DESIGN AND FABRICATION OF SOLAR STILL TECHNOLOGY WITH ACRYLIC FIBER MATERIAL

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ABSTRACT

Shortage for potable water exists in many countries even though three fourth of the earth is sheltered by water. The reason behind this is the express growth of industry and inhabitants worldwide. Solar still is the only efficient solution for water problem in hot climatic conditional areas where there is scarceness of pure water and electrical energy. Solar still is a very simple solar device that is used for converting the available saline water into pure potable water. This work presents a new material acrylic sheet as basin to reduce the bottom heat losses. By using acrylic sheet as covering it reduces the loss of heat from the still to the bottom which leads to increase in the rate of evaporation of water. The daily water production from the this work using acrylic solar still is 60 Liters/ 25m^2 Area/ Day.

I. INTRODUCTION

About 98% of the earth's water is present as brine in oceans and the remaining 2% as fresh water in the form of ice, ground water, lakes, and rivers, which supply most human and animal needs. A lesser amount of fresh water is within human reach. Nature itself provides most of the required fresh water, through hydrological cycle. The vast population and rapid growth of industry lead a worldwide imbalance between supply and demand of fresh water. Most desalination plants such as reverse osmosis, membrane distillation, multistage and multiple effect distillation use fossil fuel as a source of energy and hence it will lead depletion of nature resources. The above mentioned treatment processes are available to supply clean potable water to rural and urban peoples. However, for the people living in isolated areas, no device is available at economical cost to supply drinking water. Solar distillation is a most attractive and simple technique among other treatment process. Swedish engineer C.Wilson designed the first conventional solar still for supplying fresh water to nitrate removal community in Northern Chile at the year of 1872. The operation of solar still is like to natural hydrological cycle that includes two processes, namely evaporation and condensation. A black painted basin filled by briny water or waste water. Crystal clear collector cover is enclosed in a completely air tight area. Transparent cover passes incident solar irradiance into the basin and it is absorbed by the basin plate. Consequently basin water gets heated up and evaporates in the saturated conditions inside the still and it killing all pathogenic microorganisms present in the basin water. Water vapors rises towards the inside surface of the collector cover, where they condense to unpolluted water, due to gravity water run down along the cover bottom surface, getting collected in a collecting bottle. The still is easy to fabricate and does not require any maintenance and skilled labors.

II. LITERATURE SURVEY

A detailed review of different parameters affecting the rate of evaporation and condensation on passive solar. A review was carried out by muthu manokar et.al. They suggested that use of low thermal conductivity material as basin and placed thermal storage material in the basin improves the still productivity because it does not easily allow the heat to the atmosphere [1]. Solar radiation that passes through the transparent cover is absorbed by saline water and the basin liner of a solar still. So, the basin liner acts as an absorber of solar radiation and it is important for the liner to have a relatively high absorptance for solar radiation [2]. In practical applications, basin liners can be made of plastic or metal-sheet [3]. Some plastics are relatively low-priced while others are costly [4]. Common metal sheets applied in solar collection are copper, aluminum and steel [5].

III.DESIGN AND WORKING OF SOLAR STILL

3.1 Working principle

A solar still operates using the basic principles of evaporation and condensation. The contaminated feed water goes into the still and the sun's rays penetrate a glass surface causing the water to heat up through the greenhouse effect and subsequently evaporate. When the water evaporates inside the still, it leaves all contaminants and microbes behind in the basin. The evaporated and now purified water condenses on the underside of the glass and runs into a collection trough and than into an enclosed container. In this process the salts and microbes that were in the original feed water are left behind. Additional water fed into the still flushes out concentrated waste from the basin to avoid excessive salt build-up from the evaporated salts.

A solar still effectively eliminates all waterborne pathogens, salts, and heavy metals. Solar still technologies bring immediate benefits to users by alleviating health problems associated with water-borne diseases. For solar stills users, there is a also a sense of satisfaction in having their own trusted and easy to use water treatment plant on-site.

