3F0496-02
Enclosure 8

Florida Power Corporation

ANALYSIS/CALCULATION SUMMARY

DOCUMENT IDENTIFICATION NUMBER	DISCIPLINE	CONTROL NO.	REVISION LEVEL
	M	96-0006	0

TITLE

MUT VAPOR PRESSURE EVALUATION

CLASSIFICATION (CHECK ONE)

- [X] Safety Related
- [ ] Non Safety Related

MAR/SP/CGWR/PEERE NUMBER

VENDOR DOCUMENT NUMBER

	REVISION APPROVALS		ITEMS REVISED
Design Engineer	P.L. Bunker		
Date			
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Date/Method*		R	
Supervisor			
Date			

***VERIFICATION METHODS:** R - Design Review; A - Alternate Calculation; T - Qualification Testing

DESCRIBE BELOW IF METHOD OF VERIFICATION WAS OTHER THAN DESIGN REVIEW

PURPOSE SUMMARY

The purpose of this calculation is to determine the vapor pressure in MUT-1 during draindown following a postulated LOCA.

RESULTS SUMMARY

The results of the analysis show that the vapor pressure decreases a minimum of 0.2 psia during the draindown period following a LOCA.

1.0 PURPOSE:

The purpose of this calculation is to determine the vapor pressure change in MUT-1 during draindown following a postulated LOCA. The results of the calculation will provide input to the hydraulic calculation which determines the actual draindown level.

2.0 DESIGN INPUT:

2.1 The tank volume used is provided in Reference 4.1.

The initial gas volume is	333.586	ft^3
The total tank volume is	603.669	ft^3
The dished head volume	48.234	ft^3 / per head

2.2 The initial minimum liquid level, pressure and temperature in the MUT-1 is:

Level = 52.3"	Reference 4.7
Pressure = 12.08 psig	Reference 4.7
Pressure Indicator error 1.12 psig	Reference 4.9
Temperature = 135° F	Reference 4.7

3.0 ASSUMPTIONS/PRELIMINARY DATA:

The MUT-1 room is assumed to be at a maximum temperature of 95° F. This assumption is based on the maximum expected temperatures of 95° F in adjacent EQ Zones 23 and 24 per Reference 4.5

The MUT is assumed to be stabilized at 13.2 psig pressure during normal operation. This includes the letdown flow and recirculation flow from the make up pump. Once the letdown and recirculation flows are terminated, the addition of heat to the MUT terminates and the heat loss to the room is no longer replaced by the system flow. Therefore after termination of flow the heat transfer from the tank to the room decreases system temperature. This effect will be used to determine the change in MUT vapor pressure.

The decrease in fluid temperature is assumed to occur in the top level of the water in the tank. Any heat lost through condensation on the tank walls is replaced by evaporation from the surface of the water.

If the water should completely leave the tank during drain down then the vapor pressure would drop significantly over that calculated below. This would occur since the surface area of the water exposed to the gas is much less than that if the water were in the tank and the vapor mass lost through condensation on the tank walls would not be replaced as rapidly.

3.0 ASSUMPTIONS/PRELIMINARY DATA Cont'd:

This analysis does not contain any assumptions requiring later confirmation or preliminary data.

4.0 REFERENCES:

4.1 FPC calculation M-96-0007 Revision 0, BWST/MUT Hytran Analysis

4.2 Buffalo Tank Drawing M-6057 (G/C drawing #58-027).

4.3 Kreith, F., "Principles of Heat Transfer", second edition.

4.4 Marks, "Standard Handbook for Mechanical Engineers", eighth edition.

4.5 Environmental and Seismic Qualification Program Manual, Revision 8.

4.6 ASME Steam Tables, Third Edition

4.7 Letter FCS-14607 Design Input dated December 19, 1995 Att. 1

4.8 Operating Procedure OP-103B, Rev. 15

4.9 Calculation DC-5515-018-26.01-ME,"BWST Suction & MUT Suction Lines Tie-In Point Pressures", Rev. 5

5.0 CALCULATIONS:

For this analysis the tank volumes calculated in Reference 4.1 are used.

