

**Florida
Power**
CORPORATION

October 17, 1979

File: 3-0-3-a-3

Mr. D. F. Ross, Jr.
Director
Bulletins & Orders Task Force
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Crystal River Unit 3
Docket No. 50-302
Operating License No. DPR-72

Dear Mr. Ross:

Enclosed is Florida Power Corporation's interim response to Items 3A and 3B of Attachment A to your August 21, 1979 letter. This response addresses the sources and effect on natural circulation of noncondensable gases following a small break LOCA.

The final response to Items 3A, B, C, and D are nearing completion by B&W and will be submitted as soon as possible.

Very truly yours,

FLORIDA POWER CORPORATION

W. P. Stewart
Manager
Nuclear Operations

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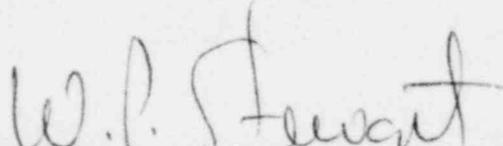
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STATE OF FLORIDA

COUNTY OF PINELLAS

W. P. Stewart states that he is the Manager, Nuclear Operations, of Florida Power Corporation; that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission the information attached hereto; and that all such statements made and matters set forth therein are true and correct to the best of his knowledge, information and belief.



W. P. Stewart

Subscribed and sworn to before me, a Notary Public in and for the State and County above named, this 17th day of October, 1979.



Notary Public

Notary Public, State of Florida at Large,
My Commission Expires: August 8, 1983

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NONCONDENSIBLE GASES

There are two possible ways in which the release of noncondensable gases in the primary system could interfere with the condensation heat transfer processes which occur in the steam generator during small loss of coolant accidents. If noncondensable gases filled the U bend at the top of the hot leg, then water vapor would have to diffuse through the noncondensable gases before they could be condensed in the steam generator. This would be a very slow process and would effectively inhibit natural circulation. Lesser amounts of noncondensibles would reduce the heat transfer by condensation because the vapor would have to diffuse through the noncondensibles to get to the condensate on the tubes.

Table 1 lists the potential sources and amounts of noncondensable gases for a 177 fuel assembly plant. However, most of these gases would not be released for small break transients. Appendix K evaluations performed for the 177FA plants demonstrate that cladding temperatures remain low and no cladding rupture nor metal water reaction occur. Thus, these sources can be neglected. Also, the steam generator is a heat sink only if primary system pressure is above ≈ 1050 psia. Therefore, gases present in the core flooding tank can be neglected in addressing the effect of noncondensable on SG condensation. The only sources of noncondensibles which might separate in the RCS are the gases dissolved in the coolant, the gases in the pressurizer, gases in the makeup and borated water storage tank and gases released from an allowed 1% failed fuel in the core. Thus, the maximum amount of noncondensable gases in the system, assuming all gas comes out of solution, no noncondensibles are lost through the break flow, that there was one percent failed fuel, and the injection of 6.4×10^4 lbm from the makeup tank and BWST (typical of ≈ 1500 sec of HPI), would be:

Dissolved in coolant	563 scf
In pressurizer	166
Fission gas	2
Fuel rod fill gas	11
MU tank	24
BWST	14
	780
Total	780 scf

This gas would occupy a volume of 21.4 ft^3 at a pressure of 1050 psia, the lowest pressure condition in the primary system for which condensation heat removal will occur. It should be noted that the assumed integrated injection flow does not have a significant effect on the total volume of noncondensibles which might be present in the primary system. Since the volume required to completely fill the U-bend in the hot leg is 125 ft^3 , the noncondensable gases will not impede the flow of vapor to the steam generator.

