Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 142 (2017) 495–500

Energy Procedia

www.elsevier.com/locate/procedia

9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK

# Influences of the key characteristic parameters on the thermal performance of a water pit seasonal thermal storage

Chun Chang[a,b,*] Binjian Nie[b],Guanghui Leng [b], Chuan Li[b], Xiaohui She[b],Xiaodong Peng[b], Jie Deng[a]

[a]*Key Laboratory of Solar Thermal Energy and Photovoltaic System, Institute of Electrical Engineering, Chinese Academy of Sciences, Haidian District, Beijing 100190, China*

[b]*Birmingham Centre for Energy Storage, University of Birmingham, Edgbaston Birmingham, B15 2TT, United Kingdom*

*Corresponding author. * Tel.: +44-07756108350 ;E-mail address: chang21st@mail.iee.ac.cn*

**Abstract**

The influence of the key characteristic parameters of a water pit seasonal thermal storage on thermal energy storage capacity in the static mode of operation is investigated in this study. An underground experimental test rig is built, and a numerical model is developed to study the natural convective flow and heat transfer in the water pit thermal storage. Results show that the water temperature close to the tank walls decreasing by the heat losses from the top and sidewalls of the tank, which creates a downward flow along the tank wall. At the center of the tank, a slight upward flow is generated, which lifts the warmer water at the bulk of the tank to a higher level. In this way, the buoyancy-driven flow gradually builds up the thermal stratification in the tank. For the influence of depth, the results indicate that the smaller the depth, the faster the thermal efficiency decreases. For the influence of slope angle, the results show that the smaller the slope angle, the faster the thermal efficiency decreases, the steeper the water pit sidewall, the smaller the maximum velocity and the maximum velocity tends to be stable over time, and the steeper the water pit sidewall, the more significant the temperature stratification in the water pit.

© 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.

*Keywords:* Natural convection; Cooling process; Water pit thermal storage; Transient laminar flow; Buoyancy; Thermal stratification

## 1. Introduction

Water heating and space heating in the building sector is responsible for one-third of related greenhouse gas emissions and more than 40% of the total energy consumption [1]. The excessive reliance on and use of fossil fuels leads to serious pollution and environmental consequences. Therefore, solar energy has attracted attentions due to its

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.
10.1016/j.egypro.2017.12.077

cleanness, inexhaustible and widespread distribution [2]. Compared with other options, a large-scale solar heating system with water pit seasonal thermal storage is the most reliable and competitive technology [3–9]. In a typical water pit thermal storage, concrete and stainless steel tanks are not used in the storage structure due to the cost reduction considerations. The principal structure of a water pit thermal storage is very simple as it consists of an excavation in the ground covered with a watertight liner and filled with water. Finally, the water pit is covered by a floating insulation layer on its top surface. Due to some reasons such as geological structure, in order to avoid sidewall collapse, the value of inclination angle or so-called slope angle between the sidewall and horizontal plane is generally limited to 30 degrees to 40 degrees [10].

To the study of underground water pit thermal storage, natural convection and temperature stratification are the two key issues. Much work has been undertaken on the free convection heat transfer in an enclosure, to promote thermal stratification and minimize de-stratification during its operation process. He et al [11]. numerically investigate the natural convection heat transfer and flow in a vertical cylindrical envelope, which at constant but different temperatures of the two end surfaces and an adiabatic lateral wall. Found that the ratio of axial length to the diameter has an effect on the average heat transfer rate under the same other conditions. Ye [12] numerically examined the flow and heat transfer performance in a rectangular thermal storage cavity with natural convection. Found that the rectangular aspect ratios affect dramatically the natural convection inside the cavity. Yang et al [13] studied the influences of ten different water tank shapes on thermal energy storage capacity and thermal stratification under laminar natural convection. Indicated that the thermal energy storage capacity is closely related to the surface area of the water tank. The thermal stratification of different shapes is determined by the flow at the bottom of the water tank and the heat transfer from the fluid to the environment. Basak et al [14] analyzed the heat transfer rate vs entropy generation due to the fluid friction and heat transfer irreversibility during natural convection for uniformly and non-uniformly heated bottom wall in trapezoidal cavities. The model is two-dimensional and the conclusion is that the total entropy generation is found to increase with Prandtl number due to increase in fluid friction with Prandtl number. Wang et al [15] also studied the thermal stratification with a novel inlet in a dynamic hot water storage tank. A three-dimensional unsteady model was performed using ANSYS. Found that the contribution of the equalizer on internal flow, which could improve the thermal stratification.

For a typical water pit thermal storage, it is buried in the ground. The top of it is provided with a thermal insulation layer and has natural convective heat loss with the ambient air. Its bottom and inclined sidewalls are surrounded by soil. The surrounding heat losses and the inclined sidewalls will affect the natural convection and thermal stratification inside the storage tank. However, the previous investigation mainly focused on the thermal stratification and natural convection of vertical cylinders or square cavities, usually, one of the top, sidewalls or bottom wall is adiabatic. The effect of inclined sidewalls of the water pit and surrounding surfaces cooling thermal boundary condition have not been fully considered yet in the literature. Therefore, in this manuscript, an experimental test rig for water pit thermal storage model was designed to obtain the experimental results. Moreover, a mathematical model and a simulation study of the cooling process in the test rig is presented. Influences of the key characteristic parameters on the thermal performance of a 100,000m$^3$ water pit seasonal thermal storage are numerically investigated by the test proved simulation model. The present work has a valuable attempt to fill the gap in the existing studies and can be used as a guide for the design of the water pit thermal storage.

## 2. Experimental setup

An experimental device was designed in order to validate the mathematical model proposed, see Fig.1a. The experimental system consists of a computer connected to a data logger, to characterize the thermal performance of the system through several thermocouples placed along a water pit shape thermal storage. As shown in Fig.1b, the water pit shape thermal storage mainly includes a glass tank, dry fine sand, an inclined sidewall stainless steel storage tank and a thermal insulation layer. The glass tank is filled with dry fine sand. In order to observe the thermal stratification more distinct, the slope angle of this small tank is enlarged to 60 degrees. The stainless-steel tank is filled with hot water and is buried in the dry fine sand inside the glass tank. The upper surface of the stainless-steel tank is at the same level with the upper surface of the dry fine sand. The thermal insulation layer is a polystyrene board, covers the upper surface of the stainless-steel tank and the dry sand. The temperature measurement system consists of twenty-four T-type thermocouples (accuracy of ±0.5K in the temperature range of -233.15K to 398.15K), an Agilent 34972A data

Download English Version:

https://daneshyari.com/en/article/7917410

Download Persian Version:

https://daneshyari.com/article/7917410

Daneshyari.com