INVESTIGATION OF ACTIVE SOLAR STILL WITH EVACUATED TUBE COLLECTOR (ETC)

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Title of the thesis

Investigations on Active Solar Still Coupled with Evacuated Tube Collector

Abstract

On the earth, 97% of water is in the oceans and only 3% water is fresh which is stored in forms of ice glares, ground water, rivers and lakes. The world population is about 7.7 billion in the year of 2019 and is expected to increase up to 10 billion in the year of 2025. The requirements of fresh water grow with the population growth. Water is one of the basic needs for human kind of about 3% of fresh water, only 0.01% water available as surface water in lakes, swamps and rivers. Therefore, there is no option other than to extract water from oceans. For that, the desalination process is an appropriate method. The aim of the research work is to develop novel designs of the active solar still coupled with Evacuated Tube Collector (ETC) with natural and forced circulation of secondary fluid. The novelty of the research work is, air or tap water circulate through ETC as secondary fluid to eliminate the scale formation on ETC tubes and increases efficiency of the solar still. Thermal models of the active solar still coupled with ETC are developed considering energy balance for inner glass cover, outer glass cover, and saline water, basin of solar still, fluid inside the fluid chamber/serpentine tube/serpentine passage and ETC temperatures for natural and forced circulation. The main objective of the research work is to experimentally investigate the performance of the active solar stills at different water depths with field conditions of Ahmedabad, India (23.0225° N, 72.5714° E). Day, night and daily yields were measured under different operating conditions. Hourly and daily energy-exergy efficiencies were also calculated. Active solar stills with natural circulation of air and water and forced circulation of air through serpentine tube/passage were fabricated and tested. The experiments were performed during the months of April and May 2016, 2017 and 2018 in the climatic conditions of Ahmedabad. The productivity was highest for active solar still with ETC with forced air circulation through air passage. The night yield recorded was higher for active solar still with ETC with natural water circulation. The optimum depth of saline water is 0.02 m and 0.03 m for natural and forced circulation of the fluids. The overall thermal efficiency and exergy efficiency are higher for active solar still with forced air circulation. The productivity of the active solar still with ETC with natural and forced circulation of air is 80% and 126% higher than the productivity of the passive solar still. Higher annual yield is achieved with forced air circulation, however the product cost is lower and the system is maintained easily for active solar still coupled with ETC with natural air circulation.

Key words: active solar still, evacuated tube collector, thermal efficiency, exergy efficiency, thermal analysis

Brief description on the state of the art of the research topic

Distillation is a process for eliminating salt content from saline water by using three principal methods thermal, electrical and pressure [1]. In the thermal distillation, the saline water boils and then the steam is collected, leaving the salt at the bottom. The vaporization phase requires more amount of energy in the distillation process. Solar distillation is analogous to the water cycle. It is a technology to produce potable water from saline water using solar energy. Solar thermal desalination is most preferable at remote area having low water availability. Solar thermal desalination uses a closed device called solar still in which water is evaporated using solar energy, a form of renewable energy, which collects distilled water after condensation of the vapor and left impurities on base. Solar still can be classified into two major types i.e. passive solar still, contains only basin part of still for evaporation and condensation process and active solar still, wherein the basin of still is connected with solar collector to supplement extra heat to raise the temperature of saline water. Different types of collector can be connected with a basin of solar still like Flat Plate Collector (FPC), Concentric Parabolic Collector (CPC), Evacuated Tube Collectors (ETC) etc. Among these, ETC has been most successful solar collector because its higher efficiency and capacity to track the sun throughout the day due to own round absorber with effective cost. Active solar still coupled with the collector can be further classified into two modes i.e. natural and forced circulation.

