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Investigation on Performance of Flat Solar Still using Different Coating Material on Absorbing Plate

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Abstract: Solar still is an apparatus which uses solar energy to produce distilled water from saline water. This can be used in remote areas effectively wherein electricity is not available. The output from a conventional stepped solar still is found to below. Hence research is required to increase the productivity of the conventional solar still. This work is an attempt to increase the productivity of solar still. The study was conducted to investigate the effect of different coating material on the absorber plate on the performance of solar still.in this project work AlN with blue anti reflective coating used as a coating material in this study because of their high heat absorbing ability. Absorber plate ofthicknesses1 millimetre and 2 millimetres used which is suitable for the conduction of heat to the working fluid. A model was designed for the experiment to find out the best coating material.
Keywords: Solar Still, Absorbing Plates, Oxide Coating, Distillate Output, Exergy Analysis

I. INTRODUCTION

A. What Is Solar Still?

Solar still is the oldest method of desalination of water. In this method, the radiation from the sun is passed through a glass cover and collected on black plate and heated it. the saline water is fed on a black plate of the basin of solar still. The heat is transfer from the black plate to water inside the basin and the water evaporated inside a closed chamber. Water vapours travel toward cooled inclined glass surface and clinged on it. as time pass this water vapours condensed on the glass surface and to form pure water droplets. This droplet sticks on this surface due to the effect of surface tension and collected in channels located at bottom of solar still by gravity effect. whatever salt and other impurities remain at the base.
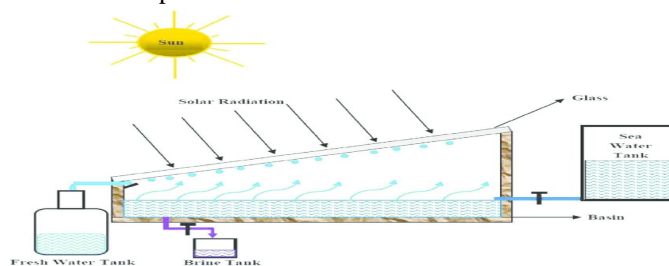

Fig 1: conventional solar still

B. Absorber Plate

The primary function of the heat absorber plate is to absorb as much as possible of the radiation reaching through the glazing at the same time to transfer the retained heat to the circulating working fluids.

In this project of AlN is used as a coating material on a flat plate for investigation because this material has high thermal conductivity and absorbability.

1) AlN cermet selective coating deposited on Al substrates via a DC PVD sputtering   system.
2) Total absorptance-96%.
3) Total Emittance of 0.06%(blue color coating is applied on this surface to achieved law emittance value.
4) AlN coating considerably improved the corrosion resistance of Al alloy in the given corrosive media.
5) According to EIS test, polarization resistance improves by this coating.
6) The optical performance of the coating remained almost unchanged after a 200-hour test (at 250∘c).

II. LITERATURE REVIEW

P. Konttinen, P.D. Lund (2009) conducted a series of accelerated aging tests in order to determine the service life of mechanically manufactured selective $C/Al_2O_3/Al$ absorber samples. These tests were mainly conducted under IEA SHC recommendations. The main degradation mechanism is found to be hydration of aluminium oxide to pseudoboehmite and boehmite, caused a decrease in service life of mechanically manufacturing coating $C/Al_2O_3/Al$.Aging test typically conducted under three different conditions: high temperatures and low humidity, service temperatures and high-humidity air containing Sulphur dioxide. and service temperatures under condensation conditions.

Manoj Kumar Sain, Godhraj Kumawat (2015) had an experiment to improve the productivity of solar still using Nano-particles because These particles increase the surface area of absorption to solar radiation. In this work, the Al2O3 used as nanoparticles and mixed with black paint is used to increase the productivity of solar still. This Experimental is performed for the single slope solar still under climatic conditions of Jaipur to check the significance of the difference in productivity of solar still with and without Nano-particle mixed black paint. the productivity enhancement due to Nano-particle mixed black paint is significant at 95% confidence interval.

