CHAPTER 3

Experimental Setup

This chapter describes the experimental setup of the experimental system used for laboratory testing at the solar thermal desalination of seawater by bubble pump technique. First, the structural design of the system will be discussed. Next, the experimental setup will be described including the input considered and data acquisition systems.

3.1 Description of the Operating System

Figure 3.1 illustrates a diagram for the desalination system functioning on solar energy with the bubble pump technique.

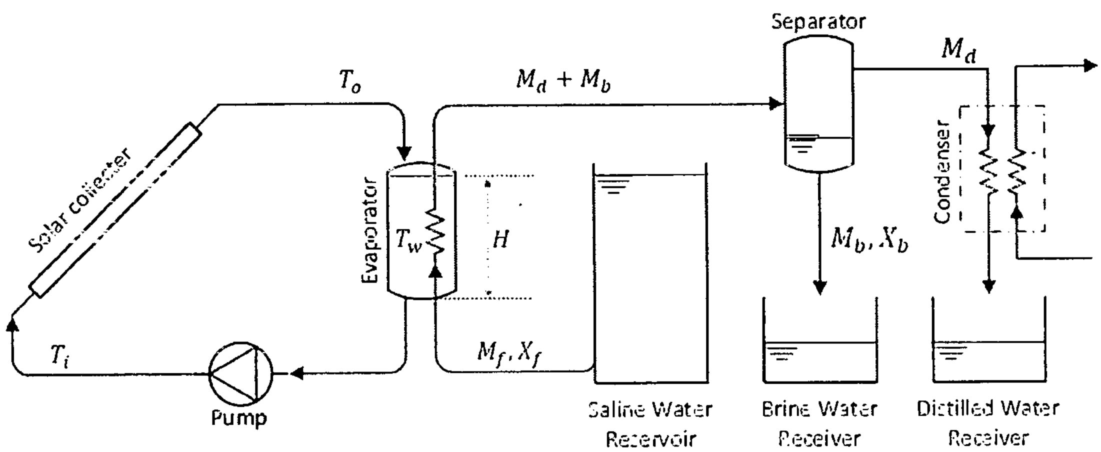


Figure 3.1 Diagram of the complete operating system.

40% of Propylene glycol was added to the water in the solar collection system to extend the boiling point of water to about 103 °C. The fed seawater (M_f) at a temperature (T_f) and a salinity (X_f) was fed into the evaporator through a coil tube in a counter-current mode, where the heat of hot water from the solar collector $(\dot{Q}_{coll})$ was transferred. After receiving the heat from the evaporator, the temperature (T_f) of the fed saline water was increased. While it reached the boiling temperature (T_b), the vapor formed at a rate of (M_d). The salt water and steam were separated in the separator tank by their densities. The vapor went through a pipe into the condenser which was cooled by cool water at a temperature (T_{cw}) and with a mass flow rate of (M_{cw}), thus the distillate could be obtained with a flow rate of (M_d). Whereas the brine water (M_b) would go through another pipe to a receiver.

3.2 The Bubble Pump Design

The heat exchange in this study was done between the salt water solution containing in the bubble pump and the hot working fluid from the solar collector. Thus, the design is a common heat exchanger of a tube inside another. The inner tube was designed in a spiral shape as it increases the size of the contact area, resulting to higher quantity of heat transfer.

The bubble pump unit in this laboratory was designed as a spiral tube enclosed in a cylindrical shaped tube as illustrated in Figure 3.2. The cylindrical tube was filled with working fluid from the solar collector which is near boiling temperature. The salt water traveling through the spiral tube exits at boiling temperature. The cylindrical tube has an internal capacity of approximately 1.4 liters.

The salt solution inside the coil tube can crystallize forming grains of salt during the system's testing. The salt crystallization can affect the system's performance and must be prevented. Therefore, water was injected into the coil tube to flush the grains of salt before and after testing.

