Simulation and experimental validation of direct heating of β heat treatment of Dhruva fuel rod

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Introduction: β heat treatment of Uranium rod is carried out for randomization of oriented grain(called texture) developed during rolling or extrusion operation. Grain randomization helps to maintain the fuel assembly integrity in the reactor under thermal cycling. In β heat treatment process, Uranium rods are heated upto 720 to 740 deg c i.e. β phase and then immediately quenched into water tank. Present system has few drawbacks like Low efficiency, manually handling of molten salt and uranium rod at high temperature.

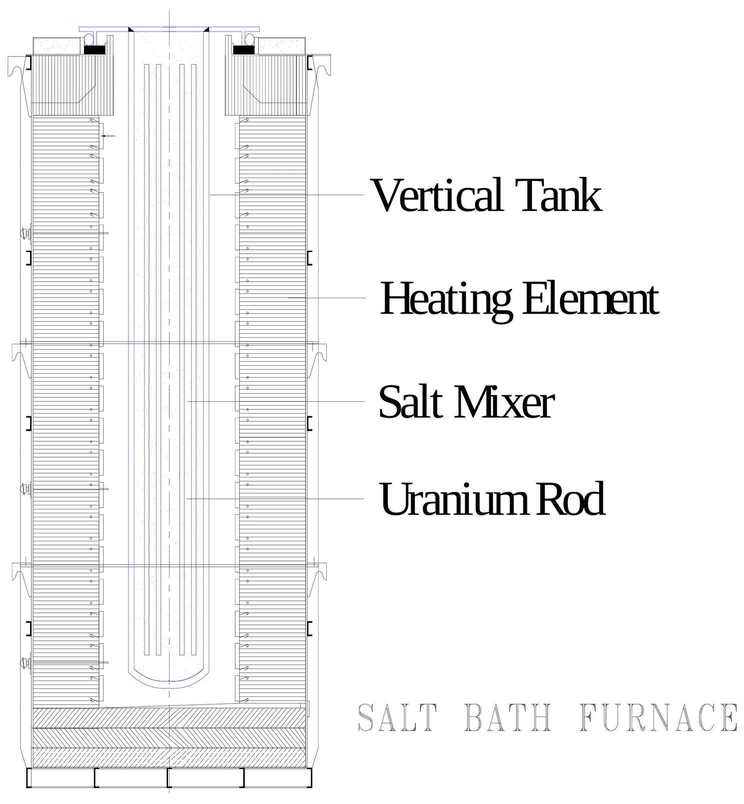


Figure 1. Present system

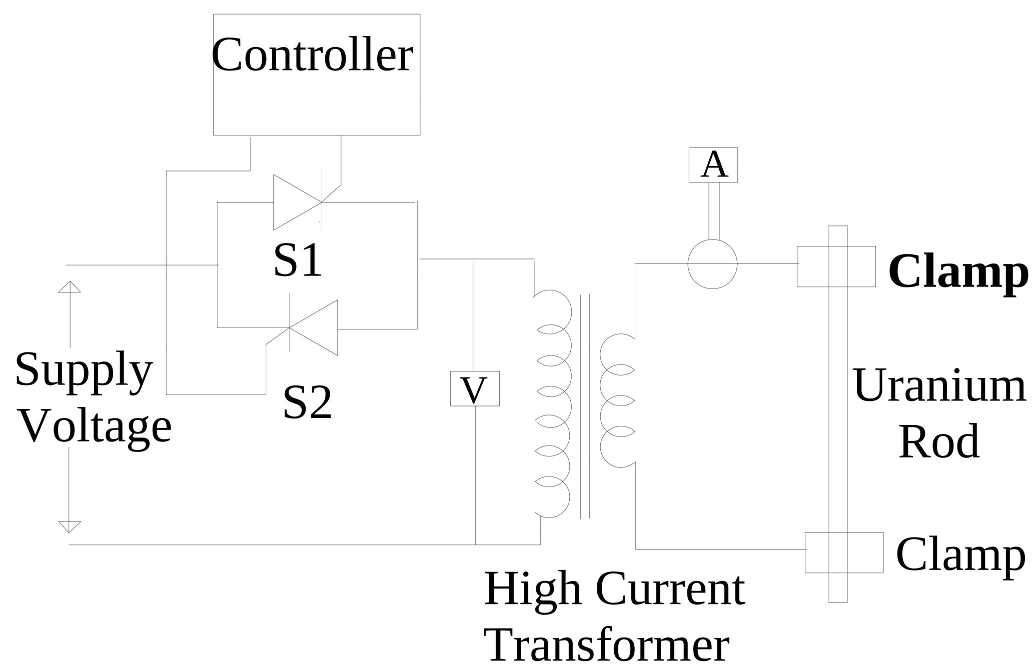


