NSP

Northern States Power Company

Prairie Island Nuclear Generating Plant

1717 Wakonade Dr. East
Welch, Minnesota 55089

August 6, 1996

Generic Letter 95-07

U S Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
Docket Nos. 50-282 License Nos. DPR-42
50-306 DPR-60

Response to Request for Additional Information Regarding Generic Letter 95-07, "Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves" (TAC NOS. M93507 and M93508)

Generic Letter 95-07 (dated August 17, 1995) was issued by the NRC requesting licensees to provide information concerning (1) the evaluation of operational configurations of safety-related, power-operated gate valves for susceptibility to pressure locking and thermal binding; and (2) analyses, and needed corrective actions, to ensure that safety-related power-operated gate valves that are susceptible to pressure locking or thermal binding are capable of performing the required safety function.

By letters dated October 16, 1995, with subject, "Response to Generic Letter 95-07: Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves," and February 12, 1996, with subject, "Response to Generic Letter 95-07: Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves," Prairie Island responded to the Generic Letter.

By letter dated July 8, 1996, the NRC staff requested additional information in order to complete its review of the Prairie Island responses to Generic Letter 95-07. The attachment to this letter provides the information requested by the staff. This letter contains no new NRC commitments, nor does it modify any prior commitments.

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Please contact Jack Leveille (612-388-1121, Ext. 4662) if you have any questions related to this letter.

Joel P. Sorensen for M.D.W.

Michael D Wadley
Plant Manager
Prairie Island Nuclear Generating Plant

c: Regional Administrator - Region III, NRC
Senior Resident Inspector, NRC
NRR Project Manager, NRC
J E Silberg

Attachments:

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING GENERIC LETTER 95-07 (including two sets of attachments to it:16 pages of calculations, 4 pages each for 4 motor valves; and the "User's Guide for PRESLOK, A Gate Valve Pressure Locking Analysis Program Using the Commonwealth Edison Model," 32 pages)

RESPONSE TO REQUEST FOR ADDITIONAL
INFORMATION REGARDING GENERIC LETTER 95-07

1. *Regarding valves MV-32195, -32196, -32197, -32198, Pressurizer PORV Block Valves, the licensee's submittal states that these valves may be susceptible to pressure locking during a postulated steam generator tube rupture event, and that a bounding calculation using the Commonwealth Edison methodology was performed. Please provide this calculation for our review.*

RESPONSE

The opening thrust requirements and existing margin are shown in the four attached, 4 page calculations. Attached also is the Westinghouse Owners Group "User's Guide for PRESLOK, A Gate Valve Pressure Locking Analysis Program Using the Commonwealth Edison Model." This methodology has been discussed at a number of industry motor operated valve meetings (e.g., refer to NUREG/CP-0152, "Proceedings of the 4th NRC/ASME Symposium on Valve and Pump Testing," dated July 1996).

The following is a summary of the Limitorque actuator/valve information, assumptions, and margin results used to calculate actuator capability:

Actuator/valve: SB-00 Limitorque actuator with a 15 ft-lb, 1700 RPM, AC motor, and overall gear ratio of 63.0. The stem diameter is 1.125 inches with a 2/3 lead and 1/3 pitch general purpose ACME threads. The weak link in the open direction is actuator capability.

Capability Assumptions: Motor nameplate torque is de-rated for design reduced voltage (squared relationship) and high ambient temperature. Pullout Efficiency of 40% and application factor of 1.0 are used (design reduced voltage is less than 90% on all four valves). Stem/stem nut coefficient of friction is conservatively assumed to be 0.20 in determining stem factor (torque to thrust conversion). VOTES measurement uncertainty is applied.

Margin Summary: The Commonwealth Edison Methodology predicts a substantial margin for each valve as follows (where margin equals actuator capability divided by total required opening thrust):

MV-32195	1.79
MV-32196	1.60
MV-32197	2.23
MV-32198	2.13

2. *Through review of operational experience feedback, the staff is aware of instances where licensees have completed design or procedural modifications to preclude pressure locking or thermal binding which may have had an adverse impact on*

plant safety due to incomplete or incorrect evaluation of the potential effects of these modifications. Please describe evaluations and training for plant personnel that have been conducted for each design or procedural modification completed to address potential pressure locking or thermal binding concerns.

RESPONSE

MV-32064, MV-32065 [MV-32167, MV-32168]: RHR to Vessel Injection (low head safety injection)

These flex wedge gate valves were determined to be susceptible to pressure locking in 1993 and were changed from their historical normally closed position to normally open and therefore are no longer a concern for pressure locking. Justification for the position change is provided in Safety Evaluation #351. Normal operating and surveillance procedures were changed to accomplish this activity. These non-complex procedural instructions are provided to plant operators in a concise and descriptive manner, thus no specific training beyond normal requalification training was necessary.

MV-32206, MV-32207, [MV-32208, MV-32209]: RHR to SI Pump Suction

These split wedge gate valves were determined to be potentially susceptible to pressure locking. The Unit 1 valves were modified in 1994 and the Unit 2 valves in 1995 by installation of bonnet vents with manual valves which are controlled administratively to prevent pressure locking.

