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ENERGY SERVICES • GLOBAL SOLUTIONS

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

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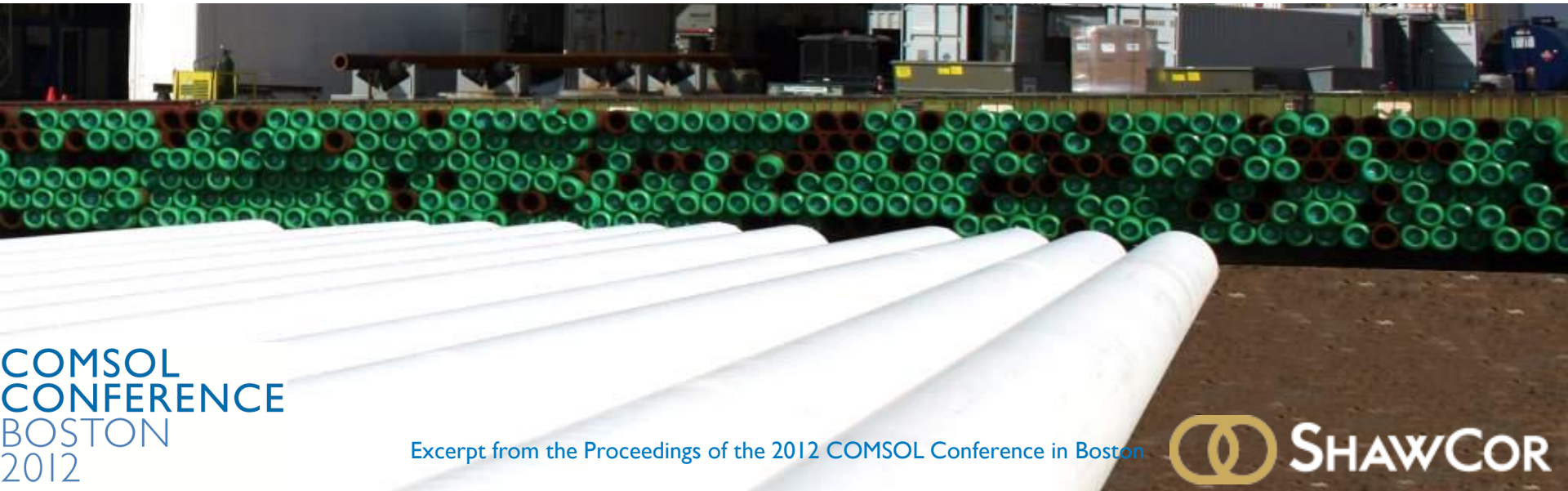

COMSOL CONFERENCE BOSTON 2012

Excerpt from the Proceedings of the 2012 COMSOL Conference in Boston

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Outline

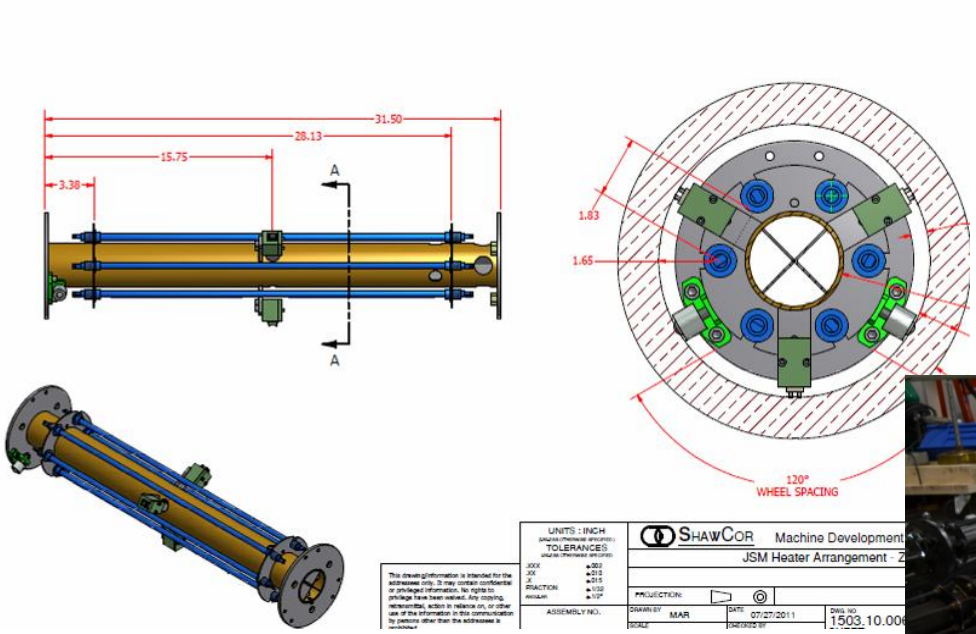
- Introduction
- Previous Heater Design & Challenge
- FEA Model
- Model Results
- Experiment test
- Conclusion

