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THEORETICAL STUDY OF SOLAR STILLS WITH REFLECTOR EXTERNAL

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Abstracts

A simple mathematical model is presented for solar cascade stills with external reflector.it is based on analytical of energy –balance equation for different element of solar cascade stills .the solar cascade still performance is investigated by computer simulation in terms of cascade stills efficiency and specific boiling times. Numerical calculations have been carried out for different tilts angle of the outer reflector on typical day (02-out) in east Algeria (Constantine) .To do this work, one has to adopt a theoretical approach who consists in simulating this behavior by a computer program using a mathematical model where all the parameters characterizing the performance of the system are evaluated instantaneously during the period of sunning, Temperature of each element of distiller, thermal efficiency.

Key word: solar distiller, solar energy, solar cascade stills

1. Introduction

On the world plan, the demand for drinking water of good quality is increasingly strong because the world population increases and the requirements out of water for industry and agriculture are increasingly high. In Algeria, the problem of drinkable water provision is already posed; initially it is necessary to install mechanisms to decrease the wasting and the escapes of water, because this substance remains insufficient. One of the solutions is the production of fresh water starting from salt water.

Nevertheless, desalination requires an energy whose cost is important, for that of the projects in the field of the solar energy showed since 1872, which solar distillation is economically more competitive when the demand for fresh water is not too large. By its privileged situation, Algeria has the largest solar layer of the Mediterranean basin. The intermediate duration of sunning of the Algerian territory exceeds the 2000 annual hours, to reach nearly 3500 hours of sunning in the desert of the Sahara. The total of received energy is estimated at 169.400 TWh/an, that is to say 5000 times the consumption of annual electricity of the country.

Several types of solar configurations of distillers were built and tested throughout the world. In the same time much of researchers proposed mathematical models to describe the transfers of heat and matter in the solar distillers

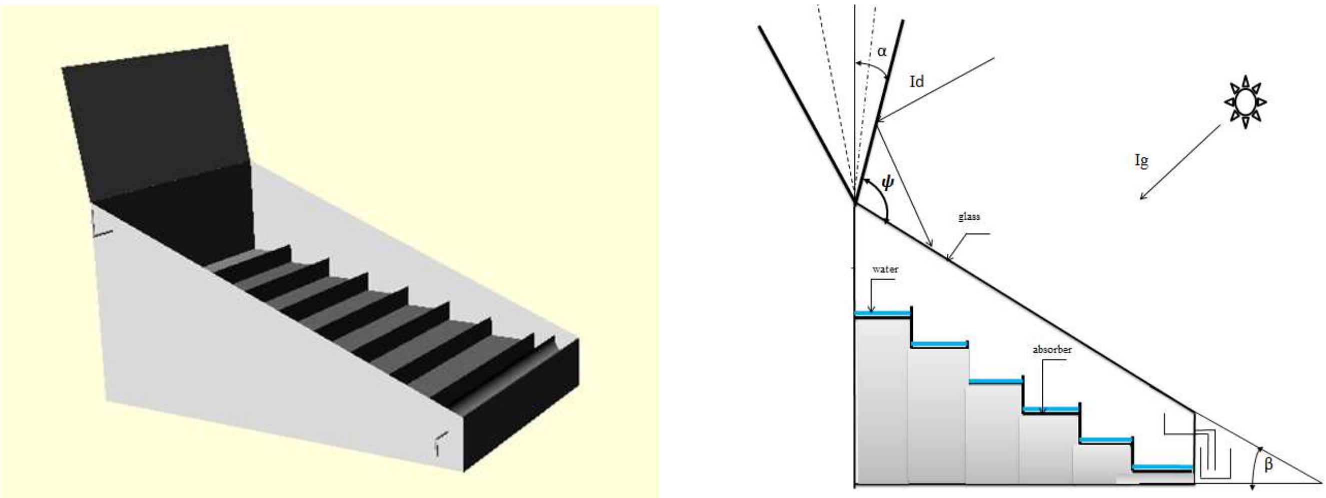


Figure1: Schematic diagram of the solar cascade stills with external reflector

2. Mathematical modeling

2.1. Equations governing the transfer of heat in the distiller

The energy balance equations for the distillation system components can be written as follows where a computer program has been developed to simultaneously solve them [1]

- **Glass**

$$M_g Cp_g \frac{dT_g}{dt} = \left(I_{ro} + I_g\right)\alpha_g A_g + q_{wg}^r + q_{wg}^c + q_{wg}^{ev} - q_{ga}^c - q_{ga}^r \tag{1}$$

$$I_{ro} = I_t \rho_0 F_{rg} A_r / A_g \tag{2}$$

$\boldsymbol{I_g}$ is the total radiation on the glass

Where $\boldsymbol{I_t}$ is the total solar radiation on the reflector, $\boldsymbol{\rho_0}$ the reflectivity of the reflector, and the view factor is

$$F_{rg} = (c + r - s)/2r \tag{3}$$

With $s = (c^2 + r^2 - 2cos\psi)^{0.5}$ using the Liu and Jordan correlation [2],[10]