Figure 2. Direct heating system (Alternative method)

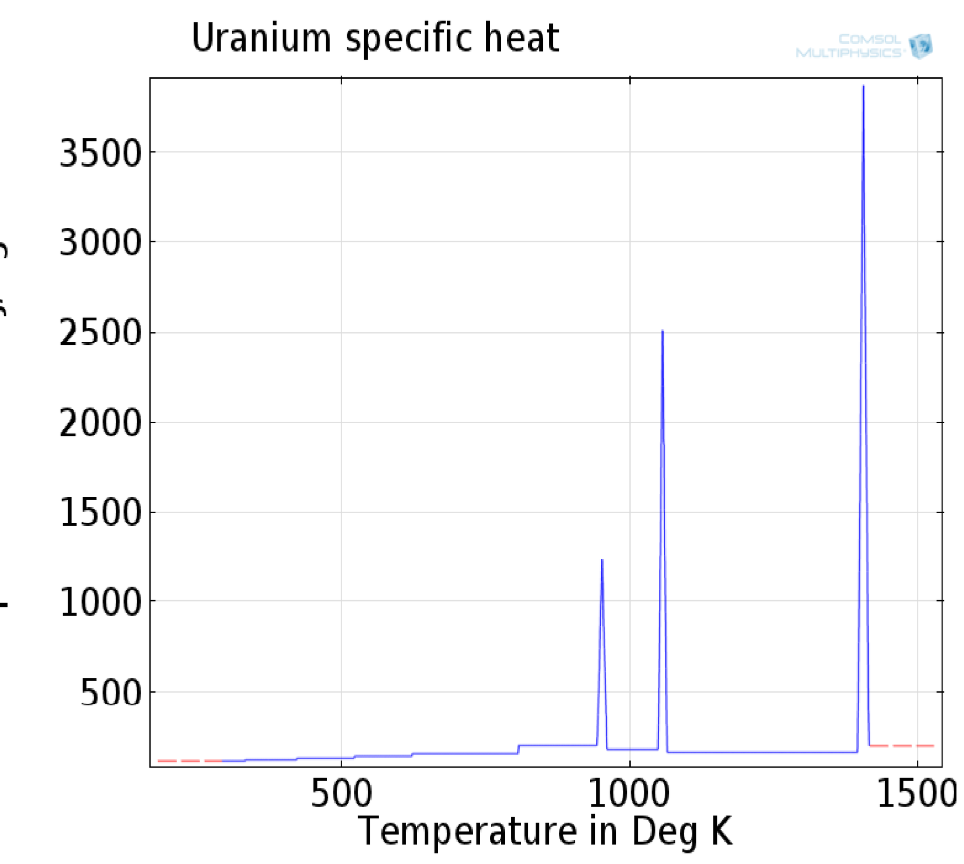
Computational Methods: Direct heating of Uranium rod is multiphysics process i.e. Electric field and heat transfer. Electric field and heat transfer field are coupled with each other by means of heat source term and temperature dependent material properties.

Electric field
$$\nabla.(\sigma(T)\nabla V) = 0$$

Heat source term
$$Q = \sigma(T)(\nabla V)^2$$

Heat transfer
$$\nabla.k\nabla T + Q = \rho c\frac{\partial T}{\partial t}$$

Effective heat capacity method is used for phase change analysis, which is based on enthalpy formulation. In this method, latent heat is divided over the temperature range to avoid specific heat capacity become infinite.



