Thermal Analysis of Induction Furnace

COMSOL CONFERENCE 2012 EDITION
Nov. 2nd & 3rd, BANGALORE

Presentor and: **Asif Ahmad Bhat*[1]**

Co-Authors: **S. Agarwal[1], D.Sujish[1], B.Muralidharan[1],**

B.P. Reddy[2], G. Padmakumar[1], K.K. Rajan[1]

[1]**Fast Reactor Technology Group,** [2]**Chemistry Group, IGCAR**

OVERVIEW

Introduction

Numerical model

Validation

Main features of the model

Geometry & Meshing

Governing equations and Boundary Conditions
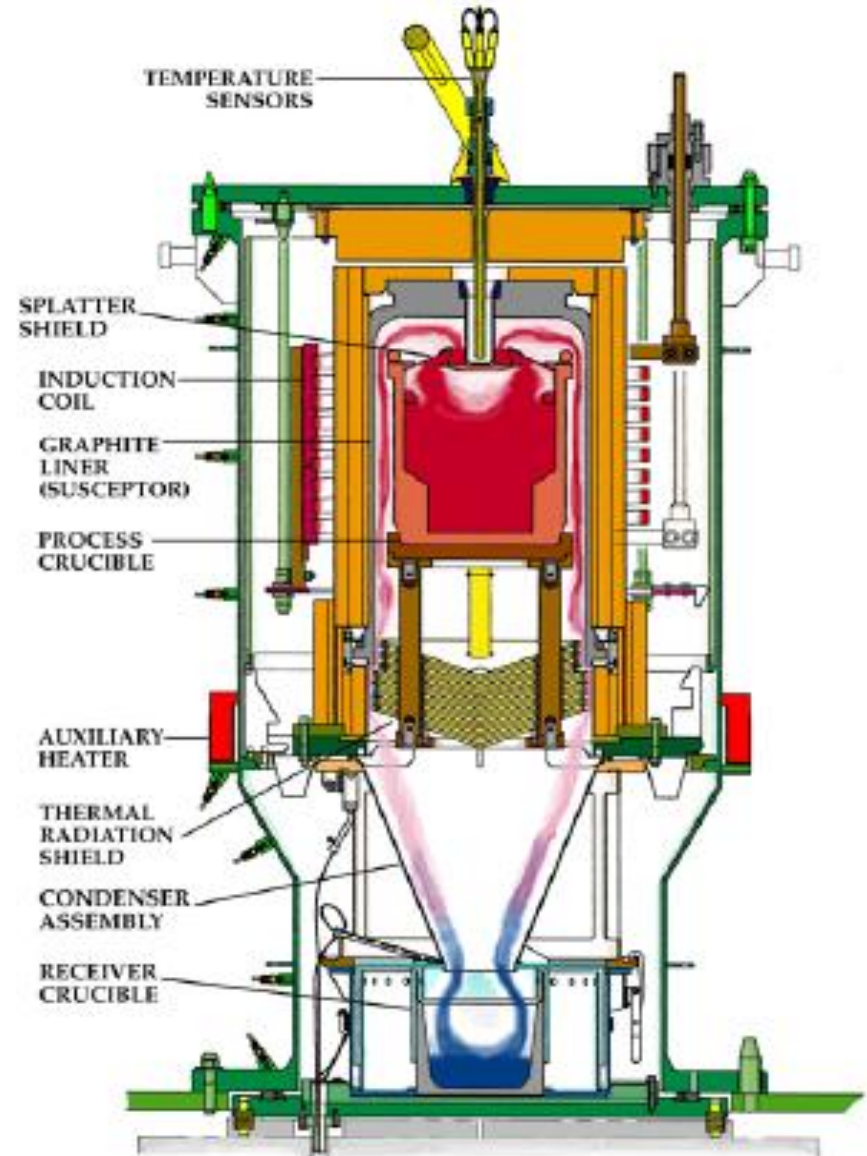
Numerical results

Conclusions

❑ **INDUCTION FURNACE**

It is a high temperature vacuum distillation furnace used for recovery of heavy metals

Functions :

- melt and consolidate of heavy metals
- distill the volatile metals and salts
- operate in inert containment box
- heat reasonably fast while being capable of holding temperature

Induction heating
Vacuum operation

TEMPERATURE SENSORS

SPLATTER SHIELD

INDUCTION COIL

GRAPHITE LINER (SUSCEPTOR)

PROCESS CRUCIBLE

AUXILIARY HEATER

THERMAL RADIATION SHIELD

CONDENSER ASSEMBLY

RECEIVER CRUCIBLE
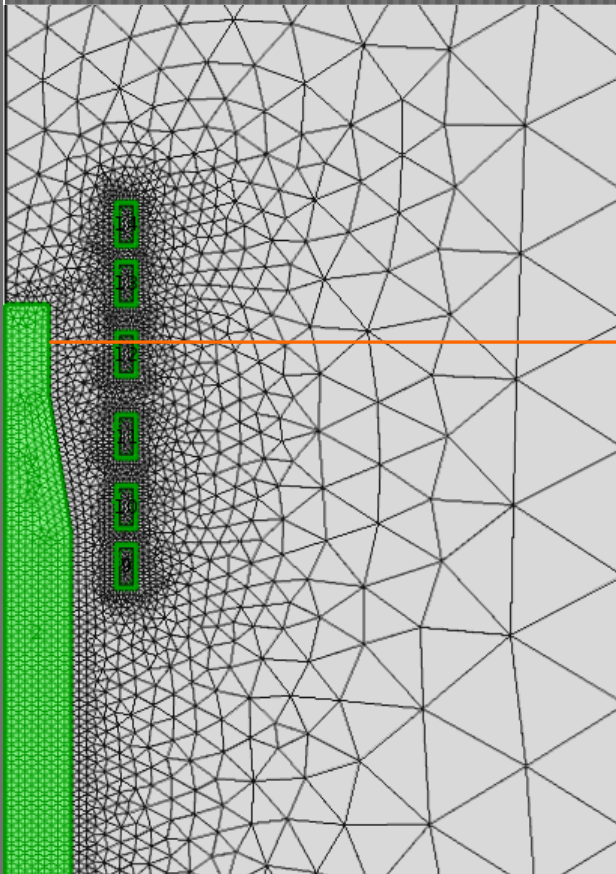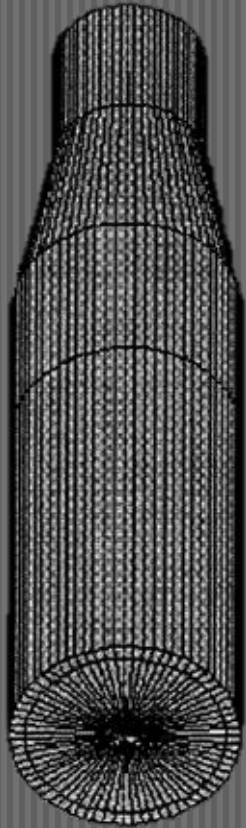
- **MOCK UP INDUCTION FURNACE**