Omara et al. [2] developed a novel model of wick type solar still coupled with evacuated glass tube water heater. It was tested using the plane, lined and square thick lined woven fabric wicks with single and double layer in a basin of wick solar still and conventional solar still. Theoretical model was developed and validated with the experimental one. The productivity of double layer was found higher than single layer for square thick lined wick and lined wick. Sampathkumar et al. developed active solar still coupled with ETC with natural circulation of saline water through ETC without reflector [3] and with a reflector and thermal storage media like black gravel [4]. The passive and active solar still both were tested and experimented simultaneously for the comparison. The day and night yield were recorded higher for active solar still with higher basin temperature than passive solar still. The use of black gravel gave higher yield for the solar still coupled with ETC. Deniz [5] and Singh et al. [6] presented thermal modelling and experimental model of a single slope active solar still coupled with ETC with reflector. The effect of water depth in the basin on yield, energy efficiency and exergy efficiency was presented. MATLAB was used for thermal simulation to predict yield and efficiency by using value of saline water temperature in the basin and in the collector, and temperature of inner glass and outer glass of a solar still. Mamouri et al. [7] developed a solar still coupled with ETC, which had five evacuated tubes with thermosiphon heat pipe. The effect of saline water depth, material of basin cover and intensity of solar radiation on the daily productivity was investigated. The maximum hourly productivity was recorded for glass cover. The thermal capacity of basin was increased with increase of water depth, but as a result output of distilled water was decreased. Mosleh et al. [8] developed Twin-glass Evacuated Tube Collector (TETC) with heat pipe coupled with parabolic trough collector. It was installed with a microcontroller-based sun tracking system to gain maximum solar heat. The experiments were carried out to evaluate the time constant, acceptance angle, the effect of water level in the basin and the effect of using aluminum foil, oil and water in the space between TETC and heat pipe on productivity. Shafii et al. [9] developed an evacuated tube collector worked as a basin of a solar still. Elimination of conventional still virtually eliminated the heat loss between the still and collector. Effect of three different parameters i.e. the amount of water present in the ETC, introducing stainless steel wool inside the ETC and inclination of ETC on productivity was experimentally evaluated. Sampathkumar and Senthilkumar [10] tested an experimental model where an ETC based solar water heater was coupled with a solar still to raise the water temperature in the basin. The solar water heaters were more effective during cold weather compared to summer season. Theoretical model was also developed and validated with the experiments. The experimentation was focused on inner glass cover temperature, water temperature in the basin and distillate yield. The tested distilled water was found safe for drinking purpose complying Bureau of Indian Standards (BIS) and World Health Organizations (WHO) standards. Panchal and Shah [11] developed a double basin active solar still coupled with evacuated glass tube. Panchal [12] carried out experiments on double basin active solar still coupled with evacuated glass tube with and without black gravel, pebbles, black granite gravel and calcium stones as thermal storage media in the upper basin to increase the productivity. The temperature of the inner glass cover, temperature of saline water and distilled water were in descending order for still with calcium stones, black gravel granite and pebbles respectively. Hence, the authors argued that calcium stones were better, sensible storage materials due to its higher specific heat capacity. Behshad et al. [13] developed a novel model of evacuated glass tubes, which itself work as a solar still with thermoelectric modules. A chamber, worked as a condenser was made from a thin G.I. sheet. The experiments were conducted with three different conditions viz. fully water filled evacuated glass tubes with propelling fan, fully water filled evacuated glass tubes without propelling fan and half water filled evacuated glass tubes without propelling fan. Tiwari et al. [14] developed thermal models for active solar still coupled with flat plate collector, concentrating collector, ETC and ETC with heat pipes. Total heat transfer coefficients, daily yields and overall thermal efficiencies for the active solar stills were obtained using the theoretical modelling. Researchers also experimentally validated the thermal model of active solar still coupled with FPC. Dev and Tiwari [15] experimentally investigated an Evacuated tube collector Integrated Solar Still (EISS). In their model, ETC based water heater was coupled with a solar still in a forced circulation mode through a pump. Hourly value of inner glass cover temperature, outer glass cover temperature, basin liner temperature, water temperature, and ambient temperature, velocity of wind, solar insolation and yield were measured. Kumar et al. [16] developed a model of the solar still coupled with ETC with forced circulation mode. The annual yield was more in force circulation compared to the natural circulation mode. The optimum mass flow rate, the values of energy and exergy efficiencies and the yield were evaluated.