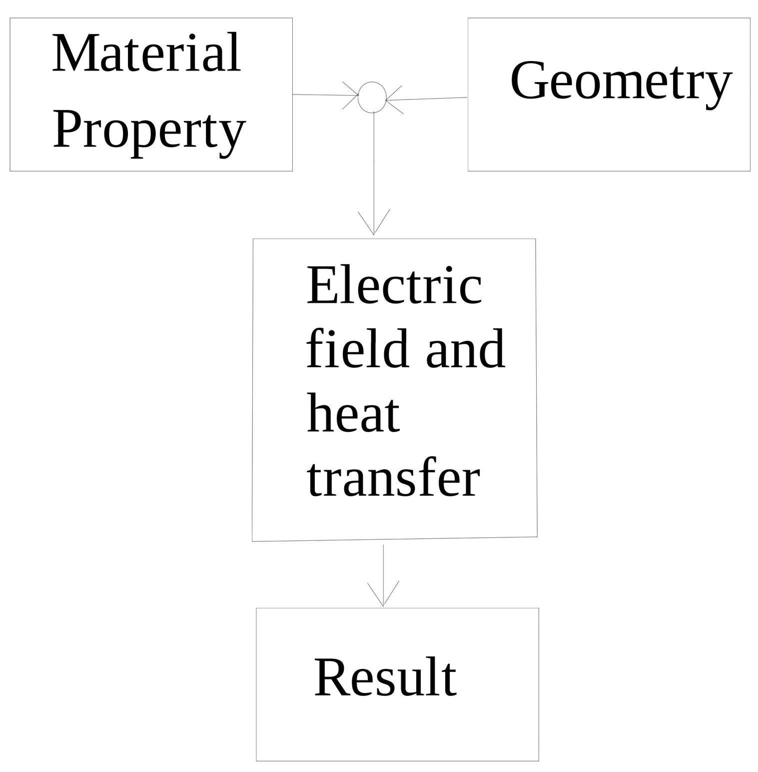
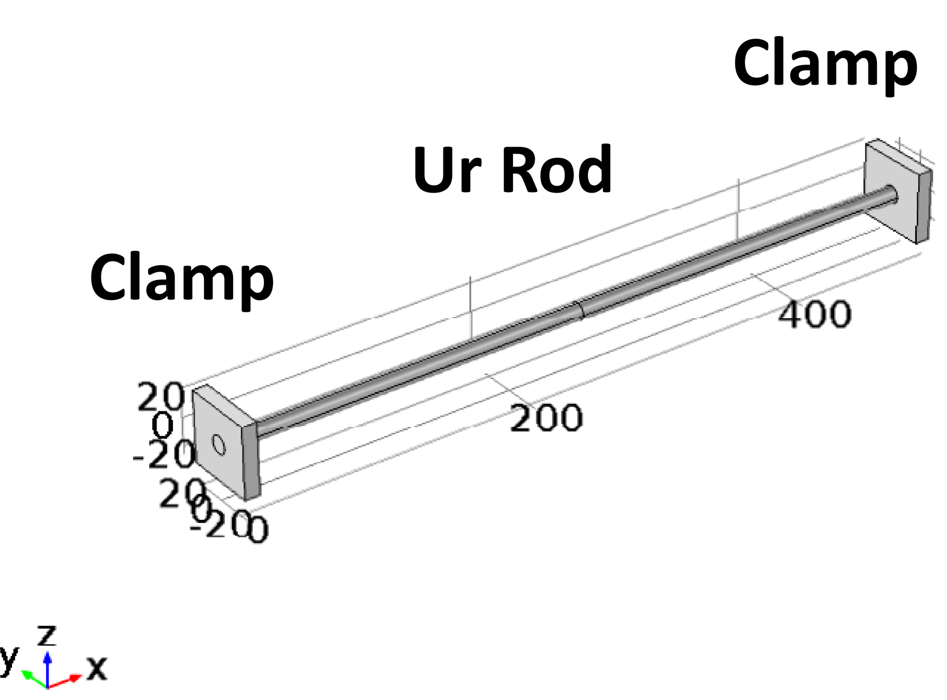


