TASK CLOSE OUT DOCUMENT

Task Scope: CHECK SHRINKAGE CALCULATIONS FOR INPUT TO EMERGENCY PROCEDURE 32

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Task No. 40 Date Complete 5/2/79

Reason felt task is complete:
Calculations complete and pressure water levels recommended.

Members of Committee

[Signatures]

Signed Committee Leader
REVIEW OF SHRINKAGE CALCULATIONS

Fred Sears who is revising Emergency Procedure 32 requested that I recheck the shrinkage calculations for a sudden cooling of the primary system from near saturation conditions. The calculations are attached.

The conclusion is that if the system heats to near saturation conditions water level can be prevented from dropping below the heater even if the total system final temperature is 100°F -- which is extremely conservative.

<table>
<thead>
<tr>
<th>Pressure of Primary System</th>
<th>Saturation Temp</th>
<th>Specific Volume</th>
<th>Shrinkage Level</th>
<th>Water Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 psi</td>
<td>532°F</td>
<td>0.0223</td>
<td>~325&quot;</td>
<td>72&quot;</td>
</tr>
<tr>
<td>600 psi</td>
<td>467°F</td>
<td>0.01975</td>
<td>~250&quot;</td>
<td>72&quot;</td>
</tr>
<tr>
<td>100°F</td>
<td>0.01613</td>
<td></td>
<td></td>
<td>325&quot;</td>
</tr>
</tbody>
</table>

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Review of Shrinkage Calculations

To assume core heated to 532°F when pour terminated

\[ \text{Mass} = K = \frac{V_1}{N_1} = \frac{V_2}{N_2} \]  
\[ (1) = 532^\circ F \text{ initial core temp} \]
\[ (2) = 230^\circ F \text{ final system temp} \]

\[ V_2 = \frac{V_2}{V_1} \]
\[ V_2 = 4000 \text{ft}^3 \text{ of core} \]
\[ N_1 = 0.2123 \quad N_2 = 0.016849 \]

\[ V_2 = \frac{0.016849 (4000)}{0.2123} \]
\[ V_2 = 3.174 \]

\[ V_1 - V_2 = 826 \text{ ft shrinkage} (7.4\%) = 6178 \text{ gal} \]

Pressurizer volume
24 gal/in
\[ 6178 \text{ gal} = 260'' \text{ shrinkage} \]

To assume initial pouring system temperature

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II. Assume final priming system temperature is 100°F

\[ V_{100} = 0.016130 \]
\[ V_2 = \frac{0.016130 (4000)}{0.2123} = 30.39 \]
\[ \Delta V = 964 \text{ gal} \]
\[
\frac{96 \text{ ft}^3 \times 7.48 \text{ gal/ft}^3}{24 \text{ gal/min}} = 300 \text{" shrinkage}
\]

**III: Volume Calculation**

- Vessel volume at 532°F: 100,000 ft³
- 0.75% primary side at 125°F
- Cold leg: 125°F
- Hot leg: 250°F

Ignored pressure volume

Vessel Volume Shrinkage = 96 ft³ × 300" shrinkage

Cold leg
\[ΔV = 5000 \left(1 - \frac{0.0163}{0.01225}\right) = 30 \text{ ft}^3\]

\[Δh = \frac{ΔV \times 7.48}{24} = \frac{30 \times 7.48}{24} = 9"\]

Hot leg
\[ΔV = 1000 \left(1 - \frac{0.0163}{0.01700}\right) = 52 \text{ ft}^3\]

Total Shrinkage = \[52 + 30 = 84\]

\[Δh = \frac{52}{7.48} x 7.48 = 16"\]

Total Shrinkage = 325" for final temp 100°F

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\[7.48 \text{ gal/ft}^3\]

24 gal/min
IV. Assume final temp is 125°F

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Initial Temp</th>
<th>Final Temp</th>
<th>Vol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold leg + 0.5% Brine</td>
<td>532</td>
<td>125°F</td>
<td>4000</td>
</tr>
<tr>
<td>Hot leg</td>
<td>250</td>
<td>1000</td>
<td>5000</td>
</tr>
</tbody>
</table>

\[ \Delta h = V_i \left(1 - \frac{V_i}{V_f}\right) \left(\frac{7.48}{24}\right) = 31V_i \left(1 - \frac{V_i}{V_f}\right) \]

\[ \Delta h = 4000(31)\left(1 - \frac{0.01625}{0.0243}\right) = 2.92'' \]

Cold leg \( \Delta h = 5000 \left(1 - \frac{0.01625}{0.01625}\right) \cdot 0.31 = 11'' \)

Hot leg \( \Delta h = 1000 \left(1 - \frac{0.01625}{0.01700}\right) \cdot 0.31 = 14'' \)

Total shrinkage for final temp 125°F = 317''

V. Dropping pressure from 9000 to 5000 psi will change the saturation temperature and specific volume from 532°F & 0.02123 ft³/lbm to 469°F and 0.01975. This will reduce the shrinkage by about 24% to \( \approx 2.55'' \)

\[ (1 - 0.01975) = 0.240 \quad (1 - 0.01625) = 0.873 \]
At 500 psig even if the vessel inventory is raised to saturation (assuming cold leg temp = 125°F and hot leg at 250°F) the total shrinkage is about 250". Even if all primary inventory is cooled to 100°F the headers will not uncover if water level is not maintained at 350" or greater. The headers are at about 70". The shrinkage from 350" would lie to 100".

**Conclusion:** Prior to restarting service pumps, farging pumps or reinitiating natural circulation assume that water level is greater than 350".