V Ramanathan, B Kanimozhi, V K Bhojwani (2017) had to work on how to increase the productivity of solar still. A flat mica plate is used as an absorbing plate in the conventional solar still to increase evaporation of the water from the input saline water. The flat plate absorber is placed in such a way that it is parallel to the glass cover of the solar still so as to maximize the absorption of solar radiations. By this modification, the maximum temperature of the absorber plate achieved was $95^{\circ}C$ in comparison to $67^{\circ}C$ of the conventional solar still and distillate output increased by 25% with a flat plate absorber compared to conventional still.

L.Cindrella (2007) have recommended The real utility ranges of the solar selective coatings regard to temperature and the type of installations of solar still. This study brings out the impact of the different combinations of the optical parameters of the selective coatings on the efficiency of solar thermal systems with various concentration ratios (CRs). Composite selective black coatings of cobalt– cadmium, and nickel–cadmium systems developed by us earlier have been analysed in the present study.

Hemin Thakkar, Dr. Hitesh Panchal (2017) Has investigation on solar still Integrated with Nano-composites with and without the use of paraffin wax as a Phase change material. For the comparison of performance, three identical 1 square meter area solar stills have used. The first solar still is without Nano-composites and PCM, second with only Nano-composites and third integrated with Nanocomposites and PCM.aluminum oxide is used as Nano-composites and coated on the surface of the Absorber plate. It has found that solar still integrated Nano-composites and phase change material found 92% more productive compared with alone solar still and only Nano-composites integrated solar still is 106 % more productive compared with alone solar still.

Teresa C. Diamantino, Rita Gonçalves, Ana Nunes, SoraiaPáscoa, M. JoãoCarvalho (2017) Objectives of this study was to investigate the degradation and durability of aluminium absorber surfaces with different PVDs and paints coatings (PCs) in outdoor exposure testing sites with different atmospheric corrosively, it was possible to conclude that OET sites, namely in places with high corrosively as in marine and/or industrial areas. During one year of outdoor exposure, it was possible to establish a ranking of the performance of anticorrosive protection of the coatings where PCs showed much higher anticorrosive protection than a PVDs (PVD2<PVD1<<PC1≅PC2<PC3).

M. Farooqa, M.G. Hutchinsb (2002) They describes the development of multilayer metal-dielectric graded index solar selective coatings in which the metallic volume fraction increases with depth, from the top(air-film interface) to bottom (film–substrate interface).On examination of multi-layer structures, it is found that multi-layer composites improve the solar absorptance due to destructive interference effects within the coating. Among the designs worked out for selective absorbers, it is perceived through calculations and experimental findings that a four-layer modified selective absorber design (4-PGSAC) gives the best efficiency among all the studied selective coatings.

III. COATING ON PLATES

A. *What is a Selective Coating?*

The efficiency of solar still increases in two ways.

1) A high Absorptivity rate, meaning the maximum amount of solar radiation transformed into heat and this heat is transfer to saline water.
2) A low emissivity rate, meaning the minimum amount of heat loss by heat emission.

Losses due to heat emission are minimized by using highly efficient absorbers are provided with selective coatings. Such coatings make it possible to absorb and transform a large part of the short-wave Solar Radiation into heat, and, simultaneously, to reduce the losses of longwave radiation emitted from the absorber itself.

IV. EXPERIMENT WORK

Fig 4. Experimental Setup

In this work Coating of AlN (with blue anti-reflective coating) on absorbing plate is used to enhance the productivity of solar still. The solar radiations are transmitted through the glass cover and captured by an absorbing plate inner bottom surface of the solar still. Water absorbs the heat and is converted into vapor within the chamber of the solar still. Single slop solar still is used from past decades but in this study effect of nitride coating on the productivity of solar still is analyzed. Experimental work is performed for the single slope solar still (SS-SS) under climatic conditions of Gandhinagar.