Figure 4.Copled field solution approach



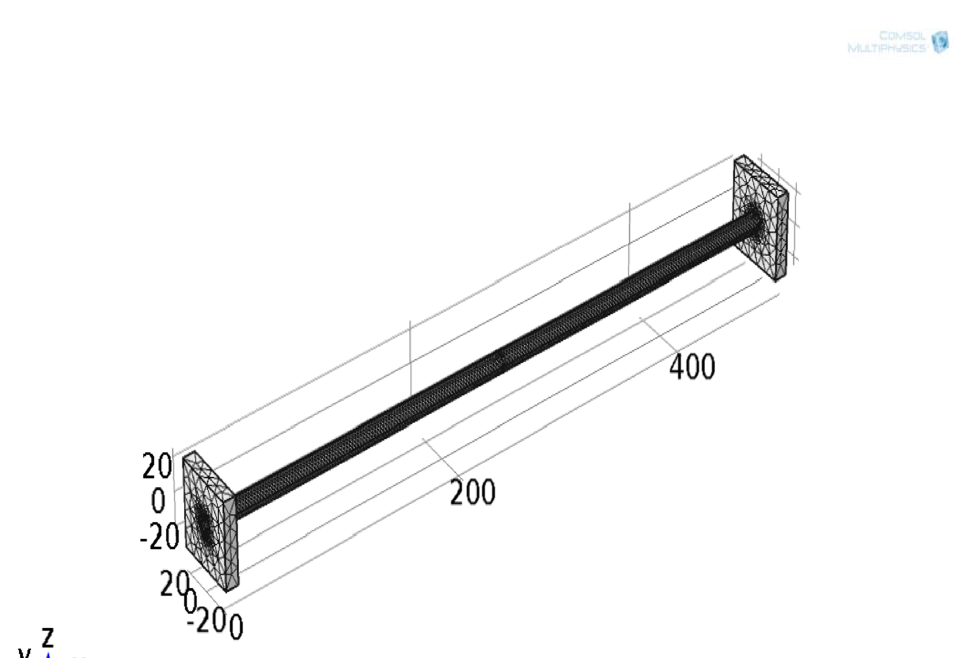


Figure 2. Geometry and meshing used for simulation

Sr no	Description	Uranium Rod (12mm dia and 500 mm L)
1	Convection coefficient	5
2	Emissivity	0.4
3	Rod conductivity	2.32X10(-3) S/m
4	Current	827 A

Results: After validation of simulation and experiment results, The same model is applied for Dhruva fuel rod and optimize the parameters like current, time, holding fixture etc.