—simulates conditions to be realized in actual furnace

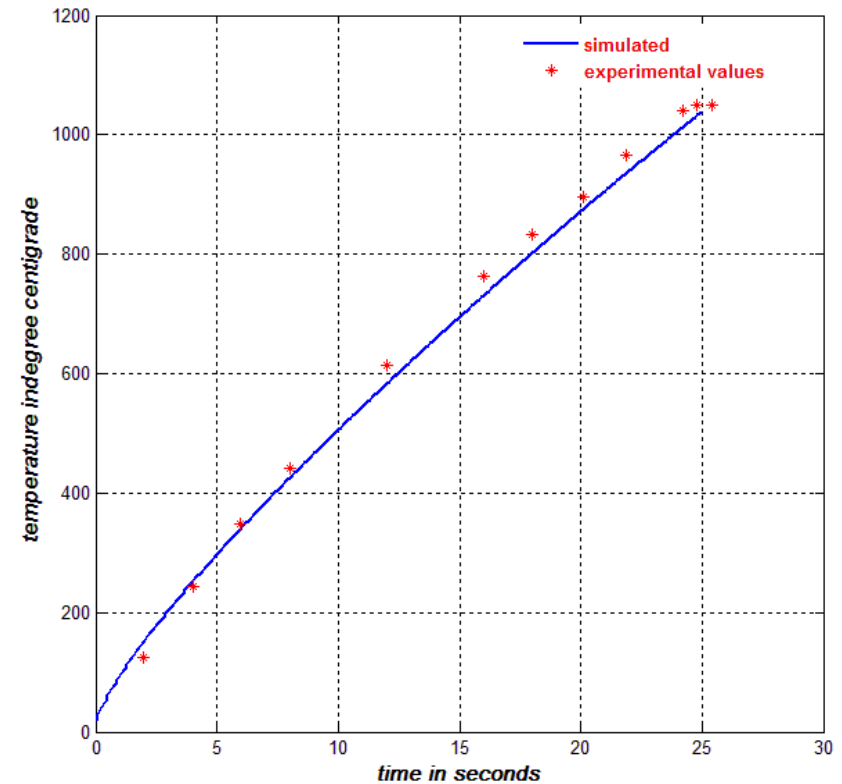—to demonstrate the melting of 10 kg copper
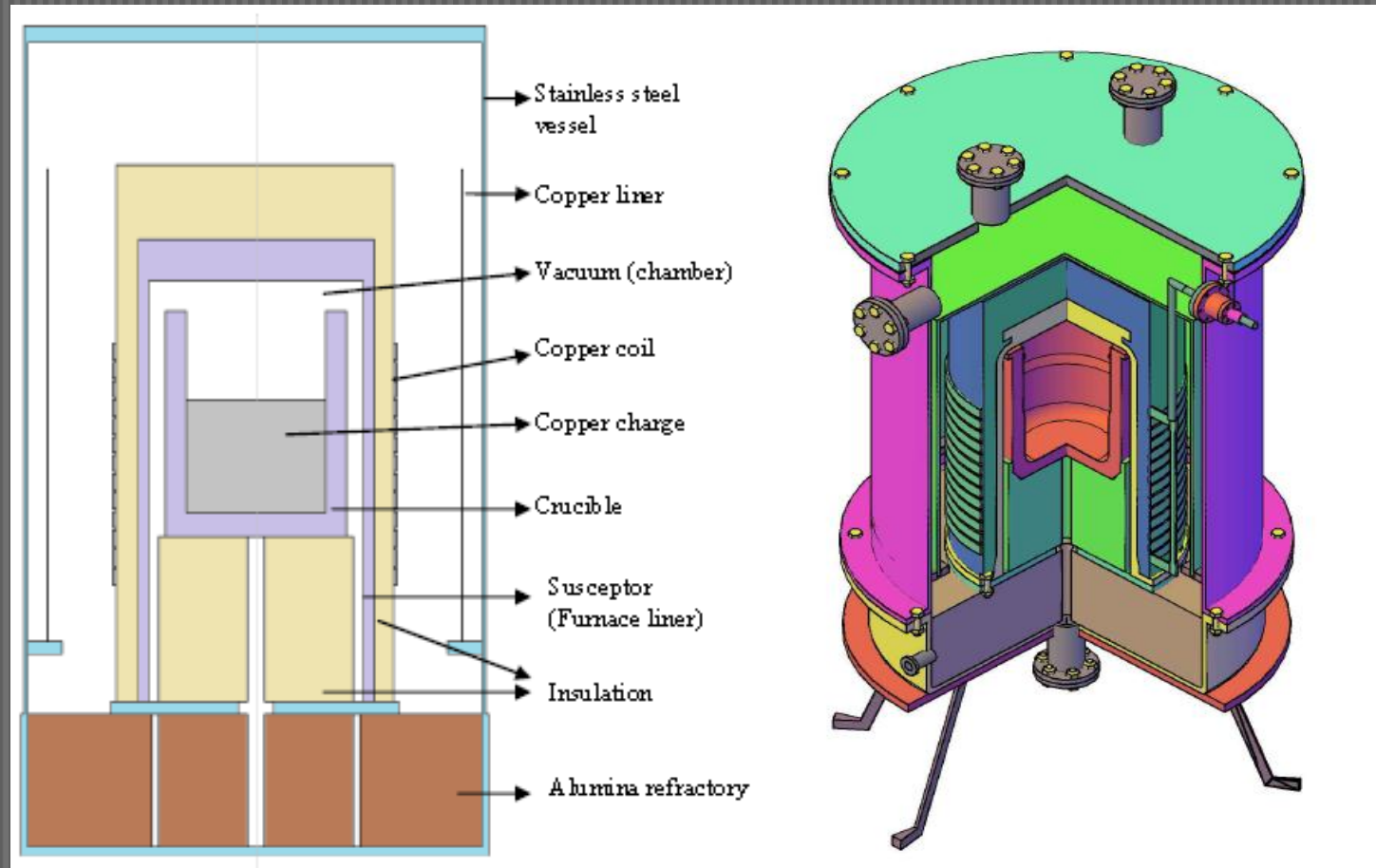
- **FOR VALIDATION**

