SI-688/693 *theoretical* bonnet pressures resulting from the assumed temperature increases are below the valve vendor hydrostatic test pressures, but are above the applicable ASME/ANSI B16.34 pressure limits for these valves. Since the *theoretical* bonnet pressures resulting from the assumed temperature increases are enveloped by the valve vendor hydrostatic tests and are transient pressures rather than working pressures, **Engineering deems this condition acceptable**, until additional analyses and/or testing can be performed to validate the pressure versus temperature predictions and determine whether the ASME B&PV code provides specific guidance related to transient valve bonnet pressurization. This issue may be transportable to other fluid filled components, which do not have a pressure relief mechanism via a pressure relief valve or via component leakage, expansion, or trapped air.

(2) MOVs SI-653/654 *theoretical* opening stem thrust requirement to overcome the postulated pressure locking loads is greater than the 74,133 lbs maximum opening weak link thrust limit. As mentioned in the Calculation's technical review, no additional actions were initiated, since this issue was previously identified and is evaluated per CRDR 9-5-0607 and 10 CFR 50.59 Screen and Evaluation #95-00226. Refer to these documents for additional information.

(3) MOVs SI-686/696 *theoretical* opening stem thrust requirement to overcome the postulated pressure locking loads is greater than the 97,310 lbs maximum actuator thrust capability. As mentioned in the Calculation's technical review, CATS action item 930561.12 was initiated to evaluate this condition with a high priority during the ongoing work effort to complete Engineering Study 13-MS-A96. The CATS action item was deemed appropriate instead of initiating a new CRDR, since a preliminary review of the design basis requirements for SI-686/696 indicate SI-686/696 would not be required to open to align/initiate shutdown cooling concurrent with the postulated temperature increase resulting from a RCS letdown line break or auxiliary steam line break event in the auxiliary building. In addition, the Calculation's technical review also stated Engineering may deem it necessary to supersede the CATS action item with a new CRDR during the detailed review of SI-686/696 per Engineering Study 13-MS-A96. As of this date, Engineering deems it appropriate to establish a new CRDR to document the evaluation of SI-686/696 *theoretical* opening stem thrust to overcome the postulated pressure locking loads exceeding the 97,310 lbs maximum actuator thrust capability. Based on the *preliminary* pressure locking and thermal binding evaluations, using nominal process conditions per Calculation 13-MC-ZZ-215 (Rev. 0) and Engineering Study 13-MS-A96 (draft), SI-686/696 may be *potentially* susceptible to pressure locking under the following concurrent conditions: (1) the valve seat and packing leakage is zero; (2) no air is trapped in the valve bonnet; (3) no credit is taken for the valve elasticity; and (4) no credit is taken for the portion/volume of stem, which is removed from the bonnet when the valve open cycle is commenced (i.e., no credit for the bonnet fluid specific volume increase). Although SI-686/696 are part of the PVNGS ASME XI Inservice Testing Program, SI-686/696 are not leak tested and maintained leak tight per 10 CFR 50 Appendix J requirements. Thus, it is reasonable the SI-686/696 gate valves to have at least 1-2 ccm minimum valve leakage. Minimum realistic valve leakage of 1-2 ccm will prevent bonnet overpressurization. Therefore, based on the above, SI-686/696 are deemed capable of performing their safety-function under design basis conditions, and **Engineering does not consider the SI-686/696 condition an immediate operability concern.**

(4) MOVs SI-671/672, SI-685/694 and SI-688/693 *theoretical* opening stem thrust requirement to overcome the postulated

pressure locking loads are less than their corresponding maximum MOV design thrust capabilities under nominal conditions per Calculation 13-MC-ZZ-215, Revision 0, and are acceptable. However, the *theoretical* opening stem thrust requirement to overcome the postulated pressure locking loads are greater than their corresponding actuator thrust capabilities using minimum voltages and pullout actuator efficiencies per the preliminary analyses performed for Engineering Study 13-MS-A96 (*draft*).

(a) SI-671/672 - The postulated temperature increase, which would lead to relatively rapid bonnet pressurization, is caused by either a RCS letdown line break or an auxiliary steam line break event in the auxiliary building. These events do not require opening SI-671/672 to establish containment spray. Thus, the use of minimum voltage to assess actuator thrust capability is overly conservative, since the postulated bonnet pressurization event would not be concurrent with opening SI-671/672. Using nominal voltage and pullout efficiency, the *theoretical* opening stem thrust requirement to overcome the postulated pressure locking loads are less than SI-671/672s' corresponding actuator thrust capabilities. **SI-671/672 is capable of performing its design basis function based on the existing applicable actuator thrust capabilities, and no immediate evaluation in addition to the normally scheduled Engineering Study 13-MS-A96 is deemed necessary or appropriate.** The bonnet overpressurization issue will be addressed as part of Item (1).

(b) SI-685/694 and SI-688/693 - The postulated temperature increase, which would lead to relatively rapid bonnet pressurization, is caused by either a RCS letdown line break or an auxiliary steam line break event in the auxiliary building. These events do not require immediately opening SI-685/694 and SI-688/693 to establish shutdown cooling. Thus, the use of minimum voltage to assess actuator thrust capability is overly conservative, since the postulated bonnet pressurization event would not be concurrent with opening SI-685/694 and SI-688/693. Using nominal voltage and running efficiency, the *theoretical* opening stem thrust requirement to overcome the postulated pressure locking loads are less than SI-685/694 and SI-688/693s' corresponding actuator thrust capabilities. However, recent industry information indicates the use of running efficiency may not be conservative and pullout efficiency may be appropriate in the determination of actuator thrust capability. On the other hand, Limitorque has not completed their evaluation of the applicability of pullout and running efficiency usage in actuator thrust calculations, and has not published any recommendations, which prohibit using running efficiency. Nevertheless, it is important to note, the *theoretical* opening stem thrust requirement to overcome the postulated pressure locking loads are greater than SI-685/694 and SI-688/693s' corresponding actuator thrust capabilities using nominal voltage and pullout efficiency. Based on the *preliminary* pressure locking and thermal binding evaluations, using nominal process conditions per Calculation 13-MC-ZZ-215 (Rev. 0) and Engineering Study 13-MS-A96 (draft), SI-685/694 and SI-688/693 may be *potentially* susceptible to pressure locking under the following concurrent conditions: (1) if the valve seat and packing leakage is zero; (2) if no air is trapped in the valve bonnet; (3) if no credit is taken for the valve pressure boundary elasticity; and (4) if no credit is taken for the portion/volume of stem which is removed from the bonnet when the valve open cycle is commenced (i.e., no credit for the bonnet fluid specific volume increase). Although SI-685/694 and SI-688/693 are part of the PVNGS ASME XI Inservice Testing Program, they are not leak tested and maintained leak tight per 10 CFR 50 Appendix J requirements. Thus, it is reasonable to assume the SI-685/694 and SI-688/693 gate valves to have at least 1-2 ccm minimum valve leakage. Minimum realistic valve leakage of 1-2 ccm will prevent bonnet overpressurization. Therefore, based on the above, SI-685/694 and SI-688/693 are deemed capable of performing their safety-function under design basis conditions, and **Engineering does not consider the SI-685/694 and SI-688/693 condition an immediate operability concern.**

(2) REQUIREMENT VIOLATED

(1) MOVs AF-34/35/36/37, SI-651/652, SI-653/654, SI-655/656, SI-671/672, SI-686/696, SI-685/694 and SI-688/693 *theoretical* bonnet pressures resulting from the assumed temperature increases are below the valve vendor hydrostatic test pressures, but are above the applicable ASME/ANSI B16.34 pressure limits.

(2) N/A. Issue previously addressed in CRDR 9-5-0607.

(3) Postulated RCS letdown line or auxiliary steam line break accident temperatures could potentially result in SI-686/696s' bonnet fluid pressure exceeding the ASME B16.34 working pressure limit and exceeding the valve/actuator assembly opening torque/thrust capability under the following concurrent conditions: (1) SI-686/696s' seat and stem packing leakage is zero; (2) no air entrapment in the valve bonnet; (3) no credit is taken for the valve pressure boundary elasticity; and (4) no credit is taken for the portion/volume of stem which is removed from the bonnet when the valve open cycle is commenced (i.e., no credit for the bonnet fluid specific volume increase).

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(4) Postulated RCS letdown line or auxiliary steam line break accident temperatures could potentially result in SI-685/694 and SI-688/693s' bonnet fluid pressure exceeding the ASME B16.34 working pressure limit and exceeding the valve/actuator assembly opening torque/thrust capability under the following conditions: (1) if SI-685/694 and SI-688/693s' seat and stem packing leakage is zero; (2) if no air entrapment in the valve bonnet; (3) if no credit is taken for the valve pressure boundary elasticity; and (4) if no credit is taken for the portion/volume of stem which is removed from the bonnet when the valve open cycle is commenced (i.e., no credit for the bonnet fluid specific volume increase).

(12) *SUGGESTED DISPOSITION*

In general, Engineering deems the conditions described in the 'Description of Condition' section to be acceptable and does not consider these conditions immediate operability concerns. However, Engineering should develop specific operability evaluations to supplement the operability discussions presented in this CRDR, as appropriate. The suggested dispositions to the above issues are:

(1) Engineering should aggressively develop a test plan and perform testing of a Borg-Warner (and Anchor-Darling for completeness) valve assembly to validate the pressure increase predictions for various temperature heat up rates and temperatures. In addition, Engineering should determine whether the ASME B&PV code provides specific guidance (frequency and cause) related to ANSI B16.34 and transient valve bonnet pressurization. If testing is not performed in a timely manner, or if the test results support the bonnet pressure predictions, Engineering should initiate appropriate corrective actions (e.g., design modifications) to prevent exceeding the ANSI B16.34 pressure limits as required by the ASME B&PV code guidance.

(2) N/A. Issue previously addressed in CRDR 9-5-0007.

(3) Engineering should finalize the SI-686/696 pressure locking and thermal binding evaluations and recommend appropriate corrective actions (e.g., procedure and/or hardware modifications) by September 1, 1995.

(4) Engineering should finalize the SI-685/694 and SI-688/693 pressure locking and thermal binding evaluations and recommend appropriate corrective actions (e.g., procedure and/or hardware modifications) by September 1, 1995.

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CONDITION REPORT/DISPOSITION REQUEST

8-30-95 INTERIM DISPOSITION FOR "POTENTIALLY SIGNIFICANT" CRDR CLASSIFICATION

Additional Direction/Comments: Determine if actual bonnet pressures exceed AMSE/ANSI B16.34 Limits.

Response

The technical review of Calculation 13-MC-ZA-215 identified the *theoretical* bonnet pressures resulting from the assumed temperature increases exceed the ANSI/ASME B16.34 working pressure limits for MOVs AF-34/35/36/37, SI-651/652, SI-653/654, SI-655/656, SI-671/672, SI-686/696, SI-685/694 and SI-688/693. It is important to note the methodology used in Calculation 13-MC-ZA-215 uses conservative assumptions and the actual development of pressure locking conditions is highly situational, and the *theoretical* bonnet pressures may not be representative of the *actual* bonnet pressures.

Although a design modification to limit any potential bonnet pressurization to pressures less than the ASME/ANSI B16.34 limits would eliminate the potential for the *theoretical* bonnet overpressurization conditions, Engineering recommends valve heatup/pressurization tests be performed to validate the conservative assumptions and *theoretical* results within Calculation 13-MC-ZA-215. In fact, Attachment 2 to Generic Letter 95-07 (issued August 17, 1995) states "the prediction of the thrust required to overcome pressure locking to be very difficult," and recommends "a combination of testing and analysis to justify adequate capability to overcome the thrust requirements of pressure locking." Therefore, the proposed valve heatup/pressurization testing would not only validate the assumptions and results of Calculation 13-MC-ZA-215, but the test results will also provide a substantive basis for decisions whether or not to perform design modifications for the MOVs evaluated within 13-MC-ZA-215.

Engineering recommends this CRDR be reclassified from "Potentially Significant" to "Adverse" with a due date of 10-31-95 to allow time for (1) performing valve heatup/pressurization testing and the subsequent test analyses, and (2) responding to the issues pertaining to the theoretical opening stem thrust requirements outlined in the CRDR's "Description of Condition."

Operability Statement

MOVs AF-34/35/36/37, SI-651/652, SI-653/654, SI-655/656, SI-671/672, SI-686/696, SI-685/694 and SI-688/693 realistically have at least a 1 ccm to 2 ccm valve seat/packing leak rate and/or air in the bonnet which will preclude bonnet overpressurization, and Engineering deems these MOVs as fully operable for an *interim* period until valve testing can be performed to validate the theoretical analyses. A more detailed evaluation will be included in the 10-31-95 CRDR dispostion.

As mentioned, the theoretical bonnet overpressurization is postulated under the following conservative concurrent conditions: (1) if the valve seat and packing leakage is zero; (2) if no air is trapped in the valve bonnet; (3) if no credit is taken for the valve pressure boundary elasticity; and (4) if no credit is taken for the portion/volume of stem which is removed from the bonnet when the valve open cycle is commenced (i.e., no credit for the bonnet fluid specific volume increase).

Jeff B[signature]
8/30/95

[illegible]

ADVERSE CRDR EVALUATION/RESPONSE/ACTIONS/APPROVAL

1) CRDR 9-5-0836

PAGE ______ OF ______

2) PREPARER:	DEPARTMENT:	EXT:	DATE:
C. Rath/ M. Orth/ P. Knaggs	NED	1936	

7) ACTION(S) COMPLETED

#	TEXT OF ACTION COMPLETED	ACTION CLOSURE DOCUMENT
	None	

8) ACTIONS NOT COMPLETE (Note: Corrective Actions must be priority 1, 2 or 3):

PRIORITY	ACTION DESCRIPTION/EXPECTED DISPOSITION DOC	ACCEPTED BY	DUE
	See Attached List of Corrective Actions		

Note: If no Corrective Actions are required, the CRDR will be closed in CATS.

9) KEYWORDS	9) REFERENCES
pressure locking, thermal binding	GL 95-07

CONTINUATION PAGES ATTACHED [X] YES [ ] NO

10) EVALUATION COMPLETED BY:	DATE:	11) APPROVAL BY CRDR OWNER	DATE:
X M. ORTH. / C. RATH / P. KNAGGS	2-16-96	X [signature]	2-16-96
12) NA CONCURRENCE (REQUIRED FOR Q-CRDRs)	**DATE:**	**13) ADDITIONAL CONCURRENCES (if required)**	**DATE:**
X NA		X N/A	

ADVERSE CRDR EVALUATION/RESPONSE/ACTIONS/APPROVAL

1) CRDR 9-5-0836			
2) PREPARER: C. Rath/ M. Orth/ P. Knaggs	DEPARTMENT: NED	EXT: 1936	DATE: 02-16-96

3) AFFECTED SYSTEMS:	4) AFFECTED COMPONENT EQID
MOV	

5) EVALUATION
See Attached Continuation Sheets for Final Disposition.

6) CAUSE (Determination of Cause is optional)
See Attached Continuation Sheets for Final Disposition.

