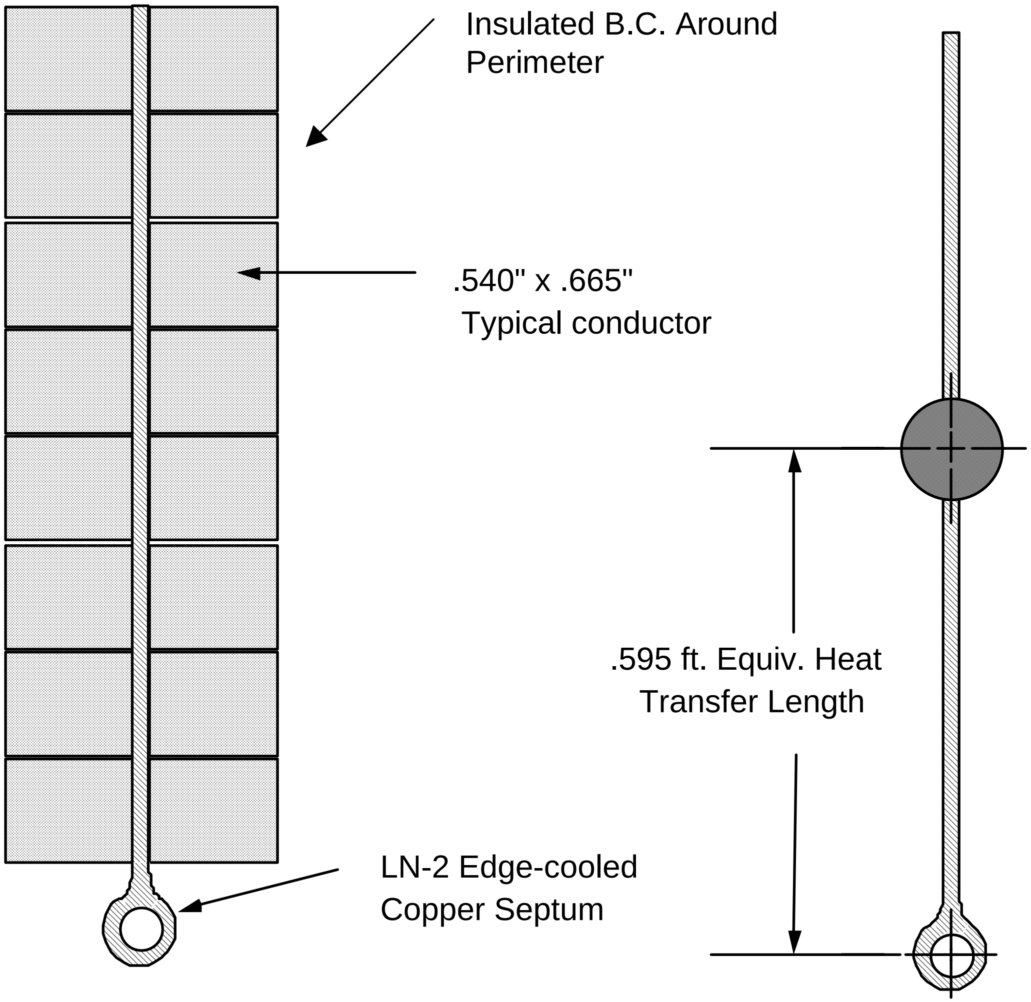
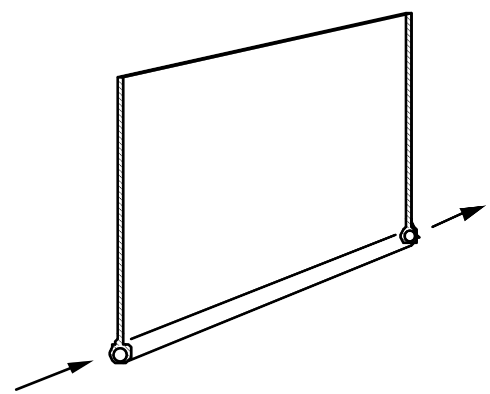
# NCSX LN2 Coil Cooling Analysis:

- Transient finite-difference code FCOOL 2.2.
- Use a “lumped Mass” to represent coil conductor.
- Use an equivalent heat transfer septum length.
- Use 13.4 kA/sq.cm. Current density.
- Use 1.2 sec. ESW, & 900 sec. Rep. Rate.
- Use a 3/8” I.D. tube, 15 ft. in length.
- Use 77 deg.K  LN2 inlet temp.
- Use 5psi pressure drop.
- Use NIST webbook parameters for LN2 coolant @250psia.
- Varied ∂P & HTL