The heat transfer during condensation is made up of the sensible heat transferred through the diffusion layer and the latent heat released due to condensation of the vapor reaching the interface (see Figure 1). The model of Colburn and Hougen(1) gives the following equation for the heat transfer in the vapor phase:

$$\phi = hg(Tg_o - Tg_i) + Kg Mg h_{fg}(Pg_o - Pg_i) \quad (1)$$

where

ϕ = condensation heat flux, btu/hr ft²

hg = heat transfer coefficient for vapor layer, Btu/hr ft² °F

Tg_o = bulk temperature, °F

Tg_i = temperature of interface, °F

Kg = mass transfer coefficient, $\frac{lb \text{ mole}}{lb_f \text{ hr}}$

Mg = molecular weight, lbm/lb mole

h_{fg} = latent heat of vaporization, Btu/lbm

Pg_o = partial pressure of vapor at bulk conditions, $\frac{lb_f}{ft^2}$

Pg_i = partial pressure of vapor at the interface,

$$\frac{lb_f}{ft^2}$$

$$Kg = \frac{1.02 D}{z RT} \left(\frac{g z^3 \rho \left(\frac{\rho_o}{\rho_i} - 1 \right)}{\mu D} \right)^{.373} \quad p/pam$$

D = diffusion coefficient, ft²/hr

z = height

R = gas constant, $1545 \frac{lb_f \text{ ft}}{lb \text{ mole } ^\circ R}$

T = absolute temperature at bulk conditions, °R

g = acceleration of gravity, ft/hr²

ρ = density, lbm/ft³

ρ_o = density at bulk conditions, lbm/ft³

ρ_i = density at interface conditions, lbm/ft³

μ = viscosity, lbm/hr ft

$$pam = \frac{p_{ai} - p_{ao}}{\ln \frac{p_{ai}}{p_{ao}}}$$

p_{ai} = partial pressure of gas at interface, $\frac{lb_f}{ft^2}$

p_{ao} = partial pressure of gas at bulk conditions, $\frac{lb_f}{ft^2}$

For the application to OTSG condensing heat transfer during small break transients, the term $hg(T_{g0} - T_{gi})$ can conservatively be neglected since the vapor velocities would be very low. Thus,

$$\phi = K_g M_g h_{fg}(P_{g0} - P_{gi}). \quad (2)$$

The heat transfer with noncondensable gases present is obtained by iteration. An interface temperature T_{gi} is assumed, which fixes P_{gi} , and the heat transfer across the liquid condensate film is computed from

$$\phi = h_f(T_{gi} - T_w) \quad (3)$$

where

$$h_f = .943 \left(\frac{\rho_f(\rho_f - \rho_g)g h_{fg} k_f^3}{\mu_f z(T_{gi} - T_w)} \right)^{1/4}$$

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- ρ_f = density of fluid, lbm/ft³
- ρ_g = density of vapor, lbm/ft³
- k_f = thermal conductivity of fluid, Btu/hr ft °F
- T_w = wall temperature, °F

