CHAPTER IV

EXPERIMENTAL APPARATUS AND PROCEDURE

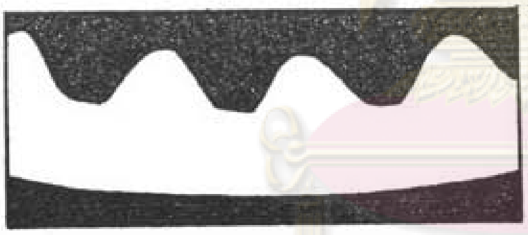
4.1 Experimental Apparatus

4.1.1 The Wickless Heat Pipe

The wickless heat pipes used in this study were either made at the Unifab Equipment Co., Ltd. using the vacuum method or at the Department of Chemical Engineering, Chulalongkorn University using the boiling method. The heat pipes were made of inner spiral grooved copper tube (The tube specification and configuration are shown in Table 4.1 and Figure 4.1 respectively.), 9.5 mm. in outer diameter and 900 mm. long. The evaporator and condenser sections are 400 mm. each, whereas the adiabatic section is 100 mm. long. Freon 113 and Freon 22 were used as the working fluid. As mentioned previously, the primary objective of this work is to test the thermal performance of the wickless heat pipes to obtain basic data to design a heat exchanger for use in the low temperature range. Both types of working fluids have operating temperatures in the range of -10 to 100 ^{o}C, which satisfy the requirement.

Table 4.1 Specification of copper grooved tube

Outside Diameter (mm.)	9.52
Average Wall Thickness (mm.)	0.41
Bottom Wall Thickness (mm.)	0.28
Groove Depth (mm.)	0.25
Lead Angle (degree)	25
Number of Groove	50
Unit Weight (g/m)	105



3/8 "x0.0138 Ave (0.011" Min)

Groove depth : 0.0059"

Lead angle : 25^{o}

Number of groove : 50

Figure 4.1 Configuration of copper grooved tube

4.1.2 The Experimental Set Up

A schematic diagram of the performance testing unit is shown in Figure 4.2 It consists of the following parts and facilities:

