International Journal of Thermal Technologies
E-ISSN 2277 – 4114
Available at http://inpressco.com/category/ijtt/

Research Article

Fabrication of Single Slope Condensing Cover Coupled with Thermoelectric Refrigeration based Cooling Chamber

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Accepted 05 Feb 2016, Available online 01 March 2016, **Vol.6, No.1 (March 2016)**

Abstract

Looking around the world we will find a huge need of clean water as almost all the water bodies are polluted. In this paper we have studied the fabrication of condensing cover coupled with thermoelectric refrigeration based cooling chamber made of hindalium metal (alloy of Al, Mg, Mn, Si, Cr) to enhance the output of conventional single slope solar still. Peltier module is used for producing thermoelectric refrigeration, Constant temperature bath is used as water storage tank for condensing cover which help in maintaining the constant temperature of water. As results of this experiment it has been observed that the temperature decrease of 4⁰C is obtained at the condensing surface of the cooling chamber and temperature drop of 5⁰C is obtained at the bottom surface of the chamber where distillate is stored.

Keywords: *Single slope solar still, condensing cover, cooling chamber, peltiers, thermoelectric refrigeration, thermal insulation, distillate output*

Introduction

Most commonly used processes for purifying the impure water is desalination and distillation. Desalination, or desalinization is the processes that remove some amount of water and other minerals from saline water. More generally, desalination may also refer to the removal of salts and minerals, as in soil desalination, which also happens to be a major issue for agricultural production. Salt water is desalinated to produce fresh water suitable for human consumption or irrigation, Whereas, Distillation is a process of separating the component substances from a liquid mixture by selective evaporation and condensation. Distillation may result in essentially complete separation (nearly pure components), or it may be a partial separation that increases the concentration of selected components of the mixture.

Methods used for desalination are mostly: thermal distillation and membrane distillation. Further they are named as multistage flash distillation (MSF), multi effect distillation (MED), and vapor compression distillation (VCD), solar distillation but is used for very small production rates.

While methods used for distillation are most commonly: simple distillation, fractional distillation, vacuum distillation, short path distillation, and steam distillation. All the processes have different applications according to the production rates or purpose.

Present energy and water scenario of the world also shows the need of clean water by using some renewable source of energy. If we look around the energy deposits in the countries we will find that these are getting depleted day by day and as a result of which the need of use some renewable source of energy arises.

Renewable energy replaces conventional non-renewable sources of energy (fuels) in four distinct areas: electricity generation, air and water heating/cooling, motor fuels, rural energy services. Wind energy, solar energy, tidal energy, geo- thermal energy, are some common examples of renewable source of energy.

Table 1 Table showing %age of water and population shared by top 7 countries

S. No.	Country	%age of Water	% share of population to total world population
1.	Brazil	17	2.46
2.	Russia	11	2.12
3.	Canada	7	0.45
4.	China	7	18.52
5.	Indonesia	6	3.09
6.	U.S.A	6	3.99
7.	India	5	14.91

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As we know from the world records, that hardly 1% of fresh clean water in available in nature. Oil reservoirs will run out in next 70 years and natural gas reservoirs will run out in next 35 years. Looking onto this data we have to switch to some other energy sources for our energy need. Here solar energy can be used for cleaning the saline water.

Use of solar still is very simple way for desalinating water, in a solar still, impure water is contained in the container, where it is heated by solar radiations and gets evaporated. The pure water vapour condenses on the cool inclined surface (glass) and drips down from the weighted low point, where it is collected and removed. As the water evaporates, water vapour rises to the condensing glass surface for collection. This process removes impurities, such as salts and heavy metals, and eliminates microbiological organisms. The end result is water cleaner than the purest rainwater.

Solar still is a very simple solar device used for converting the available brackish or waste water into the potable (useful) water. This device can be fabricated easily with available materials. The maintenance is also cheap and no skilled labour is required to make it. This device can be suitable solution to solve drinking water problem.

