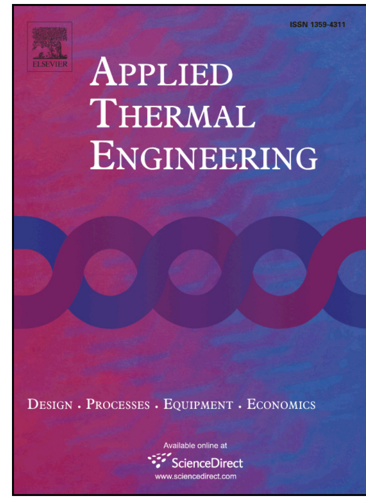

Assessment of thermal energy storage options in a sodium-based CSP plant

K. Niedermeier, J. Flesch, L. Marocco, Th. Wetzel

PII: S1359-4311(16)31066-3
DOI: http://dx.doi.org/10.1016/j.applthermaleng.2016.06.152
Reference: ATE 8563

To appear in: *Applied Thermal Engineering*

Assessment of thermal energy storage options in a sodium-based CSP plant

K. Niedermeier[a,*], J. Flesch[a], L. Marocco[a,b], Th. Wetzel[a]

[a] *Karlsruhe Institute of Technology (KIT), Institute for Nuclear and Energy Technologies, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany*
[b] *Politecnico di Milano, Department of Energy, via Lambruschini 4, 20156 Milan, Italy*

Abstract

Sodium has proven to be an efficient heat transport fluid in a central receiver system in the IEA-SSPS facility in Almeria in the 1980s with a 5 MWh_{th} direct two tank storage system. In recent years the interest in liquid metals, particularly sodium, as heat transfer fluids for concentrating solar power has reawakened. However, an assessment of thermal energy storage options in a liquid metal-based concentrating solar power system has not been performed yet. In this paper sensible, latent and thermochemical systems, described in the literature and potentially suitable for a solar power plant using sodium, are investigated. As sensible systems, direct sodium two tank and one tank thermocline storage systems with filler are considered, as well as indirect molten salt systems. Latent systems include configurations with finned tubes, packed beds of phase change material capsules and active screw type systems. In addition, metal hydride dehydrogenation, ammonia and hydroxide dissociation are considered as thermochemical storage systems. The presented storage systems are discussed and compared on the basis of the following criteria: Storage medium cost, storage density, cycling behaviour, maturity level and suitability for sodium as heat transfer fluid. As a result, the direct sodium thermocline one tank storage with filler material represents a promising direct storage option. It could be further enhanced by a cascaded arrangement of phase change capsules. Moreover, the thermochemical storage systems with ammonia or hydroxide dissociation are identified as best indirect storage options.

Keywords: Liquid metal, thermal energy storage, concentrating solar power, solar thermal electricity

1. Introduction

Within the renewable energy technologies the solar thermal electricity (STE) or concentrating solar power (CSP) is of particular interest due to the applicability of a thermal energy storage (TES) system which enables dispatchibility in energy supply, as the CSP plant can react to the electricity demand and even supply electricity after sunset. In addition, the capacity factor of the power plant can be significantly increased with a TES system. Current operational solar tower power plants work with water/steam or molten salt as heat transfer fluids (HTF). High storage capacities up to 15 h (Gemasolar) can only be achieved with molten salt two tank technology at the moment [1]. The commercially used solar salt is a binary mixture of 60 % $NaNO_3$ and 40 % KNO_3. However, the operation with molten salt is currently limited to 290 °C and 565 °C defined by the melting and the chemical decomposition temperature [2]. Liquid metals (LM) are a promising alternative due to their high boiling temperatures and excellent heat transfer characteristics [3]. Sodium, tin, lead-bismuth-eutectic and also sodium-potassium are proposed as main candidates, as they also show relatively low melting points [4], [5]. Among these, sodium possesses the best heat transfer characteristics, but presents a safety risk due to the high reactivity with humid air or water. It has already been tested as heat transfer fluid in a central receiver system in the IEA-SSPS in Almeria in the 1980s [6] with a storage system of 5 MWh_{th} [7] and regained interest in recent years [8], [9], [10].

Thermal energy storage in a sodium-based central receiver system beyond the two tank arrangement used in the IEA-SSPS has not been investigated yet in recent literature, even though it is crucial for the competitiveness of LM-based CSP with respect to the state-of-the-art molten salt technology. Particularly alternative storage options like latent and thermochemical storage have not been evaluated systematically in combination with sodium as HTF. On the basis of selected criteria (section 2) possible long term storage options (section 3) for a large scale sodium-based solar tower system are discussed. As a result, the most promising storage options are determined and research gaps are pointed out (section 4).

2. Evaluation criteria

The selected criteria are supported by data from cited literature and complemented by own calculations with specified equations. If data is missing for a quantitative assessment, only a qualitative evaluation is performed. The criteria are chosen in accordance with [1], [11].

*Corresponding author
Email address: k.niedermeier@kit.edu (K. Niedermeier)