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Mathematical Analysis of Solar Still With Storage

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Abstract - Transient mathematical models are considered for a single slope single basin solar still with and without phase change materials under the basin liner of the still. Analytical expression for heat balance equation will be obtained. The still performance has to be investigated by computer simulation. The various equations of heat balance are found out on Glass surface, Water mass, Basin lines and Storage. The storage stores the heat in the form of latent heat and deliver these heat in the night period. The efficiency of storage is calculated and performance of still is found out for a single day.

Keywords – Solar still, storage, solar radiation.

I. INTRODUCTION

Due to increase in pollution in many part of the earth water sources are getting polluted. But the demand of fresh water continuously increased with population growth. In that condition the solar still is the best option for making the water fresh by using a solar energy. The area near coastal region where sea water is available but potable water is not available in that region solar still plays an important role for supplying fresh water.

Solar stills are divided into two categories i.e. Passive stills and active stills. There are many research where reported on improvement in the productivity of solar stills. The factor affecting performances of solar still are solar intensity, mass of basin water and wind speed. The performance of solar still can be calculated by using mathematical model. These work is performed on the mathematical model of solar stills. The various equations of heat balance are found out on Glass surface, Water mass, Basin lines and storage by analyzing these equations we get temperatures at that point and it is helpful to determine the performance of solar still.

A.A. Al-Sebaii:A single basin solar still has en investigated by computer simulation under Jeddah(Saudi Arabia) weather condition. A thin layer of steric acid as a PCM has been integrated beneath the basin liner to enhance the overnight productivity of the still. And it is compare with still without PCM. The daylight productivity is found to decrease slightly with increasing the mass of PCM but overnight and daily productivity are significantly increasing with increasing mass. The PCM becomes more effective at lower masses of basin water during the winter. Therefore, it is recommended to integrate storage materials in active and wick type solar still to produce fresh water overnight.

P.I. Cooper determines the maximum efficiency of single effect solar stills, the overall efficiency of a solar still is determined by the product of an efficiency of absorption or retention of radiation and an efficiency of utilization of this absorbed energy. An ideal still has been proposed and a set of curves presented which illustrate the maximum theoretical productivities which could be expected linear relationship has been derived which indicate that the maximum attainable ideal efficiency over a day's operation will rarely exceed 60 percent.

A small solar still was constructed which embodies the futures required to attain high efficiencies. The measured efficiency rarely exceeds 50 percent. For a practical solar still installation it appears that the ultimate efficiency during times of high solar radiation intensity and ambient temperatures is restricted to about 50 percent.

Prof. Alpesh Mehta:worked on Design of solar distillation system and concluded we can conclude that the increase in temperature and hence the evaporation is maximum in the period of 11:15 am to 1:30 pm. The maximum temperature achieved is 530c which is at 1:30 pm. then the temperature decreases. The aim of our experiment was to get pure water from the brackish water available. The brackish water we have supplied was 14 liters and at the end of the experiment we got 1.5 liters. The experiment was carried out in winter season. The TDS level of purified water obtained is 81 PPM. So the water obtained is potable. Theoretically, the experiment should fetch out 2.33 liters. So the efficiency of the system is 6%.

Abdullah M. Al Shabibi and M. Tahat: This paper investigates the thermal performance of solar water still with enhanced solar heating system. A number of variables have been considered including the water depth inside the still and the inlet saline water

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temperature to the solar still from the pre-heater solar collector system. It was found that 1 cm depth gives the best performance in terms of fresh water yield and thermal efficiency. The addition of the solar water pre-heater to the system has significantly increased the inlet basin saline water temperature to almost saturated temperature and saline water in the basin needed only small heat to be vaporized and hence increases the production of fresh water and enhances the solar still thermal efficiency. Three types of still basin bottom surface were tested: flat, finned and corrugated. The finned surface was found to give the best performance. Using finned surface can increase the fresh water production by 20%. The effect of using a solar heating system was also investigated and found to enhance the still performance significantly.