It is an air tight basin, usually constructed out of concrete/cement, galvanized iron sheet or fiber reinforced plastic (FRP) with top cover of transparent material like glass, plastic etc. the inner surface of the rectangular base is blackened to efficiently absorb the solar radiation incident at the surface. There is a provision to collect the distillate at lower end of the glass cover. The brackish or saline water is fed into the basin for purification. Solar radiation that passes through the transparent roof heats water in the basin, thus evaporating water which gets condensed on the cooler underside of the glass and gets collected in collector as distillate attached to glass.

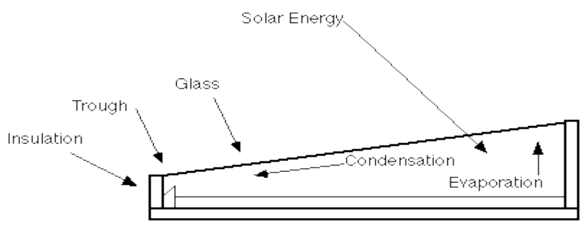


Fig.1 Single slope solar still

For further improvement various designs of solar still is fabricated to enhance output (distillate water). They are as follows: Pyramidal solar still, Spherical solar still, Hemi-spherical solar still, Double basin solar still, Tubular solar still.

The amount of distillate water from a solar still depends on different parameters. The evaporative surface area and glass cover temperature are the most effective parameters. Increasing the surface area or decreasing the cover temperature will enhance the distillate output. The factors that basically effect the performance of solar still are discussed below:

i. Brine (saltwater) mean temperature.
ii. Glass cover temperature.
iii. Distillate output in slight glass
iv. Total solar radiation intensity.
v. Ambient air temperature.
vi. Wind speed.
vii. Thermal interfaces

Meaning of refrigeration is the production of cold confinement relative to its surroundings. In this, temperature of the space under consideration is maintained at a temperature lower than the surrounding atmosphere. To achieve this, the mechanical (thermoelectric) device extracts heat from the space that has to be maintained at a lower temperature and rejects it to the surrounding atmosphere that is at a relatively higher temperature. Since the volume of the space which has to be maintained at a lower temperature is always much lower than the environment, the space under consideration experiences relatively higher change in temperature than the environment where it is rejected.

Refrigeration can be produced by the following four processes: Vapour compression refrigeration cycle, Vapour absorption refrigeration cycle, Thermoelectric Refrigeration, Magnetic Refrigeration.

Refrigeration has found its thousands of application some of which are as follows: Foodstuff conservation, Air conditioning, Ice Production, Refrigerated containers, etc.

Thermoelectric refrigerator sometimes called a thermoelectric cooler module or Peltier cooler is a semi-conductor based electric component that functions as a small heat pump. By applying a low voltage direct current (DC) power source to a thermoelectric cooler module, heat will be moved through the module from one side to the other. One module face, therefore, will be cooled while the opposite face simultaneously is heated. In a mechanical refrigeration unit, a compressor raises the pressure of a refrigerant and circulates the refrigerant through the system. In the refrigerated chamber, the refrigerant boils and in the process of changing to a vapour, the refrigerant absorbs heat causing the chamber to become cold. The heat absorbed in the chamber is moved to the condenser where it is transferred to the environment from the condensing refrigerant. In a thermoelectric cooling system, a doped semi-conductor material essentially takes the place of the refrigerant, the condenser is replaced by a finned heat sink, and the compressor is replaced by a Direct Current (DC) power source. The application of Direct Current (DC) power to the thermoelectric cooler modules causes electrons to move through the semi-conductor material. At the cold end of the semi-conductor material, heat is absorbed by the electron movement, moved through the material, and expelled at the hot end. Since the hot end of the material is physically attached to a heat sink, the heat is passed from the material to the heat sink and then in turn, transferred to the environment.

Materials and Methods

Materials

The materials which are being used for fabricating the system are as follows:

I. Hindalium metal: Hindalium metal is an alloy of aluminium, manganese, chromium, magnesium and silicon. Cooling chamber of hindalium metal is fabricated for collecting the condensed water from the top glass cover of still. Because of its quick heating and cooling property hindalium is used.

