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Design, Fabrication and Performance Analysis of Direct Contact Membrane Type Distillation System Integrated With Solar Flat Plate Collector

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ABSTRACT

Passive solar distillation system by itself gives very slow yield. The best way of improving the performance of solar distillation system is by increasing the water temperature. A large number of works have been carried out on the design and performance improvement of distillation. This paper gives direction to improve the performance of solar distillation using a flat plate collector. And also presents design, fabrication and performance analysis of direct contact membrane type distillation system integrated with solar collector. The experiments were carried out for five days in the month of May. In order to verify the designed model and results, an experiment was designed and conducted for days in ambient conditions, in specific flow rate and concentration. The comparison between the computed and measured results of the system showed a satisfactory convergence. The model is an appropriate for the verification of gain output ratio, solar collector efficiency, performance ratio etc.

Keywords: solar distillation system, flat plate collector, gain output ratio, solar collector efficiency, performance ratio

INTRODUCTION

Fresh water demands are increasing day by day because of industrialization, motorization and increased life standards of mankind. Naturally available fresh water reserves are not capable of meeting the fresh water demands because of their less availability. It has been estimated by United Nations Organization that by 2025, nearly 1800 million people around the globe will be under severe water scarcity. This situation can be tackled only if mankind finds some other ways to produce fresh water. Luckily, distillation technology developed long back resembling natural hydrological cycle has the capacity to tackle this problem but it consumes more energy and also has some negative impacts on environment.

Distillation is widely adopted in Middle East, Arab countries, North America, Asia, Europe, Africa, Central America, South America and Australia to meet their fresh water and process water demands. Nearly 10,000 tons of oil is required every year to produce 1000m^3/d of distilled water. The brine discharged from distillation plants has posed severe threats to marine aquatic life .The most common distillation plants are multi-stage flash (MSF), multi-effect distillation (MED), vapor compression (VC), reverse osmosis (RO) and electrodialysis (ED). A conventional desalination plant operated by fossil fuel has also contributed to green house gas (GHG) emissions. This has forced researchers to look for alternate way of powering distillation units by renewable energy.

Renewable energy commonly considered for distillation are solar, wind and geothermal and among these solar energy occupies nearly 57% of renewable energy based distillation market. Fossil fuel rich countries like Middle East and Arab Nations have turned their attention towards solar energy with the aim to provide distillated water in a sustainable way. Renewable energy based distillation units are highly suitable for arid, semi- arid and remote regions where no other mode of

Power supply is possible. Most of the distillation systems require thermal and or electrical input that can be provided by solar energy and hence much focus has been given to solar based systems. The

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solar thermal collectors are very well developed and now attention has been paid towards solar PV cells to reduce its cost and increase its efficiency there by considerable reduction in water production cost could be achieved. The classification of solar distillation systems is shown in Figure. 1[1].

