Conjugate Heat Transfer in Quenching Analysis

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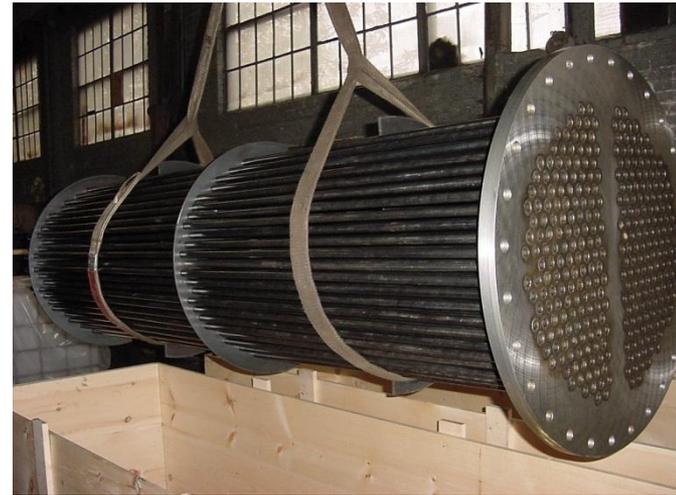# Overview

- **Conjugate heat transfer examples**
- **Heat treatment of metals**
  - **Current methodology (HTC)**
  - **Technical needs**
- **Modeling of air quench – no phase transformation**
- **Modeling of oil quench – with phase transformation**

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Conjugate Heat Transfer

Electronics

Heat Exchangers

Exhaust Manifolds

Heat Treatment of Metals

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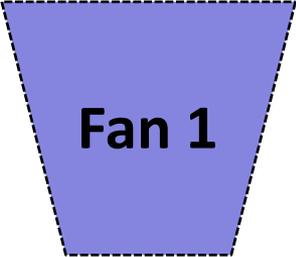
Quenching Analysis – Current Situation

- **Analysis of quenching operation**
  - **Using heat transfer coefficients (HTC)**
  - **Experimental**
  - **Relies on experience**
  - **Constant w/ time**
- **Difficult to apply to complex shapes**
- **Potential for non-unique solutions**

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Procedure for COMSOL Quenching Tool

- **Develop accurate CFD model of quenching**

- **Develop algorithm for calculating HTC**
  - **Time and position**
  - **User defined**
    - # segments
    - Min segment size
  - **Optimum segmentation**
    - Minimization of standard deviation between FEA and segmented HTC
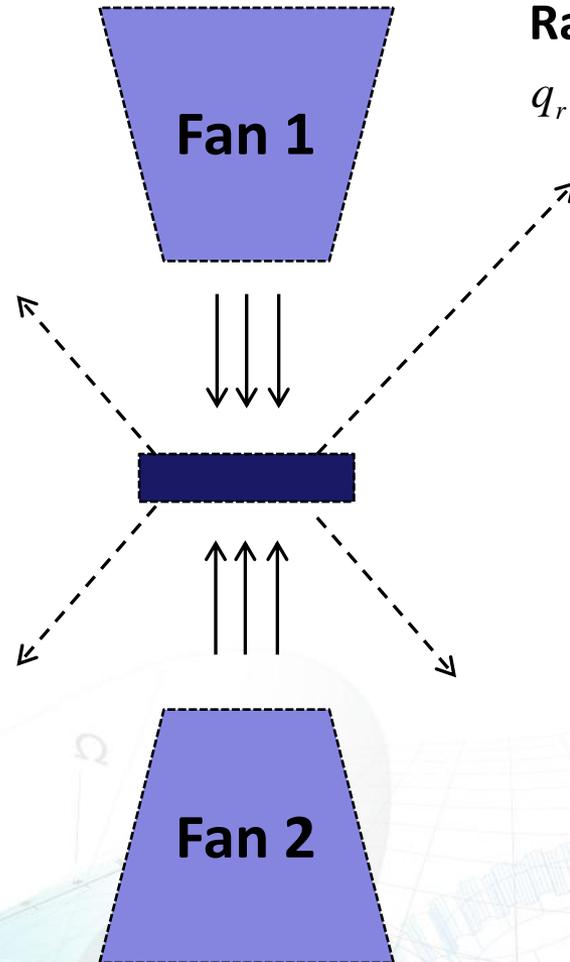
DEVELOP ACCURATE CFD MODEL

Gas Quench

Fan 1

Conduction:

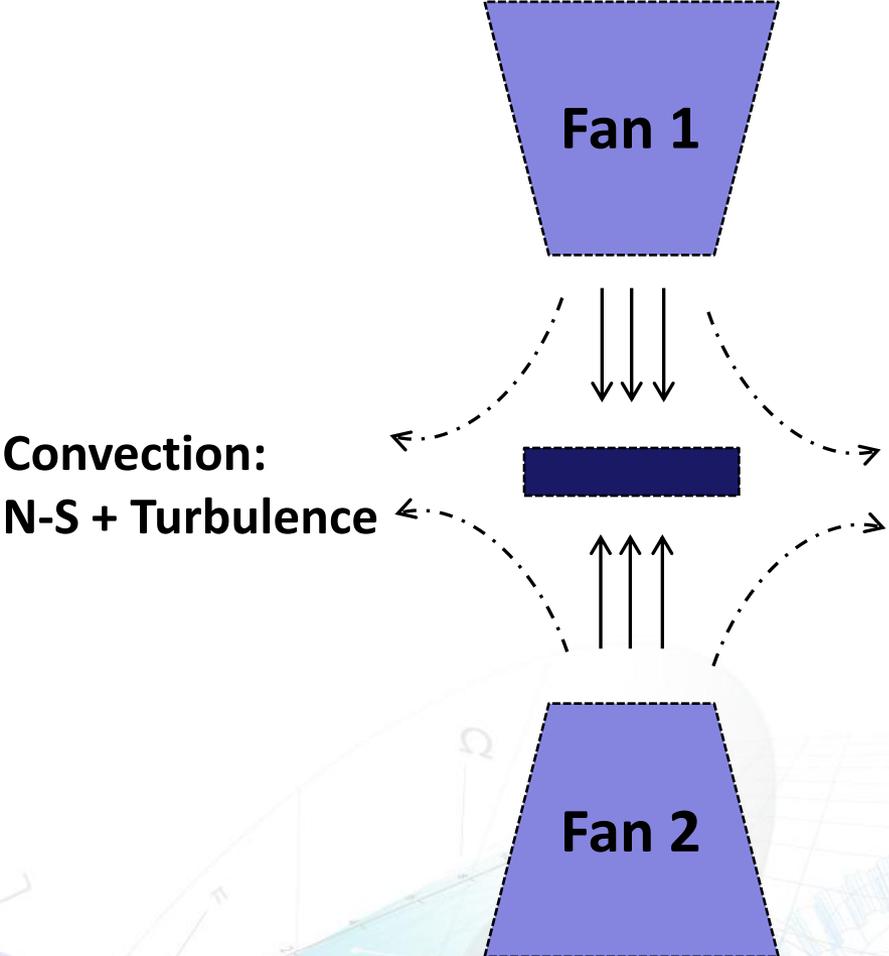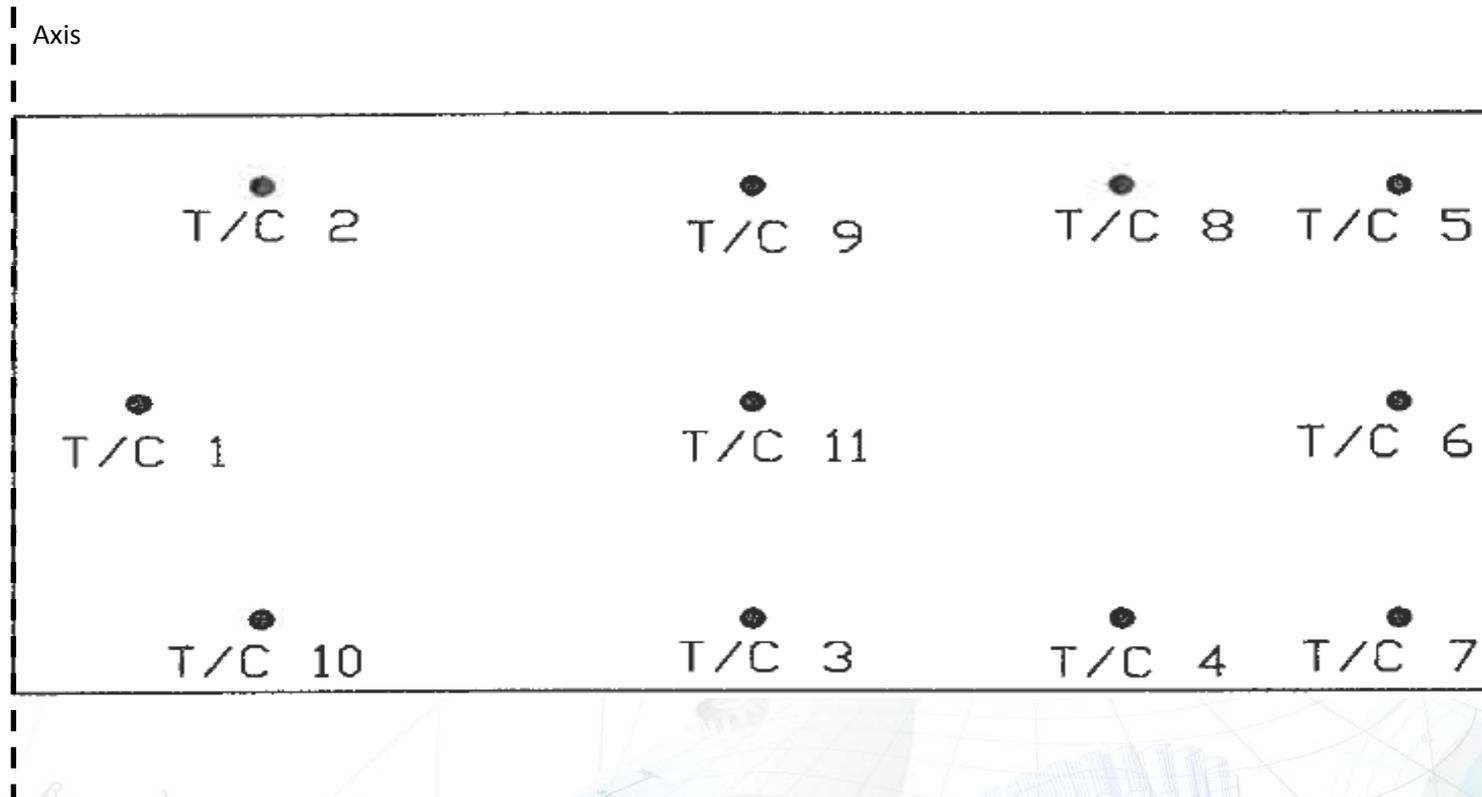$$\rho \, c_p \frac{\partial T}{\partial t} = \nabla \cdot \left(\lambda \nabla T \right)$$

Fan 2

Gas Quench

Fan 1
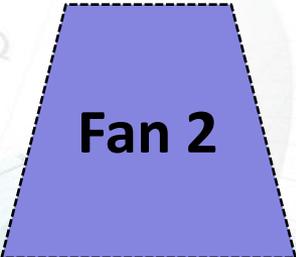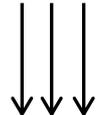
Fan 2

Radiation:

$$q_r = \varepsilon_{emis}\left(G_m + F_{amb}\sigma\, T_{amb}^4 - \sigma\, T^4\right)$$