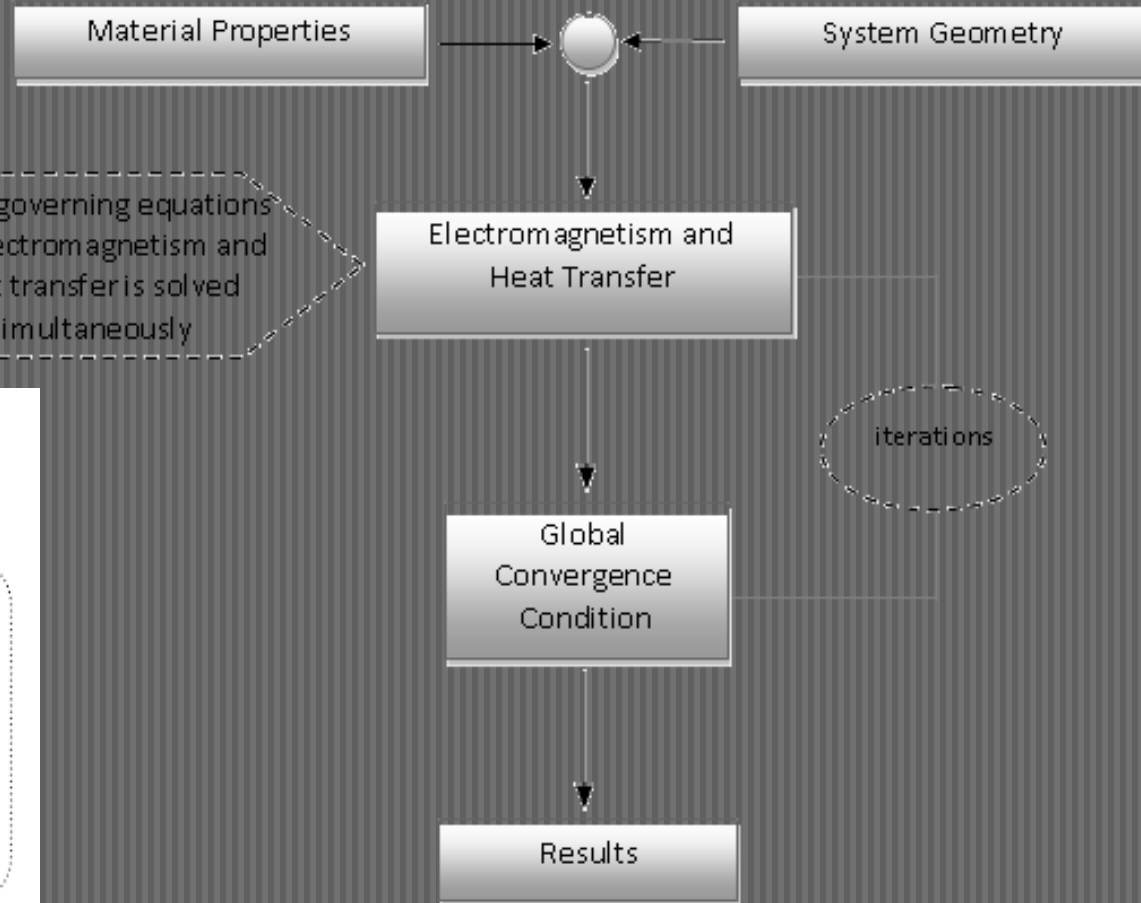| Work piece	COMSOL model of induction heating setup with meshing .	Comparison of experimental and simulated temperatures at thermocouple location..

❑ MAIN FEATURES OF THE MODEL

❑**Tightly coupled phenomena**

❑**Non linear**

$\mu(T, \omega), \sigma(T), C(T), k(T)$

Material Properties

System Geometry

Set of governing equations for electromagnetism and heat transfer is solved simultaneously