**Model Parameters:**

| | |
|---|---|
| PRESSURE DROP: | 5.00 PSI |
| VELOCITY: | 11.07 FT./SEC. |
| FLOW RATE: | 3.81 GPM |
| MDOT: | 0.43 LBS/SEC |
| PATH LENGTH: | 15.00 FT. |
| REYNOLDS NO.: | 152103.11 |
| h-film: | 5.60 BTU/SQ.FT.-SEC.-DEG.F |
| CUR. DENSITY: | 87095.96 AMPS/SQ.IN |
| ESW: | 1.20 SEC. |
| REP. RATE: | 900.00 SEC. |
| TIME INCR.: | 0.02710 SEC |
| INLET TEMP.: | 138.00 DEG. R |
| CMASS: | 4.96 LBS |
| HTL: | 0.59500 FT. |
| NODE INTERVAL: | 0.30000 FT. |
| CPCU(TI) | 0.048800 BTU/LB-DEG.R |
| code version: | 2.20 |
| CPCU(TI) | 0.048800 BTU/LB-DEG.R |



# NCSX Finite Difference Coil Cooling Model

# Film Coefficient Calculation:

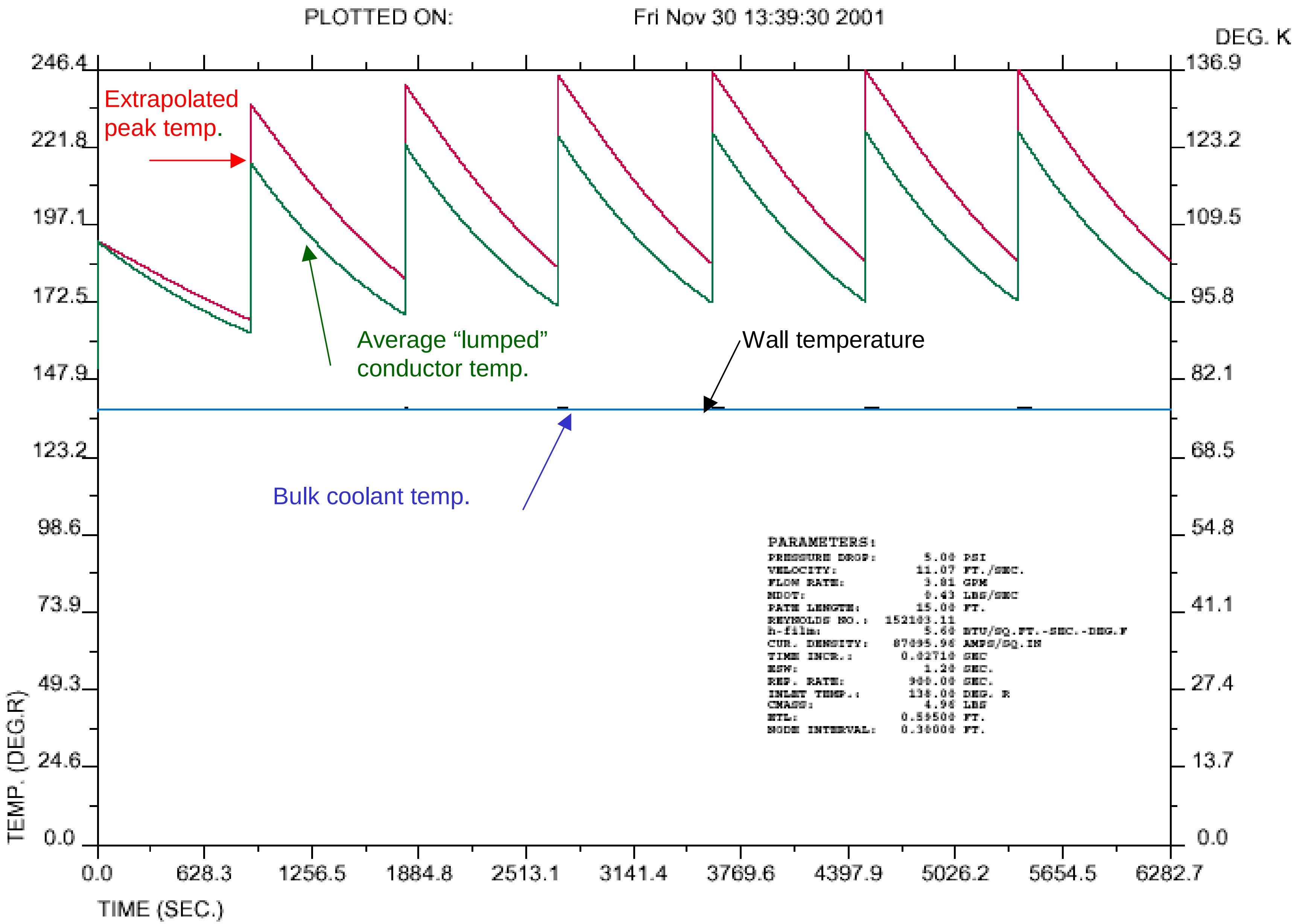
At each node, calculate a trial Nusselt Number based on a modified Ditus-Bolter expression (per Sieder-Tate) to account for the variation in viscosity across the boundary-layer,

