Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 142 (2017) 142–147

Energy Procedia

www.elsevier.com/locate/procedia

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

# Investigation on transient cooling process in a water heat storage tank with inclined sidewalls

Chun Chang[a,b,*] Guanghui Leng [b], Chuan Li[b], Binjian Nie[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*

[*]*+44-07756108350; chang21st@mail.iee.ac.cn*

**Abstract**

The transient cooling process of an underground water pit thermal storage with inclined sidewalls is investigated in this paper. An experimental device was designed in order to validate the mathematical model proposed. Materials properties have been assumed constant with temperature, except for the water's density that has been treated using the Boussinesq approximation. The simulations of temperature distributions are proved well by comparison with the experimental results. Results show that the water temperature decreasing next to the tank walls 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. The Nusselt number values show that comparing with the upper surface of the storage tank, there is more radical heat exchange at the bottom and inclined sidewalls. The maximum velocity appears near the top part of the inclined sidewalls, and its value decreases as the cooling continues.

© 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

Space heating and water heating in the building sector has long been thought to be responsible for more than 40% of the total energy consumption and one-third of related greenhouse gas emissions [1]. The excessive use of fossil fuels leads to serious pollution and environmental consequences. Therefore, renewable energy has attracted attentions due to its cleanness, inexhaustible and widespread distribution [2]. Compared with other options, large-scale solar heating system with water pit seasonal thermal storage is the most reliable and competitive technology [3–9]. In a typical water

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.2017.12.023

| **Nomenclature** | | | |
|---|---|---|---|
| $c_p$ | specific heat, $Jkg^{-1}K^{-1}$ | β | fluid thermal expansion coefficient,$K^{-1}$ |
| E | internal thermal energy, kJ | μ | dynamic viscosity of the fluid, $kgm^{-1}s^{-1}$ |
| *e* | internal thermal energy per unit mass, kJ $kg^{-1}$ | η | thermal energy storage efficiency, % |
| $\dot{F}$ | body force vector per unit volume | ρ | density, $kgm^{-3}$ |
| *g* | acceleration of gravity, $ms^{-2}$ | δ | thickness, m |
| Gr | Grashof number | ϕ | particle size, m |
| H | height, m | ν | kinematic viscosity, $m^2s^{-1}$ |
| *h* | convective heat transfer coefficient, $Wm^{-2}K^{-1}$ | λ | second viscosity coefficient |
| *k* | heat conductivity, $Wm^{-1}K^{-1}$ | θ | slope angle, ° |
| *L* | length, m | *Subscripts* | |
| Nu | Nusselt number | 0 | initial |
| p | pressure, Pa | *a* | ambient or environment |
| Pr | Prandtl number | *ave* | average |
| Ra | Rayleigh number | *b* | boundary |
| T | temperature, K | *exp* | experimental |
| ΔT | temperature difference, K | *f* | fluid |
| *t* | time, s | *ins* | insulation |
| $\vec{V}$ | velocity vector | *o* | outer |
| u | velocity in $x$ direction, $ms^{-1}$ | *ref* | reference |
| υ | velocity in $y$ direction, $ms^{-1}$ | *s* | sand |
| *w* | velocity in $z$ direction, $ms^{-1}$ | *sim* | simulation |
| *Greek symbols* | | *ss* | stainless steel |
| *a* | thermal diffusivity of the fluid, $m^2s^{-1}$ | w | wall |

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.

Natural convection and temperature stratification are the key issues to the study of underground water pit thermal storage. 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 [10]. numerically investigate the natural convection heat transfer and flow in a vertical cylindrical envelope, which with 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 [11] 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 [12] 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 [13] 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 [14] 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. To prevent the sidewall collapse, the angle between the sidewall and the bottom is usually between30 to4 0 degrees[15]. The top of it is provided with a thermal

Download English Version:

https://daneshyari.com/en/article/7916692

Download Persian Version:

https://daneshyari.com/article/7916692

Daneshyari.com