The researchers have developed different type of passive and active solar still to achieve higher daily yield and thermal efficiency. Various parameters of solar still like thickness of glass cover, material of condensing cover, depth of saline water, material of construction of solar still have been investigated. Active solar still powered by different types of solar collector viz. FPC, ETC, concentrating collector etc. have been experimented and saline water may be circulated in natural or forced circulation mode through the collectors. Thermal models for different configurations of passive and active solar still have also been presented. Literature review reveals that the single slope solar still with $1m^2$ area is simple to construct and maintain. The glass cover inclined at 20° is the best condensing cover to get proper condensation of vapour. Solar collector should be inclined at an angle equal to latitude of the place to absorb more solar energy to increase the temperature of saline water. ETC in forced circulation mode is the best collector to transfer heat to saline water and to obtain higher yield with minimum loss. The productivity of passive and active solar still are recorded 2 to 2.5

kg/m^2 and 3.19 to 6 kg/m^2 respectively. In all the designs, the saline water is directly circulated through various collectors and hence there is scale formation on the surface of collector tubes. This reduces heat transfer from the collector and eventually yield and efficiency of the active solar still decrease. So there a need to overcome the scale formation on collector tube with minimum cost and without compromising the sill performance.

Definition of the Problem

- The internal recirculation of saline water is not proper at the beginning of active solar still coupled with evacuated glass tube in natural circulation mode due to higher thermal mass.
- Also for active solar stills with forced circulation, pump is necessary to circulate the saline water in the collector tubes due to which the design becomes more complicated. The scale formation reduces the efficiency of pump with time and consumes more power.
- The saline water is used directly as a fluid in active solar still coupled with ETC. When saline water comes in contact with the surface of the evacuated glass tube, it causes scale formation over the time. The heat transfer rate from the absorber surface to the water decreases and temperature of absorber surface increases which reduces the collector performance due to scale formation.
- The productivity, heat transfer rate and life of active solar still decrease with time due to scale formation in the system.

Objective and Scope of work

- To develop novel configurations of active solar still coupled with evacuated tube collector which use air or tap water as secondary fluid in natural or forced circulation mode to avoid unlike scale formation in ETC of active solar sill
- To develop thermal models of the active solar stills to predict the performance of the stills under different operating conductions and thus to optimize the system to get desired temperature rise of the saline water in the basin.
- To design, fabricate and experiment models of active solar still coupled with ETC using secondary fluid with natural and forced circulation.

Original contribution by the thesis

To achieve the objectives of the research work, three different models of active solar still coupled with ETC were conceived, fabricated and tested which are described below:

Natural circulation mode with fluid chamber

The major components of the active solar still are ETC, solar still and fluid chamber. ETC was connected to the solar still through the fluid chamber, which was located at the bottom of a solar still with 1m^2 basin area. The novelty of the system is the use of air/ tap water with ETC as a secondary heat transfer fluid to heat up the saline water of a solar still. In order to do so, a rectangular chamber was provided beneath the basin. The fluid chamber made of Mild Steel (MS) had a height of 92 mm, length of 1000 mm and width 1000 mm. Total ten numbers of equal partition were made at the distance of 100 mm by proving vertical plates which also work as fins to increase the heat transfer rate. Ten number of evacuated glass tubes were directly connected to the ten partitions of the fluid chamber. The air/tap water inside the ETC absorbs heat from incoming solar radiation. The hot air/tap water is circulated from ETC to the fluid chamber. The heat energy of hot air/tap water gets transferred to the basin of the solar still by natural convection. Cold air/tap water is circulated back from the fluid chamber to ETC by natural circulation.

