CHAPTER IV

EXPERIMENTAL EQUIPMENTS

4.1 Ultrafiltration

The equipment used in this work is from the Paterson Candy International Ltd., type B1. Figure 4.1 to4.5 show details of the system.

4.1.1 General description

The plant is designed as a simple self contained unit of minimum hold up volume with electric motor, pump, heat exchanger and simple controls all mounted in a welded stainless steel framework. The cycle of operation of the complete Ultrafiltration plant is as follow :

Process fluid is feed to the pump inlet (1" hose connection) pressurised and supplied at pressure to the 18-tube module. In the 18-tube module the separation process takes place. The permeate passes through the semi-permeable membrane tubes into the plastic module shell and is drained away via the lower ½" (12.5 mm.) hose spigot bonded to the shell. The concentrate passes through the "tube side" of the module and is piped to the flow control valve (FCV) which maintains a fixed flow within the module. In this experiment the plant is used as a total recycle system, where the concentrate is returned to the feed tank so that the heat exchanger must be used. This is simply done by connecting the outlet of the flow control valve to the ½" OD (12.5 mm.) heat exchanger inlet.

The ½" OD (12.5 mm.) heat outlet is connected to the feed tank with flexible hose. Low pressure cooling water is passed through the plastic shell of the heat exchanger using the ½" OD (12.5 mm.) hose spigot on the shell.

4.1.2 Component description

Welded Stainless steel framework is used for the plant for the hygenic qualities corrosion resistance and rigidity.

4.1.3 18-Tube module

This unit contains 18 tubular membrane elements which are replaceable. The maximum operating pressure of the module is 40 Bar, but the type of membrane fitted may limit the pressure of operation as recommended in the unit operation.

4.1.4 Module pressure gauge (with magnetic contacts)

This instrument (0-16 Bar) indicates the pressure at which the 18-tube module is working and is fitted with two adjustable contacts which will shut down the unit should the pressure rise or fall beyond the set limits (eg. as caused by broken hose, feed fluid failure or incorrect pressure control valve operation)

4.1.5 Flow control valve

Special stainless steel flow control valve which maintains a set flow in the module (within the pressure range 0-10 Bar). The control valve is non-adjustable and to change the flow in the module the valve must be replaced with one of a different valve.

4.1.6 Start and stop buttons

Standard 2 hp. motor starter with the pressure gauge contacts connected to the starter coil. This arrangement will shut down the unit should the pressure go above or below the set limits on the gauge or should the motor be overloaded.

4.1.7 Pump (with optional flow by pass valve)

Stainless steel positive displacement lobe type pump (with mechanical shaft seals) shich may be easily dismantled for cleaning.