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CONDITION REPORT/DISPOSITION REQUEST

PRIORITY	ACTION DESCRIPTION/EXPECTED DISPOSITION DOC	ACCEPTED BY	DUE
	Initiate Engineering Document Change (EDC) to Calculation 13JC-ZZ-201 Rev. 4 to reduce MOV 13-CH-536's Design Maximum Total Close Thrust limit to 11,000 lbs to reduce its possible required cracking thrust, to ensure its available open thrust is adequate to overcome PLTB effects.	M. Renfroe	3/20/96
	Control the Maximum Total Close thrusts on MOVs 13-AF-34/35, 13-AF-36/37, 13-CH-536, 13-SG-134/138, 13-SI-604/609, 13-SI-651/652, 13-SI-653/654, 13-SI-655/656, 13-SI-671/672, 13-SI-686/696, 13-SI-685/694, & 13-SI-688/693 to ensure their available open thrusts are adequate to overcome PLTB effects, per evaluated required cracking thrusts in CRDR 9-5-0836, until modificationas are completed to prevent pressure locking. Also, investigate/evaluate the possibility of lowering the Maximum Design Total Close Thrust on all MOVs having an open safety function.	M. Renfroe	3/15/96
	Engineering to review Operation Procedures to ensure the administrative controls are sufficient to ensure the removal of the Shutdown Cooling loop from service before the RCS temperature exceeds 310 degrees F, to avoid possible thermal binding of the Safety Injection (SI) MOVs, Ref. Procedure 40OP-9ZZ01 "Cold Shutdown To Hot Standby Mode 5 To Mode 3"	M. Renfroe	3/29/96 ~~3/15/96~~
	Initiate Design Modification Work Orders (DMWOs) on the susceptible MOVs to make the appropriate design changes to prevent the potential susceptibility of the MOVs to Pressure Locking effects after final evaluations are completed.	M. Renfroe	6/28/96
	Determine ASME B&PV code specific guidance related to ANSI B16.34 and transient valve bonnet pressurization. Issue appropriate corrective actions to prevent the potential to exceed the ANSI B16.34 pressure limits as required by the ASME B&PV code guidance.	M. Renfroe	4/14/96
	Review/Evaluate potential use of the existing Thermal Binding (TB) Models (TU Electric and EMS Models) by the PVNGS Valve Program to verify and predict added open thrust due to TB effects.	M. Renfroe	4/14/96
	VSM ~~VSE~~ to schedule/perform maintenance to reduce the close torque switch settings on MOVs 13-SI-686/696 to reduce the open pullout torque requirement, target TST at 25,000 to 30,000 lbs.	M. SALAZAR	3/15/96

FINAL DISPOSITION

BACKGROUND DISCUSSION

The NRC issued Generic Letter 95-07, *Pressure Locking and Thermal Binding of Safety-related Power-Operated Gate Valves* on August 17, 1995 to formally require Licensees to take appropriate actions to analyze and eliminate the potential for gate valve pressure locking and thermal binding events. The letter requested that within 90 days each licensee *1)* perform a screening evaluation of all safety-related power-operated gate valves to identify those that are potentially susceptible to pressure locking or thermal binding, and *2)* document a basis for the operability of the potentially susceptible valves or take appropriate action. The screening evaluation using nominal process conditions was performed and documented by the PVNGS Engineering Study 13-MS-A96 Revision 0 *Gate Valve Pressure Locking and Thermal Binding Evaluations*. The Generic Letter also requested that within 180 days each licensee *1)* evaluate the operational configurations of all safety-related power-operated gate valves to identify valves that are susceptible to pressure locking or thermal binding, and *2)* perform further analysis and take needed corrective action to ensure that the susceptible valves identified are capable of performing their intended safety function under all modes of plant operation. This final disposition will serve as the basis for the PVNGS response to both of the 180 day requests.

1.0 GATE VALVE PRESSURE LOCKING SUSCEPTIBILITY EVALUATION

Identification of Valves to be Evaluated for Susceptibility to Pressure Locking

The Engineering Study 13-MS-A96 Revision 0 *Gate Valve Pressure Locking and Thermal Binding Evaluations* identified that no safety related solenoid operated gate valves are used at PVNGS. The study also identified that no safety related hydraulic operated gate valves and no safety related air operated gate valves at PVNGS have open safety functions. Based on those findings, no further evaluation of pressure locking susceptibility is required for air, solenoid and hydraulic operated valves.

The Engineering Study 13-MS-A96 Revision 0 *Gate Valve Pressure Locking and Thermal Binding Evaluations* identified the normally closed safety-related motor operated gate valves with open safety functions. The following discussion documents the evaluation of pressure locking susceptibility for that group of motor operated valves in accordance with the requirements of Generic Letter 95-07. The affected components are: AF-34/35, AF-36/37, CH-536, SG-134/138, SI-604/609, SI-651/652, SI-653/654, SI-655/656, SI-671/672, SI-686/696, SI-685/694, SI-688/693.

Analytical Methodology and Assumptions Used to Evaluate Pressure Locking Susceptibility

A discussion of the contributing loads and their calculation follows.

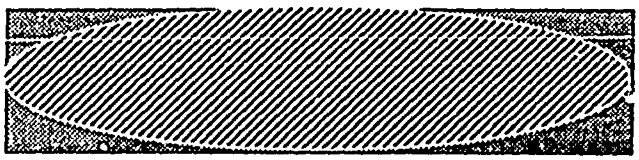
Disk Load- The load opposing valve opening due to friction in the seat caused by an unbalanced load on the gate disks. This unbalanced load is developed by application of the differential pressure (dP) between the valve bonnet and the upstream/downstream piping over the horizontal area of the

disk subjected to the dP. The load on the disks is calculated by modelling each gate disk as a flat circular plate with the outer edge simply supported and the inner edge fixed. The perimeter load, Q_a, is calculated using the methodology identified in Roark's Formulas for Stress and Strain (6th edition, Table 24, Case 2d). The perimeter load, taken at the mean seat diameter, is then multiplied by the perimeter length, $2\pi r$, to obtain the load on a single disk. This load is doubled for the two disks (Disk Force) and multiplied by the seat to gate coefficient of friction to obtain the "Disk Load".

Residual Load- The load opposing valve opening caused by wedging the valve gate into the seat. This load is adjusted to compensate for the relaxation in this load which occurs when stem motion is initiated in the open direction. This empirically derived load includes running loads. The "Residual Load" is calculated by taking the maximum allowable closing load identified in 13-JC-ZZ-201, *MOV Thrust, Torque and Actuator Sizing Calculation* inclusive of inertia and instrument uncertainty, and multiplying it by 0.67 to account for a conservatively assumed 33% relaxation in load between valve closure and when stem motion is initiated.

Note: Assuming cracking thrust is 67% of the maximum closing thrust, consistent with EPRI Topical Report TR-103237, results in conservative cracking thrusts with respect to PVNGS as-left cracking thrusts.

Vertical Load- The vertical unbalanced load across the valve disk, driven by the differential pressure between the bonnet and piping, directed into the valve seat. The "Vertical Load", F_{vert}, is calculated by multiplying the average differential pressure between the valve bonnet and the upstream and downstream pressure by the unbalanced horizontal area of the gate disks. The unbalanced horizontal area is a sum of the two ellipses projected in the horizontal plane whose perimeter is bounded by the seat sealing perimeter (see sketch below).



Plan view of the net cross-sectional area of a single gate valve disk on which the average differential pressure acts to create the Vertical Load
(Elliptical Area is Area which DP is applied across)

Stem Piston Load- The unbalanced load on the valve stem area, driven by the differential pressure between the bonnet and the atmosphere, aiding in opening of the valve. The "Stem Piston Load", F_{piston}, is calculated by multiplying the stem cross-sectional area by the bonnet pressure. This methodology assumes reduction in differential pressure between bonnet and atmosphere during accident conditions has negligible affect on stem load.

The Total Stem Thrust Required to Overcome Pressure Locking evaluated in the analysis is:

PL Stem Thrust= Disk Load + Residual Load + Vertical Load - Stem Piston Load

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The relationship between pressure and temperature used to evaluate the effects of bonnet water temperature increases on bonnet pressure was developed based on testing of a PVNGS spare 10" Borg-Warner gate valve at Commonwealth Edison's Braidwood Station test facility. The water solid valve assembly was heated in separate tests at different heat rates and the internal bonnet fluid temperature and pressure were recorded at various time intervals.

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

$$dP_I/dT = 3 \text{ psig/F [Region I, first 30F temperature change only].}$$
$$P_I = P_0 + 3 \text{ psig/F } (T_2 - T_1)$$

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

The second region [Region II] which includes the bonnet temperature increase greater than 60 F can be conservatively modeled using the highest two applicable pressurization rates: 42 psig/F at 150 F and 65 psig/F at 290 F. For Region II ($T_2 - T_1$ must be greater than 30 F),

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

where:

$$m = (65 \text{ psig/F} - 42 \text{ psig/F}) / (290 \text{ F} - 150 \text{ F}) = 0.16429 \text{ psig/F}^2$$
$$b = 42 \text{ psig/F} - (0.16429 \text{ psig/F}^2)(150 \text{ F}) = 17.3565 \text{ psig/F}$$

Thus, dP/dT becomes:

$$dP_{II}/dT = (0.16429 \text{ psig/F}^2)\, T + 17.3565 \text{ psig/F}$$

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

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

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

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

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

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

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

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CONDITION REPORT/DISPOSITION REQUEST

Evaluation of Valves for Susceptibility to Pressure Locking

The initial bonnet pressures ($P_{initial}$) used as inputs in estimating the stem loads required to overcome pressure locking are the maximum open or close pressures identified in the GL 89-10 design basis calculations for the MOVs. The references were as follows:

Calculation 13-MC-SG-811
Calculation 13-MC-SI-222
Calculation 13-MC-AF-401
Calculation 13-MC-SI-226
Calculation N001-7.01-174

The PVNGS Environmental Qualification Report was used to identify any rapid ambient temperature increases which may result in a significant increase in bonnet pressure. Calculations were performed for several of the valves to conservatively estimated the increase in bonnet temperature due to this increase in ambient temperature. Where a bonnet temperature calculation was not performed the temperature change of the fluid in the bonnet (T_{final}-$T_{initial}$) was conservatively assumed to be the same as the ambient temperature change. Since the final ambient temperature was taken from the calculations which support the EQ report it is appropriate that the initiating room temperature assumed in that analysis be used to determine the increase in room temperature (the increase in room temperature due to the transfer of a finite amount of heat will result in roughly the same temperature change when room temperatures are within the normal operating range). Daily cyclic variations in ambient temperature result in only small changes in bonnet temperatures and pressures, therefore, these normal temperature variations were not evaluated. Calculations referenced by the EQ Report are:

Calculation 13-NC-ZA-212
Calculation 13-MC-ZA-201
Calculation 13-NC-ZC-211

One case exists where the maximum process fluid temperature is a result of fluid in adjacent piping. The HPSI system could be drawing suction on the Containment Sump during a LOCA when the HPSI Hot Leg Injection Isolation Valves, SI-604 and SI-609, are called upon to perform their active safety function. The final valve bonnet temperature for this case is taken very conservatively to be the maximum Containment Sump Temperature The initial valve bonnet temperature is taken to be 60 F, the RWT (HPSI Pump suction source) minimum temperature.

The RWT and Containment Sump temperatures are documented in Technical Specification 3/4.5.4 and calculation 13-NC-ZC-206, respectively.

A spreadsheet was used to apply the described analytical methodology to determine if the susceptible valves are capable of performing the required open safety function. The susceptibility spreadsheet is attached to this disposition as Attachment 1 and is identified as "Pressure Locking Susceptibility Evaluation". The required pullout thrust for each valve was calculated using inputs of initial bonnet temperature, final bonnet temperature, initial bonnet pressure, and valve internal dimensions. A peak cracking thrust component was calculated from the maximum allowable clos-

ing thrust. A 0.6 valve factor was assumed for all valves. The resulting pullout thrust requirement was then compared with calculated degraded voltage pullout thrust capability of the actuator, and was compared with the actuator thrust limit and valve structural weak link to determine susceptibility of the existing design to pressure locking effects. Also, the resulting pullout thrust was converted to stem torque and compared to the actuator torque rating and valve structural weak link to determine susceptibility of the existing design to pressure locking effects. The evaluation determined that all of the valves are susceptible to pressure locking, except for 13JCHEHV0536.

13JCHEHV0536 motor operated valves were evaluated to be not susceptible to pressure locking because the valves are not exposed to the elevated room or fluid temperatures required for significant bonnet pressurization.

2.0 OPERABILITY EVALUATION OF PRESSURE LOCKING SUSCEPTIBLE VALVES

Identification of Pressure Locking Susceptible Valves to be Evaluated for Operability

The Engineering Study 13-MS-A96 Revision 0 *Gate Valve Pressure Locking and Thermal Binding Evaluations* identified that no safety related solenoid operated gate valves are used at PVNGS. The study also identified that no safety related hydraulic operated gate valves and no safety related air operated gate valves at PVNGS have open safety functions. Based on those findings, an operability evaluation is not required for air, solenoid and hydraulic operated valves.

The Engineering Study 13-MS-A96 Revision 0 *Gate Valve Pressure Locking and Thermal Binding Evaluations* identified the safety-related motor operated gate valves with open safety functions. The Susceptibility Evaluation performed as a part of this disposition for that group of motor operated valves identified the susceptible components to be: AF-34/35, AF-36/37, SG-134/138, SI-604/609, SI-651/652, SI-653/654, SI-655/656, SI-671/672, SI-686/696, SI-685/694, SI-688/693. An operability evaluation for the identified susceptible motor operated gate valves is provided in the following discussion.

Analytical Methodology and Assumptions Used to Evaluate Operability

A spreadsheet was used to apply the same analytical methodology as that used in the Susceptibility Evaluation to determine if the susceptible valves are capable of performing the required open safety function in their current as-left configuration. The operability spreadsheet is attached to this disposition and is identified as "Operability Tabulation". The required pullout thrust for each valve was calculated using the same inputs of initial bonnet temperature, final bonnet temperature, initial bonnet pressure, and valve internal dimensions shown in the Susceptibility Evaluation. However, the as-left peak cracking thrusts from diagnostic test data were used instead of a higher peak cracking component calculated from a design maximum allowable closing thrust. Valve factors based on published EPRI data and in situ test results were used to reduce conservatism where appropriate. Also, in some cases, credit was taken for the bonnet pressure reduction that occurs during an opening stroke because of stem displacement prior to unseating. The resulting pullout thrust requirement was then compared with calculated degraded voltage pullout thrust capability of the actuator, and was compared with the actuator thrust limit and valve structural weak link to determine component operability status. Also, the resulting pullout thrust was converted to stem torque using a conservative stem factor and then compared to the actuator torque rating and valve structural weak link to determine component operability status.

The pullout thrust requirement was compared with a calculated degraded voltage pullout thrust capability of the actuator. The degraded voltage thrust capability was calculated on the basis of the following relationship for AC powered actuators:

Degraded Voltage Maximum Stem Thrust = $(MST)(OAR)(MINV)^2(SE)(APFR)(TCF)/(SF)$

and for DC powered actuators:

Degraded Voltage Maximum Stem Thrust = $(MST)(OAR)(MINV)(SE)(APFR)(TCF)/(SF)$

where

OAR	Overall Ratio *(from 13-JC-ZZ-201)*
MINV	Minimum Voltage Ratio *(from 13-JC-ZZ-201)*
MST	Motor Starting Torque *(from 13-JC-ZZ-201)*
APFR	Application Factor
TCF	Temperature Correction Factor *(from 13-JC-ZZ-201)*
SE	Pullout Efficiency *(from Limitorque SEL Guide)*
SF	Stem Factor *(Calculated)*

Except where noted in the specific discussions below, a conservative stem thread friction coefficient of 0.12, actuator pullout efficiency, and degraded voltage adjustments were applied. An Application Factor of 0.9 was used for minimum voltage ratios more than 90 percent, and an Application Factor of 1.0 was used for minimum voltage ratios less than 90 percent, in accordance with Limitorque recommendations. Specific motor terminal voltages from 01/02/03-EC-PK-207 *DC Battery Sizing and Minimum Voltage* and 01/02/03-EC-MA-221 *AC Distribution* calculations were used as input because it provides the current effective data, although less conservative.

The pullout thrust requirement was compared with the documented maximum allowable valve and actuator thrust limits to determine operability. Thrust limits for SMB-000, SMB/SB-00, SMB/SB-0 and SMB/SB-1 actuators were increased to 163 percent of Limitorque published values on the basis of Kalsi test data *(Ref: Document No. 1707C, Rev.0, November 25, 1991)*. Thrust limits for SMB-3 actuators were increased to 110 percent of manufacturer published values. A one time allowable overload thrust limit of 250 percent of manufacturer published values was also evaluated where appropriate. In general, valve seismic and structural weak link thrust limitations shown in 13-JC-ZZ-201 *MOV Thrust, Torque, and Actuator Sizing Calculation* were used in this comparison. In some cases, specific weak link analysis limits were used to reduce conservatism.

The pullout torque requirement was compared with the documented maximum allowable valve and actuator torque limits to determine operability. Torque limits for all actuators were increased to 110 percent of Limitorque published values on the basis of manufacturer guidance *(Ref: Limitorque letter to APS dated 9/7/90)*. A one time allowable overload torque limit of 200 percent of manufacturer published values was also evaluated, where appropriate.

