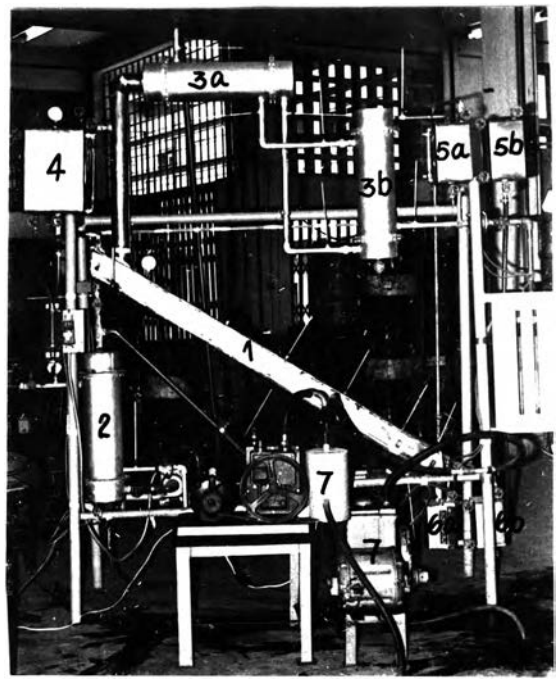
Chapter IV

EXPERIMENTAL EQUIPMENT

The equipment was designed and constructed for the present experiments. It consisted of several units connected together as shown in Figure 3. The details of each unit are as followed:

4.1 An Inclined Evaporator (Evaporating Chamber)

It was a closed rectangular chamber of 1.75 x 0.15 meter and 11 cm high, made of stainless steel of 0.2 cm thick. It was installed in an inclining position, making an angle of 60^{o} with the vertical line, as shown in Figure 4. The chamber was divided longitudinally into two parts by a stainless plate of 0.64 cm thick, the upper was 7.5 cm high while the lower was only 2.5 cm. The former, for evaporation, provided an entrance of the feed at which a feed distributor and a wier existed, a vapor outlet line connected to two condensers in series, and a concentrate outlet line connected to two concentrate- juice tanks. The latter, for circulated hot water to supply heat for the evaporation, provided an inlet and an outlet for hot water. Both lines were connected to a shell-and-tube heat exchanger. The hot water was circulated by a 0.35 H.P ADDA Electtropompa Monofase centrifugal pump which was installed on the inlet line. An orifice-meter with an attached manometer was installed on the line to indicate the flow rate. The



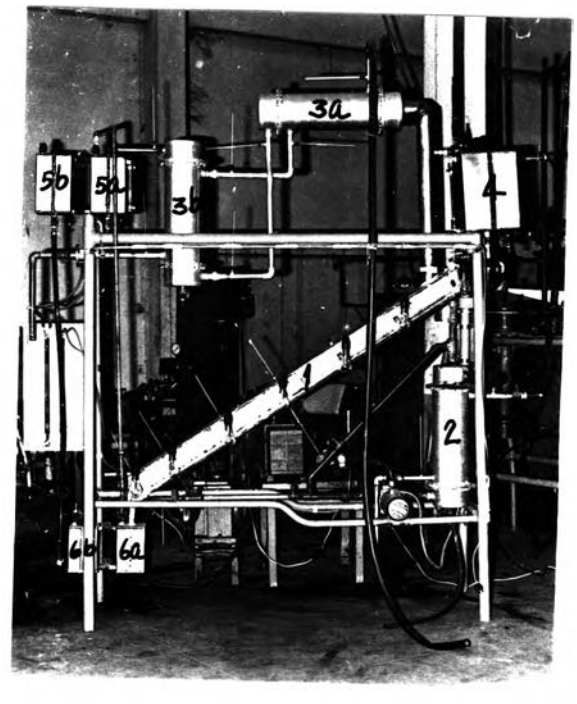
Front view

1. Evaporating chamber
2. Hot-water heater
3a. 1st condenser
3b. 2nd condenser
4. Feed tank
5a. 1st condensate tank
5b. 2nd condensate tank