II. NOMENCLATURE

α'_g	absorptivity of glass
I	solar radiation intensity (W/m^2)
T_w	temperature of water
T_g	temperature of glass
T_a	ambient temperature
T_{sky}	sky temperature
T_b	basin temperature
T_s	storage temperature
α'_w	absorptivity of water
α'_b	absorptivity of basin
C_{pw}	specific heat of water
C_{ps}	specific heat of storage
h_{cw}	convective heat transfer coefficient of water
h_{rw}	radiative heat transfer coefficient of water
h_{ew}	evaporative heat transfer coefficient of water
h_{rg}	radiative heat transfer coefficient of glass
h_{cg}	convective heat transfer coefficient of glass
m_w	water mass
m_s	mass of storage
p	productivity

III. MATHEMATICAL MODDELING

A. *For The Still Without Storage*

$I(t)=I_bR_b+I_dR_d+I_gR_r$

$T_{amb}=$

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T_{wo}=
T_{go}=
Yield=
$dT= T_{wo}- T_{go}$

$T_v=(T_{wo}+ T_{go})/2$
$C_f= 999.2+(0.1434* T_v)+(0.0001101* T_v ^2)-(0.00000006758* T_v ^3)$
$\varrho_f=353.44/(T_v+273)$
$K= 0.0244+0.00007673* T_v$
$\mu= 0.00001718+0.0000000462* T_v$
$\beta=1/(T_v+273)$
$L_1=3161500*(1-0.0007616*)$
$L_2=2493500*(1-0.00094779* T_{wo} +0.00000013132* T_{wo} ^2-$
$0.0000000047974* T_{wo} ^3)$
L=If (T_v>70) use L_2
$P_w= EXP(25.317-(5144/(T_{wo}+273)))$
$P_g= EXP(25.317-(5144/(T_g+273)))$
$G_r= 9.81*\beta*df^3*\varrho_f^2*dT/\mu^2$
$P_r=\mu*C_f/K$
$R_a=G_r*P_r$
$h_{rw}= \epsilon_{eff}*\sigma*((T_w +273)^2 + (T_g +273)^2) * (T_w +273+ T_g +273)$
$h_{cw}= (K_f/df)*const*R_a^n$
$h_{ew}= 0.016273*h_{cw}*(P_w-P_g)/(T_w-T_g)$
$h_1= h_{rw}+ h_{cw}+ h_{ew}$
$T_{sky}=T_{amb}-6$
$h_{rg}= \epsilon_g*\sigma*((((T_g+273)^4 - (T_{sky}+273)^4) / (T_g-T_a)$
$h_{cg}= 2.8+3*velocity$
$h_{2a}=h_{rg}+h_{cg}$
$h_{2b}= 5.7+3.8*velocity$
$h_2=h_{2b}$
$U_t= h_1*h_2/(h_1+h_2)$
$U_b= h_w*h_b/(h_w+h_b)$
$U_l=U_t+U_b$
$a= U_l/((20-Yield)*cw)$
$\eta_a= ((\alpha_b*h_w)/(h_w+h_b) + \alpha_w + \alpha_g *(h_1/(h_1+h_2)))$
$f(t)= (\eta_a *I(t)+U_l*T_{amb})/((20-Yield)*cw)$
$T_{wo(new)}= (f(t)/a) * (1-EXP(-1*a*0)) + T_{wo}*EXP(-1*a*0)$
$T_{go(new)}= (\alpha_g *I(t) + h_1*T_{wo(new)} + h_2*T_{amb}) / (h_1+h_2)$
$T_b=(\alpha_b *I(t) + h_w*T_{wo(new)} + h_b*T_{amb}) / (h_w+h_b)$
$M_w=h_{ew}*(T_{wo(new)}- T_{go(new)})/L*A*3600$
Total yield=$yield_{(old)}+m_w$

B. For The Still With Storage

For charging
$$T_g=\frac{\alpha'_g\, I(t) + h_1T_w + h_2T_aTa}{h_1+h_2}$$

$$T_b= \frac{\alpha'_b\ I(t)+ h_4T_s+ h_3T_w}{h_3+h_4}$$

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$T_w = \frac{\bar{f}(t)}{a}\left[1 - e^{\frac{-a}{x}t}\right] + T_{wi}e^{\frac{-a}{x}t}$

Where, $\bar{f}(t)$= α'_w I(t)+$\left[\frac{h_3\alpha'_b\, I(t) + h_3h_4T_s}{h_3+h_4}\right]$+$\left[\frac{h_1\alpha'_g\, I(t) + h_1h_2T_a}{h_1+h_2}\right]$

a= $\left[\frac{h_1h_2}{h_1+h_2} + \frac{h_3h_4}{h_3+h_4}\right]$

x= m_wC_{pw}

$T_s= \frac{\bar{f}_1(t)}{a_1}\left[1 - e^{\frac{-a_1}{x1}t}\right]+ T_{si}e^{\frac{-a_1}{x1}t}$

