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DUKE POWER

July 31, 1996

U. S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555

Subject: McGuire Nuclear Station
Docket Nos. 369, 370
Request for Additional Information -
Generic Letter 95-07, "Pressure Locking
and Thermal Binding of Safety-Related Power-
Operated Gate Valves"
TAC Nos. M93482 and M93483

On August 17, 1995, the NRC issued Generic Letter (GL) 95-07, "Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves" to request that licensees take actions to ensure that safety-related power-operated gate valves that are susceptible to pressure locking or thermal binding are capable of performing their safety functions.

Please find attached McGuire's response to the NRC's Request for Additional Information dated July 1, 1996 concerning Generic Letter 95-07.

Very truly yours,

T. C. McMeekin, Vice President
McGuire Nuclear Station

A056 1/1

MNS Response To NRC Request For Additional Information Concerning Generic Letter 95-07

1. Valves 1(2)ND0033 and 1(2)ND0018 are isolation valves connecting a common bypass line around ND Heat Exchangers A and B respectively. They are required to remain closed during Modes 1-3 when the ECCS is required. They may be opened in Mode 4 for RHR temperature control, in which case they must close on demand by operator action on the manual control. They have no safety requirement to open and as such are not subject to failure from pressure locking or thermal binding as defined by GL 95-07.

The RHR cross-tie valves are 1(2)ND0015B and ND0030A. These valves were evaluated for thermal.v-induced pressure locking as documented in the 2/13/96 submittal to GL 95-07.

2. Short term operability for 1(2)NI0183B, Low Head Injection Pump to Hot Leg Isolation, is based on test results which show that double barrier check valves prevent RCS pressure from acting on the gate valves. *However we have planned to install bonnet pressure equalization provision to the valves during the next refueling outage (1,2EOC11) to satisfy long term bonnet pressure locking concerns for these valves.* It should be mentioned that an additional test performed on 7/11/96 indicated no pressure on the downstream side of 2NI0183B. This test in addition to the test performed on 11/11/95, indicate that the hot leg check valves are holding tight and not allowing pressurization of the downstream face of 2NI0183B.

The Duke Power Safety Analysis Group has shown that a single medium head safety injection pump (NI System) recirculating to the hot legs is adequate for boron precipitation removal (see attachment 2). ND recirculation to the hot legs is therefore not required from a safety analysis perspective. However, the licensing basis has not been changed, therefore the function for this valve to open will be maintained as described.

As requested, the calculations regarding actuator thrust capability for 1(2)NI0183B are as follow:

System Conditions:

bonnet pressure = 200 psig (maximum expected conditions)
upstream pressure = 120 psig
downstream pressure = 0 psig
bonnet heatup = 0° F

Pressure Locking Force:

The open force required due to pressure locking conditions (F_{PL}) was calculated using the Westinghouse Owners Group Preslok Model as shown in attachment 1, with the inputs and result as follows:

θ (wedge angle) = 5°
V_f (valve factor, 1NI0183B) = 1.289 (close V_f from GL 89-10 program)
V_f (valve factor, 2NI0183B) = 0.534 (from highest 8/3/93 DP test in closed direction)

The disc dimensional information was obtained by measurement and is listed in the Preslok calculation in attachment 1.

These valves are made of stainless steel, as identified on the manufacturers drawing. The material properties are:

$E = 27.6.0 \times 10^6$ psi
$v = 0.3$

For 1NI0183B, F_{PL} = 11,796.5 lbf
For 2NI0183B, F_{PL} = 5,223.3 lbf

Total Unwedging Force:

1NI0183B:

From 8/31/94 VOTES testing,
Static Unwedging Force (F_{STATIC}) = 49,460.0 lbf +/- 52.0 % instrument error
F_{STATIC} = 49,460.0 lbf (1.52) = 75,179.2 lbf

$F_{Open} = F_{PL} + F_{STATIC}$ = 11,796.5 lbf + 75,179.2 lbf = 86,975.7 lbf

2NI0183B:

From 8/1/93 VOTES testing,
Static Unwedging Force (F_{STATIC}) = 25,051.0 lbf +/- 52.0 % instrument error
F_{STATIC} = 25,051.0 lbf (1.52) = 38,077.52 lbf

$F_{Open} = F_{preslok} + F_{STATIC}$ = 5,223.3 lbf + 38,077.52 lbf = 43,300.82 lbf

Available Thrust:

1NI0183B:

The valve is torque switch bypassed and limit switch controlled in the open direction.

stem factor (S) = 0.0214 (in open direction based on a stem COF = 0.15)
undervoltage factor (V) = 0.915

Note: A maximum value of 0.90 will be used for this calculation

stall torque (T_{STALL}) = 3,900.00 ft-lbf
Serial #: A1472E/2
torque at undervoltage (T_{UV}) = $(T_{STALL})(V)^2$ = (3900.00 ft-lbf)$(0.90)^2$ = 3,159.00 ft-lbf

$F_{undervoltage} = (T_{UV})/S$ = (3,159.00 ft-lbf)/0.0214 = 147,616.82 lbf

2NI0183B:

The valve is torque switch bypassed and limit switch controlled in the open direction.

stem factor (S) = 0.0264 (in open direction based on a stem COF = 0.15)
undervoltage factor (V) = 0.906

Note: A maximum value of 0.90 will be used for this calculation.

stall torque (T_{STALL}) = 1,800.00 ft-lbf
Serial #: B5483X
torque at undervoltage (T_{UV}) = $(T_{STALL})(V)^2$ = (1800.00 ft-lbf)$(0.90)^2$ = 1,458.00 ft-lbf