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

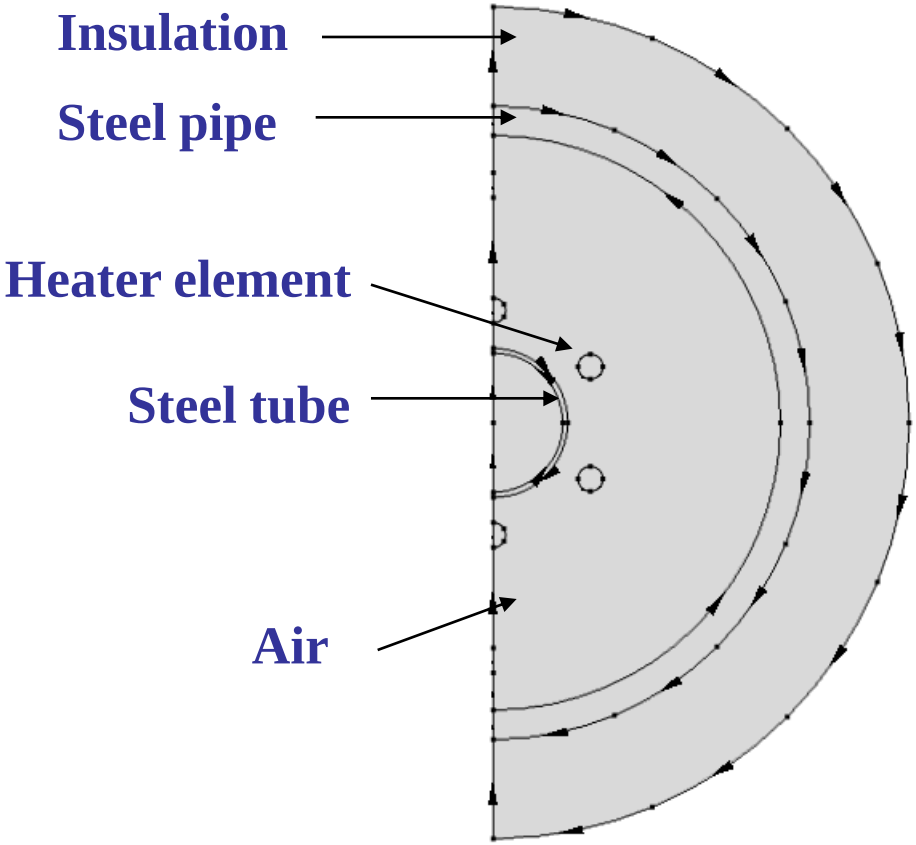
Electrical Pipe Heater Design

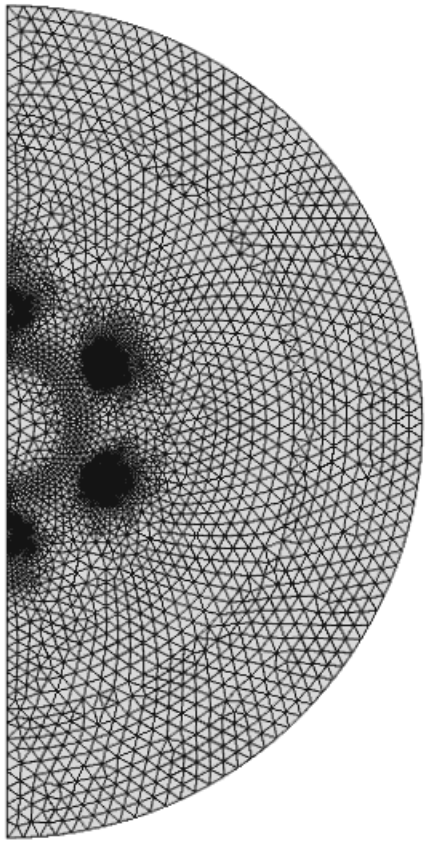
- **Heater Using tubular heater elements**



