STUDY AND DESIGN OF AN ECONOMIC FLAT PLATE SOLAR HEATER IN EGYPT

M. Sc. THESIS

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By

MONA AHMED MOHAMED FANNEY

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Praise be to God ,

Lord of the World ,

by whose grace this work

has been completed .

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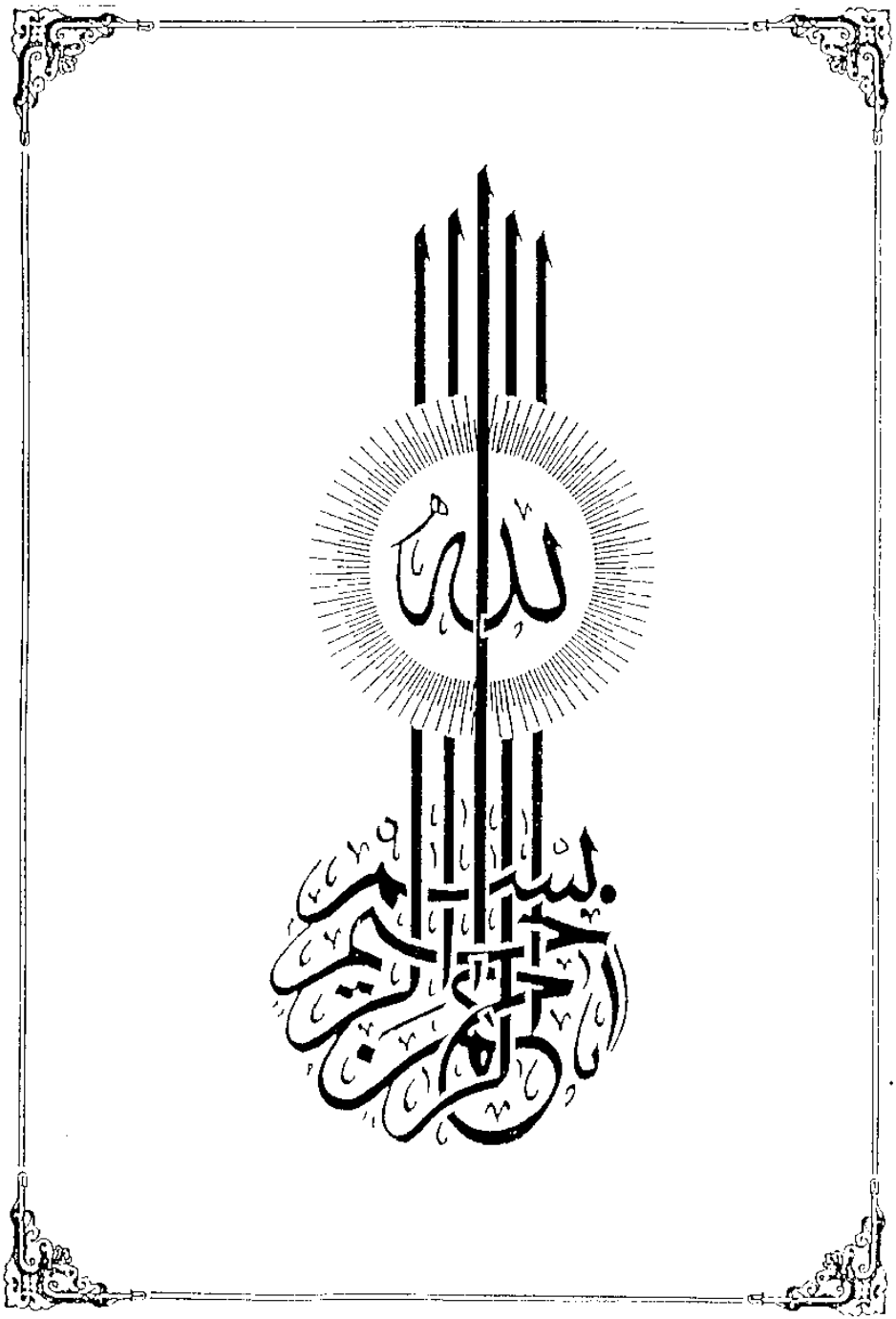

