Containment Pressurization Process

Postulated accident: release of primary or secondary coolant within the containment

- Magnitude of the peak pressure
- Time to peak peak pressure.

Final state of the water-air mixture depends on

① the initial thermodynamic state mass of the water in reactor and the air in containment

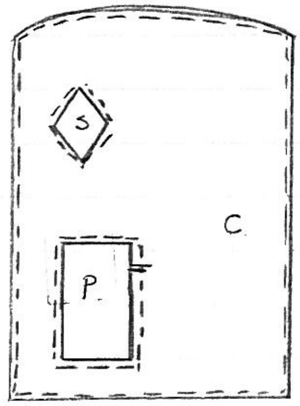
② rate of release of fluid into the containment, and heat sink and sources

③ possible exothermic reactions.

and ④ core decay heat.

Analysis of Transient Conditions

Control Volume Approach:



Break flow: $\dot{m}(t)$

First law of thermodynamics:

$$\dot{U}_{c.v} = \dot{m}(t)h_p(t) + \dot{Q}_{wpr-c} - \dot{Q}_{c-st}$$

Integrate between times 1 and 2.

$$U_2 - U_1 = +\int_1^2 h_p(t)\,\dot{m}(t)\,dt + Q_{wpr-c} - Q_{c-st}$$

Here:

$$U_2 = m_a u_{a_2} + (m_{wc_1} + m_{wpd_2})\,u_{wc_2}$$

$$U_1 = m_a u_{a_1} + m_{wc_1} u_{wc_1}$$

$$m_a u_{a_2} + (m_{wc_1} + m_{wpd_2}) u_{wc_2} = m_a u_{a_1} + m_{wa_1} + \int_1^2 h_p(t)\, \dot{m}(t)\, dt + Q_{wpr-c} - Q_{c-st}$$

$\dot{m}$ — break flow rate — from critical flow analysis

Q_{wpr-c} — heat transferred from the coolant remaining in the vessel to the containment

Q_{c-st} — heat transferred to the containment

Analysis of Final Equilibrium Pressure Conditions.

$U_2 - U_1 = Q_{n-wpr} - Q_{c-st}$ — control volume approach.

Governing Equations:

Known:

1 Initial state (designated as "1") for the primary and secondary system fluid.

2. The inital mass (m_a) and thermodynamic state of air and the relative humidity

3. The final containment condition

Energy balance:

$$m_w (u_{w_2} - u_{w_1}) + m_a c_{va} (T_2 - T_{a_1}) = Q_{n-wsys} - Q_{c-st}$$

and $m_w u_{w_1} \equiv m_{wa} u_{wa_1} + m_{wsys} u_{wsys_1}$.

$m_w u_{w_2} = (m_{wa} + m_{wsys}) u_{w_2}$

m_a — mass of air in containment

$m_w = m_{wa} + m_{wsys}$

$u = u(T, v)$ = internal energy per unit mass

u_{w_1} — internal energy of water initially in air and water initially in the failed system. ie, u_{wa_1} & u_{wsys1}

c_{va} – Specific heat of air at constant volume

T_{a_1} – initial air temperature

T_2 – final temperature

Final equilibrium pressure $p_2 = p_{w2}(T_2) + p_{a2}$

total volume $V_T = m_{w2} v_{w2}(T_2, sat) \cong m_a v_a(T_2, p_{a2})$

Each mixture occupies the total volume.

steam static quality (x_{st})

$$V_T = m_{w2}\left[v_{f2} + x_{st}\, v_{fg2}(T_2, sat)\right] \simeq \frac{m_a R_a T_2}{p_{a2}}$$

air – perfect gas.

Initial air pressure: (p_{a1}).

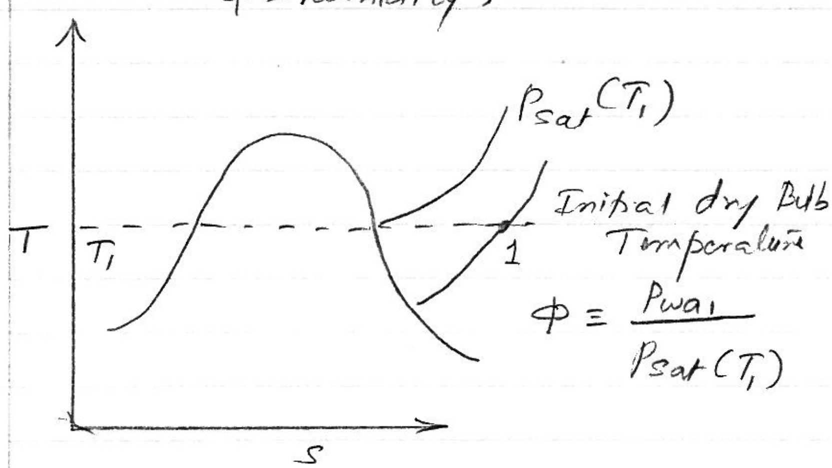
(saturated water vapor) $p_{wa_1} = \Phi\, p_{sat}(T_{a_1})$

ϕ = humidity,

$$p_{a_1} = p_1 - p_{wa_1}$$

$$m_a = \frac{p_{a_1} V_c}{R_a T_{a_1}}$$

$$p_{a_2} \simeq p_{a_1} \frac{T_2}{T_1}.$$



$$\Phi = \frac{p_{wa_1}}{p_{sat}(T_1)}$$