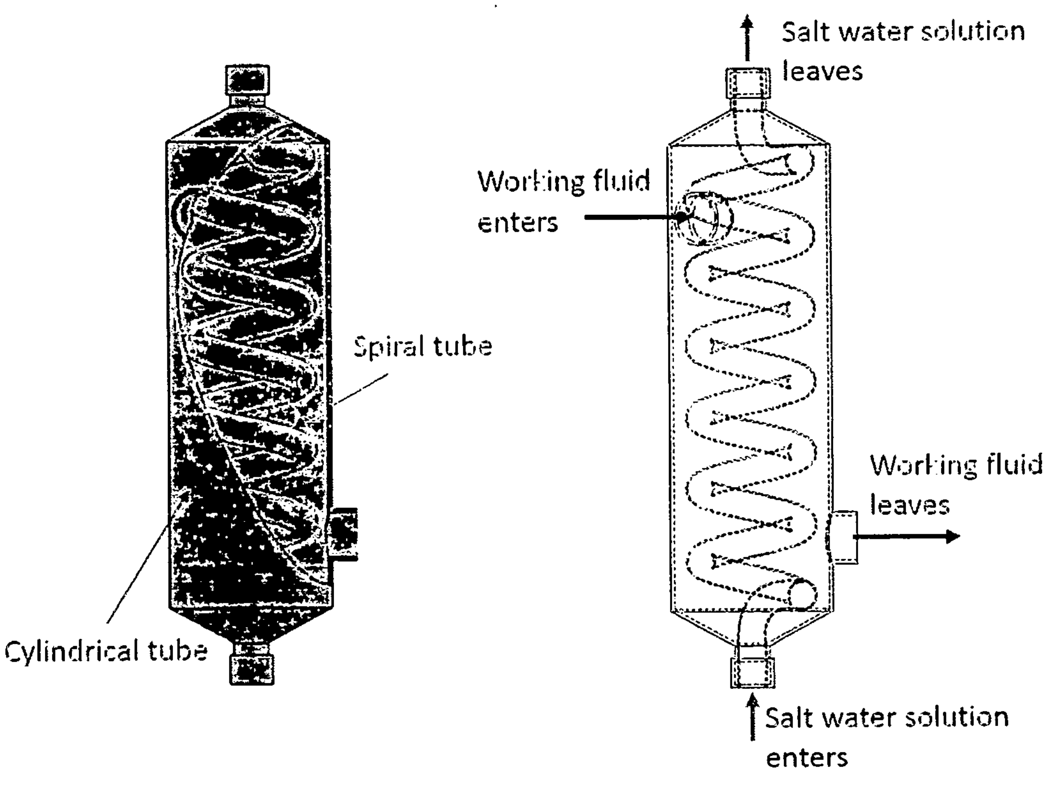


Figure 3.2 The bubble pump design.

3.3 Experimental Setup

3.3.1 Sample preparation and Data Records

The samples had salt content of 3, 3.5 and 4% of water by weight were prepared for this laboratory instead of testing natural sea water. The artificial samples of sea water were made of salt-water corresponding to the natural sea water which is a mixture of 96.5% water, 3.5% salts [16], and smaller amounts of the substances. The major dissolved substance in sea water is sodium chloride (salt). Salt content of water can vary from 3.1 to 3.9% in most parts of the ocean [17]. The samples were tested in different height levels of solution in the bubble pump which were 270, 216 and 162 mm, or 100, 80 and 60%, respectively.

The experiments were conducted during the months of November, December and January when the sky was mostly clear. (See the date of testing cases in Appendix B). The considering parameter records were shown in Figure 3.3. All temperature data (including solar radiation) were recorded every minute by a data logger. Yield rate of distilled water and brine water were manually recorded every 30 minutes.

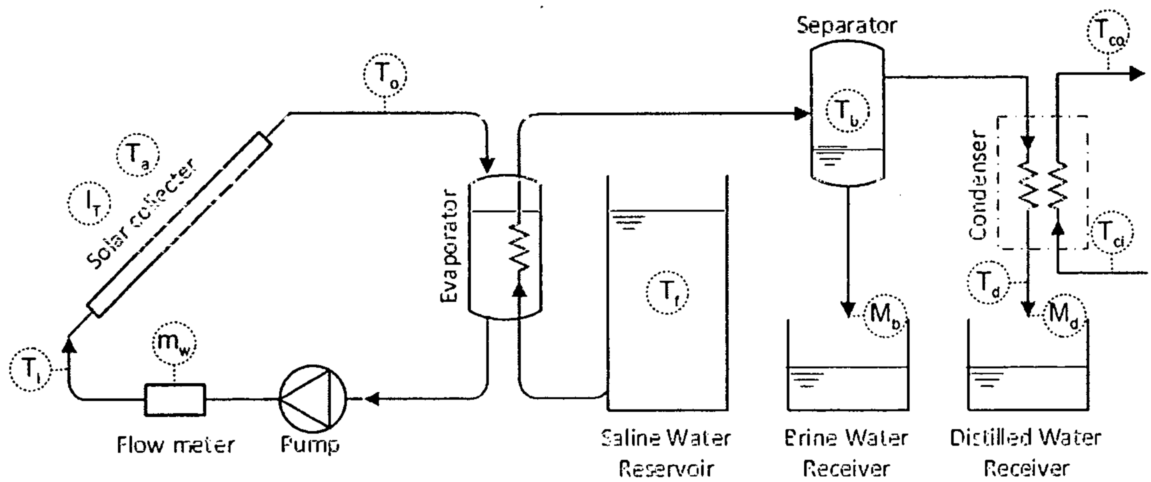
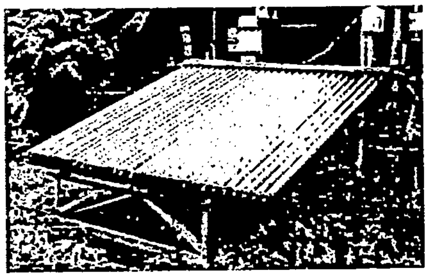
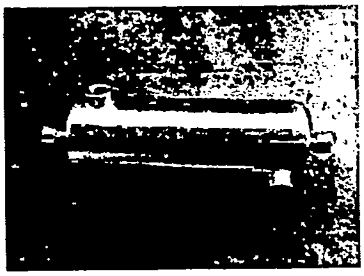