$F_{undervoltage} = (T_{UV})/S$ = (1,458.00 ft-lbf)/0.0264 = 55,227.27 lbf

Available Thrust Margin:

1NI0183B:

Since 147,616.82 lbf > 86,975.7 lbf => margin = 69.72 %

2NI0183B:

Since 55,227.27 lbf > 43,300.82 lbf => margin = 27.54 %

3. These valves were evaluated as part of the 2/13/96 response to GL 95-07. The original list of safety-related power operated gate valves included many more valves than the 84 mentioned in that submittal. During the review period, prior to 2/13/96 submittal, the scope was narrowed to 84 valves. These 84 valves were determined to have a safety function to open, or required to be in the open position to fulfill a safety function in any Mode and were closed under conditions for which they must remain operable. This criteria was specified in attachment 2 of the 2/13/96 submittal. The Pressurizer PORV Block Valves were determined not to meet this criteria based on the above discussion and thus determined not to have an active to open function. The evaluation for the 2/13/96 submittal is presented below.

Tech. Spec. 3/4.4.4 requires the Pressurizer PORV Block Valves (1(2)NC0031,0033,0035) to be open during Modes 1-3. The Block Valves are required to close to isolate a stuck open PORV. Credit is taken for one PORV to be able to open to mitigate the consequences of a Steam Generator Tube Rupture (SGTR), which means that at least one isolation valve must be open in this condition. Two PORVs (1(2)NC0032,0034) are also required for LTOP relief below 300° F with lift settings less than or equal to 400 psig per Tech. Spec. 3/4.4.9.3 which requires two isolation valves to be open at this pressure and temperature range.

Three conditions exist within the Tech. Specs. where the Block Valves may be closed for an extended period of time during plant operation.

1. One is when a Block Valve is declared inoperable. This may occur with the Block Valve in the closed position. With the Block Valve inoperable, the Tech. Specs. require that the PORV switch be placed in the 'CLOSE' position.

2. Another condition is when a PORV is declared inoperable due to excessive leakage. In this case, the associated Block Valve must be closed but power maintained to the Block Valve.

3. The third condition would be with the PORV(s) inoperable due to conditions other than excessive leakage.

If all three PORVs or Block Valves were to be inoperable, the Tech. Specs. require that at least one of the valves be restored to operable status within one hour or the plant must be taken to Mode 4. Postulating a SGTR during the one hour allowed for restoration is not credible. Also, the Emergency Procedure (EP) for the SGTR event requires verifying open or opening at least one Block Valve. This step is conducted early in the EP prior to initiating the primary system cooldown. Therefore, there will always be at least one Block Valve open in Modes 1-3 or else the plant will be shut down.

Should the situation arise where all three Block Valves were inoperable and closed and the plant was being taken to Mode 4, the LTOP requirements for the PORVs would not be required until the plant reached 300° F, in Mode 4. Although the LTOP requirements exist, the licensing basis for MNS is to attain Mode 3. However, to meet LTOP requirements, adequate time would exist to take alternate actions including establishing reliance on RHR Suction Relief Valve 1,2ND0003 (as stated in Tech Spec 3.4.9.3, license amendments No 166 and 148 for Units 1 and 2 respectively) or the plant could be held above LTOP conditions until sufficient LTOP valve requirements are achieved.

Although these valves are not presently classified as "active to open", they were evaluated for this response as shown below:

Gate Design: Flex Wedge (3")
Manufacturer: Borg-Warner

Thermal Binding Evaluation: In accordance with the Duke Power Company thermal binding screening criteria, these valve applications are potentially susceptible to thermal binding since the maximum temperature of the valves will be greater than 200° F above which valve operation could initiate thermal binding in flex wedge gate valves. The potential for thermal binding of these valves is minimized for the following reasons: (1) The valve body's are covered with insulation which would result in the valve body and wedge cooling at very similar rates, (2) the body and wedge are made of austenitic stainless steels which would expand and contract at similar rates, (3) the actuators are of the Rotork NAX type which includes an actuator spring pack to minimize stem growth concerns. The actuators are setup such that the valves are torque seated in the close direction at a value less than the full stall capability of the actuators. Actuator setup, in addition to the other mentioned items, would help to reduce the chance of occurrence of thermal binding.

Pressure Locking Evaluation: In accordance with the Duke Power Company pressure locking screening criteria, these valve applications are potentially susceptible to pressure locking since they are of the flex wedge design. Although unlikely, for conservatism, it is assumed for calculation purposes that a pressure of 2560 psig (maximum RCS pressure based on pressurizer safety setpoint + tolerance) is trapped in the bonnet with 0 psig upstream and 0 psig downstream. There is no temperature increase after closure of these valves. Therefore, thermally induced pressure locking is not a concern. The required thrust due to pressure forces was calculated using the ComEd pressure locking calculation model, assuming RCS pressure trapped in the bonnet. The results of the analysis are shown below.

Thrust (lbf)	1NC0031B	1NC0033A	1NC0035B	2NC0031B	2NC0033A	2NC0035B
Available	18,289	18,481	15,347	18,417	17,138	19,504
Required	13,021	13,507	8,776	12,192	11,305	11,057
Margin	40.46 %	36.82 %	74.88 %	51.06 %	51.60 %	76.39 %

Therefore, pressure locking is judged not to be a problem with these valves.

4. Of the known instances where valves have been modified to prevent the occurrence of pressure locking, 2NI0121A, 2NI0152B, 1NI0184A, 1NI0185B, 2NI0184A and 2NI0185B, a 10CFR50.59 evaluation has been completed to address any adverse impact on plant safety.

