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Energy efficient Solar Water Still

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Abstract: An energy efficient solar still is developed with graphite filled silica gel as adsorbent of incident radiation. The still is maintained with a porous gel which absorbs large extent of incident radiation by internal reflections. The silica gel is made with sodium silicate by acidification. It is modified with graphite powder as a blackening and absorbing agent. Na_2SiO_3 content in the still is varied from 100 to 200 g while graphite was varied from 50 to 100 grams. The water in the still is varied from 6 to 10 litres. Optimal values of parameters were identified. The resulting still yielded a maximum efficiency of 49% against 30-35% in the case with no gel.
Key words: Solar still, Desalination; Solar energy, Solar stills, Solar still efficiency, graphite assisted solar still.

INTRODUCTION :

Industrial Growth has been associated with the contamination of ground as well as surface water streams resulting in the deprivation of fresh drinking water for masses of the country growing in alarming phase. Desalination is carried out by several ways. Most of the existing desalination plants use fossil fuel as a source of energy. Although a few techniques such as multi-effect evaporation, multistage flash distillation, thin film distillation, reverse osmosis, and electro dialysis, are energy intensive and operating costs are high, direct use of solar energy represents a promising option for eliminating the major operating cost required in each case. Solar distillation represents a most attractive and simple technique among other distillation processes and is especially suited to small and tiny units at locations where solar energy is considerably abundant. Design of a solar still requires optimization of many factors: brine depth, tight seal to prevent vapor leakage, thermal insulation, cover slope, shape and material of the still. In spite of several technologies found in this area, affordable and simple processes have not yet been evolved. Simple flat plate solar heater cum collectors has been developed in the earlier studies but finds little application in practice because of its lower energy fixing capacity. In the present work, it is envisaged to improve the absorption of heat from the incident radiation and to hold the energy for sufficiently longer period allowing the system for heat transfer with suitable material. It is also aimed at the development of a collector with suitable heat exchanger. Present work deals with the development of solar collector with good heat absorption and retaining capacity. Presently it is proposed to develop collector with good energy collecting capacity accompanied. The cellular material could be developed in the prototype inorganic gel systems. Later it may be extended to the solid and colloidal systems. Solar distillation represents a most attractive and simple technique among other distillation processes and is especially suited to small-scale units at locations where solar energy is ubiquitous.

LITERATURE:

Mona M. Naim et al [1] constructed a solar still with low thermal capacity, lightweight and ease of operation in which charcoal functions both as heat absorber medium and as wick. The still they worked with presents a 15% improvement in productivity over wick-type stills. It is made of plastic outer rectangular body in which salt water is allowed to percolate through a charcoal bed of particles that extends the length of the penetration of the incident radiation. Still, and above which a glass plate is made to cover the still at an optimum distance from the charcoal bed. Factors such as size range of charcoal particles, brine flow rate, and still inclination to the horizontal have been investigated Mona M. Naim [2] developed a novel continuous single-stage solar still that makes use of a phase change energy storage mixture (PCESM) for promoting energy usage has been devised and constructed. The optimum PCESM was precisely an emulsion of paraffin wax, paraffin oil and water in a specific ratio to which aluminium turnings were added to assist in heat transfer by conduction. Factors such as concentration and flow rate of saline water, type of energy storage material and inlet water temperature were investigated for their effect on the still productivity. Results indicated that the use of an energy storage material led to a larger productivity of distilled water and that the larger the concentration of the saline water the lower the productivity of the still. Also higher flow rate and high inlet saline water temperature improved the still efficiency. The maximum productivity of the still was 4.536 L/m^2 in 6 h daytime operation plus overnight distillation due to stored energy., when the saline water flow rate was 40 ml/min, equivalent to a still efficiency of 36.2percent. Salah Abdullah, et al [3] used different types of absorbing materials to examine their effect on the yield of solar stills. These absorbing materials are of two types: coated and uncoated porous media (called metallic wiry sponges) and black volcanic rocks. The results showed that the uncoated sponge has the highest water collection during day time, followed by the black rocks and then coated metallic wiry sponges. The overall average gain in the collected distilled water taking into the consideration the overnight water collections were 28%, 43% and 60% for coated and uncoated metallic wiry sponges and black rocks respectively. El-Sebaii A. A, et al [4] presented transient mathematical models are for an active single basin solar still (ASS) with and without a sensible storage material under the basin liner of the still. Sand is used as a storage material. The flowing water temperature is assumed to vary with time and space coordinates. Analytical expressions are obtained for various temperatures of the still elements as well as for the temperature of sand. The performance of the still with and without storage is investigated by computer simulation using the climatic conditions of Jeddah (lat. 21° 42′ N, long. 39° 11′ E), Saudi Arabia. Effects of mass flow rate and thickness of the flowing water for different masses of the storage material on the daylight Pdl, overnight Pon and daily productivity Pd and efficiency ηd of the still are studied. The dependence of Pd and ηd on the thickness and thermal conductivity of the basin liner material is also investigated. It is found that Pd and ηd decrease as the mass of the storage material increases, due to the increased heat capacity of the storage material. Furthermore, Pd and ηd are found to decrease with increasing thermal conductivity of the basin linear material. Therefore, it is advisable to fabricate basin liners of ASS from cheap insulating materials such as glass and mica with an optimum thickness of 3 mm. On a summer day, a value of Pd of 4.005 (kg/m2 day) with a daily efficiency of 37.8% has been obtained using 10 kg of sand compared to 2.852 (kg/m2 day) with a daily efficiency of 27% when the still is used without storage. The annual average of daily productivity of the still with storage is found to be 23.8% higher than that when it is used without storage. Kalidasa Murugavel K., et al [5] carried out their work on a double slope single basin passive type still with basin area of 1.75 m2 and tested under laboratory conditions for a thin layer of water in the basin. Performance of the still is compared by using wick materials like light cotton cloth, light jute cloth and sponge sheet of 2 mm thickness and porous materials like washed natural rock of average size 3/8" × 1/4" and quartzite rock of average size 3/8" as spread materials. The actual solar radiation condition is simulated by 2 kW electrical resistance heater placed below the inner basin. The results showed that the still with black light cotton cloth as spread material is found to be more productive. Mukherjee, K., and , G.N. Tiwari [6] made a cost analysis on solar stills. Cost analyses of three types of solar stills, viz. a single-slope fibre-reinforced plastic (FRP) still, a double-slope FRP still and a double-slope concrete still, have been presented. The model for the economic analysis is the same for all three. The cost of producing distilled water has been calculated and is favourable compared to that for other stills. It was found that the minimum cost of distilled water produced from a conventional still is Indian rupees 13 /- approximately. Eduardo Rubio et al [7] proposed a new lumped parameters mathematical model to study the asymmetries that arise in the temperature and distillate yield in double slope solar stills. The condenser is studied as a two-element system and non-simplified equations for heat transfer and optical transmission characteristics are used. The model is tested for the case with the strongest thermal differences and validated with experimental data. Overall results show a good correlation between predictions and experimentation. Sampath Kumar A, et al [8] gave a detailed review of different studies on active solar distillation system over the years. Thermal modeling was done for various types of active single slope solar distillation system. This review would also throw light on the scope for further research and recommendations in active solar distillation system. Yadav Y.P [9] showed that a single basin solar still coupled to a flat plate solar collector using a thermo siphon mode of operation. To assess the quantitative performance of the system, numerical calculations have been carried out for a typical day in Delhi. So as to make a performance based-choice, the proposed system has been compared with that operated using a forced circulation mode. It is observed that the system with the forced circulation mode of operation performs slightly better than the system operating using the thermo siphon mode. Badran O.O, and H.A. Al-Tahaineh [10] studied the effect of coupling a flat plate solar collector on the productivity of solar stills. Other different parameters (i.e. water depth, direction of still, solar radiation) to enhance the productivity were also studied. Single slope solar still with mirrors fixed to its interior sides was coupled with a flat plate collector. It has been found that coupling of a solar collector with a still has increased the productivity by 36%. Also the increase of water depth has decreased the productivity, while the still productivity is found to be proportional to the solar radiation intensity.

EXPERIMENTATION:

Galvanized iron sheet of 0.8 mm thickness was taken and shaped into rectangular tray of dimensions 60x50x6 cm with appropriate tapering [2^0]. A semicircular channel is made and attached around the tray. The inner surface of the tray is coated with black paint. A provision is made for inlet and outlet. A slot for insertion of thermometer for the measurement of temperature is provided on the tray. Proper arrangement is made for the collection of the distillate. Entire surface of the tray is insulated with thermocol. A frame made out of thin iron rods with 65^0 inclinations is fixed over the tray and is covered with a Polythene sheet of thickness 0.2 mm. It tightly sealed and made ready for further experimentation.

