CHAPTER III

APPARATUS AND PROCEDURE

3.1 The Effect of Various Important Parameters

The apparatus used for this experimental study could be separated into 3 systems: Hot water storage system, hot water preparation system, and cold water feeding system.

3.1.1 Hot Water Storage System

The hot water storage system consisted of four cylindrical storage tanks, 1.524 m. height, made of fiber glass with 3 millimeter thickness. These four hot water storage tanks had diameters of 0.152, 0.203, 0.305, and 0.356 m.. Each tank was equipped with 3.2 cm. inlet and exit pipes. Various sizes of storage tanks had been investigated for the effect of L/D and D/d ratios, as shown in Table 2 (tank No. 5 is the tank No. 3 but is laid down on its side to make L/D ratio small). Cromel-Alumel thermocouples (range 0 - 1200 °C) were used as part of the water temperature measuring devices. Two thermocouples were placed at the water inlet (bottom of the tank) and water outlet (top of the tank) to measure the temperature of inlet and outlet water. Other thermocouple lines were placed along the side of the tank, 0.127 m. apart (all together nine measuring points) to measure the water temperature gradients. See Figure 3. The other ends of

Table 2

Dimensions of Storage Tanks

Tank No.	L m.	D m.	d m.	$\frac{L}{D}$	$\frac{D}{d}$
1	1.524	0.152	0.032	10.00	4.75
2	1.524	0.203	0.032	7.50	6.34
3	1.524	0.305	0.032	5.00	9.53
4	1.524	0.356	0.032	4.28	11.13
5	0.305	0.508*	0.032	0.60	15.88