Gas Quench

Fan 1

Convection:
N-S + Turbulence

Fan 2

Thermocouple Locations

Axis

T/C 2   T/C 9   T/C 8   T/C 5

T/C 1   T/C 11   T/C 6

T/C 10   T/C 3   T/C 4   T/C 7
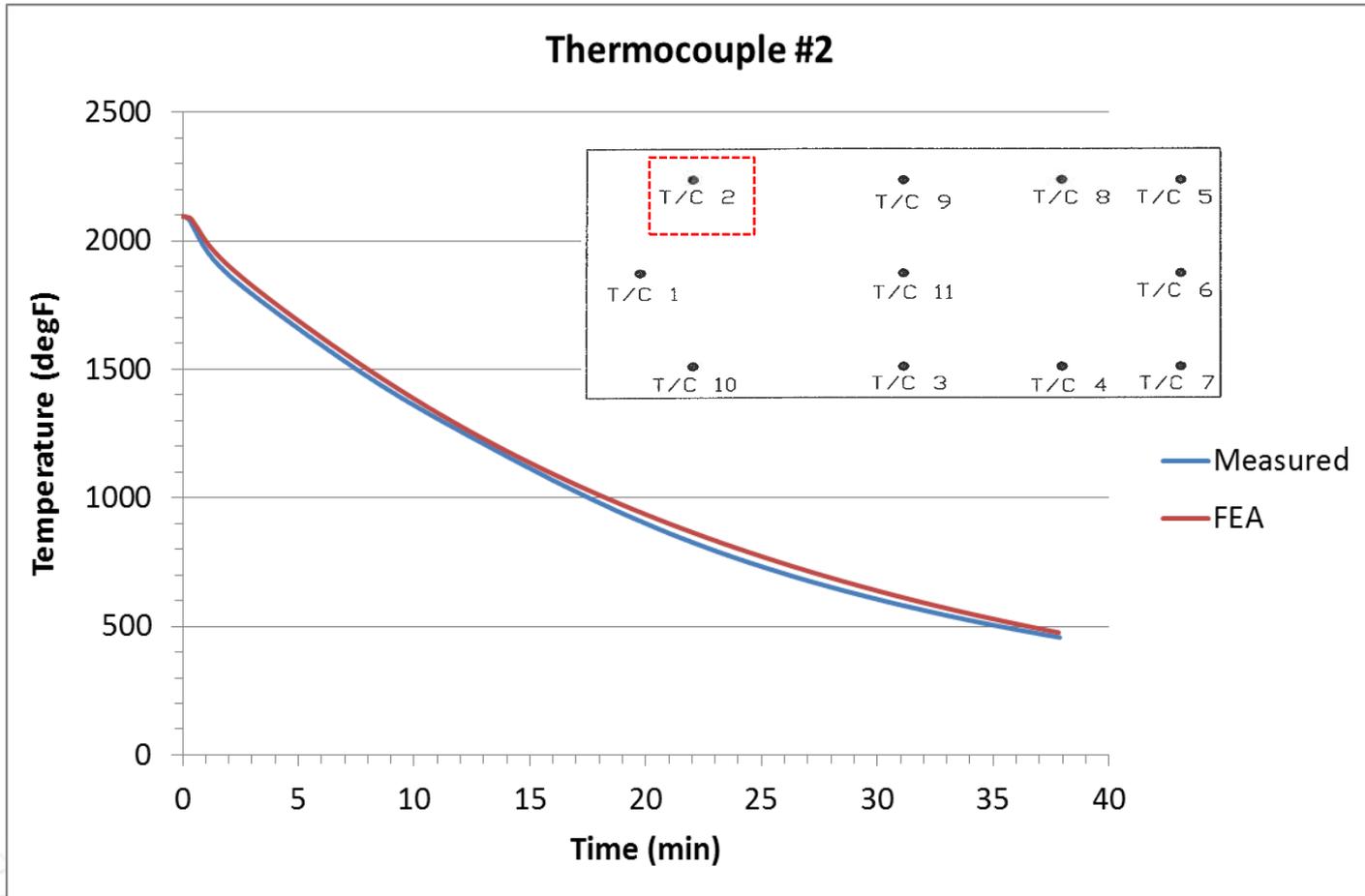
Temperature - #2