Minor modification MGMM-8272 (VN-8272A) was implemented to drill a 1/4" hole in the downstream side of the 2NI0121A valve wedge. The valve originally had a hole in the upstream side. This modification re-oriented the hole to the downstream (high pressure) side. The 50.59 evaluation concluded that placing the hole on the downstream side would improve the normal valve isolation reliability when compared to drilling a hole in the upstream side. Additionally, since the RCS is at a higher pressure than the NI System (the upstream side), NI pump runs during normal operation would not introduce a reactivity management issue due to NI System inventory being injected in the RCS.

Minor modification MGMM-8272 was implemented to drill a 1/4" hole in the downstream side of the 2NI0152B valve wedge. Through inspection, the valve was found to contain no hole in the upstream wedge, even though the design drawing indicated that the valve did have a hole. This modification placed a hole on the downstream (high pressure) side. The 50.59 evaluation indicated that a potential for the NI System to leak to the RCS during NI pump operation existed, if the RCS is at a lower pressure. The evaluation concluded that leakage into the RCS would not be a concern for shutdown or accident conditions. Additionally, potential diverted ECCS flow during cold leg recirculation will be minimized by the seating forces of the motor operator establishing an acceptable pressure boundary on the upstream side of the wedge. If required to be closed for containment isolation, a more reliable isolation would be achieved with containment pressure in addition to seating forces acting to seat the upstream wedge.

Minor modifications MGMM-7270 and 7161 were implemented to add bonnet vent bypass lines to 1NI0184B, 185A and 2NI0184B, 185A; respectively. The 50.59 evaluations indicated that no accident different than any evaluated in the SAR was created by these modifications and that neither the containment isolation function nor the ability to isolate ND flow from the containment sump is degraded.

Only a limited number of procedural changes have been implemented to address pressure locking. No procedural changes have been implemented to address thermal binding concerns. Procedure changes and the modification itself receive a 10CFR50.59 evaluation. In addition, all procedure changes are reviewed and operator updates are issued accordingly.

As a corrective action to PIP 0-M95-1852, potential pressure locking of 1(2)NS0001B and NS0018A, several procedures were updated. The controlling procedure for low head injection pump (ND system) quarterly testing was revised to monitor ND system pressure at the conclusion of pump operation. If pressure was greater than the allowed maximum, pressure would be bleed and the affected valves would be stroked (1,2NS0001B and NS0018A). Additionally, the ND system operating procedure's enclosure for alignment of the ND system for standby readiness for power operation was revised to include an evaluation of ND operation. If the ND system has been operated in RHR mode or system pressure has exceeded allowed maximum, the affected valves would be stoked (1,2NS0001B and NS0018A).

Training for plant personnel for modifications has been addressed through the Operations modification review process. As required by the modification process, each modification is reviewed by qualified operations personnel to assess the impact of the modification on Operations personnel/procedures. If new training were to be identified, generally a reading package containing pertinent information would be issued. Additionally, an SRO in the Work Control Center signs all modification work orders where Operations control is required. This process insures Operations personnel are informed of all work. To date no specific training regarding these pressure locking modifications has been conducted for operations personnel, due to the non-complex nature of these modifications. In summary, the Operations review process in conjunction with input from Engineering would ensure that appropriate training is initiated.

In the case of 1(2)NI0184B, 185A; a depiction of the bonnet vent bypass line has been added to the flow diagrams to clearly indicate that the valves are unique and that a bonnet vent provision exists for the valves in question. Graphic depiction's of the bypass lines on the flow diagrams provides assurance, in addition to the Operations modification review process, of operations awareness of the special configuration of these valves.

NSD 301 requires review of a comprehensive technical issues checklist during the early stages of development of engineering modifications which are not form, fit, or function one-to-one replacements. The technical issues checklist has been recently revised to include a review for the potential effects of pressure locking and thermal binding. This is an additional measure to ensure that the pressure locking and thermal binding issues are addressed in the modification process.

Additional Items - Changes From the 2/13/96 180 Day Response

5. The evaluations for 1(2)NI0009A, 10B documented in the 2/13/96 response to GL 95-07 have been re-evaluated since that submittal. The Susceptibility Summary Evaluation table in the 2/13/96 response indicates that these valves have bonnet relief design features. This is incorrect, the operability basis for pressure locking should be Systems Evaluation. An updated evaluation for these valves is as follows:

Valve Application: High head injection pump discharge to cold leg isolation
Safety Function: These valves are normally closed and are required to open to provide flow from the high head injection (NV System) pumps during the cold leg injection phase of ECCS operation. In the event one of these valves is incapable of opening, then that train of the NV System is inoperable.

Gate design: Flex Wedge
Manufacturer: Walworth-Greensburg

Thermal Binding Evaluation: In accordance with the Duke Power company thermal binding screening criteria, these valve applications are not susceptible to thermal binding since the maximum temperature of the valves will be less than the maximum ambient temperature of 133° F, which is less than the threshold temperature of 200° F below which valve operation could not initiate thermal binding in flex wedge gate valves.

Pressure Locking Evaluation: In accordance with the Duke Power Company pressure locking screening criteria, these valve applications are potentially susceptible to pressure locking since they are of the flex wedge design. As documented in PIP 2-M96-1066 and indicated on MCM-1205.00-0011-001, these valves do not contain a bonnet vent. These valves are designed to open with NV pump discharge pressure acting against one side of the wedge. Since NV pressure is higher than RCS pressure, the GL 89-10 differential pressure case setup bounds the GL 95-07 concern for pressure locking. Therefore, these valves are not subject to hydraulically induced pressure locking concerns.

