The pressurizer in problem 1 has a total volume of 1800 ft$^3$. The pressurizer level program is linear with T$_{ave}$, such that at HZP conditions, the programmed level is 33%, and at 100% power the programmed level is 66%. The reactor is initially at 100% power and executes a reduction in power to 80%. Assuming an initial primary side liquid mass inventory of 595,000 lbm (not including the pressurizer), how much mass inventory must be charged/let down to maintain the pressurizer level at its programmed value? You can assume a constant system pressure of 2250 psia, and the liquid temperature in the pressurizer is that of a saturated liquid at the system pressure. You can assume over the temperature and pressure range of interest

$$\rho_f = 37.1 \text{ lbm/ft}^3$$

$$\rho(T) = 46.2 - 0.1067 \times (T - 560) \text{ lbm/ft}^3$$

**SOLUTION**

The reduction in power will result in an outsurge from the pressurizer to compensate for the density increase in the primary. The outsurge is given by

$$\Delta M = V_{pr} \Delta \rho = \frac{M_0}{\rho_0} (\rho - \rho_0) = M_0 \left\{ \frac{\rho}{\rho_0} - 1 \right\}$$

where:

- $M_0 = 595,000$ lbm
- $\rho_0 = \rho @ T = 590 = 43 \text{ lbm/ft}^3$
- $\rho = \rho @ [T_{ave} = T_{ave} (80\%)]$

At 80% power,

$$T_{ave} = 560 + 30 \times 0.8 = 584 \text{ F}$$

such that

$$\rho(584) = 46.2 - 0.1067 \times (24) = 43.64 \text{ lbm/ft}^3$$

giving

$$\Delta M = 595,000 \left\{ \frac{43.64}{43} - 1 \right\}$$

$$= 8855.8 \text{ lbm}$$

The outsurge is related to the change in the pressurizer volume (and level) by

$$\Delta M = \rho_f \Delta V_{prz}$$
\[ \Delta V_{PRZ} = \frac{\Delta M}{\rho_f} = \frac{8855.8}{37.1} = 238.7 \text{ ft}^3 \]

Since the programmed level is linear with \( T_{ave} \) and \( T_{ave} \) is linear with power, the programmed level is linear with power, i.e.

\[ Level_{REF} = Level_0 + (Rx \ Pwr)_{REL} (Level_{100} - Level_0) \]

Since liquid volume is directly proportional to the level

\[ \Delta V_{REF} = V_{PRZ} \Delta Level_{REF} \]

\[ \Delta Level_{REF} = Level_{100} - Level_{80} \]
\[ = 0.2 \times 0.33 \]
\[ = 0.066 \]

\[ \Delta V_{REF} = V_{PRZ} \Delta Level_{REF} \]
\[ = 1800 \times 0.066 \]
\[ = 118.8 \text{ ft}^3 \]

The reference change in liquid volume is less than the outsurge due to the temperature change, implying the charging system will have to make up

\[ \Delta M_{CHG} = \rho_f [\Delta V_{PRZ} - \Delta V_{REF}] \]
\[ = 37.1 \times [238.7 - 118.8] \]
\[ = 4448.3 \text{ lbm} \]