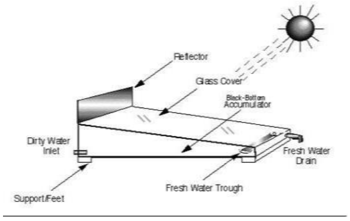

Figure.1. Working of Solar Still

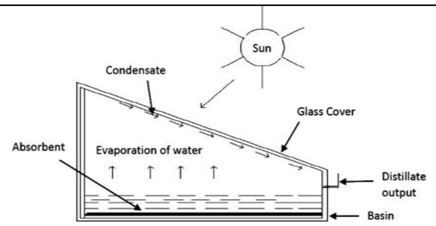

Figure.2. Concept Of Solar Still

3.2 Design objectives for an efficient solar still

For high efficiency the solar still should have high feed (un distilled) water temperature and a large temperature difference between feed water and condensing surface Low vapour leakage.

3.3 High Feed Water Temperature

A high proportion of incoming radiation is absorbed by the feed water as heat. Hence low absorption glazing and a good radiation absorbing surface are required heat losses from the floor and walls are kept low The water is shallow so there is not so much to heat.A large temperature difference can be achieved if the condensing surface absorbs little or none of the incoming radiation Condensing water dissipates heat which must be removed rapidly from the condensing surface by, for example, a second flow of water or air, or by condensing at night.

3.4 Design Considerations

Different designs of solar still have emerged. The single effect solar still is a Relatively simple device to construct and operate. However, the low productivity of the Solar still triggered the initiatives to look for ways to improve its productivity and Efficiency. These may be classified into passive and active methods. Passive methods include the use of dye or charcoal to increase the solar absorbtivity of water, applying good insulation, lowering the water depth in the basin to lower its thermal capacity, ensuring vapor tightness, using black gravel and rubber, using floating perforated black plate, and using reflective side walls. Active methods include the use of solar collector or waste heat to heat the basin water, the use of internal] and external condensers or applying vacuum inside the solar still to enhance the evaporation/condensation processes, and cooling the glass cover to increase the temperature difference between the glass and the water in the basin and hence increases the rate of evaporation.

Single-basin stills have been much studied and their behavior is well understood. The efficiency of solar stills which are well-constructed and maintained is about 50% although typical efficiencies can be 25%. Daily output as a function of solar irradiation is greatest in the early evening when the feed water is still hot but when outside temperatures are falling. At very high air temperatures such as over 45ºC, the plate can become too warm and condensation on it can become problematic, leading to loss of efficiency.

