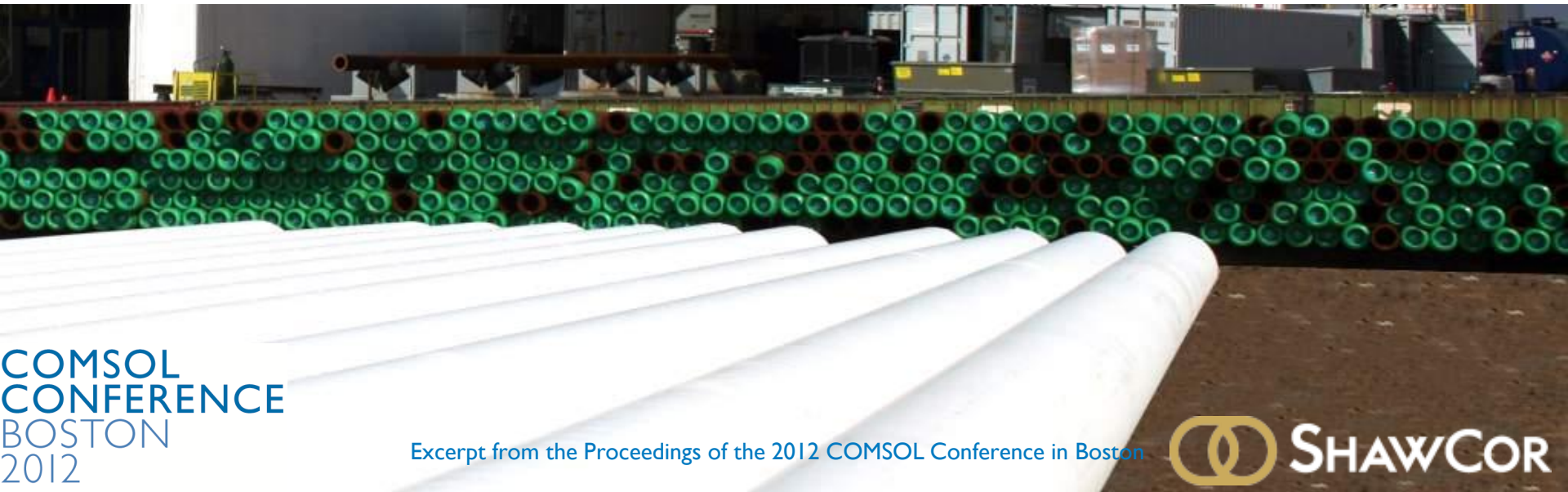


# Evaluation of Internal Electrical Heater for Pipe Temperature Control Using FEA Model

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# Outline

- Introduction
- Previous Heater Design & Challenge
- FEA Model
- Model Results
- Experiment test
- Conclusion



# Introduction



## ■ Test Requirement in Pipeline Industry

- Temperature control of steel pipe

## ■ Pipe Heating Methods

- Electrical Heating
- Oil heating

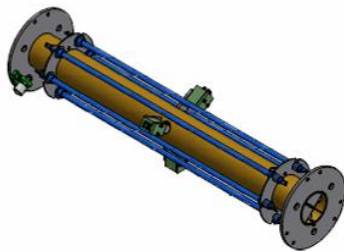
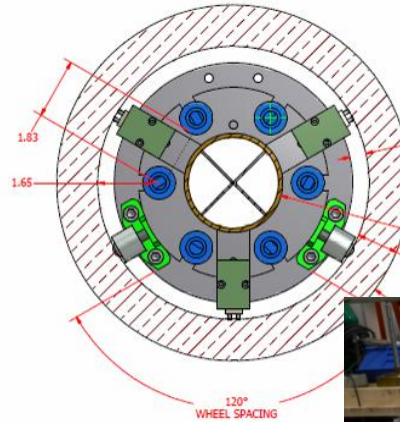
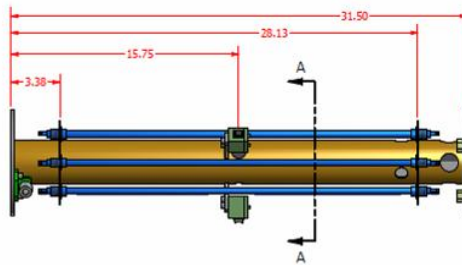
## ■ SSV (Simulated Service Vessel)

