1) The highest powered channel in a BWR has a heat flux profile $q^*_{\text{HOT}}(z)$ and mass flux $G_{\text{HOT}}$. A channel on the core periphery has a lower heat flux $q^*(z)$, but as a result of orificing of the inlet flow a lower mass flux $G$ also. Assuming either of these channels could be the limiting channel, give a step by step procedure, including all equations, for determining the maximum nominal full power the reactor can operate. Integrals which do not have closed form solutions can be left in integral form. For solutions involving iteration, it is sufficient to state which equation(s) are to be solved iteratively and the variable(s) to be iterated on. In addition to the above, you may assume the following information is known. You may also assume any necessary fluid and/or thermodynamic properties are available.

**Problem Parameters**

- Rod Diameter $D_o$
- Rod Pitch $S$
- Active Fuel Height $H$
- Total Bundle Length $L$
- System Pressure $P$
- Minimum CPR at Nominal Full Power $MCPR$
- Fraction of Energy Deposited in Fuel $\gamma_f$
- Fraction of core thermal power from hot channel $F_H$
- Fraction of core thermal power from periphery channel $F_P$
- Core Inlet Enthalpy $h_{in}$

2) Two thermal limits imposed on PWRs during normal operation are the maximum fuel centerline temperature remains below a given value $T_{max}$, and the minimum DNB ratio remains below a given value $MDNBR$. For the given information give a step by step procedure, including all equations, for determining the minimum core mass flux which satisfies these limits. For the purposes of this problem, you can assume the coolant enters the core highly subcooled, and at the minimum mass flux the equilibrium quality from the highest powered channel is slightly positive. Integrals which do not have closed form solutions can be left in integral form. For solutions involving iteration, it is sufficient to state which equation(s) are to be solved iteratively and the variable(s) to be iterated on. You may assume the following information is known. You may also assume any necessary fluid and/or thermodynamic properties/relations are available. You may also assume the fuel centerline temperature is a known function of the outer clad surface temperature $T_o(z) = T_o[T_{oc}(z), q^*_{\text{HOT}}(z)]$.

**Problem Parameters**

- Channel Heat Flux $q^*_{\text{HOT}}(z)$
- Fraction of Energy Deposited in Fuel $\gamma_f$
- Power Peaking Factor $F_g$
- Axial Peak to Average Ratio $F_z$
- Pressure $P$
- Number of fuel rods $n_{rods}$
- Fuel Height $H$
- Rod Diameter $D_o$
- Rod Pitch (square lattice) $S$
- Core Inlet Enthalpy $h_{in}$
20%

3) Flow in reactor systems is commonly determined by measuring the pressure drop across a calibrated venturi as illustrated below.

Derive an expression for the flow rate through the venturi in terms of the measured pressure drop and the diameters \( d_1 \) and \( d_2 \). You may assume friction and local losses can be characterized by a single constant loss coefficient \( K \) referenced to the velocity at \( d_1 \).

Note: For any parameter required in your solutions, if it is not specifically given in the problem statement, you should show how to obtain it in terms of the given parameters. In the correlations given below, you can assume the functional relationships for all “known functions” are available.
You may find all or some of the following relationships useful.

Mass

\[ A_x \frac{\partial \rho}{\partial t} + \frac{\partial G A_x}{\partial z} = 0 \]

Energy

\[ A_x \frac{\partial \mu}{\partial t} + \frac{\partial G h A_x}{\partial z} = q'(z) \]

Momentum

\[ \frac{1}{g_c} \frac{\partial G}{\partial t} + \frac{1}{g_c} \frac{1}{A_x} \frac{\partial}{\partial z} \left( \frac{G^2}{\rho} A_x \right) = -\frac{\partial P}{\partial z} \frac{f}{D_c} + \frac{G^2}{2 \rho g_c} \sum_j K_j \delta(z - z_j) \frac{G^2}{2 \rho g_c} - \rho \frac{g}{g_c} \sin \theta + \Delta P' \]

Heat Transfer Correlations

**Dittus-Boelter Correlation**

\[ \text{Nu} = 0.023 \text{Re}^{0.8} \text{Pr}^{0.4} \]

**Weisman Correlation**

\[ \text{Nu} = C(S / D) \text{Re}^{0.8} \text{Pr}^{\frac{1}{3}} \]

**Nucleate Boiling Correlation**

\[ q^* = \left( \frac{\xi(P)}{\xi(P_{sat})} \right) \times (T_u - T_{sat})^n \]

**Chen Correlation**

\[ q^* = h_{iw}(G, x, P)(T_u - T_s) + h_{NB}(G, x, P, T_u)(T_u - T_{sat}) \]

**Bergles and Rohsenow**

\[ q^*(z) = q_{FC}^*(z) \left[ 1 + \left( 1 - \frac{q_{NB}(z)}{q_{FC}*(z)} \right) \right]^{1/2} \]

\[ q^*(z_n) = 15.6P^{1.156}[T_{cw}(z_n) - T_{sat}]^{2.30 / \mu^{0.1024}} \]

Critical Heat Flux Correlations

**DNB Correlation**

\[ q_{crit}^* = q_{crit}^*(x, G, P, D_c, h_w) \]

**Critical Boiling Length**

\[ x_{crit} = \frac{a(G, P) L_{crit}}{L_{crit} + b(G, P)} \{ a(G, P) \text{ and } b(G, P) \text{ are known functions} \} \]