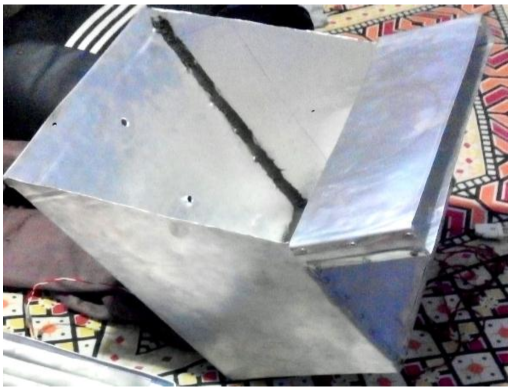


Fig.2 Hindalium alloy cooling chamber

II. Peltier Module: Peltier is a thermoelectric device which works especially on DC supply, 3 peltiers of 12V and 92Watts respectively are used for cooling the cooling chamber (i.e. maintaining cooling chamber at lower temperature). Which is being run on AC supply, by designing the circuit which will convert AC supply to DC supply to run the Peltier. Cold side of the peltier is pasted on the walls of cooling chamber by using thermal paste wile hot side is pasted to the heat sink which will sink the generated heat to the environment.

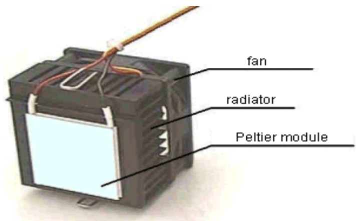


Fig.3 Peltier Module

III. Silicon Gel: Silicone gel sealant is used so as to hold the walls of the condensing cover, and as a sealant so that no leakage of water vapours could take place. Because of following reasons silicon gel is used: Silicon gel is clean and non sticky as compared to clay mud, is is uneffected of water, long lasting, easy application and removal of gel.

IV. Laminated Glass/Safety Glass: A typical laminated glass/safety glass is made up of 2.5 mm glass / 0.38 mm interlayer / 2.5 mm glass. This gives a final product that would be referred to as 5.38mm laminated glass or safety glass. The interlayer is made up of polyvinyl butyral (PVB) or Ethylene-vinyl acetate (EVA), between its two or more layers of glass. The reason why laminated glass is used is because of its lower thermal conductivity as compared to simple window glass.

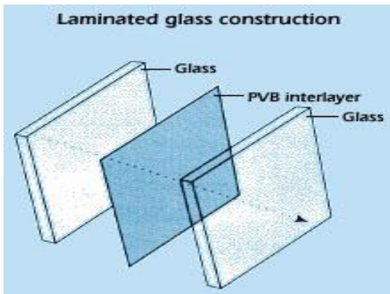


Fig.4 Laminated Glass or safety glass

V. Window Glass Channel: Small strips of window glass of thickness 2mm is used as collectors/channels to collect water droplets or output water from the glass walls of still and direct it to cooling chamber.

VI. M-Seal & Clay: Some other sealants are used for some other purpose like M-seal is used to prevent the leakage in metal, while clay is used to hold the holding condensing cover on 'constant temperature bath' and for packing purpose at different locations.

VII. Insulation Foam: Insulation of ½ inch in thickness is provided to the cooling chamber so as to prevent the heat loss. Some adhesive is used to stick the insulation foam to the cooling chamber walls.

Methods

I. Desalination: The process of removal of salt from the water.

II. Distillation: Distillation is a process of separating the component substances from a liquid mixture by selective evaporation and condensation.

III. Condensation: Condensation is the process by which water vapour in the air is changed into liquid water.

IV. Thermoelectric Effect: When two dissimilar metals are joined together with some semi-conductor sandwiched between, and when electric current passes through these plates and temperature difference is established, i.e. one side becomes cold one side becomes hot. This effect is known as thermoelectric effect.

