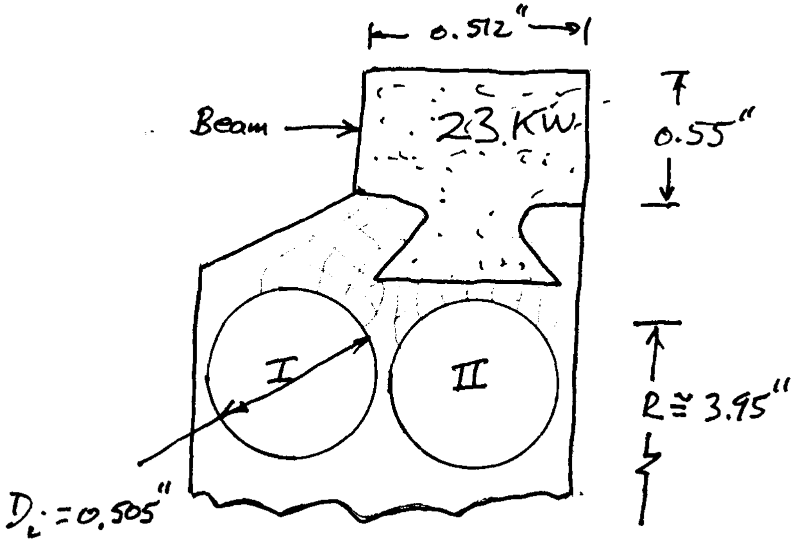
Calculations on NLC Target

(initials) 7/7/99



(1.) Only about one-half of each coil is active for heat transfer (top half)

(2.) Coil II takes perhaps about twice the heat load as coil I.

Active average heat transfer area of each coil at wetted interface:

(1.) => $A = \left(\frac{\pi D_i}{2}\right) 2\pi R = \pi^2 D_i \cdot R = \pi^2 (0.505)(3.95) = 19.7 \text{ inches}^2$

$\therefore 2A = 39.4 \text{ inches}^2$

(2.) => $q_{coil_{AVG}} = \frac{Q}{2A} = \frac{23 * 3{,}413 \ B/h}{(39.4/144)\ ft^2} = 2.87 \times 10^5 \ B/h\,ft^2$

$q_{coil_{II}} \cong 2 q_{coil_{AVG}} = 5.74 \times 10^5 \ B/h\,ft^2$ Btu/hour/ft²

$u = 9\ m/s = 29.5\ ft/s$

$\dot{V} = A_x u = \pi\left(\frac{0.2525}{12}\right)^2 29.5 = 0.0411\ \text{cfs}$

$\rho u = 62 * 29.5 * 3{,}600 = 6.6 \times 10^6\ \frac{lbs}{ft^2 h}$

$\dot{m} = \rho \dot{V} = 62(0.0411) = 2.55\ \frac{lbs}{s} = 9{,}174\ lbs/h$

$$(\Delta T)_{\text{cooling water}}\Big|_{avg} = \frac{(23/2)\,3{,}413}{(9{,}174)(1)} = 4.3\ ^\circ F = 2.4\ ^\circ C$$

$$(\Delta T)_{\text{cooling water}}\Big|_{II} \cong 2(4.3) = 8.6\ ^\circ F = 4.8\ ^\circ C$$

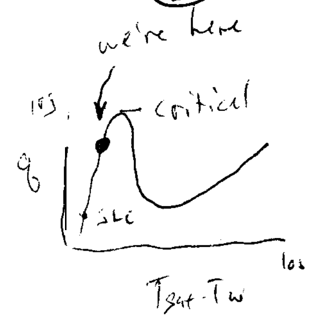
$$Re = \frac{u D_i}{\nu} = \frac{29.5 * \frac{0.505}{12}}{1.1 \times 10^{-5}} = \underline{1.13 \times 10^5}\ ;\ Pr \cong 3\ ;\ k_{H_2O} \cong 0.3\ \frac{B}{h\,ft\,^\circ F}$$

$$\frac{h D_i}{k_{H_2O}} \cong 0.023\ Re^{0.8}\ Pr^{1/3} = 366\ ;\quad h = 2{,}608\ \frac{Btu}{ft^2\,^\circ F} = 14.8\ \frac{KW}{m^2\,^\circ C}$$