Both licensed and non-licensed operators received training on this modification in 1995. The RHR System lesson plan was changed to accommodate this modification. Normal operating and surveillance procedures were changed to cycle the bonnet vents whenever conditions occur that could introduce a pressure locking condition. These non-complex procedural instructions are provided to plant operators in a concise and descriptive manner.

MV-32075, MV-32076, MV-32077, MV-32078, [MV-32178, MV-32179, MV-32180, MV-32181]: Containment Sump B to RHR Pump Suction

These flex wedge gate valves are required to open to provide water for core cooling during the recirculation phase. Each train contains two valves in series, both of which must open to provide containment sump water to the RHR Pump. These valves were determined to be susceptible to pressure locking.

The Unit 1 pumpside valves were modified in 1994 and the Unit 2 pumpside valves in 1995 by installation of bonnet vents with manual valves which are controlled administratively to prevent pressure locking.

Both licensed and non-licensed operators received training on this modification in 1995. The RHR System lesson plan was changed to accommodate this modification. Normal operating and surveillance procedures were changed to cycle the bonnet vents whenever conditions occur that could introduce a pressure locking condition. These non-complex procedural instructions are provided to plant operators in a concise and descriptive manner. These bonnet vent valves are also cycled prior to transition to the recirculation phase following a loss of coolant accident by the emergency operating procedures. A Job Performance Measure for local operator actions for this activity was revised to incorporate this modification. Training on this JPM is being conducted during the present operator requalification training cycle.

The sumpside valves are cycled administratively prior to leaving cold shutdown to ensure the bonnet and the pipe between the pumpside and sumpside valve is drained backwards to the containment sump and thus are filled with air preventing the possibility of pressure locking. These non-complex procedural instructions are provided to plant operators in a concise and descriptive manner.

General Training on Pressure Locking and Thermal Binding:

Licensed and non-licensed operators have periodically received training on MOV testing, issues (including pressure locking and thermal binding), and modifications relative to Generic Letters 89-10 and 95-07, conducted by the MOV Program Engineer.

Prairie Island Engineering and Technical Staff has received training on MOV testing, issues (including pressure locking and thermal binding), and modifications relative to Generic Letters 89-10 and 95-07, conducted by the MOV Program Engineer.

A reading assignment was prepared and routed for all system and program engineers to alert them to the nature and possibility of pressure locking and thermal binding during abnormal plant system lineups.

Com Ed Model to Provide Open Thrust Requirement for Pressure Locking - **MV-32195**

INPUTS:

Bonnet Pressure	$Pbonnet := 2235 \cdot psi$	Assume Normal Operating Pressure
Upstream Pressure	$Pup := 1000 \cdot psi$	Conservative upstream pressure after SGTR
Downstream Pressure	$Pdown := 0 \cdot psi$	PRZR PORV leaks by
Disk Thickness	$t := 0.966 \cdot in$	EPRI PPM ((B1-K1)/2)+(D1/2)*cos(theta)
Seat Radius	$a := 1.2813 \cdot in$	Velan: ((2.75+2.375)/2)/2
Hub Radius	$b := 0.8125 \cdot in$	Velan: 1.625/2, Dimension M1/2
Hub Length	$L := 0.125 \cdot in$	EPRI Dimension K1
Seat Angle	$theta := 5 \cdot deg$	Velan
Poisson's Ratio (Disk)	$\nu := 0.3$	Typical of SS
Modulus of Elast. (disk)	$E := 27.6 \cdot 10^{6} \cdot psi$	Typical of SS, Marks p. 5-5
Static Pullout Force	$Fpo := 5443.2 \cdot 1.073 \cdot lbf$	Votes test 1/10/96 x VOTES UN
Stem Diameter	$Dstem := 1.125 \cdot in$	From Eng-ME-046

Coefficient of friction between disk and seat (open):

mu = 0.4 per table 2-3. p. 2-37 EPRI Gate Valve Model Report

$mu := 0.4$

PRESSURE FORCE CALCULATIONS

Average DP across disks:

$$DPavg := Pbonnet - \frac{Pup + Pdown}{2} \qquad DPavg = 1735 \cdot psi$$

Disk Stiffness Constants:

$$D := \frac{E \cdot t^3}{12 \cdot \left(1 - v^2\right)} \qquad D = 2.278 \cdot 10^6 \ \cdot lbf \cdot in$$