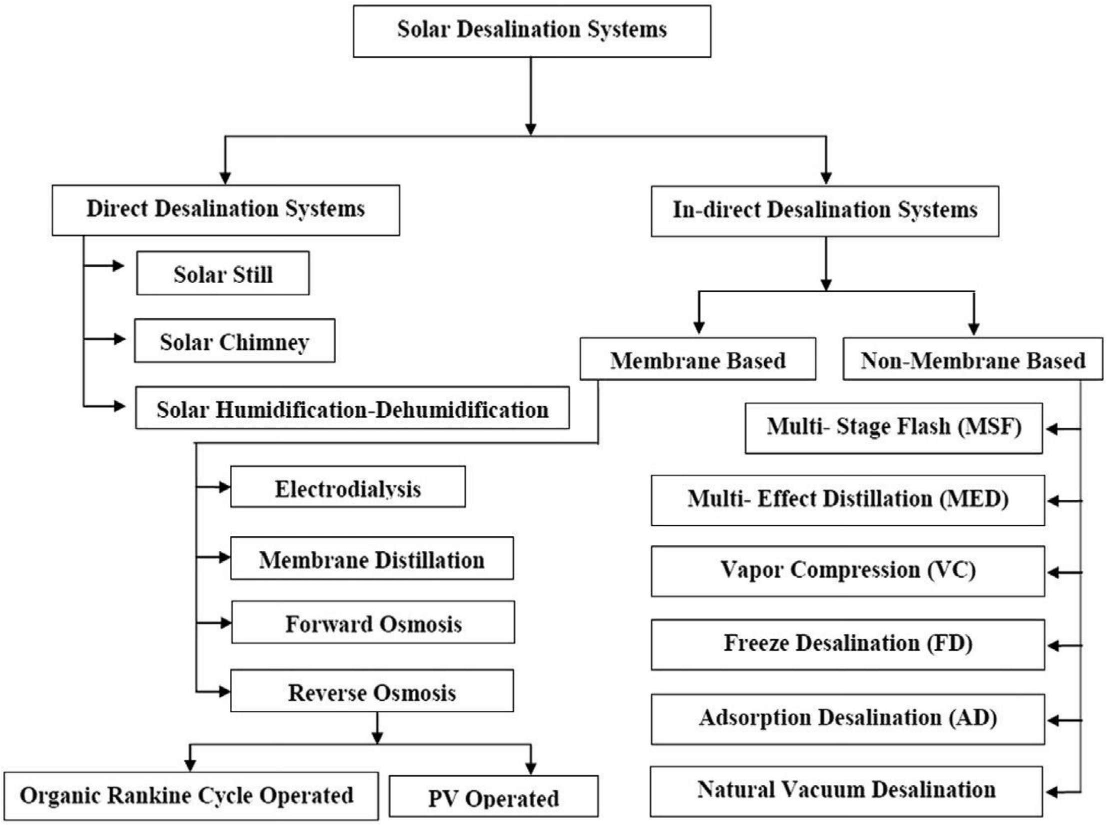

Figure1. *Classification of solar desalination systems*

The thermal desalination processes depend on the evaporation of water by the addition of heat provided by the sun or by combustion processes, this was one of mankind's earliest forms of water treatment is still a popular treatment solution. On the other hand, the development of modern polymeric materials in recent years has led to the production of membranes which allow the selective passage of water in liquid or vapor state or ions and thus providing the basis for membrane distillation processes. Among those membrane processes, RO is the leading commercial membrane distillation process which requires applying high pressure to overcome the osmotic pressure.

It is worth mentioning that both, thermal and RO are the leading distillation processes in the water market. However, those processes suffer from drawbacks and some technical difficulties which are: i) They are considered energy intensive either by the heat demand (i.e. thermal processes) or by the high pressure demand as in reverse osmosis process, this high energy consumption generates more pollutants and undesired emissions. ii) The scaling and fouling problem is one of the major challenges that adds to the complexity and cost of those processes. iii) The membrane cost and its durability in the membrane processes are still immature subjects that require more research and development[2].

These drawbacks affected the economic feasibility of those processes, which necessitates the search for alternative, environment friendly and sustainable desalination. Membrane distillation (MD) is a promising new comer to the desalination processes which can be coupled to low-grade and renewable energy source such as wind and solar energy. The developments in the use of renewable energy sources (RES) have demonstrated that it is ideally suited for distillation, when the demand of fresh water is not too large. The rapid escalation in the costs of fuels has made the RES alternative more attractive. In certain remote arid regions, this may be the only alternative. The interdependence of water and energy is increasingly evident due to their territorial, environmental and economic implications.

Innovations in the area of energy supply can improve the economic viability of prospective distillation plants considerably. Recently, considerable attention has been given to the use of renewable energy including solar, wind and geothermal as sources for distillation, especially in remote areas and islands, because of the high costs of fossil fuels. Solar energy can be used for seawater distillation either by producing the thermal energy required to drive the phase change processes or by producing the electricity required to drive the membrane processes.

It should be clarified that membrane distillation (MD) has not been yet commercialized for large-scale distillation plant in spite of its attractive features especially the possibility of coupling to low grade source of energy, this is due to the lower flux of MD and some technical problems such as the membrane wetting. However, much research has gone into developing new membranes for MD that overcomes those membrane design drawbacks.

Membrane Distillation (MD) has many applications.MD applications are such as fresh water production, heavy metal removal and food industry. Most of current MD applications are still in the laboratory or small scale pilot plant phase. Actually, there are some pilot plants that have been recently developed to produce fresh water[3].

BASIC PRINCIPLE OF MEMBRANE DISTILLATION

A Membrane distillation (MD) is a hybrid of thermal distillation and membrane processes. MD is a relatively new process that is being investigated worldwide as a low cost and energy saving alternative to conventional separation processes such as distillation and reverse osmosis. Membrane distillation (MD) process is not commercialized yet for large scale industry. The reason behind this is that MD process flux is lower than the commercialized separation processes. The principle of membrane distillation is illustrated in Figure. 2. Conventionally, membrane distillation (MD) is a thermally driven process in which a microporous membrane acts as a physical support separating a warm solution from a cooler chamber, which contains either a liquid or a gas. As the process is non-isothermal, vapor molecules (water vapor in the case of concentrating non-volatile solutes) migrate through the membrane pores from the high to the low vapor pressure side; that is, from the warmer to the cooler compartment[2].