Figure 3.3 Schematic diagram of the experimental system.

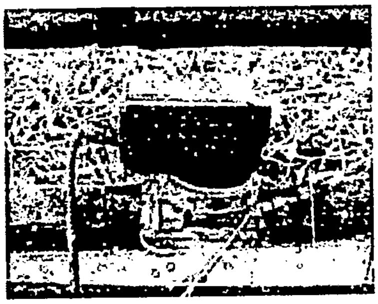
3.3.2 Main System Components

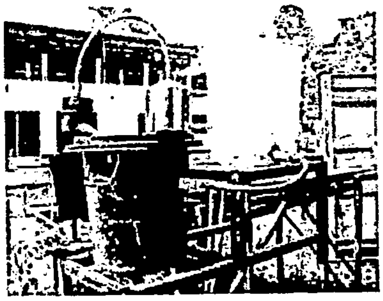
Figure 3.4 presents the pictures of the system components and the descriptions were shown in Figure 3.4. The main system unit consisted of an evacuated-tube solar collector, electrical pump, evaporator, saline water reservoir, separator and a condenser.



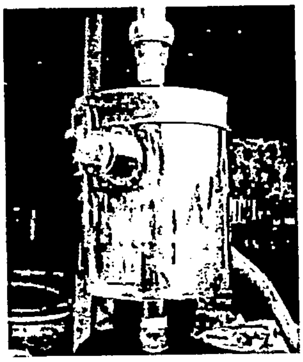


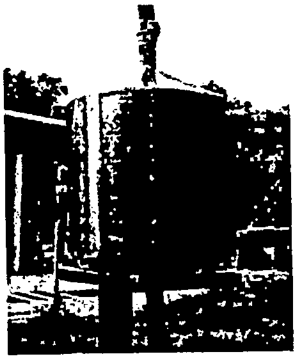
(a) Evacuated-tube solar collector (b) Evaporator

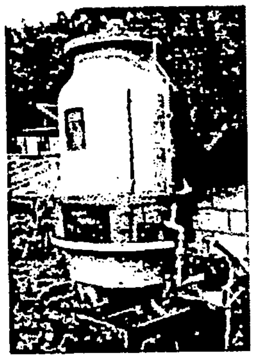




(c) Hot water pump (d) Saline water reservoir







(e) Separator (f) Condenser (g) Cooling tower

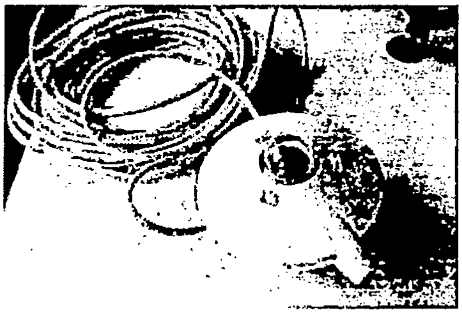
Figure 3.4 Components in the experimental setup.

Table 3.1 Descriptions of components in the system.

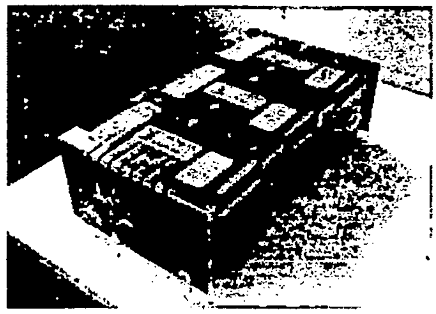
Devices	Properties
Solar collector	An evacuated-tube solar collector with $F_R(\tau\alpha)_e$ of 0.51 and $F_R U_L$ of 3.42 W/m^2K, aperture area of 2.8 m^2.
Evaporator	A coil tube installed in a shell.
Hot water pump	CP 15-1.5 Class F 1~220V I(A)=0.28 P(W)=28.
Saline water reservoir	The level of reservoir was controlled.
Separator	A small tank with volume of about 1 liter.
Condenser	Shell and tube heat exchanger.
Cooling tower	Model: BKC 10 RT. Fan Motor: 14 H.P.