Temperature - #9
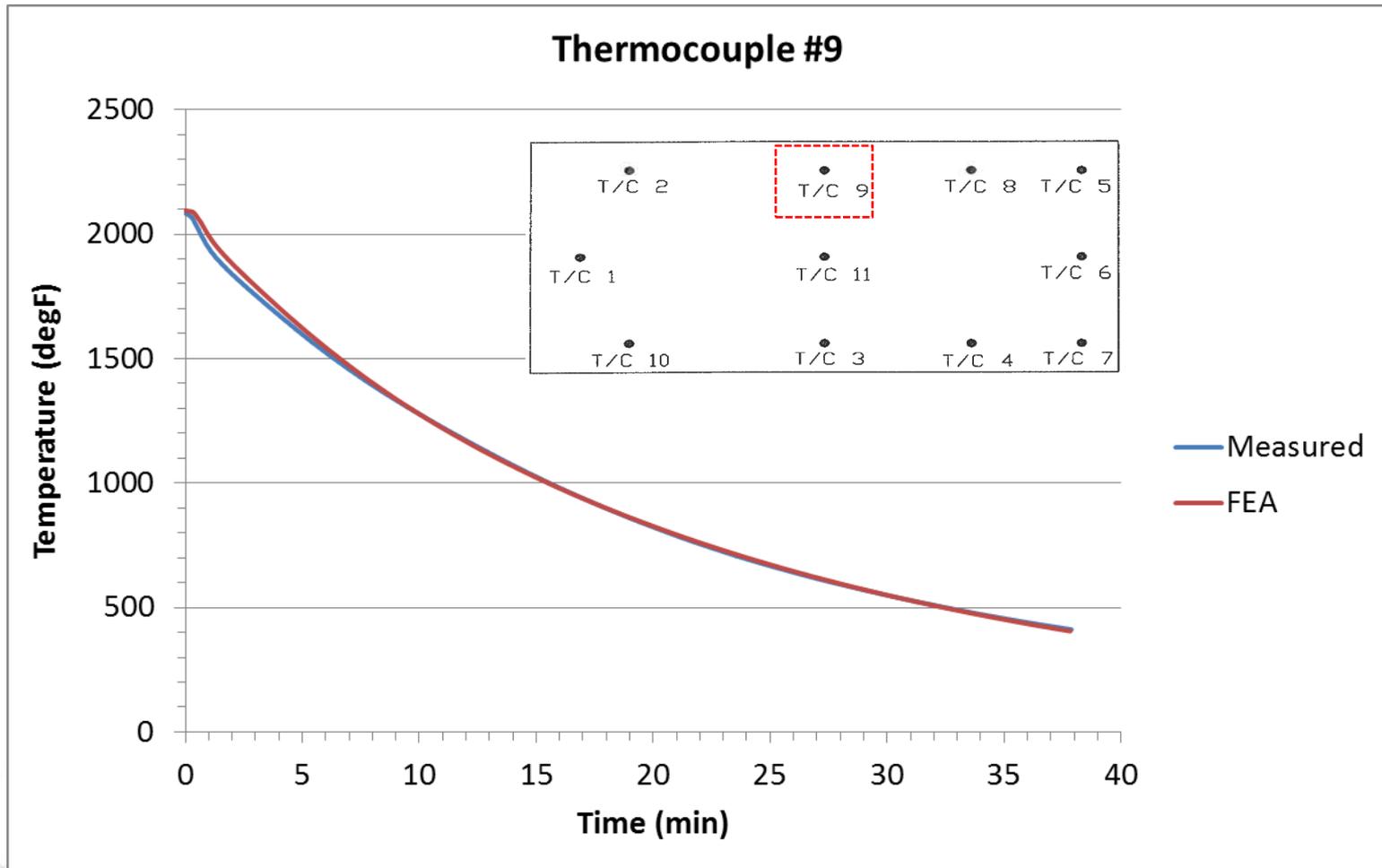
Temperature - #11
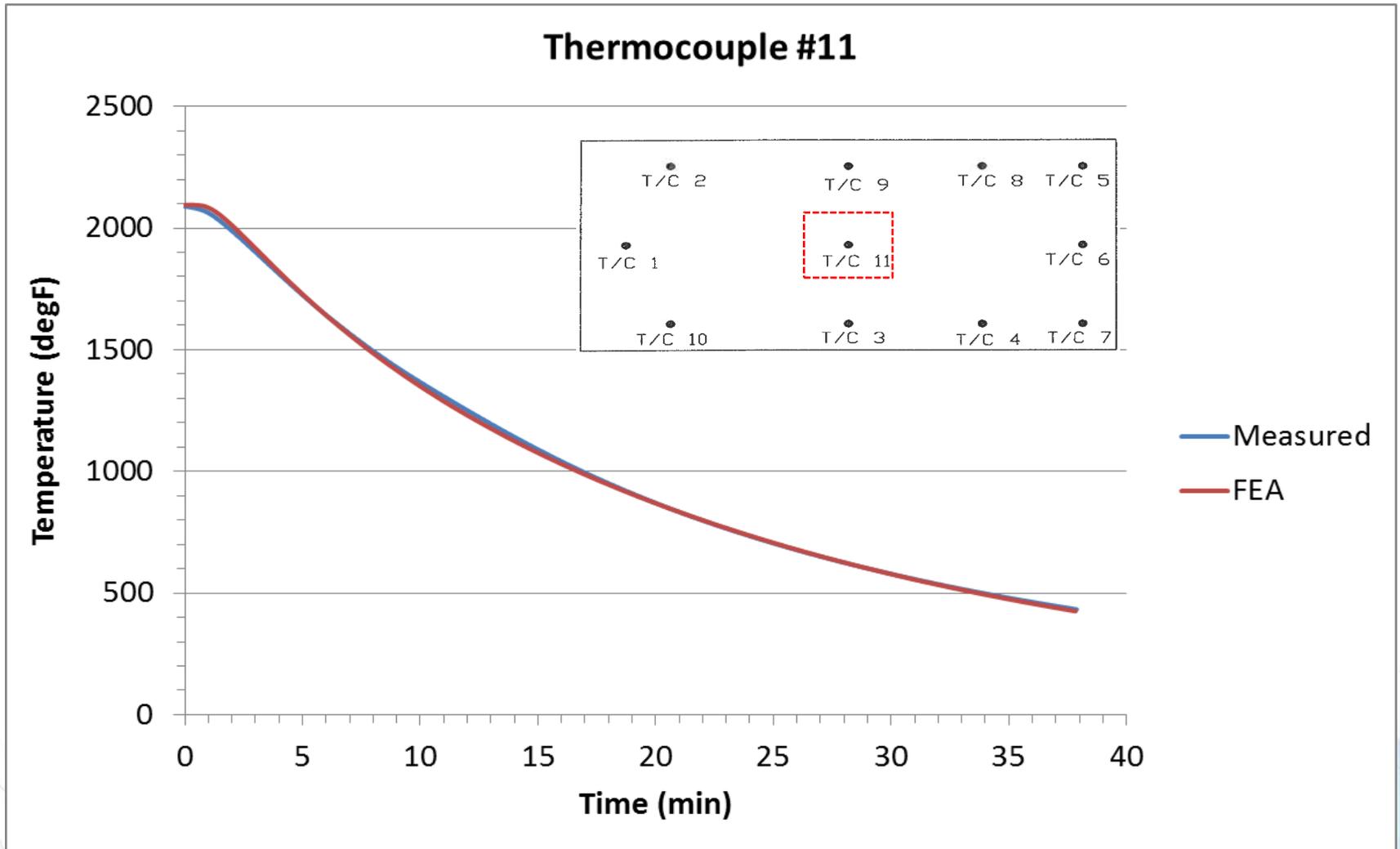
ALGORITHM FOR HTC CALCULATION