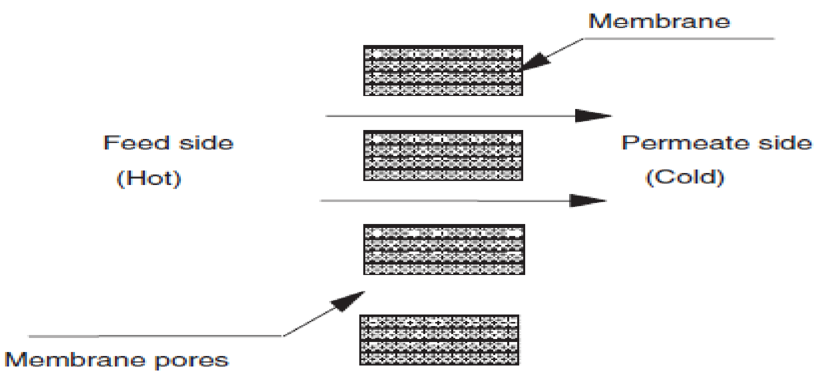

Figure2. *Principle of membrane distillation.*

Generally, the transport mechanism of MD can be summarized in the following steps:

- Evaporation of water at the warm feed side of the membrane.
- Migration of water vapor through the non-wetted pores.
- Condensation of water vapor transported at the permeate side of the membrane.

MEMBRANE DISTILLATION ADVANTAGES

All pars the benefits of membrane distillation compared to other more popular separation processes stem from:

- 100% (theoretical) rejection of ions, macromolecules, colloids, cells and other non- volatiles
- Lower operating temperatures than conventional distillation
- lower operating pressures than conventional pressure-driven membrane separation processes
- Reduced chemical interaction between membrane and process solution
- Less demanding membrane mechanical property requirements.
- Reduced vapor spaces compared to conventional distillation processes.

The last benefit is considered one of the amazing advantages of MD process, since the large vapor space required in conventional distillation column is replaced in MD by the pore volume of a micro porous membrane, which is generally of 100µm thick. Conventional distillation relies on high vapor velocities to provide intimate vapor-liquid contact while MD employs a hydrophobic micro porous membrane to support a vapor–liquid interface.

As a result, MD process equipment can be much smaller, which translates to saving in terms of footprint, and the required operating temperatures are much lower, because it is not necessary to heat the process liquids above their boiling points. Feed temperature in membrane distillation typically ranged from 60 to 90 °C, although temperature as low as 30 °C has been used. Therefore, low grade, waste and/or alternative energy sources such as solar and geothermal energy can be coupled with MD systems for a cost efficient, energy efficient liquid separation system.

Membrane Distillation Disadvantages

- Membrane wetting
- Fouling of desalination membranes
- Large membrane surface area is required because of low driving force
- Membranes are expensive

The main disadvantage of MD process is the drawback of membrane wetting. The wet ability of the micro porous membranes is a function of three main factors: the surface tension of the process solution, membrane material and the membrane structure. To overcome the membrane wetting: the process solution must be aqueous and sufficiently dilute. This limits MD for certain applications such as desalination, removal of trace volatile organic compounds from wastewater and concentration of ionic, colloids or other nonvolatile aqueous solution.

DESIGN AND FABRICATION OF THE DCMD INTEGRATED WITH A LIQUID FLAT PLATE COLLECTOR

The design features and fabrication of the direct contact membrane type distillation system integrated with a liquid flat plate collector is presented in this chapter.

Construction of the DCMD

The experimental setup, as shown in Figure.7, consists of a feed-water loop, a product water collector, a cold-water loop, a main test section, and the associated controlling, measuring and recording facilities. Figure.3 depicts the main test section, a DCMD (direct contact membrane distillation) module. The DCMD module has two cylindrical compartments 12 cm in length and 6 cm in internal diameter [4]. The feed (hot) solution enters from the top of the left-hand side compartment and leaves in the same compartment where as permeate is directly condensed on the cooling water flow in adjacent compartment. The cold water flows through the right-hand side compartment. Two compartments is separated using the membrane and a stainless net.

The net supports the membrane, which is sealed with rubber O-rings. Six holes six screws and the compartment flanges hold the parts together. The product water (distillate) drains to a collector. During the test, once the temperature and flow rate stabilized, the permeate rate and its conductivity were measured.

In these experiments, Sterlitech PTFE (polytetrafluoroethylene) Hydrophobic Membrane imported from USA is used. PTFE membranes were used with 0.2µm pore diameters, 35µm thickness and 80% porosity.

DIFFERENT PARTS OF DCMD

Cylinder Compartments

The DCMD module has two cylindrical compartments 12 cm in length and 6 cm in internal diameter. The feed (hot) solution enters from the top of the left-hand side compartment and leaves in the same compartment where as permeate is directly condensed on the cooling water flow in adjacent compartment. The cold water flows through the right-hand side compartment. Two compartments is separated using the membrane and a stainless net. It is made up of mild steel sheet of 5 mm thickness.

The net supports the membrane, which is sealed with rubber O-rings. Six screws and the compartment flanges hold the parts together [4].

Figure3. *Cylinder compartments*

Membrane

Figure. 4 *PTFE Membrane*

Sterlitech PTFE (polytetrafluoroethylene) hydrophobic membrane imported from USA is used. PTFE membranes were used with 0.2µm pore diameters, 35µm thickness and 80% porosity.

Stainless Net

Stainless net are used to filter bigger particles other than dissolved salts. And this also help to support PTFE membrane and it give strength for it. It is made up of stainless steel to avoid corrosions.