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

Geometry Factors:

$$C2 := \frac{1}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2 \cdot \left(1 + 2 \cdot \ln\left(\frac{a}{b}\right)\right)\right] \qquad C2 = 0.058$$

$$C3 := \frac{b}{4 \cdot a} \cdot \left[\left[\left(\frac{b}{a}\right)^2 + 1\right] \cdot \ln\left(\frac{a}{b}\right) + \left(\frac{b}{a}\right)^2 - 1\right] \qquad C3 = 0.006$$

$$C8 := \frac{1}{2} \cdot \left[1 + v + (1 - v) \cdot \left(\frac{b}{a}\right)^2\right] \qquad C8 = 0.791$$

$$C9 := \frac{b}{a} \cdot \left[\frac{1 + v}{2} \cdot \ln\left(\frac{a}{b}\right) + \frac{1 - v}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2\right]\right] \qquad C9 = 0.254$$

$$L3 := \frac{a}{4 \cdot a} \cdot \left[\left[\left(\frac{a}{a}\right)^2 + 1\right] \cdot \ln\left(\frac{a}{a}\right) + \left(\frac{a}{a}\right)^2 - 1\right] \qquad L3 = 0$$

$$L9 := \frac{a}{a} \cdot \left[\frac{1 + v}{2} \cdot \ln\left(\frac{a}{a}\right) + \frac{1 - v}{4} \cdot \left[1 - \left(\frac{a}{a}\right)^2\right]\right] \qquad L9 = 0$$

$$L11 := \frac{1}{64} \cdot \left[1 + 4 \cdot \left(\frac{b}{a}\right)^2 - 5 \cdot \left(\frac{b}{a}\right)^4 - 4 \cdot \left(\frac{b}{a}\right)^2 \cdot \left[2 + \left(\frac{b}{a}\right)^2\right] \cdot \ln\left(\frac{a}{b}\right)\right] \qquad L11 = 0.00063$$

$$L17 := \frac{1}{4} \cdot \left[1 - \frac{1 - v}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^4\right] - \left(\frac{b}{a}\right)^2 \cdot \left[1 + (1 + v) \cdot \ln\left(\frac{a}{b}\right)\right]\right] \qquad L17 = 0.053$$

Moment:

$$Mrb := \frac{DPavg \cdot a^2}{C8} \cdot \left[\frac{C9}{2 \cdot a \cdot b} \cdot \left(a^2 - b^2\right) - L17\right] \qquad Mrb = -239.635 \ \cdot lbf$$

$$Qb := \frac{DPavg}{2 \cdot b} \cdot \left(a^2 - b^2\right) \qquad Qb = 1.048 \cdot 10^3 \ \cdot \frac{lbf}{in}$$

Deflection due to pressure and bending:

$$ybq = Mrb \cdot \frac{a^2}{D} \cdot C2 + Qb \cdot \frac{a^3}{D} \cdot C3 - \frac{DPavg \cdot a^4}{D} \cdot L11 \qquad ybq = -5.022 \cdot 10^{-6} \cdot in$$

Deflection due to pressure and shear stress:

$$Ksa = -0.3 \cdot \left[2 \cdot \ln\left(\frac{a}{b}\right) - 1 + \left(\frac{b}{a}\right)^2\right] \qquad Ksa = -0.094$$

$$ysq = -\frac{Ksa \cdot DPavg \cdot a^2}{t \cdot G} \qquad ysq = -2.609 \cdot 10^{-5} \cdot in$$

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

$$Pforce = \pi \cdot (a^2 - b^2) \cdot DPavg \qquad Pforce = 5.35 \cdot 10^{3} \cdot lbf$$

$$ystretch = \frac{Pforce}{\pi \cdot b^2} \cdot \frac{L}{2 \cdot E} \qquad ystretch = 5.842 \cdot 10^{-6} \cdot in$$

Total Deflection due to pressure forces:

$$yq = ybq + ysq - ystretch \qquad yq = -3.696 \cdot 10^{-5} \cdot in$$

Deflection due to seat contact force and shear stress (per lbf/in):

$$ysw = \left[\frac{-1.2 \cdot \left(\frac{a}{a}\right) \cdot \ln\left(\frac{a}{b}\right) \cdot a}{t \cdot G}\right] \qquad ysw = -6.83 \cdot 10^{-8} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

Deflection due to seat contact force and bending (per lbf/in):

$$ybw = -\left(\frac{a^3}{D}\right) \cdot \left[\left(\frac{C2}{C8}\right) \cdot \left[\left(\frac{a \cdot C9}{b}\right) - L9\right] - \left[\left(\frac{a}{b}\right) \cdot C3\right] + L3\right] \qquad ybw = -1.767 \cdot 10^{-8} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$ycompr = -\left(\frac{2 \cdot a \cdot \pi}{\pi \cdot b^2} \cdot \frac{L}{2 \cdot E}\right) \qquad ycompr = -8.79 \cdot 10^{-9} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$yw = ybw + ysw + ycompr \qquad yw = -9.476 \cdot 10^{-8} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$Fs := 2 \cdot \pi \cdot a \cdot \frac{yq}{yw}$ $\quad Fs = 3139.9 \cdot lbf$

UNSEATING FORCES

Fpacking is including in measured static pullout force

$Fpiston := \frac{\pi}{4} \cdot Dstem^2 \cdot Pbonnet$ $\quad Fpiston = 2221.6 \cdot lbf$