Heat Transfer Coefficients

Top Surface - 3 Sections
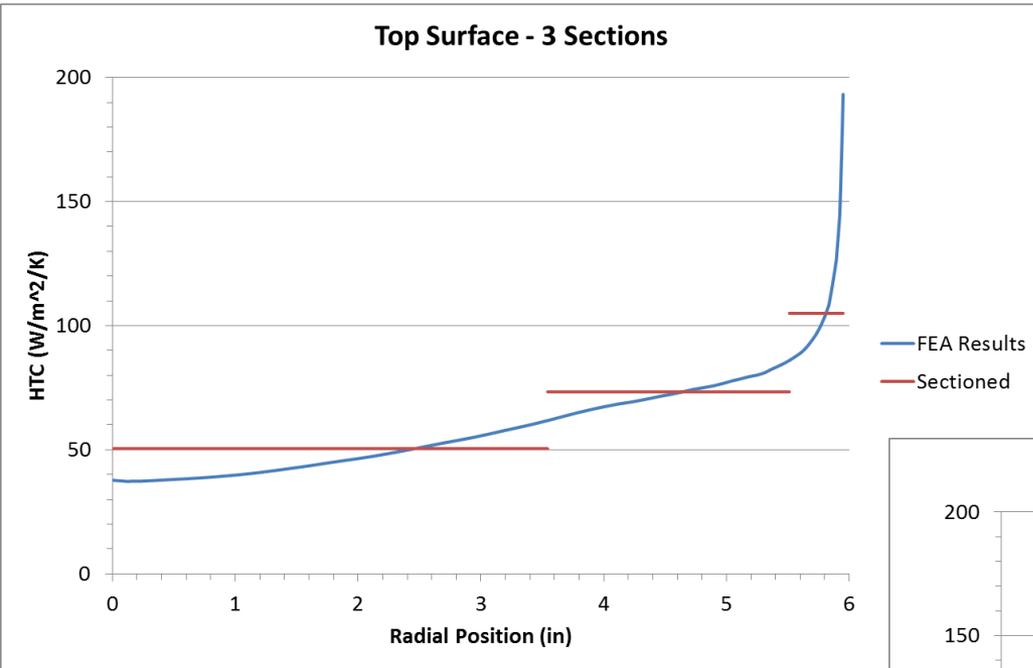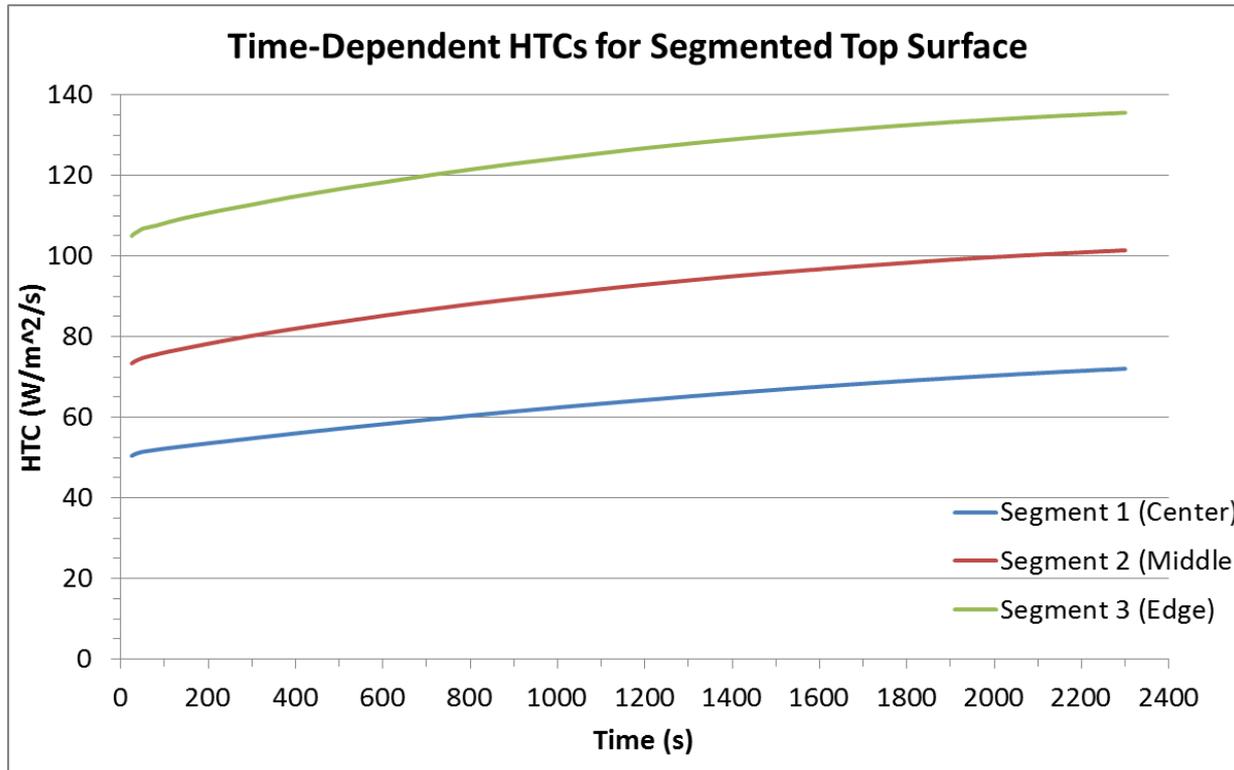
User defines # of sections
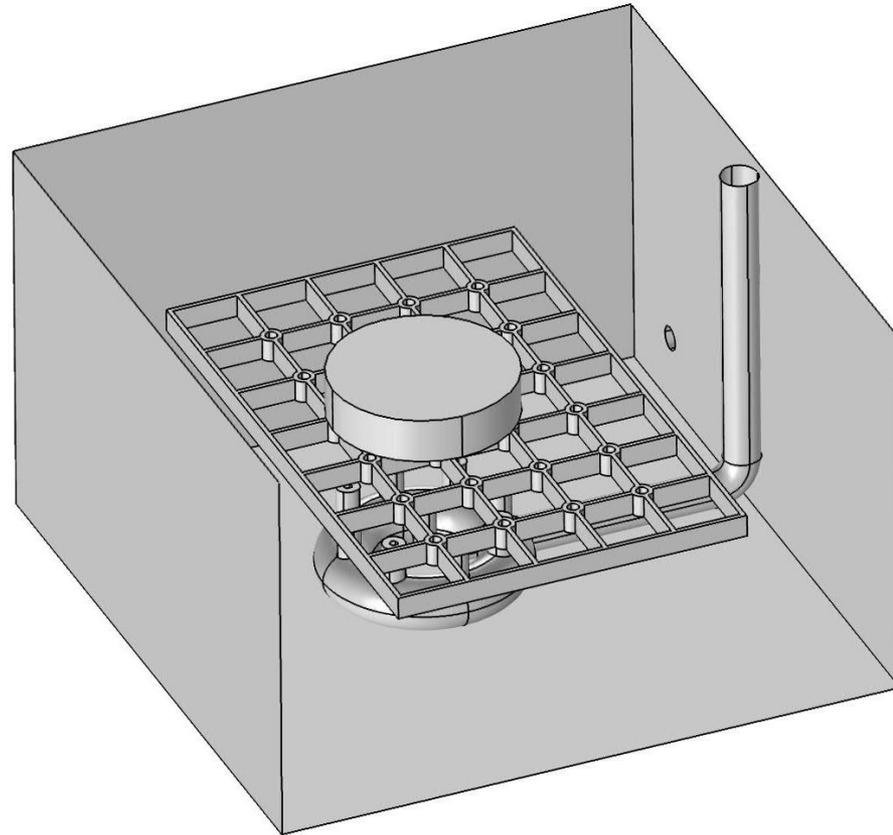