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Pressure Locking Operability Evaluation

13JAFBUV0034, 13JAFBUV0035

For the operability determination of the subject motor operated valves, conservatism was reduced by *a)* using as-left peak cracking thrust measured values, *b)* using revised weak link thrust and torque limits of the valve, *c)* using actuator running efficiency instead of pullout efficiency, *d)* taking credit for bonnet pressure reduction caused by opening stem displacement prior to unseating, and *e)* justifying a reduced value for final bonnet temperature. The weak link thrust and torque limits were calculated on the basis of Certified Material Test Reports of the as built valve components *(Ref: SDOC 13-P-221B EDC 95-01703)*. Use of actuator running efficiency for operability determination is justified because the subject valves are provided with a hammerblow device and the actuator is running prior to being loaded. Bonnet pressures that may result from pressure locking effects will be slightly reduced during the opening stroke because of stem displacement. The stem displacement that occurs prior to unseating reduces the bonnet pressure slightly and reduces the associated pullout thrust requirement. *(Ref: Calculation 13-MC-ZZ-218 Gate Valve Bonnet Pressure Decrease Due To Stem Motion)*. The final bonnet temperature is assumed to be 115F. The EQ Program Manual, Appendix A, DBA Temperature and Pressure Profile for the Main Steam Support Structure (MSSS) El. 80' shows that room temperature during HELB ramps to a peak temperature of 123F during the first 110 seconds of the event, and then ramps down to 107F within the next 15 minutes. Based on this room temperature profile, the assumption that final bonnet temperature is no more than 115F is conservative. The operability tabulation shows that the predicted pullout thrust and torque requirements are within the calculated degraded voltage capabilities of the actuator, and within the structural limitations of the valve and actuator assembly. On this basis the subject motor operated valves in the as-left configuration are considered capable of performing their safety related open function under pressure locking conditions.

13JAFAUV0036, 13JAFAUV0037

For the operability determination of the subject motor operated valves, conservatism was reduced by *a)* using as-left peak cracking thrust measured values, *b)* using revised weak link thrust and torque limits of the valve, *c)* using actuator running efficiency instead of pullout efficiency, *d)* taking credit for bonnet pressure reduction caused by opening stem displacement prior to unseating, *e)* taking credit for DC motor stall torque capability, *f)* using manual values for degraded voltage, *g)* using less conservative value for stem thread coefficient of friction, and *h)* using a reduced value for final bonnet temperature. The weak link thrust and torque limits were calculated on the basis of Certified Material Test Reports of the as built valve components *(Ref: SDOC 13-P-221B EDC 95-01703)*. Use of actuator running efficiency for operability determination is considered justified on the basis of site test data acquired on DC power actuators. Bonnet pressures that may result from pressure locking effects will be slightly reduced during the opening stroke because of stem displacement. The stem displacement that occurs prior to unseating reduces the bonnet pressure slightly and reduces the associated pullout thrust requirement *(Ref: Calculation 13-MC-ZZ-218 Gate Valve Bonnet Pressure Decrease Due To Stem Motion)*. The degraded voltage torque capability of these actuators was calculated using 90 percent of the stall torque capability shown by the manufacturer's generic motor curve for a 40 ft-lb 125 VDC motor, and was calculated on the basis of revised degraded voltage values specified in Calculation 01/02/03-EC-PK-207 *DC Battery Sizing and Minimum Voltage Calculation*. The final bonnet temperature is assumed to be 115F. The EQ Program Manual, Appendix A, DBA Temperature and Pressure Profile for the MSSS El. 80' shows

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that room temperature during HELB linearly ramps to a peak temperature of 123F during the first 110 seconds of the event, and then ramps down to 107F within the next 15 minutes. Based on this room temperature profile, the assumption that final bonnet temperature is no more than 115F is conservative. Use of reduced stem thread coefficients of friction are justified on the basis of recorded diagnostic test data. After reducing conservatisms, all of the subject valves were within limits, except for one. The required pullout thrust of 1JAFAUV0036 exceeded the valve's thrust weak link. For the subject component, the weak link is located at the stem connection to the gate, below the packing. The thrust imposed by the actuator on the weak link is equal to the pullout thrust less the running load. Therefore, the pullout thrust was reduced by 1,000 lbs. to compensate for running load. This is justified on the basis of as-left diagnostic data that shows running load to be in excess of 1,200 lbs. After this final adjustment, the operability tabulation shows that the predicted pullout thrust and torque requirements are within the calculated degraded voltage capabilities of the actuator, and within the structural limitations of the valve and actuator assembly. On this basis the subject motor operated valves in the as-left configuration are considered capable of performing their safety related open function under pressure locking conditions.

13JSGAUV0134, 13JSGAUV0138

For the operability determination of the subject motor operated valves, conservatism was reduced by *a)* using as-left peak cracking thrust measured values, and *b)* using calculated weak link thrust and torque limits of the valve. The weak link thrust and torque limits were calculated on the basis of Certified Material Test Reports of the as built valve components *(Ref: SDOC 13-P-221B EDC 95-01703)*. The operability tabulation shows that the predicted pullout thrust and torque requirements are within the calculated degraded voltage capabilities of the actuator, and within the structural limitations of the valve and actuator assembly. On this basis the subject motor operated valves in the as-left configuration are considered capable of performing their safety related open function under pressure locking conditions.

13JSIAUV0604, 13JSIBUV0609

For the operability determination of the subject motor operated valves, conservatism was reduced by *a)* using as-left peak cracking thrust measured values, *b)* using actuator running efficiency instead of pullout efficiency, *c)* using manual values for degraded voltage, and *d)* using a 0.5 valve factor. Use of actuator running efficiency for operability determination is justified because the subject valves are provided with a hammer-blow device and the actuator is running prior to being loaded. The degraded voltage torque capability of these actuators was calculated using a terminal voltage predicted by *1,2,3-EC-MA-221 AC Distribution Calculation* for LOCA with start-up transformer loading, following energization of sequenced loads. Use of this degraded voltage value is justified because the subject valves will not be repositioned for at least 30 minutes following initiation of the event. Use of a 0.5 valve factor for the subject valves is justified on the basis of recorded diagnostic test data. The operability tabulation shows that the predicted pullout thrust and torque requirements are within the calculated degraded voltage capabilities of the actuator, and within the structural limitations of the valve and actuator assembly. On this basis the subject motor operated valves in the as-left configuration are considered capable of performing their safety related open function under pressure locking conditions.

13JSIBUV0671, 13JSIAUV0672

For the operability determination of the subject motor operated valves, conservatism was reduced by *a)* using as-left peak cracking thrust measured values, and *b)* using a 0.55 valve factor. Use of a

0.55 valve factor for the subject valves is justified on the basis of recorded diagnostic test data. The operability tabulation shows that the predicted pullout thrust and torque requirements are within the calculated degraded voltage capabilities of the actuator, and within the structural limitations of the valve and actuator assembly. On this basis the subject motor operated valves in the as-left configuration are considered capable of performing their safety related open function under pressure locking conditions.

13JSIAHV0685, 13JSIBHV0694

For the operability determination of the subject motor operated valves, conservatism was reduced by *a)* using as-left peak cracking thrust measured values, *b)* using a 0.5 valve factor, and *c)* using actuator running efficiency instead of pullout efficiency. Use of a 0.5 valve factor for the subject valves is justified on the basis of in situ test data and published EPRI reports. Use of actuator running efficiency for operability determination is justified because the subject valves are provided with a hammer-blow device and the actuator is running prior to being loaded. The operability tabulation shows that the predicted pullout thrust and torque requirements are within the calculated degraded voltage capabilities of the actuator, and within the structural limitations of the valve and actuator assembly. On this basis the subject motor operated valves in the as-left configuration are considered capable of performing their safety related open function under pressure locking conditions.

13JSIAHV0686, 13JSIBHV0696

For the operability determination of the subject motor operated valves, conservatism was reduced by *a)* using as-left peak cracking thrust measured values, *b)* using actuator running efficiency instead of pullout efficiency *c)* using less conservative stem thread coefficients of friction, and *d)* using manual values for degraded voltage. Credit was taken for an extended actuator thrust rating of 200 percent. The extended thrust rating is justified on the basis of Kalsi testing that concluded Limitorque actuators are qualified for a thrust of 200 percent of rating for 763 cycles *(Ref: Document No. 1707C, Rev.0, November 25, 1991)*, and because pressure locking is expected to occur infrequently over the life of the plant. Use of actuator running efficiency for operability determination is justified because the subject valves are provided with a hammerblow device and the actuator is running prior to being loaded. Use of reduced stem thread coefficients of friction are justified on the basis of recorded diagnostic test data. The degraded voltage torque capability of these actuators was calculated using a terminal voltage predicted by *13-EC-MA-221 AC Distribution Calculation* for LOCA with start-up transformer loading, following energization of sequenced loads. Use of this degraded voltage value is justified because the subject valves will not be repositioned for at least 30 minutes following initiation of the event. After reducing conservatisms, all of the subject valves were within applicable thrust limits and were within seismic and valve weak link limits, but were outside of published actuator torque limits.

The actuator is a Limitorque SMB-1 and the design torque rating is 850 ft-lbs. Limitorque stated in a letter to PVNGS September 7, 1990 that torque up to 110 percent of rating, or in this case, 935 ft-lbs is acceptable. Limitorque stated in their Maintenance Update 92-1 that any size SMB actuator is capable of withstanding a one time allowable overload of up to two times the published torque rating, or in this case, 1700 ft-lbs without damage or sacrifice to the actuator qualification. If this rating was exceeded, or the overload occurred more than once, inspection of the actuator is recommended. For the subject actuators, the pullout torque requirement ranges from a minimum of 1,369 ft-lbs to a maximum of 1,538 ft-lbs. The torque requirements are within the calculated

degraded voltage capability of the actuator. Although, when pressure locked, all of the valves could require a torque in excess of actuator rating, none of the valves would require a torque in excess of the 200 percent extended rating of 1700 ft-lbs. Based on this discussion, and the assumption that pressure locking is a low probability occurrence, the subject motor operated valve in the as-left configuration is considered capable of performing its safety related open function. An action has been initiated to reduce the close torque switch adjustments of the subject components. This action will have the effect of reducing the pullout torque requirement as an interim measure until the valves can be modified to prevent pressure locking.

13JSIAHV0688, 13JSIBHV0693

For the operability determination of the subject motor operated valves, conservatism was reduced by *a)* using as-left peak cracking thrust measured values, *b)* using a 0.5 valve factor, and *c)* using actuator running efficiency instead of pullout efficiency. Use of a 0.5 valve factor for the subject valves is justified on the basis of diagnostic test data and published EPRI reports. Use of actuator running efficiency for operability determination is justified because the subject valves are provided with a hammerblow device and the actuator is running prior to being loaded. The operability tabulation shows that the predicted pullout thrust and torque requirements are within the calculated degraded voltage capabilities of the actuator, and within the structural limitations of the valve and actuator assembly. On this basis the subject motor operated valves in the as-left configuration are considered capable of performing their safety related open function under pressure locking conditions.

13JSIBUV0656

For the operability determination of the subject motor operated valves, conservatism was reduced by using as-left peak cracking thrust measured values. The operability tabulation shows that the predicted pullout thrust and torque requirements are within the calculated degraded voltage capabilities of the actuator, and within the structural limitations of the valve and actuator assembly. On this basis the subject motor operated valves in the as-left configuration are considered capable of performing their safety related open function under pressure locking conditions.

12JSIAUV0653, 13JSIBUV0654

The interim operability of the subject motor operated valves until implementation of pressure locking modifications was addressed by CRDR 950607, and therefore an operability evaluation is not required for this disposition.

3JSIAUV0651, 3JSIBUV0652, 3JSIAUV0653,

The subject motor operated valves have already been modified to prevent the possibility of pressure locking, and therefore an operability evaluation is not required for this disposition.

13JSIAUV0655

For the operability determination of the subject motor operated valves, conservatism was reduced by *a)* using as-left peak cracking thrust measured values, *b)* using actuator running efficiency instead of pullout efficiency, and *c)* using revised values for degraded voltage. The subject valve is assumed to be opened no sooner than two hours after initiation of event. This assumption is justified on the basis of RCS cooldown at a conservative 100F/hr rate from 565F to 335F for Shutdown Cooling Initiation *(Ref: 40EP-9EO03 Loss of Coolant Accident)*. Use of actuator running efficiency for operability determination is justified because the subject valves are provided with a hammer-

blow device and the actuator is running prior to being loaded. The degraded voltage torque capability of these actuators was calculated using a terminal voltage predicted by *13-EC-MA-221 AC Distribution Calculation* for LOCA with start-up transformer loading, following energization of sequenced loads. Use of this degraded voltage value is justified because the subject valves will not be opened sooner than two hours following initiation of the event. After reducing conservatisms, all of the subject valves were within applicable thrust limits, and actuator torque and valve seismic limits.

12JSIAUV0651, 12JSIBUV0652

For the operability determination of the subject motor operated valves, conservatism was reduced by using as-left peak cracking thrust measured values. The operability tabulation shows that the predicted pullout thrust and torque requirements are within the calculated degraded voltage capabilities of the actuator, and within the structural limitations of the valve and actuator assembly. On this basis the subject motor operated valves in the as-left configuration are considered capable of performing their safety related open function under pressure locking conditions.

3.0 GATE VALVE THERMAL BINDING SUSCEPTIBILITY EVALUATION

Discussion

Thermal binding is associated with a wedge gate valve that is closed while the system is hot and is allowed to cool before the valve is re-opened. An increase in the required open thrust sometimes occurs due to different expansions and contractions of the wedge gate, valve seats and valve body. Solid-wedge gate valves are most susceptible to thermal binding, however, flexible-wedge gate valves may experience thermal binding effects at significant temperature changes.

Further evaluation is required to justify the functional capability of the flexible-wedge gate valves identified in Engineering Study 13-MS-A96 to overcome possible thermal binding effects on the valves and resolve the possible plant condition which may cause thermal binding. This justification will be based on the margin of available thrust to overcome possible thermal binding effects.

Identification of Valves to be Evaluated for Susceptibility to Thermal Binding

The Engineering Study 13-MS-A96 Revision 0 *Gate Valve Pressure Locking and Thermal Binding Evaluations* identified that no safety related solenoid operated gate valves are used at PVNGS. The study also identified that no safety related hydraulic operated gate valves and no safety related air operated gate valves at PVNGS with open safety functions. Based on those findings, no further evaluation of thermal binding susceptibility is required for air, solenoid and hydraulic operated valves.

The Engineering Study 13-MS-A96 Revision 0 *Gate Valve Pressure Locking and Thermal Binding Evaluations* identified safety-related motor operated gate valves with open safety functions. The following discussion documents the evaluation of thermal binding susceptibility for that group of motor operated valves in accordance with the requirements of Generic Letter 95-07. The affected components are: AF-34/35, AF-36/37, CH-536, SG-134/138, SI-604/609, SI-651/652, SI-653/654, SI-655/656, SI-671/672, SI-686/696, SI-685/694, SI-688/693.

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Methodology and Assumptions Used to Evaluate Thermal Binding Susceptibility

(a) A review of the motor operated flexible-wedge gate valves identified in Study 13-MS-A96 was performed to identify:

(1) Valves with a safety function to open

(2) Valves having a close to open decrease temperature delta of over 80 degrees F

(3) Valves having a significant close to open decrease temperature delta (over 200 F)

(b) Thermal binding will not be considered to create a credible binding thrust load for valves which are closed at temperatures which are less than their safety function opening temperatures.

(c) The extent of the thermal binding effects (additional required opening thrust) will be considered directly related to the close to open temperature decrease, based on the initial results of the pressure locking and thermal binding testing performed by Commonwealth Edison Company. The thermal binding test results show that a 10" Borg-Warner 300 # Class Gate valve experienced an 18% increase in the required unseating thrust at an 88 F open to close decrease temperature delta and a 38% increase in the required unseating thrust at a 215 F open to close temperature decrease, See ComEd Company Memorandum "Pressure Locking / Thermal Binding Test Data", Attachment 4.

(d) For the valves determined to have a close to open temperature decrease of over 80 degrees F, justification of the capability of the gate valve to perform its intended open safety function will be performed using the following equation:

Percent Available Thrust = (Open Thrust Limit - Cracking Thrust)/Cracking Thrust

Where:

The Cracking Thrust will be equal to the latest measured As-Left open cracking thrust, per the Open Diagnostic As-Left Thrust Test Signature for each gate valve identified. Since, it was determined that the open available thrust/torque limit is based on the motor stall capability because the Torque Switch (TS) is bypassed for at least 20% of the open stroke for all the gate valves identified, the motor pullout thrust capacity of the actuator will be used as the maximum limiting open thrust, unless otherwise noted. Note: the motor pullout thrust capacity is based on those values listed in the operability tabulation sheet "Calculated Actuator Pullout and Torque Capability", See Attachment 2.

(e) Thermal binding will only be considered to create a credible binding thrust load for valves which are closed at temperatures which could decrease more than 200 F before the valve is opened. (Ref: SOER 83-9) Therefore, only valves determined to have a significant close to open decrease temperature delta (over 200 degrees F) will be considered as needing resolution of the possible plant condition, which may cause thermal binding (periodically opening the valve as it cools, administrative procedure changes etc.).

Evaluation of Valves for Susceptibility to Thermal Binding

Valve Design Engineering has completed the review of the motor operated flexible-wedge gate valves with a safety function to open for thermal binding susceptibility. Corrective actions have been initiated to resolve the possible plant condition which may cause thermal binding for valves having a possible decreasing temperature delta of over 200 degrees F after closure based on their design basis conditions.