These valves are subject to no temperature conditions while closed that are greater than the possible normal ambient conditions. There is a significant amount of piping forming a dead leg between the warmer cold leg injection/recirculation piping. Thus, the valves would not be expected to heat up significantly prior to their required operation. Therefore, these valves are not subject to any thermally induced pressure locking effects.

6. Since submittal of the 2/13/96 response to GL 95-07, 1NI0121A has been assumed for analysis purposes not to contain a bonnet relief design feature (hole in wedge) as a basis for pressure locking operability. 2NI0121A and 2NI0152B were inspected internally during the 2EOC10 refueling outage. 2NI0121A was modified by moving the hole in the wedge from the upstream side to the downstream wedge face. A hole was placed in the downstream wedge face of 2NI0152B after inspection showed no hole present in the upstream face. An updated evaluation of 1(2)NI0121A, 152B is listed below.

Valve Application: Medium head injection pumps to hot leg isolations
Safety Function: These valves are required to open provide flow from the medium head injection (NI System) pumps to the hot legs during hot leg recirculation phase of ECCS operation. In the event one of these valves is incapable of opening, then that train of the NI System is inoperable.
Gate Design: Flex Wedge
Manufacturer: Walworth-Greensburg

Thermal Binding Evaluation: In accordance with the Duke Power Company thermal binding screening criteria, these valve applications are not susceptible to thermal binding since the maximum temperature of the valves will be less than the maximum ambient temperature of 120° F, which is less than the threshold temperature of 200° F below which valve operation could not initiate thermal binding in flex wedge gate valves.

Pressure Locking Evaluation: In accordance with the Duke Power Company pressure locking screening criteria, these valve applications are potentially susceptible to pressure locking since they are of the flex wedge design. As discussed in PIP 2-M96-1066, MGMM-8272 installed a small equalization port in 2NI0121A and 2NI0152B in the downstream side of the valve wedges to act as a vent, should the bonnets become pressurized. Therefore; 2NI0121A, 152B are not subject to pressure locking. 1NI0121A, 152B have been assumed not to contain a bonnet relief design feature (hole in the wedge), as was evaluated in PIP 2-M95-1066 and PIP 1-M95-2066, respectively.

When 1NI0121A, 152B are required to open, upon initiation of hot leg recirculation, the bonnet pressure could be a maximum of 1550 psig. The 1550 psig could result from medium head injection (NI System) pump discharge head. This pressure could be applied by the NI pumps in injection and cold leg recirculation Modes of ECCS operation. Check valve leakage (1NI0123, 126, 127, 134 for 1NI0121A and

1NI0156, 157, 159, 160 for 1NI0152B) from the RCS could potentially pressurize the downstream side of 1NI0121A and 1NI0152B. However, pressure transmission through the downstream check valves was shown to not be a concern based on testing performed on 4/24/96 for 1NI0121A and 11/14/95 and 1/22/96 for 1NI0152B. The upstream pressure could be as low as 150 psig (ND pump discharge head) and the downstream pressure could be as low as 0 psig.

1NI0121A, 152B are subject to no temperature conditions while closed that are greater than the possible normal ambient conditions. There is a significant amount of piping forming a dead leg between the warmer cold leg injection/recirculation piping. Thus, the valves would not be expected to heat up significantly prior to their required operation. Therefore, 1NI0121A, 152B are not subject to any thermally induced pressure locking conditions. The required thrust due to pressure forces was calculated using the ComEd pressure locking calculation model, assuming NI pump discharge head trapped in the bonnet. The results of the analysis are shown below with margin.

Thrust (lbf)	1NI0121A	1NI0152B
Available	19,699.48	18,253.52
Required	19,349.08	15,137.45
Margin	1.81 %	20.59 %

Corrective Action: In the 2/13/96 response to GL 95-07 a commitment was made to inspect 1NI0152B during the next refueling outage (1EOC11) and install a bonnet vent if one does not already exist. Reliance on check valves to preclude pressure locking is for short term operability considerations only. Therefore, PIP 0-M96-1066 contains a corrective action to open and inspect 1NI0121A during the next refueling outage (1EOC11) and install a bonnet vent if one does not exist to satisfy the long term pressure locking concern for these valves.

7. The Susceptibility Evaluation Summary table in the 2/13/96 response to GL 95-07 lists the pressure locking basis for operability for 1(2)ND0058A and 1(2)NI0136B as being analysis, which is incorrect. The correct basis for operability should be Systems Evaluation.

8. The corrective action for 2NS0029A on page 12 of the 2/13/96 response to GL 95-07 incorrectly lists 2NS0029A as 2NS0029B.

9. In general, the margin numbers supplied in the 2/13/96 response to GL 95-07 have changed since the original submittal as part of refinement of the supporting calculation. However, all valves evaluated still show acceptable positive margin for short-term operability. It should be mentioned that the most severe drop in margin occurred for valves 1(2)NV0221A, 222B. The new results of the required thrusts due to pressure locking forces are shown below with margin.

Thrust (lbf)	1NV0221A	1NV0222B	2NV0221A	2NV0222B
Available	7,887.73	10,599.27	10,030.06	11,172.39
Required	6,808.86	9,392.76	9,060.94	10,703.96
Margin	15.85 %	12.85 %	10.70 %	4.38 %

Corrective Actions: The method of calculation used to determine margin for these valves is acceptable for short-term operability considerations only. Currently, modifications to install bonnet pressure equalization provisions to the 1(2)NV0221A, 222B are planned for the next refueling outage (1,2EOC11). As an alternative to modification, Engineering is evaluating a procedural revision to alleviate the pressure locking concern. Either the modifications or procedure change will be made to satisfy the long term pressure locking concern for these valves.