$Fvert := \pi \cdot a^2 \cdot \sin(theta) \cdot (2 \cdot Pbonnet - Pup - Pdown)$ $\quad Fvert = 1559.8 \cdot lbf$

$Fpreslock := 2 \cdot Fs \cdot (mu \cdot \cos(theta) - \sin(theta))$ $\quad Fpreslock = 1955.1 \cdot lbf$

$Ftotal := Fpiston + Fvert + Fpreslock + Fpo$ $\quad Fpo = 5840.6 \cdot lbf$

$Ftotal = 7133.8 \cdot lbf$ This is the total unseating force under pressure lock conditions

Margin Calculation:

Thrust capability at RV and cof = 0.20: $ST := 12789 \cdot lbf$ From Eng-ME-046

$Margin := \frac{ST}{Ftotal}$

$Margin = 1.793$ Open Margin at Design RV and cof = 0.20

Com Ed Model to Provide Open Thrust Requirement for Pressure Locking - **MV-32196**

INPUTS:

Bonnet Pressure	Pbonnet := 2235·psi	Assume Normal Operating Pressure
Upstream Pressure	Pup := 1000·psi	Conservative upstream pressure after SGTR
Downstream Pressure	Pdown := 0·psi	PRZR PORV leaks by
Disk Thickness	t := 0.966·in	EPRI PPM ((B1-K1)/2)+(D1/2)*cos(theta)
Seat Radius	a := 1.2813·in	Velan: ((2.75+2.375)/2)/2
Hub Radius	b := 0.8125·in	Velan: 1.625/2, Dimension M1/2
Hub Length	L := 0.125·in	EPRI Dimension K1
Seat Angle	theta := 5·deg	Velan
Poisson's Ratio (Disk)	v := 0.3	Typical of SS
Modulus of Elast. (disk)	$E := 27.6 \cdot 10^{6} \cdot psi$	Typical of SS, Marks p. 5-5
Static Pullout Force	Fpo := 6241.9·1.073·lbf	Votes test 1/11/96 x VOTES UN
Stem Diameter	Dstem := 1.125·in	From Eng-ME-046

Coefficient of friction between disk and seat (open):

mu = 0.4 per table 2-3. p. 2-37 EPRI Gate Valve Model Report

mu := 0.4

PRESSURE FORCE CALCULATIONS

Average DP across disks:

$$DPavg := Pbonnet - \frac{Pup + Pdown}{2} \qquad DPavg = 1735 \cdot psi$$

Disk Stiffness Constants:

$$D = \frac{E \cdot t^3}{12 \cdot \left(1 - v^2\right)}$$ $D = 2.278 \cdot 10^6 \cdot lbf \cdot in$

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

Geometry Factors:

$$C2 = \frac{1}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2 \cdot \left(1 + 2 \cdot \ln\left(\frac{a}{b}\right)\right)\right]$$ $C2 = 0.058$

$$C3 = \frac{b}{4 \cdot a} \cdot \left[\left[\left(\frac{b}{a}\right)^2 + 1\right] \cdot \ln\left(\frac{a}{b}\right) + \left(\frac{b}{a}\right)^2 - 1\right]$$ $C3 = 0.006$

$$C8 = \frac{1}{2} \cdot \left[1 + v + (1 - v) \cdot \left(\frac{b}{a}\right)^2\right]$$ $C8 = 0.791$

$$C9 = \frac{b}{a} \cdot \left[\frac{1 + v}{2} \cdot \ln\left(\frac{a}{b}\right) + \frac{1 - v}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2\right]\right]$$ $C9 = 0.254$

$$L3 = \frac{a}{4 \cdot a} \cdot \left[\left[\left(\frac{a}{a}\right)^2 + 1\right] \cdot \ln\left(\frac{a}{a}\right) + \left(\frac{a}{a}\right)^2 - 1\right]$$ $L3 = 0$

$$L9 = \frac{a}{a} \cdot \left[\frac{1 + v}{2} \cdot \ln\left(\frac{a}{a}\right) + \frac{1 - v}{4} \cdot \left[1 - \left(\frac{a}{a}\right)^2\right]\right]$$ $L9 = 0$

$$L11 = \frac{1}{64} \cdot \left[1 + 4 \cdot \left(\frac{b}{a}\right)^2 - 5 \cdot \left(\frac{b}{a}\right)^4 - 4 \cdot \left(\frac{b}{a}\right)^2 \cdot \left[2 + \left(\frac{b}{a}\right)^2\right] \cdot \ln\left(\frac{a}{b}\right)\right]$$ $L11 = 0.00063$

$$L17 = \frac{1}{4} \cdot \left[1 - \frac{1 - v}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^4\right] - \left(\frac{b}{a}\right)^2 \cdot \left[1 + (1 + v) \cdot \ln\left(\frac{a}{b}\right)\right]\right]$$ $L17 = 0.053$