Electromagnetism and Heat Transfer

iterations

Global Convergence Condition
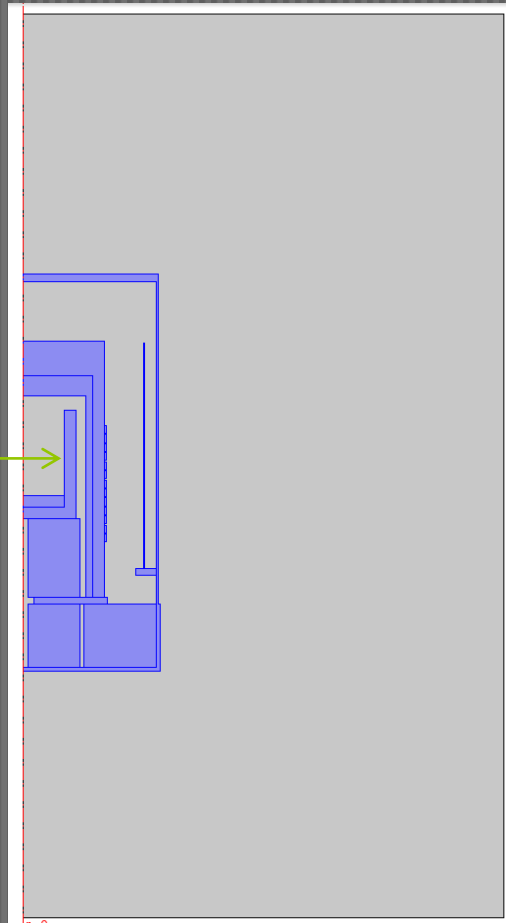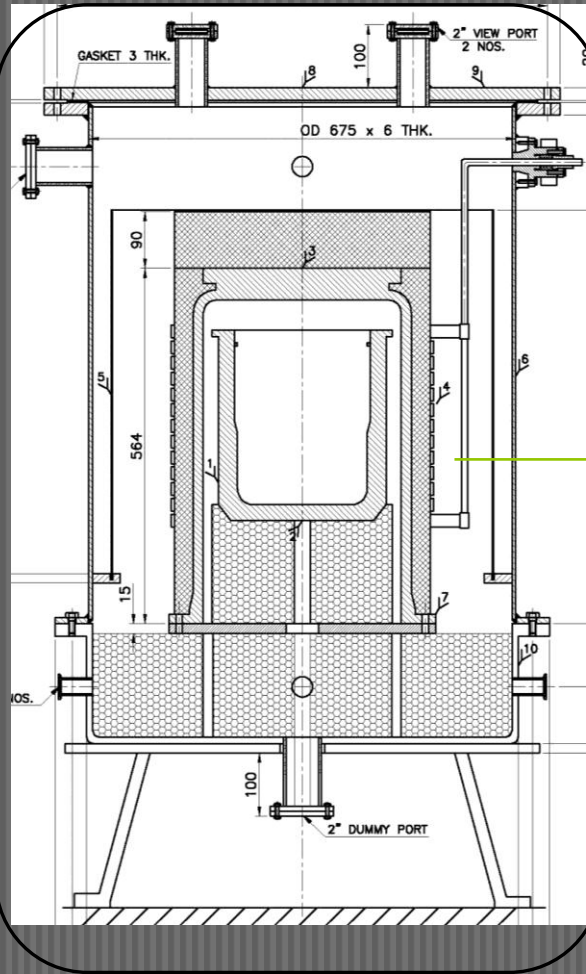
Results

ELECTROMAGNETISM
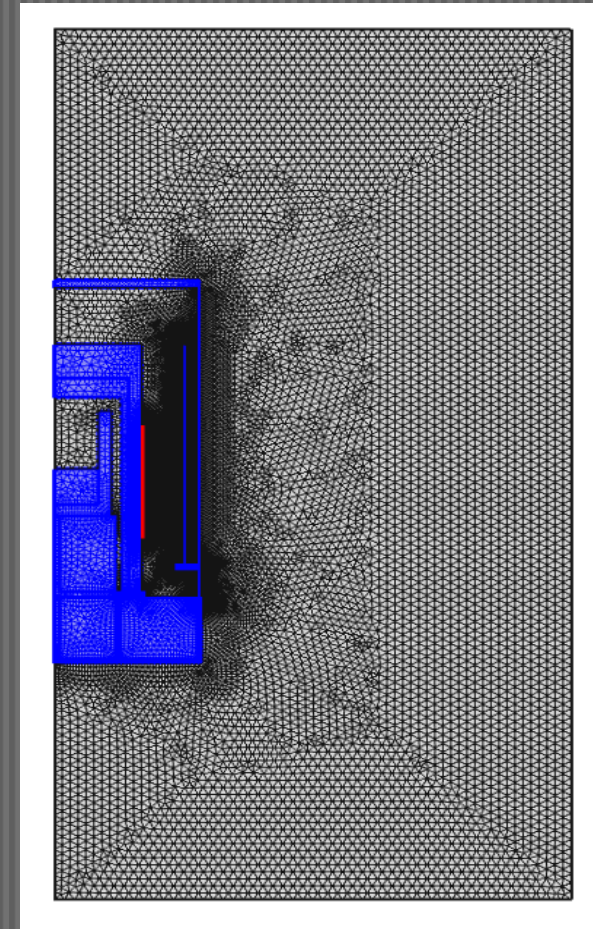
Faraday's law

Joule heating

properties dependent on magnetic field and temperature

HEAT TRANSFER

□ **GEOMETRY** 2D axi- symmetric model of the mock-up cathode processor created in COMSOL

□ **MESHING**

GOVERNING EQUATIONS AND BOUNDARY CONDITIONS

Electromagnetic field - Maxwell's equations

$$(j\omega\sigma - \omega^2\epsilon_0\epsilon_r)A + \nabla \times (\mu_0^{-1}\mu_r^{-1}B) = J_e$$

$$B = \nabla \times A$$

- These equations are solved in copper charge, coil, crucible, susceptor, insulation, alumina, and air domains.

- The input data for the coil is 400 A external current with a working frequency of 8 kHz.

- In the outer boundaries of computational domain the magnetic insulation boundary condition is used, which imposes that the normal component of magnetic field has to be zero