Top Surface - 6 Sections
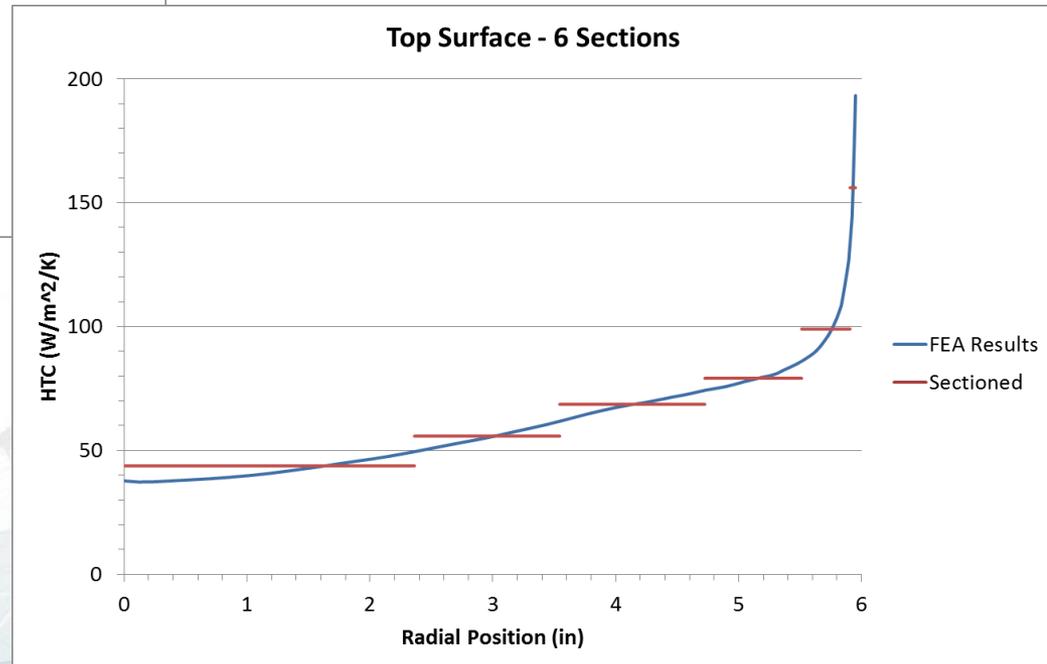
Section size dependent on gradient
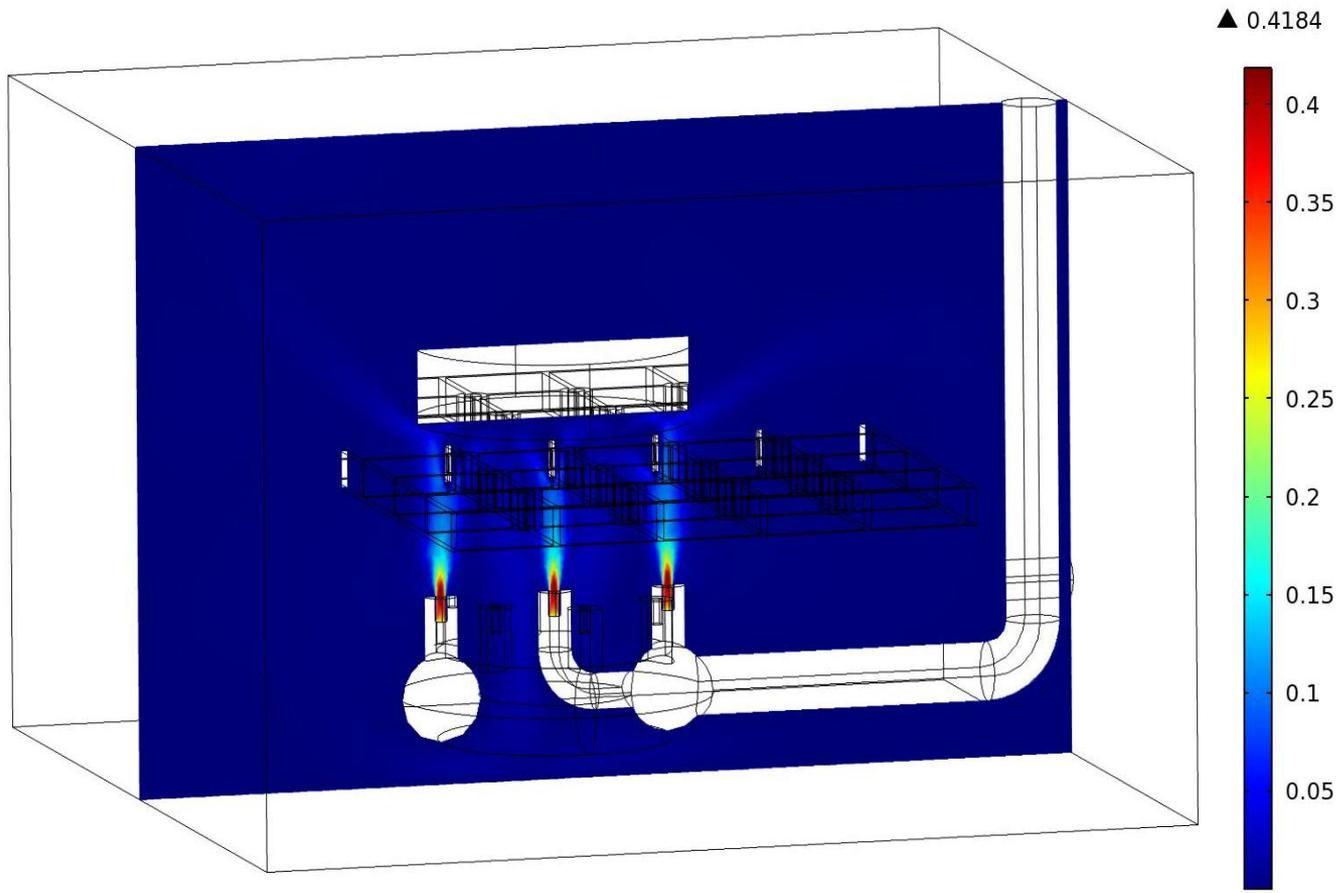