ENCLOSURE 4

PVNGS ENGINEERING CALCULATION
13-MC-SI-330, "CALCULATION OF BONNET FLUID TEMPERATURE FOR MOV SI-604/609"

Palo Verde Nuclear Generating Station

CALCULATION REVISION/TITLE SHEET

CALCULATION NO.	REV.	CLASS:	AFFECTED SHEET NO(S)
13MC-SI-330	0	Q [X] QAG [ ] NQR [ ]	All

CALCULATION TITLE	ISSUED
CALCULATION OF BONNET FLUID TEMPERATURE FOR MOV SI-604/609	2/14/96

PLANT CHANGE DOCUMENT	REFERENCE(S)
N/A	NONE

REASON FOR CHANGE

N/A

DESCRIPTION OF CHANGE

NEW CALCULATION

Preparer	RE	Second Party Verification	Mech.	Civil	Elec.	I & C	Independent Verification	Other (Specify Org.)	Other (Specify Org.)	
[signature]	[signature]	N/A	N/A	N/A	N/A	N/A	[signature]	N/A	N/A	N/A
02/13/96	02/13/96						2/13/96			
Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	

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

CALCULATION SHEET

CALC. TITLE MOV SI604/609 BONNET FLUID TEMPERATURE CALC. NO 13-MC-SI-330

SUBJECT ______ SHEET NO. 1

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0	J. A. BROWN	2/13/96	A. AMR [signature]	2/13/96						

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1	J. A. BROWN	2/13/96	A. AMR	2/13/96						

I PURPOSE

The purpose of this calculation is to evaluate the maximum bonnet fluid temperature in valves SIA-HV-604 and SIB-HV-609 during a LOCA and prior to opening. This calculation will be used to assess the potential of valve pressure locking.

II SUMMARY OF RESULTS

The maximum steady state bonnet fluid temperature has been calculated to be 119.8 °F.

III ASSUMPTIONS

1. Assume that the sump fluid temperature does not decrease from the sump and that the maximum sump temperature following a LOCA conservatively remains constant.
2. The valve piping and body are assumed adiabatic to maximize the final bulk fluid temperature.

IV CRITERIA

The objective is to predict a conservative value for the maximum bonnet fluid temperature. There are no specific criteria since these results will be used as input for evaluation of the potential for valve pressure locking. All input data and calculated values will be such that the final result will be conservatively high.

V INPUT DATA

1. Sump fluid temperature equals a maximum of 231°F [Ref. 6].
2. Stainless Steel data [Ref. 2]
   - Density (68°F)........ 488 lb_m/ft^3
   - Specific Heat (68°F)........ 0.110 BTU/lb_m °F
   - Thermal Conductivity (212 °F)........ 10.0 BTU/hr ft °F
3. Water data [Ref. 2]
   - Density (168 °F)........ 61.1 lb_m/ft^3
   - Specific Heat (168°F)........ 1.001 BTU/lb_m °F
   - Thermal Conductivity (168 °F)........ 0.385 BTU/hr ft °F
   - Viscosity (168°F)........ 0.451×10^{-5} ft^2/s
   - Prandtl Number (168 °F)........ 2.5
   - Coefficient of Expansion........ 2.95×10^{-4} $°F^{-1}$
4. Valve bonnet water volume - (Calculated) [Ref. 7]........ 0.25 ft^3
5. Maximum Auxiliary Building atmospheric temperature [Ref. 6]........ 104°F

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VI CALCULATIONS

DISCUSSION-

The problem geometry is described in Figure 1. The objective is to assess the (bulk) temperature of the bonnet fluid of valves HV-604/HV-609, identified as T_W.