Program PRESLOK, Version 1
Revision 0
December 22, 1995
1NI 0183B

This Mathcad Program is designed to calculate the estimated opening force under pressure locking scenarios for flex-wedge gate valves using a calculational methodology that accounts for wedge stiffness resisting pressure locking forces. This program was prepared by the Westinghouse Owner's Group based upon the calculational methods developed by Commonwealth Edison.

This section of the program reads the thirteen items of input data from the plinput1.dat file.

$i := 0..12$

$input_i := READ(plinput1)$

$P_{bonnet} := input_0 \cdot psi$

$P_{up} := input_1 \cdot psi$

$P_{down} := input_2 \cdot psi$

$t := input_3 \cdot in$

$a := input_4 \cdot in$

$b := input_5 \cdot in$

$Hub_{length} := input_6 \cdot in$

$\theta := input_7 \cdot deg$

$\nu := input_8$

$E := input_9 \cdot psi$

$D_{stem} := input_{10} \cdot in$

$F_{po} := input_{11} \cdot lbf$

$VF := input_{12}$

Program PRESLOK, Version 1

INPUTS:

Bonnet Pressure	$P_{bonnet} = 200 \cdot psi$
Upstream Pressure	$P_{up} = 120 \cdot psi$
Downstream Pressure	$P_{down} = 0 \cdot psi$
Disk Thickness (taken at centerline of the hub vertically)	$t = 2.27 \cdot in$
Seat Radius (corresponding to mean seat diameter)	$a = 4.89 \cdot in$
Hub Radius (taken at plane of symmetry, perpendicular to the hub, radius of circle of equivalent area for non-circular hubs)	$b = 2.025 \cdot in$
Seat Angle	$\theta = 5 \cdot deg$
Poisson's Ratio (disk material at temperature)	$\nu = 0.3$
Modulus of Elasticity (disk material at temperature)	$E = 2.76 \cdot 10^{7} \cdot psi$
Static Pullout Force (measured value from diagnostic test)	$F_{po} = 0 \cdot lbf$
Close Valve Factor	$VF = 1.29$
Stem Diameter	$D_{stem} = 2.375 \cdot in$
Hub Length (from inside face of disk to inside face of disk)	$Hub_{length} = 1.37 \cdot in$

PRESSURE FORCE CALCULATIONS

Coefficient of friction between disk and seat:

$$\mu := VF \cdot \frac{\cos(\theta)}{1 + VF \cdot \sin(\theta)}$$ $\mu = 1.155$

Average DP across disks:

$$DPavg := P_{bonnet} - \frac{P_{up} + P_{down}}{2}$$ $DPavg = 140 \cdot psi$

Disk Stiffness Constants

$$D := \frac{E \cdot (t)^3}{12 \cdot \left(1 - \nu^2\right)}$$ $D = 2.956 \cdot 10^7 \cdot lbf \cdot in$

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

Geometry Factors:

$$C_2 := \frac{1}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2 \cdot \left(1 + 2 \cdot \ln\left(\frac{a}{b}\right)\right)\right]$$ $C_2 = 0.1315$

$$C_3 := \frac{b}{4 \cdot a} \cdot \left[\left[\left(\frac{b}{a}\right)^2 + 1\right] \cdot \ln\left(\frac{a}{b}\right) + \left(\frac{b}{a}\right)^2 - 1\right]$$ $C_3 = 0.0212$

$$C_8 := \frac{1}{2} \cdot \left[1 + \nu + (1 - \nu) \cdot \left(\frac{b}{a}\right)^2\right]$$ $C_8 = 0.71$

$$C_9 := \frac{b}{a} \cdot \left[\frac{1 + \nu}{2} \cdot \ln\left(\frac{a}{b}\right) + \frac{1 - \nu}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2\right]\right]$$ $C_9 = 0.2973$

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

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

Geometry Factors: (continued)

$$L_{11} := \frac{1}{64}\cdot\left[1 + 4\cdot\left(\frac{b}{a}\right)^2 - 5\cdot\left(\frac{b}{a}\right)^4 - 4\cdot\left(\frac{b}{a}\right)^2\cdot\left[2 + \left(\frac{b}{a}\right)^2\right]\cdot\ln\left(\frac{a}{b}\right)\right] \qquad L_{11} = 0.0035$$

$$L_{17} := \frac{1}{4}\cdot\left[1 - \frac{1-\nu}{4}\cdot\left[1 - \left(\frac{b}{a}\right)^4\right] - \left(\frac{b}{a}\right)^2\cdot\left[1 + (1+\nu)\cdot\ln\left(\frac{a}{b}\right)\right]\right] \qquad L_{17} = 0.1155$$

Moment

$$M_{rb} := \frac{-DPavg\cdot a^2}{C_8}\cdot\left[\frac{C_9}{2\cdot a\cdot b}\cdot\left(a^2 - b^2\right) - L_{17}\right] \qquad M_{rb} = -857.8\cdot lbf$$

$$Q_b := \frac{DPavg}{2\cdot b}\cdot\left(a^2 - b^2\right) \qquad Q_b = 684.8\cdot\frac{lbf}{in}$$

Deflection due to pressure and bending:

$$y_{bq} := M_{rb}\cdot\frac{a^2}{D}\cdot C_2 + Q_b\cdot\frac{a^3}{D}\cdot C_3 - \frac{DPavg\cdot a^4}{D}\cdot L_{11} \qquad y_{bq} = -4.3516\cdot 10^{-5}\cdot in$$