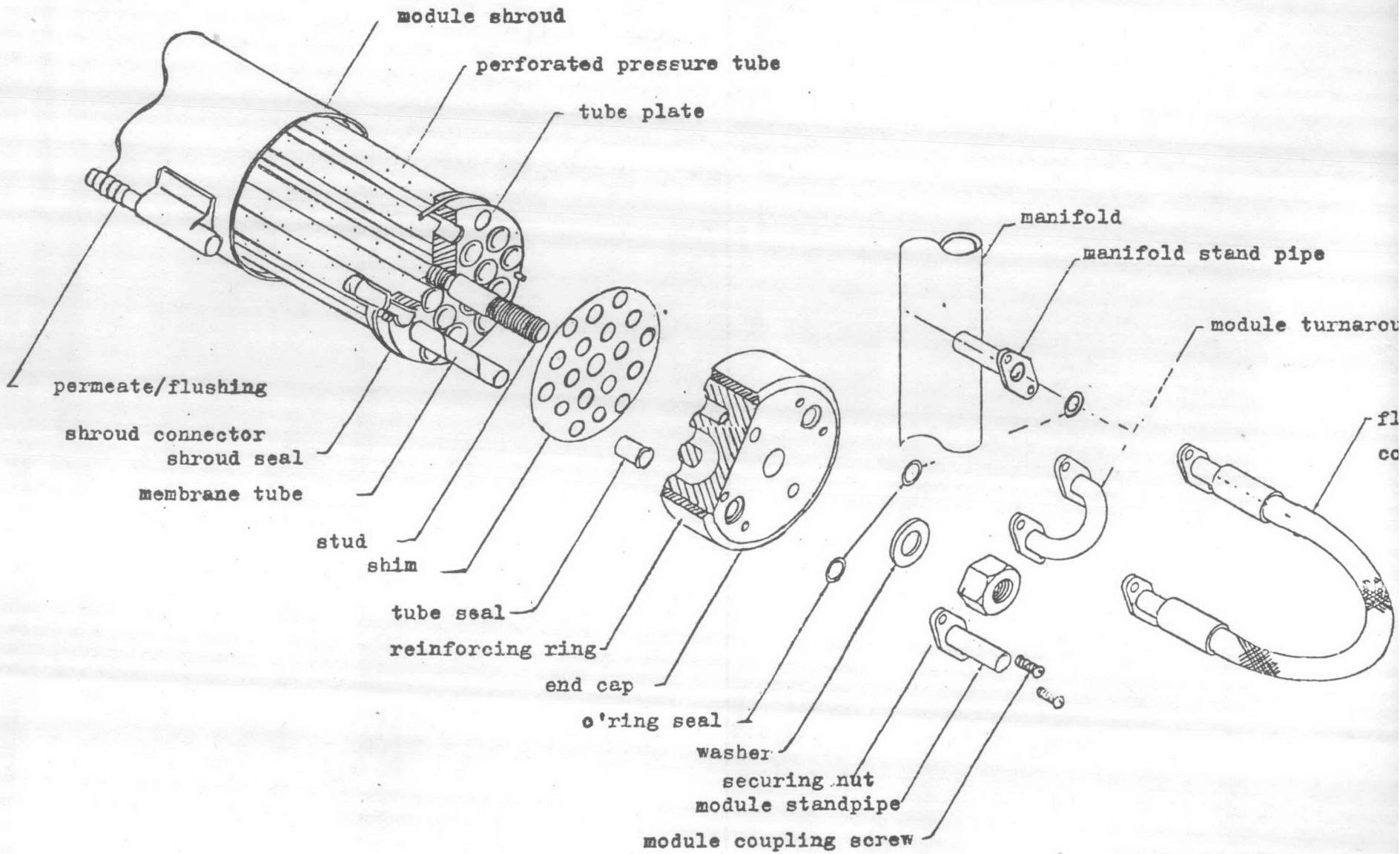
4.1.8 Motor

2 hp. 3 phase TEFC foot mounted motor on simple adjustable slide rails for drive belt tensioning and alignment.

4.1.9 Heat exchanger

A tubular type heat exchanger similar in construction to the 18-tube module. The process fluid is piped from the outlet of the flow control valve (or reject flow meter if fitted) and passed through eighteen tubes (in series) within the exchanger, whilst cooling water is pumped, at low pressure, through the plastic shell.