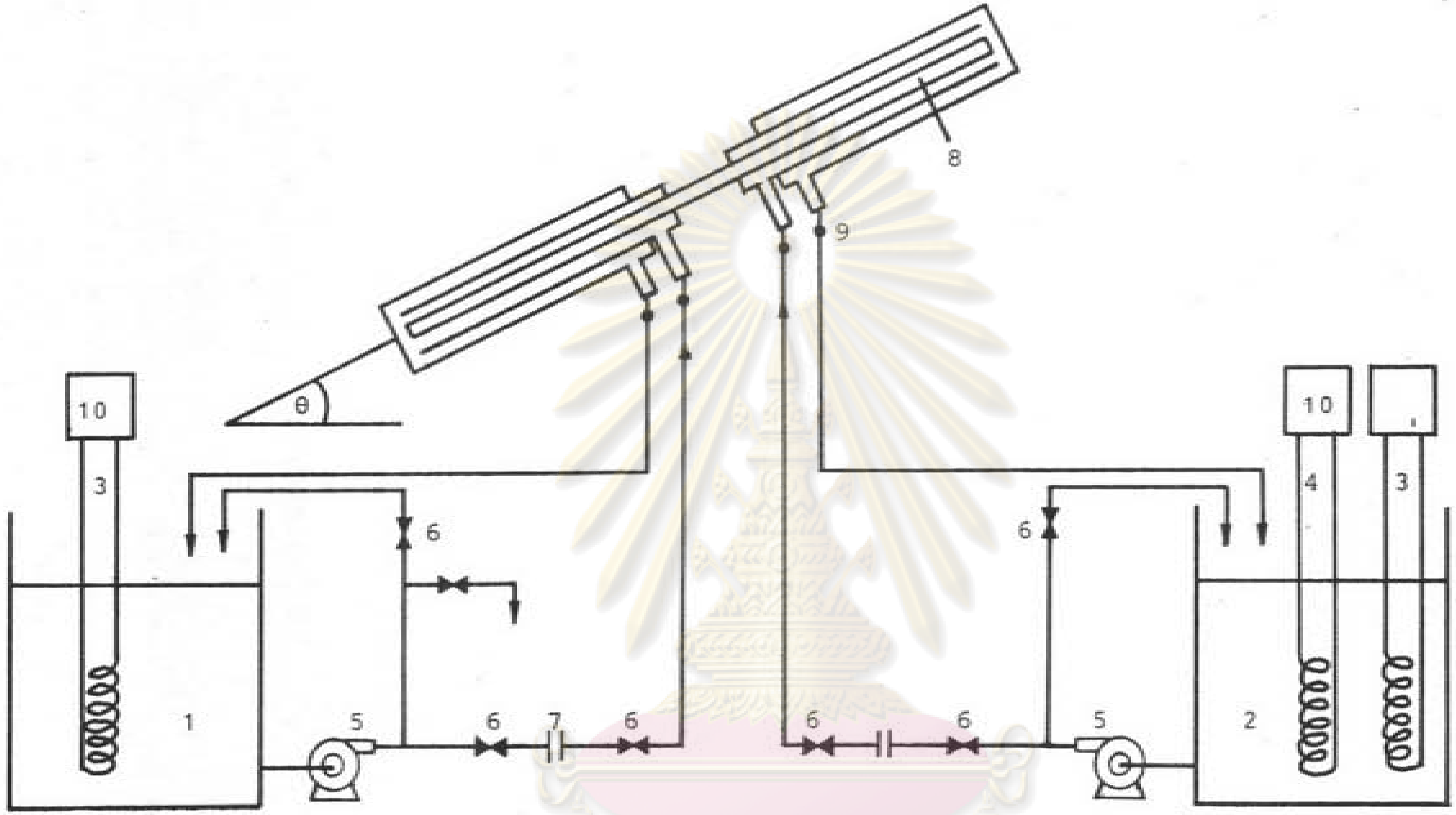


Figure 4.2 Schematic diagram of the experimental set up.

1. hot water tank 2. cold water tank
3. heating coil 4. cooling coil
5. water pump 6. valve
7. orifice meter 8. heat pipe
9. thermocouple 10. temperature controller

1. Hot Water Tank

A hot water tank is use to generate and store hot water for supply to the heating jacket. Two heating coils of 2000 W and 1000 W were used to heat the water. The temperature of the hot water was controlled by an on-off temperature controller in order to maintain a constant temperature in each test run. The power supply to each heater was connected to a variac to get rid of the offset by adjusting the voltage supplied to each heater.

2. Cold Water Tank

Like the hot water tank, the cold water tank is used to generate and store water for supply to the cooling jacket. A compression type air-conditioning cooling coil using Freon 22 as working fluid was used to cool the water. The water temperature was controlled by an on-off temperature controller. Besides the cooling coil, a 1000 W heater was also used to apply a little heat to the water so that the water temperature could be controlled accurately.

3. Heating and Cooling Jackets

The heating and cooling jackets were installed around the evaporator and condenser sections, respectively. The tested heat pipe exchanged heat between the hot and cold water flowing around the evaporator and condenser sections. At the inlet and outlet of each jacket, the Pt 100 Ω resistance bulb thermometers were inserted to measure the inlet and outlet temperature of water.

4. Centrifugal Pumps.

Two centrifugal pumps (0.5 H.P.) were used to circulate the water in the hot and cold water tanks and to pump the water through the jackets.

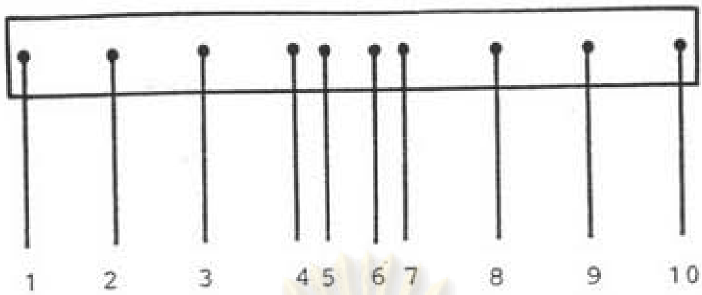


Figure 4.3 The tested heat pipe.

