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Molten salt facilities, lessons learnt at pilot plant scale to guarantee commercial plants; heat losses evaluation and correction

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ABSTRACT

This paper presents the importance of the thermal losses in the performance evaluation of thermal storage systems. In order to reinforce this statement, an evaluation of a pilot plant whose size is sufficiently representative for the extrapolation of results at larger scales has been carried out. The evaluation of the heat losses of a molten salt pilot plant with 8.1 MWh_{th} built in Spain by Abengoa is presented. While the storage materials development has attracted a lot of attention from the researchers, the performance of a two-tank storage system has not been evaluated in detail. The relevance of the design of conventional systems such as insulation, mechanical assembly or foundation, are found to be the key for the feasibility of a TES system. Different performance scenarios were performed and based on experimental results, decisions for reengineering of the pilot plant could be taken to improve commercial storage plants.

1. Introduction

The mixture known as "solar salt" is formed by a non-eutectic binary mixture of 60%wt. sodium nitrate and 40%wt. potassium nitrate [1,2]. This mixture has a freezing point of 220 °C, making it necessary to keep the system fully insulated and with heat tracing installation to avoid problems. Any problems either in design, mechanical assembly, or other operating systems will cause freezing of the system and to stop operation of the blockade. These systems are designed to counter at all times the inherent thermal losses working at such high temperature. It is very important to calculate these heat losses to ensure the operability of the plant.

Molten storage tank heat losses were first evaluated in the CESA-I central receiver plant in Spain in 1984 [3,4] and latter at the Solar Two project in 2002 [5]. Later on, different authors have estimated the overall heat transfer coefficient giving correlations that consider heat losses [6]. Nevertheless, none of them evaluated local heat losses and thermal bridges in a real molten salts installation.

The aim of the salts pilot plant built in Solúcar (Sevilla, Spain) was the experimentation of the thermal energy storage technology by sensible heat storage with a mixture of molten salts chosen specifically for this project. The storage system has a capacity of 8.1 MWh_{th}, which is 4 h of the solar power to which was connected; a 600 m solar loop with 2.025 MW_{th} parabolic troughs. The storage system tested was an indirect double tank. In a previous paper [7], the pilot plant is described in detail and the start-up process is analysed and recommendations are given. In this paper, the heat losses are evaluated and corrections are suggested and analysed. Heat losses were evaluated with thermography during the start-up period and with temperature profiles during operation in order to make an energy and exergy analysis. Energy analysis evaluates the energy from a quantitative point of view, whereas exergy analysis assesses the energy on quantity as well as the quality. The aim of the work carried out has been to identify the magnitudes and the locations of real energy losses, in order to improve the existing systems, processes or components in a molten salts double tank configuration thermal energy storage system.

2. Pilot plant description

A very detailed description of the pilot plant can be found in the previous publication [7]. Here only a broad description is given. The

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Table 1
Characteristics of the insulation materials used in the tanks.

Material	Thickness (mm)	Density (kg/m^3)	Maximum service temperature (°C)
Spintex 342-G-145	30 to 100	125	750
Superwool™ 607 ™ Blanket	50	128	750

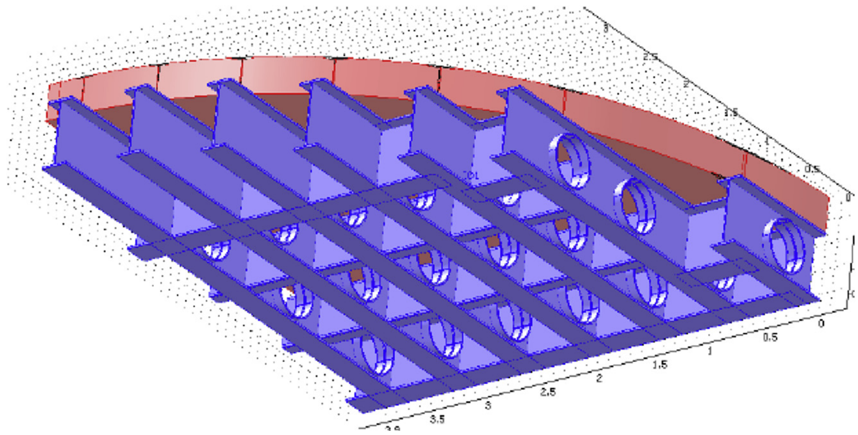

Fig. 1. Initial state of tanks support structures and foundation [7].

installation has two storage tanks connected to a solar field by a heat exchanger. Each tank has 8 m diameter and about 6 m height (4.4 m cylindrical wall) and is able to store all the salts needed in the process. The heat exchanger is a flat plate heat exchanger working at counter-flow with a power of 2.1 MW_{th} and installed following the concept of free-drainage.

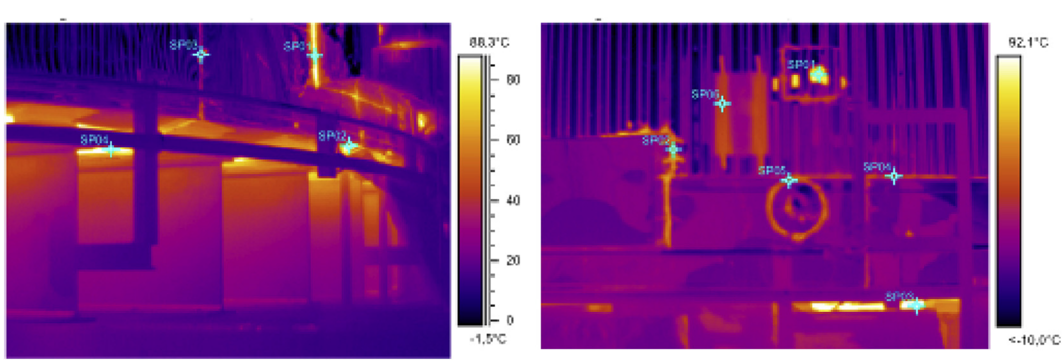

Fig. 2. Storage tanks foundation. Left, hot tank; right, cold tank.

The salt used is the so-called “solar salt”, a non-eutectic mixture of 40% wt. KNO_3 and 60% wt. $NaNO_3$. This mixture melts at 204 °C and solidifies at 220 °C, and it is stable up to nearly 600 °C. During operation the temperature of the salts changes between 288 °C and 388 °C, with a maximum operation temperature of 400 °C. Usually, in the cold tank the salts are at 288 °C and in the hot one at 388 °C.

The tanks were insulated with Spintex 342-G-145 from Isover. The bottom of the tank was protected with Superwool™ 607™ blanket from Thermal Ceramics, covered with a galvanized shell. The properties of the insulation materials are presented in Table 1.

The tanks walls were insulated with two mineral wool blankets with 250 mm thickness. Special care was taken in the non-homogeneous parts, that is, where instrumentation and sensors were located. The insulation material was protected with an aluminium corrugated sheet. The domes of the two tanks were insulated with two 250 mm thickness mineral wool blankets and were protected with aluminium corrugated sheet.

Fig. 3. Lack of insulation material in the storage tanks.