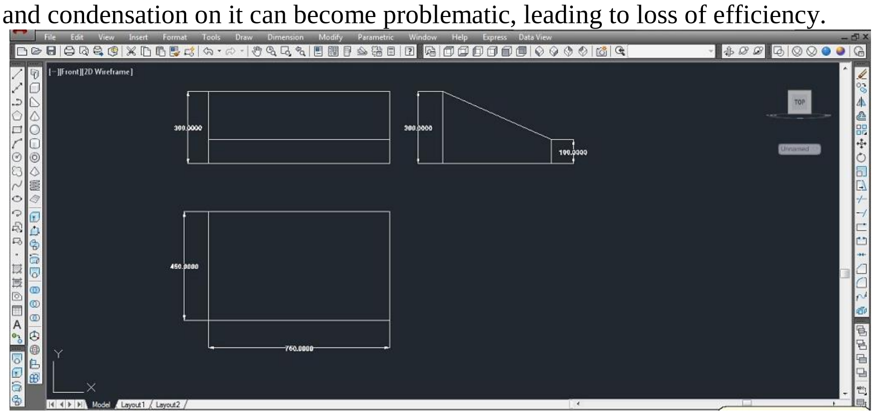

Figure.3. 2D-Drafting in Auto cad

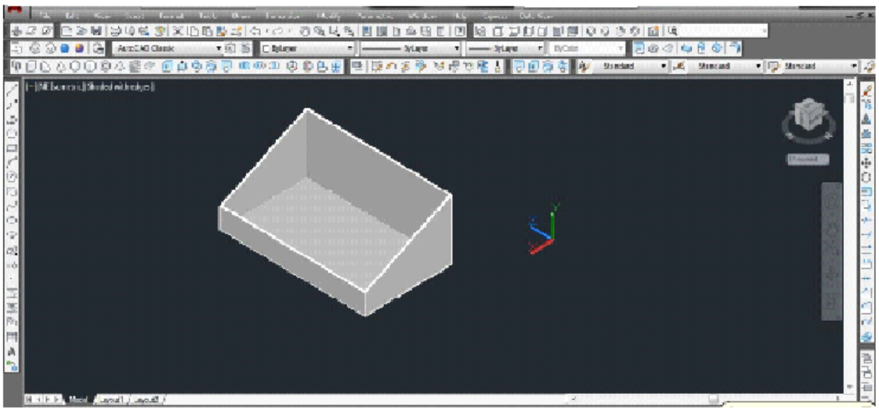

Figure. 4. 3-D drafting in Auto CAD

3.5 Heat Transfer Analysis

The equations governing the heat transfer rates are:-

a. Conduction

Q = - k A dT / dx

b. Convection

$Q = h A (T_{surface} - T_{ambient})$

Both the losses are greatly dependant on the area and temperature difference between the medium i.e., water and ambient. Hence if we can reduce temperature of the whole system we can reduce the heat loss and hence improve the efficiency. But reducing operating temperature will come at the cost of lower rated of evaporation and consequently lower rated of condensation leading to slower distillation. So now the problem boils down to increasing the rated of evaporation at lower temperature.(Mass loss rate) / (Unit area) = (Vapor Pressure - Ambient Partial Pressure) * sqrt ((Molecular Weight)/(2*pi*R*T));

The Vapor Pressure of a liquid at a given temperature is a characteristic property of that liquid. Vapor pressure of a liquid is intimately connected to boiling point. Vapor Pressures are influenced by Temperature logarithmically and this relationship is defined with the Clausius Clapyron Equation: Log P2 / P1 = Delta H vaporization [1 / T1 - 1/T2] / 2.303 (R),where: R = universal gas law constant = 8.31 J/mol-K = 8.31 X 10-3 Kj / mol-K P1 and P2 = vapor pressure at T1 and T2,T1 and T2 = Kelvin Temperature at the initial state and final state at 373K the pressure is 1 atm.

We all know that boiling takes place when the ambient temperature equals that of the vapor pressure of the liquid. This means that we can increase the rate of evaporation by reducing the pressure of the vessel. This will ensure higher rates of evaporation even at low temperatures.Constructing a solar water distiller using available utensils like plastic for casing, aluminum for absorption of heat, glass and the thermocol for insulation. Got the temperature of water up to 60 degrees and 100 ml of distilled water in 4 hours. Surface area is 12 sq.mt(1 sq feet)

3.6 Assembling and Manufacture

Fabrication of the whole unit is pretty straig ht forward and involves metal cutting, welding, glass cutting, sealing, painting and drilling. All these processes can be done at any local workshop using simple machines – lathe, drill, welding, milling etc.

The steps in the process of assembling are outlined as follows:

1. The outer box will be fabricated first. It will be made of double wall and will be filled with glass wool to provide insulation.
2. The stages will be fabricated second the collector holes will be made at the time of fabrication. Finally the stages will be assembled inside the outer covering.
3. The collector tubes are then made and attached to the lowermost stage.
4. The holes are provided for