❑ **GOVERNING EQUATIONS AND BOUNDARY CONDITIONS**

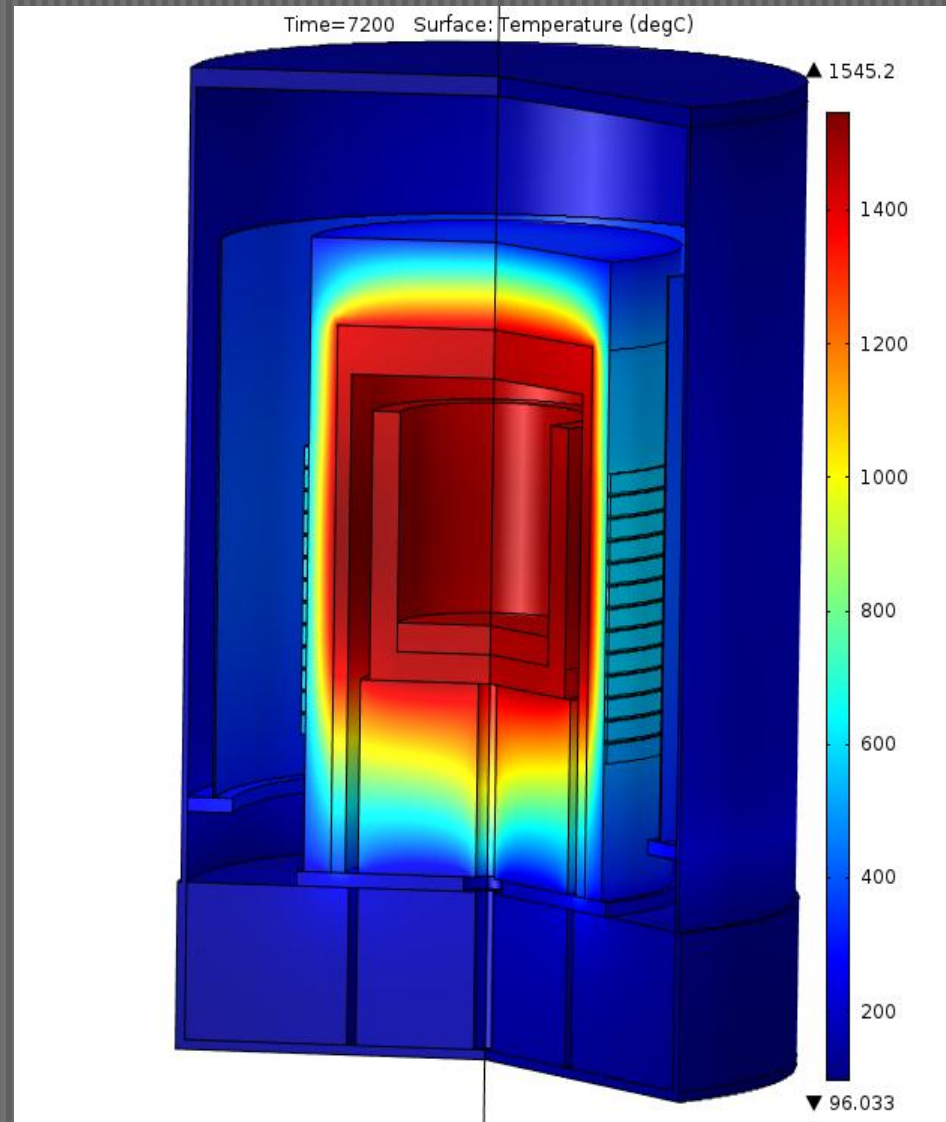**Thermal field – Fourier equation**

$$\rho c \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + Q$$

- Solid computational domains of the model,

- All the initial temperatures are set to 30°c.

- All the inside free surfaces in the model are allowed to participate in surface to surface radiation.

- The outer vessel wall surfaces are allowed to participate in surface to ambient radiation and convective cooling using suitable values of *h.*
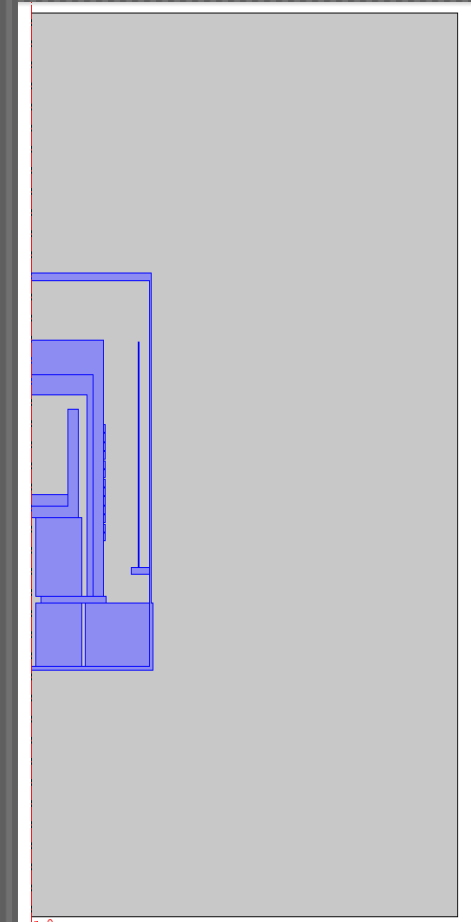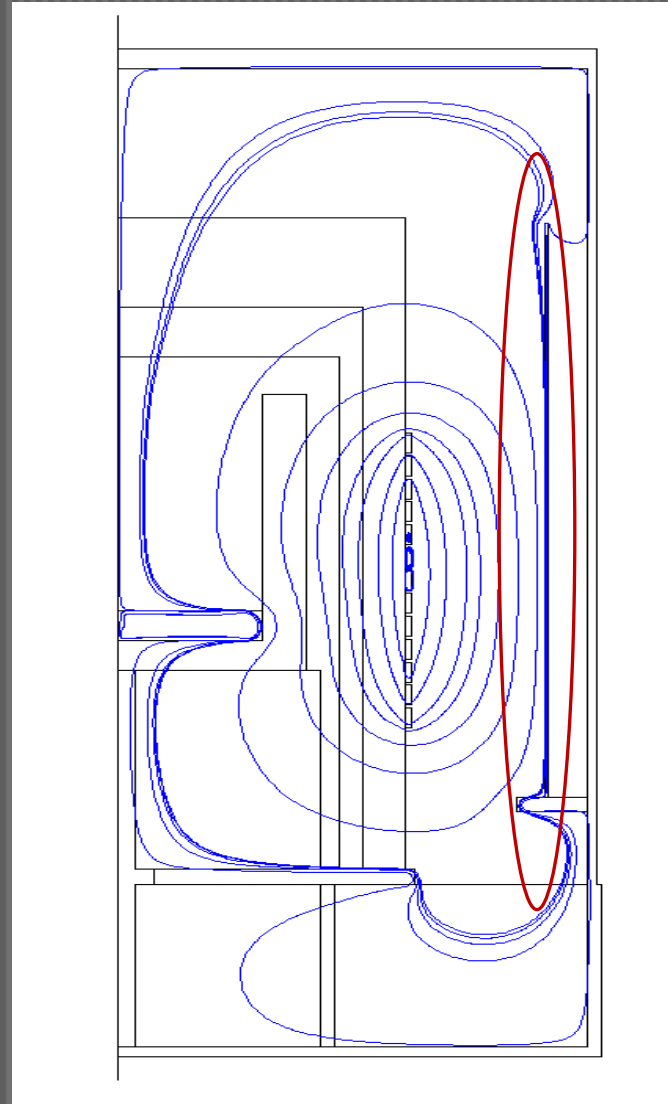
Magnetic flux density (streamline representation) inside the furnace.