- Control the steel pipe temperature
- Electrical Heater

# Electrical Pipe Heater Design



## ■ Heater Using tubular heater elements



<small>This design information is intended for the addressee only. It may contain confidential or proprietary information. No rights or privileges have been waived. Any copying, reproduction, action in reliance on, or other use of the information in this communication by anyone other than the addressee is prohibited.</small>	UNITS - INCH <small>(UNLESS OTHERWISE SPECIFIED)</small> TOLERANCES: <small>(UNLESS OTHERWISE SPECIFIED)</small>	SHAWCOR Machine Development JSM Heater Arrangement - Z
	XXX ±.003 XX ±.015 X ±.030 ASSEMBLY ±.125	PROJECTION: DRAWN BY: MAR DATE: 07/27/2011 CHECKED BY: [Signature]

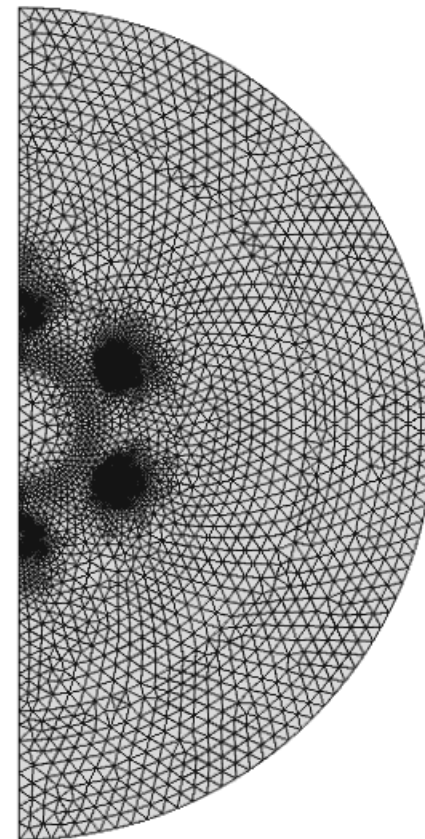
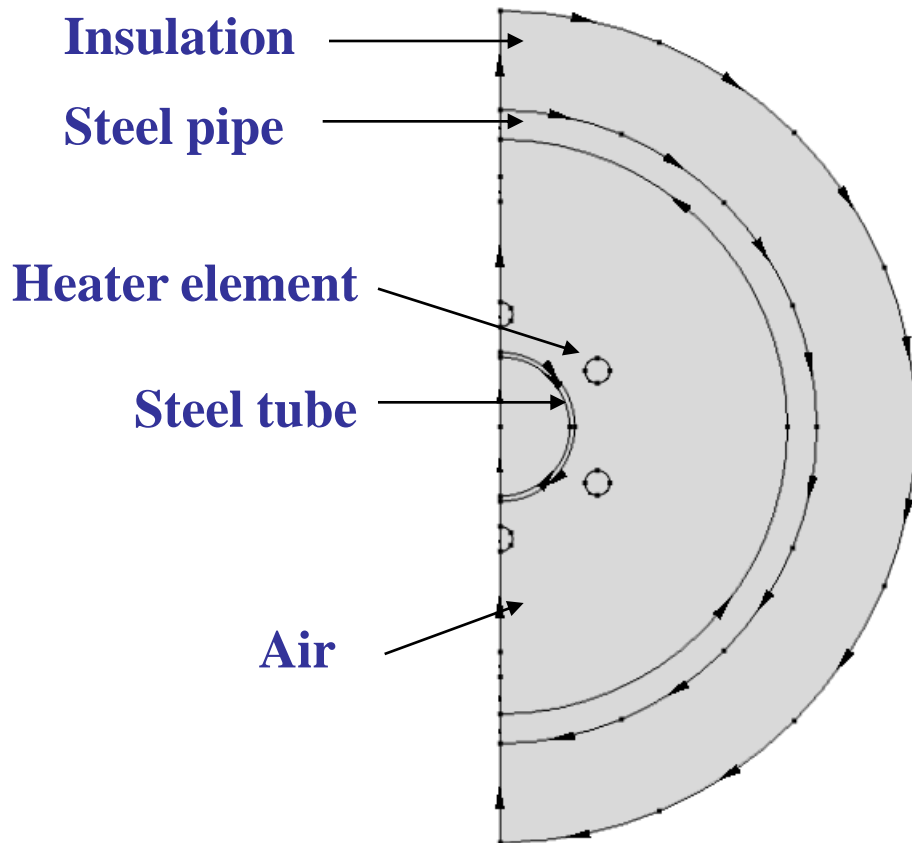