Fig 5. AlN with Blue Anti Reflective Coating on the Plate

A. *Convectional Solar Still*
1) *Components*
a) Glass cover
b) Basin
c) Cast iron stand
d) Silicon sealant with gun
e) Water tank.
f) Measuring cup for pure water
g) Absorbing plate
h) Temperature Measurement

B. *Dimension of Solar Still*

The Dimension of A Wooden Box

1) The width of the wooden box:0.5m
2) Length of the wooden box:0.5m
3) High sidewall height:0.35m
4) Law sidewall height:0.15m

C. *The Dimension of The Glass Cover*

1) The width of glass:0.55m
2) Length of glass:0.5m
3) The thickness of glass:3.5mm
4) The angle of inclination of glass cover:23.22°

V. RESULT AND DISCUSSION

TABLE □

Reading With Black Colour Coating On Absorbing Plate

Time in hr	Solar Insolation $(W/m^{2)}$	$T_{Go}(\square)$	$T_{Gi}(\square)$	$T_w(\square)$	$T_a(\square)$	Mass of distilled water in (ml)	(η)
9.00 am	370	32.3	36.7	26.9	23	-	-
10.00 am	570	38.5	44.6	32.2	25	10	4.73%
11.00 am	750	42.8	51.6	41.3	27	25	9%
12.00 pm	890	46.3	58.1	54.3	29	55	16.68%
1.00 pm	1025	54.5	64.9	59.3	30	80	21.07%
2.00 pm	900	52.1	65.9	61.6	31	85	25.5%
3.00 pm	700	51.5	62.2	58.9	31	80	30.85%
4.00 pm	520	46.2	53	48	32	70	36.34%
5.00 pm	310	42.8	48.2	42.7	34	50	43.54%
TOTAL	6035					455ml	$\eta_{(Daily)=}$20.35%

TABLE III

Reading With Aln (With Blue Antireflective) Coating On Absorbing Plate

Time in hr	Solar Insolation (W/m^2)	$T_{Go}(\square)$	$T_{Gi}(\square)$	$T_w(\square)$	$T_a(\square)$	Mass of distilled water in (ml)	(η)
9.00 am	390	34.9	40	30.2	23	-	-
10.00am	590	36.6	45	34.3	25	20	9.47%
11.00am	810	43.1	52.6	44.5	27	40	13.33%
12.00pm	920	46.8	58.7	53.1	29	70	20.86%
1.00 pm	940	52.2	63.9	59.1	30	95	27.28%
2.00 pm	850	52.9	65.8	62.1	31	100	31.76%
3.00 pm	670	50.8	66.1	61.4	31	95	38.28%
4.00 pm	435	47.3	63.6	56.7	32	75	46.55%
5.00 pm	220	42.6	53.8	50.00	34	45	55%
TOTAL	5825					540	$\eta_{(Daily)=}$25%

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A. Calculation of Efficiency of Solar Still Based on Distilled Output at 12pm(850W/m^2,100ml)

$$\eta = \frac{m \times hfg}{Ig \times A}$$

m= Daily output (lit./day)
h_{fg}= Latent heat of water (MJ/kg)
A= Aperture area of still (m^2)
I_g= Daily global solar radiation (kWh/m^2/day)
m = 70ml/hr.
   =0.095kg/hr.
h_{fg}= 2.43 MJ/kg
A= 0.5m×0.5m
  =0.25m^2
Ig= 940
  =0.940kWh/m^2/hr.

$$\eta = \frac{(0.095)(2.43 \times 10^6)}{(0.940)(0.25) \times 3600 \times 10^3}$$

   =0.3176
   =31.76%

B. Calculation of Efficiency of Solar Still Based on Temperature at 12pm(850W/m^2,100ml)

$$P_w = \exp\left(25.317 - \frac{5144}{Tw}\right)$$

$$= \exp\left(25.317 - \frac{5144}{273.15+62.1}\right)$$

= exp (9.9732)
P_w =21443.996 N/m^2

$$P_g = \exp\left(25.317 - \frac{5144}{273.15+52.9}\right)$$

$$= \exp(25.317 - 15.77)$$

$$= \exp(9.5402)$$

P_g =13907 N/m

$$h_{c\text{-}w\text{-}g} = 0.88 \times \sqrt[3]{\left[(Tw - Tgi) + \frac{(Pw - Pgi) \times Tw}{268.9 \times 10^3 - Pw}\right]}$$

$$= 0.88 \times \sqrt[3]{\left[(335.25 - 326.5) + \frac{(21443.996 - 13907) \times 335.25}{268.9 \times 10^3 - 21443.996}\right]}$$