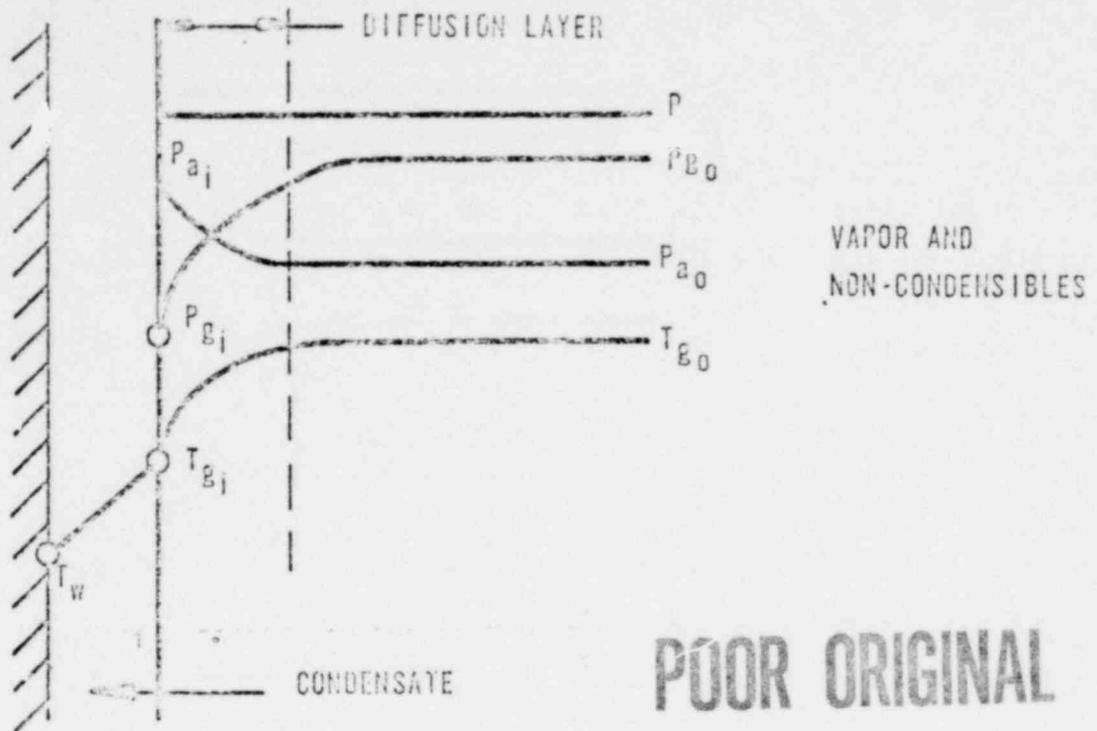
The partial pressure of the gas at the bulk conditions can be calculated from the mole fraction of noncondensable gases. When the heat flux computed from equation 2 matches that computed by equation 3, the proper interface temperature has been found.

The impact of noncondensibles on the condensation heat transfer process during a small break was examined for the 0.04 ft² and 0.01 ft² cold leg breaks analyzed for the 177-FA plants. The breaks utilize the SG for heat removal for a significant portion of the transient. Hand calculations were performed, using the theory presented above, to ascertain the effect of non-condensibles on the transient.

The amount of noncondensable gases, assuming that all gases come out of solution, would be 2.61 moles. The effect of these gases is to raise the pressure and primary temperature to obtain the same heat transfer. Assuming that the noncondensibles accumulated only within the steam generator upper plenums and the steam generator tubes, the system pressure increase, due to noncondensibles, would only be 25 psi, for a 0.04 ft² break, and 40 psi, for a 0.01 ft² break. It should be noted that this effect is predominantly due to the inclusion of the partial pressure of the noncondensibles, which is 24 psi for the 0.04 ft² break and 34 psi for the 0.01 ft² break, in the total system pressure. These calculations represent the maximum impact as they were computed at the time of maximum condensation heat flux for the respective cases.

As shown, the influence of noncondensibles does not significantly effect the condensation heat transfer process. The estimates made are conservative in that they assumed all the gas is located in the steam generators (none is in the top of the reactor vessel or pressurizer) and no gases escape through the break. Thus, the presence of noncondensable gases in the system should not significantly affect the small break transient.

FIGURE 1



- P = TOTAL PRESSURE
- P_{a_i} = PARTIAL PRESSURE OF GAS AT INTERFACE, lb_f/ft^2
- P_{a_0} = PARTIAL PRESSURE OF GAS AT BULK CONDITIONS, lb_f/ft^2
- P_{g_i} = PARTIAL PRESSURE OF VAPOR AT INTERFACE, lb_f/ft^2
- P_{g_0} = PARTIAL PRESSURE OF VAPOR AT BULK CONDITIONS, lb_f/ft^2
- T_w = WALL TEMPERATURE, °F
- T_{g_i} = TEMPERATURE AT INTERFACE, °F
- T_{g_0} = BULK TEMPERATURE, °F

REFERENCE: 1) COLBURN, A.P. AND HOUGEN, D. W., "DESIGN OF COOLER CONDENSERS FOR MIXTURES OF VAPORS WITH NONCONDENSING GASES", IND. ENG. CHEM. 26(11), 1934.

