Class Exercise in Thermal Analysis

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ATR NSUF User Week Experimenter Course

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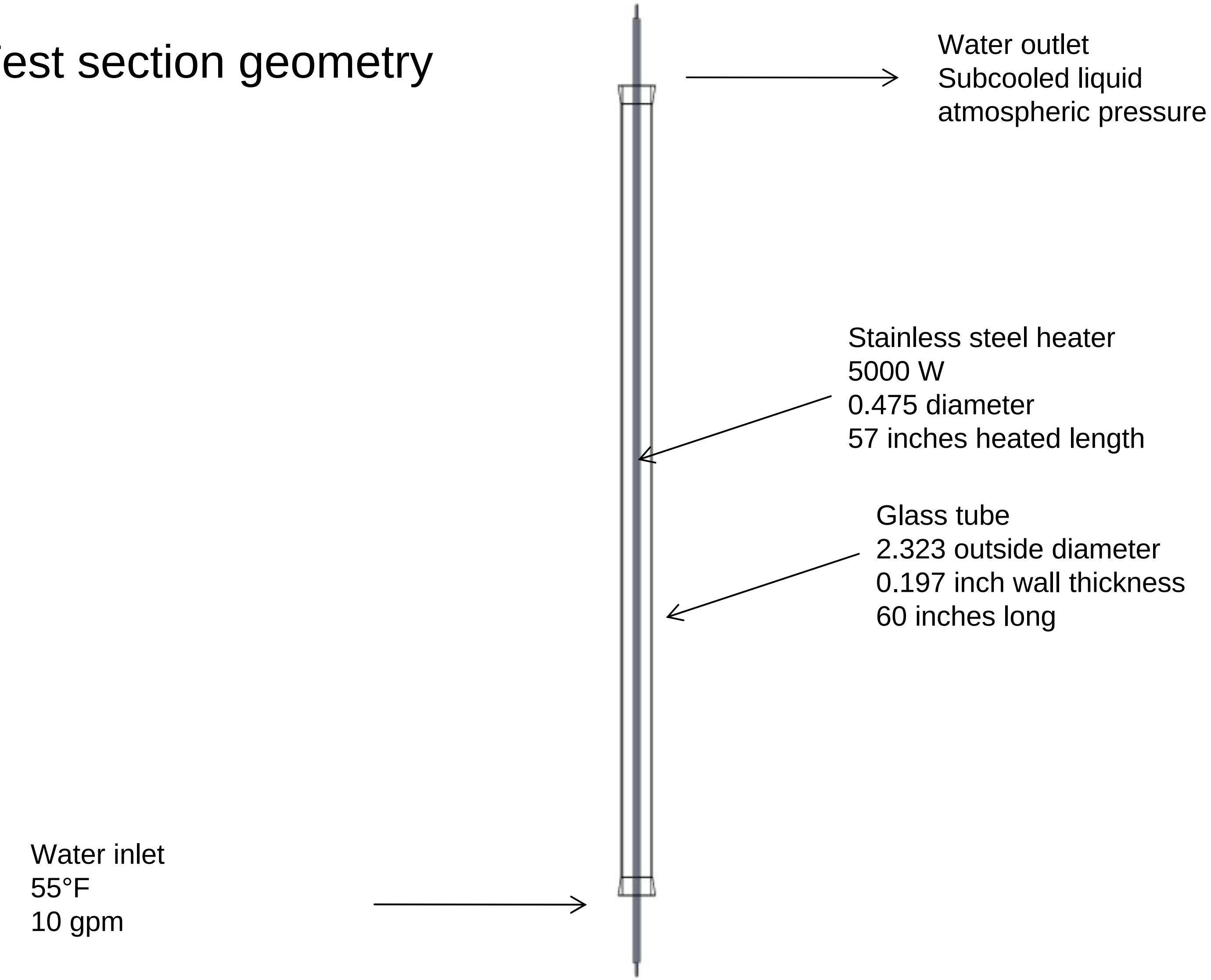
Outline

- ISU flow test
  - Test section geometry
- Class exercise using ABAQUS
  - Model geometry
  - Material properties
  - Boundary conditions
  - Heat loads
  - Mesh
  - Results (temperature and heat flux)
- Calculating safety factors
  - Departure from nucleate boiling (DNB)
  - Flow instability (FI)

ISU flow test

- Test section geometry



Class exercise using ABAQUS

- Model geometry

$D_{he} = 0.475 \cdot in$	Heater outside diameter
$D_i = 1.93 \cdot in$	Glass tube inside diameter
$D_o = 2.323 \cdot in$	Glass tube outside diameter
$L_{test} = 60 \cdot in$	Length of test section
$L_{he} = 57 \cdot in$	Length of heated section