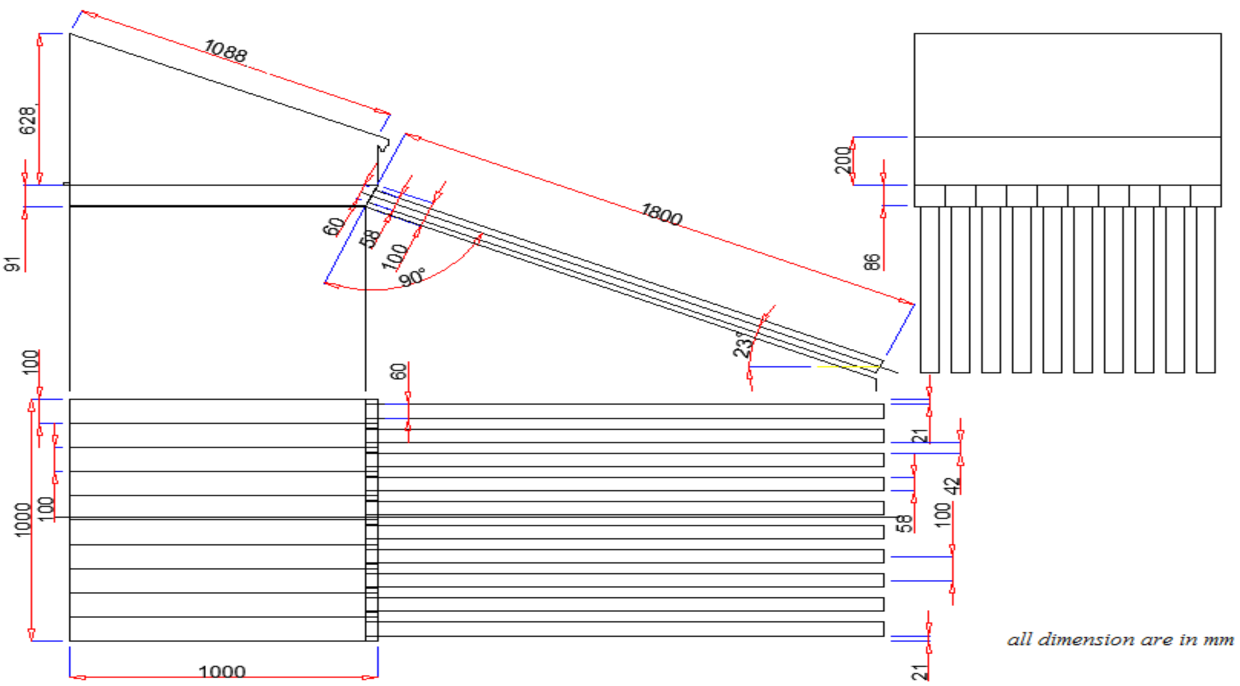
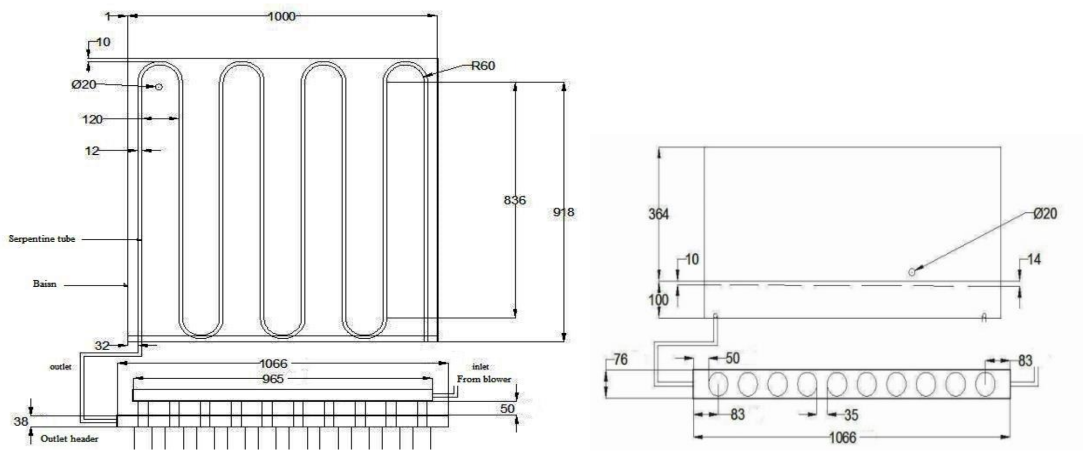