Where, $\bar{f}_1(t)$= $\left[\frac{h_4\alpha'_b\, I(t) + h_3h_4T_w}{h_3+h_4}\right]$+$h_4$ T_a

a_1= $\left[\frac{h_3h_4}{h_3+h_4} + h_5\right]$

x_1= m_sC_{ps}

For Discharging

Put I(t)=0

Solving equations 1, 2, 3, & 4 for T_g, T_b, T_w, T_s

$T_g=\frac{h_1T_w + h_2T_aTa}{h_1+h_2}$

$T_b= \frac{h_4T_s + h_3T_w}{h_3+h_4}$

$T_w = \frac{\bar{f}(t)}{a}\left[1 - e^{\frac{-a}{x}t}\right] + T_{wi}e^{\frac{-a}{x}t}$
Where, $\bar{f}(t)$=$\left[\frac{h_3h_4T_s}{h_3+h_4}\right]$+$\left[\frac{h_1h_2T_a}{h_1+h_2}\right]$

a= $\left[\frac{h_1h_2}{h_1+h_2} + \frac{h_3h_4}{h_3+h_4}\right]$

x= m_wC_{pw}

$T_s= \frac{\bar{f}_1(t)}{a_1}\left[1 - e^{\frac{-a_1}{x1}t}\right]+ T_{si}e^{\frac{-a_1}{x1}t}$