Moment:

$$Mrb = \frac{DPavg \cdot a^2}{C8} \cdot \left[\frac{C9}{2 \cdot a \cdot b} \cdot \left(a^2 - b^2\right) - L17\right]$$ $Mrb = 239.635 \cdot lbf$

$$Qb = \frac{DPavg}{2 \cdot b} \cdot \left(a^2 - b^2\right)$$ $Qb = 1.048 \cdot 10^3 \cdot \frac{lbf}{in}$

Deflection due to pressure and bending:

$$ybq = Mrb\cdot\frac{a^2}{D}\cdot C2 + Qb\cdot\frac{a^3}{D}\cdot C3 - \frac{DPavg\cdot a^4}{D}\cdot L11 \qquad ybq = -5.022\cdot 10^{-6}\ \cdot in$$

Deflection due to pressure and shear stress:

$$Ksa = -0.3\cdot\left[2\cdot\ln\left(\frac{a}{b}\right) - 1 + \left(\frac{b}{a}\right)^2\right] \qquad Ksa = -0.094$$

$$ysq = \frac{Ksa\cdot DPavg\cdot a^2}{t\cdot G} \qquad ysq = -2.609\cdot 10^{-5}\ \cdot in$$

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

$$Pforce = \pi\cdot(a^2 - b^2)\cdot DPavg \qquad Pforce = 5.35\cdot 10^{3}\ \cdot lbf$$

$$ystretch = \frac{Pforce}{\pi\cdot b^2}\cdot\frac{L}{2\cdot E} \qquad ystretch = 5.842\cdot 10^{-6}\ \cdot in$$

Total Deflection due to pressure forces:

$$yq = ybq + ysq - ystretch \qquad yq = -3.696\cdot 10^{-5}\ \cdot in$$

Deflection due to seat contact force and shear stress (per lbf/in):

$$ysw = \left[\frac{-1.2\cdot\left(\frac{a}{a}\right)\cdot\ln\left(\frac{a}{b}\right)\cdot a}{t\cdot G}\right] \qquad ysw = -6.83\cdot 10^{-8}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

Deflection due to seat contact force and bending (per lbf/in):

$$ybw = -\left(\frac{a^3}{D}\right)\cdot\left[\left(\frac{C2}{C8}\right)\cdot\left[\left(\frac{a\cdot C9}{b}\right) - L9\right] - \left[\left(\frac{a}{b}\right)\cdot C3\right] + L3\right] \qquad ybw = -1.767\cdot 10^{-8}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$ycompr = -\left(\frac{2\cdot a\cdot\pi}{\pi\cdot b^2}\cdot\frac{L}{2\cdot E}\right) \qquad ycompr = -8.79\cdot 10^{-9}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$yw = ybw + ysw + ycompr \qquad yw = -9.476\cdot 10^{-8}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$Fs := 2 \cdot \pi \cdot a \cdot \frac{yq}{yw}$ $\quad Fs = 3139.9 \cdot lbf$

UNSEATING FORCES

Fpacking is including in measured static pullout force

$Fpiston := \frac{\pi}{4} \cdot Dstem^2 \cdot Pbonnet$ $\quad Fpiston = 2221.6 \cdot lbf$

$Fvert := \pi \cdot a^2 \cdot \sin(theta) \cdot (2 \cdot Pbonnet - Pup - Pdown)$ $\quad Fvert = 1559.8 \cdot lbf$

$Fpreslock := 2 \cdot Fs \cdot (mu \cdot \cos(theta) - \sin(theta))$ $\quad Fpreslock = 1955.1 \cdot lbf$

$Ftotal := Fpiston + Fvert + Fpreslock + Fpo$ $\quad Fpo = 6697.6 \cdot lbf$

$Ftotal = 7990.8 \cdot lbf$ This is the total unseating force under pressure lock conditions

Margin Calculation:

Thrust capability at RV and cof = 0.20: $ST := 12759 \cdot lbf$ From Eng-ME-046

$Margin := \frac{ST}{Ftotal}$

$Margin = 1.597$ Open Margin at Design RV and cof = 0.20

Com Ed Model to Provide Open Thrust Requirement for Pressure Locking - **MV-32197**

INPUTS:

Bonnet Pressure	Pbonnet = 2235·psi	Assume Normal Operating Pressure
Upstream Pressure	Pup = 1000·psi	Conservative upstream pressure after SGTR
Downstream Pressure	Pdown = 0·psi	PRZR PORV leaks by
Disk Thickness	t = 0.966·in	EPRI PPM ((B1-K1)/2)+(D1/2)*cos(theta)
Seat Radius	a = 1.2813·in	Velan: ((2.75+2.375)/2)/2
Hub Radius	b = 0.8125·in	Velan: 1.625/2, Dimension M1/2
Hub Length	L = 0.125·in	EPRI Dimension K1
Seat Angle	theta = 5·deg	Velan
Poisson's Ratio (Disk)	v = 0.3	Typical of SS
Modulus of Elast. (disk)	$E = 27.6 \cdot 10^6 \cdot psi$	Typical of SS, Marks p. 5-5
Static Pullout Force	Fpo = 4233.4·1.073·lbf	Votes test 6/3/95 x VOTES UN
Stem Diameter	Dstem = 1.125·in	From Eng-ME-046