$$= 0.88 \times \sqrt[3]{19.41}$$

$h_{c\text{-}w\text{-}g}$ = 2.3584 W/m^2K

$$h_{e\text{-}w\text{-}g} = 16.273 \times 10^{-3} \times h_{c\text{-}w\text{-}g} \times \frac{(Pw - Pg)}{(Tw - Tgi)}$$

$$= 16.273 \times 10^{-3} \times 2.3584 \times \frac{(7536.276)}{(9.2)}$$

$h_{e\text{-}w\text{-}g}$ = 31.43 W/m^2K
$E_{e\text{-}w\text{-}g}$ = $h_{e\text{-}w\text{-}g} \times (Tw - Tgi)$
= 31.43×9.2
$E_{e\text{-}w\text{-}g}$ = 289.22 W/m^2

$$\eta_e = \frac{Ee\text{-}w\text{-}g}{IG}$$

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$$= \frac{289.22}{850}$$

$$= 0.3238$$

η_e = 32.38% (energy efficiency)

$$\eta_{ex} = \frac{(h_{e-w-g}) \times (T_w - T_{gi}) \times \left(1 - \frac{T_a}{T_w}\right)}{I_{gs}\left[1 + \frac{1}{3}\left(\frac{T_a}{T_s}\right)^4 - \frac{4}{3}\left(\frac{T_a}{T_s}\right)\right]}$$

$$= \frac{289.22 \times \left(1 - \frac{31 - 273.15}{335.25}\right)}{850\left[1 + \frac{1}{3}\left(\frac{31 - 273.15}{6000}\right)^4 - \frac{4}{3}\left(\frac{31 + 273.15}{6000}\right)\right]}$$

$$= \frac{289.22 \times (1 - 0.907)}{850\left[1 + \frac{1}{3}0.05069^4 - \frac{4}{3}(0.05069)\right]}$$

$$= \frac{26.89}{850 \times [0.9324]}$$

$$= 0.0399$$

η_{ex} = 3.99% (exergy efficiency)

C. Energy Analysis of Passive Solar Distillation System
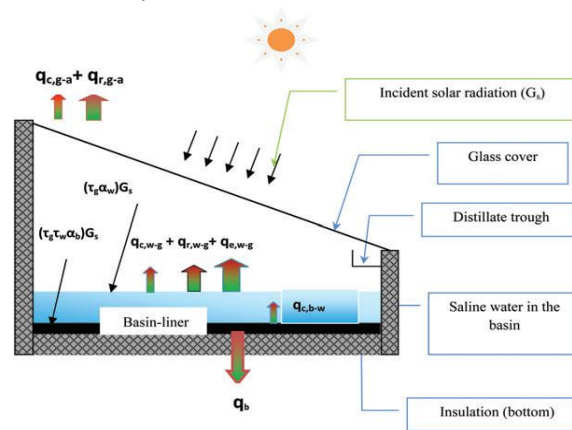

Fig 6: A schematic diagram of single-effect, single-basin horizontal passive solar still showing the mechanism of major energy transfer

D. Energy distortions

(T_a=31□, T_b=68.5□, T_w=62.1□, T_{gi}=52.9□, T_{go}=45□, I=850W/m², V_{wind}=11km/hr, m_o=100ml)

1) Basin-Liner

$$E_{d-b} = [(\tau_g \tau_w \alpha_b) \times E_{sun\times}] - E_w$$
$$E_{d-b} = [(0.77 \times 0.94 \times 0.3 \times 850)] - 28$$
$$= 188.96 - 28$$
$$E_{d-b} = 160.5 \text{ W/m}^2$$

2) Saline Water

$$E_{d-w} = [(\tau_g \alpha_w) \times E_{sun}] + E_w - E_{w-g} + M_w C_w \frac{dT_w}{dt}$$
$$= [(0.77 \times 0.7 \times 850] + 28 - 379.316$$
$$= 486.14 - 379.316$$
$$E_{d-w} = 106.834 \text{ W/m}^2$$