Where $\emptyset$= latitude, δ =solar declination, ω = hour angle and β=tiled angle of glass and reflector

$$I_g = I_b R_{bc} + I_d(1 + cos(\beta))/2 + (I_b + I_d)\, I_d(1 - cos(\beta))/2 \tag{4}$$

Or

$$R_{bc} = \frac{cos(\emptyset-\beta)cos\delta cos\omega + sin(\emptyset-\beta)sin\delta}{cos\emptyset cos\delta cos\omega + sin\emptyset sin\delta} \tag{5}$$

- **Saline water**

$$\mathrm{M_w Cp_w \frac{dT_w}{dt} = (I_{ro} + I_w)\alpha_w A_w - q_{wg}^r - q_{wg}^c - q_{wg}^{ev} - q_{bw}^c} \tag{6}$$

- **Absorber**

$$M_b Cp_b \frac{dT_b}{dt} = (I_{ro} + I_b)\alpha_b A_b - q_{loss} - q_{bw}^c \tag{7}$$

2.2. Heat Transfer Coefficients

- **Convective heat transfer from the water mass to de the glass cover**

$$h_{wg}^{c} = 0.884\left[\left\{\left(T_w - T_g\right) + \frac{\left(P_V^{w} - P_V^{g}\right)}{268.9\times10^{3} - p_V^{w}}\right\} \times \frac{1+\cos(\beta)}{2}\right]^{\frac{1}{3}} \quad (8)$$

- **Radiative Convective heat transfer from the water mass to de the glass cover**

$$h_{wg}^{r} = \varepsilon_{eff} \times \sigma\left(T_w^2 + T_g^2\right) \times \left(T_w + T_g\right) \quad (10)$$

$$\boldsymbol{\varepsilon}_{\mathbf{eff}} = \frac{1}{\frac{1}{\varepsilon_w} + \frac{1}{\varepsilon_g} - 1} \quad (11)$$

ε_w: emissivity coefficient of water.

ε_g: emissivity of coefficient the glass cover.

σ: Stefan-Boltzmann Constant ($5.6697.10^{-8}$[$WM^{-2}K^{-4}$])

- **Evaporative heat transfer from the water mass to de the glass cover**

$$h_{wg}^{ev} = 16.276 \times 10^{-3} \times h_{wg}^{c} \times \frac{\left(P_v^{w} - P_v^{g}\right)}{\left(T_w - T_g\right)} \quad (12)$$

$$P_v^{g} = e^{\left(25.317 - \frac{5144}{T_g + 273}\right)} \quad (11)$$

$$P_V^{w} = e^{\left(25.317 - \frac{5144}{T_w + 273}\right)} \quad (12)$$

- **Radiative heat transfer from the glass cover to an ambient**

$$h_{ga}^{r} = \varepsilon_g \times \sigma \times \left(T_g^2 + T_c^2\right) \times \left(T_g + T_c\right) \quad (13)$$

Tc: Is the sky temperature

This temperature is given according to the room temperature

$$\mathbf{T_c = T_a - 6} \quad (14)$$

- **Convective heat transfer from the glass cover to an ambient**

$$h_{ga}^{c} = 5.7 + 3.8 \times V \quad (16)$$

With V: Speed of the wind in M/S

- **Convective heat transfer from the absorber to the saline water**

$$h_{bw}^{c} = \frac{Nu \times \lambda_w}{L} \quad (17)$$

$$Nu = c(Gr \times Pr)^{n} \quad (18)$$

If $Gr < 10^5$ $Nu = 1$

- **Heat exchange between the saline water and the absorber is done only by conduction**

If $10^5 <$ Si $Gr > 2\times10^7$

$$Nu = 0.14 \times (Gr \times Pr)^{0.33} \quad (19)$$

If $Gr < 2\times 10^7$

$$N_u = \frac{\lambda_w}{L} \times 0.54 \times (Gr \times Pr)^{0.25} \quad (20)$$

- **Thermal Losses Coefficient between from the basin to an ambient**

According to **V .VElMRUGAN** [1] , **Ub**=14W/ K M^2 [1],[3]

2.3 Thermal efficiency

Is the ratio of the quantity of energy evaporated by (m^2), with the quantity of incidental total energy by (m^2) on a horizontal surface. It is defined by:

$$\eta_g = \frac{m_d L_v}{(I_{ro}+I_g)\alpha_g A_g} \quad (21)$$

Lv: the evaporative heat latent

md: the flow still.

