STUDIES ON SOLAR AIR HEATERS FOR CROP DRYING

BY

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DEDICATED TO MY

PARENTS
WIFE, CHILDREN
BROTHER AND SISTERS

C E R T I F I C A T E

It is certified that the thesis entitled, "Studies on Solar Air Heaters for Crop Drying", has been completed by Mr. R.B. Mahajan under our supervision. It is original in nature and we have permitted the candidate to submit it for the degree of Doctor of Philosophy in Solar Energy.

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Mahajan

(R.B. Mahajan)

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NOMENCLATURE

A Collector area (m^2)

B Breadth of the air heater (m)

C_a Specific heat of air, (KJ/Kg°C)

C_g Specific heat of glass, (KJ/Kg°C).

C_p Specific heat of metallic plate, (KJ/Kg°C)

D Hydraulic diameter of the heater (m)

F_R Heat removal efficiency factor

F_p Plate efficiency factor

G Air mass flow rate per unit area (Kg/m^2-hr.)

Gr. Greashof number

Pr Prandtl number

g Acceleration due to gravity, (m/sec^2)

h_{cag} Convective heat transfer coefficient between stagnant air and the glass cover, (W/m^2 °C).

h_{cfg} Convective heat transfer coefficient between fluid and glass cover, (W/m^2 °C).

h_{cpf} Convective heat transfer coefficient between metallic plate and the fluid, (W/m^2 °C).

$h_{rg_1g_2}$ Radiative heat transfer coefficient between two glass covers, g_1 and g_2, (W/m^2 °C).

h_{rgs} Radiative heat transfer coefficient between glass cover and the sky, (W/m^2 °C).

h_{rpf} Radiative heat transfer coefficient between the metallic plate and fluid, (W/m^2 °C).

h_{rpg} Radiative heat transfer coefficient between metallic plate and the glass cover, (W/m^2 °C).

h_{cgw} Convective heat transfer coefficient between glass cover and the wind (W/m^2 °C).

$h_{rp_1p_2}$	Radiative heat transfer coefficient between two metallic plate P_1 and P_2 ($W/m^2\ ^\circ C$).
$I(t)$	Solar intensity incident on the glass cover at time (t) at an inclination of 45°, (W/m^2).
I_m	Amplitude of mth harmonic of $I(t)$, (W/m^2).
K_p	Thermal conductivity of the metallic plate ($W/m\ ^\circ C$).
L	Length of the metallic plate (i.e. the absorbing plate), (m).
m	Number of harmonics
M_f	Mass of fluid (air, (Kg/m^2)
M_g	Mass of glass cover (Kg/m^2)
M_p	Mass of the absorbing metallic plate (Kg)
Nu	Nusselt number
P	Wetted Perimeter
Q_u	Amount of useful heat collected (W/m^2) or (Cal/cm^2-day).
Q_{conv}	Amount of heat lost by convection, (W/m^2)
Q_{cond}	Amount of heat lost by conduction (W/m^2)
Q_{rad}	Amount of heat lost by radiation (W/m^2)
Q_L	Total amount of heat lost by thermal losses, (W/m^2).
Re	Reynold number
$T_A(t)$	Ambient temperature at time t ($^\circ C$)
T_{Am}	Amplitude of the mth harmonic of $T_A(t)$, ($^\circ C$),
T_f	Fluid temperature, ($^\circ C$)
T_g	Temperature of glass cover, ($^\circ C$)
T_{in}	Inlet air temperature, ($^\circ C$)
T_{out}	Outlet air temperature, ($^\circ C$)
T_{exp}	Experimental temperature ($^\circ C$)

T_p Metallic plate temperature (^oC)

T_S Sky temperature (^oC)

T_W Temperature of the wind blowing (^oC)

$T(x,t)$ Temperature distribution in the air heating system at a point specified by x at time t (^oC)

t Time (hr.)

U_L Overall heat loss coefficient ($W/m^2\ ^oC$)

U_R Overall heat loss coefficient from the back of the air heat ($W/m^2\ ^oC$).

V Wind velocity (m/sec.)

v Velocity of exit air (m/sec.)

x Position coordinate (m).

Greek Symbols

α_{g_1} Fraction of solar radiation absorbed by the glass plate.

α_{g_2} Fraction of solar radiation absorbed by the lower glass plate.

α_p Fraction of solar radiation absorbed by the metallic plate.

Volume coefficient of expansion ($^oC^{-1}$)

τ_g Transmittance of the glass cover.

δ	Thickness of the absorbing plate of the air heater (m)
ρ	Density of the fluid (air) (Kg/m^3).
μ	Kinematic viscosity (Kg/m-h)
σ	Stefan's constant (W/m^2 $^{\circ}$C^{-4})
ω	Angular frequency.
η_i	Instantaneous efficiency
η_{av}	Average efficiency
ε	Emissivity of the metallic plate.

S U M M A R Y

The main objective of the investigations carried out in this thesis is to study the effect of various parameters on the performance of different configurations of conventional, Matrix and Augmented Integrated Rock System (AIRS) solar energy collector. Analytical and experimental studies for identification of efficient configurations are the main features of this work.

The transient analysis of matrix type solar air heater has been attempted in order to determine the dependence of the transient behaviour on various design parameters. The various parameters like mass flow rate, plate length, matrix thickness etc. are studied in detail. Moreover, experiments were also conducted to validate the predicted exit fluid temperature and to find out the economy of the system under investigation to be used mainly for agricultural requirements.

The performance results of matrix type solar air heater connected in series with an solar dehydrator unit are also presented. The drying ratio, rehydration ratio, culinary and organoleptic characteristics for some hor-ticultural crops like lady's finger and Fenugreek are also studied.

An exhaustive experimental study carried out on Augmented Integral Rock Sys tem is attempted for the first time, to show the versatality of the system for energy storage purposes along with fabrication details. Experiments were

conducted for varying mass flow rate, varying depth of the rock bed and number of glazing. The results obtained from thermal decay of the energy during off sun hours, stored in an integrated rock bed collecting and storage system while using a night insulation cover in addition to glass covers are also discussed in detail.

A self consistent periodic analysis of double glazed flat plate solar air heater connected in series with integrated rock bed collector cum storage unit has been developed. The theory of a double glazed flat plate solar air heater is also developed. The aim of this study was to improve the performance of solar air heater by using more number of glass covers and also to compare the experimental and predicted exit fluid temperature from the model developed, so as to confirm its applicability for obtaining higher temperature which can be stored in the integrated rock bed system. This system will provide continuous low grade heat during its operation as well as during off sun hours in the late evening and early morning.

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