FEA model of Heater

- 2-D FEA model of electrical heater





FEA model of Heater

- **Governing Equations:**
  - For air region:

$$\begin{cases} \dfrac{\partial(\rho u)}{\partial x}+\dfrac{\partial(\rho u)}{\partial y}=0 \\ \rho u\left(\dfrac{\partial u}{\partial x}+\dfrac{\partial u}{\partial y}\right)=-\dfrac{\partial p}{\partial x}+\mu\left(\dfrac{\partial^2 u}{\partial x^2}+\dfrac{\partial^2 u}{\partial y^2}\right) \\ \rho v\left(\dfrac{\partial v}{\partial x}+\dfrac{\partial v}{\partial y}\right)=-\dfrac{\partial p}{\partial y}+\mu\left(\dfrac{\partial^2 v}{\partial x^2}+\dfrac{\partial^2 v}{\partial y^2}\right)-\rho g \\ \rho c_P\left(u\dfrac{\partial T}{\partial x}+v\dfrac{\partial T}{\partial y}\right)=\dfrac{\partial}{\partial x}\left(k\dfrac{\partial T}{\partial x}\right)+\dfrac{\partial}{\partial y}\left(k\dfrac{\partial T}{\partial y}\right) \end{cases}$$

for solid region:

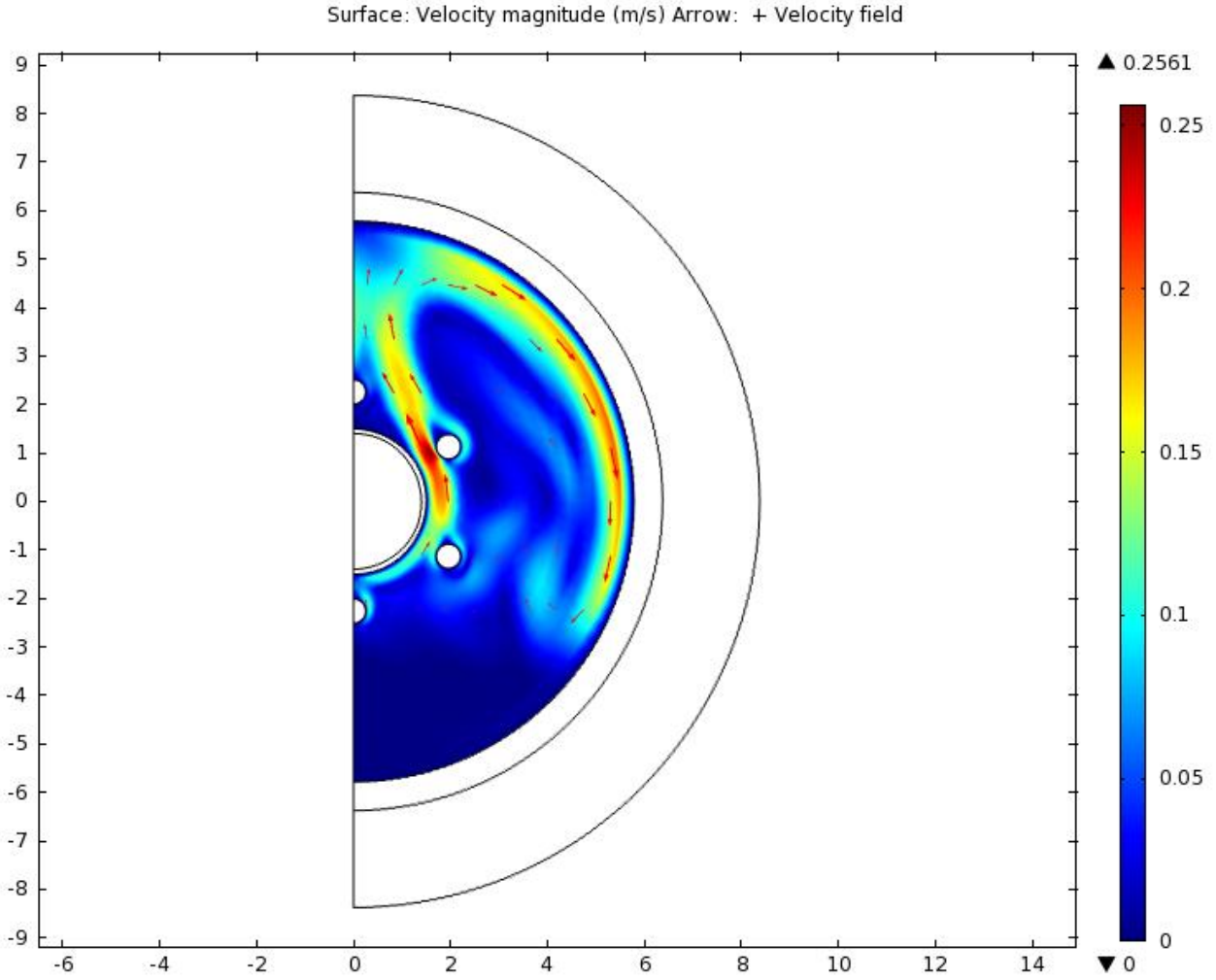
$$\rho c_p\left(\frac{\partial T}{\partial x}+\frac{\partial T}{\partial y}\right)=k\frac{\partial^2 T}{\partial x^2}+k\frac{\partial^2 T}{\partial y^2}$$

