Available online at www.sciencedirect.com
ScienceDirect
Renewable Energy 33 (2008) 2084–2096
RENEWABLE ENERGY
www.elsevier.com/locate/renene

Experimental investigation of a solar energy heating system under the climatic conditions of Edirne

Berrin Karacavus*, Ahmet Can

Department of Mechanical Engineering, Trakya University, 22030 Edirne, Turkey

Received 7 November 2006; accepted 30 November 2007
Available online 28 January 2008

Abstract

Seasonal storage of solar energy to supply the heat requirement of buildings in Edirne (41°39′54″N) has been examined experimentally. Solar energy has been stored in a cylindrical underground storage unit. Measurement values have been recorded per hour by means of a computerized recorder between July 2005 and May 2006. Monthly average temperature values of the heat storage unit and the surrounding ground have been calculated through the measurement results. The transient heat transfer which takes place between the heat storage unit and the surrounding ground has been calculated by means of the QuickField finite-element analysis program. It has been determined that the most significant deviations between the theoretical and the experimental temperature values turn out to be in question during the heating period. The annual solar fraction of the solar energy heating system has been determined as 53% for space heating and 85% for domestic water heating.

Keywords: Solar energy; Seasonal storage; Temperature distribution; Solar fraction

1. Introduction

Approximately 50% of the energy is used for heating purposes in the building sector. Due to this reason, solar energy systems ought to be planned as a support for space heating, besides the energy saving precautions. Seasonal storage in appropriate places is necessary to make use of solar energy in winter, as it is bounteous and abundant during summer months.

Solar energy is seasonally stored in the steel tanks, caverns, vertical pipes in clay, in underground steel tanks, in vertical and horizontal pipes embedded in the ground, in aquifers, and underground concrete tanks. Lund and Ostmann [1] have developed a numerical model for the determination of the performance of a heat storage installation, where solar energy is transferred into a cylindrical heat exchanger placed underground and the residences are heated by a heat pump during the seasons in which heating is required. Bankston [2] has examined the designation and performance of the storage units in solar energy heating systems with seasonal storage; 60% of the heat load required for the building was met by means of this system. Inalli [3] has theoretically analyzed the underground cylindrical storage and the solar energy heating system by considering the temperature distribution in the area of the storage as two dimensional and solved the heat transfer problem by applying the finite Fourier transform technique and a finite-difference method. Chung et al. [4] has carried out an economical and performance analysis of the central solar energy heating system for the climatic conditions of Korea using the TRNSYS simulation program and found out that more than 39% of the total heat load with 184 m^2 collector area and 600 m^3 storage volume was met by solar energy. Yumrutas and Unsal [5] examined the periodic performance average of a solar-assisted ground-coupled heat pump space heating system with seasonal energy storage in a hemispherical surface tank placed underground by using analytical and computational methods. Nordell and Hellstrom [6] evaluated performance of a solar-heated low temperature space-heating system with seasonal storage in the ground

*Corresponding author. Fax: +90 284 2261225.
E-mail address: berrink@trakya.edu.tr (B. Karacavus).

0960-1481/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.renene.2007.11.018

Nomenclature

A_c	solar collector area (m^2)
α	thermal diffusivity (m^2/s)
$C_{p,cf}$	specific heat of collector fluid (kJ/kg K)
$C_{p,HW}$	specific heat of domestic hot water (kJ/kg K)
D	diameter (m)
d_h	hydraulic diameter (m)
d_{ots}	outside diameter (m)
F	annual solar fraction (%)
f_{sh}	monthly solar fraction for space heating (%)
f_{HW}	monthly solar fraction for domestic hot water heating (%)
F	annual solar fraction (%)
H	heat transfer coefficient ($W/m^2 K$)
I	global solar radiation on the unit area of horizontal surface (W/m^2)
I_c	monthly average global solar radiation on the unit area of the tilted surface (W/m^2)
$\dot{m}_{cf}$	mass flow rate of collector fluid (kg/s)
$\dot{m}_{HW}$	mass flow rate of domestic hot water (kg/s)
Q_{sh}	load for space heating (kWh)
Q_{HW}	load for domestic hot water heating (kWh)
Q_L	total heat load of building (kWh)
$Q_{sh,sys}$	supplied heat load for space heating from heating system (kWh)
$Q_{HW,sys}$	supplied heat load for domestic water from heating system (kWh)
T	temperature (°C)
$(UA)_b$	building loss coefficient (W/K)
V_W	wind speed (m/s)
η_c	thermal efficiency of the used collectors (%)
$\eta_{c,ave}$	monthly average thermal efficiency of the used collectors (%)

Subscript

A	outside air
a,ave	outside air average
com	comfort
HW	domestic hot water
WN	network water
ci	collector inlet
co	collector outlet
si	storage unit inlet
so	storage unit outlet
sw,ave	storage unit water average
sw,max	storage unit water maximum
s,ave	sand average
a,ave	outside air average
g,ave	ground average
exp,jan	experimental January
the,jan	theoretical January
exp,feb	experimental February
the,feb	theoretical February
exp,mar	experimental March
the,mar	theoretical March
exp,apr	experimental April
the,apr	theoretical April
exp,may	experimental May
the,may	theoretical May
exp,jul	experimental July
the,jul	theoretical July
exp,aug	experimental August
the,aug	theoretical August
exp,sep	experimental September
the,sep	theoretical September
exp,oct	experimental October
the,oct	theoretical October
exp,nov	experimental November
the,nov	theoretical November
exp,dec	experimental December
the,dec	theoretical December

using the simulation models TRNSYS and MINSUN together with the ground storage module DST. They suggested an economically feasible design for a total annual heat demand of about 2500 MWh. It was found that the total annual cost of solar heating system was reduced by 20% to about 800 SEK MWh^{-1}, which was lower than the best conventional alternative. Melis and Spate [7] have performed a scientific research on the 23 houses which were constructed for 136 students at Julich Solar Campus. 50–60% of the total heat load has been supplied through this system. Schmidt et al. [8] planned a central heating system with seasonal solar energy storage in Hamburg in 1995 and put their plan into practice. More than 50% of the annual space heating and domestic water heating requirements have been met by means of storing the solar energy in seasonal terms. Ucar and Inalli [9] have achieved the simulation of a central solar heating system with seasonal storage for two storage types placed underground as cylindrical and trapeze under the climatic circumstances of Adana, Elazig, Istanbul, and Trabzon.

Turkey, owing to its geographical location, benefits more from solar energy than most of the other countries. Average of sunshine per year in Turkey is 2640 h (totally 7.2 h/day), and the total average radiation value is 1311 $kWh/m^2/yr$ (totally 3.6 $kWh/m^2/day$). As for the Marmara Region, the total average of sunshine per year is 2409 h, and the total average radiation value is 1168 $kWh/m^2/yr$ [10].

Domestic water heating systems constitute the most common usage of solar energy in Turkey. The amount of solar collectors installed in 2001 in Turkey is about 7.5 million m^2 [10]. Seasonally storing the solar energy and using it for the heating system of the buildings is important