Water containing salts and impurities is introduced into the still through the inlet. A mixture of sodium silicate, hydrochloric acid and graphite powder of -200 mesh size is also introduced into the still. The still is now kept in the sunlight. The temperature of the bath in the still is noted at regular intervals of time. At the end of the experiment the amount of distillate collected and the amount of water left out are recorded. The data of incident radiation is obtained from meteorological department of Visakhapatnam. The efficiency of the still is calculated as follows

$\acute{\eta} = Q_{absorbed} / Q_{incidental,}$ Where

$Q_{incidental}$ = quantity of energy incident on the tray is calculated for the present tray area

$Q_{absorbed} = mL$, quantity of energy absorbed in the tray and is calculated for the present tray area for steady state collection.

$Q_{absorbed} = m\,C_p(T-T_0)$ quantity of energy absorbed in the tray and is calculated for the present tray area for unsteady state collection.
The amount of water evaporated during unsteady state is neglected in the present calculation.

RESULTS AND DISCUSSION:

Four variables were investigated for their effect on the productivity of the still, namely amount of silicate, amount of acid, amount of graphite powder and water depth. Na_2SiO_3 is varied from 100 to 200 g. Hydrochloric acid is varied from 100 to 200 g, while graphite is varied from 50 to 100 g. The water in the still is varied from 6 to 10 lit. The variables varied were tabulated as shown in the table – 1.

The results obtained consisted of temperature raise versus time and the quantity of heat absorbed is calculated as mentioned above. Results indicated that the use of an energy storage material led to a larger productivity of distilled water .The maximum productivity of the still was 1.6 L/m^2 in 6 h daytime operation plus overnight distillation due to stored energy, equivalent to a still efficiency of 49%. Graphs are drawn for heat absorbed versus time of the day and shown as fig.1A to fig.1D. It reveals the heat absorption increased followed by a constant region.

Table 1:

S.no	silicate, g	acid ml	graphite g	water taken ml	initial temp 0C	final temp 0C	water collected ml
1	100	100	50	6000	28	50.6	320
2	150	100	50	6000	28	53.5	355
3	200	100	50	6000	30	54.6	335
4	150	50	50	6000	29	52.1	275
5	150	150	50	6000	28	48.4	320
6	150	200	50	6000	29	51.1	295
7	150	100	50	8000	28	49.9	260
8	150	100	50	10000	28	48.5	250
9	150	100	75	6000	28	51.2	300
10	150	100	100	6000	28	51.5	315