Fig. 1 Design of active solar still coupled with ETC with natural circulation

Forced circulation mode with serpentine tube/serpentine passage

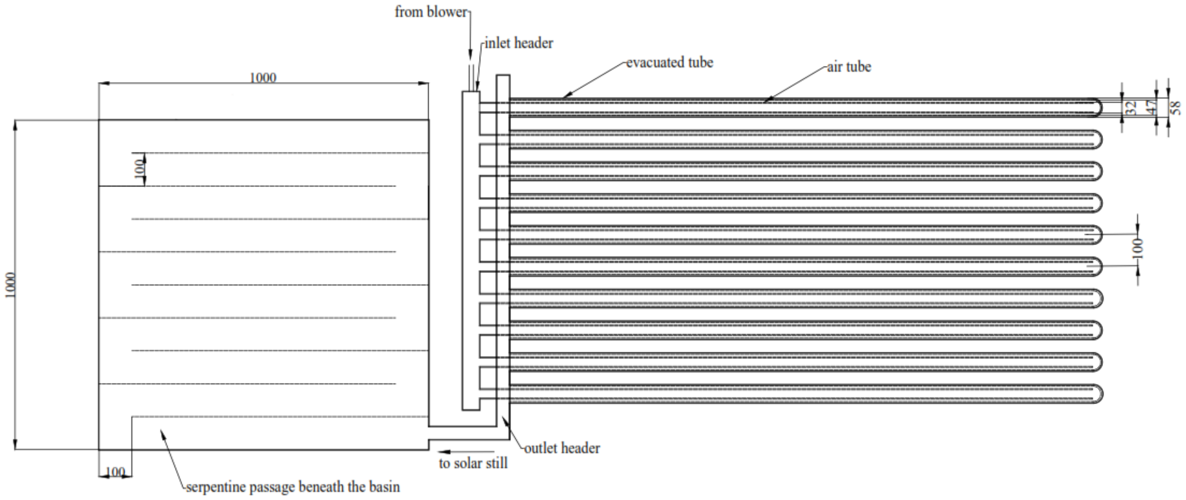
The major components of the active solar still are ETC with arrangement of forced circulation of air and solar still with serpentine tube welded to the basin or serpentine passage beneath the basin. The atmospheric air is sucked by blower and supplied to the inlet header of ETC. The evacuated tube has one open end, so a metal tube also referred as air tube, is provided inside the evacuated tube concentrically to circulate the air through it. The air tube was made from mild steel has outer diameter of 31.75 mm and thickness of 1.6 mm. The one end of all air tube is connected to inlet header and the other end is open inside the evacuated tube certain distance away from the closed end of the evacuated tube to form the fluid passage. The mouth of all the evacuated tubes were connected to outlet header. The forced air coming out from the blower is distributed to certain number of air tubes via inlet header. The air coming out from the other end inside evacuated tube flow through the annuals space between the air tube and absorber of the evacuated tube. The forced air is heated up while flowing the annuals space and collected by outer header, which is connected, to the inlet of serpentine tube/serpentine passage. In one of the designs the serpentine tube arrangement is welded to the top surface of the basin of solar still having 1m^2 basin area. The serpentine tube was made from MS with inner diameter of 9 mm and outer diameter of 12 mm. The hot air is circulated through the serpentine tube and thus transfer the heat to the saline water inside the basin.



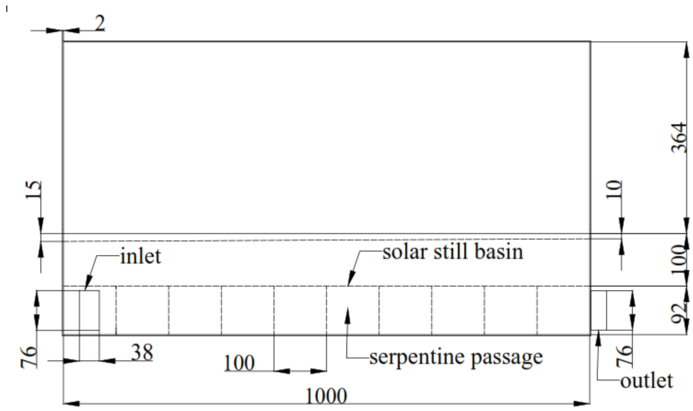
(a) Top view **(b) Front view**

Fig. 2 Schematic diagram of top view and front view for serpentine arrangement

In the second design a serpentine passage is provided beneath the basin. The serpentine passage made from MS has a height of 92 mm and width of 100 mm. Overall width and length of the serpentine passage is 1000 m as shown in Fig. 3. The hot air from the ETC enters the serpentine passage and while flowing through the passage transfers heat to the basin of the solar still before leaving through outlet of serpentine passage.