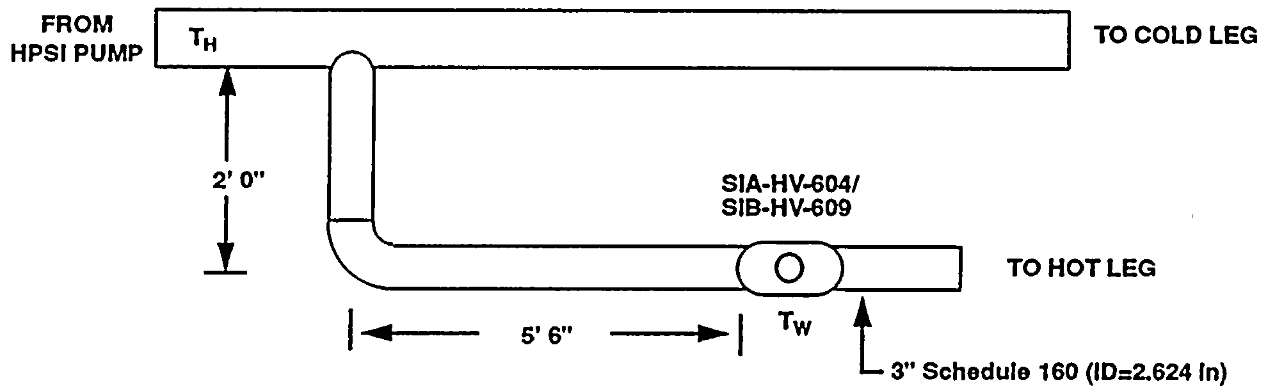

FIGURE 1 - The hot leg injection line branches from the HPSI discharge line immediately downstream of the pump discharge. Following a LOCA, the pump suction is re-aligned from the RWT to the containment sump. Flow in the cold-leg injection line, excluding heat loss along the suction piping, results in a temperature (T_H) equal to that of the fluid in the sump. The hot-leg injection isolation valves, SIA-HV-604 and SIB-HV-609 are opened no later than 3 hours after the event.

The temperature of the bonnet fluid is a function of the conditions in the upstream piping and the heat transfer properties at the valve. Typical analyses consider the upstream fluid to be stagnant and the principle mode of energy transfer to be conduction. However, recent analyses and experimental work [Refs. 3, 4, and 5 and references contained therein] have identified that density gradients established in pipes, as a result of end temperature differences, generate natural convection cells which result in higher axial temperatures as compared to that resulting from conduction alone. Furthermore, the time scales associated with natural convection is much smaller than that for conduction; thus, the profiles are more readily established.

Analysis of the bonnet fluid temperature thus becomes dependent on the model of the valve subjected to these conditions. Figure 2 defines the model.

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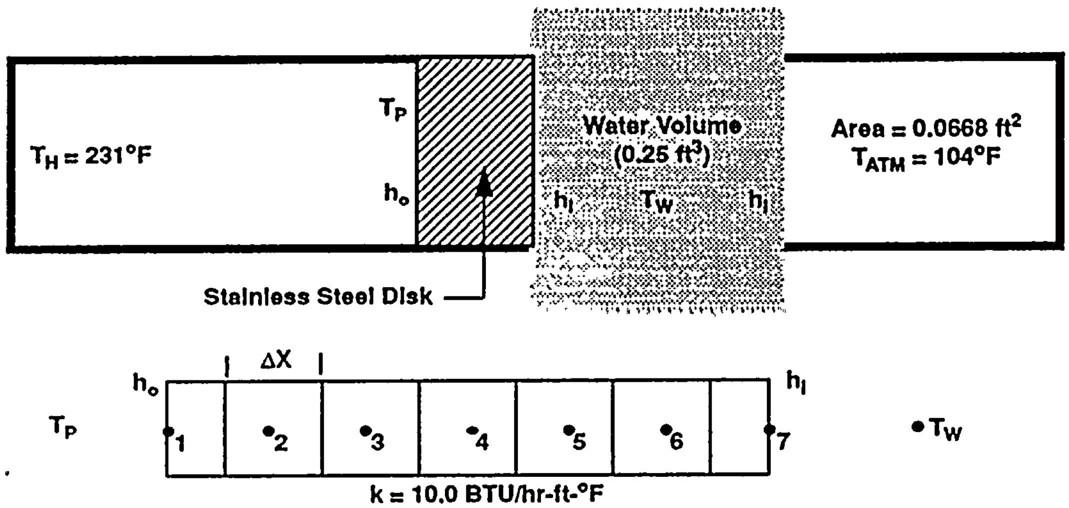

FIGURE 2 - The problem is modeled as a one-dimensional fin with an effective upstream temperature of T_P imposed on the upstream face of the valve disk. Heating of the water volume occurs as a result of heat flow through disk, as a function of the outside and inside film coefficients, h_i and h_o, respectively. Heat loss from the water volume occurs only through the valve body along the downstream piping. The balance of the piping and valve body is assumed adiabatic. The bottom figure details the exploded view of the steel disk, assumed here to be 1.0 inches. T_W represents the bulk bonnet fluid temperature.

The bonnet fluid is idealized as a control volume with one dimensional heat flow in through the upstream piping and heat loss through the downstream piping. Heat transfer from the piping fluid through the valve body wall is approximated by assuming that conduction occurs over a one inch stainless steel slab, typical of the physical dimensions of this style valve, with natural convective heat transfer on either side. The upstream piping and valve body are conservatively assumed adiabatic. Heat loss to the discharge side of the valve is assumed relative to fluid temperatures equal to the maximum pump room temperatures during a LOCA.

The model is completed by assessing the upstream fluid temperature and estimating the heat transfer coefficients. The one dimensional transient model is solved by a finite element approach.