TABLE 1

SOURCES OF NONCONDENSIBLES - 177 FA PLANT

Source	Gas	Total available				1% FAILED FUEL				1% METAL-WATER REACTION			
		Total Volume scf	Individual Gas Volumes sc ^e	Total Mass lb.	Individual Gas Masses lb.	Total Vol. scf	Ind. Gas Vol. scf	Total Mass lb.	Individual Gas Masses lb.	Total Vol. scf	Ind. Gas Vol. scf	Total Mass lb.	Individual Gas Masses lb.
Dissolved in reactor coolant	H ₂ & N ₂	563	H ₂ - 305 N ₂ - 158	14	H ₂ - 1.7 N ₂ - 12.3								
Pressurizer steam space	H ₂ & N ₂	136	H ₂ - 65 N ₂ - 71	5.9	H ₂ - 0.4 N ₂ - 5.5								
Pressurizer water space	H ₂ & N ₂	30	H ₂ - 20 N ₂ - 10	0.91	H ₂ - 0.11 N ₂ - 0.8								
Fission gases in core	Kr & Xe	186	Kr - 20 Xe - 166	65.5	Kr - 4.8 Xe - 60.7	1.9	Kr - 0.2 Xe - 1.7	0.66	Kr - 0.05 Xe - 0.61	1.9			
Fuel rod fill gas	He & some N ₂ & O ₂	1133	He - 1092 N ₂ - 32 O ₂ - 9	14.8	He - 11.5 N ₂ - 2.8 O ₂ - 0.8	11.3	He - 10.9 N ₂ - 0.3 O ₂ - 0.1	0.15	He - 0.12 N ₂ - 0.03 O ₂ - 0.01	11.3			
Metal water reaction (100%)	H ₂	416,500	-	2320	-					4165	-	23.2	-
MU tank gas space	H ₂ & N ₂	726	H ₂ - 421 N ₂ - 305	26.1	H ₂ - 2.3 N ₂ - 23.8								
MU tank water space	H ₂ & N ₂	24	H ₂ - 16 N ₂ - 8	0.71	H ₂ - 0.09 N ₂ - 0.62								
BWST	Air (N ₂ & O ₂)	1383	N ₂ - 902 O ₂ - 481	121.2	N ₂ - 70.3 O ₂ - 50.9								
CF tank gas space (two tanks)	N ₂	26,248	-	2047	-								
CF tank water space (two tanks)	N ₂	964	-	75	-								

Assumptions

1. RCS contains 40 std. cc H₂/Kg water & 20 std. cc N₂/Kg water, with water volume = 10,690 ft³ at 583F and 2200 psia.
2. Pressurizer water contains 40 std. cc H₂/Kg water & 20 std. cc N₂/Kg water with Henry's Law relation between water space and steam space at 650F. Water volume = 825 ft³ and steam volume = 716 ft³
3. Fission gases based on inventory in core at 292 EFPD.
4. Fuel rod gas based on each rod containing 0.0375 gmol He, 0.0011 gmol N₂ and 0.00029 gmol/O₂.
5. Metal-water reaction based on 52,000 lb. Zr cladding.
6. MU tank values based on tank containing 200 ft³ gas space and 400 ft³ water space at 120F with the water containing 40 std. cc H₂/Kg and 20 std. cc N₂/Kg with Henry's Law relationship between gases in water and in gas space.
7. BWST contains 450,000 gallons of water saturated with air, i.e., 15 std. cc N₂/Kg and 8 std. cc O₂/Kg.
8. Each CF tank contains 1040 ft³ water and 370 ft³ gas space with 600 psig N₂ at 120F with Henry's Law relation between water and gas.
9. Values for 1% failed fuel based on Xe and Kr fission product inventory and fuel rod fill gas (He) in 1% of fuel rods being released to coolant.
10. Values for 1% metal-water reaction based on gases in Item 9 above and H₂ released from 1% of Zr cladding (520 lb.) reacting with coolant.

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