Figure 3. Experimental Equipment

6a. 1st concentrate-juice tank
6b. 2nd concentrate-juice tank
7. Vacuum pumps

Rear view



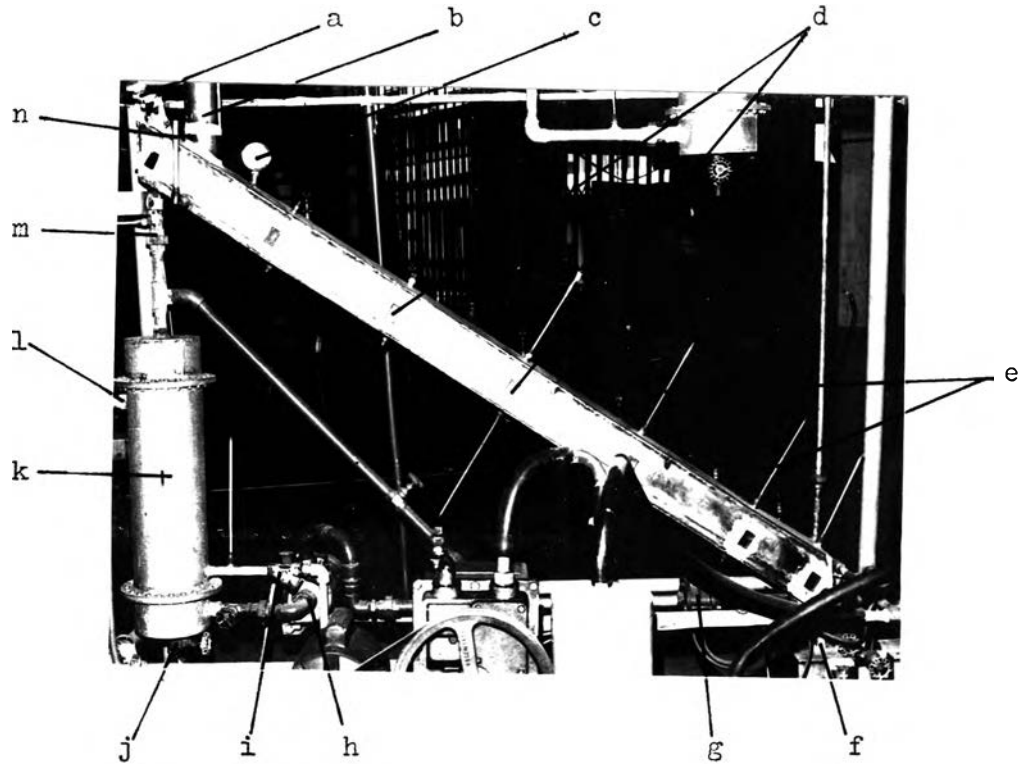


Figure 4. The Evaporating Chamber and the Hot-water Heater

a. feed entrance line
b. vapor outlet line
c. vacuum pressure gauge
d. glass windows
e. thermometers
f. entrance to concentrate-juice tank
g. hot-water orifice meter
h. centrifugal pump
i. steam trap
j. hot-water inlet/draining
k. hot-water heater
l. steam inlet
m. hot-water outlet
n. hot-water safety vent

rate was controlled by a regulating value and a by-pass line. In the regard of safety, a vent line, 1.27 cm inside diameter of thick-wall plastic tubing extended vertically upward to a height of about 6 meters was installed at the most upper portion of the lower chamber for releasing excess hot water. There were glass windows 5 ×6.5 cm, on each side of the upper chamber for visual observation of the evaporation. Several thermometers and a vacuum gauge were also attached to the chamber for indicating temperatures and vacuum prossuro respectively. A regulating valvo and a rotameter were also installed on the feed inlet lino for controlling and indicating, respectively, the feed rate.

4.2 Hot-Water Heater

It was a shell-and-tube heat exchanger of 66 cm high and 17 cm inside diameter, had 19 tubes of 0.95 cm inside diameter arranged in triangular pitch with center-to-center distance of 3.5 cm, and was made of mild steel. See Figure 4. The exchanger was heated by saturated steam which entered the shell side, and the steam condensate discharged through a steam trap to atmosphere. There were a regulating valve and a pressure gauge installed on the steam inlet line for controlling the steam flow rate.

4.3 Condensers

Two condensers resembled the hot-water heater were constructed and used to condense water vapor from the evaporator. The first one,

installed horizontally, was connected to the evaporating chamber. The second one, with a drain at the bottom and installed vertically, was connected in series to the first. See Figure 5. The second condenser was required on the purpose to ensure the total condensation of vapors. The vapors entered the tube side of the condensers while cooling water entered the shell side countercurrently. There were a regulating valve and an orifice-meter with attached manometer installed on the cooling-water inlet line for controlling and indicating, respectively, the water flow rate. Thermometers were also installed to indicate temperatures of the inlet and outlet streams of the condensers.

4.4 Feed Tank

A square 25 × 25 cm and 35.5 cm high tank was constructed from stainless steel sheet of 0.2 cm thick, and it was used as a feed tank. See Figure 5. A vacuum pressure gauge and a vent line were attached at the top. The tank also had a feed inlet, a thermometer, a drain line, and a feed outlet. A glass tube of 1.27 cm diameter and 30.5 cm long was connected to the tank for observing the feed level.