Table 1 below provides a summary of the motor-operated gate valves identified as having an open safety function and possibly being susceptible to thermal binding effects:

Table 1. Summary of Motor-Operated Valves Possibly Susceptible to Thermal Binding

Tag Number	Worst Case Close Hot Temp (F)	Worst Case Cold Open Temp (F)	Normal Close/Open Temp (F)	Accident Open Temp (F) Range	Possibly Susceptible to Thermal Binding[1]	Open Capability Evaluation Required
AF-34/35	124	50	84	84 to 124	NO	NO
AF-36/37	124	50	84	84 to 124	NO	NO
CH-536	120	60	94	94 to 120	NO	NO
SG-134/138	575	553	564	553 to 587	NO	NO
SI-604/609	74	60	74	74 to 231	NO	NO
SI-651/652	350 [2]	110	210	110 to 368	YES	YES
SI-653/654	350 [2]	110	210	110 to 368	YES	YES
SI-655/656	200	87	87	87 to 104	NO	YES
SI-671/672	87	87	87	87 to 104	NO	NO
SI-686/696	200	77	77	77 to 104	NO	YES
SI-685/694	200	77	77	77 to 112	NO	YES
SI-688/693	200	77	77	77 to 104	NO	YES

[1] Based on a 200 F temperature decrease criteria per INPO SOER 83-9. The actual temperature decrease required to thermally bind the valve may be lower or higher. Based on actual operating experience at PVNGS, some of these valves have undergone large temperature decreases, although less than 200 F, and have not thermally bound. Thus, the 200 F criteria is deemed appropriate.

[2] It is important to note, the RCS is warmed up with one train of shutdown cooling secured but both suction paths are aligned to provide LTOP protection until the RCS temperature is greater than 291 F. Thus, for the purposes of this evaluation , the warm-up of SI-651/652/653/654 to maximum temperature based on SDC UFSAR temperature of 350 F will be considered as the high close temperature.

AF-34/35/36/37

The worst case close temperature is based on the possible closure of these valves after an AFAS-1 or AFAS-2 open and the worst case open is based on the AF pump room minimum design temperature. This worst case temperature change is less than 80F and is not considered applicable to the operation of these valves during a design basis safety function requirement. Since AF-34/35/36/37 are generally opened at the same or slightly higher temperature than their closure temperature, and the worst case possible temperature change is less than 80F, AF-34/35/36/37 are not deemed susceptible to thermal binding.

CH-536

The worst case close temperature is based on maximum RWT water temperature and the possible closure of this valve after an automatic open at a low-low VCT level indication and loss of power to CH-514. The worst case open temperature is based on the minimum RWT water temperature. This

worst case temperature change is less than 80F and is not considered applicable to the operation of this valve during a design basis safety function requirement. Since CH-536 is generally opened at the same or slightly higher temperature than its closure temperature and the worst case possible temperature change is less than 80F, CH-536 is deemed not susceptible to thermal binding.

SG-134/138

SG-134/138 are normally closed after Operations performs the AF turbine driven pump ASME XI test in Mode 3 or 1 and are cycled opened and closed during the bi-monthly ASME XI testing. Therefore the worst case hot temperatures is based on the temperature at the first Tech Spec Steam Generators (SGs) relief pressure set point of 1262.5 pisg per the ASME Steam Tables. The worst case cold temperature is the SGs normal operating temperature based on the assumption if pressure drops in one of the SGs the other one is used to drive the AF turbine driven pump. Since SG-134/138 are opened at the same or slightly lower temperature than their closure temperature to perform their safety function (i.e., Decrease Temperature of 22 F), SG-134/138 are deemed not susceptible to thermal binding.

SI-604/609

The worst case close temperature is based on the valve reaching the Calculated HPSI Pump Room temperature per 13-MC-HA-269 and the worst case open temperature is based on the AF pump room minimum design temperature. This worst case temperature change is less than 80F and is not considered applicable to the operation of these valves during a design basis safety function requirement. Since SI-604/609 open safety function is at a higher temperature than their closure temperature, SI-604/609 are deemed not susceptible to thermal binding.

SI-651/652/653/654

These valves may be closed initially at a Shut Down Cooling (SDC) UFSAR temperature of 350 F and they may cool down to room operating temperature of 110 F for a potential change in temperature of 240 F. However, when the SDC loop is isolated the temperature may be as low as 230 F but could be as high as 350 F, as the operation procedures are written. Therefore, these valves do have the possibility of experiencing a temperature decrease of greater than 200 degrees F, and are deemed as susceptible to thermal binding. A capability evaluation will be performed and corrective actions initiated to ensure the SDC is isolated under 310 F.

SI-655/656

These valves could be closed initially at a SDC UFSAR temperature of 350 F. However, per Operating Procedure 40OP-9SI02 these valves are required to be re-opened or left open until the pipe line is cooled to below 200 degrees F and than closed. Therefore, 200 degrees F will be used as the maximum close temperature and 87 degrees F as the cold open temperature based on the projected room temperature per Calculation 13-MC-HA-269. It is deemed that a 113 F temperature decrease is not significant enough for a 12-inch flex-wedge gate valve to thermally bind. However, SI-655/656 will be evaluated for required open safety functional capability.

SI-671/672

The worst case temperatures are based on the projected room temperature per Calculation 13-MC-HA-269. These valves are opened at the same or higher temperature than their closure temperature. Therefore, SI-671/672 are deemed not susceptible to thermal binding.

SI-686/696

These valves could be closed initially at a SDC UFSAR temperature of 350 F. However, per Operating Procedure 40OP-9SI02 when Shut Down Cooling is in standby and the temperature is above 200 degrees F these valves are required to be re-opened or left open until the pipe line is cooled to below 200 degrees F and than closed. Therefore, 200 degrees F will be used as the maximum close temperature and 77 degrees F as the cold open temperature based on the projected room temperature per Calculation 13-MC-HA-269. It is deemed that a 113 F temperature decrease is not significant enough for a 12-inch flex-wedge gate valve to thermally bind. However, SI-686/696 will be evaluated for required open safety functional capability.

SI-685/694

These valves could be closed initially at a SDC UFSAR temperature of 350 F. However, per Operating Procedure 40OP-9SI02 when Shut Down Cooling is in standby and the temperature is above 200 degrees F these valves are required to be re-opened or left open until the pipe line is cooled to below 200 degrees F and than closed. Therefore, 200 degrees F will be used as the maximum close temperature and 77 degrees F as the cold open temperature based on the projected room temperature per Calculation 13-MC-HA-269. It is deemed that a 113 F temperature decrease is not significant enough for a 12-inch flex-wedge gate valve to thermally bind. However, SI-685/694 will be evaluated for required open safety functional capability.

SI-688/693

These valves could be initially closed at 200 F based on the possible heat transfer to the dead leg piping on each side of these valves due to the SDC termination temperature. The cool down to 77 F is based on the projected room temperature per Calculation 13-MC-HA-269. The change in temperature is 123 F (less than 200 F). Therefore, SI-688/693 are deemed not susceptible to thermal binding. However, SI-688/693 will be evaluated for required open safety functional capability.

4.0 OPERABILITY EVALUATION OF THERMAL BINDING SUSCEPTIBLE VALVES

Identification of Valves to be Evaluated for Thermal Binding Operability

Valve Design Engineering has completed the thermal binding susceptibility review of the motor operated flexible-wedge gate valves with a safety function to open. Engineering has concluded that thermal binding effects will not prevent the subject MOVs from performing their open safety function. This conclusion is based on the valves' most recent closing temperature and open as-left cracking thrusts. The conclusion is based on the initial results of the pressure locking and thermal binding testing performed by Commonwealth Edison Company. Results of the thermal binding effects testing show that a 10" Borg-Warner 300 # Class Gate valve experienced a 18% increase in the required unseating thrust at an 88 F temperature decrease and a 38% increase in the required unseating thrust at a 215 F temperature decrease, See Attachment 4.

Corrective actions have been initiated to resolve the possible plant condition which may cause thermal binding for the valves having a possible temperature decrease of over 200 degrees F after closure and to adjust the current Design Maximum Design Total thrust limit setpoint to reduce the

required open cracking thrust, when appropriate.

Attachment 3 lists the MOVs that may be subjected to an 80F or more decrease in temperature between the time the valve is closed and when the valve is required to perform its safety function. The attachment shows the calculated available thrust to overcome any added open thrust due to possible thermal binding effects. An evaluation to ensure these MOVs have the capability to perform their open safety function against possible thermal binding effects follows:

__Thermal Binding Operability Evaluation__

13-SI-651/652/653/654
Design Basis Functional Description
These MOVs are normally closed 12" 1500# Class Borg-Warner flex-wedge gate valves on the shutdown cooling suction lines from the RCS hot legs, and are remotely opened to establish shutdown cooling and for LTOP protection. They also isolate the SI System from the RC System. SI-653/654 valves also function as inboard Containment isolation valves (Penetrations 26 and 27) Since, these valves could be closed at a SDC UFSAR temperature of 350 F and they may cool down to room operating temperature of 110 F, a potential decrease in temperature of 240 F is possible. However, Engineering has investigated the Control Room Logs and the applicable RCS and Pressurize Heat-up and Cool-down Rate Record, kept in Procedure 40ST-9RC01 Appendix A to determine the actual times/temperatures when the SDC system was last isolated in all three units.

Unit 1: It was determined from the Unit 1 Control Room Log dated 11-23-95 (night shift), SDC was isolated at 274 F. Therefore, these valves can only experiencing a temperature decrease of 164 degrees F which is within the range of the thermal binding test performed by Commonwealth Edison Company. Based on these valves having a minimum of 126% additional opening thrust available over the measured cracking thrusts to compensate for any added open thrust due to thermal binding effects, Unit 1 SI-651/652/653/654 valves are considered capable of performing their open safety function.

Unit 2: It was determined from the Unit 2 Control Room Log dated 3-23-95 (day shift), SDC was isolated at 248 F. Therefore, these valves can only experiencing a temperature decrease of 138 degrees F which is within the range of the thermal binding test performed by Commonwealth Edison Company. Based on these valves having a least 276% additional opening available thrust over the measured cracking thrusts to compensate for any added open thrust due to thermal binding effects, Unit 2 SI-651/652/653/654 valves are considered capable of performing their open safety function.

Unit 3: It was determined from the Unit 2 Control Room Log dated 3-23-95 (day shift), SDC was isolated at 300 F. Therefore, these valves can only experiencing a temperature decrease of 190 degrees F which is within the temperature range of the thermal binding test performed by Commonwealth Edison Company. Based on these valves having a least 185% additional opening thrust available over the measured cracking thrusts of these valves to compensate for any added open thrust due to thermal binding effects, Unit3 SI-651/652/653/654 valves are considered capable of performing their open safety function.

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13-SI-655/656

Design Basis Functional Description

These valves are normally closed 12" 300 # Class Borg-Warner gate valves on the shutdown cooling suction lines from the RCS hot legs, and are remotely opened to establish shutdown cooling. These valves also function as Containment outboard isolation valves (Penetrations 26 & 27).

Since, Operating Procedure 40OP-9SI02 requires these valves be re-opened or left open until the SDC loop is cooled to below 200 degrees F, than closed and the worst case cold open temperature is 87 degrees F, a 113 F temperature decrease is possible. This temperature delta is within the temperature range of the thermal binding test performed by Commonwealth Edison Company. Based on these valves having at least 121% additional opening thrust available over the measured cracking thrusts of these valves to overcome any added required open thrust due to thermal binding effects, 13 SI-655/656 valves are considered capable of performing their open safety function.

13-SI-686/696

Design Basis Functional Description

These valves are normally closed 20" 300 # Class Borg-Warner gate valves on the shutdown cooling heat exchanger discharge header, and are remotely opened to establish shutdown cooling flow through the heat exchanger.

Since, Operating Procedure 40OP-9SI02 requires these valves be re-opened or left open until the SDC loop is cooled to below 200 degrees F and the worst case cold open temperature is 77 degrees F based on the projected room temperature per Calculation 13-MC-HA-269, a 123 F temperature decrease is possible. This temperature delta is within the temperature range of the thermal binding test performed by Commonwealth Edison Company. Based on these valves having at least 564% additional opening thrust available over the measured cracking thrusts of these valves to overcome any added required open thrust due to thermal binding effects, 13 SI-686/696 valves are considered capable of performing their open safety function.

13-SI-685/694

Design Basis Functional Description

These valves are normally closed 10" 300 # Class Borg-Warner gate valves isolating the shutdown cooling heat exchanger inlet, and are remotely opened to establish shutdown cooling flow through the heat exchanger.

Since, Operating Procedure 40OP-9SI02 requires these valves be re-opened or left open until the SDC loop is cooled to below 200 degrees F and the worst case cold open temperature is 77 degrees F based on the projected room temperature per Calculation 13-MC-HA-269, a 123 F worst case temperature decrease is possible. This temperature delta is within the temperature range of the thermal binding test performed by Commonwealth Edison Company. Based on these valves having at least 143% additional opening thrust available over the measured cracking thrusts of these valves to overcome any added required open thrust due to thermal binding effects, 13-SI-685/694 valves are considered capable of performing their open safety function

13-SI-688/693

Design Basis Functional Description

These valves are normally closed 10" 300 # Class Borg-Warner gate valves on the shutdown cooling heat exchanger bypass header from the containment spray pump discharge, and are remotely opened to ensure CS is available during cooldown when the plant is on SDC.

Since these valves can experience a close temperature of 200 F based on the possible heat transfer

to the dead leg piping on each side of these valves due to the SDC termination temperature and could possibly cool down to 77 F based on the projected room temperature, the change in temperature could be 123 F (less than 200 F). This temperature delta is within the temperature range of the thermal binding test performed by Commonwealth Edison Company. Based on these valves having at least 220% additional opening thrust available over the measured cracking thrusts of these valves to overcome any added required open thrust due to thermal binding effects, 13-SI-688/693 valves are considered capable of perfoiming their open safety function.

CRDR CONTINUATION SHEET

CRDR 9 - 5 - 0136

CONDITION REPORT/DISPOSITION REQUEST

ATTACHMENTS

1) Pressure Locking Susceptibility Evaluation Table	5 pages
2) Operability Tabulation Table	7 pages
3) Available Thrust for Thermal Binding Effects Table	1 page
4) ComEd Memorandum "Pressure Locking / Thermal Binding Test Data"	6 page

Pressure Locking Susceptibility : Mark E Outk / 2-15-96

Pressure Locking Operability: [signature] / 2-15-96

Thermal Binding: Sonji K Watson for Peter Knaggs / 2-15-96

Mark Orth ____________

Chuck Rath ____________

Revision 0

PRESSURE LOCKING CALCULATIONS

Valve Tag (size)	SYSTEM INPUTS						VALVE INPUTS						
	Tinitial	Tfinal	Pinitial	Pup	Pdown		a	b	theta	nu	VF	Valve Structural Limit	
												Thrust	Torque
A/D Gate Valves:													
AF-34/35 (6")	104	123	1,801	0	0		2.63	0.88	5	0.3	0.6	34,900	517
AF-36/37 (6")	104	125	1,816	0	0		2.63	0.88	5	0.3	0.6	34,900	517
SG-134/138 (6")	587	587	1,383	0	0		2.63	0.88	5	0.3	0.6	35,000	550
BW/IP Gate Valves:													
CH-536 (3")	104	104	97	0	0		1.50	1.11	5	0.3	0.6	10,705	124
SI-604/609 (3")	60	231	1,960	660	0		1.38	1.11	5	0.3	0.6	10,705	124
SI-651/652 (12")	120	368	2,561	0	0		5.25	3.0	5	0.3	0.6	179,786	5,009
SI-653/654 (12")	120	368	465	0	0		5.25	3.0	5	0.3	0.6	74,133	2,342
SI-655 (12")	104	216	470	0	0		5.25	3.0	5	0.3	0.6	80,000	1,113
SI-656 (12")	104	121	470	0	0		5.25	3.0	5	0.3	0.6	80,000	1,113
SI-671 (8")	104	104	326	326	0		4.07	2.4	5	0.3	0.6	30,248	478
SI-672 (8")	104	104	326	326	0		4.07	2.4	5	0.3	0.6	30,248	478
SI-685/694 (10")	104	112	458	0	0		5.13	2.7	5	0.3	0.6	37,835	597
SI-686/696 (20")	104	104	458	0	0		9.50	5.0	5	0.3	0.6	128,368	2,805
SI-688/693 (10")	104	104	630	0	0		5.13	2.7	5	0.3	0.6	37,835	597

