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Performance evaluation of fresnel lens concentrated solar water heater cum distillation unit

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■ **ABSTRACT :** A composite unit of Fresnel lens concentrated solar water cum distillation unit, having a capacity of 70 liters was developed to perform the functions of water heating and distillation. In this system two insulated tanks with glass cover were fabricated where one was used for water heating and the second tank was for condensation of water vapour. Solar energy concentrated by Fresnel lens was absorbed by the plate and surrounding water contained in water heating tank was heated by this absorber plate's heat through conduction. Water vapour from hot water was condensed in dehumidification tank by the comparatively colder surfaces of copper tube used to feed fresh water and top slanting glass surface. Condensed water was collected in a collection trough. Overall efficiency of solar water heater was found to be 42.38 per cent and 27.48 per cent for distillation unit. The final hot water outlet temperature was 65.12 and the yield of distilled water was 4.72 kg/m^2/day. The total cost of the composite unit was Rs. 7524.

■ **KEY WORDS :** Solar water heater, Solar distillation, Dehumidification, Composite unit

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Many scientists have worked on various aspects of solar water heating and distillation technology throughout the world. The solar energy is capable to harness directly or indirectly for water heating, space heating, distillation, drying cooking etc. Conversion of solar energy into the thermal energy can be achieved by employing collectors. The efficiency of solar appliances can be increased by incorporating solar concentrators. Xie *et al.* (2011) studied about the recent development of the concentrated solar energy applications using Fresnel lenses. Nahar (2002) studied that many companies in India manufacture solar water heaters but these were not becoming popular in the domestic sector because of their high cost. Umamaheswaran (2005) studied details of the construction, testing and analysis of parabolic trough collector/reflector configuration for small scale domestic purpose water distillation application. Singh (2011) carried out experimental study was conducted in a single slope solar still integrated with solar water heater.

Distillation is one of many processes that can be used for water purification. Access to safe drinking water may be more difficult in the future, due to various reasons such as population growth, environmental pollution and climate change. Significantly elevated levels of arsenic and fluorides in the groundwater have been detected, which can cause diseases like the fluorosis in the exposed population. A solution which meets up all the proposed requirements and offers adequate water quality at an affordable price is the technology of solar distillation. By adding raw water in distilled water it can be converted in to consumable water. The composite unit of solar water heater and distillation unit can add advantages like reducing the overall cost of system making it more versatile

Ahmed *et al.* (2010) designed a solar still system and built to utilize solar energy in the Gulf States environment to produce drinking water from the sea. The result found that the efficiency of the solar still with a cooling tube was about 4 per cent lower than that of the solar still without a cooling tube. Sengar and Kurchania (2008) developed and evaluated solar geyser cum distiller device, having a capacity of 100 l. Overall efficiency of SGD for winter and summer was found to be 36.70 and 27.48 per cent, respectively. The yields of distilled water were 5007 ml/m^2 day in winter and 5275 ml/m^2 day in summer, respectively. Badran *et al.* (2010) designed, built and tested a portable solar water heater. A normal satellite dish of 150 cm diameter was used as a concentrator for solar radiation. The highest efficiency obtained for this mode was 77 per cent. Galvez *et al.* (2009) developed a solar multi-stage membrane distillation concept in order to develop a high-efficiency and cost-effective system for seawater desalination.

■ METHODOLOGY

System description :

Water heating tank and water dehumidification tank were constructed and were connected in the present Fresnel lens concentrated solar water cum distillation unit (FLCSWHD), having 70 lit water heating capacity as shown in Plate1. The solar energy concentrated by Fresnel lens was absorbed by the plate which was placed in water heating tank. Surrounding water contained in water heating tank was heated by this absorber plate's heat through conduction. Water of both tanks was heated by natural convection.

The dehumidification tank was covered by glass and it was inclined towards distillation collecting trough. It was divided into two chambers to hold hot water and to collect condensed water. In water dehumidification tank a copper tube was provided. This copper tube carried inlet water for solar water heater. Hence, copper tubes surface area was cooler and it helped in condensation of incoming water vapour. The condensation also took place on the surface of inclined glass cover. This condensation slides down the slope and was collected in distilled water collecting trough. One pipe outlet provided at upper portion of water heating tank to get hot water and another pipe outlet provided at bottom of dehumidification tank to get distilled water as shown in Plate A.

Plate A: Experimental set up of FLCSWHD

Performance evaluation :

The FLCSWHD unit tested for no load condition and full load condition in month of April 2012 to find out its performances. Temperature corrected electronic sensors with 0.1°C accuracy were used to measure the water temperature at different points of the FLCSWHD. Digital solarimeter was used to measure the instantaneous solar radiation on the surface of collectors. All measurements were taken during the period of 9:00 to 18:00. No load test was conducted to evaluate the performance of Fresnel lens concentrator solar water heater without load (water) in the container. During no load test absorber plates temperature and for full load test hot water outlet temperature was principally observed.

Performance calculations :

Solar water heater efficiency :

Efficiency of the integrated solar water heater is defined as a ratio of amount of heat stored in the tank till evening to the total solar input received by the collector for the same period of time *i.e.*

$$\eta_{overall} = \frac{m\,s \times (T_f - T_a)}{I\,A_a\,\Delta t}$$

where,

$(T_f - T_a)$ –is difference in temperature of water in the evening and ambient temperature at the subsequent morning in ^{0}C, m is Mass of water in storage tank in kg, s is specific heat of water in kJ/kg ^{0}C, I is solar radiation in W/m^2, A_a is aperture area in m^2 and Dt is time interval in hr.

