EXPERIMENTAL INVESTIGATIONS ON A MULTI-STAGE TOWER TYPE OF SOLAR DESALINATION UNIT

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1. Introduction

A multi-effect distillation is one kind of practical technology which can be combined with solar heating system to produce fresh water from seawater. El-Nashar and Qamhiyeh (1990) had calculated the performance of MES evaporators under unsteady state operating conditions. The performance of a multi-effect solar desalination system was investigated by Abdel Dayem (2006) on the base of experimental study and numerical calculation. Zheng et al. (2006) developed a new kind of solar desalination unit, which is a triple-stage desalination unit, and the performance of the unit was tested under steady state conditions. Afterwards Chen (2007) and Chen (2009) continued to investigate the parameters optimization and the heat and mass transfer of the unit (Zheng et al. 2006) by simulation. In this paper one quadruple-stage tower type of solar desalination unit is developed on the basis of the unit (Zheng et al. 2006). The influences of the parameters on the fresh water production and the performance ratio of the solar desalination unit will be tested indoors under steady state conditions. The parameters of the unit are the flow rates of the heating water for the evaporator and the cooling water for the condenser, the flow rate of the feedstock, the inlet temperature of the heating water for the evaporator and the cooling water for the condenser, the start-up pressure inside the unit, etc, which will be classified into key parameters and secondary parameters after the experimental study based on how much the influences of the parameters are on the production of fresh water and the performance ratio of the unit. The experimental results also can be used to validate a simulation model proposed for the theoretical calculation for multi-stage tower type of solar desalination units and the optimization of the parameters.

2. Description of a multi-stage tower type of solar desalination unit

2.1. Overview of the solar desalination unit

As shown in Fig.1 the quadruple-stage tower type of solar desalination unit has a cylindrical outer shape with a height of 3260 mm and a diameter of 880 mm. It is composed of an evaporator, the first stage of evaporator-condenser, the second stage of evaporator-condenser, the third stage of evaporator-condenser and a condenser. See Fig.2. The shell of the unit is made of stainless steel and the components inside the unit are made of copper. The first stage of evaporator-condenser, the second stage of evaporator-condenser, the third stage of evaporator-condenser and a condenser are separated.

2.2. Evaporator and condenser

Evaporator and condenser are designed in the same way. They are made of 222 copper pipes with a length of 300 mm and a diameter of 25 mm. The copper pipes are connected with one upper copper plate and one bottom copper plate vertically. See Fig.3. The heat exchange area for evaporator and for condenser is about 6.22 m^2.

Fig.1: Photo of the solar desalination unit.

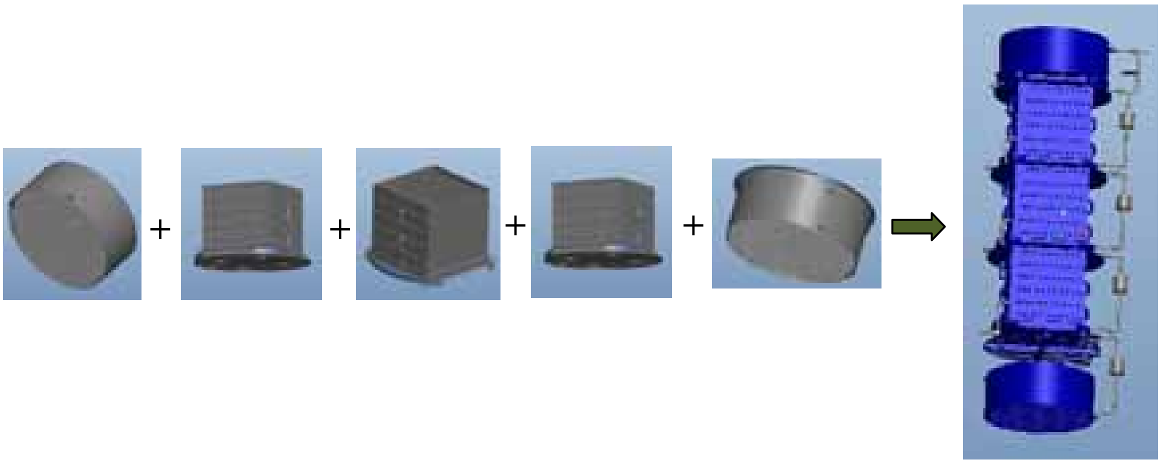


Fig.2: Components of the solar desalination unit.

Fig.3: Photo of the evaporator and condenser.

2.3. Evaporator-condensers

The first stage of evaporator-condenser, the second stage of evaporator-condenser and the third stage of evaporator-condenser have the same structures. All of them are made of 121 copper pipes with a length of 480 mm and a diameter of 22 mm. The pipes are connected horizontally with the walls of the evaporator-condensers. See Fig.4. The heat exchange area for the evaporator-condensers is 4.0 m^2.

