a) The maximum heat flux in the critical channel is related to the critical power in the core by

\[
q_{\text{max, crit}}^* = \frac{\dot{Q}_{\text{crit}}}{n\pi DH} = q_{0,\text{crit}}^* \cdot Z(z_{\text{max}})
\]

The maximum heat flux in the hot channel is related to the core thermal output by

\[
q_{\text{max, hot}}^* = \frac{\dot{Q}_{\text{hot}}}{n\pi DH} = q_{0,\text{hot}}^* \cdot Z(z_{\text{max}})
\]

giving

\[
\frac{q_{\text{max, crit}}^*}{q_{\text{max, hot}}^*} = \frac{\dot{Q}_{\text{crit}}}{\dot{Q}_{\text{hot}}} = \frac{q_{0,\text{crit}}^*}{q_{0,\text{hot}}^*} = \text{CPR}
\]

also

\[
\text{CPR} = \frac{q_{\text{crit}}^*}{q_{\text{hot}}^*} = \frac{\int_0^H Z(z)/\pi D \, dz}{\int_0^H Z(z)/\pi D \, dz} = \frac{q_{0,\text{crit}}^*}{q_{0,\text{hot}}^*}
\]

therefore

\[
\frac{q_{\text{crit}}}{q_{\text{hot}}} = \text{CPR} = \frac{q_{0,\text{hot}}^*}{q_{0,\text{hot}}^*} = \frac{\dot{Q}_{\text{crit}}}{\dot{Q}_{\text{hot}}}
\]

b) The critical quality is related to the heat flux in the critical channel and the core mass flux by

i) \[
x_{\text{crit}} = \frac{a(G,P)(H-H_o)}{H-H_o + b(G,P)} = \frac{1}{GA_h \gamma_f} \int_{H_o}^H q_{0,\text{crit}}^* Z(z)\pi D \, dz
\]

where \( H_o \) is the non boiling height and satisfies

ii) \[
GA_h \gamma_f (H_H_o) = \int_0^H q_{0,\text{hot}}^* Z(z)\pi D \, dz
\]

and \( A_s = S^2 - \pi D^2 / 4 \)

For a given CPR, the magnitude of the heat flux in the critical channel is related to the core thermal output by

\[
q_{\text{max, crit}}^* = \frac{\dot{Q}_{\text{crit}}}{n\pi DH} = q_{0,\text{crit}}^* \cdot Z(z_{\text{max}}) \frac{\dot{Q} \times \text{CPR} \times \gamma_f F_q}{n\pi DH}
\]

where \( z_{\text{max}} \) satisfies
\[ \frac{dZ}{dz} \bigg|_{z_{\text{max}}} = 0 \]

giving

\[ q_{0,\text{coll}}^* = \frac{q_{\text{max},\text{coll}}}{Z'(z_{\text{max}})} \]

Equations i) and ii) are then two equations in two unknowns which can be iteratively solved for \( H_o \) and \( G \). Alternately, Equation ii) can be solved for the mass flux

\[ G(H_o) = \int_0^{H_o} q_{0,\text{coll}}^* Z(z) \pi Ddz \]

which with equation i) is a single non linear equation in \( H_o \) which can be solved iteratively. Given \( H_o \), the mass flux is given directly by Equation iii). The core mass flow rate is then

\[ \dot{m}_c = G \times A_x \times n_{\text{rods}} \]

c) For these flow conditions, the wall temperature is obtained from the Chen correlation

\[ q'(z) = h_o(G, x, P)[T_w(z) - T_{w}(z)] + h_{w}(G, x, P, T_w(z))[T_w(z) - T_{\text{sub}}] \]

where

i) \( G = \frac{\dot{m}_x}{A_x} \)

ii) \( x(z) = \begin{cases} \frac{h(z) - h_f}{h_f} & h(z) > h_f \\ h_f & h(z) < h_f \end{cases} \)

iii) \( h(z) = h_n + \frac{n_{\text{rods}}}{\dot{m}_x \gamma_f} \int_0^z q'(z) \pi Ddz \)

iv) \( T_w(z) = T_w(h(z), P) \)

or

\[ \frac{dZ}{dz} \bigg|_{z_{\text{max}}} = 0 \]

giving

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where

i) \( G = \frac{\dot{m}_x}{A_x} \)

ii) \( x(z) = \begin{cases} \frac{h(z) - h_f}{h_f} & h(z) > h_f \\ h_f & h(z) < h_f \end{cases} \)

iii) \( h(z) = h_n + \frac{n_{\text{rods}}}{\dot{m}_x \gamma_f} \int_0^z q'(z) \pi Ddz \)

iv) \( T_w(z) = T_w(h(z), P) \)

or
The Chen correlation is than a single non linear equation in $T_w(z)$ which can be solved iteratively at any location.