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# FEA model of Heater



## ■ 2-D FEA model of electrical heater



# FEA model of Heater



## ■ Governing Equations:

– For air region:

for solid region:

$$\left\{ \begin{array}{l} \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} = 0 \\ \rho u \left( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right) = -\frac{\partial p}{\partial x} + \mu \left( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) \\ \rho v \left( \frac{\partial v}{\partial x} + \frac{\partial v}{\partial y} \right) = -\frac{\partial p}{\partial y} + \mu \left( \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) - \rho g \\ \rho c_p \left( u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} \right) = \frac{\partial}{\partial x} \left( k \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left( k \frac{\partial T}{\partial y} \right) \end{array} \right.$$

$$\rho c_p \left( \frac{\partial T}{\partial x} + \frac{\partial T}{\partial y} \right) = k \frac{\partial^2 T}{\partial x^2} + k \frac{\partial^2 T}{\partial y^2}$$

# FEA model of Heater



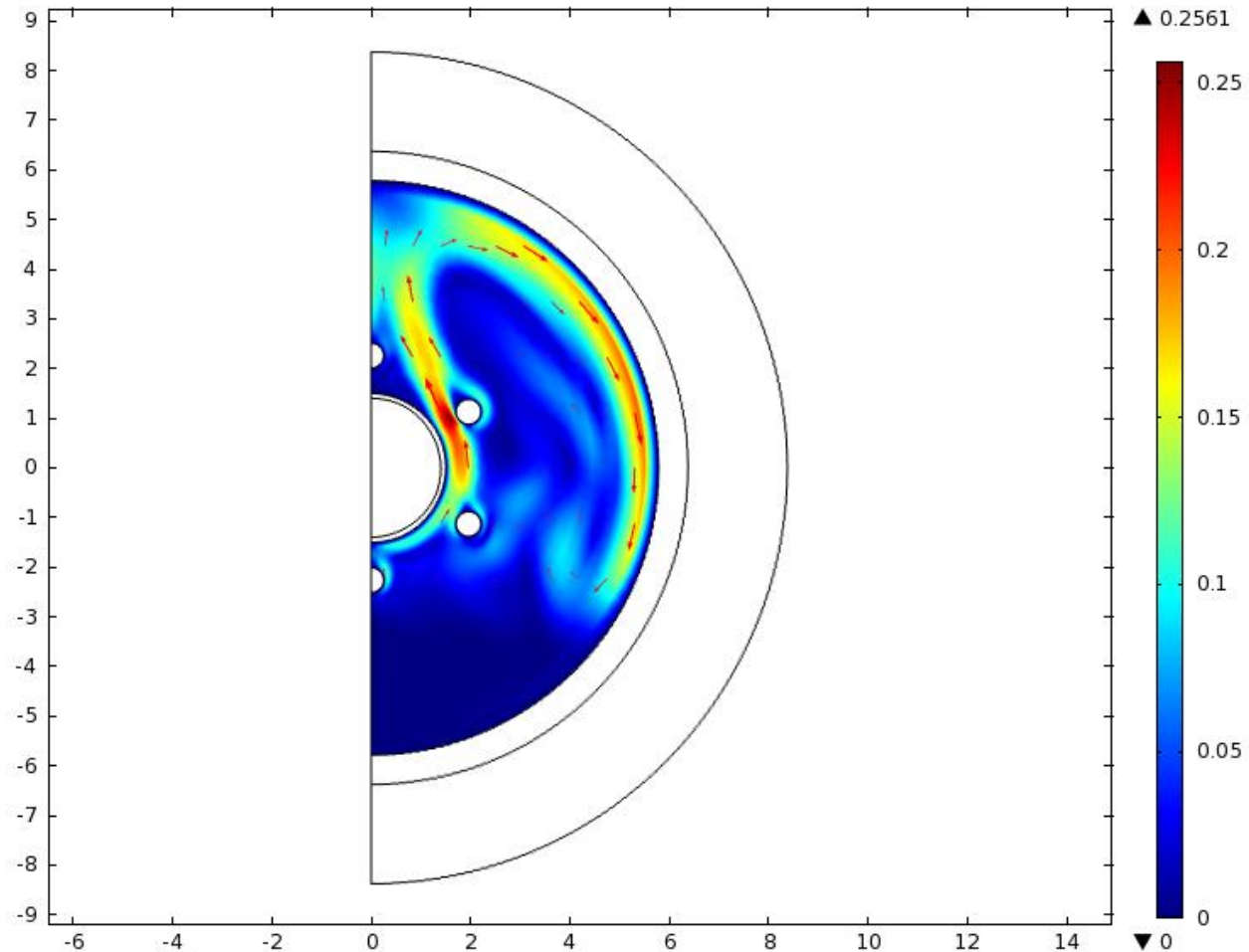
- **Boundary conditions for the air flow are:**
  - $u=0, v=0$  at the steel tube and the steel pipe
  - at  $x=0$
- **The boundary conditions for the heat transfer:**
  - $T=210\text{ }^{\circ}\text{C}$  at the heater element
  - Convection at the external surface of the insulation layer.
  - $T_0=4\text{ }^{\circ}\text{C}$  ( in the real SSV test, water temperature is controlled to  $4\text{ }^{\circ}\text{C}$ ).
  - Isothermal condition, at  $x=0$