Where, $\bar{f}_1(t)$= $\left[\frac{h_3h_4T_w}{h_3+h_4}\right]$+$h_4$ T_a

a_1= $\left[\frac{h_3h_4}{h_3+h_4} + h_5\right]$

x_1= m_sC_{ps}

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IV. RESULTS

A. Variation of temperature for the solar still without storage

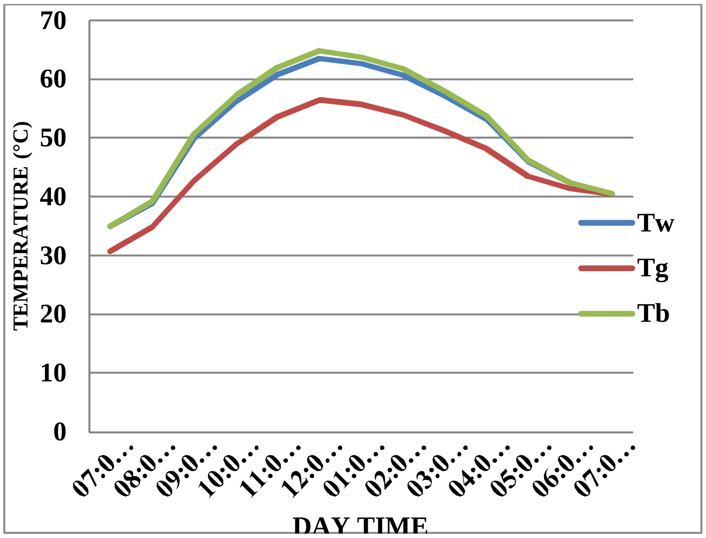

Fig. variation of temperature for still without storage

B. Mathematical vs practical productivity of solar still without storage

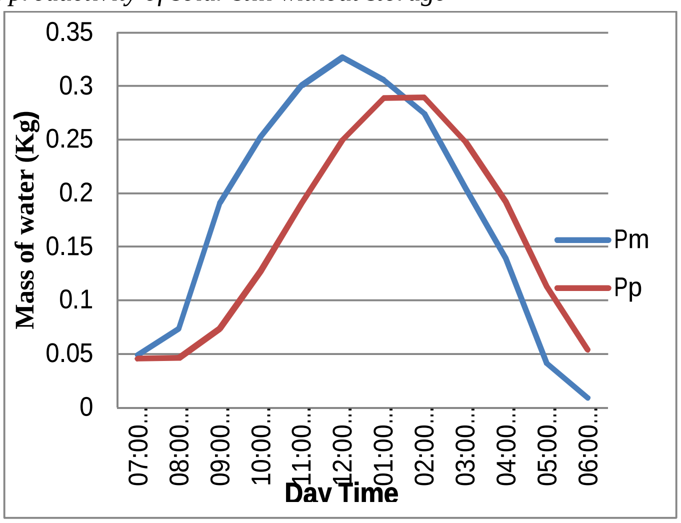

Fig. variation in productivity for solar still without storage

C. Variation of temperature for the solar still with storage Charging mode

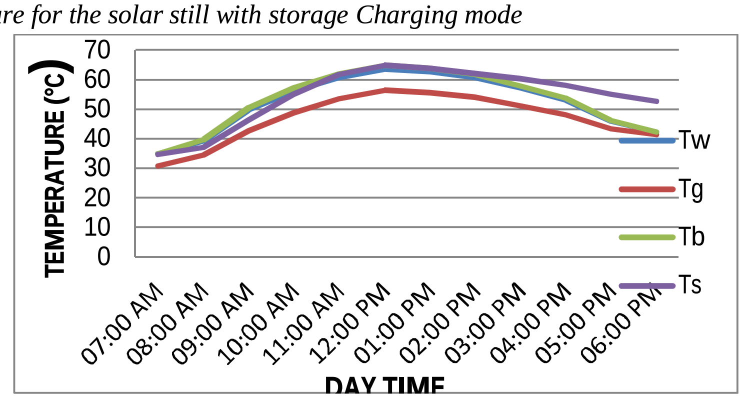

Fig. variation of temperature for still with storage

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D. Mathematical vs practical productivity of solar still with storage Charging mode

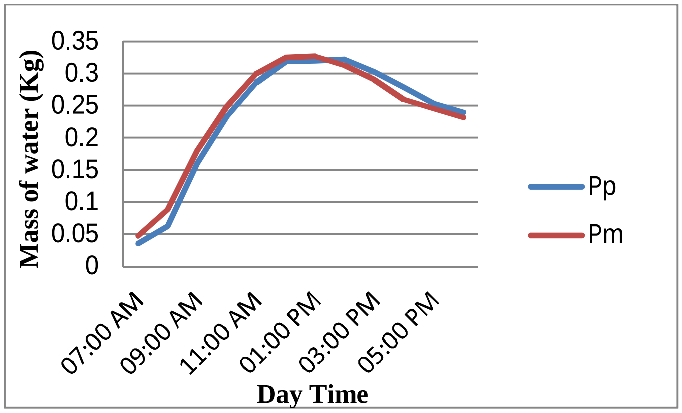

Fig. variation in productivity for solar still with storage

E. Variation of temperature for the solar still with storage discharging mode

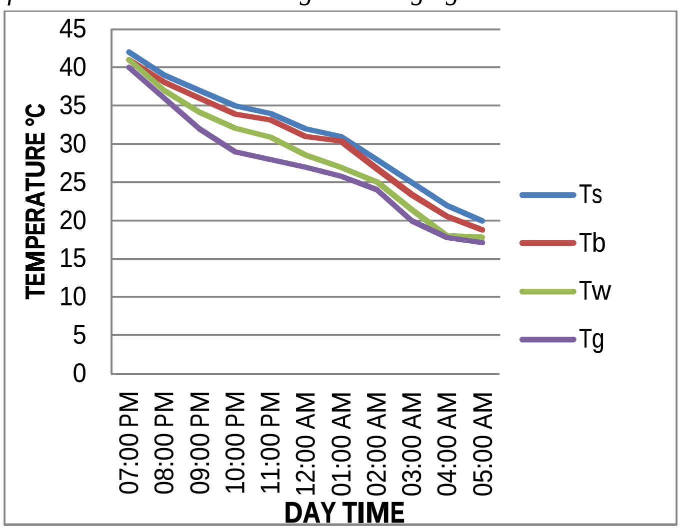

Fig. variation of temperature for still with storage

F. Mathematical vs practical productivity of solar still with storage Discharging mode

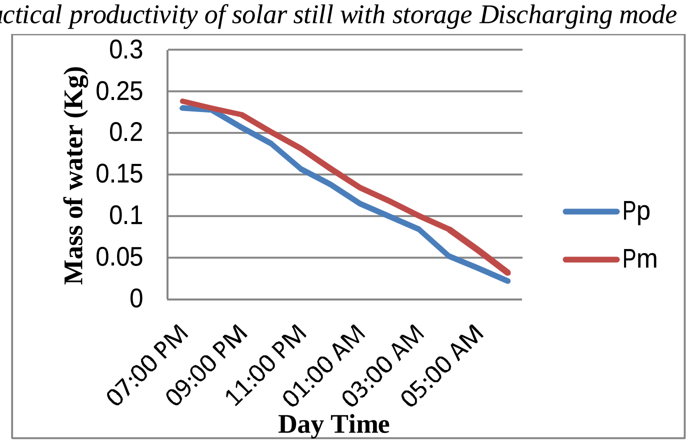

Fig. variation in productivity for solar still with storage

V. CONCLUSION

The mathematical modelling gives the overall idea about the temperature variation and productivity of solar still. Thus to solve the

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equation a program is needed so that it can same time the simplest way to solve the energy balance equation was using excel spread sheet . The formulae was feed and the I(t) and Ta from experiment observation was need to calculate the still temperature on hourly basis. In this project the mathematical analysis of solar still is done. The temperature of solar still on the various point is to be calculated using the mathematical model then variation in productivity for a single day is calculated. The solar irradiation for the Nagpur region over the day period is calculated. For the solar still without storage the modelling is done on the basis of top, bottom and side loss coefficient and the values of temperature at glass, water and basin are calculated in excel sheet.