Figure 4.1 18 - Tube Module



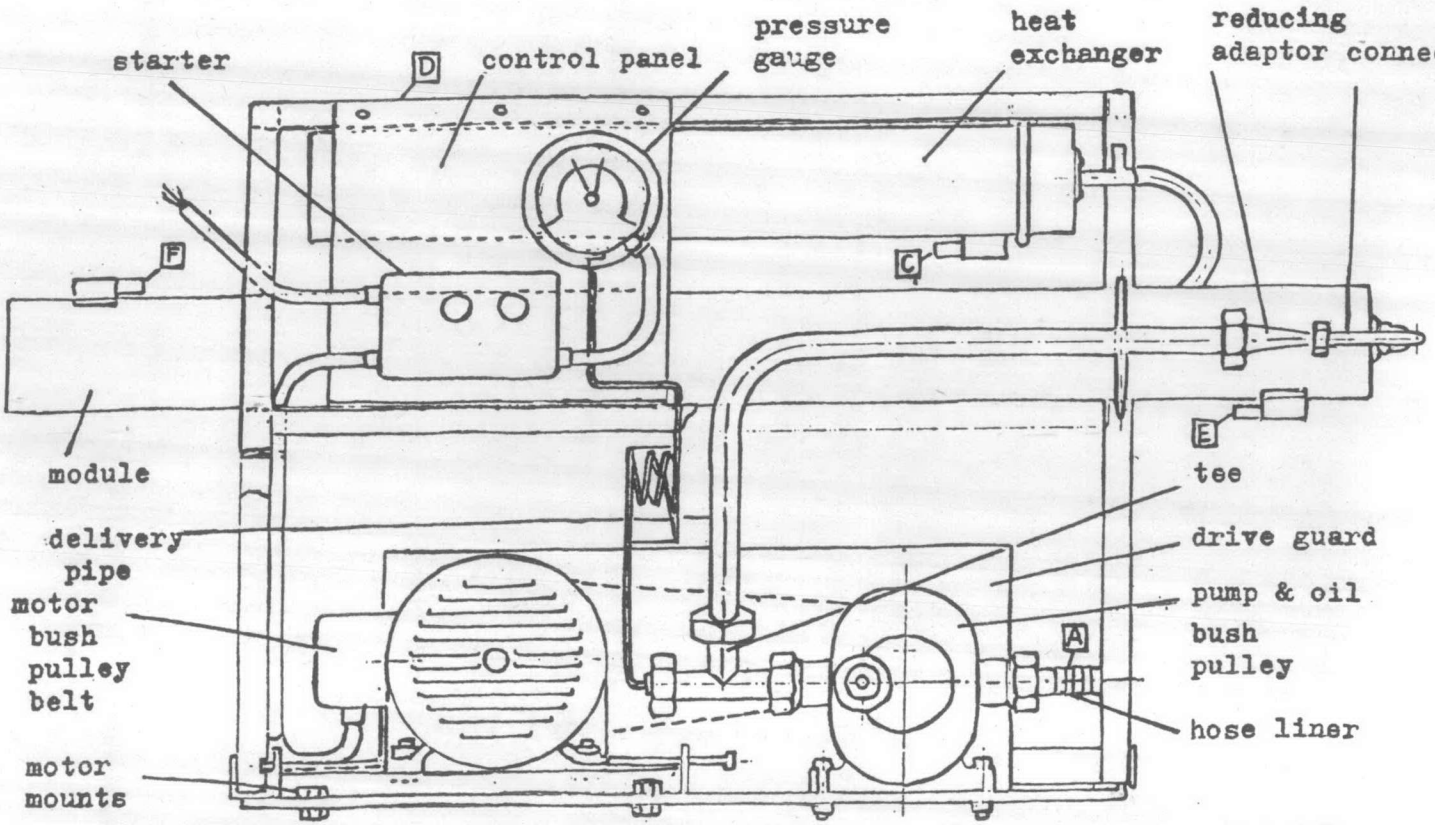


Figure 4.2 Ultrafiltration plant (front view)

A- pump inlet
B- reject outlet
C- cooling water 'i
D- cooling water 'out
E- permeat outlet
F- flushing outlet

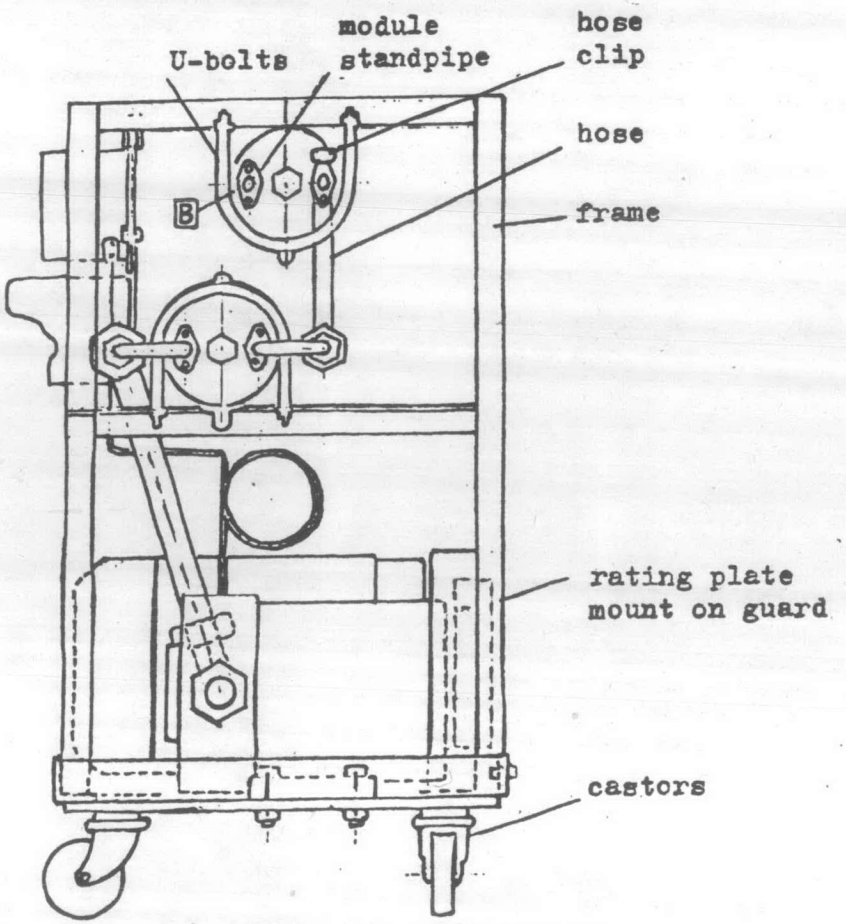


Figure 4.3 Ultrafiltration plant (profile view)