Methodology

In this design we have fabricated a condensing cover with length 465mm, width 360mm, higher height 380mm, lower height 60mm, made of laminated glass (safety glass), and a hindalium alloy cooling chamber (Hindalium = alloy of Aluminum, Magnesium, Manganese, Chromium and Silicon). Condensing cover is mounted on the "constant temperature bath" for indoor simulation and cooling chamber is based on thermoelectric refrigeration proces. Cooling chamber is fabricated with hindalium alloy having length 200mm, width 330mm, higher height 380mm, lower height 200mm, water storage of capacity of 13.2 liters (tank measured till lower height i.e. 200mm). We used Peltier module for producing thermoelectric refrigeration; specification of thermoelectric peltier cooler is 12V and 92.6Watts. 3 thermoelectric peltier coolers are used of same specification with heat sink to dissipate heat from peltier's hot side. Peltiers works on DC supply, so an electric circuit is designed to convert AC supply to DC supply. Electric circuit is consisting of an 18Watt transformer, diodes, resistors, capacitors, LED's, switches, etc. This circuit enabled us to run thermoelectric peltier cooler with AC supply. Thermocouples and electrical temperature indicators were used to measure temperature at various points in the setup. Example: temperature at glass cover, temperature at water surface, etc. Insulation is being provided to insulate cooling chamber by using insulating foam.

Fig.5 Experimental Setup of Fabricated Model

Now in the beginning we added water in constant temperature bath up to height of 21cm from base. Water is being heated in bath up to 65^0C by giving electric supply to constant temperature bath, after reaching 65^0, condensing cover is placed on the bath and desalination/distillation process starts. Water vapours starts rising up and begins to condense on the walls of the condensing cover and its top cover. The condensed water on walls and water vapours inside condensing cover starts moving to cooling chamber with the help of channels and opening passage in cooling chamber placed separately. Mean time peltiers are put to ON by giving AC electric supply which leads to maintain lower temperature inside the cooling chamber, which helped in increased condensation rate inside the cooling chamber. As a result water vapors are condensed in cooling chamber which leads in increased output with an advantage that the output we obtained is at lower temperature than in conventional solar still. As a result of this we can achieve cold water also which can be used for any required purpose. By using thermocouple we have achieve output distillate temperature as well as other temperature also. Output cold water is measured in beaker, which tells us about the performance of condensing cover without coupling with cooling chamber and performance with cooling chamber coupled. By using no peltier, 1 peltier, 2 peltiers, 3 peltiers in working, performances are being measured on the basis of which further results and discussions are given.

Technical specifications of Experimental setup

Various parts and equipments are used in the work. Their technical specifications are as follows:

1. Transformer 230V-12V output.
2. Peltier 92.6 watts, 12V voltage, 3.8 amp current
3. Capacitors 4700µF, 50WV
4. Diodes 5804
5. Red-Green LED's
6. ON-OFF Switches
8. 1 KΩ Resistor
7. J-type Thermocouple (0-400^0C)
8. No. of Fins = 7
9. Constant temperature bath ranges up to 110^0C
10. Heat Sink cooler fan: Rated voltage: 12VDC, Operating voltage: 10.8V-13.2VDC, Fan speed: 3200RPM+/-10 percent
11. Voltage across the thermocouple = 0.45V