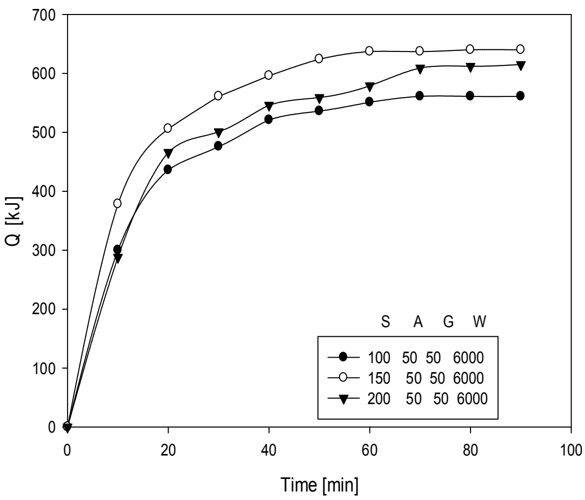

Fig1A Quantity of heat aborbed with time- effect of silicate

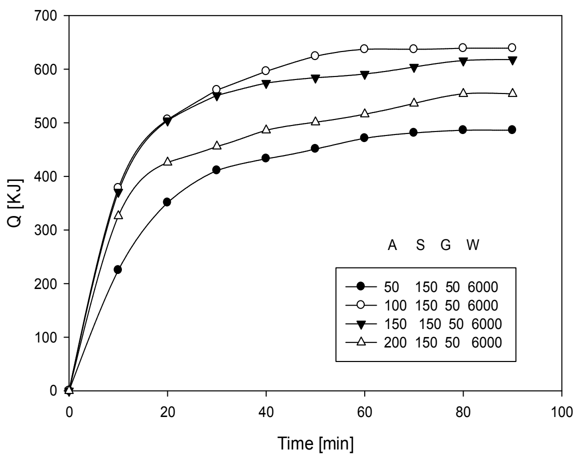

Fig1B Quantity of heat aborbed with time- effect of acid

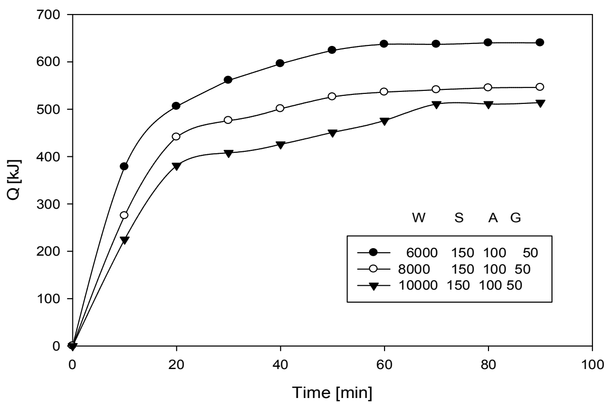

Fig1C Quantity of heat aborbed with time- effect of silicate

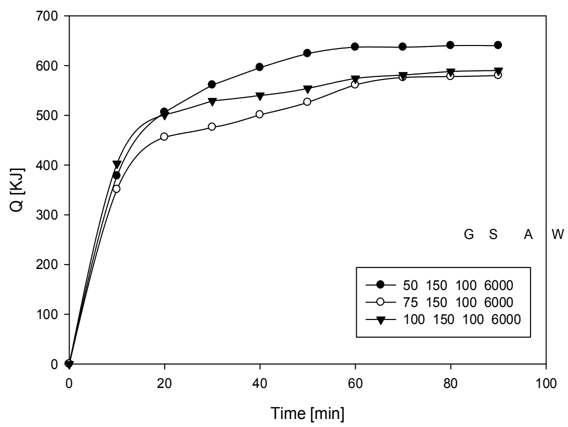

Fig1D Quantity of heat aborbed with time- effect of graphite

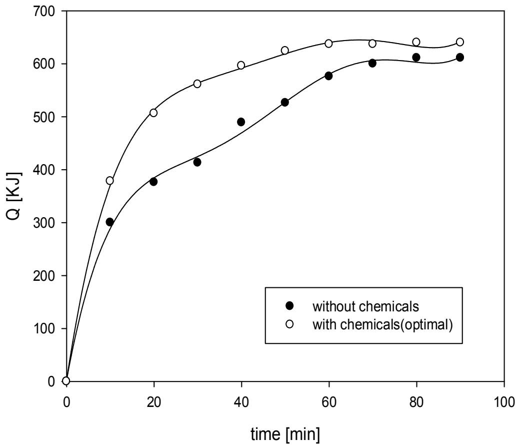

Fig -1E. Comparision of Q vs t with and without chemicals

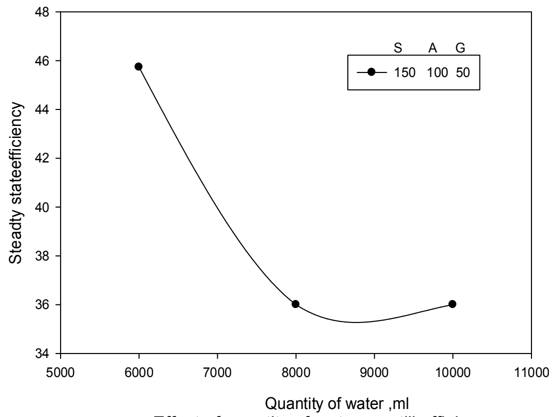

Fig.2. Effect of quantity of water on still efficiency

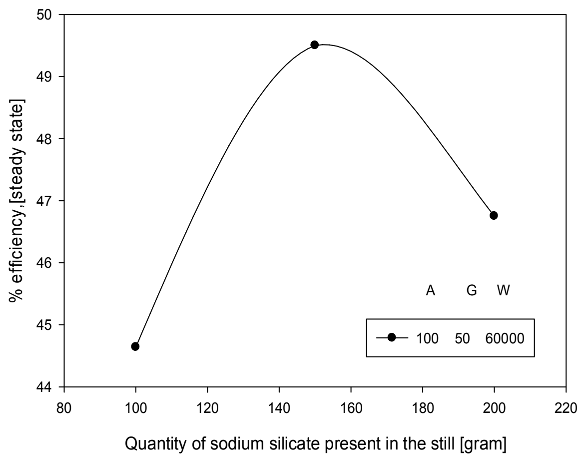

Fig.3. Effect of sodium silicate on still efficiency

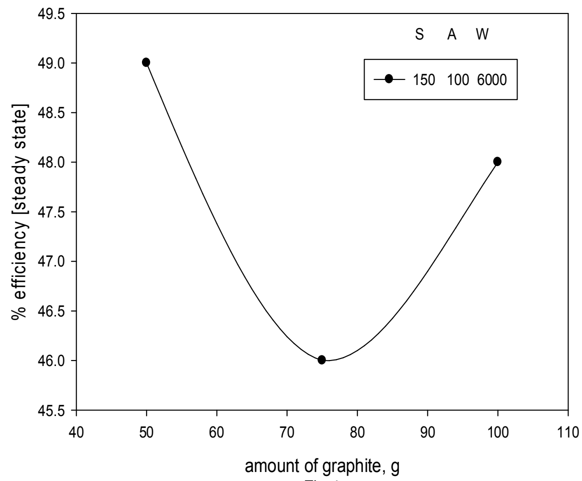

Fig.4

EFFECT OF QUANTITY OF WATER

Depth of the water plays as imported role in the collection. A graph is drawn as percent collection efficiency versus quantity of water present in the still and shown in figure- 2. The efficiency is decreasing to minimum with increase in quantity of water and remained constant with further increase.

EFFECT OF SODIUM SILICATE GEL

A graph is drawn as efficiency versus and quantity of graphite used is shown as figure 3. The figure reveals the following information. The solar still maintained with gel by adding acidified sodium silicate together with graphite as suspension to form the gel. Graphite powder served as a blackening agent and also reduces the heat capacity of the gel which in turn helps in the elevation of temperature. The raised temperature enhances the evaporation and hence the water collected. The quantities of water, graphite and acid are fixed as shown in the figure 3 while sodium silicate quantity is increased. The increase in silicate increased the efficiency of collection to a maximum followed by a decrease. It indicates better gel formation and dispersion. The peak efficiency is observed at 150 grams. In further experimentation, silicate quantity is maintained at 150g and other parameter were varied and their effects were investigated.