Collecting Tanks

Collecting tanks are used for storing brine solution as well as cold solutions. In the experiment plastic tanks are used to avoid corrosion. Tank connectors are used to carry solutions from tank to pipe lines without any leakage.

Insulation

Insulations are provided on the surface of the cylinders to reduce heat loss. Thermocol material is used as the insulating material. Thermal conductivity of thermo coal material is 0.033W/mK.

Sealant

Sealants are provided for preventing the leakage of water. M Seal and araldite are used as sealant during fabrication.

The proposed work aims to investigate the effect of integrating a flat plate collector in a direct contact membrane type distillation system. Experimental studies are carried out to study the performance of the direct contact membrane type distillation system integrated with a liquid flat plate collector and to do the thermal modelling of the same.

FLAT PLATE COLLECTOR

A simple flat plate collector has a coated flat heat absorber plate with channels or tubing in contact with the plate for passage of working fluid. Transparent covers of glass sheet are placed on the upper side of absorber plate to reduce thermal losses. Thermal insulation is provided between the absorber plate and the casing. The panel is installed on a support structure.

Flat plate collectors absorb both beam and diffuse components of radiant energy. Hence they can function without need for tracking the sun. Also they absorb energy even during cloudy and hazy atmosphere.

In this experiment liquid flat plate collector consists of a toughened glass cover of thickness 5 mm an absorber plate made up of copper having length 1m, width 0.5 m and thickness 1mm is placed 7cm below the glass cover. Absorber tubes (5 by 8 inch) made of copper is weld to the absorber plate placed at the top. The absorber surface reduces convection and radiation losses to the atmosphere and the back insulation to reduce the conduction losses. Set up consist total 7 numbers of copper tubes each of length 1m placed at 6cm from one another. These copper tubes are interconnected by using 'T' and 'Elbow' joints (12 T joints and 2 Elbow joints). First and last of copper tubes having a length of 1.15m. Aluminium foil of 0.5 cm is placed 1cm below the absorber tubes to reduce the bottom heat loss from the LFPC. Wood material insulation of thickness 2cm is provided at bottom and sides of collector to prevent heat losses. FPC is almost always mounted in a stationary position with an orientation optimized for the particular location for the time of year in which the solar device is intended to operate.

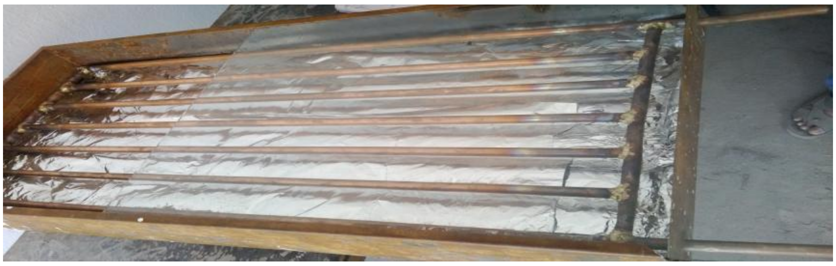

Figure5. *Flat Plate Collector*

DESIGN OF DCMD

Basic calculation for the still design are given below,

- Daily yield = 6.5 litre/day
- Latent heat of vaporisation = 2437.8kJ/kg
- Density of water = 1000kg/m^3 at the standard atmospheric condition
- Efficiency of DCMD = 0.65(65% is a common still efficiency)
- Average daily solar radiation on location = 5.59 kWh/m^2/day
- Useful solar radiation = 5.59x0.65
  = 3.6335kWh/m^2/day
  = 13080.6kJ/m^2/day
- Yield produced per day = 13080.6/2437.8
  = 5.36litres/m^2/day
- Total area of membrane required = 6.5/5.36
  = 1.21m
  = 1m approx
- Average solar still yield =6.5Kg/day (for a direct contact membrane type distillation)

For the design of a direct contact membrane type distillation integrated with liquid flat collector (LFPC); which produces 110 more percentage of distilled water produced by direct contact membrane type distillation.

= 6.5x110/100

= 7.15kg/day

There fore

Total yield = 6.5+7.15

= 13.65kg/day (210% of initial yield)

Area of membrane for producing $38x10^{-3}$ kg/d = $2.9x10^{-3}m^2$

= $2.8x10^{-3}m^2$

Table1. *Specification of direct contact membrane type distillation system*

Type	Direct Contact Type
Basin liner material	Polytetrafluoroethylene (PTFE)
Area of membrane	$0.0028m^2$
Material for cylindrical shell	Mild Steel
Length of cylindrical compartment	60mm
Pore diameter	0.2 µm
Thickness of membrane	35 µm
Porosity	80%

DESIGN OF LIQUID FLAT PLATE COLLECTOR

Heat input = 0.68 x latent heat of water

= 0.68x2437.8

= 167.59kJ/h

(a) Design of absorber plate:

Heat input = (area) x (daily average solar radiation) x (efficiency of flat plate collector)