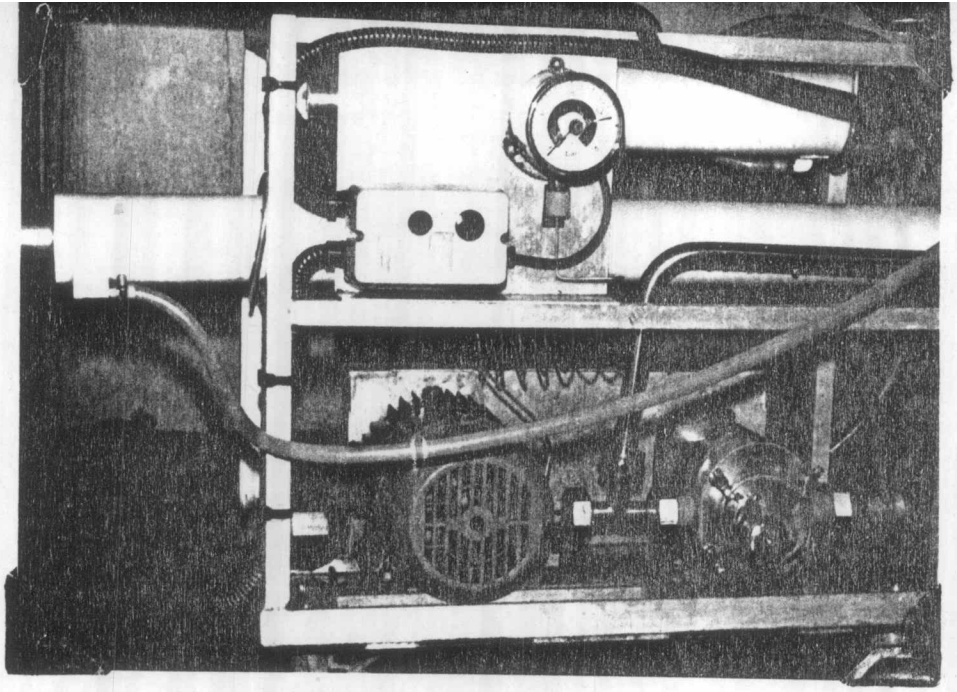


Figure 4.4 Ultrafiltration System

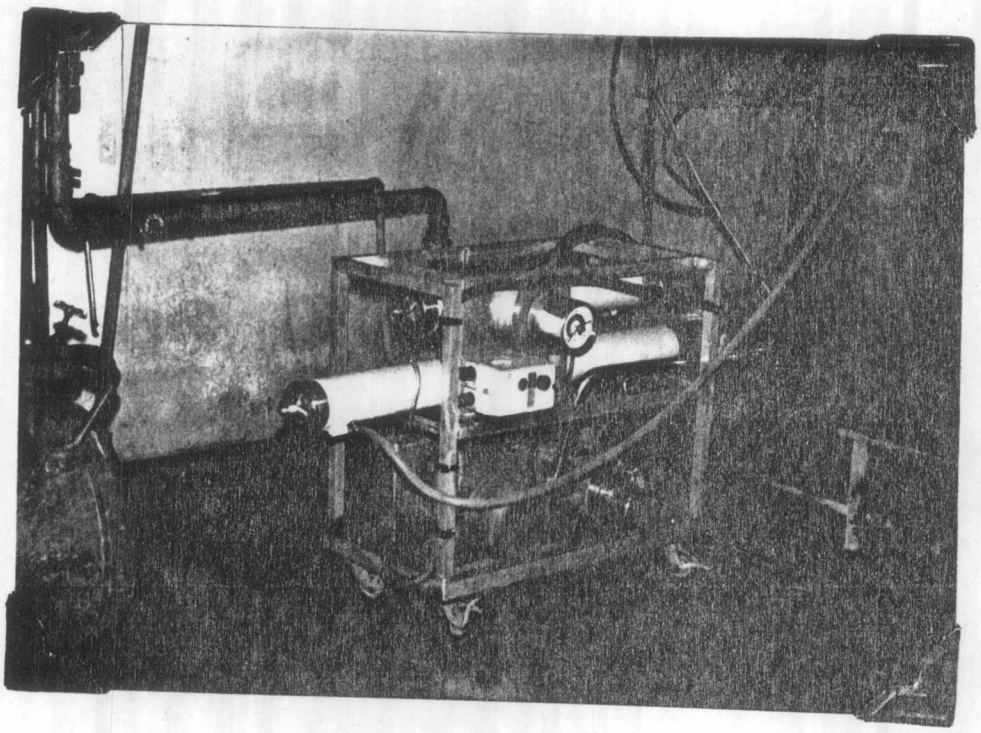


Figure 4.5 Ultrafiltration plant

4.2 Ultrafiltration membranes

Two types of Ultrafiltration membranes were used in the experiments. They are T2/A and T6/B which the characteristics are as follow :

4.2.1 Membrane type T2/A

General Characteristic :

This membrane is the tightest of the cellulose acetate ultrafiltration membrane with a norminal 97% rejection of 6,000 molecular weight polyethylene glycol under standard test conditions.