Since this is lower than 17 $\frac{KW}{m^2\,^\circ C}$ reported in ZDR, Vol. I, use it for conservatism

$$\therefore\ T_w - T_{H_2O}\Big|_{max} = \frac{q_{max}}{h} = \frac{5.74 \times 10^5}{2{,}608} = 220\ ^\circ F$$

$\therefore\ T_w \cong 68.6 + 220 = 288.6\ ^\circ F > T_{sat} \cong 230\ ^\circ F$: SUBCOOLED BOILING



CHF = Critical Heat Flux (use MacBeth) High Velocity Region

$$a = 1.77\,(0.505)^{-0.553}\,(6.6)^{-0.26} = 1.58$$

$$c = 0.0166\,(0.505)^{-1.4}\,(6.6)^{-0.937} = 0.0074$$

$$\therefore \quad \frac{q_{crit}}{10^6} = \frac{1.58 + \frac{1}{4}(0.0074)(0.505)(6.6)\,(\overset{T_{sat}}{230} - \overset{T_{H_2O}}{68})}{\left[1 + (0.0074)(2\pi * 3.95)\right]} = 2.18$$

Since $q_{max} = 0.574 \times 10^6 \frac{B}{h\,ft^2} < q_{crit} = 2.18 \times 10^6 \frac{B}{h\,ft^2}$,

a crisis will not develop, but $DNBR = \frac{2.18}{0.574} = 3.8$ is not a lot of margin!

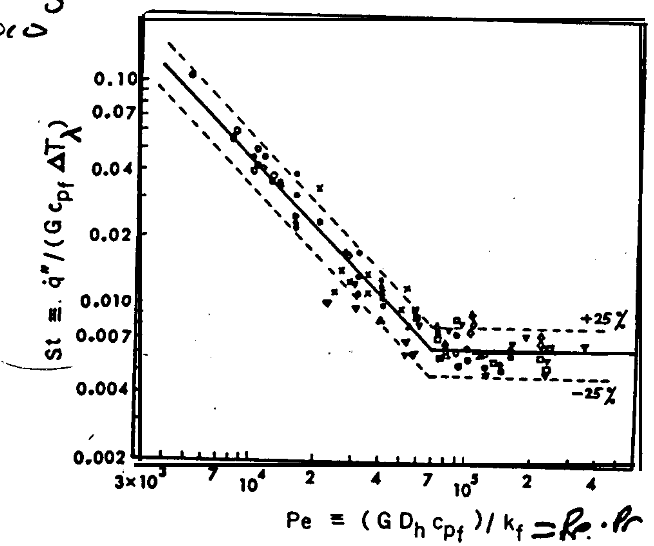
Nucleate Boiling but not film boiling

ONV = ONset of significant Voiding (Saha – Zuber)

1 pump
2 parallel water circuits
Flow oscillation can occur

$$Re \cdot Pr = (1.13 \times 10^5)\,3 = 3.4 \times 10^5 > 0.7 \times 10^5$$

$$\frac{q_{osv}}{\rho u c_p (T_{sat} - T_{H_2O})} = 0.0065$$



$$q_{osv} = 6.95 \times 10^6 \frac{B}{h\,ft^2\,°F}$$

Since $q_{max} = 0.574 \times 10^6 \frac{B}{h\,ft^2\,°F} >$ O.K.

Summary

- Subcooled boiling is likely on the outer regions of coil II
- Time-averaged heating is not large enough to cause a burnout crisis, but DNBR ≅ 3.8 is not much margin
  - Need to consider superimposed transient flux caused by beam near coils
  - Should consider better orientation of target to coils to avoid overheating either and increasing DNBR
- Two-phase flow instabilities are not likely since $q_{ONV} \gg q_{max}$. Therefore, both coils may operate in parallel using a single pump.