Deflection due to pressure and shear stress:

$$K_{sa} := -0.3\cdot\left[2\cdot\ln\left(\frac{a}{b}\right) - 1 + \left(\frac{b}{a}\right)^2\right] \qquad K_{sa} = -0.2804$$

$$y_{sq} := \frac{K_{sa}\cdot DPavg\cdot a^2}{t\cdot G} \qquad y_{sq} = -3.8958\cdot 10^{-5}\cdot in$$

Deflection due to hub stretch:

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

$$y_{stretch} := \frac{P_{force}}{\pi\cdot b^2}\cdot\frac{Hub_{length}}{(2\cdot E)} \qquad y_{stretch} = 1.6787\cdot 10^{-5}\cdot in$$

Total Deflection due to pressure forces:

$$y_q := y_{bq} + y_{sq} - y_{stretch} \qquad y_q = -9.9261\cdot 10^{-5}\cdot in$$

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

$$y_{sw} := -\left[\frac{1.2 \cdot \left(\frac{a}{a}\right) \cdot \ln\left(\frac{a}{b}\right) \cdot a}{t \cdot G}\right] \qquad y_{sw} = -2.147 \cdot 10^{-7} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$y_{bw} := -\left(\frac{a^3}{D}\right) \cdot \left[\left(\frac{C_2}{C_8}\right) \cdot \left[\left(\frac{a \cdot C_9}{b}\right) - L_9\right] - \left[\left(\frac{a}{b}\right) \cdot C_3\right] + L_3\right] \qquad y_{bw} = -3.241 \cdot 10^{-7} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

Deflection due to hub compression:

$$y_{cmpr} := -\left(\frac{2 \cdot \pi \cdot a}{\pi \cdot b^2} \cdot \frac{Hub_{length}}{2 \cdot E}\right) \qquad y_{cmpr} = -5.919 \cdot 10^{-8} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$y_w := y_{bw} + y_{sw} + y_{cmpr} \qquad y_w = -5.98 \cdot 10^{-7} \cdot \frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$F_s := 2 \cdot \pi \cdot a \cdot \frac{y_q}{y_w} \qquad F_s = 5100 \cdot lbf$$

UNSEATING FORCES

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

$$F_{piston} := \frac{\pi}{4} \cdot D_{stem}{}^2 \cdot P_{bonnet} \qquad F_{piston} = 886 \cdot lbf$$

$$F_{vert} := \pi \cdot a^2 \cdot \sin(\theta) \cdot \left(2 \cdot P_{bonnet} - P_{up} - P_{down}\right) \qquad F_{vert} = 1833.2 \cdot lbf$$

$$F_{preslock} := 2 \cdot F_s \cdot (\mu \cdot \cos(\theta) - \sin(\theta)) \qquad F_{preslock} = 10849.3 \cdot lbf$$

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

$$F_{total} = 11796.5 \cdot lbf$$

Program PRESLOK, Version 1
Revision 0
December 22, 1995
2NI 0183B

This Mathcad Program is designed to calculate the estimated opening force under pressure locking scenarios for flex-wedge gate valves using a calculational methodology that accounts for wedge stiffness resisting pressure locking forces. This program was prepared by the Westinghouse Owner's Group based upon the calculational methods developed by Commonwealth Edison.

This section of the program reads the thirteen items of input data from the plinput1.dat file.

$i := 0..12$

$input_i := READ(plinput1)$

$P_{bonnet} := input_0 \cdot psi$

$P_{up} := input_1 \cdot psi$

$P_{down} := input_2 \cdot psi$

$t := input_3 \cdot in$

$a := input_4 \cdot in$

$b := input_5 \cdot in$

$Hub_{length} := input_6 \cdot in$

$\theta := input_7 \cdot deg$

$\nu := input_8$

$E := input_9 \cdot psi$

$D_{stem} := input_{10} \cdot in$

$F_{po} := input_{11} \cdot lbf$

$VF := input_{12}$

Program PRESLOK, Version 1

INPUTS:

Bonnet Pressure	$P_{bonnet} = 200 \cdot psi$
Upstream Pressure	$P_{up} = 120 \cdot psi$
Downstream Pressure	$P_{down} = 0 \cdot psi$
Disk Thickness (taken at centerline of the hub vertically)	$t = 2.27 \cdot in$
Seat Radius (corresponding to mean seat diameter)	$a = 4.89 \cdot in$
Hub Radius (taken at plane of symmetry, perpendicular to the hub, radius of circle of equivalent area for non-circular hubs)	$b = 2.025 \cdot in$
Seat Angle	$\theta = 5 \cdot deg$
Poisson's Ratio (disk material at temperature)	$\nu = 0.3$
Modulus of Elasticity (disk material at temperature)	$E = 2.76 \cdot 10^{7} \cdot psi$
Static Pullout Force (measured value from diagnostic test)	$F_{po} = 0 \cdot lbf$
Close Valve Factor	$VF = 0.534$
Stem Diameter	$D_{stem} = 2.375 \cdot in$
Hub Length (from inside face of disk to inside face of disk)	$Hub_{length} = 1.37 \cdot in$

PRESSURE FORCE CALCULATIONS

Coefficient of friction between disk and seat:

$$\mu := VF \cdot \frac{\cos(\theta)}{1 + VF \cdot \sin(\theta)} \qquad \mu = 0.508$$

Average DP across disks:

$$DPavg := P_{bonnet} - \frac{P_{up} + P_{down}}{2} \qquad DPavg = 140 \cdot psi$$