Energy balance equation are used for the modelling of solar still with storage. The equation are made for each point on solar still i.e. glass, water, basin and storage. After solving these equations using differential equation method we got the values of temperature at glass, water, basin and storage point. This modelling shows the behaviour of temperature and productivity in solar still for the whole day.

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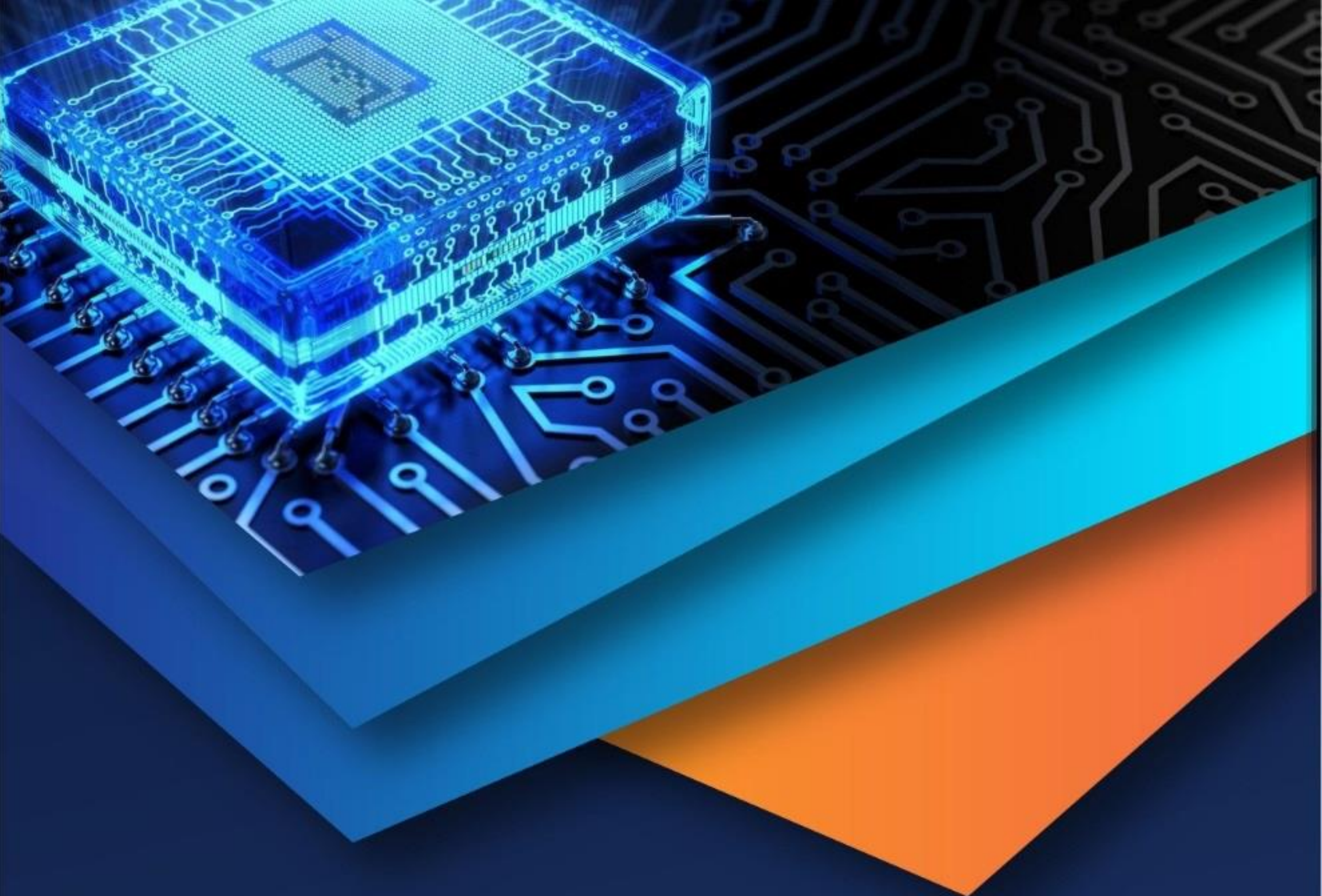

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