Typical uses :

- Concentration of fermentation liquors with partial salt removal.
- Concentration of antibiotics.

Membrane performance standard test conditions

Feed solution:	300 mg/l polyethylene glycol (MW.6,000) in water
Feed pressure :	10 Bar
Minimum feed flow :	9 l/min.
Temperature :	15^{o}C
Polyethylene Glycol passage :	1.5% to 5%
Water flux :	25 to 40 l/m^{2}hr

Maximum operating temperature

30^{o}C at pH 3 to 6

15^{o}C at pH 2 to 8

Maximum operating pressure

25 Bar

Tolerance to free chlorine

Continuous exposure - 1 mg/l max.

Short exposure - 50 mg/l max.

Tolerance to solvents

Low concentration of many solvents (eg. acetone) in water can be tolerated but some organic substances with molecular weight 80 to 105 (eg. methyl isobutyl ketone) severely reduce flux.

4.2.2 Membrane type T6/B

General characteristics :

This membrane is a versatile non-celluosic membrane with a nominal 80% rejection of 70,000 molecular weight dextran under standard test conditions.

Typical uses :

- Concentration of waste soluble oil emulsions.
- Concentration and purification of enzymes
- Extraction of lignosulphonates from pulping effluents.
- Electro-phoretic paint recovery.
- Separation of protein from cheese whey with greater than 98% true protein retension.
- Preconcentration of skim milk for cheese making.

Membrane performance standard test conditions:

Feed solution :	150 mg/l of 70,000 MW. dextran in water
Feed Pressure :	4 Bar, after first pressuring at 15 Bar for 15 min. on water.
Minimum feed flow :	12 l/min.
Temperature :	$15^{o}C$
Dextran T70 passage :	10% to 30%
Water flux :	32 to 50 $l/m^2hr.$

Maximum operating temperature :

Up to 60^{o} C at pH 2 to 11

Maximum operating pressure :

10 Bar

Tolerance to free chlorine :

Continuous exposure	- 10 mg/l max.
Short exposure	- 200 mg/l max.

Tolerance to solvent :

Low concentrations of many solvents in water can be tolerated but the following should be avoided :

Dimethyl formamide, dimethyl sulphoxide, dimethyl acetamide phenols, dichloroacetic acid, quaternary ammonium compounds.

4.3 Reverse Osmosis

The equipment used in this work is also from the Paterson Candy International Ltd., type B1. See Figure 4.6-4.12

4.3.1 General description

The plant is designed as a simple self-contained unit of minimum hold up volume with electric motor, triplex pump, module, heat exchanger and controls all mounted in a welded aluminium framework.

The cycle of operation of the complete Reverse Osmosis plant is as follows :

Process fluid is fed to the pump inlet (½" hose connection) pressurised and supplied at pressure (via a flexible hose) to the 18-tube module. In the 18-tube module the separation takes place. The permeate passes through the semi-permeable membrane tubes into the plastic module shell and is drained away via the lower ½" (12.5 mm.) hose spigot bonded to the shell. The concentrate passes through the "tube side" of the module and is piped (via flexible rubber hose) to the pressure control valve (PVC) which maintains the set pressure within the module.

In this experiment the plant is being used as a total recycle system (ie. where the concentrate is returned to the feed tank) it may be neccessary to cool the concentrate with the heat exchanger provided. This is simply done by connecting the outlet of the pressure control valve to the ½" OD (12.5 mm.) heat exchanger inlet.

The ½" OD (12.5 mm.) heat exchanger oultet is connected to the feed tank with flexible hose. Low pressure (0.75 Bar) cooling water is passed through the plastic shell of the heat exchanger using the ½" OD (12.5 mm.) hose spigots on the shell.

4.3.2 Weld aluminium framework

Framework is constructed with high duty grade of aluminium for corrosion resistance, rigidity and lightness.

4.3.3 18-Tube module

This unit contains 18 tubular membrane elements which are replaceable. The maximum operating pressure of the module is 80 Bar, but the types of membrane fitted may limit the pressure of operation.

4.3.4 Module pressure gauge (with magnetic contacks)

This instrument (0-100 Bar) indicated the pressure at which the 18-tube module is working, and is fitted with adjustable contacts which will shut down the plant should the pressure rise or fall beyond the set limit (eg. as caused by broken hose, feed fluid failure or incorrect pressure control valve operation).

4.3.5 Pressure control valve

A hand operated, spring loaded, fine control valve which maintains a set pressure in the module. All wetted parts are stainless steel except the delrin seat which is easily replaceable. At each start up this valve must be fully openned.