The tank dimensions are provided in References 4.1 and 4.2.

Tank volume = 590.16 ft^3. Reference 4.1

Dished head volume = 41.48 ft^3.

Tank OD = 8 ft. Reference 4.2

Tank overall height = 13.42 ft Rererence 4.2

Tank cylindrical height = 10.25 ft Reference 4.2

The approximate surface area is as follows:

Cylinder

$$A = \pi * D * H = \pi * 8.0 * 10.25 = 257.6\ ft^2.$$

5.0 **CALCULATIONS Cont'd:**

For the dished head the area of circular plate is conservatively used:

$$A = \pi * D^2 /4 = \pi * 8^2 /4 = 50.3 \text{ ft}^2$$

The heat removed from the tank (due to natural convection up the tank walls) can be conservatively calculated using the following formula.

$Q = h\, A\, \Delta T$ Reference 4.3

Where h = natural convection heat transfer coefficient

$h = 0.18 \ (\Delta T)^{0.333}$ Reference 4.3

A = surface area of tank.

ΔT = temperature difference (tank to air)

$h = 0.18 * (40°F)^{.333} = 0.61$ BTU/HR-FT^2-F

The tank upper head can be treated as a horizontal flat plate with the characteristic dimension equal to the diameter. The natural convection heat transfer coeficient is calculated below:

$h*D/k = 0.48 (Gr)^{0.25}$

Where h = natural convection heat transfer coefficient

Gr = Grashoff Number = $(1.44*10^{+6} /F\text{-ft}^3) * D^3 * 45$ F

Gr = $3.318\ 10^{10}$

k = thermal conductivity of air = .00146 BTU/hr-ft-F

D = Diameter = 8 Ft

Therefore:

$h = 0.48 * (3.318\ 10^{10})^{0.25} * .00146/8 = 0.08$ BTU/HR-FT^2-F

Using only the top head and cylindrical portion of the tank for surface area, the heat loss is calculated. Note that it is assumed that the water remaining in the tank loses no heat to the environment. Heat loss from the water is used to raise the gas temperature and replace the mass loss due to condensation on the walls through evaporation.

$Q_c = (0.61*257.6 + .08*50.3)*(135 - 95) = 7250$ BTU/HR

The radiant temperature factor from Table 5-25 (Ref. 4.3) is taken to be 1.2 for a 95° wall temperature and a 135° tank temperature. Assuming a view factor of 1 and an emissivity of 0.8 for the tank and the walls the radiant heat transfer is:

$\mathfrak{F}_{1-2} = 1/(1/.8 + 1/.8-1) = 0.67$ Reference 4.3 pg 227

$h_r = 1.2 * 0.67 = 0.8$ Reference 4.3 pg 230

Therefore $Q_r = 0.8 * (257.6 + 50.3) * (135-95) = 9850$ BTU/HR

5.0 CALCULATIONS Cont'd:

The total heat removed from the tank by convection and radiation from the tank walls to the room is:

$$Q = 7250 + 9850 = 17100 \text{ BTU/HR}$$

Calculation of heat loss from the water to the hydrogen gas as the level drops and the gas expands.

The gas would normally cool as it expands in an adiabatic fashion assuming the level drop were fast. However the level in the tank drops slowly and the heat transfer from the water surface to the gas keeps the gas in thermal equilibrium with the water. The calculation below is an attempt to quantify the energy loss from the water as the gas expands from it's initial pressure to it's final state in the tank (assumed to be bottom dished head).