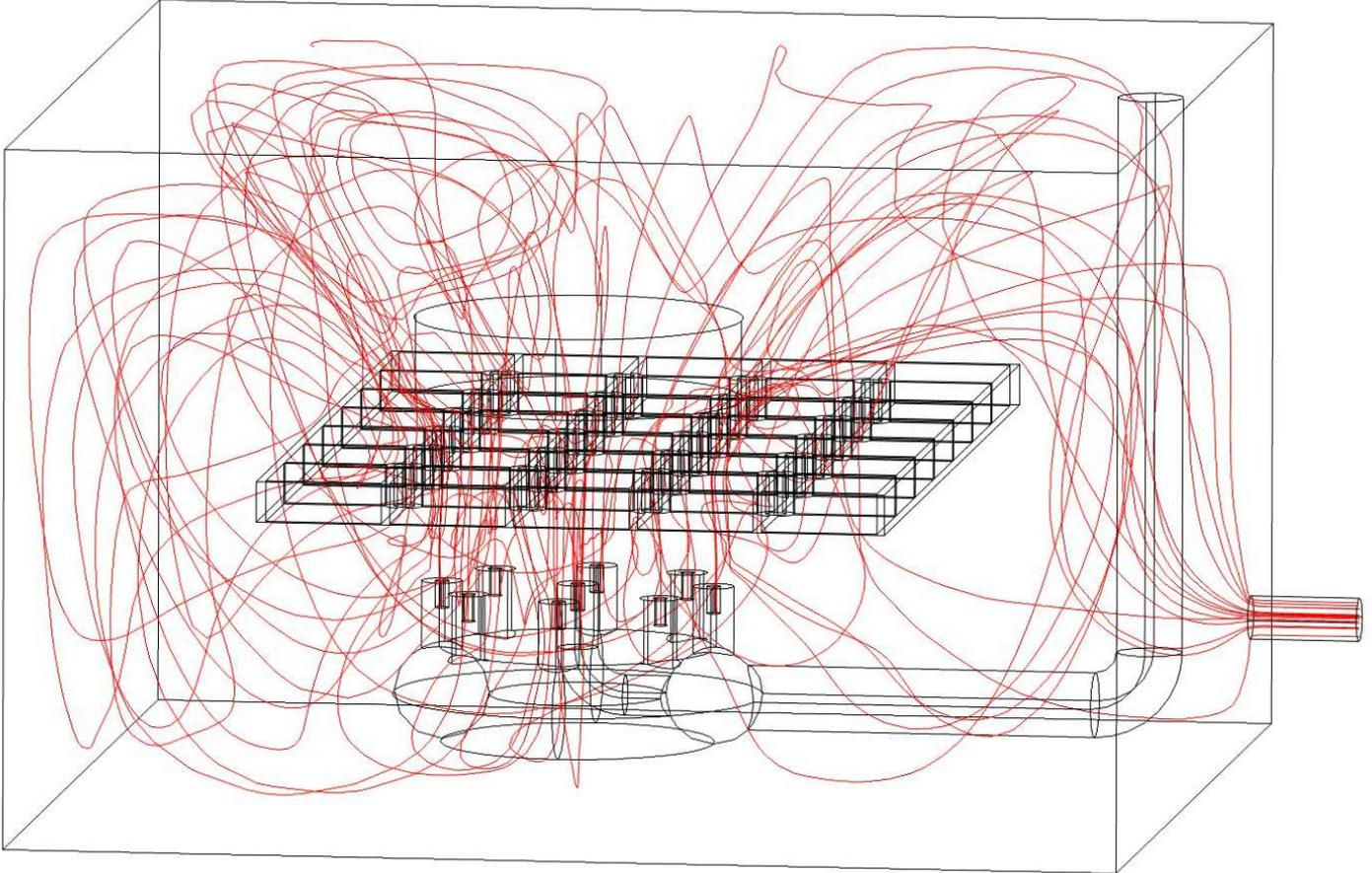
Variation w/ Time
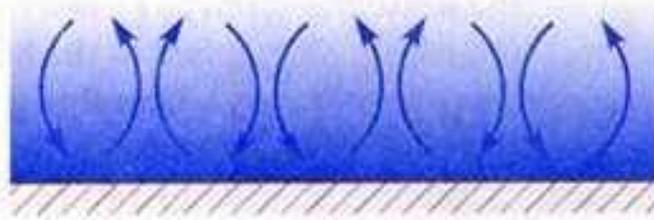
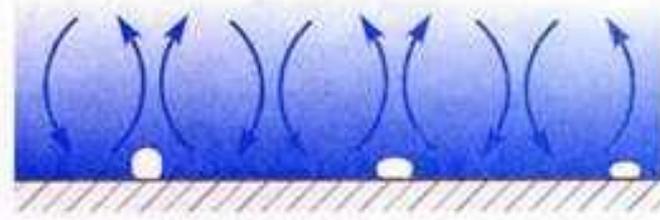# Liquid Quench