EVALUATION OF THE UPSTREAM FLUID TEMPERATURE-

The presence of turbulence induced by flow in the HPSI injection line will tend to cause localized fluid motion along the branch line within a distance from the tee. This promotes the hotter main branch fluid within the branch line, thus transposing the boundary condition. Turbulence induced by flow in the main header pipe has been shown to exist up to 15 diameters along the branch pipe for similar conditions [Ref. 5]. Beyond this distance, the fluid is relatively stagnant and a natural convective cell may

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develop. The length of branch pipe over which natural convection will occur is the pipe length from tee to valve minus 15 diameters (3.3 feet) or 4.2 feet.

Within this quasi-stagnant portion of the piping, natural convection currents will develop. Reference 4 provides an analytic assessment of the temperature profiles for this configuration. These analyses, supported by data, suggest that the fluid temperature decays to approximately one-half the absolute difference of the end temperatures, at a length corresponding to 20 pipe diameters;

$$\theta = \frac{T_H - T}{T_H - T_C} = 0.5|_{20\,(x/D)}$$

where T_H and T_C are the up-stream hot fluid and the ambient temperatures, respectively. Applying this relationship. the fluid temperature at the up-stream side of the valve is

$$\theta = \frac{231 - T}{231 - 104} = 0.5|_{20\,(x/D)}$$

which results in an up-stream fluid temperature at the valve of 168°F.

NATURAL CONVECTION HEAT TRANSFER COEFFICIENTS-

The heat transfer coefficient between the metal and water is due to natural convection and can be obtained from Reference 1for vertical plates and cylinders as follows.

$$h_i = 0.555\left(\frac{K}{L}\right)(GrPr)^{0.25}$$

Where:

K= Thermal conductivity of water, BTU/hr F ft = o.385 at 160oF

L= Vertical length of bonnet ft = 0.50 ft

The Grashoff number is defined as follows [Ref. 1]

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$$Gr = \frac{g\beta(T_H - T_C)L^3}{\nu^2}$$

Substituting and solving for a temperature difference of 100°F yields Gr equal to 4.68×10^8. The convective heat transfer coefficient is 55.5 Btu/hr F ft2. This value is assumed applicable to both the fluid/metal interfaces on both sides of the valve gate (i.e. model slab).

TRANSIENT MODEL-

The model depicted in Figure 2 has been reduced to the following finite difference equations:

NODE 1

$$\frac{\Delta x}{2} A\rho C_P \frac{(T_1^{t+1} - T_1^t)}{\Delta t} = h_o A(T_P^t - T_1^t) + \frac{kA}{\Delta x}(T_2^t - T_1^t)$$

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$$\Delta x A\rho C_P \frac{(T_N^{t+1} - T_N^t)}{\Delta t} = \frac{kA}{\Delta x}(T_{N-1}^t - T_N^t) + \frac{kA}{\Delta x}(T_{N+1}^t - T_N^t)$$

NODE 7

$$\frac{\Delta x}{2} A\rho C_P \frac{(T_7^{t+1} - T_7^t)}{\Delta t} = h_i A(T_W^t - T_7^t) + \frac{kA}{\Delta x}(T_6^t - T_7^t)$$

WATER MASS

$$V_W \rho_W C_{PW} \frac{(T_W^{t+1} - T_W^t)}{\Delta t} = h_i A(T_7^t - T_W^t) + h_i A(T_{atm}^t - T_W^t)$$

RESULTS-

The model, defined above and with substitution of the calculated values for the convective heat transfer coefficient, yields a steady state bonnet fluid temperature of 119.8°F and attains this value within 20 minutes of the time the hot upstream fluid reaches the valve disk.

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1	J. A. BROWN	2/13/96	A. AMR (signature)	2/13/96						

VII REFERENCES

1.... Incropera, F. P., and Dewitt, D. P., Fundamentals of Heat and Mass Transfer, 3rd ed., Wiley.

2.... Welty, J. R., Wicks, C. E., and Wilson, R. E., Fundamentals of Momentum, Heat, and Mass Transfer, 3rd ed., Wiley.

3.... Combustion Engineering Report CE NPSD-915, "Prediction of Temperature in the Safety Injection Lines Subject to Thermal Stratification due to Natural Convection - Final Methodology ," CEOG Task 741, December 1993.

4.... Combustion Engineering Report CE NPSD-907, "Temperatures in the Safety Injection Lines Due to Thermal Stratification - Final Technical Basis," May, 1993.

5.... Combustion Engineering Report CE NPSD-979, "Thermal Stratification in the Shutdown Cooling Piping - Final Report," January, 1995.

6.... PVNGS Equipment Qualification Program Manual, Revision 5.

7.... PVNGS SDOC N001-11.04-27, Rev. 17, Model 77910 Valve Details.