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 °C at the heater element
  - Convection at the external surface of the insulation layer.
  - T_0= 4 °C (in the real SSV test, water temperature is controlled to 4 °C).
  - Isothermal condition, at x=0

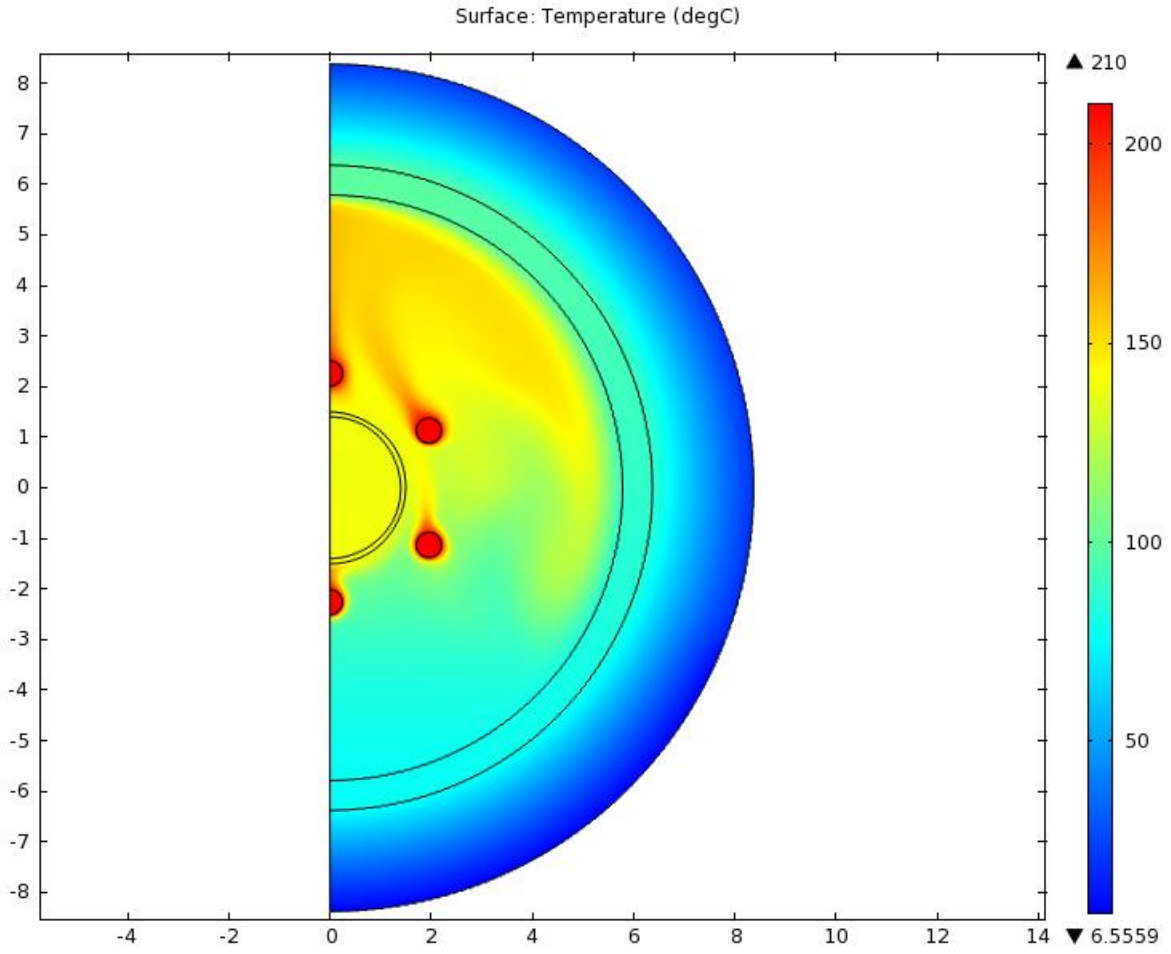
FEA model of Heater

- **Air flow around the heater in the pipe**



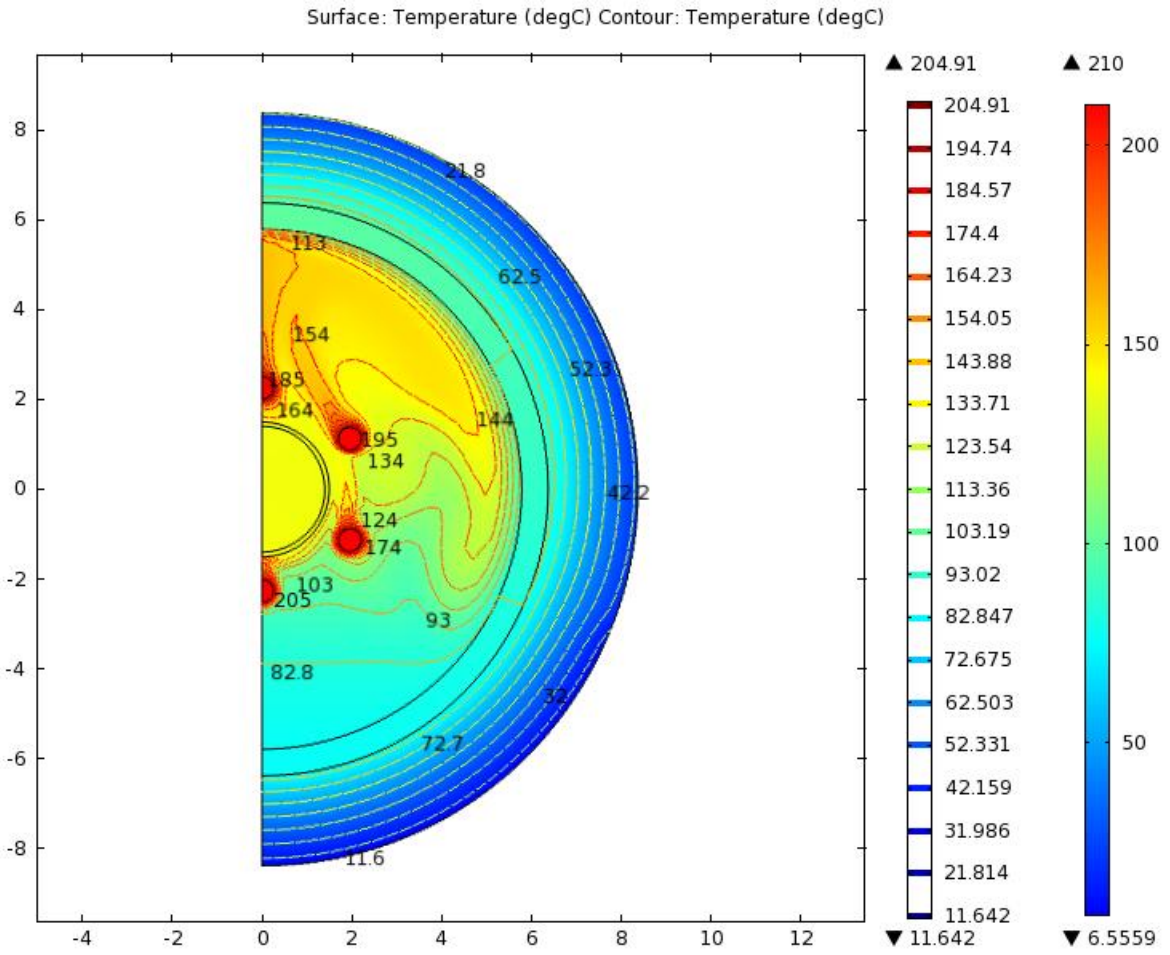
FEA model of Heater

