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Irradiation-Duration Effect on the Performance of Solar Hot Water Storage Tanks containing Phase Change Material (PCM)

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Extended Abstract

Efforts are continuously made to improve the efficiency of domestic solar hot water storage tanks by using PCMs [1]. The idea is to add latent heat storage capacity, at fixed temperatures, to the hot water storage tanks. The studies examined the improvement gains achievable through applications of different PCMs with various geometries and settings. However, the identification of the important parameters that directly affects the merit of PCM additions was not explicitly addressed. In the current work, efforts were made to explore the gains provided by the PCM as function of several parameters, among them the expected diurnal-solar-irradiation duration. This parameter turned out to be of prime importance for determining whether the PCM addition is warranted. This has direct relevance to spreading geographically the installation of solar water storage tanks, owing to the efficiency contribution of the PCM addition. The evaluation of the PCM efficiency contribution, in respect of the sun exposure duration was conducted analytically and experimentally. For comparison, experiments were made with two identical 300 litter water tanks, where only one of which contained PCM, first with melting temperatures of 40^{o}C and then 65^{o}C. The PCM was in the form of paraffin plates confined within aluminium shells. The PCM assembly where of horizontal plates stacked vertically with spacers to allow for both, horizontal water advection and preservation of vertical thermal stratification. Thermocouples were used to collect temperature-distribution data for performance analyses and model prediction verifications. The water was heated in common tilted flat plate solar collectors. Analyses of results clearly indicate that the sun exposure time is a key factor affecting the performance contribution of the PCM, with the strongest favourable influence in climates of short solar irradiation time. Additionally, analyses indicate that the choice of PCM melting point should correspond to the peak solar irradiation period. To explore the implication of these findings, the PCM thermal properties are considered. PCMs specific heat are usually smaller than that of water. Therefore, replacing a water volume portion by PCM reduces the storage tank average specific heat. This is advantageous since less solar energy is required to raise the tank temperature to a useful level, say to 40^{o}C for bathroom showers. Furthermore, for limited duration of solar irradiation, it would be favourable to collect the solar energy at the desired useful temperature and store it as latent heat. This prevents further water-temperature rise to provide both, better solar-collector efficiency and reduced water tank heat losses. Conversely, for long sun exposure time, across large temperature rises, the PCM combined sensible and latent heat storage capacity may not exceed that of water, which practically eliminates the principal advantage of PCM additions.

References

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