* Hydraulic Radius

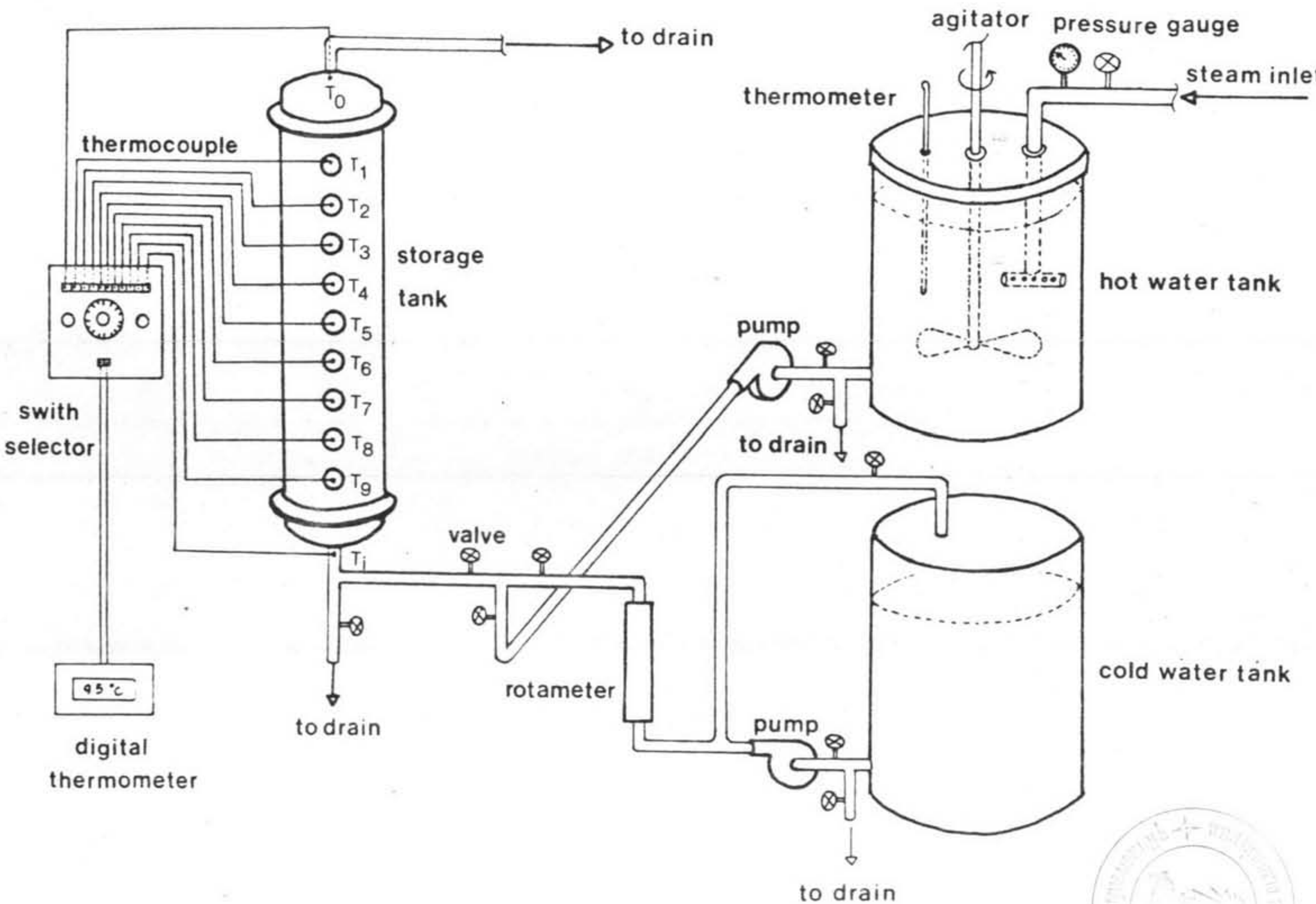

Figure 3 Schematic of apparatus

thermocouples were connected to a selector switch in order to detect the point of desire temperature readings. Two wires were extended from the selector switch and connected to a Digital thermometer type 2809 Yokogawa Electrical Works LTD. The temperature of the water could be read out directly from this Digital thermometer in degree celcius.

3.1.2 Hot Water Preparation System

Hot water preparation system consisted of a 200-liter hot water tank equipped with a stirrer for well mixing purpose. The tank could be closed or opened with a lid. The water outlet was located near the base of the tank and connected with a Tee-fitting; one exited to a centrifugal pump 0.35 horsepower. This pump could draw the hot water with a maximum flow rate of 25 l./min. into the hot water storage tank. The other exit was used for draining purpose. The steam pipe was connected from the boiler, constructed through the lid, and extended further toward the center of the tank. Direct steam would be used for heating up the water to a desire temperature. There was also a thermometer with coupling attached to the tank for hot water temperature reading. All hot water pipes and preparation tank were insulated with micro-fiberglass 3.00 cm thick.

3.1.3 Cold Water Feeding System

Cold water feeding system consisted of a 200-liter tank which would be used for storing the cold water and keeping the water head constant throughout the experiment. The water outlet was located near the base of the tank and connected with a Tee-fitting; one exited to a centrifugal pump 0.35 horsepower with a maximum flow rate of 24 l./min.. The other exit was used for draining water. There was a bypass from the pump outlet back to the tank, so the pump could run with a constant speed. Calibrated rotameter with a maximum capacity of 14 l./min. and connected to the pump outlet was used for measuring the flow rate of the cold water to the storage tank.

To start the experiment, the hot water was prepared by spraying steam directly into the cold water in the preparation tank. The agitator was turned on for the better mixing between the cold water and the hot steam. When the temperature reached 100 °C, the steam was shut off. The hot water was then, pumped into one of the storage tanks until the water filled up the tank and started to overflow. At this moment, the hot water temperature throughout the storage tank was approximately 96 °C. Tap water was drawn into the cold water tank and the flow rate was adjusted to approximately the same as the flow rate of the hot water overflown from the storage tank. The cold water was then pumped through the calibrated rotameter and passed to the bottom of the storage tank, forcing hot water out through the top port. Cold water flow rates were set for 30, 50, 70, and 90 % of the rotameter. The temperature differences between the inlet and outlet water were measured as well as the temperature differences along the side of the tank. The temperature of the hot water was recorded for every ½ or 1 minute until all the hot water had been replaced by cold water and the temperature throughout the tank did not change. This would be for one tank size experiment. With the same procedure, four other storage tanks had been repeated.