(a) Top view



(b) Front view

Fig. 3 Schematic diagram of top view and front view for serpentine passage

In both the designs, heat is transferred to saline water by secondary fluid air while flowing through the serpentine tube/serpentine passage, thus increasing the temperature of saline water, which leads to higher evaporation rate of saline water and hence daily yield and efficiency of active solar still are increased.

Methodology of Research

Three designs of active solar still as discussed in previous section were conceived to eliminate the scale formation on the surface of evacuated tubes. The solar stills were fabricated and tested in the climatic conditions of Ahmedabad, India (23.0269° N, 72.6454° E). The ETC was kept at an inclination of 23°, approximately equal to the latitude of the place, towards south. This ensured that the ETC receives maximum solar insolation from the sun. Before start of every set of experiments the saline water was drained from solar still and the basin was cleaned. Saline water having salinity of 35 ppm was stored in the storage tank. Initially saline water was fed from storage tank to the still as per desired water depth and was kept for one day to properly record the thermal inertia effect. Saline water depth was kept constant during each experiment. The tap water was filled in the fluid chamber and ETC for natural water circulation. The blower was set with the full volume flowrate during forced circulation mode. The volume flow rate of air was measured using an orifice meter. The observations of solar intensity, temperatures of the basin, saline water, inner glass cover, outer glass cover, fluid in fluid chamber/serpentine tube/serpentine passage, ETC were recorded at an interval of 30 minutes from 9.00 to 17.00 hr on a particular day. The day yield was recorded at an interval of one hour from 9.00 to 17.00 hr. The cumulative night yield for the duration from 17.00 to 9.00 hr (next day) was recorded at 9.00 hr on the next day. Hourly, daily and exergy efficiencies were calculated from the observations and compared with estimated values obtained from the thermal analysis. The average thermal efficiency, exergy efficiency, annual yield and product cost were found using following equations.

Hourly Yield

$$m_{ew} = \left[\frac{h_{ewgi} \Delta t_w A_S}{h_{fg}} \right] \tag{1}$$

Total Daily Yield [17]

$$M_{ew} = \sum_{t=1}^{24} m_{ew} \tag{2}$$

Efficiency of Active solar still [17]

$$\eta = \frac{m_{ew} \times h_{fg}}{(\mathrm{I}_s(\mathrm{t})\ \mathrm{A_S} + \mathrm{I_c}(\mathrm{t})\mathrm{A_c}) \times 3600} \tag{3}$$

Exergy Efficiency [18]

$$\eta_{Ex} = \frac{Ex_{out}}{Ex_{in}} \tag{4}$$

The average annual yield $\sum m_{ew\,year}$ is calculated using average monthly solar radiation data from National Renewable Energy Laboratory (NREL).

The product cost of distilled water can be calculated as [19]

$$W_c = \frac{C}{\sum m_{ew\,year}} \tag{5}$$

Results and Comparisons

Thermal models have been devloped to predict the performance of active solar stills described earlier under different operating conditions. To calculate the estimated hourly yield and thermal efficiency, observations of solar intensity, saline water temperature and inner glass cover temperature were given as input to the thermal model. Computed values of estimated hourly yiels and theoretical thermal efficiency for optimum depth obtained for the four cases are summerized in Table 1.

Table 1 Estimated hourly yield and theoretical thermal efficiency of active solar still coupled with ETC in natural and forced circulation modes

Active solar still coupled with ETC	Natural Air Circulation through fluid chamber		Natural Water Circulation through fluid chamber		Forced Air Circulation through Serpentine tube		Forced Air Circulation through Serpentine passage	
Optimum Water Depth (m)	0.02		0.02		0.03		0.03	
Time (h)	Estimated hourly yield (liter)	Theoretical thermal efficiency η_{th} (%)	Estimated hourly yield (liter)	Theoretical thermal efficiency η_{th} (%)	Estimated hourly yield (liter)	Theoretical thermal efficiency η_{th} (%)	Estimated hourly yield (liter)	Theoretical thermal efficiency η_{th} (%)
09:00	0.14	5.70	0.23	9.22	0.01	0.54	0.07	4.69
10:00	0.44	11.41	0.63	12.48	0.16	7.99	0.34	14.77
11:00	1.06	18.62	1.09	16.82	0.60	17.82	1.00	25.09
12:00	1.89	20.67	1.61	18.85	1.11	18.44	1.66	27.14
13:00	2.65	24.52	2.17	21.02	1.82	25.82	2.37	29.15
14:00	3.45	33.54	2.79	28.37	2.48	26.31	3.08	29.35
15:00	3.68	28.58	3.40	24.88	3.05	38.59	3.82	36.35
16:00	4.01	20.92	3.89	20.86	3.83	55.37	4.89	54.48
17:00	4.16	16.18	4.37	16.41	4.36	74.42	5.91	70.90

