*NRC RAI 18:*

*The October 23, 2008, supplemental response identified on page 59 that the assumptions made about the settling of particulate down to 100 microns in size were benchmarked against NRC-sponsored settling tests. Please identify the NRC-sponsored tests being referenced in this discussion.*

WF3 Response 18:

The "NRC-sponsored settling tests" is referring to NUREG/CR-6916, titled "Hydraulic Transport of Coating Debris", Naval Surface Warfare Center, Carderock Division. The particulate settling size for the various materials is based on a force balance that accounts for hydraulic drag, gravity, and hydrostatic forces as prescribed in WCAP-16406-P. The developed relationship is compared (benchmarked) to the data in NUREG/CR-6916 Table 3-2 to demonstrate that the relationship produces conservative results. The data from NUREG/CR-6916 was not used as a basis for any materials settling size or depletion determination. Particulate settling is only analyzed to occur in the reactor lower plenum.

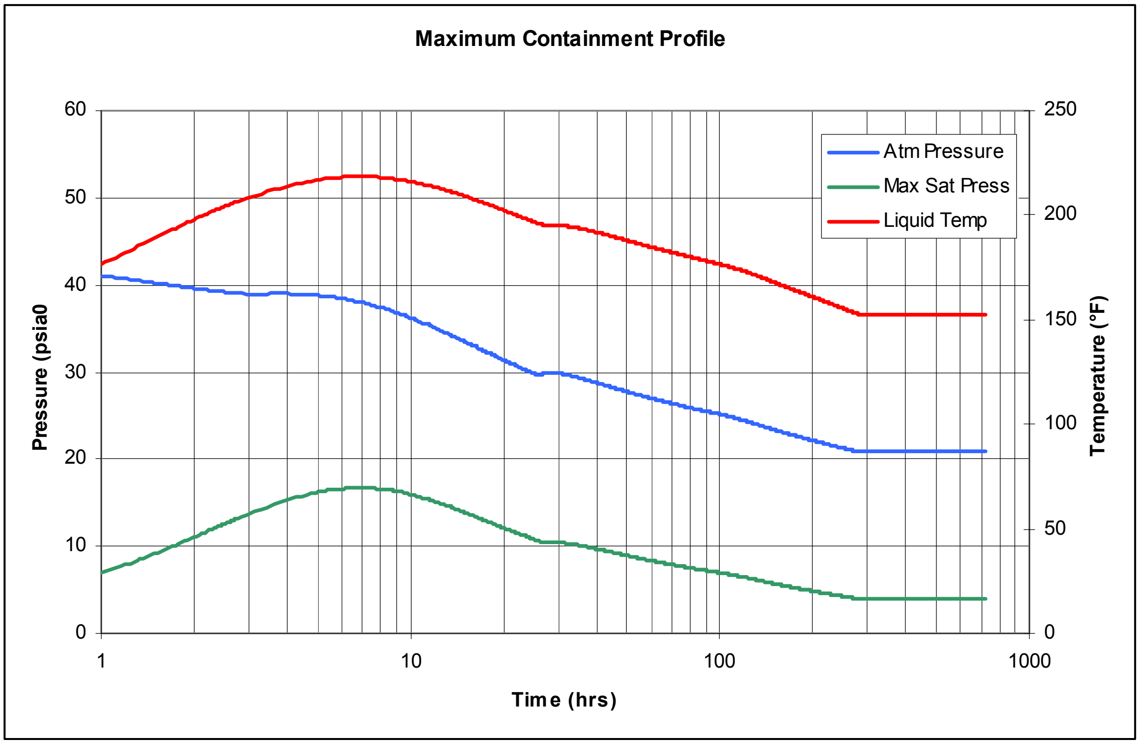
*NRC RAI 33:*

*The supplemental response dated October 23, 2008, stated that flashing at the strainer would not occur because the strainer submergence is 8 inches and the maximum head loss is about 6 inches. This is true for a large-break LOCA, but does not address a small-break LOCA, which has a bounding submergence of about 2 inches. Please provide an evaluation for flashing during a small-break LOCA at the most limiting condition. This may require an evaluation of head loss versus submergence over time or credit for accident-generated pressure.*

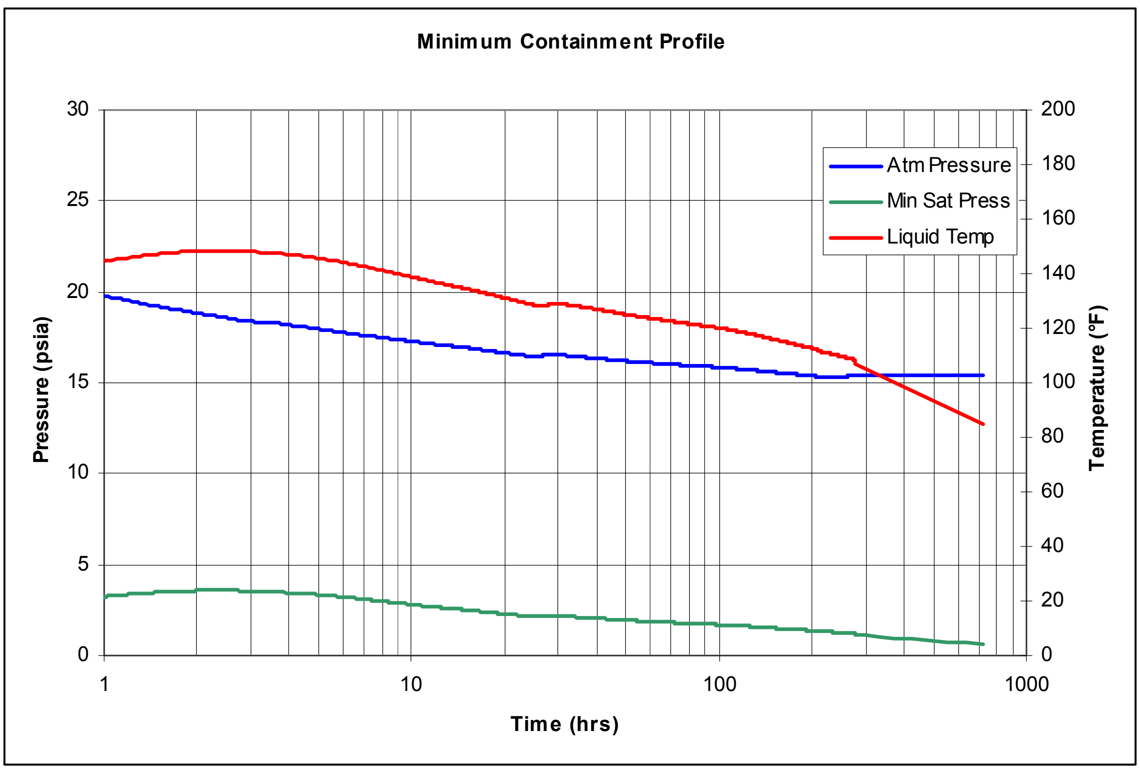
WF3 Response 33:

Credit for 1 psi of containment overpressure will provide > 2 ft flashing margin when submergence is less than the bounding head loss. Sump temperature will exceed 210 degrees Fahrenheit for only ~11 hrs during the event and the time to reach 210 degrees post Recirculation Actuation Signal is ~2.2 hrs. The maximum temperature profile is based on; (1) 1 of 2 Containment Spray Trains operating, (2) 1 of 4 Containment Fan Coolers operating, and (3) minimum Safety Injection flow. Waterford 3 Technical Specifications require containment pressure to be maintained between 14.275 psia and about 1 psig (27 inches water).

When expected containment pressure is compared to the saturation pressure of the sump fluid throughout the duration of an event it can be seen that adequate margin exists to support the 1 psi overpressure credit. Two cases are presented below. The first graph shows the comparison for the maximum sump temperature evaluation. The second shows the comparison for the minimum sump temperature evaluation.



Maximum Containment Profile
Atm Pressure
Max Sat Press
Liquid Temp
Pressure (psia0
Temperature (°F)
Time (hrs)
0
10
20
30
40
50
60
0
50
100
150
200
250
1
10
100
1000

Minimum Containment Profile
Atm Pressure
Min Sat Press
Liquid Temp
Pressure (psia)
Temperature (°F)
Time (hrs)
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160
180
200
1
10
100
1000

*NRC RAI 33a:*

*Please provide an evaluation of gas evolution downstream of the strainer that could reach the pump suction. Please provide the percentage of evolved gas estimated at the pump inlet. Evaluate the effects of any potential gas ingestion to the pumps taking suction from the sump as described in RG 1.82, Appendix A. The staff is concerned that any gasses that are stripped from the fluid as it passes through the strainer could collect within the strainer and eventually transport to the pump suction as larger air pockets. In addition, the staff has not received information that would characterize the redissolution of air or gas as the static head on the fluid increases as it flows to the pumps suction. If re-dissolution of air is credited, please provide an evaluation of the variables that could affect the redissolution.*

WF3 Response 33a:

The solubility of air in water is a maximum at the lowest temperature of interest. The table of dissolved air in water at 25 °C clearly shows that the solubility is proportional to absolute pressure. The difference of solubility is 0.023 g Air / kg Water per one atm. A conservatively bounding pressure difference across the strainer of 2.5 ft (0.07 atm) is used in this analysis.

Assuming conservatively that the water entering the strainer is fully saturated with air, the bounding difference of solubility of air in water is:

0.07 * 0.023 = 0.00169 g Air / kg Water or 1.69E-6 kg Air / kg Water

| Dissolved Air in Water (25 °C)(77 °F) | | | | | | |
|---|---|---|---|---|---|---|
| Gauge Pressure (atm) | 0 | 1 | 2 | 3 | 4 | 5 |
| Dissolved Air (g/kg) | 0.023 | 0.045 | 0.068 | 0.091 | 0.114 | 0.136 |

The densities are:

Air – 1.169 kg/m3 at 25 °C and one atm
Water – 997 kg/m3 at 25 °C

The volume ratio therefore becomes;

(1.69E-6 kg Air / kg Water) * (997 kg/m3) / (1.169 kg/m3) = 0.0014 or 0.14%

As the flow stream leaves the sump it travels downward where it experiences an increase in pressure due to the elevation difference (~30 ft). This increase in pressure would promote some of the air re-dissolving back into the water and void size reduction due to compression. Conservatively neglecting the re-dissolution of air and using the ideal gas law to evaluate the void compression, the 0.14% void fraction equates to a 0.07% void fraction at the pump suction.

$P_1V_1 = P_2V_2$; therefore $V_2 = P_1V_1/P_2$
$P_1$ = 14.7 psia * 2.31 ft/psi = 34 ft
$P_2 = P_1$ + 30 ft = 64 ft
$V_2$ = 0.14% * 34 ft / 64 ft = 0.07%

Using the relationship from Regulatory Guide 1.82, it can be seen that the 0.07% void fraction will have a negligible effect (<1 ft) on pump required net positive suction head.

$NPSH_{required'} = NPSH_{required} * (1+0.5*\alpha)$ where $\alpha$ is the air ingestion rate in percent by volume
Highest $NPSH_{required}$ for any ECCS pump operating at runout conditions is 21.765 ft

21.765 ft * (1 + 0.5 * 0.07%) = 22.527 ft or an increase of 0.762 ft