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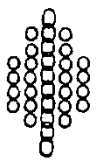

C O N T E N T S

SUMMARY

S U M M A R Y

This work presents a theoretical and an experimental investigation for the thermal performance of two systems of solar collector, namely:

1- The traditional collectors: Three types has been developed and investigated with different shaped tubes such as: Type I of rectangular serpentine tubes, type II of circular serpentine tubes and type III of separate tubes.

2- The compact collectors: Three types with different form of design have been developed and tested such as: steel box, gypsum basin and steel basin.

The collectors were tested under typical weather conditions of Cairo, Egypt at the field of tests at the Building Research Center in Dokki.

Computer programs have been developed for each type and for each collector. The data used to run the programs were the same as recorded during the measurments. The proggrams have been used to investigate some construction factors to improve the thermal performance of the collectors.

The theoretical approach deals with the estimation of the incident solar radiation on the tilted surfaces, the overall heat loss coefficient, the fluid heat transfer coefficient, temperature of plate, cover and fluid and the efficiency which is given by a set of equations.

Generally, the outlet water temperature reaches to 78°C for the intermittent discharge per half hour interval, 55°C for the continuous discharge of 0.004 $kg/m^2.s$, 52°C for the discharge at the end of the day and 39°C for the discharge of 10 kg/m^2 per hour or for the continuous discharge 0.004 kg/m^2s from the storage.

An economical study is also included to indicate the cost of each collector and to compare between them. The cost reaches to 43 L.E. for the steel basin which gives 44.8 kg at the end of the day (i.e. at 1330 hour) with outlet water temperature 52°C.

The study also introduced the compact system acts as a solar collector and storage which has a low cost, simple technology, good thermal performance and is suitable for rural areas.

NOMENCLATURE

A_c	:	collector area.	m^2
a_o, a , a_1 , b:		Coefficient in empirical relationships	non
C_A	:	cost per unit of collector area.	L.E
C_b	:	bond conductance.	$W/m^2°C$
C_E	:	cost of equipment.	L.E.
C_p	:	specific heat.	KJ/Kg°C
C_S	:	total cost of equipment.	L.E
D	:	diameter damping factor	m
d	:	market discount rate.	non
e	:	emissive power (base of natural logarithm)	non
F	:	fin efficiency factor.	non
F'	:	collector efficiency factor.	non
F''	:	collector flow factor.	non
F_R	:	collector heat removal factor.	non
g	:	gravitational acceleration.	m/sec^2
Gr	:	grashof number.	non
G_{sc}	:	solar constant	W/m^2
h_{fi}	:	heat transfer coefficient between the fluid and the wall.	$W/m^2°C$
h_{p-c}	:	heat transfer coefficient by convection between plate and cover.	$W/m^2°C$
h_{p-w}	:	heat transfer coefficient by convection between plate and water.	$W/m^2°C$

h_r	:	heat transfer coefficient by radiation.	$W/m^{2\circ}C$
$h_{r_{c-a}}$	:	heat transfer coefficient by radiation between cover and air.	$W/m^{2\circ}C$
$h_{r_{p-c}}$	:	heat transfer coefficient by radiation between plate and cover.	$W/m^{2\circ}C$
h_w	:	heat transfer coefficient by convection between plate and water.	$W/m^{2\circ}C$
h_{w-c}	:	heat transfer coefficient by convection between water and cover.	$W/m^{2\circ}C$
I	:	is the incident radiation on a horizontal plane	W/m^2
I_b	:	is the hourly incident beam radiation on a horizontal plane.	W/m^2
I_d	:	is the hourly incident diffuse radiation on a horizontal plane.	W/m^2
I_i	:	is an unpolarized incident radiation in a medium.	W/m^2
I_{on}	:	is the normal incident extraterrestrial radiation on the plane on the n the day of the year.	W/m^2
I_r	:	is the unporalized reflected radiation from a medium.	W/m^2
I_T	:	is the incident radiation on a tilted plane.	W/m^2
i	:	is the inflation rate.	non
K	:	is the extinction coefficient.	m^{-1}
k	:	is the thermal conductivity,	$W/m^{2\circ}C$