# FEA model of Heater



## ■ Air flow around the heater in the pipe

Surface: Velocity magnitude (m/s) Arrow: + Velocity field

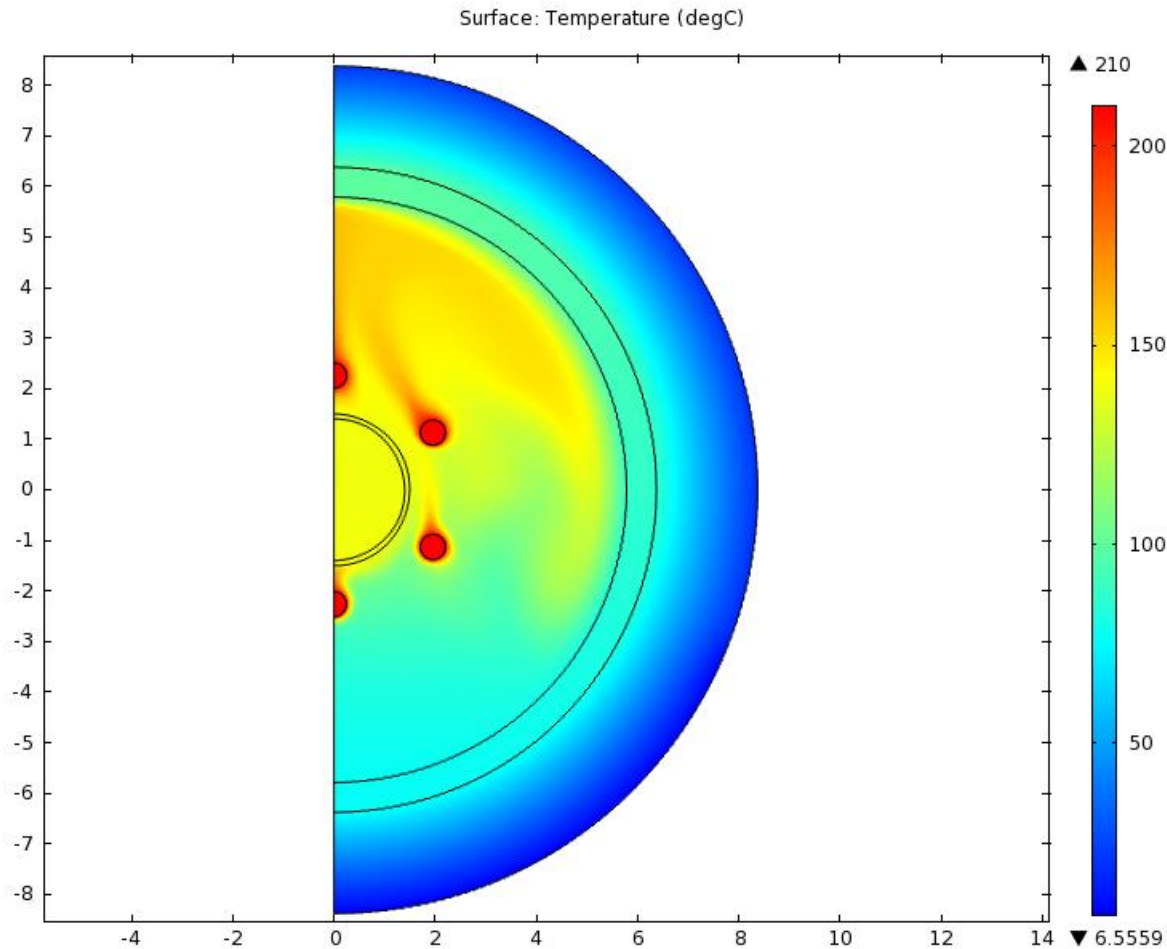




# FEA model of Heater



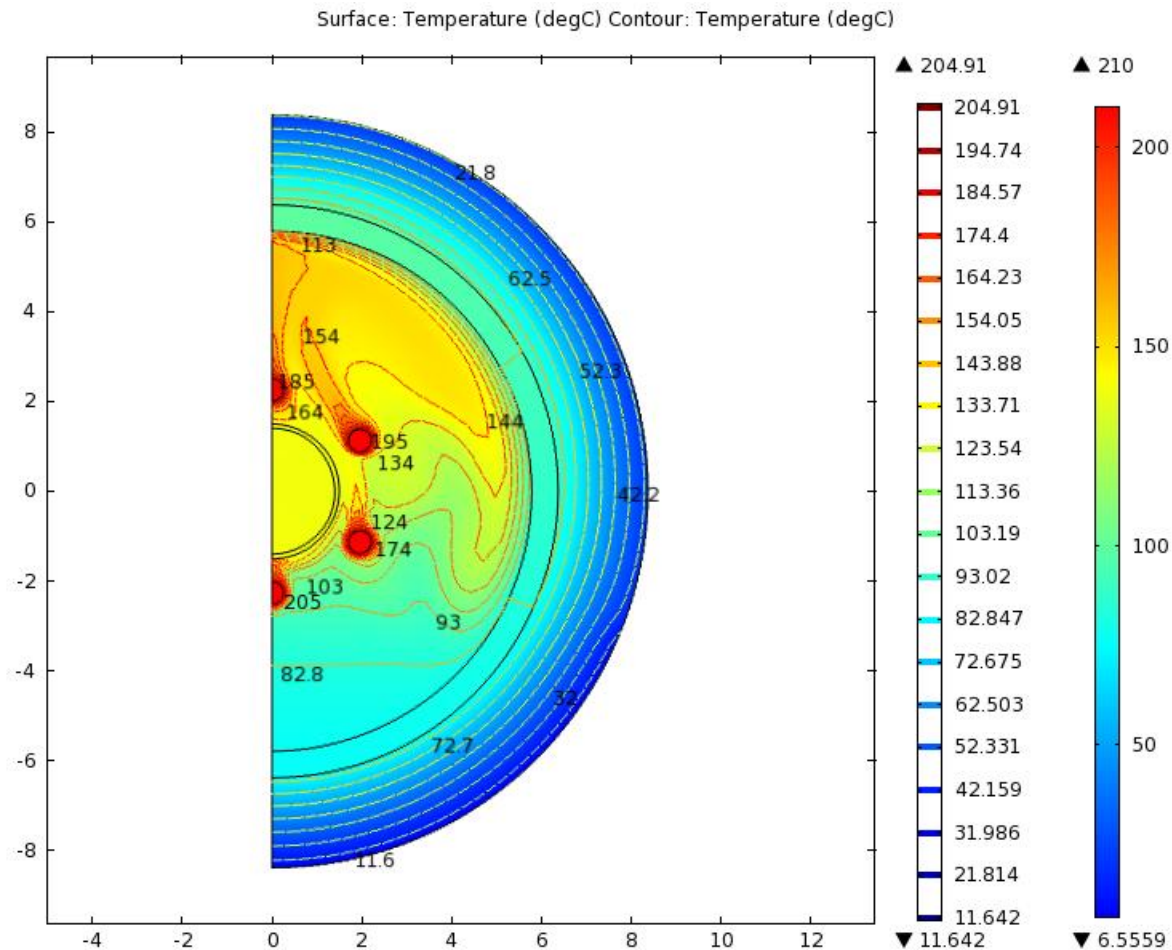
## ■ 2-D Temperature distribution



# FEA model