a. Collecting distilled water

b. Transporting saline water

c. To attach the pump

5. The whole system is sealed using sealant to prevent the air from leaking in from the atmosphere.

3.7 Experiment set up and Procedure

The brackish or salt water is pour into the solar still through the inlet pipe of diameter of 20 mm and then closed by an air tight cap for maintained the solar still air tight so that the water vapour does not escape into the atmosphere. The solar still is placed such the inclined top glass cover is facing the south direction so that more amount of solar radiations go by into the solar still. Brackish water is filled into the solar still, after the sun raises, the solar radiations starts to enter into the solar still which leads to heating up of the aluminum fins and water. As aluminum has a thermal conductivity of 160 W/mk, it helps in conducting more amount of heat to the basin water which leads to the evaporation of water. This water vapour starts to condense on the bottom surface of the collector cover. This condensed water starts to slide down on the bottom surface of the glass due to the 30 inclination of the glass. This condensed water then gets collected in the collected bottle. This distilled water is collected in the beaker and then the amount of distilled water collected is measured. The thermocouples are placed to measure the temperature change at the fins, water, water vapour and glass bottom surface of the solar still and also ambient temperature with one hour interval. The solar still is made up of the following components acrylic box, aluminum fin, water collector and glass cover. Solid works software are used for component design in the part module and assembled in the assembled module and then exploded in the exploded view. The working of the solar still is that when the solar radiations from the sun enter inside the solar still through the glass cover of thickness 4 mm due to which the aluminum fin which has higher thermal conductivity gets heated and conducts heat to the basin water due to which basin water vaporizes into water vapor and then condenses on the collector cover and then gets collected in the water collector and passed into the measuring beaker through the outlet tube. The overall experimental set up of acrylic solar still.

Figure.5. Fabricated Solar Still With Acrylic Material

Figure.6. Top View fabricated Solar Still with Acrylic Material

Figure.7. Distillation Process in fabricated Solar Still with Acrylic material

Figure.8.Collection Of Distilled Water Process

3.8 MATERIALS

3.8.1 Acrylic Fibers

Acrylic is a plastic manufactured using one or more derivatives of acrylic acid. Polymethyl Methacrylate acrylic, or PMMA, is one of the more widely used forms of acrylic due to its exceptional weatherability, strength, clarity and versatility. There are a variety of acrylic polymer grades available for extrusion and injection molding manufacturing processes. Transparent, translucent opaque and colored polymers are available with varying levels of heat resistance, light transmissions, impact strength, flow rates and release capabilities. PMMA acrylic sheet exhibits glass-like qualities – clarity, brilliance, transparency, translucence – at half the weight with up to 10 times the impact resistance. It can be tinted or colored, mirrored or made opaque. A number of coatings can be applied to a sheet or finished part for performance enhancing characteristics such as scratch resistance, anti-fogging, glare reduction and solar reflectivity.Because it's thermoplastic and softens under extremely high temperatures, acrylic can be formed to virtually any shape. Incredibly durable, acrylic is a suitable solution for over a broad temperature range, and has superior weathering properties compared to other plastics.

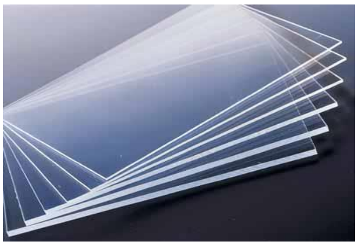

Figure.9. Acrylic Fibers

Figure.10. Aluminum metal sheet

Figure.11. Transparent Glass

3.8.2. Aluminum

Aluminium is remarkable for its low density and its ability to resist corrosion through the phenomenon of passivation. Aluminum metal, when in quantity, is very shiny and resembles silver because it preferentially absorbs far ultraviolet radiation while reflecting all visible light so it does not impart any color to reflected light, unlike the reflectance spectra of copper and gold. Another important characteristic of aluminium is its low density, 2.70 g/cm^3.Aluminium is a relatively soft, durable, lightweight, ductile, and malleable with appearance ranging from silvery to dull gray, depending on the surface roughness. It is nonmagnetic and does not easily ignite. A fresh film of aluminium serves as a good reflector (approximately 92%) of visible light and an excellent reflector (as much as 98%) of medium and far infrared radiation. The yield strength of pure aluminium is 7–11 MPa, while aluminium alloys have yield strengths ranging from 200 MPa to 600 MPa. Aluminium has about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded.Aluminium atoms are arranged in a face-centered cubic (FCC) structure. Aluminium has a stacking-fault energy of approximately 200 mJ/m^2.Aluminium is a good thermal and electrical conductor, having 59% the conductivity of copper, both thermal and electrical, while having only 30% of copper's density. Aluminium is capable of superconductivity, with a superconducting critical temperature of 1.2 kelvin and a critical magnetic field of about 100 gauss (10 milliteslas). Aluminium is the most common material for the fabrication of superconducting qubits.