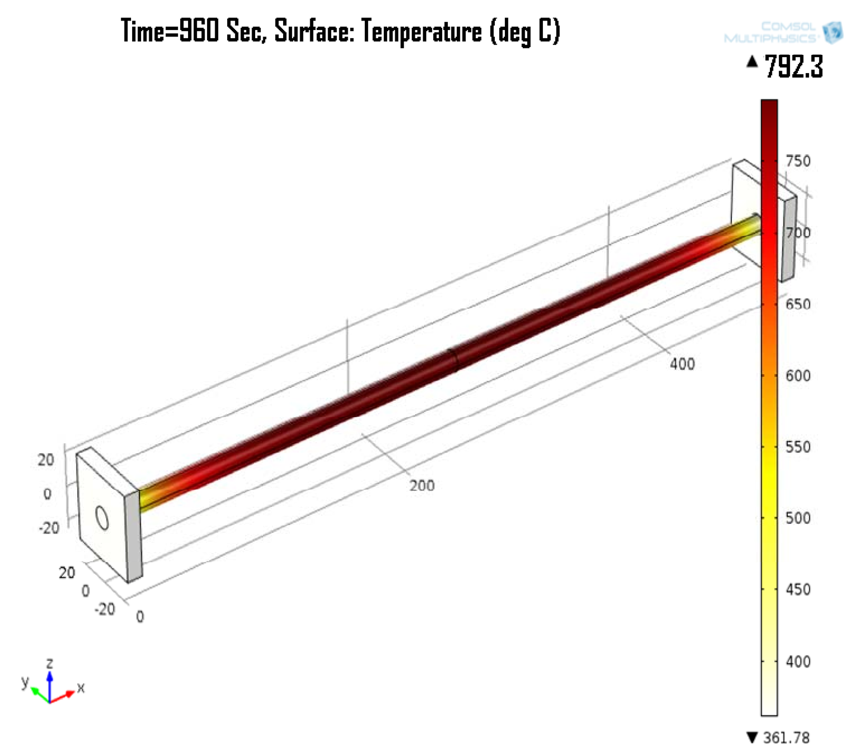


Figure 5. Simulation result **Figure 6**. Experiment result

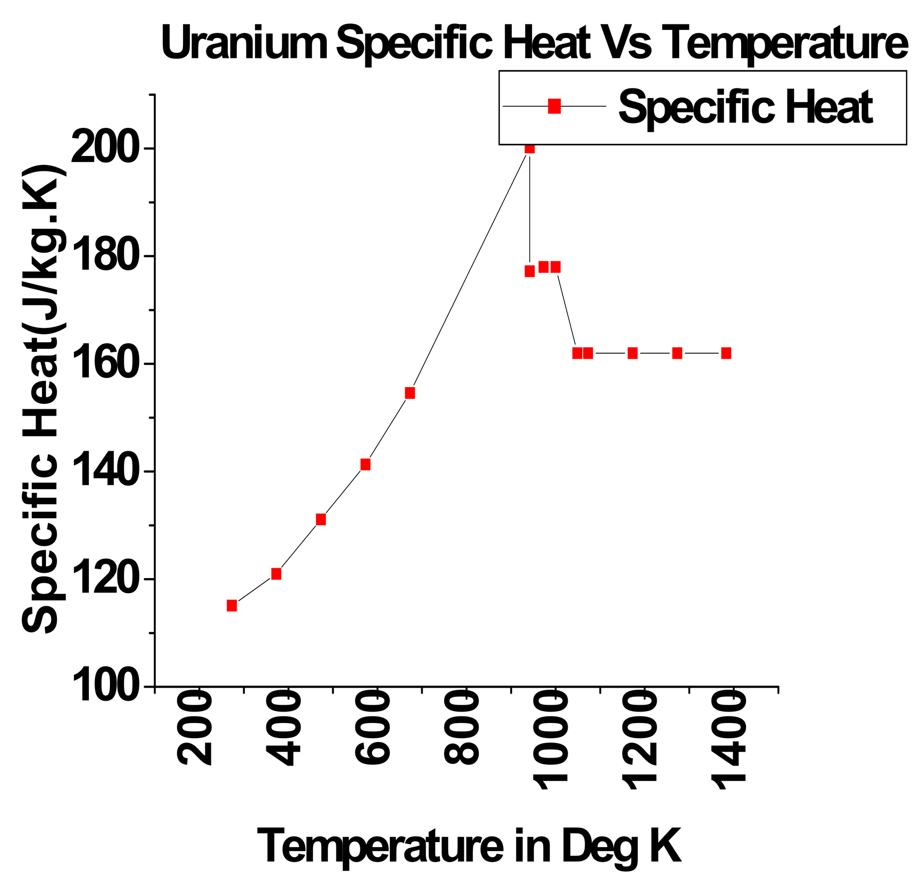