Time=7200 Surface: Temperature (degC)

3D Temperature distribution in mock-up induction furnace after 2 hours

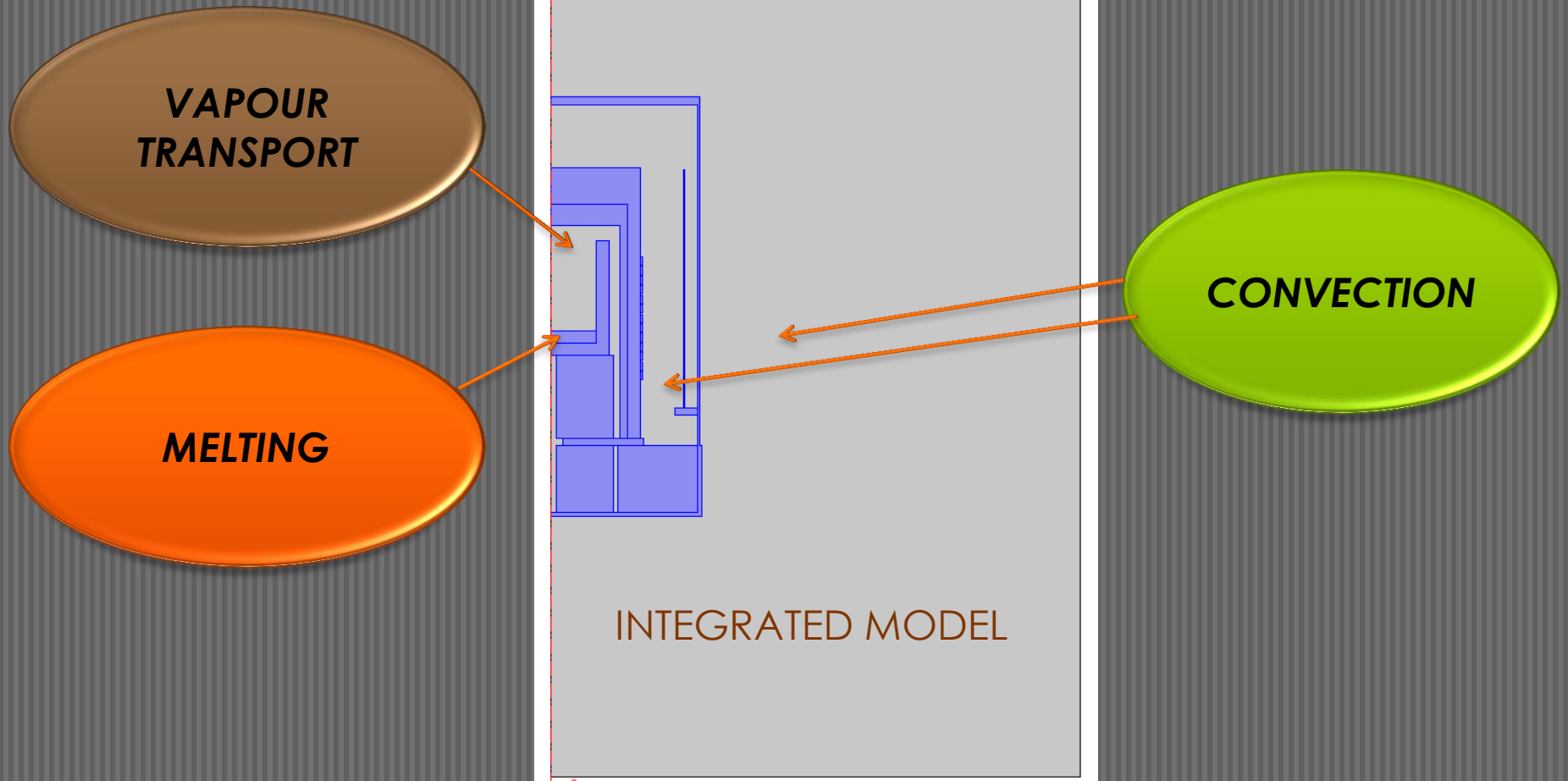Time=7200   Surface: Temperature (degC)
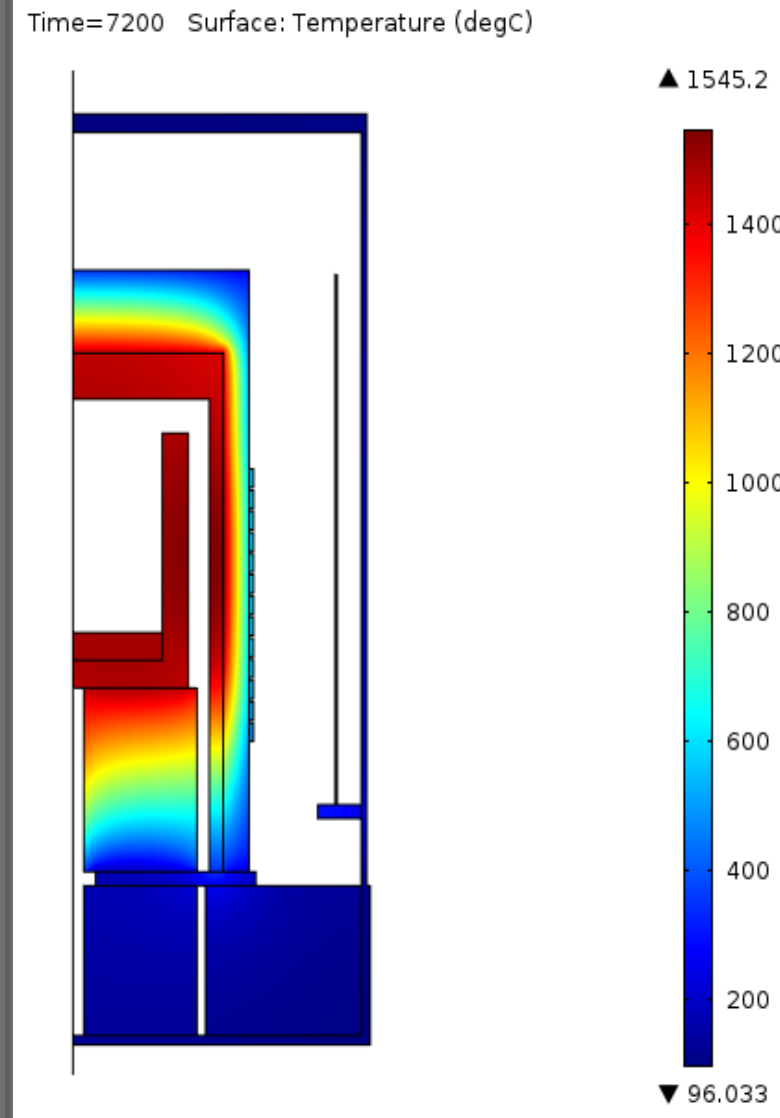