Disk Stiffness Constants

$$D := \frac{E \cdot (t)^3}{12 \cdot \left(1 - \nu^2\right)} \qquad D = 2.956 \cdot 10^7 \cdot lbf \cdot in$$

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

Geometry Factors:

$$C_2 := \frac{1}{4} \cdot \left[1 - \left(\frac{b}{a}\right)^2 \cdot \left(1 + 2 \cdot \ln\left(\frac{a}{b}\right)\right)\right] \qquad C_2 = 0.1315$$

$$C_3 := \frac{b}{4 \cdot a} \cdot \left[\left[\left(\frac{b}{a}\right)^2 + 1\right] \cdot \ln\left(\frac{a}{b}\right) + \left(\frac{b}{a}\right)^2 - 1\right] \qquad C_3 = 0.0212$$

$$C_8 := \frac{1}{2} \cdot \left[1 + \nu + (1 - \nu) \cdot \left(\frac{b}{a}\right)^2\right] \qquad C_8 = 0.71$$

$$C_9 := \frac{b}{a} \cdot \left[\frac{1 + \nu}{2} \cdot \ln\left(\frac{a}{b}\right) + \frac{1 - \nu}{4} \left[1 - \left(\frac{b}{a}\right)^2\right]\right] \qquad C_9 = 0.2973$$

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

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

Geometry Factors: (continued)

$$L_{11} := \frac{1}{64}\cdot\left[1 + 4\cdot\left(\frac{b}{a}\right)^2 - 5\cdot\left(\frac{b}{a}\right)^4 - 4\cdot\left(\frac{b}{a}\right)^2\cdot\left[2 + \left(\frac{b}{a}\right)^2\right]\cdot\ln\left(\frac{a}{b}\right)\right] \qquad L_{11} = 0.0035$$

$$L_{17} := \frac{1}{4}\cdot\left[1 - \frac{1-\nu}{4}\cdot\left[1 - \left(\frac{b}{a}\right)^4\right] - \left(\frac{b}{a}\right)^2\cdot\left[1 + (1+\nu)\cdot\ln\left(\frac{a}{b}\right)\right]\right] \qquad L_{17} = 0.1155$$

Moment

$$M_{rb} := \frac{-DPavg\cdot a^2}{C_8}\cdot\left[\frac{C_9}{2\cdot a\cdot b}\cdot\left(a^2 - b^2\right) - L_{17}\right] \qquad M_{rb} = -857.8\cdot \text{lbf}$$

$$Q_b := \frac{DPavg}{2\cdot b}\cdot\left(a^2 - b^2\right) \qquad Q_b = 684.8\cdot\frac{\text{lbf}}{\text{in}}$$

Deflection due to pressure and bending:

$$y_{bq} := M_{rb}\cdot\frac{a^2}{D}\cdot C_2 + Q_b\cdot\frac{a^3}{D}\cdot C_3 - \frac{DPavg\cdot a^4}{D}\cdot L_{11} \qquad y_{bq} = -4.3516\cdot 10^{-5}\cdot\text{in}$$

Deflection due to pressure and shear stress:

$$K_{sa} := -0.3\cdot\left[2\cdot\ln\left(\frac{a}{b}\right) - 1 + \left(\frac{b}{a}\right)^2\right] \qquad K_{sa} = -0.2804$$

$$y_{sq} := \frac{K_{sa}\cdot DPavg\cdot a^2}{t\cdot G} \qquad y_{sq} = -3.8958\cdot 10^{-5}\cdot\text{in}$$

Deflection due to hub stretch:

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

$$y_{stretch} := \frac{P_{force}}{\pi\cdot b^2}\cdot\frac{Hub_{length}}{(2\cdot E)} \qquad y_{stretch} = 1.6787\cdot 10^{-5}\cdot\text{in}$$

Total Deflection due to pressure forces:

$$y_q := y_{bq} + y_{sq} - y_{stretch} \qquad y_q = -9.9261\cdot 10^{-5}\cdot\text{in}$$

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

$$y_{sw} := -\left[\frac{1.2\cdot\left(\frac{a}{a}\right)\cdot\ln\left(\frac{a}{b}\right)\cdot a}{t\cdot G}\right] \qquad y_{sw} = -2.147\cdot10^{-7}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$y_{bw} := -\left(\frac{a^3}{D}\right)\cdot\left[\left(\frac{C_2}{C_8}\right)\cdot\left[\left(\frac{a\cdot C_9}{b}\right)-L_9\right]-\left[\left(\frac{a}{b}\right)\cdot C_3\right]+L_3\right] \qquad y_{bw} = -3.241\cdot10^{-7}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

Deflection due to hub compression:

$$y_{cmpr} := -\left(\frac{2\cdot\pi\cdot a}{\pi\cdot b^2}\cdot\frac{Hub_{length}}{2\cdot E}\right) \qquad y_{cmpr} = -5.919\cdot10^{-8}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$y_w := y_{bw} + y_{sw} + y_{cmpr} \qquad y_w = -5.98\cdot10^{-7}\ \cdot\frac{in}{\left(\frac{lbf}{in}\right)}$$

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

$$F_s := 2\cdot\pi\cdot a\cdot\frac{y_q}{y_w} \qquad F_s = 5100\cdot lbf$$

UNSEATING FORCES

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

$$F_{piston} := \frac{\pi}{4}\cdot D_{stem}{}^2\cdot P_{bonnet} \qquad F_{piston} = 886\cdot lbf$$

$$F_{vert} := \pi\cdot a^2\cdot\sin(\theta)\cdot\left(2\cdot P_{bonnet} - P_{up} - P_{down}\right) \qquad F_{vert} = 1833.2\cdot lbf$$

$$F_{preslock} := 2\cdot F_s\cdot(\mu\cdot\cos(\theta) - \sin(\theta)) \qquad F_{preslock} = 4276.1\cdot lbf$$