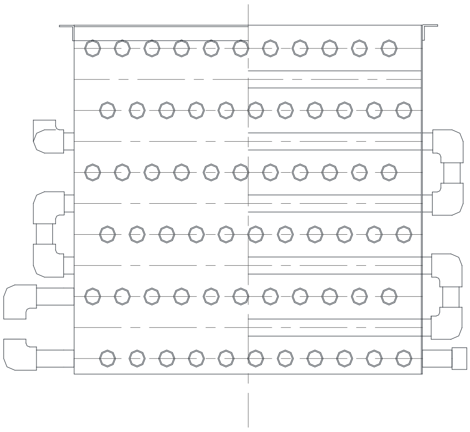


Fig.4: Diagram and photo of the evaporator-condensers.

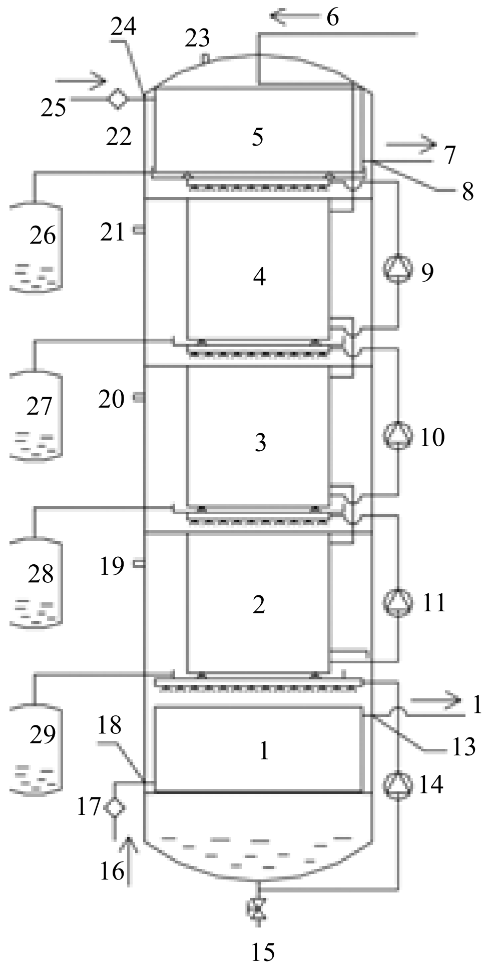
Fig.5: Experimental setup.

3. Experimental setup

Fig.5 shows that one quadruple-stage solar desalination system is tested indoors under steady state condition. The experimental setup includes a hot water storage tank, a cool water tank, a desalination unit, four fresh water tanks, pumps, sensors and data logger. Those parameters, which are the flow rates of heating water and cooling water, the inlet and the outlet temperatures of heating and cooling water, the pressures and the temperatures in different stages, the mass of fresh water entered into the fresh water tanks from different stages, the mass of sea water entered into the desalination unit, are measured.

3.1. Operating principle

The schematic diagram of the solar desalination unit is shown in Fig.6. Before the fresh water production, the desalination unit is evacuated to a certain value to reduce the boiling temperature of sea water inside the desalination unit. Hereafter the hot water with a temperature higher than the boiling temperature inside the desalination unit flows through the evaporator. The seawater outside the evaporator will evaporate. While the circulation pump in the first stage is operating, the sea water is sprayed from the spouts on the top of the stage and flow through the outer surface of the horizontal tubes. The sea water outside the horizontal tubes evaporates and the vapour from evaporator condenses inside the horizontal tubes. The evaporation and condensation in the second stage and the third stage of evaporator-condensers take place in the same way as they do in the first stage of evaporator-condenser. The feedstock is absorbed into the desalination unit from outside. The feedstock flows through the condenser, the third stage of evaporator-condenser, the second stage of evaporator-condenser, the first stage of evaporator-condenser and finally reaches the evaporator.



1.Evaporator; 2.First stage evaporator-condenser; 3.Second stage evaporator-condenser; 4.Third stage evaporator-condenser; 5.Condenser; 6. Inlet for feedstock (see water); 7.Outlet for cooling water; 8.Sensor for the outlet temperature of cooling water; 9, 10 and 11.Cirlculation pumps; 12.Outlet of heating water; 13.Sensor for the outlet temperature of heating water; 14. Cirlculation pump; 15.Outlet for ejected sea water; 16.Inlet for heating water; 17.Flow meter for heating water; 18.Sensor for the inlet temperature of heating water; 19, 20 and 21. Sensors for temperatures and pressures; 22. Flow meter for cooling water; 23.Sensors for temperatures and pressures; 24.Sensor for the inlet temperature of cooling water; 25.Inlet of cooling water; 26, 27, 28 and 29.Storage tank for fresh water.

Fig.6: Schematic diagram of the solar desalination unit.

4. Performance ratio

Performance ratio (PR) is a parameter introduced to evaluate desalination units. It is defined as:

$$PR = (mh_f)/E \quad \text{(Eq.1)}$$

where m is the total mass of the fresh water produced by the desalination unit (kg).

h_f is the latent heat of sea water (kJ/kg).

E is the thermal energy supplied to the evaporator by the heating water (kJ).

5. Experimental study in the future

The influences of the parameters, such as the flow rates of the heating water and the cooling water, the flow rate of the feedstock, the inlet temperatures of the heating water and the cooling water, the start-up pressure inside the unit, on the fresh water production and the performance ratio of the solar desalination unit will be carried out.

6. References

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