$$Nu = C \bullet (Rey)^{0.8} (Pr)^{0.33} (\mu_b/\mu_w)^{0.14}$$

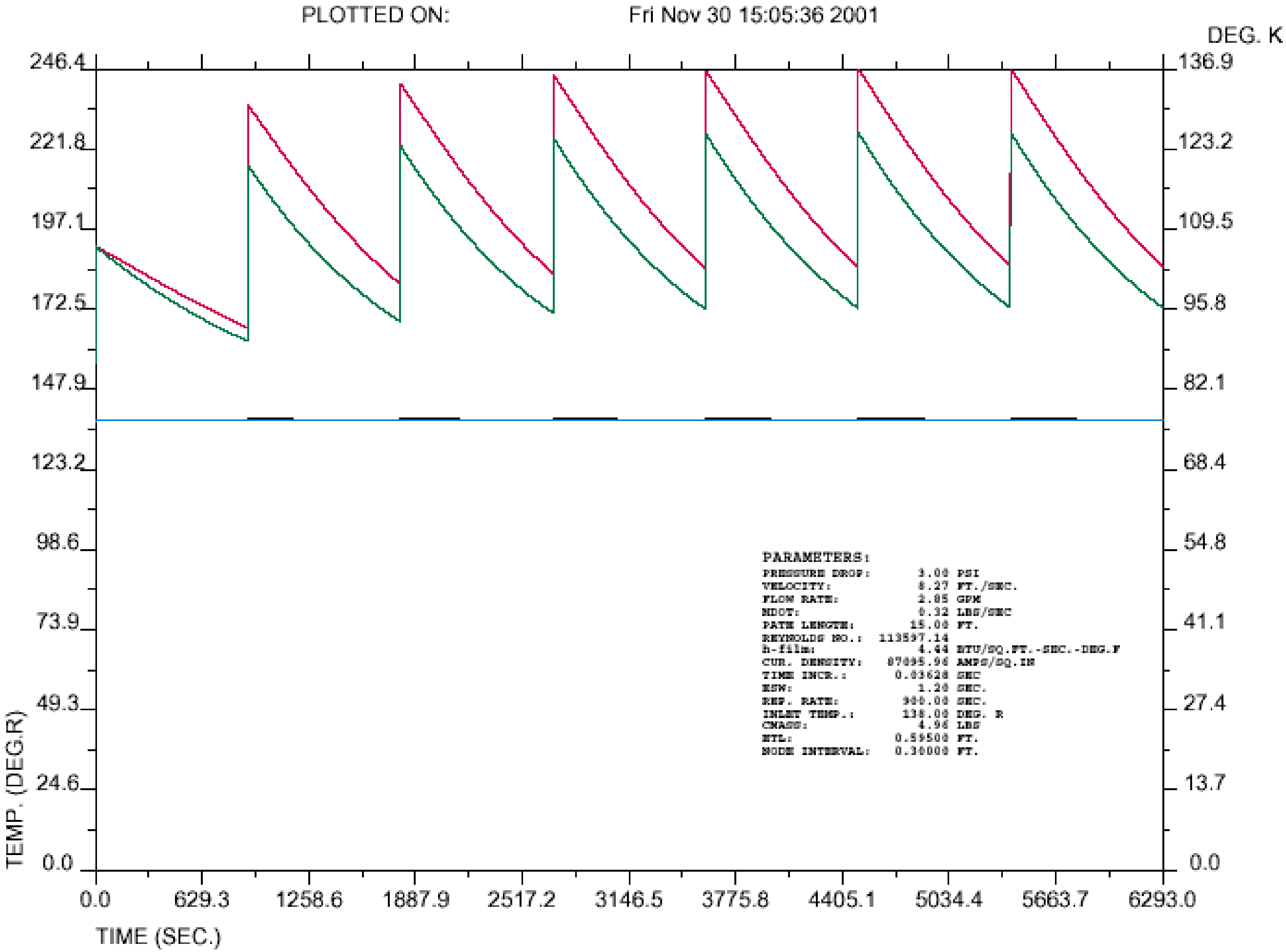
using an assumed wall temperature for $\mu_w$ and the up-stream bulk coolant temperature for all other flow parameters.

