Construction and Performance Analysis of a Single Slope and a Pyramid Cover Solar Still with Storage Media and Electrical Backup

By

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Certificate

This is to certify that the thesis entitled **"Construction and Performance Analysis of a Single Slope and a Pyramid Cover Solar Still with Storage Media and Electrical Backup"**, submitted to Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for the award of Degree of **Doctor of Philosophy in Physics** by **Mrs. S. Kalaivani,** is the record of original research work carried out by her during the period from July 2009 to July 2014 under my supervision and guidance and the thesis has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or similar title to any University or Institution.

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Declaration

I hereby declare that the matter embodied in the thesis entitled **"Construction and Performance Analysis of a Single Slope and a Pyramid Cover Solar Still with Storage Media and Electrical Backup"**, is the results of investigations carried out by me in the Department of Physics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, under the supervision and guidance of **Dr. S. Rugmini Radhakrishnan,** Professor (Retd), Department of Physics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, and it has not been submitted for the award of any Degree / Diploma / Associateship / Fellowship of any other University or Institution.

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Signature of the Supervisor

Signature of the Candidate

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S. Kalaivani

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NOMENCLATURE

A - Area of the still, m^2

C - Specific heat, J/Kg °C

g - Acceleration due to Gravity, m/sec

G_r - Grashof number

h - Thickness of insulation, m

h_{be} - External heat transfer coefficient through base, $W/m^2°C$

h_{ce} - External convective heat transfer coefficient from top cover to ambient, $W/m^2°C$

h_{ci} - Internal convective heat transfer coefficient from water to top cover, $W/m^2°C$

h_{ei} - Internal evaporative heat transfer coefficient from water to top cover, $W/m^2°C$

h_{re} - External radiative heat transfer coefficient from top cover to ambient, $W/m^2°C$

h_{ri} - Internal radiative heat transfer coefficient from water to top cover, $W/m^2°C$

I - Solar insolation incident on top cover per unit area per unit time, $W/m^2°C$

k - Thermal conductivity of water, W/m ^oC

L - Latent heat of water, J kg^{-1}

$\dot{m}_e$ - Distillate output per hour, kg/m^2

M_e - Distillate output, kg/m^2

N_u - Nusselt number

P_a - Partial pressure of water vapor at atmospheric temperature, Pa

P_c - Partial pressure of water vapor at top cover temperature, Pa

P_r - Prandtl number

P_w - Partial pressure of water vapor at water temperature, Pa

q_l - Rate of which heat is lost by convection and re-radiation from the top and by conduction from the bottom and side, W/m^2

Q_{be} - External conductive heat transfer through base, W/m^2

Q_{ce} - External convective heat loss from top cover to atmosphere, W/m^2

Q_{ci} - Internal convective heat loss from water surface to top surface, W/m^2

$Q_{e\,i}$ - Internal evaporative heat loss from the water surface to top cover, W/m^2

Q_e - Total amount of solar energy used for evaporation, J/m^2 per day

Q_{re} - External radiative heat loss through radiation from the top cover to atmosphere, W/m^2

Q_{ri} - Internal radiative heat loss from the water surface to top cover, W/m^2

Δt - Time interval, sec

T_a - Air temperature °C

T_{amb} - Ambient temperature, °C

T_c - Top cover temperature, °C

T_{sky} - Sky temperature °C

T_w - Water temperature °C

U_L - Overall heat transferred coefficient from absorbing surface of the still to ambient, W/m^2 ˚C

V - Wind speed, m/sec

x_1 - Spacing between water surface and top cover, m

Greeks symbols

η - Efficiency, %

α - Absorptivity

β' - Coefficient of volumetric thermal expansion, $^{\circ}C^{-1}$

ε - Emissivity

λ - Thermal conductivity of water, $Wm^{-1}{}_{\circ}C^{-1}$

μ - Dynamic viscosity of water, $Ns\ m^{-2}$

ν_f - Fluid velocity, m/sec

ρ - Partial mass density of water vapour, Kgm^{-3}

σ - Stefan–Boltzman constant, $Wm^{-2}K^{-4}$

τ - Coefficient of transmission

Indices

a - Air

amb - Ambient

b - Base

c - Cover

ce - External convection

ci - Internal convection

ei - Internal evaporation

re - External radiation

ri - Internal radiation

w - Water

PAPERS PUBLISHED IN JOURNALS

1. **Kalaivani. S,**Rugmini Radhakrishnan, Kalithasan B and Selvakumar. B, (2011), **"Enhanced Distillate Yield of Acrylic Pyramid Top Cover Solar Still With and Without Tar Coated Blue Metal",** *IEEE Xplore,* pp.296-305.

   (Impact Factor: 2.0)

2. **Kalaivani. S,**Rugmini Radhakrishnan. and Selvakumar. B., (2012), **"Heat Mass Transfer and Thermophysical Analysis for Double Slope Step Type Solar Still"**,*International Journal of Current Research and Review*, Vol. 2, Issue. 4, pp. 141-148.

   (ISSN No: 0975 5241, IC Value: 4.18)

3. **Kalaivani. S,** Rugmini Radhakrishnan. and Selvakumar. B., (2012), **"Experimental Behaviour of a Pyramid Type Solar Still Coupled and Decoupled to an Electrical Temperature Controller"**, *International Journal of Current Research and Review,* Vol. 4, Issue. 8, pp. 63-76.

   (ISSN No: 0975 5241, IC Value: 4.18)

4. **Kalaivani. S.** and Rugmini Radhakrishnan., (2012), **"Improvement of Pyramid Type Solar Still Performance Using Wax Latent Heat Material",** *International Journal of Current Research and Review,* Vol. 04, Issue 19 pp. 69-77.

   (ISSN No: 0975 5241, IC Value: 4.18)

5. **Kalaivani. S.** and Rugmini Radhakrishnan., (2013), **"Heat Mass Transfer and Thermophysical Analysis for Pyramid Type Solar Still",** *International Journal of Science and Research,* Vol. 02, Issue 9, pp. 181-184.

   (ISSN No: 2319 7064, Impact Factor: 1.0)

6. **Kalaivani. S.** and Rugmini Radhakrishnan., (2013), **"Physical and Chemical Analysis of Distillate using Acrylic Pyramid Top Cover Solar Still With and Without Sensible Energy Storage Material – Tar Coated Blue Metal and Charcoal Powder",** *International Journal of Recent Scientific Research,* Vol. 04, Issue 8, pp. 1239-1241.

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