3. Numerical Calculation

The numerical resolution of the systems of equation precedent to be carried out by the method of **Euler Modifier,** We chose one day typical,. The Calculate realized in Constantine by taking account of the geographical coordinates of the site, Northern Latitude 37°.17, longitude 6°.62 Is, the slope of the cover 30°.a One outer reflector with dimensions1×1m is hinged on the northern edge of the distiller the angle between the reflector and glass is **Ψ** compared to the horizontal one with an azimuth of 0° compared to the South. We initiated assuming the temperature of various elements of the stills to be equal to ambient temperature. Using known initial values for different temperature, different heat-transfer coefficients are calculated. The temperature of elements of the stills may be calculated for time interval was equal one hour.

4. Results And Discussion

The total radiation on the outer reflector is made up of three components: direct radiation diffuse radiation and solar radiation diffusely reflected from ground. Figure 1 shows the diurnal variation of global radiation on the outer reflector for different tilt angles of the outer reflector.

It clear from **figure1** that the total radiation on the outer reflector vary with tilt angle of angles of the outer reflector **α** we shows that in **α**=10° total irradiation reach these maximum values ,we shows also that total irradiation decrease with increasing angle of reflector **α.**

The **figure 2** shows the variation of total irradiation on cover surface of distiller with different tilt angle of outer reflector, the angle tilt of cover was **30°** with horizontal. The same ones notices that the **figure**

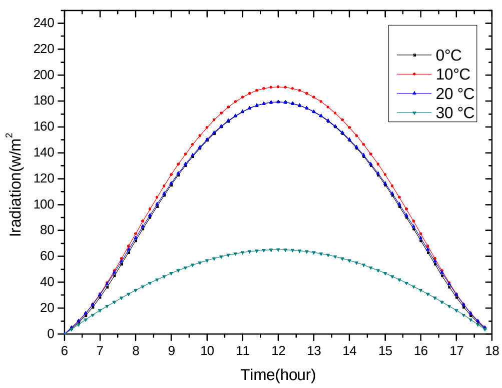


Figure1: effet of reflector tilt on the calculated of solar irradiation on the reflector

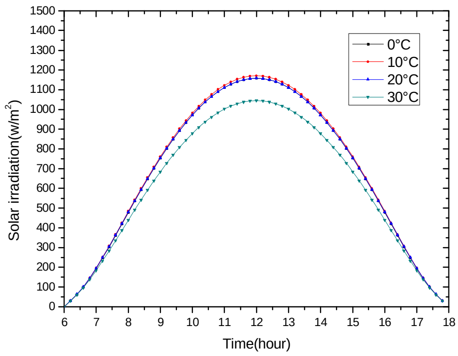
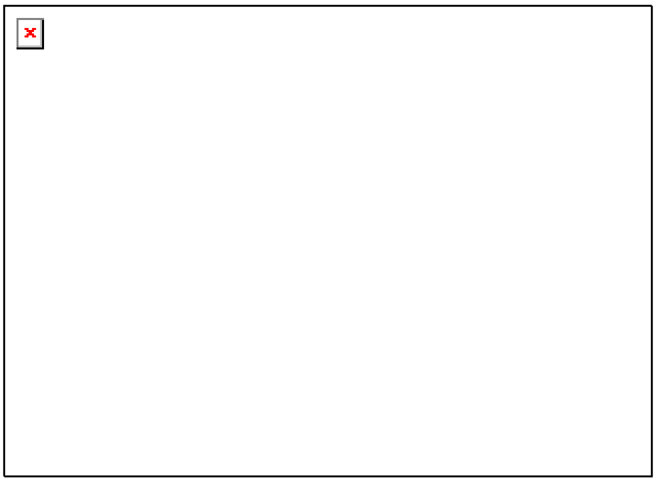


Figure2: effet of reflector tilt on the calculated of total solar irradiation on the stills

The **figure 3** illustre the diurnal variation of temperature each element stills.the optimum tilt of reflector angle of the outer reflector is 10°and the tilt of cover angle is 25°with horizontal surface .this temperature increase wiht increasing solar irradiation, the maximum values reaches between 10:00h and 14:00 h.we remark also the bac temperature was higher that other elements stills,this because a solar irradiation absorbed by bac element .

The **figure 4** illustre the variation of water temperature during day with and without reflector externel,the angle of angles of the outer reflector **α** we shows that in **α**=10° and we remark that this temperature increase with inreasing of solar irradiation .the soloar irradation tranform into heat quantity aborbed by mass water that arise increasing of his temperaur.

If we want to compare the results got with and without reflector externel ,we remark an increase of 15% - 20% for resulted obtained by reflectors external.