Coefficient of friction between disk and seat (open):

mu = 0.4 per table 2-3. p. 2-37 EPRI Gate Valve Model Report

mu = 0.4

PRESSURE FORCE CALCULATIONS

Average DP across disks:

$$DPavg = Pbonnet - \frac{Pup + Pdown}{2} \qquad DPavg = 1735 \cdot psi$$

Disk Stiffness Constants:

$$D = \frac{E \cdot t^3}{12 \cdot \left(1 - v^2\right)} \qquad D = 2.278 \cdot 10^6 \cdot lbf \cdot in$$

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

Geometry Factors:

$$C2 = \frac{1}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2 \cdot \left(1 + 2 \cdot \ln\left(\frac{a}{b}\right)\right)\right] \qquad C2 = 0.058$$

$$C3 = \frac{b}{4 \cdot a} \cdot \left[\left[\left(\frac{b}{a}\right)^2 + 1\right] \cdot \ln\left(\frac{a}{b}\right) + \left(\frac{b}{a}\right)^2 - 1\right] \qquad C3 = 0.006$$

$$C8 = \frac{1}{2} \cdot \left[1 + v + (1 - v) \cdot \left(\frac{b}{a}\right)^2\right] \qquad C8 = 0.791$$

$$C9 = \frac{b}{a} \cdot \left[\frac{1 + v}{2} \cdot \ln\left(\frac{a}{b}\right) + \frac{1 - v}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2\right]\right] \qquad C9 = 0.254$$

$$L3 = \frac{a}{4 \cdot a} \cdot \left[\left[\left(\frac{a}{a}\right)^2 + 1\right] \cdot \ln\left(\frac{a}{a}\right) + \left(\frac{a}{a}\right)^2 - 1\right] \qquad L3 = 0$$

$$L9 = \frac{a}{a} \cdot \left[\frac{1 + v}{2} \cdot \ln\left(\frac{a}{a}\right) + \frac{1 - v}{4} \cdot \left[1 - \left(\frac{a}{a}\right)^2\right]\right] \qquad L9 = 0$$

$$L11 = \frac{1}{64} \cdot \left[1 + 4 \cdot \left(\frac{b}{a}\right)^2 - 5 \cdot \left(\frac{b}{a}\right)^4 - 4 \cdot \left(\frac{b}{a}\right)^2 \cdot \left[2 + \left(\frac{b}{a}\right)^2\right] \cdot \ln\left(\frac{a}{b}\right)\right] \qquad L11 = 0.00063$$

$$L17 = \frac{1}{4} \cdot \left[1 - \frac{1 - v}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^4\right] - \left(\frac{b}{a}\right)^2 \cdot \left[1 + (1 + v) \cdot \ln\left(\frac{a}{b}\right)\right]\right] \qquad L17 = 0.053$$

Moment:

$$Mrb = \frac{DPavg \cdot a^2}{C8} \cdot \left[\frac{C9}{2 \cdot a \cdot b} \cdot \left(a^2 - b^2\right) - L17\right] \qquad Mrb = 239.635 \cdot lbf$$

$$Qb = \frac{DPavg}{2 \cdot b} \cdot \left(a^2 - b^2\right) \qquad Qb = 1.048 \cdot 10^3 \cdot \frac{lbf}{in}$$

Deflection due to pressure and bending:

$$ybq = Mrb \cdot \frac{a^2}{D} \cdot C2 + Qb \cdot \frac{a^3}{D} \cdot C3 - \frac{DPavg \cdot a^4}{D} \cdot L11 \qquad ybq = -5.022 \cdot 10^{-6} \cdot in$$

Deflection due to pressure and shear stress:

$$Ksa = -0.3 \cdot \left[2 \cdot \ln\left(\frac{a}{b}\right) - 1 + \left(\frac{b}{a}\right)^2\right] \qquad Ksa = -0.094$$

$$ysq = \frac{Ksa \cdot DPavg \cdot a^2}{t \cdot G} \qquad ysq = -2.609 \cdot 10^{-5} \cdot in$$

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

$$Pforce = \pi \cdot (a^2 - b^2) \cdot DPavg \qquad Pforce = 5.35 \cdot 10^{3} \cdot lbf$$

$$ystretch = \frac{Pforce}{\pi \cdot b^2} \cdot \frac{L}{2 \cdot E} \qquad ystretch = 5.842 \cdot 10^{-6} \cdot in$$

Total Deflection due to pressure forces:

$$yq = ybq + ysq - ystretch \qquad yq = -3.696 \cdot 10^{-5} \cdot in$$

Deflection due to seat contact force and shear stress (per lbf/in):

$$ysw = \left[\frac{-1.2 \cdot \left(\frac{a}{a}\right) \cdot \ln\left(\frac{a}{b}\right) \cdot a}{t \cdot G}\right] \qquad ysw = -6.83 \cdot 10^{-8} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