Daily average solar radiation = 5.59 $kWh/m^2/day$

Efficiency of flat plate collector = 0.4

Area of absorber plate = (heat input) / (daily average solar radiation x efficiency of flat plate collector)

Area of absorber plate = heat input /(daily average solar radiation x efficiency of flat plate collector)

= 167.59/ (0.4x5.59x3600/24)kJ/hr m^2

= 167.59/335.4 = $0.5m^2$

Hence

Length = 1m

Width = 0.5m

(b) Design of copper tube inside the flat plate collector

Spacing between copper tube=6cm (assumption)

Number of copper tubes inside the flat plate collector = width/space

= $0.5m/7x10^{-2}m$

= 7

Since it contains seven tubes; each having length 1m,

Total length of copper tubes = 7m

Specification of the Selected Flat Plate Collector

- 27^0 is the tilt angle of flat plate collector (optimum tilt angle for the latitude of location)
- Water heating type flat plate collector
- Area of flat plate collector=$1x0.5m^2$

EXPERIMENTAL SET UP

The experimental set up consists of a DCMD coupled with a flat plate collector. The flat plate collector is integrated with DCMD in such a way that the hot water from the collector plate under natural circulation mode to the membrane module. The feed (hot) solution enters from the top of the left-hand side compartment and leaves in the same compartment where as permeate is directly condensed on the cooling water flow in adjacent compartment. The cold water flows through the right-hand side compartment. Two compartments is separated using the membrane and a stainless net. Layout of experimental set up is given in Figure. 7.

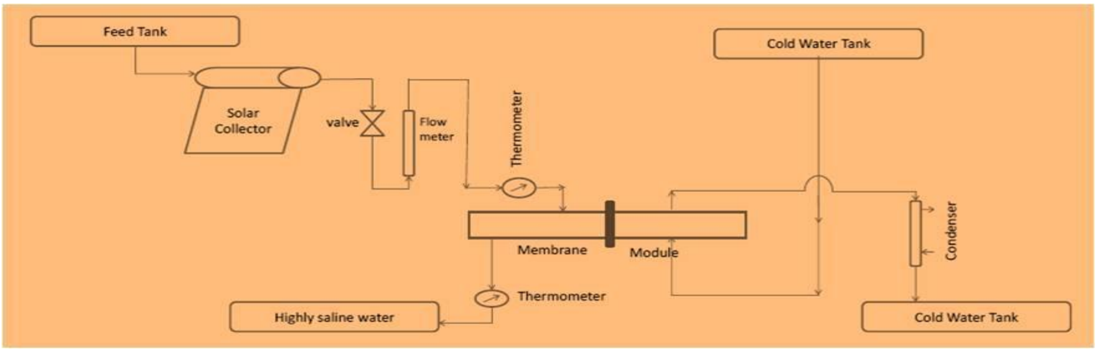

Figure6. *Experimental Setup represented in line diagram.*

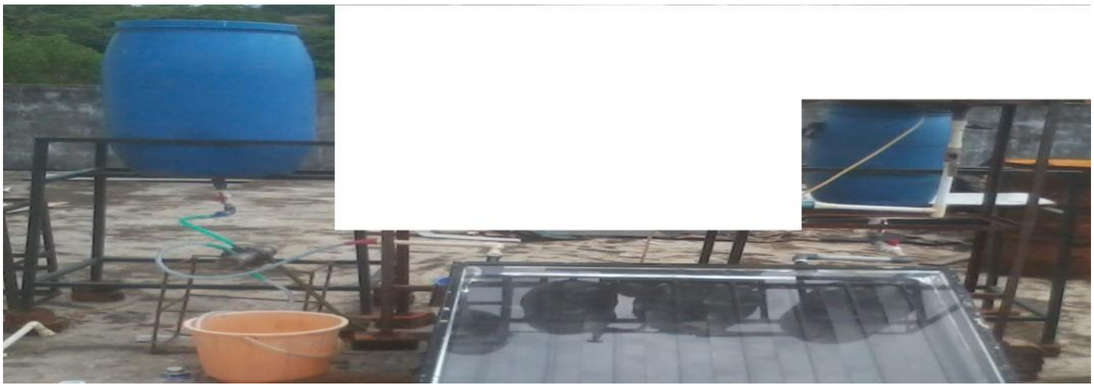

Figure7. *Experimental Setup*

The collector plate faces south inclined at 27^0 to receive maximum possible radiation. The collector plate absorbs solar energy and transfers energy to water flowing through tubes.

The direct contact membrane type distillation system integrated with a liquid flat plate collector is mounted on iron stands. Outdoor experiments are conducted in LBS, Kasaragod, Kerala starting from 25^{th} May 2014 at 5% concentrated saline water. Hourly ambient temperature, inlet & outlet temperature of solution from solar collector , solar intensity, and distillate yield are measured for 9 hours. Accumulated yield at evening is measured from 9 am in the morning.