3.3.3 Measuring Instrumentation

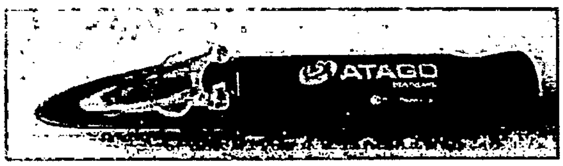
Figure 3.5 showed the pictures of the system components with the description shown in Table 3.2.



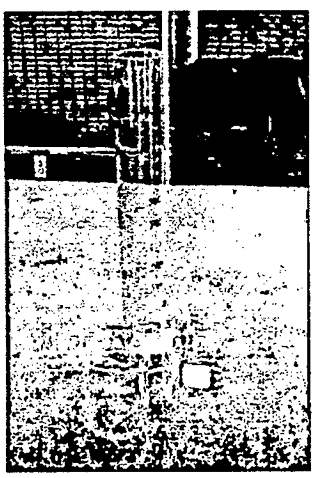
(h) Pyranometer



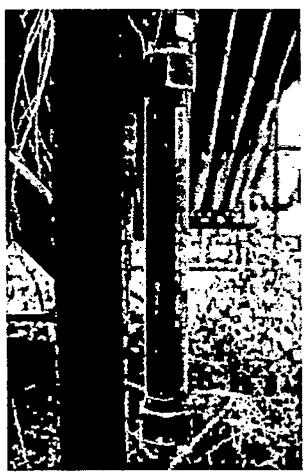
(i) Data logger



(j) Salinity measurement



(k) Measuring glasses



(l) Flow meter

Figure 3.5 Measuring instrumentation.

Table 3.2 Descriptions of measuring instrumentation in the system.

Pyranometer	Brand: WISCO Model DL2000, Accuracy $\pm 0.5\%$.
Data logger	Brand: WISCO Model DL2000, Accuracy $\pm 0.5\%$.
Salinity measurement	Brand: Atago 2313, Accuracy $\pm 0.1\%$.
Measuring glasses	Accuracy $\pm 10ml$.
Flow meter	Brand: Nitto Model VA 10S-15. Accuracy $\pm 10\ kg/h$.

3.4 Problem during Testing

The salt solution could be considered as a cooling system as it absorbed the heat from the solar working fluid,. When the amount of salt water solution in the salt solution reservoir was insuficient, the PVC pipe in the solar collector system ruptured (see Figure 3.6). The rupture was caused by pressure beyond the limits of PVC pipe to contain.

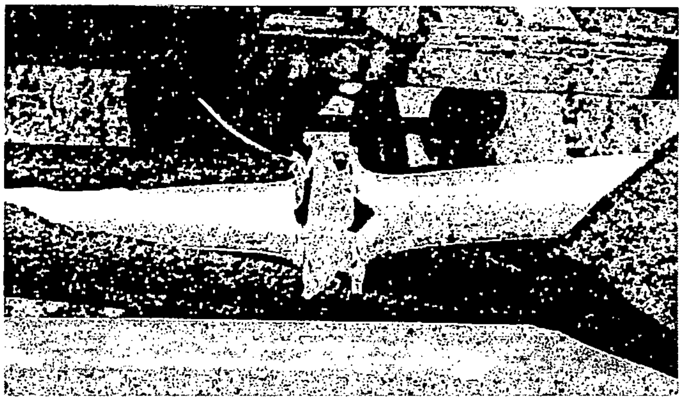


Figure 3.6 The explosion on the pipe of the solar collector system.

3.5 Expected Results from Experimental Investigation

The overall heat transfer coefficient of the evaporator (UA) would be empirically correlated. The influence of the design parameters on the distilled water productivity rate can be investigated directly. The effect of reservoir level and initial salinity of the salt water solution on the distilled water production would be numerically examined from the experimental data. The model of the bubble pump was the relationship of the distilled water rate (M_d) with the outlet temperature from the solar collector(T_o), the initial salinity of the solution (X_f) and the reservoir level of the bubble pump(H). The bubble pump model would be used for whole system simulation to find the distilled water yield with the experimental verification.