Calculate the heat transfer from the lumped heat capacity of the interior node to the conductor/coolant boundary (wall) node and the heat transfer across the thermal boundary layer using the film coefficient derived from this trial Nusselt number.

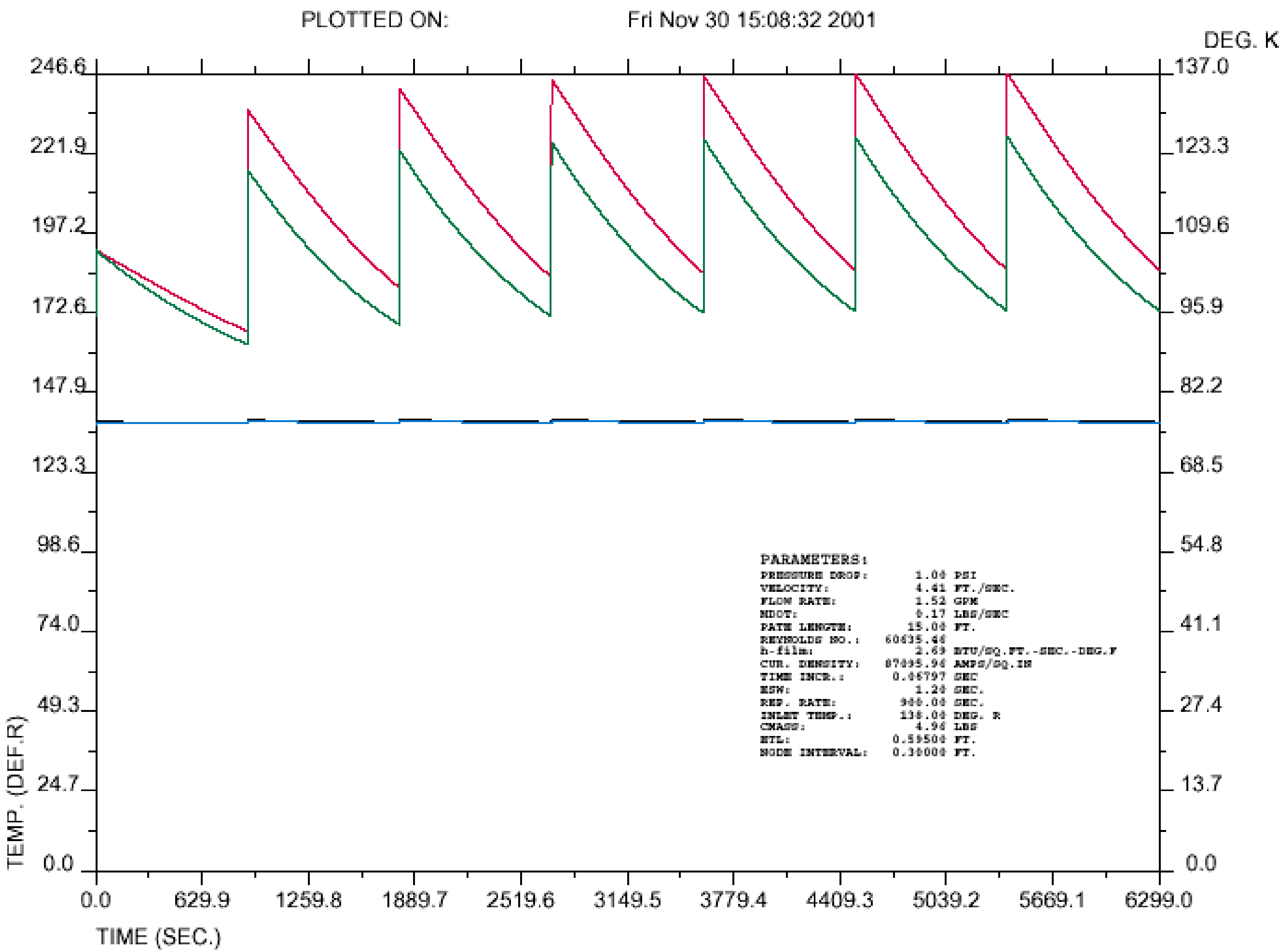
Compare these heat transfer quantities and iterate the Nusselt number calculation, by modifying the (wall) node temperature & viscosity term, until the two values converge.