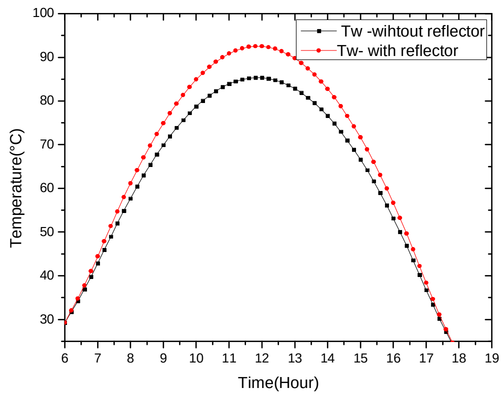
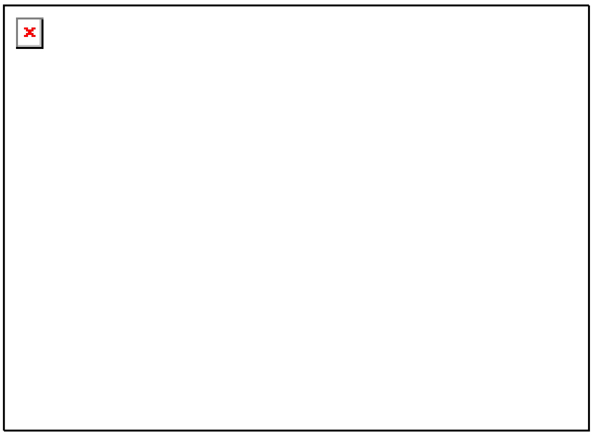


Figure 3:diurnal variation temperature

of temperature elements stills

Figure4:diurnal variation of

water temperature with and without reflector



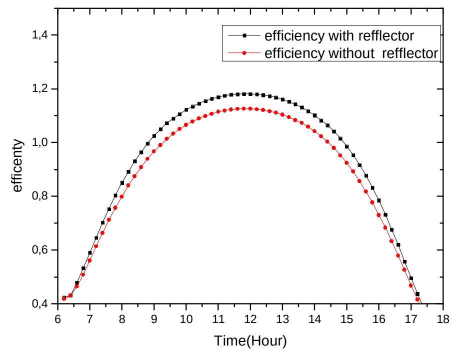


figure5 : Hourly variation of distilled water

with and without reflector externel

figure 6: Hourly variation of efficiency

with and without reflector externel

Figure 5 shows hourly variation of distilled water yield day with and without reflector externel,the angle of the outer reflector **α** we shows that in **α**=10 . we remark that the maximum amount of distilled water was obtained between the hours 12.00 to 12.00 because The total solar radiation in this interval was maximum,if used reflectro external the total solar radiation would have an increase of solar power absorbed by water ,the ditilled water would be inerase to of 10% - 15%.

Figure 6 illustre houlrly variation of efficiency stills,with and without reflector externel at the same angle that it calculated for distilled water (**α**=10).the global effiency is the relationship between the quantity energy absorbed by saline water and the incidental solar radiation on the surface of the cover.we remark that a different betwenn the results got when the still with reflector externel. This diffrencs appeared above all to interval between 12:00 and 14:00

5. Conclusion

In this paper the solar thermal still with and without flat radiation reflector externel has been considered

The change of optimal positionr reflectors during the day have been optimise for cover still fixed at β=25° position in oorder to obtain the maximum concentrationof solar radiationintensity.according to numerical calculation indicated that the optimal angle position of the tefflector externel was the lowest (10°) in the season estival

The results have shown the positive of reflecctor at the distillet water yield and efficiency of stills that about 15% again water distillted,there was an averge energy fain of a bout 20% in the summer period.This energy gain is expected to reduce the pays of stills .

6. Nomenclature

symbol	Nom, unit
A	Absorption coefficient
a	Thermal diffusivity, M^2/S
Cp	specific heat with constant pressure, *j/Kg. °C*
h^c	Coefficient of heat exchange by convection, $W/M^2.°C$
h^r	Coefficient of heat exchange per radiation, $W/M^2.°C$
h^{ev}	Coefficient of heat exchange per evaporation, W/M^2.
U	Total coefficient of the thermal losses, $W/M^2.\ K$
Ig	Incidental radiation total, W/M^2
P	Pressure, *Pa*
q^c	Heat flow exchanged by convection, *W*
q^r	Heat flow exchanged by radiation, *W*
q^{ev}	Heat flow exchanged by evaporation, *W*
T	Temperature,*°C*
V	Speed of the wind, *M/S*

Grec symbol	
α	Absorption coefficient
β	Slope of glass
η	Effectiveness ,%
ε	Emissivity,
μ	Dynamic viscosity, *Kg/M.S*
ν	Kinematic viscosity, M^2/S
τ	Coefficient of transmission
ρ	Density, Kg/M^3

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