4.3.6 Start and stop buttons

These buttons actuate the pump motor starter and overloaded unit inside the electrical control box. Should the motor be overloaded or the pressure rise or fall below the set limits, the motor will automatically stop.

4.3.7 Pump

Vertical triplex plunger pump with all stainless steel wetted parts (except rubber sealing rings and chevron packings). The pump is provided with a gland washing system which requires water flow rate of approximately 1 titre per minute from a suitable water supply. After washing the water is led to drain.

4.3.8 Motor

3 hp. 3 phase T.E.F.C. foot mounted motor on simple adjustable slide rails for drive belt tensioning and alignment.

4.3.9 Heat exchanger

A tubular type heat exchanger similar in construction to the 18-tube module. The pressure fluid is piped from the outlet of the pressrue control valve and passed through all eighteen tubes (in series) within the exchanger, whilst cooling water is pumped at low pressure, through the plastic shell.

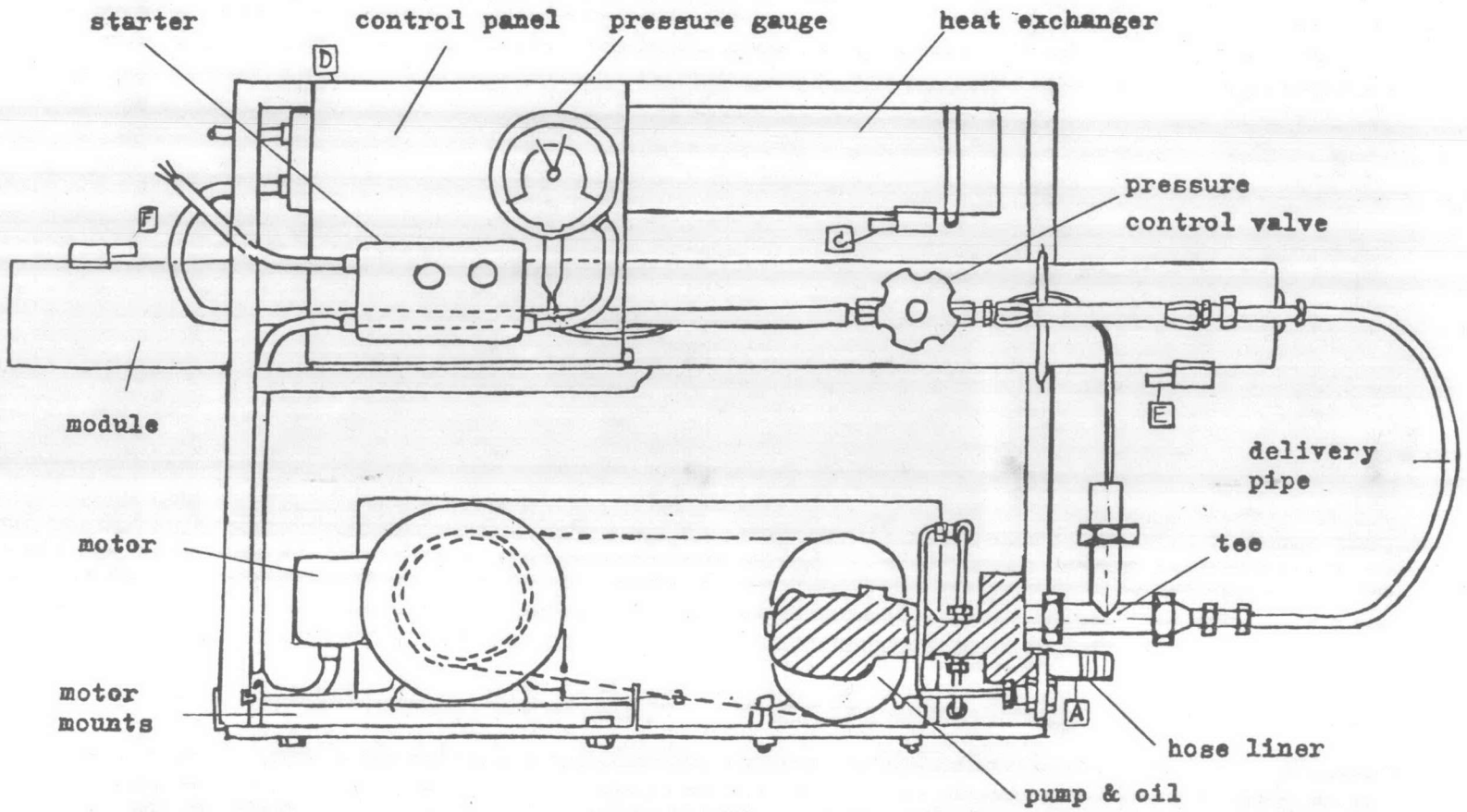


Figure 4.6 Reverse Osmosis plant (front view)