MOV ACTUATOR/STEM INPUTS								MOTOR INPUTS					MOV MISC INPUTS	
OAR	P.O. Ef	COF	Dstem	Pstem	Lstem	Actuator Stuctural Limit		Vfull	Vmin	MTorq	n	TDF	Max Close Load	% Residual Load
42.5	0.4	0.12	1.5	0.333	0.667	90,000	935	460	385	60	2	0.96	50,000	67%
40.18	0.4	0.12	1.5	0.333	0.667	90,000	935	115	93.66	40	1	1	50,000	67%
43.69	0.4	0.12	1.5	0.333	0.667	33,600	550	125	97.44	40	1	1	33,600	67%
30	0.4	0.12	0.875	0.167	0.333	28,000	275	460	401	7.5	2	0.99	11,000	67%
36.2	0.4	0.12	0.875	0.167	0.333	28,000	275	460	[illegible]14	15	2	0.97	19,600	67%
98.5	0.38	0.12	2.75	0.333	0.667	154,000	3,630	460	369	100	2	0.95	154,000	67%
88.4	0.4	0.12	2.75	0.333	0.667	90,000	935	460	456	40	2	0.89	46,517	67%
88.4	0.4	0.12	2.75	0.333	0.667	90,000	935	460	394	40	2	0.88	46,517	67%
88.4	0.4	0.12	2.75	0.333	0.667	90,000	935	460	384	40	2	0.96	46,517	67%
27.97	0.45	0.12	1.375	0.250	0.500	48,000	550	460	386	25	2	0.98	30,248	67%
27.97	0.45	0.12	1.375	0.250	0.500	48,000	550	460	386	25	2	0.98	30,248	67%
39.11	0.4	0.12	1.5	0.250	0.500	48,000	550	460	415	25	2	0.98	33,600	67%
82.57	0.4	0.12	2.125	0.333	0.667	90,000	935	460	404	60	2	0.98	53,429	67%
58.13	0.4	0.12	1.5	0.250	0.500	48,000	550	460	414	25	2	0.98	33,600	67%

Calculation of Minimum Available Torque and Thrust at Motor Stall					CALCULATION OF DP ACROSS DISKS			Calculation of Disk Loa			
Stem Factor	Avail Torque	Avail Thrust	VDF		Pfinal	DPavg		C2	C3	C8	C9
0.0160	686	42,752	0.700		1,858	1858		0.1614	0.0277	0.6887	0.2898
0.0160	524	32,633	0.814		1,879	1879		0.1614	0.0277	0.6887	0.2898
0.0160	545	33,963	0.780		1,383	1383		0.1614	0.0277	0.6887	0.2898
0.0087	68	7,825	0.760		97	97		0.0307	0.0025	0.8417	0.2034
0.0087	171	19,721	0.810		8,638	8308.5		0.0173	0.0011	0.8781	0.1615
0.0224	2,288	102,095	0.643		16,365	16365.[illegible]		0.0770	0.0098	0.7643	0.2752
0.0224	1,133	50,551	0.900		14,269	14269.4		0.0770	0.0098	0.7643	0.2752
0.0224	913	40,743	0.734		4,587	4586.9		0.0770	0.0098	0.7643	0.2752
0.0224	946	42,220	0.697		521	521		0.0770	0.0098	0.7643	0.2752
0.0133	217	16,330	0.704		326	163		0.0712	0.0088	0.7717	0.2698
0.0133	217	16,330	0.704		326	163		0.0712	0.0088	0.7717	0.2698
0.0139	345	24,759	0.900		482	482		0.0917	0.0127	0.7471	0.2861
0.0192	1,498	77,964	0.771		458	458		0.0918	0.0127	0.7470	0.2862
0.0139	461	33,119	0.810		630	630		0.0917	0.0127	0.7471	0.2861

								Residual Closing L	Vertical Load	Stem Piston
Perpindicular to the Seat Using Roark Thin Plate Theory								Load at Cracking	On Disks	Load
L11	L17	mu	Qb	Qa	Pforce	Disk Load		Residual Load	Fvert	Fpiston
0.00552	0.1395	0.5680	3,303	-1,074	35,905	20,159		33,500	7,038	3,283
0.00552	0.1395	0.5680	3,341	-1,066	36,311	20,387		33,500	7,117	3,320
0.00552	0.1395	0.5680	2,459	-799	26,726	15,005		22,512	5,239	2,444
0.00017	0.0289	0.5680	26	-13	310	144		7,370	120	58
0.00005	0.0166	0.5680	1,479	-796	17,189	7,809		13,132	8,944	5,194
0.00113	0.0699	0.5680	28,384	-12,712	954,363	476,372		103,180	247,014	97,204
0.00113	0.0699	0.5680	24,749	-11,084	832,133	415,361		31,166	215,378	84,754
0.00113	0.0699	0.5680	7,956	-3,563	267,491	133,519		31,166	69,234	27,244
0.00113	0.0699	0.5680	904	-405	30,383	15,166		31,166	7,864	3,095
0.00096	0.0649	0.5680	207	-94	5,533	2,740		20,266	2,957	484
0.00096	0.0649	0.5680	207	-94	5,533	2,740		20,266	2,957	484
0.00163	0.0824	0.5680	934	-400	28,734	14,634		22,512	6,933	852
0.00164	0.0826	0.5680	1,648	-705	93,885	47,825		35,797	22,635	1,624
0.00163	0.0824	0.5680	1,221	-523	37,557	19,127		22,512	9,062	1,113

Total Stem Thrust Req'd to Overcome Press Locking	Total Torque Required to Overcome Pressure Locking	MOV Min Avail Thrust due to Structural Limit or Motor Torque Limit			CHAPTER 15 EVENT RESULTING IN THE MAXIMUM INCREASE IN BONNET TEMPERATURE PRIOR TO REQ'D ACTIVE OPEN FUNCTION
Ftotal	Required Torque	Limiting Thrust	Suscept?		Reqd by GL 95-07
57,414	921	32,223	Yes		HELB
57,684	926	32,223	Yes		HELB
40,312	647	33,600	Yes		ALL (Normal Conditions)
7,576	66	7,825	No		ALL (Normal Conditions)
24,690	214	10,705	Yes		LOCA
729,363	16,346	102,095	Yes		MSLB
577,151	12,935	41,719	Yes		MSLB
206,674	4,632	40,743	Yes		HELB
51,101	1,145	41,719	Yes		HELB
25,479	339	16,330	Yes		LOCA
25,479	339	16,330	Yes		LOCA
43,227	602	24,759	Yes		HELB
104,634	2,010	48,663	Yes		ALL (Normal Conditions)
49,587	691	33,119	Yes		ALL (Normal Conditions)

Run Date/Time
[illegible]06 14:14

INPUT DATA AND ASSUMPTIONS

[illegible] Tag (size)	Assumed Bonnet Tinitial	Assumed Heat Source Tsource	Heat Source	Assumed Bonnet Tfinal	Assumed Bonnet Pinitial	Calculated Bonnet Pfinal	Assumed Pup	Assumed Pdown	A/L Cracking Thrust
1-AF-34 (6")	104	124	Room	115	1,801	1,634	1,801	0	23,187
2-AF-34 (6")	104	124	Room	115	1,801	1,634	1,801	0	21,102
3-AF-34 (6")	104	124	Room	115	1,801	1,634	1,801	0	19,609
1-AF-35 (6")	104	124	Room	115	1,801	1,634	1,801	0	20,648
2-AF-35 (6")	104	124	Room	115	1,801	1,634	1,801	0	24,765
3-AF-35 (6")	104	124	Room	115	1,801	1,634	1,801	0	17,573
1-AF-36 (6")	104	125	Room	115	1,816	1,649	0	0	24,161
2-AF-36 (6")	104	125	Room	115	1,816	1,649	0	0	19,121
3-AF-36 (6")	104	125	Room	115	1,816	1,649	0	0	21,801
1-AF-37 (6")	104	125	Room	115	1,816	1,649	0	0	10,290
2-AF-37 (6")	104	125	Room	115	1,816	1,649	0	0	17,584
3-AF-37 (6")	104	125	Room	115	1,816	1,649	0	0	20,713
1-SG-134 (6")	587	587	Ambient	587	1,383	1,383	0	0	8,667
2-SG-134 (6")	587	587	Ambient	587	1,383	1,383	0	0	13,700
3-SG-134 (6")	587	587	Ambient	587	1,383	1,383	0	0	14,265
1-SG-138 (6")	587	587	Ambient	587	1,383	1,383	0	0	4,614
2-SG-138 (6")	587	587	Ambient	587	1,383	1,383	0	0	11,206
3-SG-138 (6")	587	587	Ambient	587	1,383	1,383	0	0	14,515
1-CH-536 (3")	104	104	Ambient	104	97	97	0	0	4,100
2-CH-536 (3")	104	104	Ambient	104	97	97	0	0	4,687
3-CH-536 (3")	104	104	Ambient	104	97	97	0	0	4,754
1-SI-604 (3")	104	231	Fluid	130	1,960	2,038	660	0	6,393
2-SI-604 (3")	104	231	Fluid	130	1,960	2,038	660	0	6,202
3-SI-604 (3")	104	231	Fluid	130	1,960	2,038	660	0	7,599
1-SI-609 (3")	104	231	Fluid	130	1,960	2,038	660	0	7,130
2-SI-609 (3")	104	231	Fluid	130	1,960	2,038	660	0	6,414
3-SI-609 (3")	104	231	Fluid	130	1,960	2,038	660	0	6,011
1-SI-651 (12")	120	368	Room	160	467	1,015	0	0	55,170
[illegible]651 (12")	120	368	Room	160	467	1,015	0	0	35,011
[illegible]1 (12")	120	368	Room	160	467	1,015	0	0	44,880
[illegible]52 (12")	120	368	Room	160	467	1,015	0	0	78,512
2-SI-652 (12")	120	368	Room	160	467	1,015	0	0	30,770
3-SI-652 (12")	120	368	Room	160	467	1,015	0	0	62,320
1-SI-653 (12")	120	368	Room	160	467	1,015	0	0	18,064
2-SI-653 (12")	120	368	Room	160	467	1,015	0	0	16,531
3-SI-653 (12")	120	368	Room	160	467	1,015	0	0	20,544
1-SI-654 (12")	120	368	Room	160	467	1,015	0	0	11,128
2-SI-654 (12")	120	368	Room	160	467	1,015	0	0	14,261
3-SI-654 (12")	120	368	Room	160	467	1,015	0	0	17,506
1-SI-655 (12")	104	216	Room	121	470	521	0	0	13,413
2-SI-655 (12")	104	216	Room	121	470	521	0	0	21,585
3-SI 655 (12")	104	216	Room	121	470	521	0	0	18,469
1-SI-656 (12")	104	121	Room	121	470	521	0	0	8,418
2-SI-656 (12")	104	121	Room	121	470	521	0	0	19,065
3-SI-656 (12")	104	121	Room	121	470	521	0	0	16,912
1-SI-671 (8")	104	104	Ambient	104	326	326	326	0	8,731
2-SI-671 (8")	104	104	Ambient	104	326	326	326	0	9,626
3-SI-671 (8")	104	104	Ambient	104	326	326	326	0	6,933
1-SI-672 (8")	104	104	Ambient	104	326	326	326	0	9,514
2-SI-672 (8")	104	104	Ambient	104	326	326	326	0	8,479
3-SI-672 (8")	104	104	Ambient	104	326	326	326	0	3,745
1-SI-685 (10")	104	112	Room	112	458	482	0	0	13,740
2-SI-685 (10")	104	112	Room	112	458	482	0	0	9,188
3-SI-685 (10")	104	112	Room	112	458	482	0	0	4,240
1-SI-694 (10")	104	112	Room	112	458	482	0	0	9,643
2-SI-694 (10")	104	112	Room	112	458	482	0	0	14,011
3-SI-694 (10")	104	112	Room	112	458	482	0	0	4,904
1-SI-686 (20")	104	104	Ambient	104	458	458	0	0	9,423
2-SI-686 (20")	104	104	Ambient	104	458	458	0	0	18,498
3-SI-686 (20")	104	104	Ambient	104	458	458	0	0	11,114
1-SI-690 (20")	104	104	Ambient	104	458	458	0	0	19,802
2-SI-690 (20")	104	104	Ambient	104	458	458	0	0	19,839
[illegible] (20")	104	104	Ambient	104	458	458	0	0	15,241
[illegible] (10")	104	104	Ambient	104	630	630	0	0	10,362
2-SI-688 (10")	104	104	Ambient	104	630	630	0	0	9,412
3-SI-688 (10")	104	104	Ambient	104	630	630	0	0	8,476
1-SI-693 (10")	104	104	Ambient	104	630	630	0	0	7,302
2-SI-693 (10")	104	104	Ambient	104	630	630	0	0	12,146
3-SI-693 (10")	104	104	Ambient	104	630	630	0	0	7,154

[illegible]

[illegible]te/Time
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VALVE DIMENSIONAL CONFIGURATION

