Electromagnetic and Thermal Modeling of Vacuum Distillation Furnace

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Abstract

Dendritic deposits of heavy metals are obtained from electro-refining operation of spent metallic fuels. During the course of operation, the eutectic molten salt and cadmium gets entrained in these deposits. To consolidate these dendritic deposits of heavy metals, the entrained salt and cadmium is removed by vacuum evaporation carried out in high temperature vacuum retort called as vacuum distillation furnace (VDF). VDF is operated at a temperature of 700-1400 °C and at a pressure of 0.01-600 torr. The heating mechanism in VDF is based on Induction. The charge in the crucible is heated indirectly by radiation. While in the furnace, the entrained salt and cadmium boil off and subsequently condenses in a separate crucible, and the heavy metals melt and form an ingot in graphite crucible. Figure 1 shows the schematic layout of the VDF.
A transient electromagnetic and thermal analysis of the VDF is being carried out using COMSOL Multiphysics® to optimize the various electrical parameters, operational and geometrical parameters. The aim of current study is to arrive at the optimal voltage, frequency and number of radiation shields required to maintain the suitable temperature gradient between the evaporation and condensation regions of VDF.
A 2D-axisymmetric model of the VDF was set-up in COMSOL Multiphysics®. The geometry was imported from AutoCAD®. COMSOL Material Library was used to assign materials to the model. The Induction Heating Physics was being used for this analysis. Parametric sweep study was used for frequency and voltage. After getting suitable values of frequency and voltage to attain a requisite temperature, analysis was carried out using different number of radiation shields. Figure 2 shows the average temperature rise with time in the crucible at a frequency of 2.5 kHz. The temperature is plotted for various coil voltages.
This paper details the transient modeling of induction heated VDF with complex geometry. The findings from this study have direct implications on process design, mechanical design and operation of VDF.

Figures used in the abstract

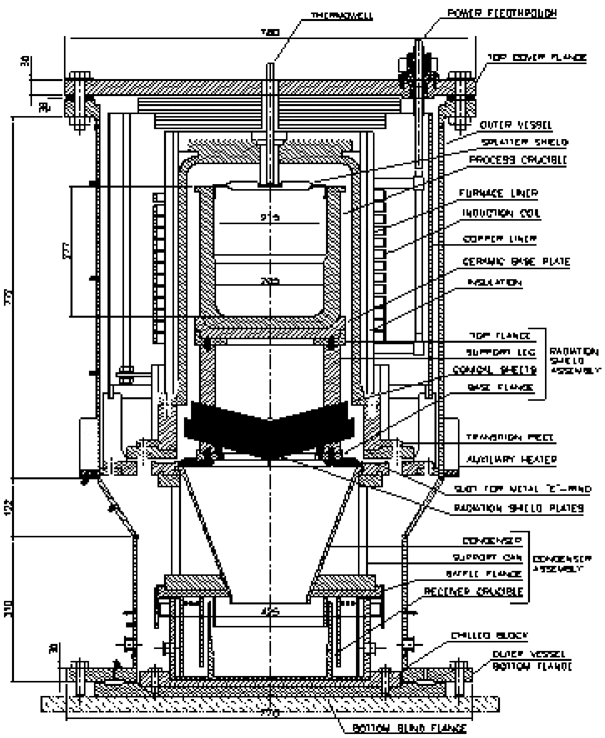

Figure 1: Schematic Layout of VDF

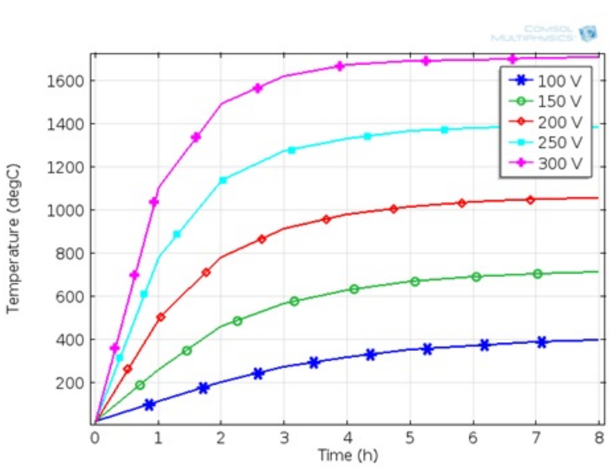

Figure 2: Average Temperature Rise of Crucible with Time at Different Voltages of coil.