4.5 Condensate Tanks

Two square 15 × 15 cm and 25 cm high tanks were constructed from stainless steel of 0.2 cm thick. Both tanks were used as condensate tanks. They were connected together at the top for equalising

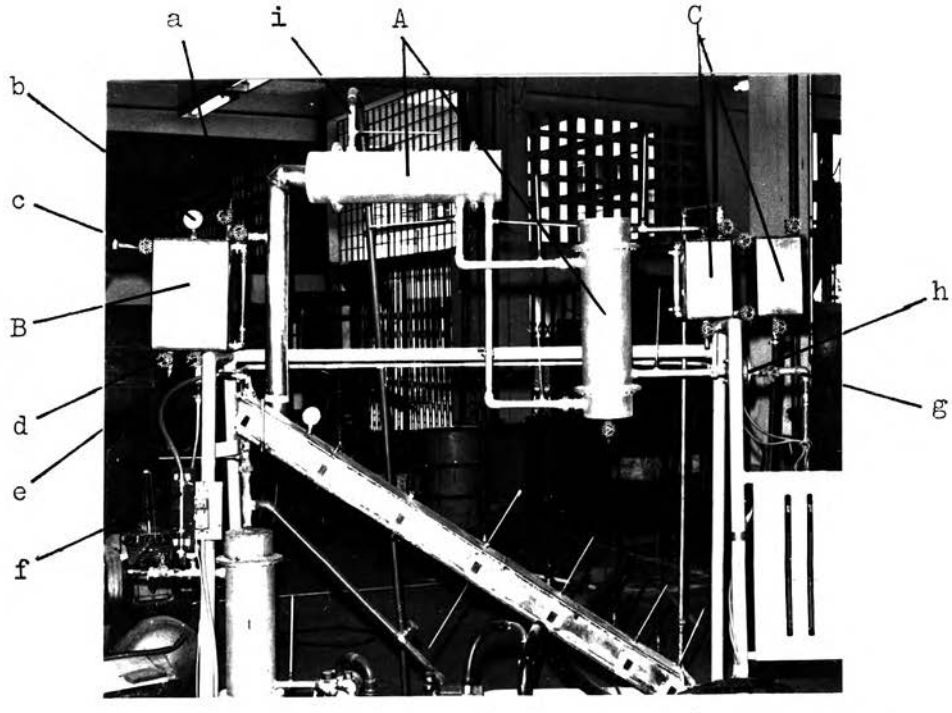
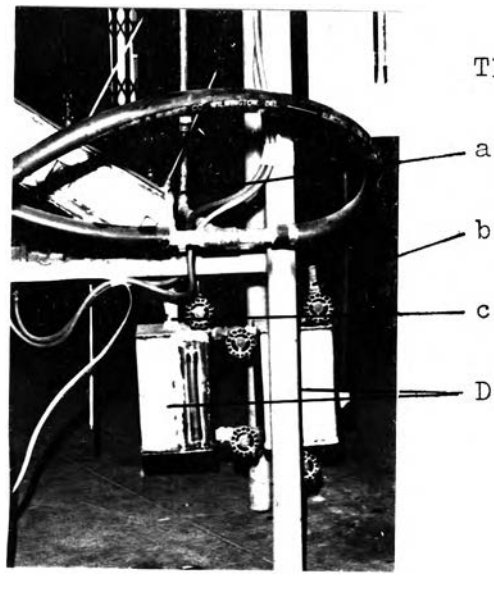


Figure 5. The Feed Tank, Condensers, and Condensate Tanks

Figure 6.

The Concentrated-juice Tanks



A. Condensers

B. Feed tank

C. Condensate tanks

   a. vent valve

   b. vacuum pressure guage

   c. feed inlet

   d. drain line

   e. feed outlet

   f. rotameter

   g. cold-water inlet

   h. cool-water orifice meter

   i. cold-water outlet

D. Concentrated-juice tanks

   a. line to vacuum pump

   b. vent valve

   c. line from the evaporating chamber

the vacuum pressure and at the bottom for condensate to flow from one to the other. On each connecting line there was a valve for disconnecting the tanks from each other. See Figure 5. Each tank had a vent valve at the top, for either connecting to two vacuum pumps or releasing vacuum, and a drain valve at the bottom for discharging the condensato. The first condensate tank had also a condensate inlet line connected to the tube side of the vertical condenser. Tho second tank had an attached 1.27 cm diameter glass tube for indicating the condensate level in the tank.

4.6 Concentrate-juice Tanks

Two square 12.5×12.5 cm and 20 cm high tanks were constructed from stainless steel sheet of 0.2 cm thick. Both tanks were used as concentrated-juice tanks (or receiver tanks) they were connected together at the top for equalizing the vacuum pressure and at the bottom for concentrate-juice to flow from one to the other. On each connecting line there was a valve for disconnecting the tanks from each other. See Figure 6. Each tank had a vent valve at the top, for either connecting to the vacuum pumps or releasing vacuum, and a drain valve at the bottom for discharging the concentrate. The first concentrate-juice tank had also an inlet line for the concentrate to flow from the evaporating chamber into the tank, and an attached 1.27 cm diameter glass tube for indicating the juice level in the tank.

4.7 Vacuum Pumps

Two vacuum pumps were used. The first one, Welch Duo-Seal Cat.No.1402, had 3/4 H.P and the second one, of Wagner Electric Corp. Type KA, had 1/2 H.P. Both pumps were connected in parallel to assist each other in evacuating the evaporating system. The suction line of the pumps was connected to the vent lines of the first condensate tank and of the first concentrate-juice tank.