From the highest temperature, T_h , the final temperature reading, T_1 , and the temperature reading at various time, T_o , dimensionless temperatures $(T_o-T_1) / (T_h- T_1)$ was calculated at different time. And from the flow rate, Q , the volume of the storage tank, V , dimensionless time Qt/V was calculated. The values of dimensionless temperature and dimensionless time were then plotted at different flow rate for the same tank and for different tank sizes at constant flow rate. Finally, hot water extraction efficiency could be evaluated.

3.2 The Effect of Cold Water Inlet Location

One of the storage tank with a diameter of 0.305 m. was chosen for this experimental study. The cold water was pumped into the tank to replace the hot water, as in part (1). However this time, the water inlet was being reversed by feeding the cold water into the top of the tank and forcing the hot water out from the bottom. Hence, the piping outlet had to be altered to prevent a large amount of uncontrollable water flow due to gravitational force. This could be done by connecting the pipe from the bottom outlet up height to the same length of the storage tank. Thus the water outflow would have the same flow rate as the water inflow. The procedure was, then repeated as in part (1). The inlet-outlet water temperatures as well as the temperatures along the tank were recorded. The water flow rate was kept at 30, 50, 70, and 90 % of the rotameter.

3.3 The Effect of Heat Conduction through the Tank Wall

One of the storage tanks with a diameter of 0.203 m. was chosen for this study purpose. The tank wall inside was lined with a copper sheet 1.5 mm. thick. Two sets of thermocouples were placed at the top and the middle of the tank. Each set consisted of two thermocouples which are aligned in the same plane, one was extended to the center of the tank and the other was connected to the surface of the copper sheet. (See Fig. 4). In this respect, the temperature difference of the water between the center of the tank and the wall could be investigated to see the effect of the heat conduction. The procedure of pumping cold water into the storage tank and extracting hot water out as well as temperature recording was the same as in part (1). The volume flow rate of cold water was kept at 30, 50, 70, and 90 % of the rotameter.

Fig. 5 shows the photographs of the experimental Apparatus.

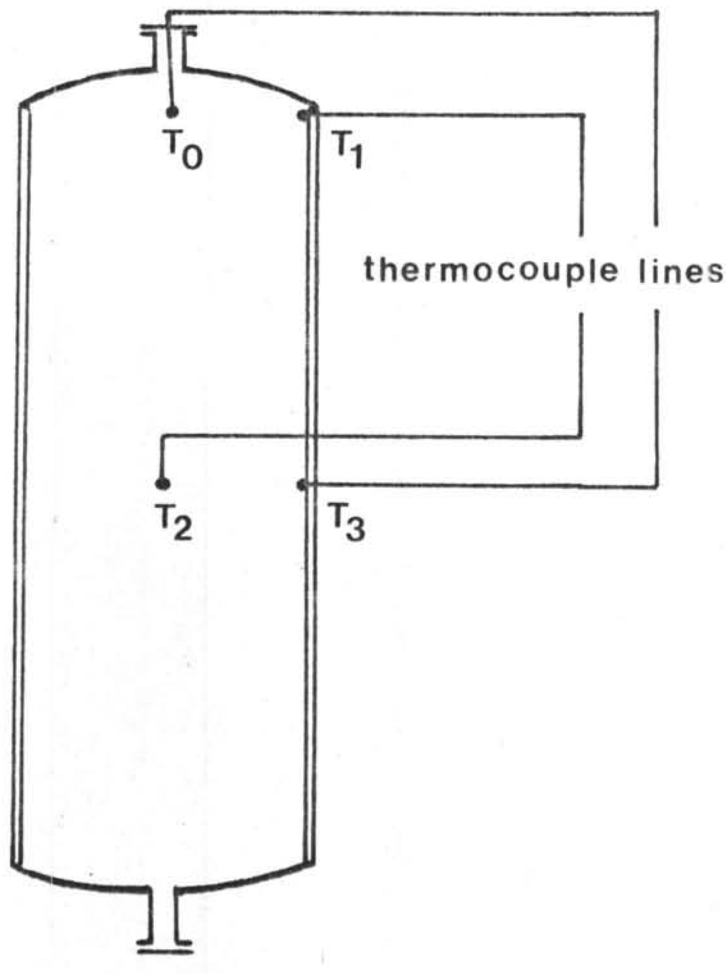

Figure 4 Location of temperature measurement in a copper lined storage tank

Figures 5

Photographs of Experimental Apparatus