ABSTRACT

Commercial acceptance and the economics of solar thermal technologies are tied to the design and development of efficient, cost-effective thermal storage systems. Thermal storage units that utilise latent heat storage materials have received greater attention in the recent years because of their large heat storage capacity and their isothermal behaviour during the charging and discharging processes. One major issue that needs to be addressed is that most phase-change materials (PCM) with high energy storage density have an unacceptably low thermal conductivity and hence heat transfer enhancement techniques are required for any latent heat thermal storage (LHTS) applications. In the present research, three heat transfer enhancement methods are investigated.

In the first method the enhancement of heat transfer in a thermal storage system consisting of a cylindrical vertical tube with internal longitudinal fin arrangement is investigated. A complete analytical and numerical model is developed for the above using the enthalpy formulation to study the effect of non-dimensional parameters on the performance of the LHTS unit. The generalised H-T relationship, developed in the present work accommodates materials having either constant or a range of phase change temperatures. This relationship simplifies the solving procedure by numerical methods for phase change problems. The unique feature in the numerical model is that it takes into
account the heat flow in the circumferential direction along the boundary wall. The requirement of fins and the need for consideration of the circumferential heat flow are analysed for a practical range of Biot numbers and other physical and geometrical parameters. The validation of the numerical model using the experimental results is explained. The temperature distribution along the radial direction in the fin, along the circumferential direction in the boundary wall and within the PCM region, the interface location in the PCM region, the surface heat flux and the frozen volume fraction are shown and discussed for a practical range of parameters. The combined effect of Biot and Stefan number, fin enhancement factor and subcooled factor are presented. Correlations are developed for two different ranges of Biot numbers. These results will be very useful in the selection of design parameters for LHTS units.

In the second heat transfer enhancement method, the cylindrical tube is filled with high conductivity lessing rings (which are commonly used in the chemical reactors to enhance the surface contact) of 1 cm diameter with the molten paraffin. Theoretical simulation work is done for this method to find the effective thermal conductivity using the experimental data. In the third method, a small amount of water is added to the paraffin and the tube is maintained under vacuum so as to create vapour bubbles during the phase change process to promote heat transfer by bubble movement/agitation. Experimental results are presented for this and due to the complexities of the process, theoretical work was not attempted. Experiments are also conducted on a large storage capacity.
vessel that contains a mixture of PCM-lessing rings and its performance is reported.

Based on the results of the parametric studies on fin configuration and the experimental studies on different heat transfer enhancement techniques, suitable configurations for domestic water heating and air heating applications are suggested.