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

$$F_{total} = 5223.3\cdot lbf$$

August 24, 1992

C. W. Boyd, Mechanical/Nuclear Engineering Manager
Catawba Nuclear Station

Attention: S. L. Williams

Subject: McGuire Nuclear Station
Catawba Nuclear Station
Background Information on Hot Leg Recirculation for the ND DBD
MC-1552.00, CN-1552.00

Attached is the final draft of the discussion of hot leg recirculation for the Catawba ND Design Basis Specification. The information presented is equally applicable to McGuire. If you have any questions please call me at 382-7565.

H. Jackson Lee, Jr.

H. Jackson Lee, Jr., Senior Engineer
Nuclear Engineering Group
Nuclear Services Division

HJL/

cc: J. W. Byrd, Jr. (MNS)
W. H. Barron (CNS)
D. M. McGinnis (MNS)
S. R. Frye (CNS)
D. A. Baxter (MNS)

10 CFR 50.46(b)(4) and (5) require that the core geometry and the ECCS be such that the core is amenable to long term cooling. If a LOCA is large enough that the coolant level cannot accumulate above a certain level, as in the case of a double-ended guillotine rupture of the main coolant loop piping, coolant injected into the same side of the NC system as the break will not be effective for core cooling via sensible heat removal. The flow injected into the cold legs will keep the reactor vessel downcomer full of liquid. After core reflood is completed the core will be covered by a two-phase mixture. Boiling in the core will convert some of the reactor vessel liquid into steam. The static head of liquid in the downcomer will force additional liquid into the core to replace that which is boiled. Any liquid in excess of this core boiloff requirement will exit through the break. For example, if there is a large cold leg LOCA any excess liquid injected into intact cold legs will not flow through the core but will simply enter the downcomer and exit through the broken cold leg. Likewise, for a large hot leg LOCA any excess liquid injected into intact hot legs will not flow through the core but will simply enter the upper plenum and exit through the broken hot leg. If water is only injected from a single direction relative to the core, i.e. only into the cold legs or only into the hot legs, this situation can result in a volume of relatively stagnant borated water surrounding the core. Since no water is forced through the core, that stagnant volume is kept heated to the saturation temperature, and the water boils, leaving the boric acid behind. If this process continues the boric acid concentration in the core region could exceed the solubility limit, resulting in the deposition of solid boric acid on the fuel rods and other core structures.

To prevent the precipitation described above, the ECCS systems are realigned to inject water into both the hot and cold legs. If the break is on a cold leg, the flow from the NI, and possibly the ND, pumps is injected into the hot legs and must flow through the core to exit through the break. Likewise, if the break is on a hot leg, the flow from the NV pumps continues to inject into the cold legs and must flow through the core to exit through the break. The flow of liquid through the core reduces the boric acid concentration in the core region. Both flow directions are used because the location of the break (hot leg vs. cold leg) might not be able to be reliably determined.

If the LOCA is small enough that the NC system level can refill to an elevation that allows liquid from the core to reach the break, the transfer to a hot leg recirculation alignment is not necessary. This criterion is obviously met for breaks in which NC system subcooling is restored. For larger breaks, the exact elevation to which the system must refill to make a hot leg recirculation alignment unnecessary has not been explicitly calculated. A decision would be made prior to the procedural hot leg recirculation initiation time. Flow through the 44 unplugged reactor vessel upper head cooling nozzles, an area of 65 in^2 at the elevation of the reactor vessel flange, would probably allow sufficient core liquid outflow to preclude continued boric acid buildup.

Even if it were concluded that the hot leg recirculation alignment was necessary, consideration of existing conditions determines the specific valve manipulations that would be made. First, as stated below, only a limited amount of hot leg injection flow is necessary to both remove decay heat at the switchover time and dilute the core region boron concentration. If at least this much flow can be provided by the available NI pump(s) when aligned for hot leg recirculation, a direct ND hot leg injection flow path need not be aligned. Further, the FSAR Section 6.2.1.1.3.1 peak containment pressure transient analysis takes credit, as shown in Table 6-17, for a certain amount of ND auxiliary containment spray flow. Simultaneous alignment of an ND pump for direct hot leg injection and auxiliary containment spray is unlikely, because of the relative resistances of the two flow paths, to result in significant auxiliary containment spray. Therefore, an ND pump which is the sole means of providing auxiliary containment spray should not be aligned to direct hot leg injection unless it can be verified that there exists an equivalent amount of normal containment spray heat removal capacity beyond that already credited in peak containment pressure transient analysis.

The mechanism for preventing boron precipitation with the hot leg recirculation alignment is that the excess flow, i.e., the flow above the decay heat removal requirement, is assumed to be at the core region boron concentration and removes at least a boron mass equal to that which is carried into the core region by safety injection flow. Calculation DPC-1552.08-00-0064 documents the flow required to remove decay heat at the time of the emergency alignment to hot leg recirculation. The additional flow required for boron dilution is not explicitly calculated but is approximately 10 gpm, much less than the decay heat removal flow requirement. A single NI pump, at the time of hot leg recirculation alignment in the emergency procedures, is predicted to be able to supply much more than the minimum amount of core cooling and boron dilution flow required. Therefore, the ND pump need not be realigned for direct hot leg injection for the accidents evaluated in the FSAR.