Experiments were conducted with three models of active solar still coupled with ETC. With first model, experiments were conducted with natural circulation of air and tap water as secondary fluid. Active solar still coupled with ETC with forced circulation of secondary fluid air was tested with two different arrangements viz. air circulation through serpentine tube provided in the basin and through serpentine passage located beneath the basin.

Solar intensity, temperatures of basin, saline water, inner glass cover, outer glass cover, fluid inside ETC/air inlet and outlet of ETC were recorded at an interval of 30 min. The results of hourly yield, efficiency and exergy efficiency for the four cases are summerized in Table 2.

Table 2 Hourly yield, thermal efficiency and exergy efficiency of active solar still coupled ETC in natural and forced circulation modes

Active solar still coupled with ETC	Natural Air Circulation through Air chamber			Natural Water Circulation through Air chamber			Forced Air Circulation through Serpentine tube			Forced Air Circulation through Serpentine passage		
Optimum Water Depth (m)	0.02			0.02			0.03			0.03		
Time (h)	hourly yield liter	thermal efficiency η (%)	Exergy efficiency η_{Ex}(%)	hourly yield liter	thermal efficiency η (%)	Exergy efficiency η_{Ex}(%)	hourly yield liter	thermal efficiency η (%)	Exergy efficiency η_{Ex}(%)	hourly yield liter	thermal efficiency η (%)	Exergy efficiency η_{Ex}(%)
09:00	0.00	0.00	0.08	0.00	0.00	0.20	0.00	0.00	0.03	0.00	0.00	0.53
10:00	0.12	4.71	0.20	0.23	9.00	0.24	0.08	4.36	1.08	0.40	25.69	2.55
11:00	0.33	7.74	0.64	0.55	12.01	0.38	0.35	11.04	3.59	0.98	28.86	6.06
12:00	0.73	14.52	0.91	1.10	20.02	0.59	0.87	18.91	4.20	1.72	30.79	6.54
13:00	1.57	33.10	1.06	1.78	26.05	0.78	1.53	24.12	5.38	2.50	31.60	7.66
14:00	2.47	36.47	1.53	2.53	30.30	1.21	2.28	30.13	6.59	3.28	34.22	8.67
15:00	3.16	28.80	0.67	3.11	23.96	1.11	3.00	36.03	8.97	4.14	44.01	9.20
16:00	3.48	13.36	0.46	3.59	20.76	0.94	3.63	45.25	11.63	4.80	50.78	16.96
17:00	3.70	9.95	0.22	3.97	16.63	0.71	4.18	75.83	12.12	5.40	70.27	19.95

Comparison of daily yield, overall thermal efficiency, exergy efficiency, annual yield and cost of production for the four cases of testing of active solar stills coupled with ETC is given in Table 3.

Table 3 Comparison of daily yield, thermal efficiency, exergy efficiency, annual yield and cost of product for optimum depth of saline water for different cases

Types of Active solar still coupled with ETC	**Fluid chamber**	**Fluid chamber**	**Serpentine tube**	**Serpentine passage**
Mode of circulation for secondary fluid	Natural	Natural	Forced	Forced
Secondary fluid	Air	Tap water	Air	Air
Optimum depth of saline water (m)	0.02	0.02	0.03	0.03
Maximum temperature of saline water achieved (°C)	58	50	72	67
Maximum temperature of secondary fluid achieved in ETC (°C)	215	57	111	118
Daily yield (l/day)	5.40	5.95	5.88	6.80
Estimated daily yield (l/day)	5.86	6.35	6.06	7.31
Overall thermal efficiency η (%)	22.73	24.72	31.43	38.80
Overall estimated thermal efficiency η_{th}%	25.00	26.70	32.57	42.05
Overall exergy efficiency η_{Ex}%	0.61	0.65	5.28	8.17
Annual yield (l/year)	1965.22	2165.38	2139.91	2474.29
Cost of product (INR)	1.16	1.12	1.48	1.28

Achievements with respect to objectives

- Three novel designs of active solar still coupled with ETC have been successfully fabricated and tested.