Deflection due to seat contact force and bending (per lbf/in):

$$ybw = \left(\frac{a^3}{D}\right) \cdot \left[\left(\frac{C2}{C8}\right) \cdot \left[\left(\frac{a \cdot C9}{b}\right) - L9\right] - \left[\left(\frac{a}{b}\right) \cdot C3\right] + L3\right] \qquad ybw = -1.767 \cdot 10^{-8} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$ycompr = -\left(\frac{2 \cdot a \cdot \pi}{\pi \cdot b^2} \cdot \frac{L}{2 \cdot E}\right) \qquad ycompr = -8.79 \cdot 10^{-9} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$yw = ybw + ysw + ycompr \qquad yw = -9.476 \cdot 10^{-8} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$Fs := 2 \cdot \pi \cdot a \cdot \frac{yq}{yw} \qquad Fs = 3139.9 \cdot lbf$$

UNSEATING FORCES

Fpacking is including in measured static pullout force

$$Fpiston := \frac{\pi}{4} \cdot Dstem^2 \cdot Pbonnet \qquad Fpiston = 2221.6 \cdot lbf$$

$$Fvert := \pi \cdot a^2 \cdot \sin(theta) \cdot (2 \cdot Pbonnet - Pup - Pdown) \qquad Fvert = 1559.8 \cdot lbf$$

$$Fpreslock := 2 \cdot Fs \cdot (mu \cdot \cos(theta) - \sin(theta)) \qquad Fpreslock = 1955.1 \cdot lbf$$

$$Ftotal := -Fpiston + Fvert + Fpreslock + Fpo \qquad Fpo = 4542.4 \cdot lbf$$

$Ftotal = 5835.7 \cdot lbf$ This is the total unseating force under pressure lock conditions

Margin Calculation:

Thrust capability at RV and cof = 0.20: $ST := 12994 \cdot lbf$ From Eng-ME-046

$$Margin := \frac{ST}{Ftotal}$$

$Margin = 2.227$ Open Margin at Design RV and cof = 0.20

Com Ed Model to Provide Open Thrust Requirement for Pressure Locking - **MV-32198**

INPUTS:

Bonnet Pressure	$Pbonnet := 2235 \cdot psi$	Assume Normal Operating Pressure
Upstream Pressure	$Pup := 1000 \cdot psi$	Conservative upstream pressure after SGTR
Downstream Pressure	$Pdown := 0 \cdot psi$	PRZR PORV leaks by
Disk Thickness	$t := 0.966 \cdot in$	EPRI PPM ((B1-K1)/2)+(D1/2)*cos(theta)
Seat Radius	$a := 1.2813 \cdot in$	Velan: ((2.75+2.375)/2)/2
Hub Radius	$b := 0.8125 \cdot in$	Velan: 1.625/2, Dimension M1/2
Hub Length	$L := 0.125 \cdot in$	EPRI Dimension K1
Seat Angle	$theta := 5 \cdot deg$	Velan
Poisson's Ratio (Disk)	$v := 0.3$	Typical of SS
Modulus of Elast. (disk)	$E := 27.6 \cdot 10^{6} \cdot psi$	Typical of SS, Marks p. 5-5
Static Pullout Force	$Fpo := 4391.2 \cdot 1.073 \cdot lbf$	Votes test 6/3/95 x VOTES UN
Stem Diameter	$Dstem := 1.125 \cdot in$	From Eng-ME-046

Coefficient of friction between disk and seat (open):

mu = 0.4 per table 2-3. p. 2-37 EPRI Gate Valve
Model Report

$mu := 0.4$

PRESSURE FORCE CALCULATIONS

Average DP across disks:

$$DPavg := Pbonnet - \frac{Pup + Pdown}{2} \qquad DPavg = 1735 \cdot psi$$

Disk Stiffness Constants:

$$D := \frac{E \cdot t^3}{12 \cdot \left(1 - \nu^2\right)} \qquad D = 2.278 \cdot 10^6 \cdot lbf \cdot in$$

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

Geometry Factors:

$$C2 := \frac{1}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2 \cdot \left(1 + 2 \cdot \ln\left(\frac{a}{b}\right)\right)\right] \qquad C2 = 0.058$$

$$C3 := \frac{b}{4 \cdot a} \cdot \left[\left[\left(\frac{b}{a}\right)^2 + 1\right] \cdot \ln\left(\frac{a}{b}\right) + \left(\frac{b}{a}\right)^2 - 1\right] \qquad C3 = 0.006$$

$$C8 := \frac{1}{2} \cdot \left[1 + \nu + (1 - \nu) \cdot \left(\frac{b}{a}\right)^2\right] \qquad C8 = 0.791$$

$$C9 := \frac{b}{a} \cdot \left[\frac{1 + \nu}{2} \cdot \ln\left(\frac{a}{b}\right) + \frac{1 - \nu}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2\right]\right] \qquad C9 = 0.254$$