Class exercise using ABAQUS

- Material properties

Thermophysical properties of stainless steel, glass, and water:

$\rho_{SST} = 0.29 \frac{lb}{in^3}$ $\rho_{glass} = 0.081 \frac{lb}{in^3}$ $\rho_{H2O} = 0.036 \frac{lb}{in^3}$

$c_{p\_SST} = 0.12 \frac{BTU}{lb \cdot R}$ $c_{p\_glass} = 0.199 \frac{BTU}{lb \cdot R}$ $c_{p\_H2O} = 0.998 \frac{BTU}{lb \cdot R}$

$k_{304\_SST} = 0.783 \frac{BTU}{hr \cdot in \cdot R}$ $k_{glass} = 0.067 \frac{BTU}{hr \cdot in \cdot R}$ $k_{H2O} = 0.03 \frac{BTU}{hr \cdot in \cdot R}$

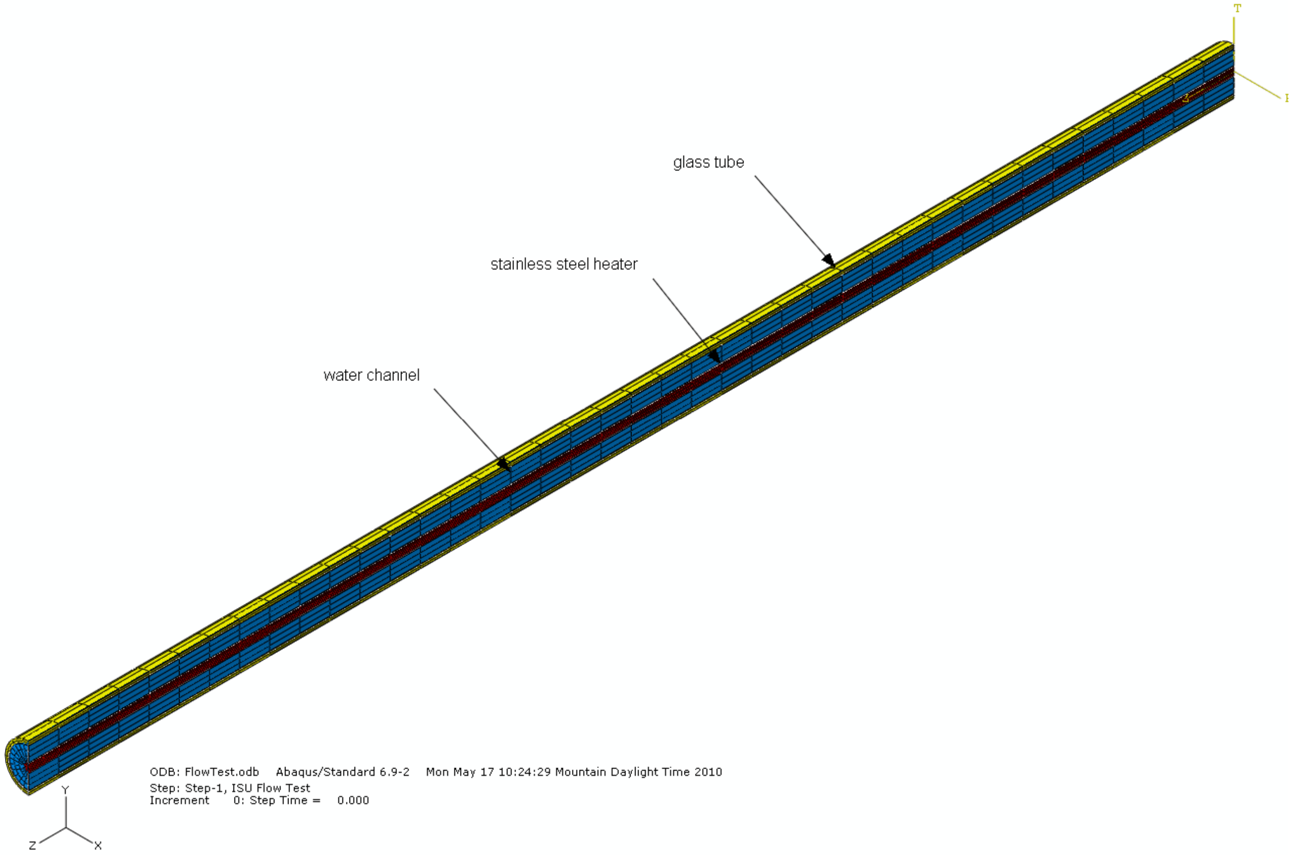
Class exercise using ABAQUS

- Boundary conditions and heat loads

$T_{inlet} = 55\ °F$	Water inlet temperature
$m_f = 1816\ \frac{lb}{in^2 \cdot hr}$	Water mass flow rate per unit area of flow channal
$Q_{he} = 1689\ \frac{BTU}{hr \cdot in^3}$	Body heat flux at heater
$h = 1.853\ \frac{BTU}{hr \cdot in^2 \cdot R}$	Turbulent heat transfer coefficient