Valve Tag (size)	Given theta	nu	Assumed VF	Given Dstem	Calculated mu	Calculated DPavg	Given a	Given b	Calculated C2	Calculated C3	Calculated C8	Calculated C9	Calculated L11	Calculated L17
1-AF-34 (6")	5	0.3	0.6	1.50	0.5680	734	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
2-AF-34 (6")	5	0.3	0.6	1.50	0.5680	734	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
3-AF-34 (6")	5	0.3	0.6	1.50	0.5680	734	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
1-AF-35 (6")	5	0.3	0.6	1.50	0.5680	734	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
2-AF-35 (6")	5	0.3	0.6	1.50	0.5680	734	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
3-AF-35 (6")	5	0.3	0.6	1.50	0.5680	734	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
1-AF-36 (6")	5	0.3	0.6	1.50	0.5680	1649	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
2-AF-36 (6")	5	0.3	0.6	1.50	0.5680	1649	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
3-AF-36 (6")	5	0.3	0.6	1.50	0.5680	1649	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
1-AF-37 (6")	5	0.3	0.6	1.50	0.5680	1649	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
2-AF-37 (6")	5	0.3	0.6	1.50	0.5680	1649	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
3-AF-37 (6")	5	0.3	0.6	1.50	0.5680	1649	2.63	0.94	0.1523	0.0257	0.6947	0.2936	0.0049	0.1323
1-SG-134 (6")	5	0.3	0.6	1.50	0.5680	1383	2.63	0.97	0.1482	0.0248	0.6976	0.2949	0.0046	0.1290
2-SG-134 (6")	5	0.3	0.6	1.50	0.5680	1383	2.63	0.97	0.1482	0.0248	0.6976	0.2949	0.0046	0.1290
3-SG-134 (6")	5	0.3	0.6	1.50	0.5680	1383	2.63	0.97	0.1482	0.0248	0.6976	0.2949	0.0046	0.1290
1-SG-138 (6")	5	0.3	0.6	1.50	0.5680	1383	2.63	0.97	0.1482	0.0248	0.6976	0.2949	0.0046	0.1290
2-SG-138 (6")	5	0.3	0.6	1.50	0.5680	1383	2.63	0.97	0.1482	0.0248	0.6976	0.2949	0.0046	0.1290
3-SG-138 (6")	5	0.3	0.6	1.50	0.5680	1383	2.63	0.97	0.1482	0.0248	0.6976	0.2949	0.0046	0.1290
1-CH-536 (3")	5	0.3	0.5	0.88	0.4773	97	1.50	1.09	0.0337	0.0029	0.8348	0.2106	0.0002	0.0316
2-CH-536 (3")	5	0.3	0.5	0.88	0.4773	97	1.50	1.09	0.0337	0.0029	0.8348	0.2106	0.0002	0.0316
3-CH-536 (3")	5	0.3	0.5	0.88	0.4773	97	1.50	1.09	0.0337	0.0029	0.8348	0.2106	0.0002	0.0316
1-SI-604 (3")	5	0.3	0.5	0.88	0.4773	1708	1.38	1.06	0.0241	0.0018	0.8580	0.1851	0.0001	0.0229
2-SI-604 (3")	5	0.3	0.5	0.88	0.4773	1708	1.38	1.06	0.0241	0.0018	0.8580	0.1851	0.0001	0.0229
3-SI-604 (3")	5	0.3	0.5	0.88	0.4773	1708	1.38	1.06	0.0241	0.0018	0.8580	0.1851	0.0001	0.0229
1-SI-609 (3")	5	0.3	0.5	0.88	0.4773	1708	1.38	1.06	0.0241	0.0018	0.8580	0.1851	0.0001	0.0229
2-SI-609 (3")	5	0.3	0.5	0.88	0.4773	1708	1.38	1.06	0.0241	0.0018	0.8580	0.1851	0.0001	0.0229
3-SI-609 (3")	5	0.3	0.5	0.88	0.4773	1708	1.38	1.06	0.0241	0.0018	0.8580	0.1851	0.0001	0.0229
1-SI-651 (12")	5	0.3	0.6	2.75	0.5680	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
[illegible](12")	5	0.3	0.6	2.75	0.5680	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
[illegible](12")	5	0.3	0.6	2.75	0.5680	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
[illegible](12")	5	0.3	0.6	2.75	0.5680	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
2-SI-652 (12")	5	0.3	0.6	2.75	0.5680	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
3-SI-652 (12")	5	0.3	0.6	2.75	0.5680	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
1-SI-653 (12")	5	0.3	0.65	2.75	0.6128	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
2-SI-653 (12")	5	0.3	0.65	2.75	0.6128	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
3-SI-653 (12")	5	0.3	0.65	2.75	0.6128	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
1-SI-654 (12")	5	0.3	0.65	2.75	0.6128	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
2-SI-654 (12")	5	0.3	0.65	2.75	0.6128	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
3-SI-654 (12")	5	0.3	0.65	2.75	0.6128	1015	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
1-SI-655 (12")	5	0.3	0.6	2.75	0.5680	521	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
2-SI-655 (12")	5	0.3	0.6	2.75	0.5680	521	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
3-SI-655 (12")	5	0.3	0.6	2.75	0.5680	521	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
1-SI-656 (12")	5	0.3	0.6	2.75	0.5680	521	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
2-SI-656 (12")	5	0.3	0.6	2.75	0.5680	521	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
3-SI-656 (12")	5	0.3	0.6	2.75	0.5680	521	5.25	3.00	0.0770	0.0096	0.7643	0.2752	0.0011	0.0699
1-SI-671 (8")	5	0.3	0.55	1.38	0.5228	163	4.07	2.41	0.0705	0.0066	0.7727	0.2690	0.0009	0.0643
2-SI-671 (8")	5	0.3	0.55	1.38	0.5228	163	4.07	2.41	0.0705	0.0066	0.7727	0.2690	0.0009	0.0643
3-SI-671 (8")	5	0.3	0.55	1.38	0.5228	163	4.07	2.41	0.0705	0.0066	0.7727	0.2690	0.0009	0.0643
1-SI-672 (8")	5	0.3	0.55	1.38	0.5228	163	4.07	2.41	0.0705	0.0066	0.7727	0.2690	0.0009	0.0643
2-SI-672 (8")	5	0.3	0.55	1.38	0.5228	163	4.07	2.41	0.0705	0.0066	0.7727	0.2690	0.0009	0.0643
3-SI-672 (8")	5	0.3	0.55	1.38	0.5228	163	4.07	2.41	0.0705	0.0066	0.7727	0.2690	0.0009	0.0643
1-SI-685 (10")	5	0.3	0.5	1.50	0.4773	482	5.17	2.70	0.0932	0.0130	0.7455	0.2869	0.0017	0.0637
2-SI-685 (10")	5	0.3	0.5	1.50	0.4773	482	5.17	2.70	0.0932	0.0130	0.7455	0.2869	0.0017	0.0637
3-SI-685 (10")	5	0.3	0.5	1.50	0.4773	482	5.17	2.70	0.0932	0.0130	0.7455	0.2869	0.0017	0.0637
1-SI-694 (10")	5	0.3	0.5	1.50	0.4773	482	5.17	2.70	0.0932	0.0130	0.7455	0.2869	0.0017	0.0637
2-SI-694 (10")	5	0.3	0.5	1.50	0.4773	482	5.17	2.70	0.0932	0.0130	0.7455	0.2869	0.0017	0.0637
3-SI-694 (10")	5	0.3	0.5	1.50	0.4773	482	5.17	2.70	0.0932	0.0130	0.7455	0.2869	0.0017	0.0637
1-SI-686 (20")	5	0.3	0.6	2.13	0.5680	458	9.52	5.03	0.0912	0.0126	0.7477	0.2858	0.0018	0.0620
2-SI-686 (20")	5	0.3	0.6	2.13	0.5680	458	9.52	5.03	0.0912	0.0126	0.7477	0.2858	0.0018	0.0620
3-SI-686 (20")	5	0.3	0.6	2.13	0.5680	458	9.52	5.03	0.0912	0.0126	0.7477	0.2858	0.0018	0.0620
1-SI-696 (20")	5	0.3	0.6	2.13	0.5680	458	9.52	5.03	0.0912	0.0126	0.7477	0.2858	0.0018	0.0620
2-[illegible](20")	5	0.3	0.6	2.13	0.5680	458	9.52	5.03	0.0912	0.0126	0.7477	0.2858	0.0018	0.0620
[illegible]0")	5	0.3	0.6	2.13	0.5680	458	9.52	5.03	0.0912	0.0126	0.7477	0.2858	0.0018	0.0620
[illegible]10")	5	0.3	0.5	1.50	0.4773	630	5.17	3.16	0.0647	0.0076	0.7807	0.2626	0.0008	0.0592
2-SI-688 (10")	5	0.3	0.5	1.50	0.4773	630	5.17	3.16	0.0647	0.0076	0.7807	0.2626	0.0008	0.0592
3-SI-688 (10")	5	0.3	0.5	1.50	0.4773	630	5.17	3.16	0.0647	0.0076	0.7807	0.2626	0.0008	0.0592
1-SI-693 (10")	5	0.3	0.5	1.50	0.4773	630	5.17	3.16	0.0647	0.0076	0.7807	0.2626	0.0008	0.0592
2-SI-693 (10")	5	0.3	0.5	1.50	0.4773	630	5.17	3.16	0.0647	0.0076	0.7807	0.2626	0.0008	0.0592
3-SI-693 (10")	5	0.3	0.5	1.50	0.4773	630	5.17	3.16	0.0647	0.0076	0.7807	0.2626	0.0008	0.0592

[illegible] Date/Time
[illegible] 14:14

CALCULATED ACTUATOR PULLOUT THRUST AND TORQUE REQUIREMENT

	PULLOUT THRUST REQUIRED							PULLOUT TORQUE REQUIRED					
[illegible] Tag (size)	Given A/L CrThr	Calculated Fpiston	Calculated Fvert	Calculated Qb	Calculated Qs	Calculated Fplock	Calculated Ftotal	Given Dstem	Given Pstem	Given Lstem	Assumed COF	Calculated SF	Calculated TQstem
1-AF-34 (6")	23,187	2,888	6,189	1,206	-410	7,702	34,191	1.50	0.3333	0.6667	0.12	0.0160	549
2-AF-34 (6")	21,102	2,888	6,189	1,206	-410	7,702	32,106	1.50	0.3333	0.6667	0.12	0.0160	515
3-AF-34 (6")	19,809	2,888	6,189	1,206	-410	7,702	30,813	1.50	0.3333	0.6667	0.12	0.0160	494
1-AF-35 (6")	20,648	2,888	6,189	1,206	-410	7,702	31,652	1.50	0.3333	0.6667	0.12	0.0160	508
2-AF-35 (6")	24,765	2,888	6,189	1,206	-410	7,702	35,769	1.50	0.3333	0.6667	0.12	0.0160	574
3-AF-35 (6")	17,573	2,888	6,189	1,206	-410	7,702	28,577	1.50	0.3333	0.6667	0.12	0.0160	458
1-AF-36 (6")	24,161	2,914	6,246	2,711	-922	17,315	44,606	1.50	0.3333	0.6667	0.09	0.0142	637
2-AF-36 (6")	19,121	2,914	6,246	2,711	-922	17,315	39,768	1.50	0.3333	0.6667	0.12	0.0160	638
3-AF-36 (6")	21,801	2,914	6,246	2,711	-922	17,315	42,448	1.50	0.3333	0.6667	0.12	0.0160	631
1-AF-37 (6")	10,290	2,914	6,246	2,711	-922	17,315	30,937	1.50	0.3333	0.6667	0.12	0.0160	496
2-AF-37 (6")	17,584	2,914	6,246	2,711	-922	17,315	38,231	1.50	0.3333	0.6667	0.12	0.0160	613
3-AF-37 (6")	20,713	2,914	6,246	2,711	-922	17,315	41,360	1.50	0.3333	0.6667	0.12	0.0160	664
1-SG-134 (6")	8,667	2,444	5,239	2,195	-762	14,297	25,758	1.50	0.3333	0.6667	0.12	0.0160	413
2-SG-134 (6")	13,700	2,444	5,239	2,195	-762	14,297	30,791	1.50	0.3333	0.6667	0.12	0.0160	494
3-SG-134 (6")	14,265	2,444	5,239	2,195	-762	14,297	31,356	1.50	0.3333	0.6667	0.12	0.0160	503
1-SG-138 (6")	4,814	2,444	5,239	2,195	-762	14,297	21,905	1.50	0.3333	0.6667	0.12	0.0160	351
2-SG-138 (6")	11,206	2,444	5,239	2,195	-762	14,297	28,297	1.50	0.3333	0.6667	0.12	0.0160	454
3-SG-138 (6")	14,515	2,444	5,239	2,195	-762	14,297	31,606	1.50	0.3333	0.6667	0.12	0.0160	507
1-CH-536 (3")	4,100	58	120	28	-14	127	4,288	0.88	0.1667	0.3333	0.12	0.0087	37
2-CH-536 (3")	4,887	58	120	28	-14	127	5,075	0.88	0.1667	0.3333	0.12	0.0087	44
3-CH-536 (3")	4,754	58	120	28	-14	127	4,942	0.88	0.1667	0.3333	0.12	0.0087	43
1-SI-604 (3")	6,393	1,225	2,110	368	-193	1,592	8,870	0.88	0.1667	0.3333	0.12	0.0087	77
2-SI-604 (3")	6,202	1,225	2,110	368	-193	1,592	8,679	0.88	0.1667	0.3333	0.12	0.0087	75
3-SI-604 (3")	7,599	1,225	2,110	368	-193	1,592	10,076	0.88	0.1667	0.3333	0.12	0.0087	87
1-SI-609 (3")	7,130	1,225	2,110	368	-193	1,592	9,607	0.88	0.1667	0.3333	0.12	0.0087	83
2-SI-609 (3")	6,414	1,225	2,110	368	-193	1,592	8,891	0.88	0.1667	0.3333	0.12	0.0087	77
3-SI-609 (3")	6,011	1,225	2,110	358	-193	1,592	8,488	0.88	0.1667	0.3333	0.12	0.0087	73
1-SI-651 (12")	55,170	6,030	15,324	1,761	-789	29,552	94,015	2.75	0.3333	0.6667	0.12	0.0224	2,107
[illegible]651 (12")	35,011	6,030	15,324	1,761	-789	29,552	73,856	2.75	0.3333	0.6667	0.12	0.0224	1,655
[illegible] (12")	44,880	6,030	15,324	1,761	-789	29,552	83,725	2.75	0.3333	0.6667	0.12	0.0224	1,876
[illegible] (12")	78,512	6,030	15,324	1,761	-789	29,552	117,357	2.75	0.3333	0.6667	0.12	0.0224	2,630
2-SI-652 (12")	30,770	6,030	15,324	1,761	-789	29,552	69,615	2.75	0.3333	0.6667	0.12	0.0224	1,560
3-SI-652 (12")	62,320	6,030	15,324	1,761	-789	29,552	101,165	2.75	0.3333	0.6667	0.12	0.0224	2,267
1-SI-653 (12")	18,084	6,030	15,324	1,761	-789	31,882	59,260	2.75	0.3333	0.6667	0.12	0.0224	1,328
2-SI-653 (12")	16,531	6,030	15,324	1,761	-789	31,882	57,707	2.75	0.3333	0.6667	0.12	0.0224	1,293
3-SI-653 (12")	20,544	6,030	15,324	1,761	-789	31,882	61,720	2.75	0.3333	0.6667	0.12	0.0224	1,383
1-SI-654 (12")	11,128	6,030	15,324	1,761	-789	31,882	52,304	2.75	0.3333	0.6667	0.12	0.0224	1,172
2-SI-654 (12")	14,261	6,030	15,324	1,761	-789	31,882	55,437	2.75	0.3333	0.6667	0.12	0.0224	1,242
3-SI-654 (12")	17,506	6,030	15,324	1,761	-789	31,882	58,682	2.75	0.3333	0.6667	0.12	0.0224	1,315
1-SI-655 (12")	13,413	3,095	7,864	904	-405	15,166	33,348	2.75	0.3333	0.6667	0.12	0.0224	747
2-SI-655 (12")	21,585	3,095	7,864	904	-405	15,166	41,520	2.75	0.3333	0.6667	0.12	0.0224	931
3-SI-655 (12")	18,469	3,095	7,864	904	-405	15,166	38,404	2.75	0.3333	0.6667	0.12	0.0224	861
1-SI-656 (12")	8,418	3,095	7,864	904	-405	15,166	28,353	2.75	0.3333	0.6667	0.12	0.0224	635
2-SI-656 (12")	19,065	3,095	7,864	904	-405	15,166	39,000	2.75	0.3333	0.6667	0.12	0.0224	874
3-SI-656 (12")	16,912	3,095	7,864	904	-405	15,166	36,847	2.75	0.3333	0.6667	0.12	0.0224	826
1-SI-671 (8")	8,731	484	2,957	205	-94	2,508	13,712	1.38	0.2500	0.5000	0.12	0.0133	182
2-SI-671 (8")	9,626	484	2,957	205	-94	2,508	14,607	1.38	0.2500	0.5000	0.12	0.0133	194
3-SI-671 (8")	6,933	484	2,957	205	-94	2,508	11,914	1.38	0.2500	0.5000	0.12	0.0133	158
1-SI-672 (8")	9,514	484	2,957	205	-94	2,508	14,495	1.38	0.2500	0.5000	0.12	0.0133	193
2-SI-672 (8")	8,479	484	2,957	205	-94	2,508	13,460	1.38	0.2500	0.5000	0.12	0.0133	179
3-SI-672 (8")	3,745	484	2,957	205	-94	2,508	8,726	1.38	0.2500	0.5000	0.12	0.0133	116
1-SI-685 (10")	13,740	852	7,050	955	-407	12,609	32,547	1.50	0.2500	0.5000	0.12	0.0139	453
2-SI-685 (10")	9,188	852	7,050	955	-407	12,609	27,995	1.50	0.2500	0.5000	0.12	0.0139	390
3-SI-685 (10")	4,240	852	7,050	955	-407	12,609	23,047	1.50	0.2500	0.5000	0.12	0.0139	321
1-SI-694 (10")	9,643	852	7,050	955	-407	12,609	28,450	1.50	0.2500	0.5000	0.12	0.0139	396
2-SI-694 (10")	14,011	852	7,050	955	-407	12,609	32,818	1.50	0.2500	0.5000	0.12	0.0139	457
3-SI-694 (10")	4,904	852	7,050	955	-407	12,609	23,711	1.50	0.2500	0.5000	0.12	0.0139	330
1-SI-686 (20")	9,423	1,624	22,731	1,642	-704	47,839	78,368	2.13	0.3333	0.6667	0.10	0.0175	1,369
2-SI-686 (20")	18,498	1,624	22,731	1,642	-704	47,839	87,443	2.13	0.3333	0.6667	0.09	0.0166	1,451
3-SI-686 (20")	11,114	1,624	22,731	1,642	-704	47,839	80,059	2.13	0.3333	0.6667	0.12	0.0192	1,538
1-SI-696 (20")	19,802	1,624	22,731	1,642	-704	47,839	88,747	2.13	0.3333	0.6667	0.09	0.0166	1,473
2-SI-696 (20")	19,839	1,624	22,731	1,642	-704	47,839	88,784	2.13	0.3333	0.6667	0.09	0.0166	1,473
[illegible] (20")	15,241	1,624	22,731	1,642	-704	47,839	84,186	2.13	0.3333	0.6667	0.09	0.0166	1,397
[illegible] (10")	10,362	1,113	9,214	948	-441	13,656	32,119	1.50	0.2500	0.5000	0.12	0.0139	447
2-[illegible]88 (10")	9,412	1,113	9,214	948	-441	13,656	31,169	1.50	0.2500	0.5000	0.12	0.0139	434
3-SI-688 (10")	8,476	1,113	9,214	948	-441	13,656	30,233	1.50	0.2500	0.5000	0.12	0.0139	421
1-SI-693 (10")	7,302	1,113	9,214	948	-441	13,656	29,059	1.50	0.2500	0.5000	0.12	0.0139	405
2-SI-693 (10")	12,146	1,113	9,214	948	-441	13,656	33,903	1.50	0.2500	0.5000	0.12	0.0139	472
3-SI-693 (10")	7,154	1,113	9,214	948	-441	13,656	28,911	1.50	0.2500	0.5000	0.12	0.0139	403

[illegible]