Figure 7.Uranium Specific Heat

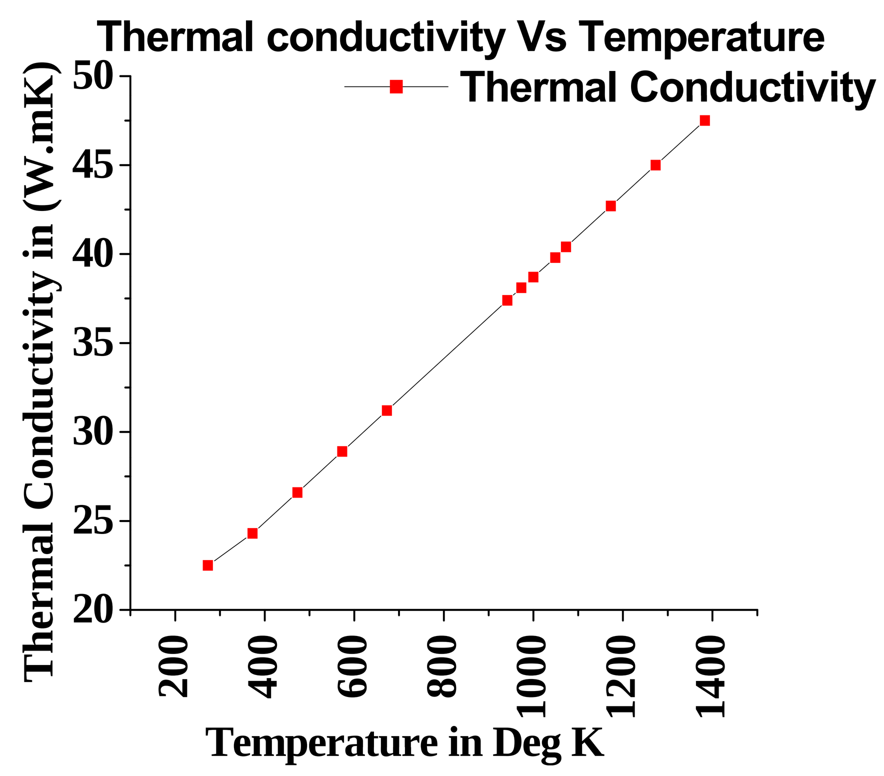
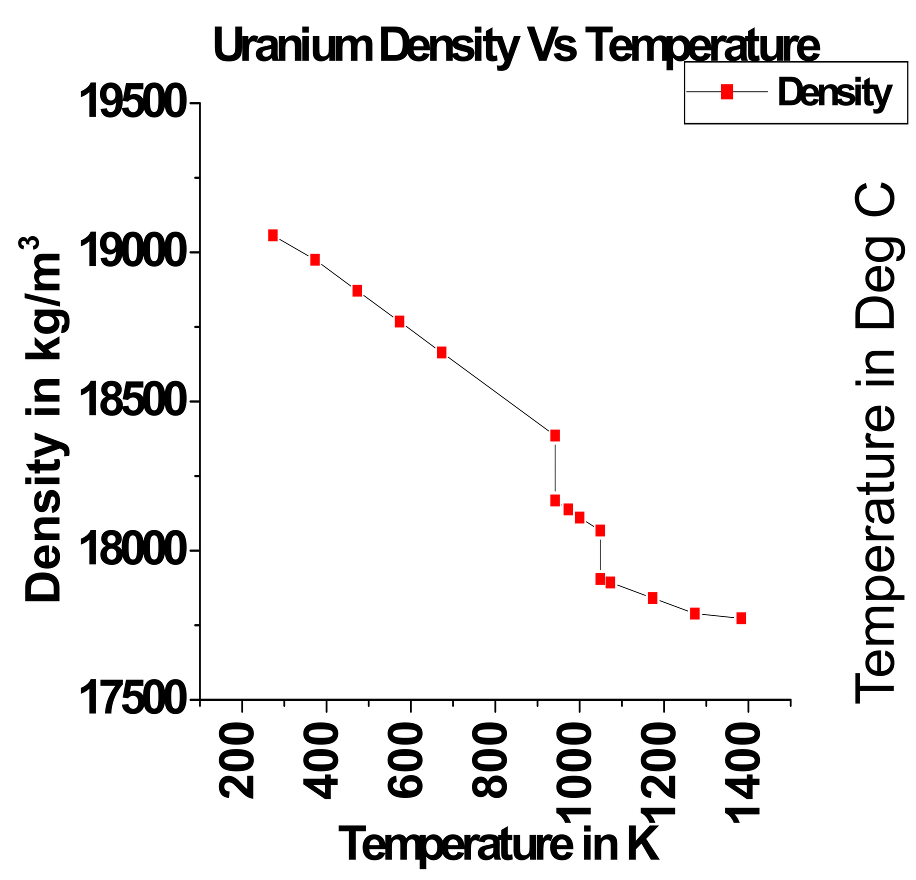