WORKING OF THE DCMD

The set up consists of a direct contact membrane type distillation system integrated with a liquid flat plate collector. The DCMD module has two cylindrical compartments 12 cm in length and 6 cm in internal diameter. The feed (hot) solution enters from the top of the left-hand side compartment and leaves in the same compartment where as permeate is directly condensed on the cooling water flow in adjacent compartment. The cold water flows through the right-hand side compartment. Two compartments is separated using the membrane and a stainless net. It is insulated to reduce the heat loss of the surrounding and is made water tight to avoid water leakage.

The vapor formed in the hot compartment is passed through the hydrophobic membrane to other compartment where it is condensed along with the cold water and flow along with it.

Instrumentation Used

Temperature Measurement

For the performance calculation of DCMD integrated with solar collector, it is essential to know the values of temperatures at different positions of setup. Since the present experimental set up is a flat plate collector integrated DCMD, performance evaluation of flat plate collector is also important.

Here in this setup we are using thermometers for measuring temperature of the inlet and outlet solution from the solar collector and membrane module.

Measurement of Yield

The measurement of the output of solar distillation (yield) is important since the performance of it is measured in terms of yield. The yield is measured every hour starting from 9 am to 5 pm. At night the accumulation value of yield is measured. Amount of yield produced from the system can be measured using the measuring jar having a capacity of 500 ml.

Measurement of Global Radiation

Global solar radiation is the total amount of solar energy received by the earth surface, usually expressed as Wm^{-2} .about 99% of global solar radiation has wavelengths between 300 and 3000 nm. This includes ultraviolet (300-400 nm), visible (400-700 nm) and infra red (700-3000 nm) radiation. Global solar radiation is the sum of direct, diffuse and reflected solar radiation. Direct solar radiation passes directly through the atmosphere to the earth surface. Diffuse solar radiation is scattered in the atmosphere and reflected solar radiation reaches a surface and is reflected to adjacent surfaces. Solar radiation incident on the earth's atmosphere is relatively constant; the radiation at the earth's surface varies widely due to:

- Atmospheric effects, including absorption and scattering
- Local variations in the atmosphere such as water vapor, clouds and pollution
- Latitude of the location
- The season of the year and the time of the day

The above effects have several impacts on the solar radiation received at the earth's surface. These changes include variations in the overall power received, the spectral content of the light and the angle from which light is incident on a surface. In addition, a key change is that the variability of the solar radiation at a particular latitude. Desert regions tend to have lower variations due to local atmospheric phenomenon such as clouds. Equatorial regions have low variability between seasons. The amount of energy reaching the surface of the earth every hour is greater than the amount of energy used by the earth's population over an entire day. The values of global solar radiation are obtained from CPCRI, Kasaragod.

GOR Calculation for the DCMD Integrated with a Liquid Flat Plate

Collector. Mathematically, the GOR is calculated from [5]:

$$GOR= (m_d \Delta Hv) / [m_h C_p(T_{hi}-T_{ho})] \quad (1)$$

where m_d is the distillate flow rate (kg/h), ΔH_v the latent heat of vaporization (J/kg), m_h the feed flow rate (kg/h), C_p the feed specific heat (J/kg K), T_{hi}, T_{ho} the feed temperatures (in K) at the module inlet and outlet**.**

PR Calculation for the DCMD Integrated with a Liquid Flat Plate Collector.

The PR of the desalination process is commonly defined as kg distillate per 2326 kJ of heat consumed [5].

$$PR= m_d / [m_h Cp(T_{hi}-T_{ho})] \quad (2)$$

Where m_d is the distillate flow rate (kg/h), m_h the feed flow rate (kg/h), C_p the feed specific heat (J/kg K), T_{hi}, T_{ho} the feed temperatures (in K) at the module inlet and outlet**.**

Solar Collector Efficiency Calculation for the DCMD Integrated with a Liquid Flat Plate Collector.

The solar collector efficiency relating the thermal energy gained to solar radiation on the collector plane (η_S) is given by[6]:

$$\eta_S = m_f C_p(T_{so}-T_{si})] / IA \quad (3)$$

Where I is the solar irradiation (W/m^2) and A is the area of the solar collector (m^2). m_f is mass flow rate (ml /min), T_{so}, T_{si} are temperature of inlet and outlet of solar collector in ^0C.

EXPERIMENTAL RESULTS

Temperature distributions in the system are shown in Figure7. The maximum yield of the system correlates very well with the temperature distribution of the solar still, where maximum ambient temperature in occurs at around 1.00 pm with the highest temperature 33^0C. The temperature is minimum at 8:00 am. Here plotted temperatures are the average valves for each hour in the last week of May 2015.