Ru[illegible]te/Time [illegible]4.14

CALCULATED DEGRADED VOLTAGE PULLOUT THRUST AND TORQUE CAPABILITY

	DEGRADED VOLTAGE PULLOUT TORQUE CAPABILITY									DEGRADED VOLTAGE PULLOUT THRUST CAPABILITY					
V[illegible]g (size)	Given MT	Given OAR	Given Vfull	Given Vmin	Given n	Assumed Actuator Eff	Calculated VDF	Given TDF	Calculated DegV PO TQ	Given Dstem	Given Pstem	Given Lstem	Assumed COF	Calculated SF	Calculated THstem
1-AF-34 (6")	60	42.50	460	385	2	0.50	0.70	0.96	857	1.50	0.3333	0.6667	0.12	0.0160	53,440
2-AF-34 (6")	60	42.50	460	385	2	0.50	0.70	0.96	857	1.50	0.3333	0.6667	0.12	0.0160	53,440
3-AF-34 (6")	60	42.50	460	385	2	0.50	0.70	0.96	857	1.50	0.3333	0.6667	0.12	0.0160	53,440
1-AF-35 (6")	60	42.50	460	385	2	0.50	0.70	0.96	857	1.50	0.3333	0.6667	0.12	0.0160	53,440
2-AF-35 (6")	60	42.50	460	385	2	0.50	0.70	0.96	857	1.50	0.3333	0.6667	0.12	0.0160	53,440
3-AF-35 (6")	60	42.50	460	385	2	0.50	0.70	0.96	857	1.50	0.3333	0.6667	0.12	0.0160	53,440
1-AF-36 (6")	56.7	40.18	125	98.91	1	0.50	0.79	1.00	901	1.50	0.3333	0.6667	0.09	0.0142	63,400
2-AF-36 (6")	56.7	40.18	125	98.88	1	0.50	0.79	1.00	901	1.50	0.3333	0.6667	0.12	0.0160	56,161
3-AF-36 (6")	56.7	40.18	125	98.88	1	0.50	0.79	1.00	901	1.50	0.3333	0.6667	0.12	0.0160	56,161
1-AF-37 (6")	56.7	40.18	125	98.27	1	0.50	0.79	1.00	896	1.50	0.3333	0.6667	0.12	0.0160	55,815
2-AF-37 (6")	56.7	40.18	125	96.62	1	0.50	0.77	1.00	880	1.50	0.3333	0.6667	0.12	0.0160	54,878
3-AF-37 (6")	56.7	60.15	125	95.44	1	0.50	0.76	1.00	1,302	1.50	0.3333	0.6667	0.12	0.0160	81,149
1-SG-134 (6")	40	43.69	125	97.44	1	0.40	0.78	1.00	545	1.50	0.3333	0.6667	0.12	0.0160	33,983
2-SG-134 (6")	40	43.69	125	97.44	1	0.40	0.78	1.00	545	1.50	0.3333	0.6667	0.12	0.0160	33,983
3-SG-134 (6")	40	43.69	115	97.44	1	0.40	0.85	1.00	592	1.50	0.3333	0.6667	0.12	0.0160	36,916
1-SG-138 (6")	40	43.69	125	97.44	1	0.40	0.78	1.00	545	1.50	0.3333	0.6667	0.12	0.0160	33,983
2-SG-138 (6")	40	43.69	125	97.44	1	0.40	0.78	1.00	545	1.50	0.3333	0.6667	0.12	0.0160	33,983
3-SG-138 (6")	40	43.69	115	97.44	1	0.40	0.85	1.00	592	1.50	0.3333	0.6667	0.12	0.0160	36,916
1-CH-536 (3")	7.5	30.00	460	401	2	0.40	0.76	0.99	68	0.88	0.1667	0.3333	0.12	0.0067	7,825
2-CH-536 (3")	7.5	30.00	460	401	2	0.40	0.76	0.99	68	0.88	0.1667	0.3333	0.12	0.0067	7,825
3-CH-536 (3")	7.5	30.00	460	401	2	0.40	0.76	0.99	68	0.88	0.1667	0.3333	0.12	0.0067	7,825
1-SI-604 (3")	15	36.20	460	427	2	0.50	0.90	0.97	237	0.88	0.1667	0.3333	0.12	0.0067	27,391
2-SI-604 (3")	15	36.20	460	433	2	0.50	0.90	0.97	237	0.88	0.1667	0.3333	0.12	0.0067	27,391
3-SI-604 (3")	15	36.20	460	432	2	0.50	0.90	0.97	237	0.88	0.1667	0.3333	0.12	0.0067	27,391
1-SI-609 (3")	15	36.20	460	432	2	0.50	0.90	0.97	237	0.88	0.1667	0.3333	0.12	0.0067	27,391
2-SI-609 (3")	15	36.20	460	447	2	0.50	0.90	0.97	237	0.88	0.1667	0.3333	0.12	0.0067	27,391
3-SI-609 (3")	15	36.20	460	433	2	0.50	0.90	0.97	237	0.88	0.1667	0.3333	0.12	0.0067	27,391
1-SI-651 (12")	100	132.81	460	415	2	0.35	0.90	0.95	3,974	2.75	0.3333	0.6667	0.12	0.0224	177,333
2-S[illegible] (12")	100	98.50	460	425	2	0.35	0.90	0.95	2,948	2.75	0.3333	0.6667	0.12	0.0224	131,521
[illegible]2")	100	132.81	460	421	2	0.35	0.90	0.95	3,974	2.75	0.3333	0.6667	0.12	0.0224	177,333
[illegible]12")	100	132.81	460	427	2	0.35	0.90	0.95	3,974	2.75	0.3333	0.6667	0.12	0.0224	177,333
2-S[illegible]52 (12")	100	132.81	460	433	2	0.35	0.90	0.95	3,974	2.75	0.3333	0.6667	0.12	0.0224	177,333
3-SI-652 (12")	100	132.81	460	424	2	0.35	0.90	0.95	3,974	2.75	0.3333	0.6667	0.12	0.0224	177,333
1-SI-653 (12")	40	88.40	460	456	2	0.50	0.90	0.89	1,416	2.75	0.3333	0.6667	0.12	0.0224	63,189
2-SI-653 (12")	40	88.40	460	456	2	0.50	0.90	0.89	1,416	2.75	0.3333	0.6667	0.12	0.0224	63,189
3-SI-653 (12")	40	88.40	460	456	2	0.50	0.90	0.89	1,416	2.75	0.3333	0.6667	0.12	0.0224	63,189
1-SI-654 (12")	40	88.40	460	456	2	0.50	0.90	0.89	1,416	2.75	0.3333	0.6667	0.12	0.0224	63,189
2-SI-654 (12")	40	88.40	460	456	2	0.50	0.90	0.89	1,416	2.75	0.3333	0.6667	0.12	0.0224	63,189
3-SI-654 (12")	40	88.40	460	456	2	0.50	0.90	0.89	1,416	2.75	0.3333	0.6667	0.12	0.0224	63,189
1-SI-655 (12")	40	88.40	460	416	2	0.50	0.90	0.88	1,400	2.75	0.3333	0.6667	0.12	0.0224	62,479
2-SI-655 (12")	40	88.40	460	426	2	0.50	0.90	0.88	1,400	2.75	0.3333	0.6667	0.12	0.0224	62,479
3-SI-655 (12")	40	88.40	460	423	2	0.50	0.90	0.88	1,400	2.75	0.3333	0.6667	0.12	0.0224	62,479
1-SI-656 (12")	40	88.40	460	429	2	0.40	0.90	0.96	1,222	2.75	0.3333	0.6667	0.12	0.0224	54,527
2-SI-656 (12")	40	88.40	460	435	2	0.40	0.90	0.96	1,222	2.75	0.3333	0.6667	0.12	0.0224	54,527
3-SI-656 (12")	40	88.40	460	425	2	0.40	0.90	0.96	1,222	2.75	0.3333	0.6667	0.12	0.0224	54,527
1-SI-671 (8")	25	29.60	460	386	2	0.45	0.70	0.98	230	1.38	0.2500	0.5000	0.12	0.0133	17,281
2-SI-671 (8")	25	27.97	460	386	2	0.45	0.70	0.98	217	1.38	0.2500	0.5000	0.12	0.0133	16,330
3-SI-671 (8")	25	29.60	460	386	2	0.45	0.70	0.98	230	1.38	0.2500	0.5000	0.12	0.0133	17,281
1-SI-672 (8")	25	27.97	460	386	2	0.45	0.70	0.98	217	1.38	0.2500	0.5000	0.12	0.0133	16,330
2-SI-672 (8")	25	27.97	460	386	2	0.45	0.70	0.98	217	1.38	0.2500	0.5000	0.12	0.0133	16,330
3-SI-672 (8")	25	27.97	460	386	2	0.45	0.70	0.98	21[illegible]	1.38	0.2500	0.5000	0.12	0.0133	16,330
1-SI-685 (10")	25	39.10	460	427	2	0.55	0.90	0.98	474	1.50	0.2500	0.5000	0.12	0.0139	34,034
2-SI-685 (10")	25	39.10	460	434	2	0.55	0.90	0.98	474	1.50	0.2500	0.5000	0.12	0.0139	34,034
3-SI-685 (10")	25	39.10	460	433	2	0.55	0.90	0.98	474	1.50	0.2500	0.5000	0.12	0.0139	34,034
1-SI-694 (10")	25	39.10	450	432	2	0.55	0.90	0.98	474	1.50	0.2500	0.5000	0.12	0.0139	34,034
2-SI-694 (10")	25	39.10	460	447	2	0.55	0.90	0.98	474	1.50	0.2500	0.5000	0.12	0.0139	34,034
3-SI-694 (10")	25	39.10	460	432	2	0.55	0.90	0.98	474	1.50	0.2500	0.5000	0.12	0.0139	34,034
1-SI-686 (20")	60	82.57	460	426	2	0.50	0.90	0.98	2,185	2.13	0.3333	0.6667	0.10	0.0175	125,092
2-SI-686 (20")	60	82.57	460	433	2	0.50	0.90	0.98	2,185	2.13	0.3333	0.6667	0.09	0.0166	131,650
3-SI-686 (20")	60	82.57	460	432	2	0.50	0.90	0.98	2,185	2.13	0.3333	0.6667	0.12	0.0192	113,710
1-SI-696 (20")	60	82.57	460	431	2	0.50	0.90	0.98	2,185	2.13	0.3333	0.6667	0.09	0.0166	131,659
2-SI-696 (20")	60	82.57	460	446	2	0.50	0.90	0.98	2,185	2.13	0.3333	0.6667	0.09	0.0166	131,650
3[illegible]20")	60	82.57	460	431	2	0.50	0.90	0.98	2,185	2.13	0.3333	0.6667	0.09	0.0166	131,659
[illegible]0")	25	58.13	460	427	2	0.40	0.90	0.98	513	1.50	0.2500	0.5000	0.12	0.0139	36,799
2-[illegible] (10")	25	58.13	460	433	2	0.40	0.90	0.98	513	1.50	0.2500	0.5000	0.12	0.0139	36,799
3-SI-688 (10")	25	58.13	460	432	2	0.40	0.90	0.98	513	1.50	0.2500	0.5000	0.12	0.0139	36,799
1-SI-693 (10")	25	58.13	460	432	2	0.40	0.90	0.98	513	1.50	0.2500	0.5000	0.12	0.0139	36,799
2-SI-693 (10")	25	58.13	460	447	2	0.50	0.90	0.98	641	1.50	0.2500	0.5000	0.12	0.0139	45,920
3-SI-693 (10")	25	58.13	460	432	2	0.40	0.90	0.98	513	1.50	0.2500	0.5000	0.12	0.0139	36,799

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THRUST COMPARISON

Valve Tag (size)	STRUCTURAL DESIGN THRUST LIMITS: VALVE Thrust	ACTUATOR: Model	ACTUATOR: Des Thrust	ACTUATOR: 1.4 or 1.6 x Th	ACTUATOR: 2.5 x Th	THRUST COMPARISON: Thrust Limit	Req Thrust	Margin
1-AF-34 (6")	44,175	SMB-1	45,000	73,350	112,500	44,175	34,191	29%
2-AF-34 (6")	46,165	SMB-1	45,000	73,350	112,500	46,165	32,106	44%
3-AF-34 (6")	49,000	SMB-1	45,000	73,350	112,500	49,000	30,813	59%
1-AF-35 (6")	44,175	SMB-1	45,000	73,350	112,500	44,175	31,652	40%
2-AF-35 (6")	46,165	SMB-1	45,000	73,350	112,500	46,165	35,769	29%
3-AF-35 (6")	34,900	SMB-1	45,000	73,350	112,500	34,900	28,577	22%
1-AF-36 (6")	44,175	SMB-1	45,000	73,350	112,500	45,175	44,608	1%
2-AF-36 (6")	46,165	SMB-1	45,000	73,350	112,500	46,165	39,768	16%
3-AF-36 (6")	46,165	SMB-1	45,000	73,350	112,500	46,165	42,448	9%
1-AF-37 (6")	44,175	SMB-1	45,000	73,350	112,500	44,175	30,937	43%
2-AF-37 (6")	46,165	SMB-1	45,000	73,350	112,500	46,165	38,231	21%
3-AF-37 (6")	46,165	SMB-1	45,000	73,350	112,500	46,165	41,360	12%
1-SG-134 (6")	37,500	SB-0	24,000	39,120	60,000	33,963	25,758	32%
2-SG-134 (6")	38,500	SB-0	24,000	39,120	60,000	33,963	30,791	10%
3-SG-134 (6")	37,000	SB-0	24,000	39,120	60,000	36,916	31,356	18%
1-SG-138 (6")	35,000	SB-0	24,000	39,120	60,000	33,963	21,905	55%
2-SG-138 (6")	38,500	SB-0	24,000	39,120	60,000	33,963	28,297	20%
3-SG-138 (6")	37,000	SB-0	24,000	39,120	60,000	36,916	31,606	17%
1-CH-536 (3")	10,705	SMB-00	14,000	22,820	35,000	7,825	4,288	82%
2-CH-536 (3")	10,705	SMB-00	14,000	22,820	35,000	7,825	5,075	54%
3-CH-536 (3")	10,705	SMB-00	14,000	22,820	35,000	7,825	4,942	58%
1-SI-604 (3")	10,705	SMB-00	14,000	22,820	35,000	10,705	8,870	21%
2-SI-604 (3")	10,705	SMB-00	14,000	22,820	35,000	10,705	8,679	23%
3-SI-604 (3")	10,705	SMB-00	14,000	22,820	35,000	10,705	10,076	6%
1-SI-609 (3")	10,705	SMB-00	14,000	22,820	35,000	10,705	9,607	11%
2-SI-609 (3")	10,705	SMB-00	14,000	22,820	35,000	10,705	8,891	20%
3-SI-609 (3")	10,705	SMB-00	14,000	22,820	35,000	10,705	8,488	26%
[illegible]SI-651 (12")	179,786	SMB-3	140,000	154,000	350,000	154,000	94,015	64%
[illegible]651 (12")	179,786	SMB-3	140,000	154,000	350,000	131,521	73,856	78%
[illegible]651 (12")	179,786	SMB-3	140,000	154,000	350,000	154,000	83,725	84%
1-SI-652 (12")	179,786	SMB-3	140,000	154,000	350,000	154,000	117,357	31%
2-SI-652 (12")	179,786	SMB-3	140,000	154,000	350,000	154,000	69,615	121%
3-SI-652 (12")	179,786	SMB-3	140,000	154,000	350,000	154,000	101,165	52%
1-SI-653 (12")	74,133	SMB-1	45,000	73,350	112,500	63,189	59,260	7%
2-SI-653 (12")	74,133	SMB-1	45,000	73,350	112,500	63,189	57,707	9%
3-SI-653 (12")	74,133	SMB-1	45,000	73,350	112,500	63,189	61,720	2%
1-SI-654 (12")	74,133	SMB-1	45,000	73,350	112,500	63,189	52,304	21%
2-SI-654 (12")	74,133	SMB-1	45,000	73,350	112,500	63,189	55,437	14%
3-SI-654 (12")	74,133	SMB-1	45,000	73,350	112,500	63,189	58,632	8%
1-SI-655 (12")	80,000	SMB-1	45,000	73,350	112,500	62,479	33,348	87%
2-SI-655 (12")	80,000	SMB-1	45,000	73,350	112,500	62,479	41,520	50%
3-SI-655 (12")	80,000	SMB-1	45,000	73,350	112,500	62,479	38,404	63%
1-SI-656 (12")	80,000	SMB-1	45 000	73,350	112,500	54,527	28,353	92%
2-SI-656 (12")	80,000	SMB-1	45,000	73,350	112,500	54,527	39,000	40%
3-SI-656 (12")	80,000	SMB-1	45,000	73,350	112,500	54,527	36,847	48%
1-SI 671 (5")	30,248	SB-0	24,000	39,120	60,000	17,281	13,712	26%
2-SI-671 (8")	30,248	SB-0	24,000	39,120	60,000	16,330	14,607	12%
3-SI 671 (8")	30,248	SB-0	24,000	39,120	60,000	17,281	11,914	45%
1-SI 672 (3")	30,248	SB-0	24,000	39,120	60,000	16,330	14,495	13%
2-SI-672 (8")	30,248	SB-0	24,000	39,120	60,000	16,330	13,460	21%
3-SI 672 (8")	30,248	SB-0	24,000	39,120	60,000	16,330	8,726	87%
1-SI-685 (10")	37,835	SMB-0	24,000	39,120	60,000	34,034	32,547	5%
2-SI-685 (10")	37,835	SMB ^	24,000	39,120	60,000	34,034	27,995	22%
3-SI-685 (10")	37,835	SMB-0	24,000	39,120	60,000	34,034	23,047	48%
1-SI-694 (10")	37,835	SMB-0	24,000	39,120	60,000	34,034	28,450	20%
2-SI-694 (10")	37,835	SMB-0	24,000	39,120	60,000	34,034	32,818	4%
3-SI-694 (10")	37,835	SMB-0	24,000	39,120	60,000	34,034	23,711	44%
1-SI-686 (20")	128,368	SMB-1	45,000	90,000	112,500	90,000	78,368	15%
2-SI-686 (20")	128,368	SMB-1	45,000	90,000	112,500	90,000	87,443	3%
3-SI 686 (20")	128,368	SMB-1	45,000	90,000	112,500	90,000	80,059	12%
[illegible]SI-696 (20")	128,368	SMB-1	45,000	90,000	112,500	90,000	88,747	1%
[illegible]696 (20")	128,368	SMB-1	45,000	90,000	112,500	90,000	88,784	*1%
[illegible]96 (20")	128,368	SMB-1	45,000	90,000	112,500	90,000	84,186	7%
[illegible]SI-688 (10")	37,835	SMB-0	24,000	39,120	60,000	36,799	32,119	15%
2-SI-688 (10")	37,835	SMB-0	24,000	39,120	60,000	36,799	31,169	18%
3-SI-688 (10")	37,835	SMB-0	24,000	39,120	60,000	36,799	30,233	22%
1-SI-693 (10")	37,835	SMB-0	24,000	39,120	60,000	36,799	29,059	27%
2-SI-693 (10")	37,835	SMB-0	24,000	39,120	60,000	37,835	33,903	12%
3-SI-693 (10")	37,835	SMB-0	24,000	39,120	60,000	36,799	28,911	27%