3) Glass Cover

$$E_{d-g} = [(\alpha_g) \times E_{sun}] + E_{w-g} - E_{g-a}$$

$$= [0.16 \times 850] + 379.316 - 212.8$$
$$E_{d-g} = 303.01 \text{ W/m}^2$$

4) *Energetic Efficiency*

$$\eta_{e\text{-basin liner}} = \frac{hw \times (Tb - Ta)}{(\tau g \tau w \alpha b) \times Esun}$$

$$= \frac{28}{188.49}$$

$$= 0.1485$$

$\eta_{e\text{-basin liner}} = 14.85\%$

$$\eta_{e\text{-basin water}} = \frac{Ew - g}{[(\tau g \alpha b) \times Esun] - Ew}$$

$$= \frac{379.16}{485}$$

$$= 0.7519$$

$\eta_{e\text{-basin water}} = 75.19\%$

$$\eta_{e\text{-glass cover}} = \frac{(he - w - g) \times (Tw - Tgi)}{(Ew - g) + (\alpha g \times Esun)}$$

$$= \frac{31.43 \times 9.2}{51.5}$$

$$= 0.5614$$

$\eta_{e\text{-glass cover}} = 56.14\%$

$$\eta_{e\text{-solar still}} = 1 - \frac{\text{exergy distruction or irreversibilies}}{Esun}$$

$$= 1 - \frac{160.5 + 106.84 + 303.016}{850}$$

$$= \frac{280}{850}$$

$$= 0.3294$$

$\eta_{e\text{-solar still}} = 32.94\%$

E. *Charts For Different Coating Material Of Passive Solar Still Are Shown As Following*
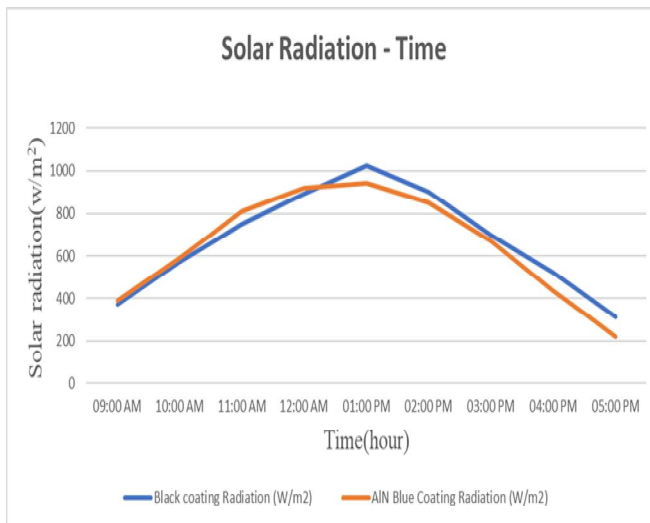

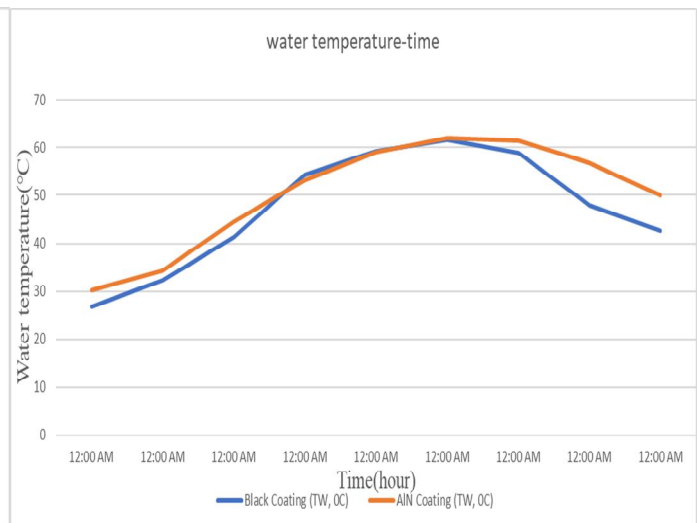Fig 8: Variation in Solar Radiation Vs Time
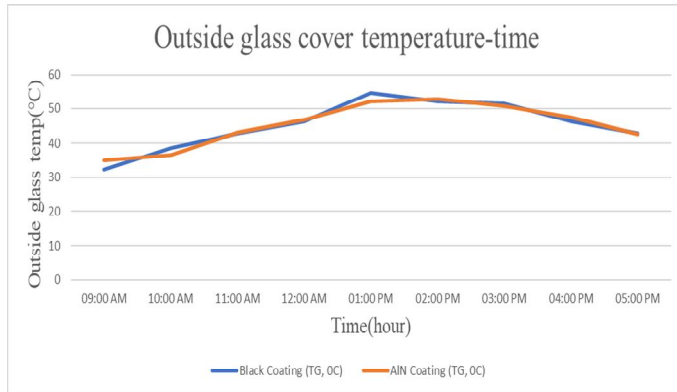
Fig 9:: Variation in Water Temperature Vs Time