Figure 8. Uranium Thermal Conductivity



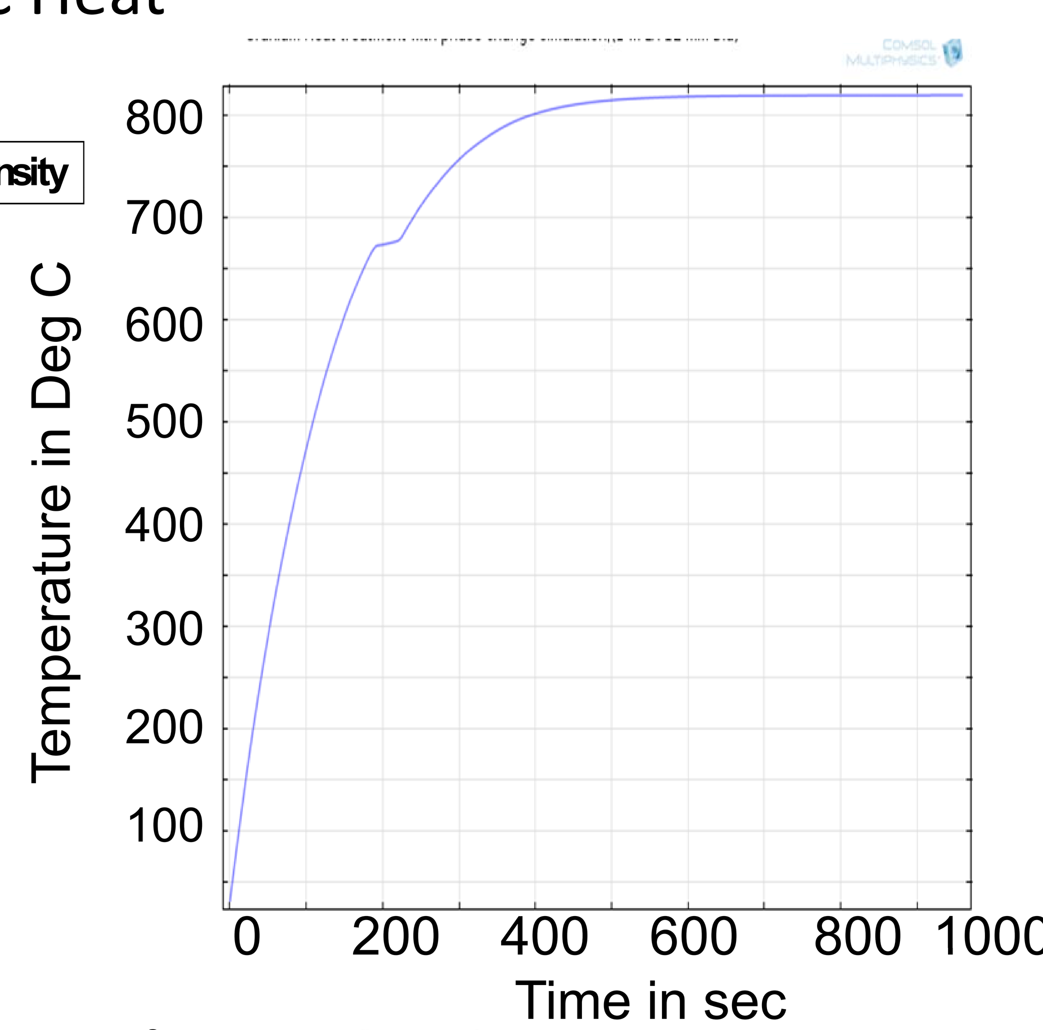


Figure 9.Uranium Density **Figure 10**. Time Vs Temperature

Conclusions: Direct heating technique is more efficient, safe and less time consuming compared to indirect resistance heating technique.

References:

1. Bor-jenq Wang, Samy Y Hilali, Electrical thermal modeling using ABAQUS, ABAQUS user conference, 1995.
2. Hanyu Ye, El Mehdi boudoudou, Coupled Electro-thermal field simulation in HVDC –cables COMSOL conference in Stuttgart, 2011.
3. Hou-cheng huang, Asif S, Usmani, Finite element analysis for heat transfer, Springer-Verlag London limited 1994.