Applied Thermal Engineering 48 (2012) 24–31

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Criteria for performance improvement of a molten salt thermocline storage system

Xiaoping Yang [a,b,*], Xiaoxi Yang [a], Jing Ding [c], Youyuan Shao [a], Frank G.F. Qin [a], Runhua Jiang [a]

[a] *Guangdong Provincial Key Laboratory of Distributed Energy Systems, Dongguan University of Technology, Dongguan, China*
[b] *Key Laboratory of Enhanced Heat Transfer and Energy Conservation of the Ministry of Education, South China University of Technology, Guangzhou, China*
[c] *School of Engineering, Sun Yat-Sen University, Guangzhou, China*

HIGHLIGHTS

► Four criteria for describing the performance of a molten salt thermocline thermal energy storage system are studied.
► The effects of the physical properties of different filler materials on performance are also discussed.
► Filler particles with a small diameter and low thermal conductivity can improve efficiency η_1.
► Filler particles with large volume-specific heat capacity and small porosity can increase thermal storage capacity.

ARTICLE INFO

Article history:
Received 30 September 2011
Accepted 20 April 2012
Available online 27 April 2012

Keywords:
Molten salt
Thermocline
Filler material
Performance

ABSTRACT

Thermal energy storage is considered to be an important subsystem for solar thermal power stations because of the fluctuations in sunshine over time. A molten salt thermal storage tank contains thermally stratified fluid, with hot temperature on the upper level and cold temperature in the lower level. Although a few studies have explored molten salt thermocline energy storage for solar thermal plants, the criteria for performance improvement are still not understood adequately. To this end, this paper summarizes four criteria for describing the performance of a molten salt thermocline energy storage system. The criteria emphasize different aspects of the storage process, including thermal storage capacity, entropy generation, efficiency η_1 based on outlet temperature, and efficiency η_2 based on thermocline thickness. The effects of the physical properties of different filler materials on the performance are also discussed. The findings indicate that filler particles with higher density, higher specific heat, lower diameter, lower thermal conductivity, and lower porosity should be selected to increase thermal storage capacity and efficiency. However, increasing the density and specific heat will also lead to higher entropy generation in the system.

1. Introduction

With the increasingly worsening problems related to energy crises, climate change, and other environmental issues, experts and authorities agree that the development and utilization of new and renewable energy have become issues of serious concern [1]. Exhaust gases, dust, and fumes emitted by solar electric generation systems (SEGS) cause minimal pollution. Most importantly, these systems do not emit carbon dioxide (the greenhouse gas primarily responsible for global climate change) during operation. Hence, an SEGS has huge potential as a renewable energy source.

The output of a simple solar-only power plant depends strongly on solar input, which may or may not correspond closely with the load profile of a utility company. Thermal energy storage (TES) can be used to store energy for delivery at a later time, or to facilitate the generation of plant output during intermittent cloudy weather conditions. To improve power generation efficiency, reduce operational costs, and increase the stability and continuity of solar thermal systems, thermal storage equipment is needed to balance the mismatch between solar energy supply and electricity consumption [2–4].

A thermocline tank uses a single tank to store thermal energy. Inside the tank, a thermal gradient or thermocline separates the hot fluid from the cold fluid. The heat transfer fluid (HTF) maintains

* Corresponding author. Guangdong Provincial Key Laboratory of Distributed Energy Systems, Dongguan University of Technology, No.1 University Road, Songshan Lake, Dongguan, China. Tel./fax: +86 769 22861808.
E-mail address: 103194140@qq.com (X. Yang).

1359-4311/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2012.04.046