Assuming the gas behaves as an isentropic (closed) system the total energy lost due to expansion can be calculated as follows:

$$T_2/T_1 = (V_1/V_2)^{(k-1)}$$ Reference 4.4 4-18

Where;
- T = initial and final temperatures
- V = initial and final volumes
- k = 1.41 isentropic exponent for hydrogen

The energy loss for a closed system is:

$$u_2 - u_1 \approx h_2 - h_1 = c_v \ (T_2 - T_1)$$

Where;
- c_v = specific heat = 2.43 BTU/LBM-°R Reference 4.3

The initial gas volume is	333.586	ft^3
The total tank volume is	603.669	ft^3
The dished head volume	48.234	ft^3

$$T_2/T_1 = (333.586/535.435)^{(1.41-1)} = 0.8237$$

Assuming an initial temperature of 135°F the final temperature is:

$$T_2 = 0.8237\ (135 + 460) = 490\ °R\ (30°F)$$

5.0 CALCULATIONS Cont'd:

Note that this temperature is never achieved due to heat transfer from the vessel and the water. However the temperature difference between the water and the gas may be used to determine the enthalpy change in the gas. The enthalpy change is made up by heat transfer from the water.

$h_2 - h_1 = c_v\ (T_2 - T_1) = 2.43 * (135 - 30) = 355$ BTU/Lbm of hydrogen

The initial hydrogen inventory is calculated below using the perfect gas law:

PV = mRT therefore m = PV/RT, R = 767 ft-lbf/lbm-R for H_2:

Initial tank pressure is 13.2 psig References 4.8 & 4.9
The initial gas pressure is 13.2 psig - 2.5375 psig
2.5375 psig = vapor pressue at 135°F Reference 4.6
$P_{H2} = 13.2 - 2.54 = 10.66$ psig

$M = (10.66+14.696)\text{psi}*333.59\text{ft}^3*144\text{in}^2/\text{ft}^2/(767\text{ft-lbf/lbm-R} *595\text{R})$
m = 2.669 lbm

The energy required to replace that lost due to expansion is:

Q = 355 BTU/LBM * 2.669 LBM = 947 BTU

The heat loss due to the expansion of hydrogen is much less than that lost due to heat transfer from the tank to the room.

The total heat lost from the water conservatively assuming tank drawdown occurs in 30 minutes is;

Q = 947BTU + 17100BTU/HR * 0.5 HR = 9497 BTU

It is assumed this heat is lost from the top portion of the liquid level in the tank. Therefore the total heat loss is averaged over the volume of fluid remaining in the bottom head.

Change in H_2O enthalpy is 9497BTU/(48.234 ft^3*61.46Lbm/ft^3)
$\Delta h = 3.20$ BTU/LBM

The initial H_2O enthalpy is 102.95 BTU/LBM (at 135 °F)

5.0 CALCULATIONS Cont'd:

The final enthalpy of the water remaining in the tank is

102.95 - 3.20 = 99.75 BTU/LBM

From the steam tables(Reference 4.6) the final water temperature is 131.7°F. At this temperature the vapor pressure is 2.32 psia.

The initial vapor pressure is 2.5375 psia.

Therefore the vapor pressure drop is approximately 0.2 psia. If the tank were completely empty the vapor pressure would eventually drop to room temperature or approximately 0.95 psia. Therefore the vapor pressure drop calculated above, due to heat transfer from the tank to the environment and expansion of the hydrogen gas is a conservative estimate of the expected decrease in vapor pressure.

The primary assumption that effects these results is that the heat loss from the water occurs from the top level of the water. Once the water leaves the tank the pressure in the tank would drop to approximately 0.95 psia since condensation from the gas/vapor space would not be replaced by the boil off or evaporation of the water in the tank. The results are appropriate due to the other conservative assumptions used in the calculation. These are:

1. No heat transfer from the bottom head to the environment.
2. Water is assumed fully mixed and isothermal.
3. No credit taken for pump heat which tends to raise the initial temperature in the tank before the letdown flow and pump recirculation are isolated.
4. The total tank surface area calculated does not take into account the dished head geometry.
5. The gas/vapor region is assumed saturated at all times.
6. MUT-1 drawdown occurs in a period of greater than 30 minutes (Reference 4.1).

6.0 RESULTS/CONCLUSIONS:

The vapor pressure in the vapor space can conservatively be assumed to be initially at 2.54 psia. As the tank is drawn down the vapor pressure decreases linearly to 2.34 psia.