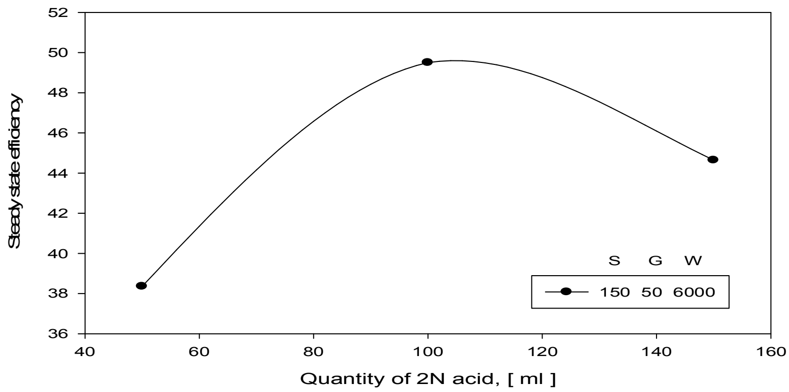

Fig. 5. Effecct of Acid on Still Efficiency

EFFECT OF GRAPHITE

Figure 4 indicate effect of graphite on efficiency. Graphite in the present investigation is varied and efficiencies were recorded. The result indicates larger amount of graphite recorded better efficiencies. The efficiency decreased to minimum with increase in quantity of the graphite and increased with further increase. 50g of graphite powder was considered as most suitable for the range of variables covered in the present study.

EFFECT OF ACID

Effect of acid on the efficiency could observe from figure 5. When acid acts on sodium silicate a silica gel is formed. The formation of the gel depends on the quantity of acid added to the still. 2N acid was used in the present study. As the quantity of acid was increased efficiency rose to a maxima followed by a decline. The peak value is obtained at 100 ml of 2N Hydrochloric acid. In further experimentation the quantity of HCl is maintained at this constant value.

CONCLUSIONS:

1. The still with gel achieved a maximum of 49% collection efficiency against the still without gel 36%.
2. 150g of sodium silicate, 100ml of 2N HCl, and 50g of graphite recorded peak performance.
3. The technology is highly useful in tropical countries like India where the demand for the fresh water is very high.
4. The technology is useful for the society and greater savings of energy could be achieved.

NOMENCLATURE:

A= weight of graphite (grams)
G= weight of sodium (grams)
L = latent heat of water, J Kg^{-1}
S= weight of sodium silicate (grams)
W=quantity of water (mL)
$Q_{incidental}$ = quantity of energy incident on the tray is calculated for the present tray area
$Q_{absorbed}$ = mL, quantity of energy absorbed in the tray and is calculated for the present tray area for steady state collection.
m = mass of water, kg
C_p= Specific heat of water, $Jmol^{-1}K^{-1}$
T = Temperature in K^{-1}
T_0 = initial Temperature in K^{-1}
ή = Efficiency ($Q_{absorbed}/Q_{incidental}$).

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