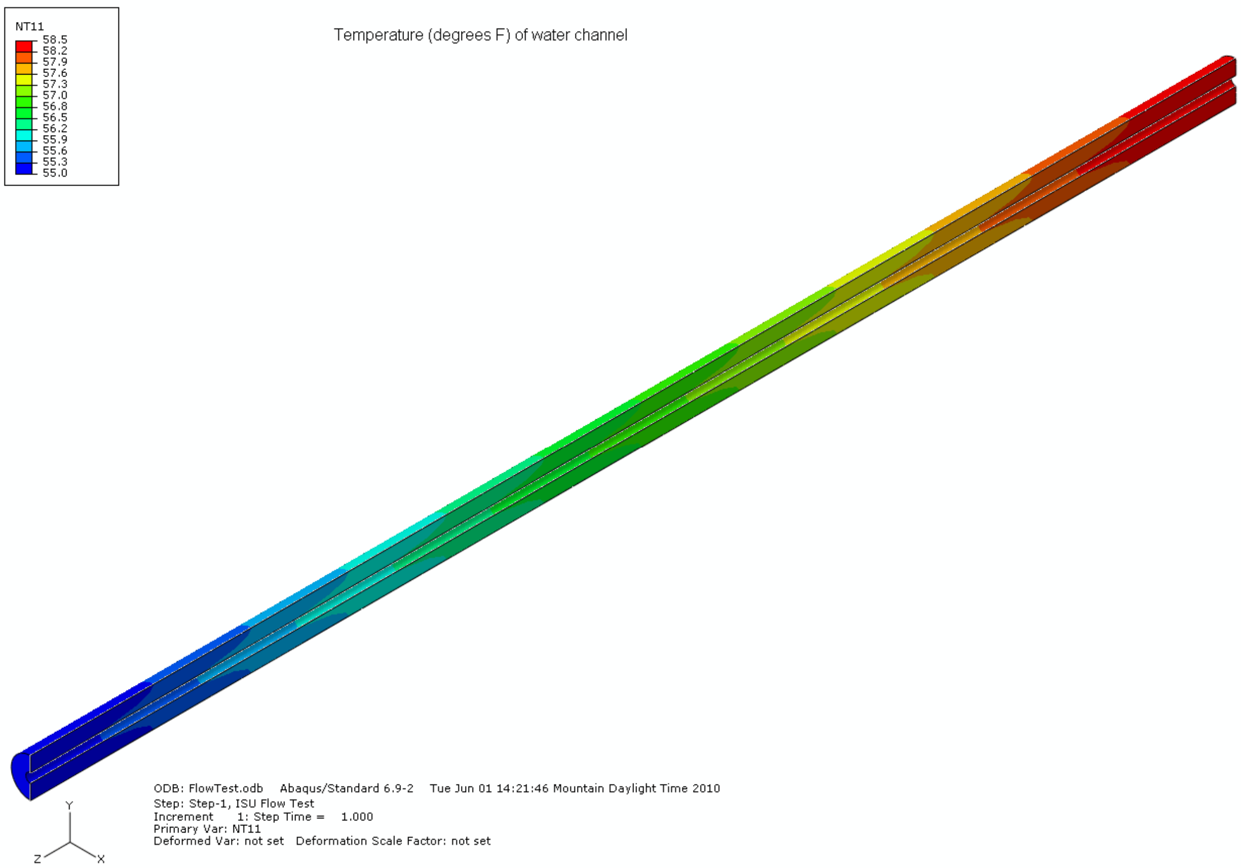
Class exercise using ABAQUS

- Finite element mesh



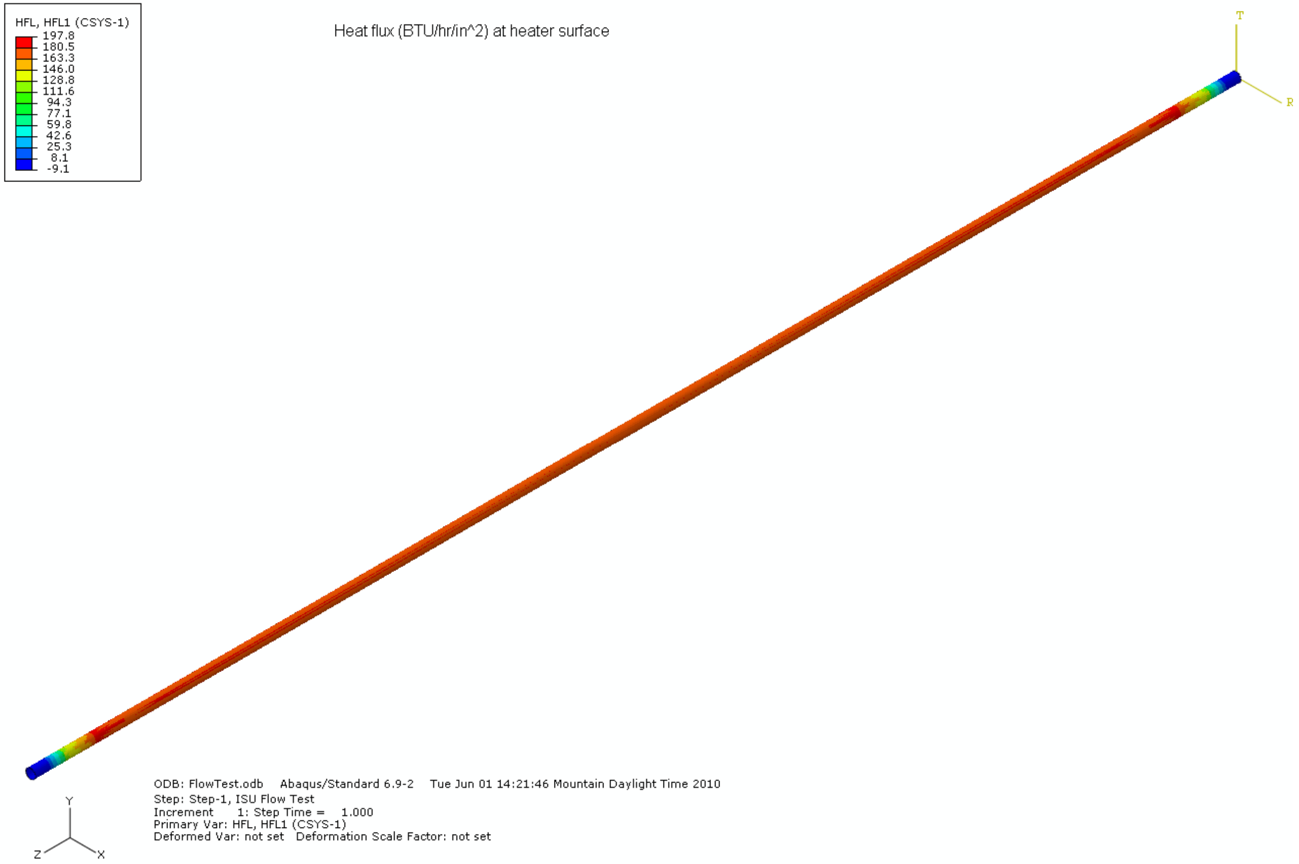
Class exercise using ABAQUS

- Water channel temperature distribution (°F)



Class exercise using ABAQUS

- Heater surface radial heat flux distribution (BTU/hr/in^2)



Safety factors

- Critical heat flux in flow boiling

$$q_{chf} = 1.8 \cdot \left(12915 \cdot \frac{d_{hy}}{d_{hy} + d_{he}} + 127 \cdot \frac{v}{d_{hy}^{\,0.35}} \right) \cdot \left(60 \cdot \ln(P) - 80.8 \cdot \frac{P}{P + 13.5} - 0.25 \cdot v - T_o \right)$$

P	Pressure (psi)
d_{hy}	Hydraulic diameter (ft)
d_{he}	Heated diameter (ft)
v	Velocity (ft/s)
T_o	Temperature (C)

Safety factors

- Departure from nucleate boiling ratio (DNBR)

$$q_{chf} = 13016 \frac{BTU}{hr \cdot in^2}$$ Critical heat flux

$$q_{he} = 198 \frac{BTU}{hr \cdot in^2}$$ Actual heat flux

$$\frac{q_{chf}}{q_{he}} = 65.7$$ DNBR

Safety factors

- Flow instability ratio (FIR)

$$\Delta T_c = T_{sat} - T_{inlet}$$

Critical temperature rise

$$\Delta T = T_{outlet} - T_{inlet}$$

Actual temperature rise

$$T_{inlet} = 55\ ^{\circ}F$$

$$T_{outlet} = 58.4\ ^{\circ}F$$

$$T_{sat} = 212\ ^{\circ}F$$

$$\frac{\Delta T_c}{\Delta T} = 45.9$$

FIR