A - pump inlet
B - reject outlet
C - cooling water 'i
D - cooling water 'o
E - permeate outlet
F - flushing outlet

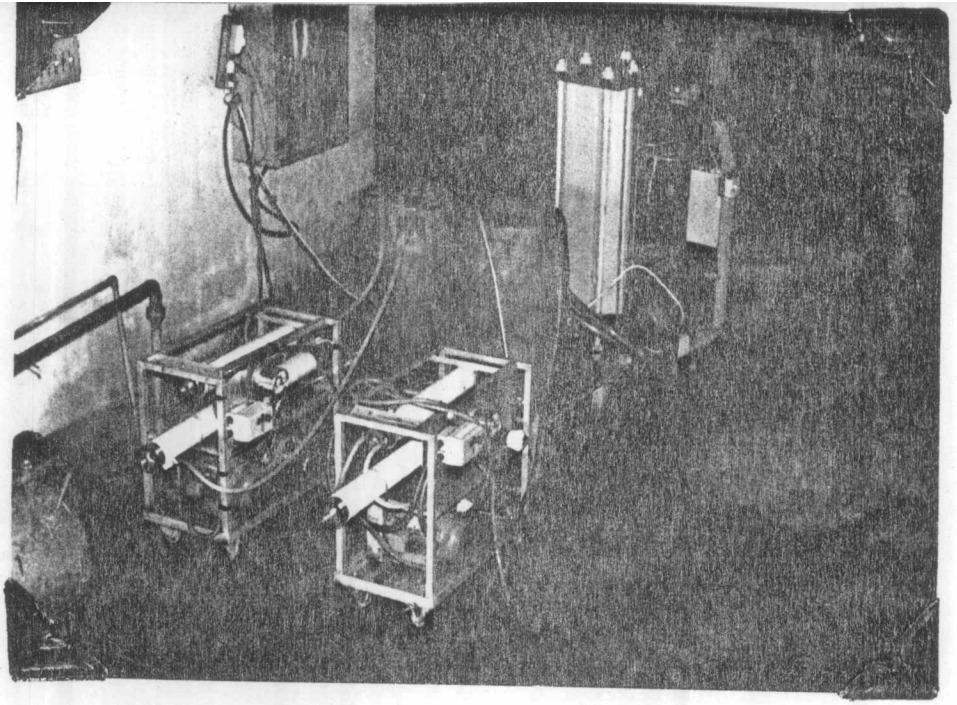


Figure 4.7 Ultrafiltration and Reverse Osmosis system

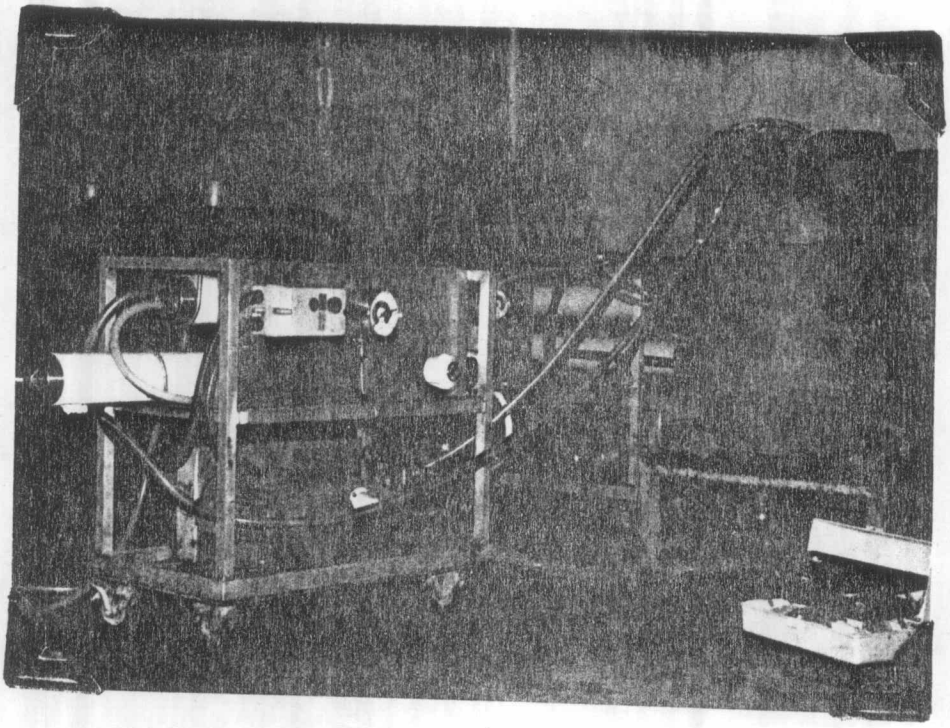