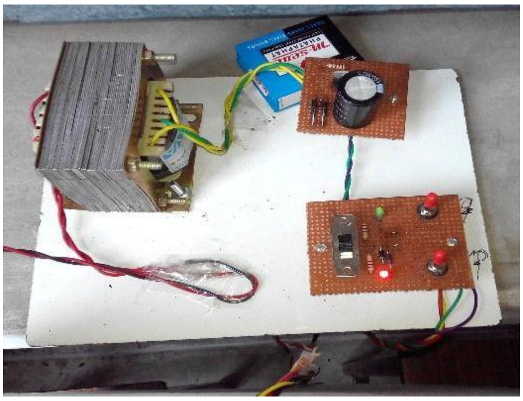


Fig.7 Controller circuit for Peltier Module

Detailed dimension of Experimental Setup

Table 2 Detailed dimensions of Condensing cover

S. No.	Parameters	Dimensions at 35^0 in mm
1.	Length	465
2.	Width	360
3.	Lower height	60
4.	Higher height	380

Detailed views of Fabricated Setup

Condensing cover

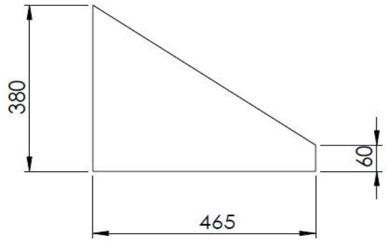


Fig.6 Front View of condensing cover

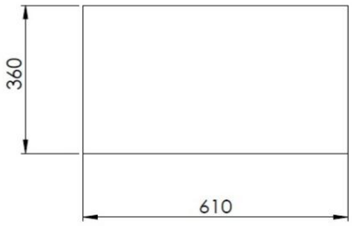


Fig.8 Top view of condensing cover

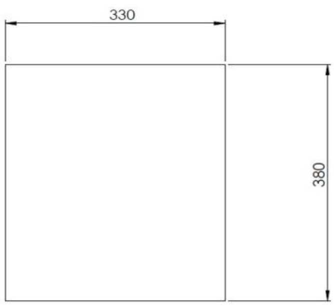


Fig.9 Side view of Condensing cover

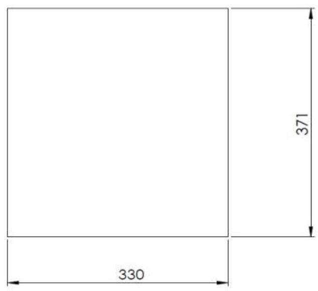


Fig.10 Side view of still (Inner glass wall of condensing cover)

Cooling Chamber

Table 3 Detailed dimensions of Cooling Chamber

S. No.	Parameters	Dimensions at 350 in mm
1.	Length	200
2.	Width	330
3.	Lower height	200
4.	Higher height	375

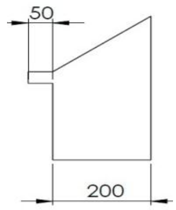


Fig.11 Front view of cooling chamber

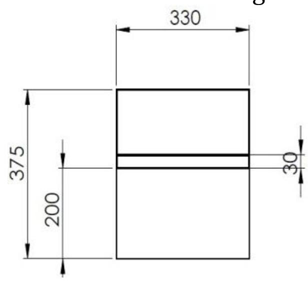
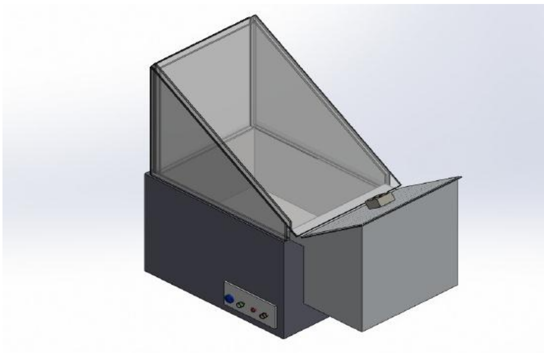
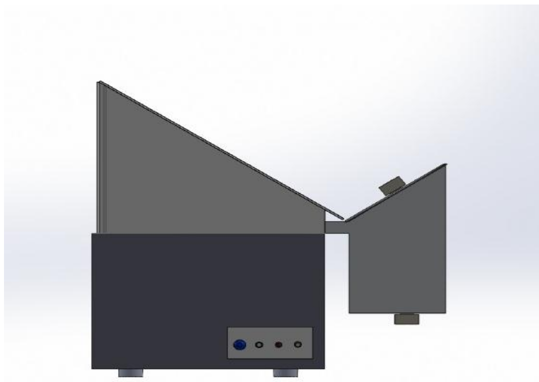


Fig.12 Side View of cooling chamber

Assembled view of fabricated setup (using solid works 2010)





Conclusions

The following conclusions were made from the above fabricated model:

1. A condensing cover was fabricated using laminated glass, Window glass, silicone gel sealant, clay.
2. A cooling chamber was fabricated using Hindalium alloy sheet, M-seal, and 3 Peltier 92.6 watts, 12V voltage, 3.8 amp current and Heat Sink cooler fan: Rated voltage:12VDC, Operating voltage: 10.8V-13.2VDC, Fan speed: 3200RPM+/-10 percent.

3. Temperature drop of 4^0C is obtained in cooling chamber running at 3 peltiers.

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