2D Temperature distribution in mock-up induction furnace after 2 hours
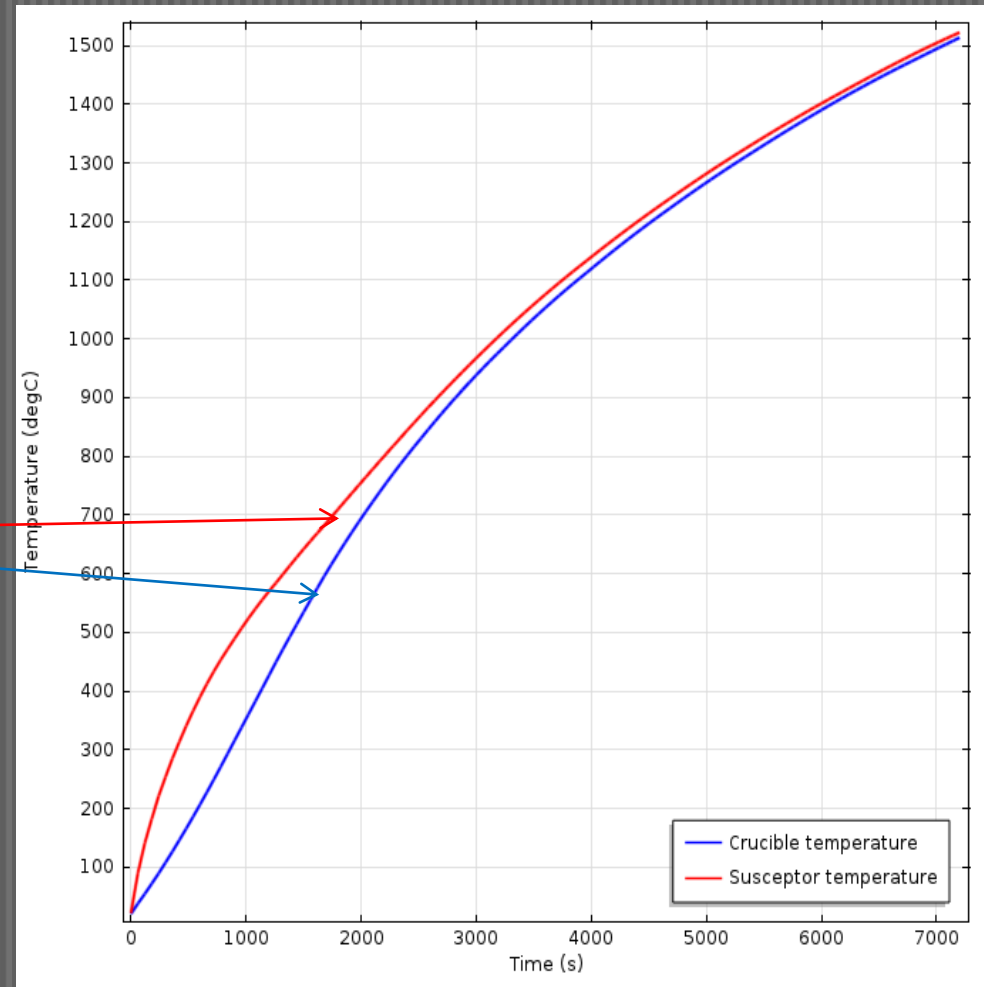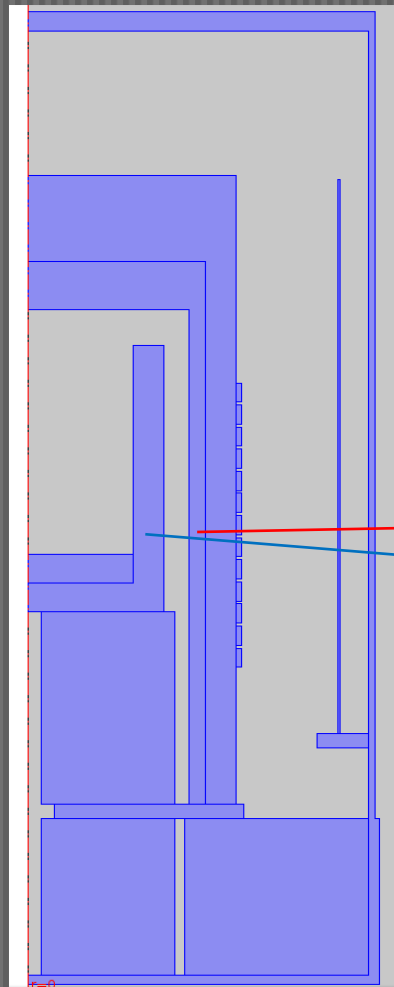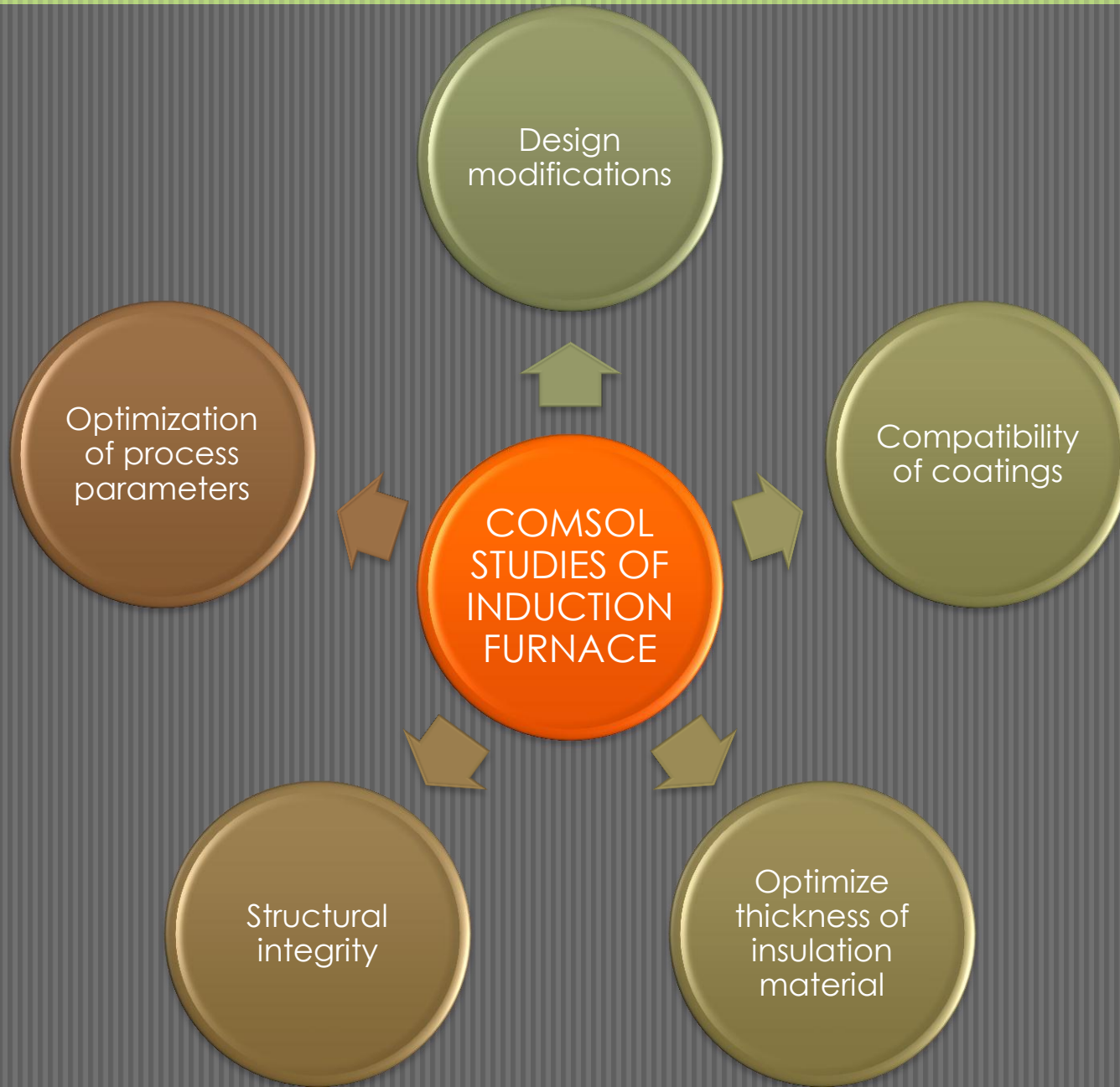
Temperature rise with time at the indicated points on the susceptor and crucible respectively.