3.8.3. Transparent Glass

Glass is a non-crystalline amorphous solid that is often transparent and has widespread practical, technological, and decorative usage in, for example, window panes, tableware, and optoelectronics. The most familiar, and historically the oldest, types of glass are "silicate glasses" based on the chemical compound silica (silicon dioxide, or quartz), the primary constituent of sand. The term glass, in popular usage, is often used to refer only to this type of material, which is familiar from use as window glass and in glass bottles. Of the many silica-based glasses that exist, ordinary glazing and container glass is formed from a specific type called soda-lime glass, composed of approximately 75% silicon dioxide (SiO_2), sodium oxide (Na_2O) from sodium carbonate (Na_2CO_3), calcium oxide, also called lime (CaO), and several minor additives.

RESULTS AND DISCUSSIONS

Solar still shows the variations of Aluminium fin temperature with respect to time. Aluminium fin stores the heat energy and it will be dissipated the temperature at the time of low solar radiation. It can heat the upper surface of water level and hence it will increase the evaporation rate. Solar still shows the variations of water temperature with respect to time. The maximum water temperature was 69°C around 12 P.M for simple solar still. The water temperature of the solar still mainly depends on the solar radiation. In finned acrylic solar still, aluminum fins gives excess temperature to water. Solar still shows the variation of productivity with respect to time. From the graph it is very clear that A large amount of distilled water is obtained between the time period of 12.00 PM to 2.00 PM as most of the solar radiations pass into the glass thus increasing the temperature of the aluminum fins which leads to the increase in the amount of heat conduction to the brackish water or salt water. A maximum of 80 ml of distilled water is obtained during the time period of 12.00 PM to 1.00 PM. It is clear that the amount of distilled water obtained depends mainly on the solar intensity and the material used for heat absorption purpose

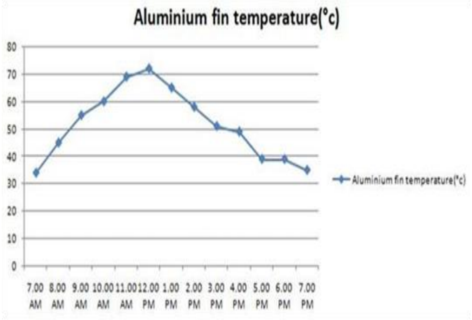

Figure.12. Variation of Aluminum Temperature with Time

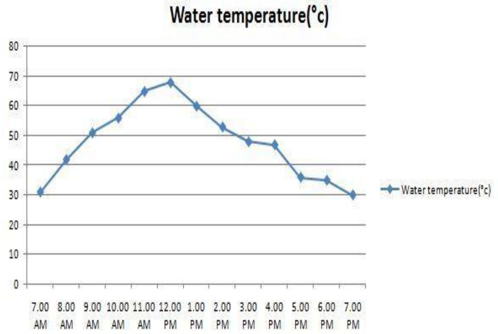

Figure.13. Variation of Water Temperature with Time

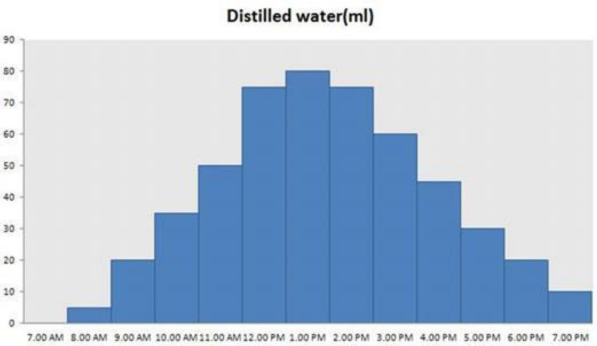

Figure.14. Variation of Productivity With Respect To Time

CONCLUSION

A new Acrylic solar still is designed, fabricated and tested in telangana climatic condition. An Aluminum fin is placed on the basin is used as surface heating technique to increase the evaporation rate. By using acrylic sheet as casing as it has very low thermal conductivity, it reduces the loss of heat from the still to the bottom which leads to increase in the rate of evaporation of water. The daily productivity of single basin single slope finned acrylic solar still is 60 Liters/ 25 m^2/ Day.

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