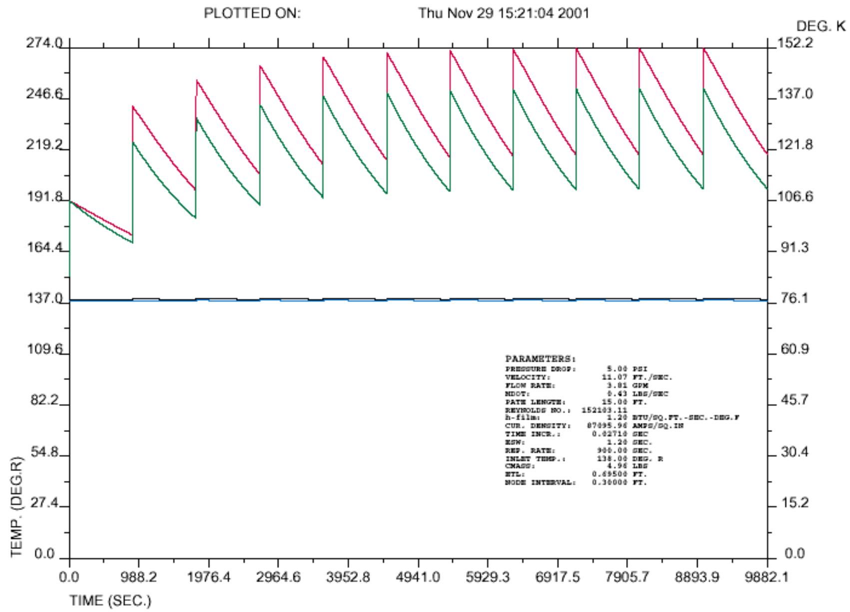

NCSX-COIL COOLING, HTL=.595, 5 PSI, RE-RUN 2



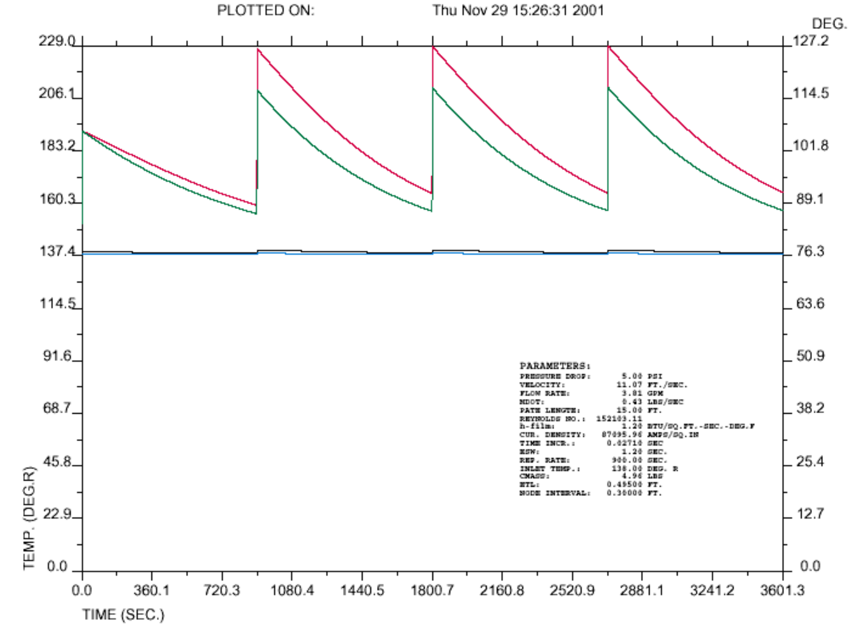

NCSX-COIL COOLING, HTL=.595, 3 PSI, RE-RUN



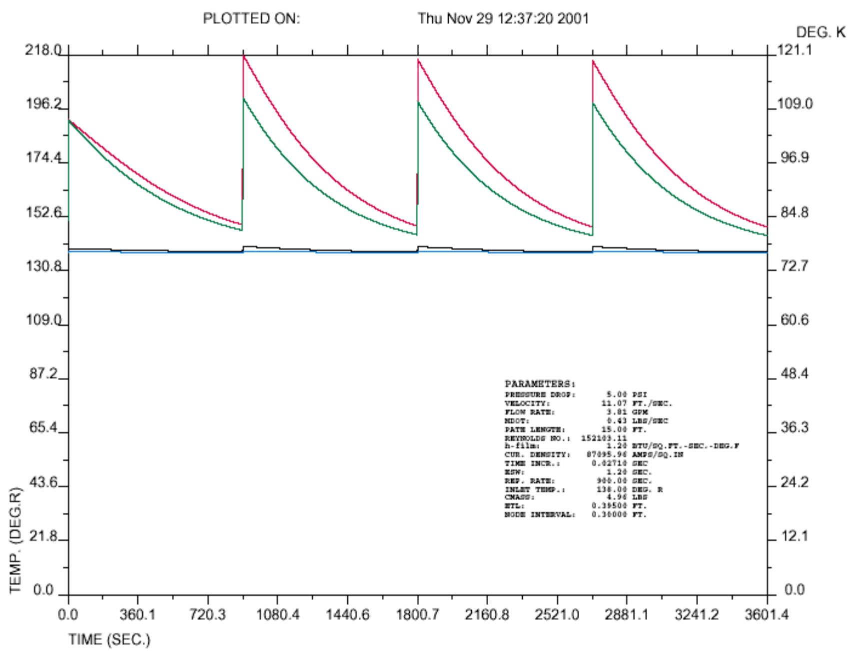

NCSX-COIL COOLING, HTL=.595, 1 PSI, RE-RUN



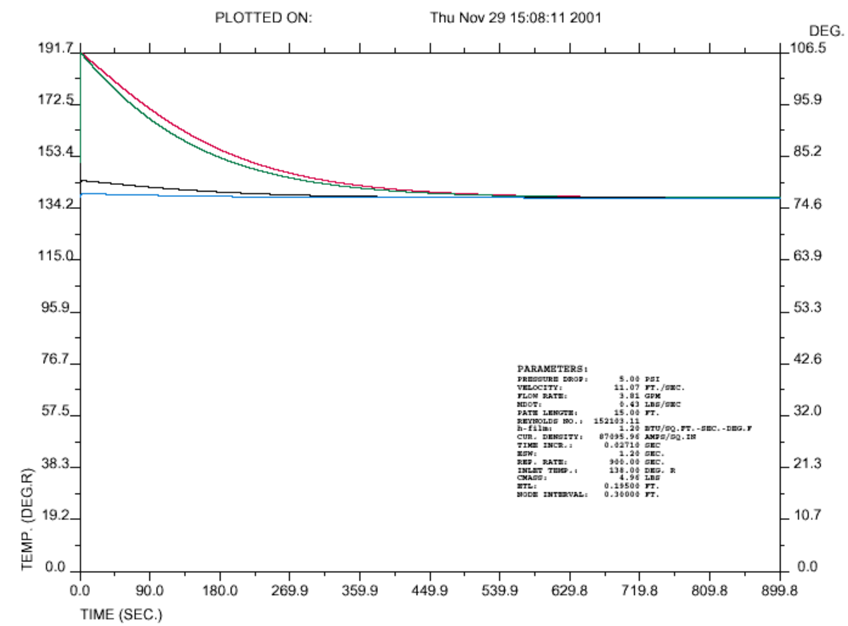

NCSX-COIL COOLING, HTL=.695, 5 PSI




NCSX-COIL COOLING, HTL=.495, 5 PSI




NCSX-COIL COOLING, HTL=0.395, 5 PSI




NCSX-COIL COOLING, HTL=0.195, 5 PSI

# Conclusions

- Heat Transfer dominated by internal conductance (ie, not very sensitive to film coeff.).

- Single-phase LN2 cooling feasible, even @ fairly low pressures (>$P_{sat}$ @$T_{peak}$ or nucleate boiling @ lower pressures) .

- More cooling (or $I^2t$ ) margin if cooled from both ends.

- For a 15 ft. single circuit, once thru $\partial P$ of 5 psi provides sufficient flow for $I^2t$ investigated.