Efficiency of solar distillation unit (η) :

$$\eta = \frac{Q_e}{I}$$

where,

$$Q_e = Me \times f$$

where,

Me is daily output of distill water in kg/ m^2-day and f is latent heat of vaporization of water in W/kg

■ RESULTS AND DISCUSSION

Experimental observations have been shown in Table 1 and 2. Variation of solar radiation on collector surface during the measurement period was noted as 670 W/m^2 to 1085 W/m^2

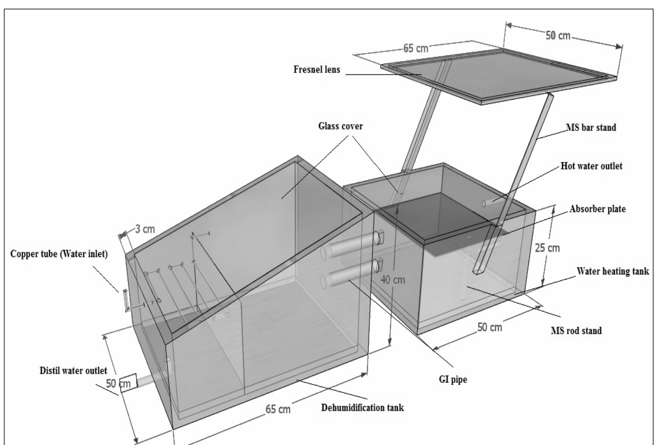

Fig. 1 : Isometric X-ray view of solar water heater coupled with distillation unit

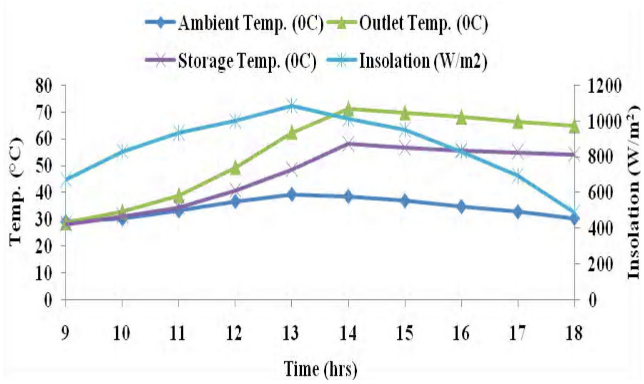

Fig. 2 : Full load thermal performance of solar water heater curve

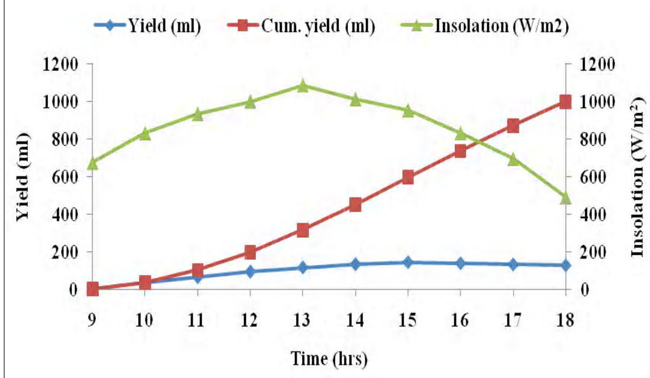

Fig. 3 : Thermal performance of solar water distillation unit curve

Table 1 : Performance of solar water heater full load test

Time (hrs)	Ambient temperature (°C)	Outlet temperature (°C)	Storage temperature (°C)	Insolation (W/m^2)
9:00	29.16	28.88	28.24	672.64
10:00	30.22	33.12	31.38	831.2
11:00	33.28	39.1	34.52	933.64
12:00	36.78	49.54	40.82	999.36
13:00	39.4	62.64	48.66	1085.74
14:00	38.64	71.42	58.3	1011.82
15:00	37	69.92	56.8	952.94
16:00	34.8	68.34	55.86	831.02
17:00	32.88	66.66	55.14	693.9
18:00	30.46	65.12	54.26	488.76
Total				8501.02

Table 2 : Performance of solar distillation unit

Time (hrs)	Ambient temperature (°C)	Yield (ml)	Cumulative yield (ml)	Insolation (W/m^2)
9:00	27.7	0	0	672.64
10:00	30.22	35.2	35.2	831.2
11:00	33.28	66.2	101.4	933.64
12:00	36.78	95.4	196.8	999.36
13:00	39.4	118.4	315.2	1085.74
14:00	38.64	135.8	451	1011.82
15:00	37	146.4	597.4	952.94
16:00	34.8	140.8	738.2	831.02
17:00	32.88	134.2	872.4	693.9
18:00	30.46	128.8	1001.2	488.76
next day 8.30		602.2	1603.4	8501.02

in month of April 2012. Overall efficiency of solar water heater was found to be 42.38 per cent and 28.78 per cent for solar distillation unit. Temperature coming out from tank was 20-25^0 C more than the ambient temperature. Total distilled water in 24 hours produced from distillation unit was 1.603 for 0.325 m^2 collector area *i.e.* 4.72 kg/m^2/day.

Conclusion :

The composite unit performed the functions of water heating and distillation satisfactorily. The maximum temperatures of hot water outlet 71.42^{0}C at 14:00 hrs and subsequent morning and evening outlet water temperature was 28.88^{0}C and 65.12^{0}C, respectively. Total distilled water in 24 hours produced from distillation unit was 4.72 kg/m^2/day.

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