$$L3 := \frac{a}{4 \cdot a} \cdot \left[\left[\left(\frac{a}{a}\right)^2 + 1\right] \cdot \ln\left(\frac{a}{a}\right) + \left(\frac{a}{a}\right)^2 - 1\right] \qquad L3 = 0$$

$$L9 := \frac{a}{a} \cdot \left[\frac{1 + \nu}{2} \cdot \ln\left(\frac{a}{a}\right) + \frac{1 - \nu}{4} \cdot \left[1 - \left(\frac{a}{a}\right)^2\right]\right] \qquad L9 = 0$$

$$L11 := \frac{1}{64} \cdot \left[1 + 4 \cdot \left(\frac{b}{a}\right)^2 - 5 \cdot \left(\frac{b}{a}\right)^4 - 4 \cdot \left(\frac{b}{a}\right)^2 \cdot \left[2 + \left(\frac{b}{a}\right)^2\right] \cdot \ln\left(\frac{a}{b}\right)\right] \qquad L11 = 0.00063$$

$$L17 := \frac{1}{4} \cdot \left[1 - \frac{1 - \nu}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^4\right] - \left(\frac{b}{a}\right)^2 \cdot \left[1 + (1 + \nu) \cdot \ln\left(\frac{a}{b}\right)\right]\right] \qquad L17 = 0.053$$

Moment:

$$Mrb := \frac{DPavg \cdot a^2}{C8} \cdot \left[\frac{C9}{2 \cdot a \cdot b} \cdot \left(a^2 - b^2\right) - L17\right] \qquad Mrb = -239.635 \cdot lbf$$

$$Qb := \frac{DPavg}{2 \cdot b} \cdot \left(a^2 - b^2\right) \qquad Qb = 1.048 \cdot 10^3 \cdot \frac{lbf}{in}$$

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$$ybq := Mrb\cdot\frac{a^2}{D}\cdot C2 + Qb\cdot\frac{a^3}{D}\cdot C3 - \frac{DPavg\cdot a^4}{D}\cdot L11 \qquad ybq = -5.022\cdot 10^{-6}\ \cdot in$$

Deflection due to pressure and shear stress:

$$Ksa := -0.3\cdot\left[2\cdot\ln\left(\frac{a}{b}\right) - 1 + \left(\frac{b}{a}\right)^2\right] \qquad Ksa = -0.094$$

$$ysq := \frac{Ksa\cdot DPavg\cdot a^2}{t\cdot G} \qquad ysq = -2.609\cdot 10^{-5}\ \cdot in$$

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$$Pforce := \pi\cdot\left(a^2 - b^2\right)\cdot DPavg \qquad Pforce = 5.35\cdot 10^{3}\ \cdot lbf$$

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Total Deflection due to pressure forces:

$$yq := ybq + ysq - ystretch \qquad yq = -3.696\cdot 10^{-5}\ \cdot in$$

Deflection due to seat contact force and shear stress (per lbf/in):

$$ysw := \left[\frac{-1.2\cdot\left(\frac{a}{a}\right)\cdot\ln\left(\frac{a}{b}\right)\cdot a}{t\cdot G}\right] \qquad ysw = -6.83\cdot 10^{-8}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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$$ybw := -\left(\frac{a^3}{D}\right)\cdot\left[\left(\frac{C2}{C8}\right)\cdot\left[\left(\frac{a\cdot C9}{b}\right) - L9\right] - \left[\left(\frac{a}{b}\right)\cdot C3\right] + L3\right] \qquad ybw = -1.767\cdot 10^{-8}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$ycompr := -\left(\frac{2\cdot a\cdot\pi}{\pi\cdot b^2}\cdot\frac{L}{2\cdot E}\right) \qquad ycompr = -8.79\cdot 10^{-9}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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$$yw := ybw + ysw + ycompr \qquad yw = -9.476\cdot 10^{-8}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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$Fs := 2 \cdot \pi \cdot a \cdot \frac{yq}{yw}$ $Fs = 3139.9 \cdot lbf$

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Fpacking is including in measured static pullout force

$Fpiston := \frac{\pi}{4} \cdot Dstem^2 \cdot Pbonnet$ $Fpiston = 2221.6 \cdot lbf$

$Fvert := \pi \cdot a^2 \cdot \sin(theta) \cdot (2 \cdot Pbonnet - Pup - Pdown)$ $Fvert = 1559.8 \cdot lbf$

$Fpreslock := 2 \cdot Fs \cdot (mu \cdot \cos(theta) - \sin(theta))$ $Fpreslock = 1955.1 \cdot lbf$

$Ftotal := -Fpiston + Fvert + Fpreslock + Fpo$ $Fpo = 4711.8 \cdot lbf$

$Ftotal = 6005 \cdot lbf$ This is the total unseating force under pressure lock conditions

Margin Calculation:

Thrust capability at RV and cof = 0.20: $ST := 12789 \cdot lbf$ From Eng-ME-046

$Margin := \frac{ST}{Ftotal}$

$Margin = 2.13$ Open Margin at Design RV and cof = 0.20