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TORQUE COMPARISON

	STRUCTURAL DESIGN TORQUE LIMITS					TORQUE COMPARISON			NOTES
	VALVE	ACTUATOR LIMITS							
Valve Tag (size)	Torque	Model	Des Torque	1.1 x Tq	2.0 x Tq	Torque Limit	Req Torque	Margin	
1-AF-34 (6")	654	SMB-1	850	935	1,700	654	549	19%	1, 8, 10, 19
2-AF-34 (6")	683	SMB-1	850	935	1,700	683	515	33%	1, 8, 10, 19
3-AF-34 (6")	725	SMB-1	850	935	1,700	725	494	47%	1, 8, 10,19
1-AF-35 (6")	654	SMB-1	850	935	1,700	654	506	29%	1, 8, 10, 19
2-AF-35 (6")	683	SMB-1	850	935	1,700	683	574	19%	1, 8, 10, 19
3-AF-35 (6")	517	SMB-1	850	935	1,700	517	458	13%	1, 8, 10, 19
1-AF-36 (6")	654	SMB-1	850	935	1,700	654	637	3%	1, 3, 8, 10, 11, 12, 13, 19
2-AF-36 (6")	683	SMB-1	850	935	1,700	683	638	7%	1, 8, 10, 11, 13, 19
3-AF-36 (6")	683	SMB-1	850	935	1,700	683	681	0%	1, 8, 10, 11, 13, 19
1-AF-37 (6")	654	SMB-1	850	935	1,700	654	496	32%	1, 8, 10, 11, 13, 19
2-AF-37 (6")	683	SMB-1	850	935	1,700	683	613	11%	1, 8, 10, 11, 13, 19
3-AF-37 (6")	683	SMB-1	850	935	1,700	683	664	3%	1, 8, 10, 11, 13, 19
1-SG-134 (6")	575	SB-0	500	550	1,000	545	413	32%	1
2-SG-134 (6")	600	SB-0	500	550	1,000	545	494	10%	1
3-SG-134 (6")	575	SB-0	500	550	1,000	550	503	9%	1
1-SG-138 (6")	550	SB-0	500	550	1,000	545	351	55%	1
2-SG-138 (6")	600	SB-0	500	550	1,000	545	454	20%	1
3-SG-138 (6")	575	SB-0	500	550	1,000	550	507	8%	1
1-CH-536 (3")	124	SMB-00	250	275	500	68	37	82%	6
2-CH-536 (3")	124	SMB-00	250	275	500	68	44	54%	6
3-CH-536 (3")	124	SMB-00	250	275	500	68	43	58%	6
1-SI-604 (3")	124	SMB-00	250	275	500	124	77	62%	5, 6, 8, 15
2-SI-604 (3")	124	SMB-00	250	275	500	124	75	65%	5, 6, 8, 15
3-SI-604 (3")	124	SMB-00	250	275	500	124	87	42%	5, 6, 8, 15
1-SI-609 (3")	124	SMB-00	250	275	500	124	83	49%	5, 6, 8, 15
2-SI-609 (3")	124	SMB-00	250	275	500	124	77	61%	5, 6, 8, 15
3-SI-609 (3")	124	SMB-00	250	275	500	124	73	69%	5, 6, 8, 15
[illegible]I-651 (12")	5,687	SMB-3	3 300	3,630	6,600	3,630	2,107	72%	16
[illegible]51 (12")	5,687	SMB-3	3,300	3,630	6,600	2,948	1,655	78%	16
[illegible]51 (12")	5,687	SMB-3	3,300	3,630	6,600	3,630	1,876	93%	16, 18
1-SI-652 (12")	5,687	SMB-3	3,300	3,630	6,600	3,630	2,630	38%	16
2-SI-652 (12")	5,687	SMB-3	3,300	3,630	6,600	3,630	1,560	133%	16
3-SI-652 (12")	5,687	SMB-3	3,300	3,630	6,600	3,630	2,267	60%	16, 18
1-SI-653 (12")	2,342	SMB-1	850	935	1,700	935	1,328	-30%	4, 8, 16
2-SI-653 (12")	2,342	SMB-1	850	935	1,700	935	1,293	-28%	4, 8, 16
3-SI-653 (12")	2,342	SMB-1	850	935	1,700	935	1,383	-32%	4, 8, 16, 18
1-SI-654 (12")	2,342	SMB-1	850	935	1,700	935	1,172	-20%	4, 8, 16
2-SI-654 (12")	2,342	SMB-1	850	935	1,700	935	1,242	-25%	4, 8, 16
3-SI-654 (12")	2,342	SMB-1	850	935	1,700	935	1,315	-29%	4, 8, 16
1-SI-655 (12")	1,113	SMB-1	850	935	1,700	935	747	25%	8, 17
2-SI-655 (12")	1,113	SMB-1	850	935	1,700	935	931	0%	8, 17
3-SI-655 (12")	1,113	SMB-1	850	935	1,700	935	861	9%	8, 17
1-SI-656 (12")	1,113	SMB-1	850	935	1,700	935	635	47%	
2-SI-656 (12")	1,113	SMB-1	850	935	1,700	935	874	7%	
3-SI-656 (12")	1,113	SMB-1	850	935	1,700	935	826	13%	
1-SI-671 (8")	478	SB-0	500	550	1,000	230	182	26%	2
2-SI-671 (8")	478	SB-0	500	550	1,000	217	194	12%	2
3-SI-671 (8")	478	SB-0	500	550	1,000	230	158	45%	2
1-SI-672 (8")	478	SB-0	500	550	1,000	217	193	13%	2
2-SI 672 (8")	478	SB 0	500	550	1,000	21:	179	21%	2
3-SI-672 (8")	478	SB-0	500	550	1,000	217	116	87%	2
1-SI-685 (10")	597	SMB-0	500	550	1,000	474	453	5%	6, 8
2-SI-685 (10")	597	SMB-0	500	550	1,000	474	390	22%	6, 8
3-SI-685 (10")	597	SMB-0	500	550	1,000	474	321	48%	6, 8
1-SI 694 (10")	597	SMB-0	500	550	1,000	474	396	20%	6, 8
2-SI 694 (10")	597	SMB-0	500	550	1,000	474	457	4%	6, 8
3-SI-694 (10")	597	SMB-0	500	550	1,000	474	330	44%	6, 8
1-SI-686 (20")	2,805	SMB-1	850	935	1,700	1,700	1,369	24%	8, 12, 14
2-SI-686 (20")	2,805	SMB-1	850	935	1,700	1,700	1,451	17%	8, 12, 14
3-SI-686 (20")	2,805	SMB-1	850	935	1,700	1,700	1,538	11%	8, 14
[illegible]SI-696 (20")	2,805	SMB-1	850	935	1,700	1,700	1,473	15%	8, 12, 14
[illegible]96 (20")	2,805	SMB-1	850	935	1,700	1,700	1,473	15%	8, 12, 14
[illegible]96 (20")	2,805	SMB-1	850	935	1,700	1,700	1,397	22%	8, 12, 14
1-SI-688 (10")	597	SMB-0	500	550	1,000	513	447	15%	6
2-SI-688 (10")	597	SMB-0	500	550	1,000	513	434	18%	6
3-SI-688 (10")	597	SMB-0	500	550	1,000	513	421	22%	6
1-SI-693 (10")	597	SMB-0	500	550	1,000	513	405	27%	6
2-SI-693 (10")	597	SMB-0	500	550	1,000	550	472	16%	6, 8, 9
3-SI-693 (10")	597	SMB-0	500	550	1,000	513	403	27%	6

NOTES

General Notes	Applied A/L Cracking Thrusts *Assumed VF = 0.6 unless noted.* Actuator Thrust Limit equal to 2.0 x Manufacturer Design Thrust Rating is used for operability determination of SMB - 1, 0, 00, 000 actuators per Kalsi Report 1707C Rev. 0. Actuator Thrust Limit equal to 1.4 x Manufacturer Design Thrust Rating is used for operability determination of SMB/SB - 2 actuators per Limitorque Maintenance Update 92-1. Actuator Thrust Limit equal to 1.1 x Manufacturer Design Thrust Rating is used for operability determination of SMB/SB - 3 actuators. Assumed stem thread coefficient of 0.12 unless otherwise noted. Assumed pullout efficiency, unless noted. For AC actuators, assumed motor terminal degraded voltage identified by Calculation 1,2,3-EC-MA-221.
Note 1	Applied valve specific allowable thrust and torque weak link limits
Note 2	Valve factor of 0.55 is assumed on the basis of published EPRI test data and in situ test data
Note 3	Valve weak link of 44,175 is located at the stem to disc connection. This value was increased by 1,000 lbs to compensate for as-left running load and allow a valid limiting comparison with the required pullout thrust.
Note 4	SI-653/654 were identified as susceptible to PL per CRDR 950607. Interim operability is already covered.
Note 5	Valve is assumed to be repositioned at least 90 minutes after LOCA initiation. Voltage corresponding to manual start with rated running current during LOCA with startup transformer loaded & RCPs running is applied for Vmin. Ref: 1,2,3-EC-MA-221.
Note 6	Valve Factor of 0.5 is assumed based on published EPRI test data and site test data.
Note 7	Deleted
Note 8	Assumed actuator running efficiency
Note 9	Deleted
Note 10	The calculated bonnet pressure was reduced by 200 psi to take credit for pressure reduction caused by stem opening displacement prior to unseating the disc
Note 11	Motor torque value is based on stall torque off the generic motor curve for a 40 ft-lb 125 VDC motor, decreasing that value to the nearest whole number, and multiplying that value by 0.9.
Note 12	As-left diagnostic traces for the subject valves were reviewed to obtain actual as-left values for COF.
Note 13	Values for Vmin retrieved from 01/02/03-EC-PK-207 DC Battery Sizing and Minimum Voltage Calculation.
Note 14	Deleted.
Note 15	Reference CalcMC-SI-330 for final bonnet temperature.
Note 16	Bonnet initial pressure of 467 PSIG corresponding to LTOP setpoint was assumed.
Note 17	Tfinal was determined by calculation 13-MC-SI-331.
Note 18	Subject valve has already been modified to prevent pressure locking
Note 19	Bonnet temperature Tfinal is assumed to be 115F. This based on EQ Program Manual, Appendix A, DBA Temperature and Pressure Profile for the MSSS El 80'. The profile shows that room temperature during HELB ramps to peak temperature of 123F within 110 seconds, then ramps down to 107F within the next 15 minutes. The assumption that bonnet temperature increases to 115F because of the HELB DBA temperature profile is conservative.

Abbreviations

theta	half of the gate disc angle
Dstem	stem diameter
mu	disc friction coefficient
SF	stem factor
COF	stem coefficient of friction
TQstem	stem torque
THstem	stem thrust
Vmin	minimum degraded voltage
OAR	actuator overall ratio
MT	motor starting torque
VDF	voltage degradation factor
DegV PO TQ	degraded voltage pullout torque
Pstem	stem thread pitch
Lstem	stem thread lead

AVAILABLE THRUST FOR THERMAL BINDING EFFECTS

EQID#	A/L Measured Static Unseating Load (OPEN) (lbs)	OPEN Thrust Limit Motor Stall Thrust Capacity (lbs)	Available Thrust for Thermal Binding (TB) effects (lbs)	Percent Avail. Thrust to overcome TB effects	As-left Maximum Temperature Delta (degree F)
1SIAUV0651	55170	177333	122163	221%	164
2SIAUV0651	35011	131521	96510	276%	138
3SIAUV0651	44880	177333	132453	295%	190
1SIBUV0652	78512	177333	98821	126%	164
2SIBUV0652	30770	177333	146563	476%	138
3SIBUV0652	62320	177333	115013	185%	190
1SICUV0653	18084	63189	45105	249%	164
2SICUV0653	16531	63189	46658	282%	138
3SICUV0653	20544	63189	42645	208%	190
1SIDUV0654	11128	63189	52061	468%	164
2SIDUV0654	14261	63189	48928	343%	138
3SIDUV0654	17506	63189	45683	261%	190
1SIAUV0655	13413	69558	56145	419%	113
2SIAUV0655	21585	69558	47973	222%	113
3SIAUV0655	18469	69558	51089	277%	113
1SIBUV0656	8418	42220	33802	402%	113
2SIBUV0656	19065	42220	23155	121%	113
3SIBUV0656	16912	42220	25308	150%	113
1SIAHV0685	13740	34034	20294	148%	123
2SIAHV0685	9188	34034	24846	270%	123
3SIAHV0685	4240	24752	20512	484%	123
1SIBHV0694	9643	34034	24391	253%	123
2SIBHV0694	14011	34034	20023	143%	123
3SIBHV0694	4904	24752	19848	405%	123
1SIAHV0688	10362	33119	22757	220%	123
2SIAHV0688	9412	33119	23707	252%	123
3SIAHV0688	8476	33119	24643	291%	123
1SIBHV0693	7302	33119	25817	354%	123
2SIBHV0693	12146	41399	29253	241%	123
3SIBHV0693	7154	33119	25965	363%	123
1SIAHV0686	9423	85768	76345	810%	123
2SIAHV0686	18496	131659	113163	612%	123
3SIAHV0686	11114	77964	66850	601%	123
1SIBHV0696	19802	131659	111857	565%	123
2SIBHV0696	19839	131659	111820	564%	123
3SIBHV0696	15241	131659	116418	764%	123

Memorandum

ATTACHMENT 4 CRDR 9-5-0836
Page 1 of 6

In Reference
Refer to DOC ID # DG96-000078

ComEd

Date: January 16, 1996

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I. Garza

Subject: Pressure Locking / Thermal Binding Test Data

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

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

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

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

Brian D. Bunte
MOV Program Lead
Commonwealth Edison Company

Attachments

ATTACHMENT 1

BONNET DEPRESSURIZATION RATE DATA

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

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

ENCLOSURE 3

PVNGS ENGINEERING CALCULATION 13-MC-ZZ-217, "GATE VALVE OPEN THRUST REQUIRED DURING POTENTIAL PRESSURE LOCKING CONDITIONS"