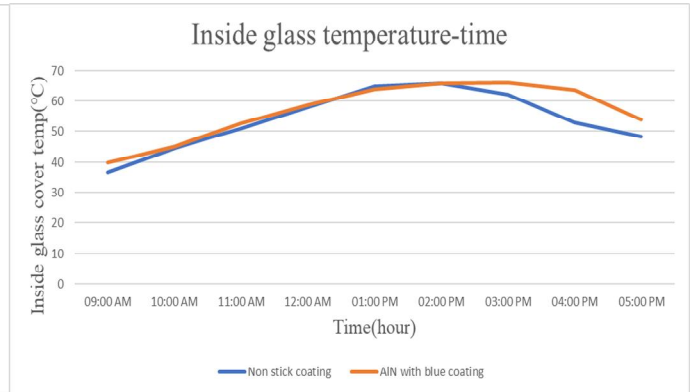Fig 10: Inside Glass Temperature Vs Time
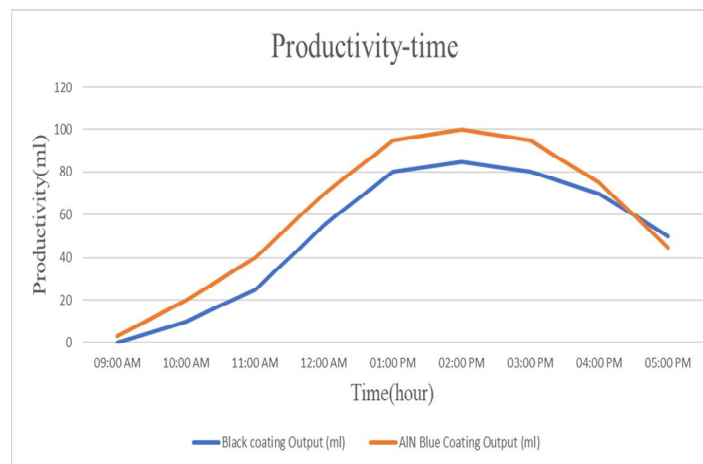

Fig 11: Outside Glass Cover Temperature Vs Time

Fig 12: Productivity Vs Time

VI. CONCLUSION

In this experiment, when the AlN (with antireflective blue) coating is used as absorbing plate then the temperature difference between outer and inner surface of condensing glass cover is increase compared to non-stick coating. at this time productivity of the solar still gradually increased. Maximum productivity of the solar still comes from 12:00 pm to 2:00 pm. In this experiment we got maximum productivity with AlN (with antireflective blue) coating on absorbing plate.

On the basis of the results, the following conclusions are drawn:

A. We got maximum productivity with AlN (with antireflective blue) coating on absorbing plate.
B. solar radiation is get maximum during 13:00-14:00 time period. Hence output also got maximum at this time.
C. water temperatures, inside glass covers temperatures, outside glass covers temperatures, output of passive solar still are goes higher for AlN (with blue antireflective) coating compare to simple black coating of absorbing plates.
D. Efficiency of solar still with AlN (with antireflective blue) coating on absorbing plate at 12pm got 31.75% (based on distillate output).
E. Efficiency of solar still with AlN (with antireflective blue) coating on absorbing plate at 12pm got 32.38% (based on temperature).
F. Efficiency of solar still with AlN (with antireflective blue) coating on absorbing plate at 12pm got 32.84% (based on energy destruction).
G. Energy loss through Basin-Liner, Saline water, Glass cover are 160.5 W/m^2, 106.834 W/m^2 and 303.01 W/m^2 respectively.
H. Energy efficiency of Basin-Liner, Saline water, Glass cover are 14.85%, 76%, 56.14% respectively.
I. The exergy efficiency of solar still is lower than the energy efficiency. (η_e=32.38%, η_{ex}=3.99%).

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