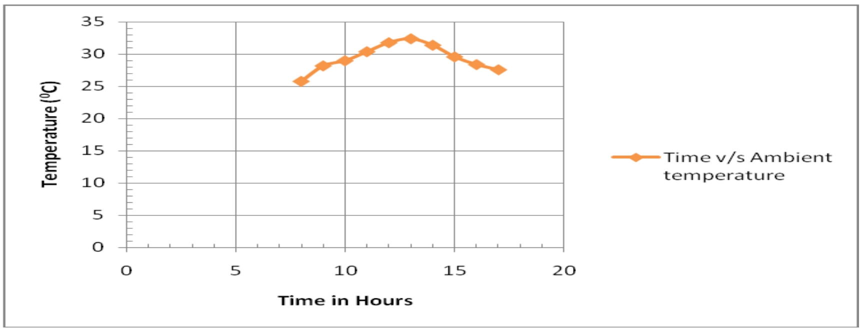

Figure7. *Ambient Temperature vs. time graph*

Figure 8 shows the variation of solar irradiation with respect to time. From the graph it is observed that solar intensity reaches its maximum value at 13.00 pm. After that suddenly get decreased. It is clear that maximum solar irradiation 771 W/m^2. And has minimum of 363W/m^2 corresponds to 17.00pm. Here plotted values of solar irradiations are the average valves for each hour in the last week of May 2015.

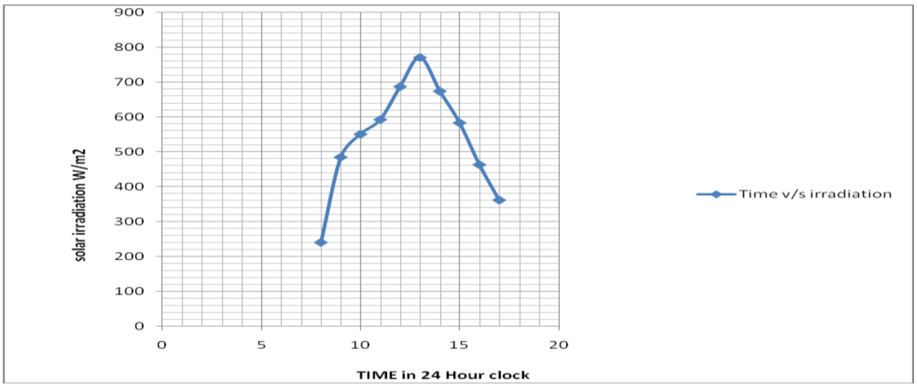

Figure8. *Solar irradiation vs. time graph*

Figure 8 shows the effect of solar irradiation on system output and also variation of solar irradiation with respect to time. From the graph it is observed that solar intensity reaches its maximum value at 13.00 pm, and still output reaches it's maximum at 13.00 pm. After that both suddenly get decreased.

It can be seen from the Figure that the maximum yield of 5.88ml/hr of the system occurs at 13.00 pm. The maximum yield of the solar still correlates very well with the temperature distributions of the solar still, where the maximum temperatures in the system occur at around 13.00 pm. Here plotted mass flow rate are the average valves for each hours in the last week of May 2015.

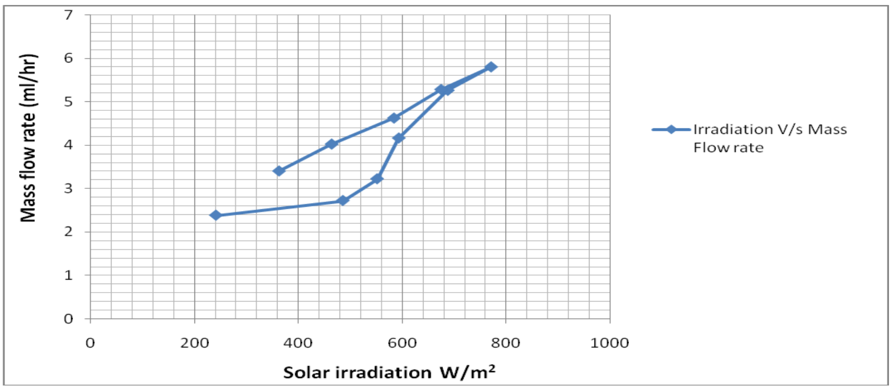

Figure9. *solar irradiation vs. mass flow rate*

Figure 10 shows the efficiency of solar collector with respect to irradiation when it is tilted at optimum angle of 27^0. The experiment was conducted at five days of months May. The maximum solar collector efficiency obtaining is lower solar irradiations and temperatures due to high temperature difference in inlet and outlet of solar collectors.