of Heater



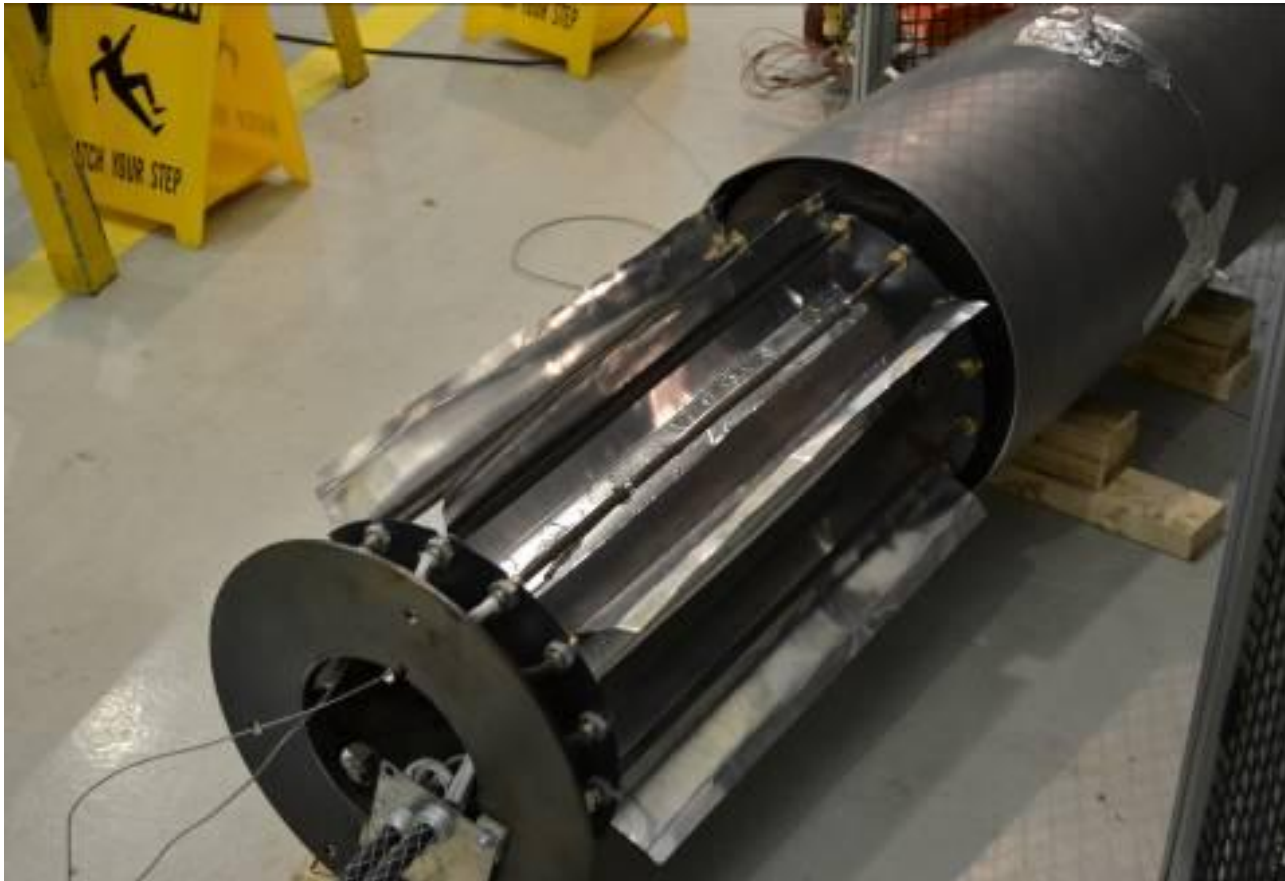
## ■ 2-D Temperature distribution



# Heater Test



- Confirm with heater test experiment



# CONCLUSIONS



- **The COMSOL model built performs well and agreed with well with experimental test results.**
- **The model revealed the problems existed in the heater design.**
- **FEA modeling offered provides a very good basics and reference for the future design of electric heater for heating pipe test.**

# Thank You



- **Thank you very much!**
  
- **Contact:**
  - Email: [bxu@shawcor.com](mailto:bxu@shawcor.com)