- **2-D Temperature distribution**



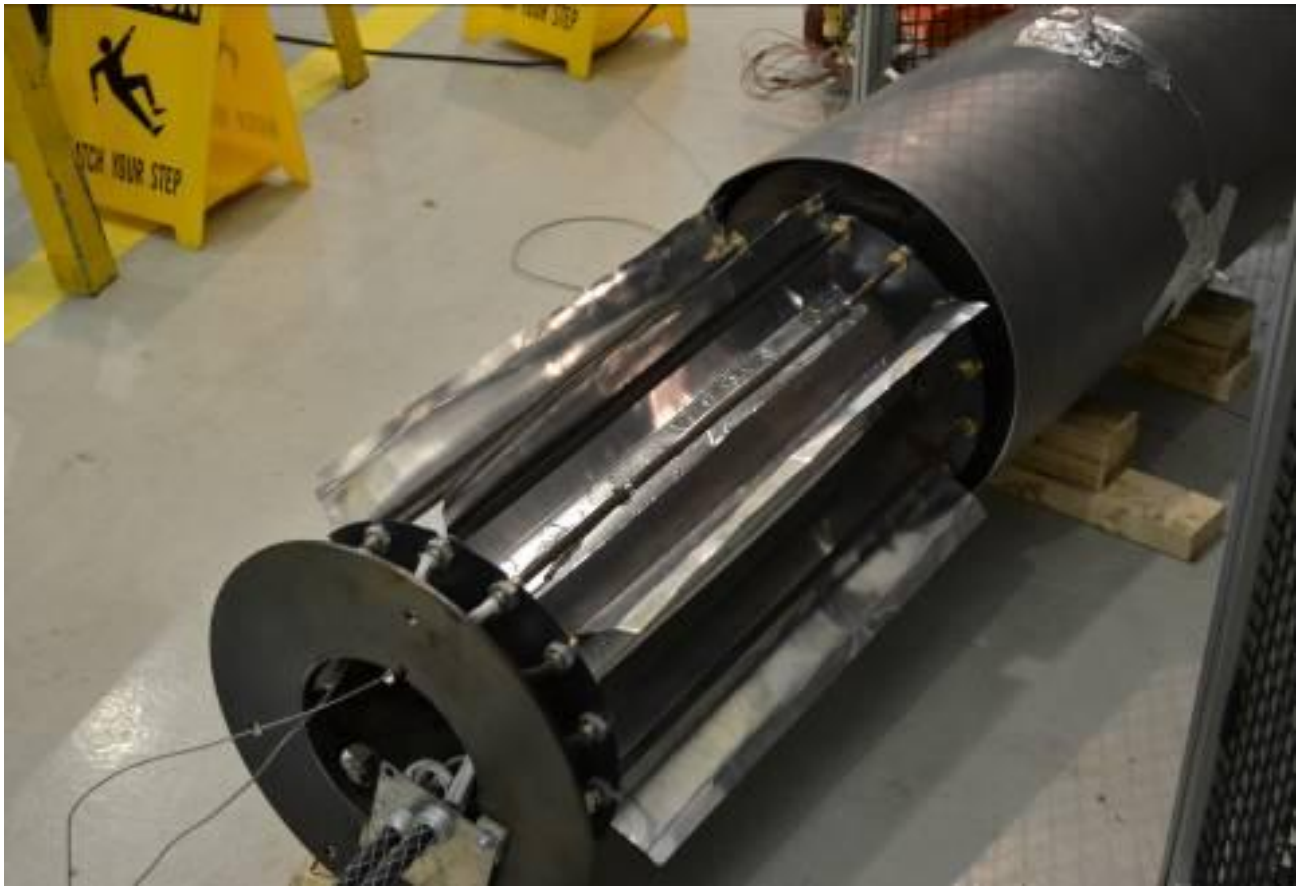
FEA model of Heater

- **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!**

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