- The designs are capable of transferring heat to the saline water through secondary fluids thus eliminating the unlike scale formation on the surface of evacuated tubes of the ETC.
- Air as secondary fluid performs comparable to water thus reducing cost and bulk of the solar still.
- The efficiency of active solar still is increased due to increased evaporation rate with raise in saline water temperature.
- The daily productivity achieved is higher compared to other research works, even though heat collected by ETC is transferred through secondary fluid.
- The product cost is less with ease of maintaining the solar still.

Conclusion

Following conclusions have been drawn from the research work

- Literature review reveals that the scale formation occurs due to circulation of saline water through the evacuated tube collector. This reduces useful heat gain of ETC and eventually efficiency of active solar still. To overcome the problem, use of secondary fluids like air, tap water is proposed for transfer of heat collected by ETC. It is also found that very few researchers have developed active solar still coupled with ETC with forced circulation of saline water.
- The maximum air outlet temperature of 200°C and 110°C was obtained with natural and forced circulation through ETC respectively.
- The maximum saline water temperature of 72°C was obtained with forced circulation of air through serpentine tube.
- The maximum yield of 6.80 l/m^2 was obtained with forced air circulation through serpentine passage. This yield is 20.58%, 12.50% and 13.53% higher than that with natural air circulation, natural water circulation and forced air circulation through serpentine tube respectively in the active solar still.
- The night yield of active solar still with natural water circulation was 1.98 l/m^2. This was higher compared to natural and forced circulation of air due to higher heat capacity of the water.
- Optimum saline water depth was 0.02 m for active solar still with natural circulation of air and water while the same was 0.03 m for both the arrangements of forced air circulation through ETC.

- Hourly efficiency of active solar still with natural circulation of air and water increases during morning hours with increase in solar intensity, becomes maximum about two hours after solar noon and then starts decreasing with decrease in solar radiation. While in cases of active solar still with forced air circulation through ETC, hourly efficiency continues to raise even during afternoon hours due to heat released by thermal mass of ETC.
- The overall efficiency of active solar still achieved are 22.73%, 24.72%, 31.43% and 38.80% for natural air circulation, natural water circulation, forced air circulation with serpentine tube and serpentine passage respectively.
- Use of secondary fluid inside evacuated glass tube prevents scale formation and hence increases the efficiency of ETC, which eventually increases the performance of the active solar still.
- The maximum overall exergy efficiency obtained was 8.17% with active solar still with forced air circulation through serpentine passage.
- The annual yield of active solar still coupled with ETC with natural air circulation, natural water circulation, forced air circulation with serpentine tube and serpentine passage are 1965.2, 2165.4, 2139.9 and 2474.3 liter respectively.
- The distilled water production of active solar still coupled with ETC with natural air circulation, natural water circulation, forced air circulation with serpentine tube and serpentine passage are 80%, 98.33%, 96% and 126.63% higher than passive solar still respectively.
- The distilled water product cost of active solar still coupled with ETC with natural air circulation, natural water circulation, forced air circulation with serpentine tube and serpentine passage are 1.16 INR, 1,12 INR, 1.48 INR and 1.28 INR respectively for the 20 years life of the system.
- The maintenance cost of active solar still with natural air circulation is lower. It can also be maintained easily.
- The output distilled water was tested and found safe for drinking purpose as per BIS and WHO standards.

Publication

- Jigar Rajput, Prexa Parikh and Bhatt N M, “A Review of Solar Stills Augmented with Thermal Storage Media”, *GIT-Journal of Engineering and Technology*, vol. 9, pp. 132-143, 2016, ISSN 2249 – 6157

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