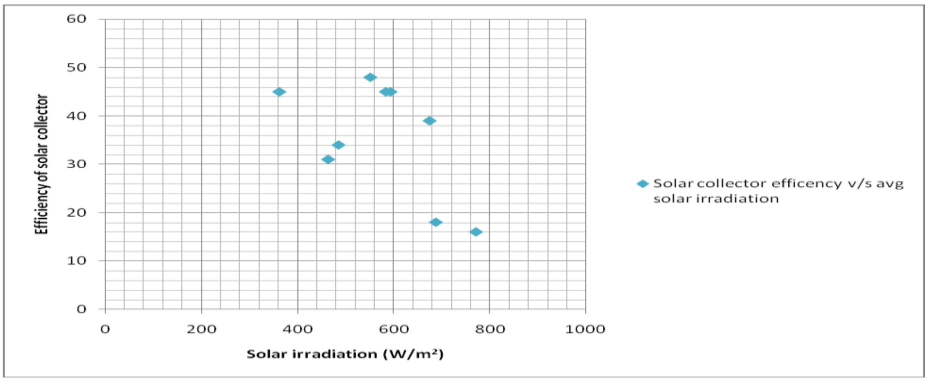

Figure10. *Solar collector efficiency vs. Solar irradiation*

Figure 11 shows the gain output ratio with respect to irradiation when it is tilted at optimum angle of 27^0. The experiment was conducted at five days of months May. The value ranges between 0.5 to 0 .6. And the trend is linearly increasing with respect to increase in solar irradiation.

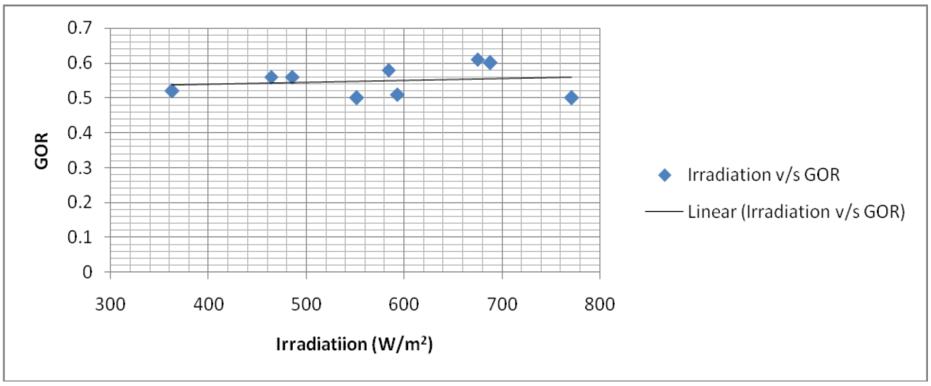

Figure11. *GOR vs. irradiation*

Figure12 shows the performance ratio with respect to the solar irradiation. Here in the graph it is plotted the PR for average values corresponding to each hours in the last week of May 2015. Trend is linearly decreasing with respect to increase in solar irradiation. Value of PR ranges between 0.2 and 0.26.

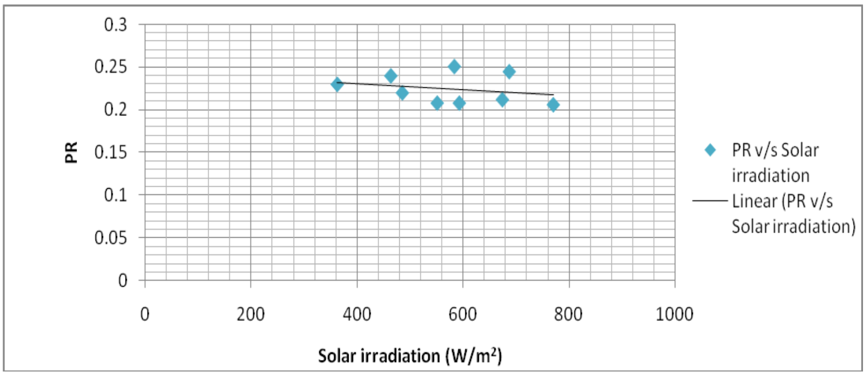

Figure12. *PR vs. Solar irradiation*

CONCLUSION

The solar energy distillation plants are relatively inexpensive, low technology systems, especially useful where the need for small plants exists. However there is still much room for innovation and improvement. It is well known that solar distillation exhibits a considerable economic advantage over other salt water processes, because of cost free energy and reduced operating cost.

The operation of the DCMD type solar distillation system coupled with a flat plate collector has been designed and investigated it experimentally. Distillation yield at month May is plotted at different time intervals. Experiments were conducted at 5% concentrated saline water. It is observed that the still output is greater in the climatic conditions of Kasaragod.

Saline water temperature is higher than the water temperature earlier, since the system is directly coupled to the liquid flat plate collector. Maximum temperature occurs 13.00 hour for the solar flat plate collector.

From still yield vs. time graph it is observed that still output is maximum at 13.00 hour and then decreases towards 17.00 hour. The intensity of radiation is also maximum at 13.00 hour. It was also observed that intensity of radiation is maximum for 25^{th}- 27^{th} than 28^{th} & 29^{th} of May. So the output is also maximum for 25^{th} -27^{th} of the month may. Form still yield vs. intensity graph, it is found that still yield is directly proportional to the intensity of solar radiation.

Theoretical value of still output is 13.65kg/m^2 and the actual value obtained is little lesser. The difference may be due to minor leakage or may be due to variation of solar irradiation from the given data. Gain output ratio of the system is found between .5 and .6 which is competing with other conventional distillation system [6].

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AUTHOR'S BIOGRAPHY

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