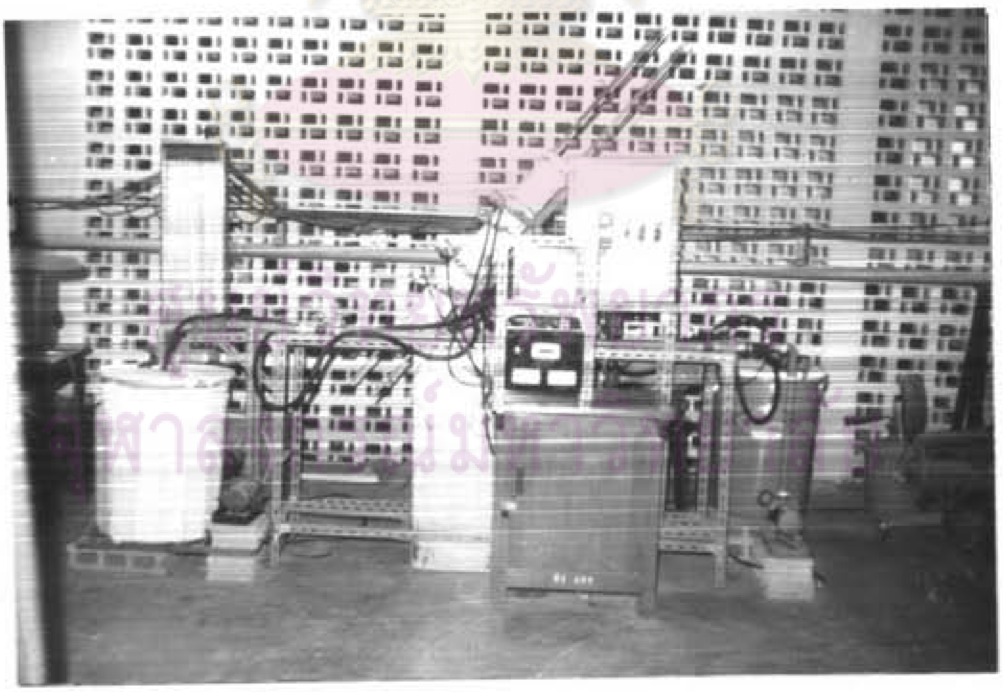


Figure 4.4 Photograph of the experimental set up.

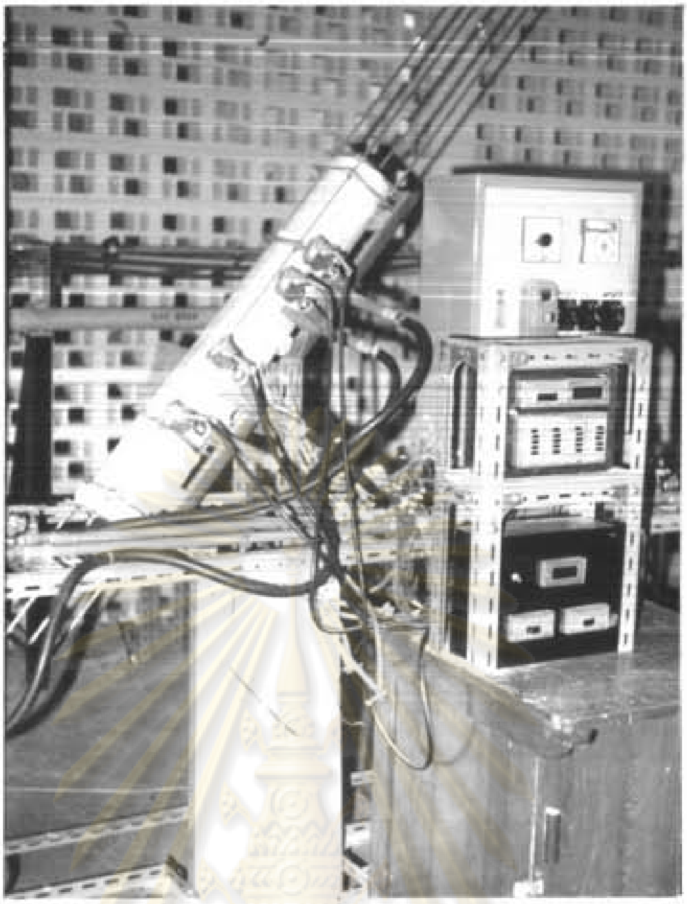


Figure 4.5 Photograph of temperature indicators and selector switchboxes.