Velocity Magnitude (m/s) - Oil

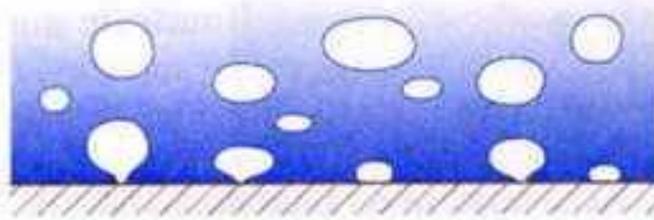# Streamlines

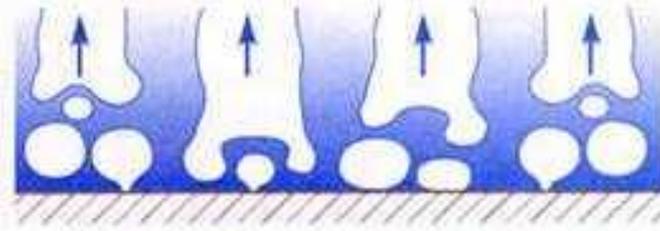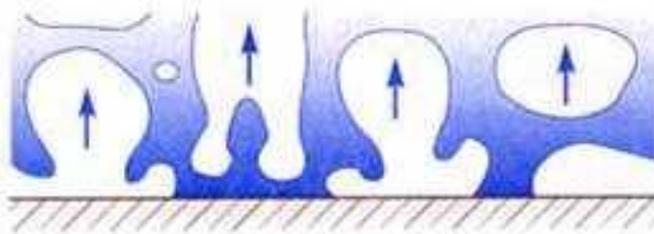**Outlet**

Stages of Boiling

1. Natural convection

Onset of boiling

2. Individual bubble regime

3. Regime of slugs and bubbles

4. Transition film-boiling
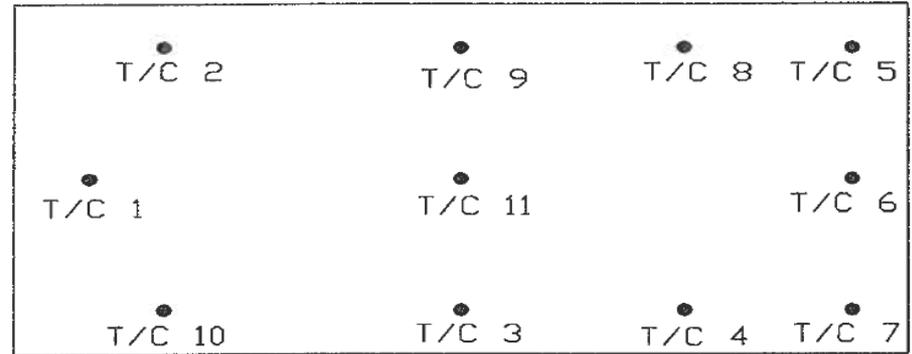
5. Stable film boiling

'Principles of Heat Transfer", Kreith, Bohn, West Pub. Co., 1993

Oil Quench Data
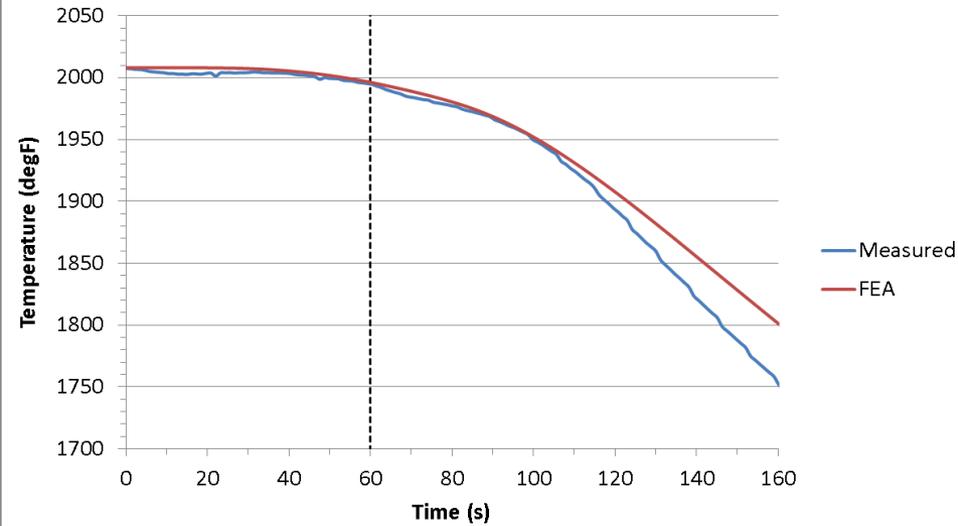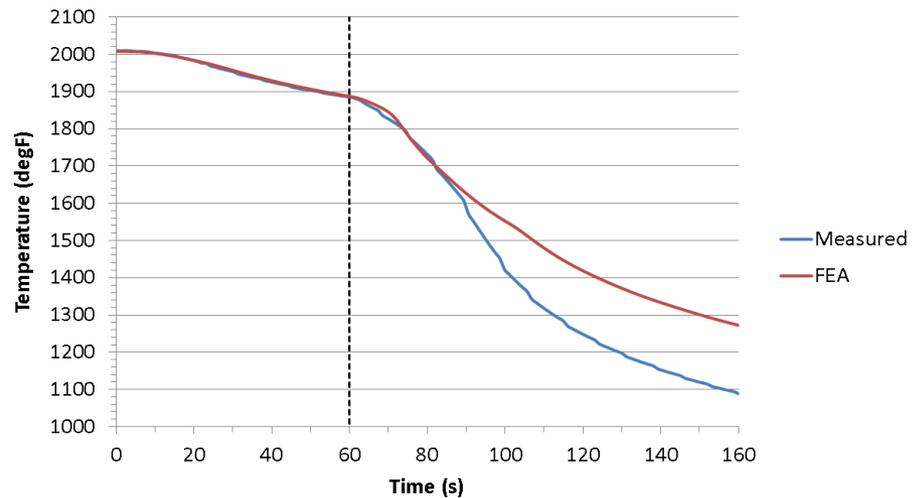
Summary

- **Quenching analysis developed**
  - **Gas**
  - **Liquid**

- **HTC calculation process developed**
  - **User defined**
  - **Applicable to any shape**
  - **Computationally based**
  - **Captures time history effects**