- Transient Thermal analysis of mock-up induction furnace is being carried out in this study which is highly important for operation and control of the process.

- Preliminary model : it will aid in improving the design.

- The results of this study have shown that the temperature of the crucible rises to 1500 °C in 2 hours of heating time at frequency of 8 kHz and current of 400 A. copper is likely to melt under these conditions.

- The studies reveal that copper-liner is effective in reducing the electromagnetic coupling between the coil and the vessel and thus prevents vessel from getting heated up by this effect.

- The coil temperatures are above the acceptable temperature of copper material, hence different cooling technique is to be adopted.

- These results will be compared with the experimental results which will be obtained during the operation of mock up facility.

FURTHER STUDY

VAPOUR TRANSPORT

MELTING

CONVECTION

INTEGRATED MODEL

IMPORTANCE

Design modifications

Optimization of process parameters

Compatibility of coatings

COMSOL STUDIES OF INDUCTION FURNACE

Structural integrity

Optimize thickness of insulation material

Thermal Analysis of Induction Furnace

Thanks for your attention

Thermal Analysis of Induction Furnace

MOCK UP INDUCTION FURNACE

S. No	Parameter	Value
1	Frequency	8 kHz
2	Current	400 A
3	Height of copper in the crucible	30 mm (for 3.5 kg)
4	Time of heating	7200 s (2 hours)
5	Time step for computation	60 s

Thermal Analysis of Induction Furnace

- **FOR VALIDATION**

Parameter	Value
Total Voltage	77 V
Electrical Power	13 – 15 kW
Frequency	10 KHz
Time of Heating	25 s
Time step for Computation	0.1s

❑ **MESHING**

- Physics –controlled

- Triangular elements

- Extremely fine

- 34580 elemets