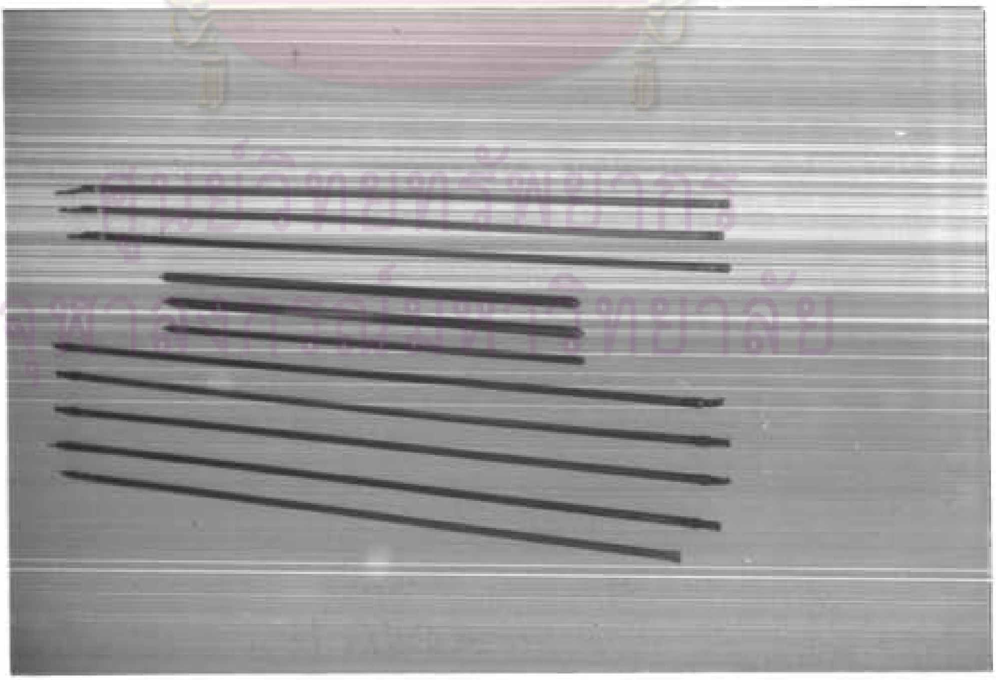


Figure 4.6 Photograph of the heat pipes.

5. Orifice Meters

The quantity of heat exchanged between the hot and cold water could be determined if the temperature difference between the inlet and outlet of either stream was known together with its mass flow rate. The sharp edge orifice plates were used in this experiment to measure the flow rates. The pressure drop across each orifice plate was measured by a manometer filled with carbon tetrachloride, and the pressure drop of each plate was calibrated against the flow rate prior to the experiments.

6. Thermocouples and Temperature Indicator

The measurement of the temperature profile along the tested heat pipe was normally carried out using 20 sets of Chromel-Alumel type thermocouple (320 micron in diameter) attached onto the outer wall of the heat pipe. The attached positions are as shown in Figure 4.3, with two sets of thermocouple being used at each axial position. The measured temperatures were displayed on a temperature indicator via a 20-point selector switchbox.

4.2 Experimental Procedure

Once the heat pipe to be tested was installed properly in the testing unit, the following steps were performed.

1. First the inclination angle of the heat pipe from the horizontal level was adjusted to the desired value.

2. Next the temperatures of the hot and cold waters in the tanks were set and maintained at the desired values.

3. When the water temperatures had reached the desired values the flowrates of both streams, which were indicated by manometers, were adjusted and kept constant during the whole test run.

4. When the steady state had been reached, the inlet and outlet temperatures of the hot and cold waters as well as the surface temperatures along the heat pipe were recorded.

5. Next the experiment was repeated at a new flowrate by repeating steps 3 and 4.

6. The above procedure was repeated to see the effects of the main parameters, that is, the inclination angle, the temperature difference between the hot and cold streams and the liquid fill quantity in the heat pipe.

4.3 Analysis of experimental data

When the necessary experimental data had been obtained the heat transfer rate through the heat pipe was calculated from the inlet and outlet temperature difference together with the flow rate of either stream as follows:

$$Q = \rho F C_p (T_i - T_o) \tag{1}$$

The effective thermal conductivity, k_{eff}, of the heat pipe was next calculated using the formula suggested by E. Schmidt (45)

$$k_{eff} = \frac{LQ}{A_{cross} \Delta T_m} \tag{2}$$

The temperature difference ΔT_m is the difference between the average wall temperature of the evaporator and condenser sections. A_{cross} is the cross sectional area of the pipe based on the outer tube diameter. L is the distance between the middle points of the evaporator and condenser sections, which was 500 mm. in this study.