L	:	thickness.	m
l	:	length.	m
m	:	mean, mortgage interst rate, constant	non
$\dot{m}$	:	mass flow rate.	Kg/m^2S
n	:	medium, day of the year, constant in equations	non
N	:	number of covers, term of mortgage or economic analysis.	
N_u	:	Nusselt number.	non
N_{u_f}	:	Nusselt number for water fluid in tubes or boxes	non
P_r	:	Prandth number.	non
P_{wF}	:	present worth factor.	non
P_{wN}	:	present worth of the payment.	non
Q	:	energy per unit time.	W/m^2
Q_a	:	total solar energy absorbed by collector.	W/m^2
Q_L	:	rate of energy losses.	W/m^2
Q_S	:	rate of energy storage.	W/m^2
Q_U	:	rate of useful energy gain.	W/m^2
r	:	raduis, ratio.	m, non
R_a	:	Raleigh number	non
R_b	:	ratio of beam radiation on tilted plane to that on horizontal plane.	non
R_e	:	Renold number.	non
r_{per}	:	the perpendicular component of reflection of unpolarized radiation.	non

r_{par}	:	the parallel component of reflection of unpolarized radiation.	non
r	:	the total reflection of unpolarized radiation.	non
s	:	absorbed solar energy per unit area.	W/m^2
T	:	temperature.	°C
T_a	:	ambient temperature.	°C
T_c	:	cover temperature.	°C
T_f	:	fluid temperature.	°C
T_{fi}	:	inlet fluid temperature.	°C
T_{fm}	:	mean fluid temperature.	°C
T_{fo}	:	outlet fluid temperature.	°C
T_p	:	plate temperature.	°C
T_{pm}	:	mean plate temperature.	°C
T_s	:	storage temperature.	°C
T_{sky}	:	sky temperature.	°C
T_w	:	water temperature.	°C
U_b	:	back loss coefficient.	$W/m^2°C$
U_e	:	edge loss coefficient.	$W/m^2°C$
U_L	:	overall loss coefficient.	$W/m^2°C$
U_S	:	storage loss coefficient.	$W/m^2°C$
U_t	:	top loss coefficient.	$W/m^2°C$
V	:	wind speed.	m/s
W	:	distance between tubes.	m

Greek :

α	:	absorptance, thermal diffusivity	m^2/s
β	:	slope	degree
γ	:	surface azimuth angle.	degree
δ	:	declination	degree
ϵ	:	emittance.	non
η	:	efficiency.	non
θ	:	angle between surface normal and incident radiation.	degree
ν	:	Kinametic viscosity	m^2/s
μ	:	viscosity	K_g/ms
ρ	:	reflectance.	non
ρ_d	:	diffuse reflection	non
σ	:	Stefan - Boltzman constant.	w/m^2K^4
τ	:	transmittance.	non
τ_a	:	transmittance by absorption	non
τ_b	:	beam transmition.	non
τ_d	:	diffuse transmition.	non
τ_{per}	:	transmittance perpendicular component.	non
τ_r	:	transmition by reflection.	non
ϕ	:	latitude angle.	degree
ω	:	hour angle.	degree

Abbreviations :

C	:	calculated
M	:	measured.
$T_{f,t}$	:	hourly fluid temperature.
$\overline{T_p}$	:	daily mean plate temperature.
$T_{p,t}$	:	hourly mean plate temperature.