Figure 4.8 Reverse Osmosis system

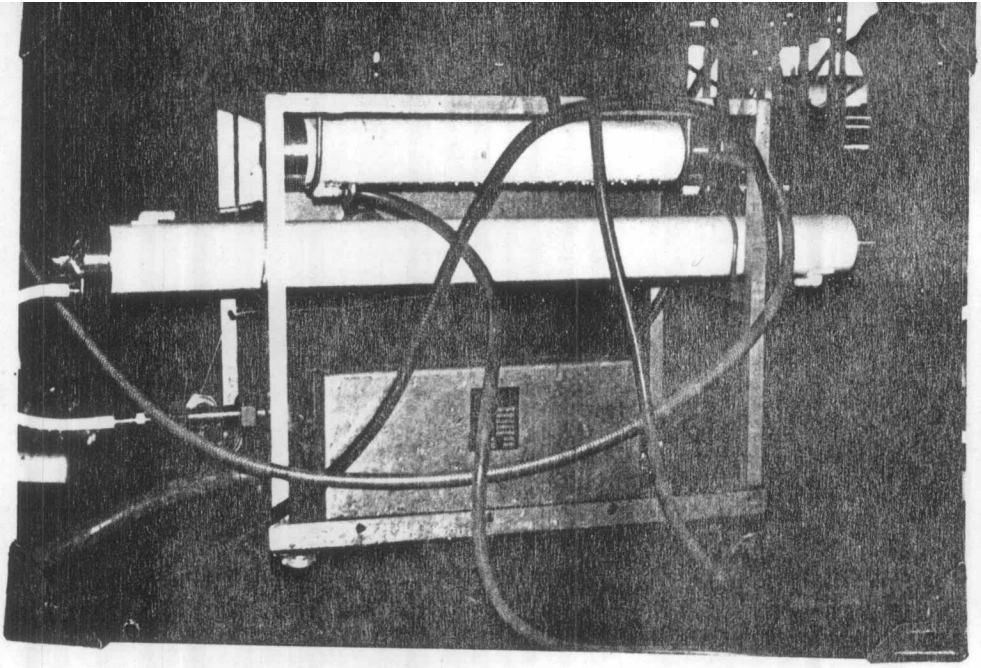


Figure 4.9 Back view of Reverse Osmosis plant

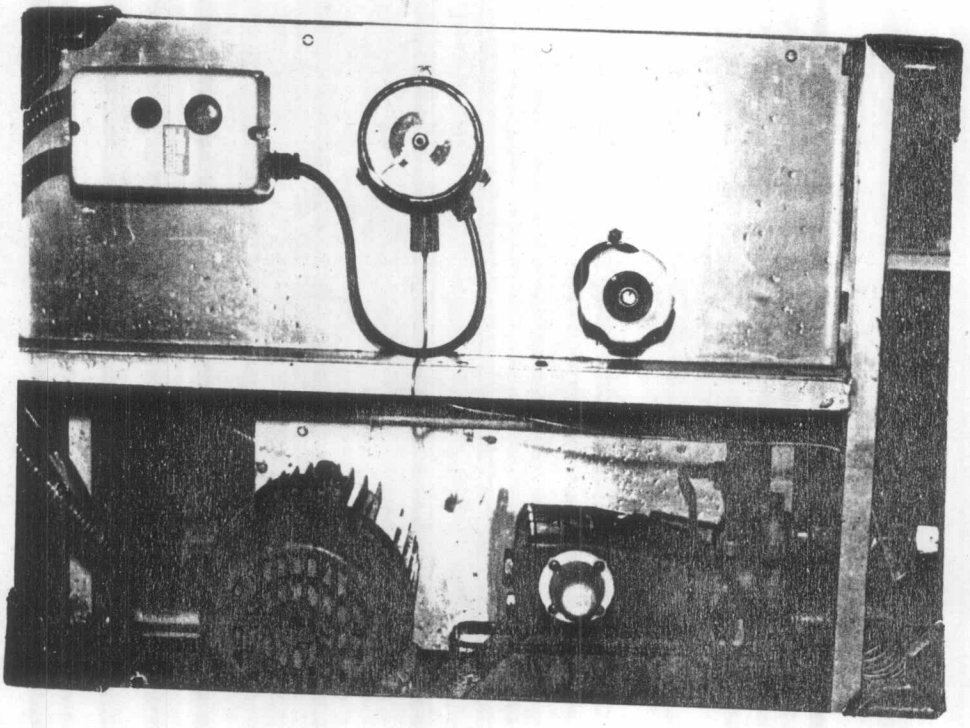


Figure 4.10 Front view of Reverse Osmosis plant

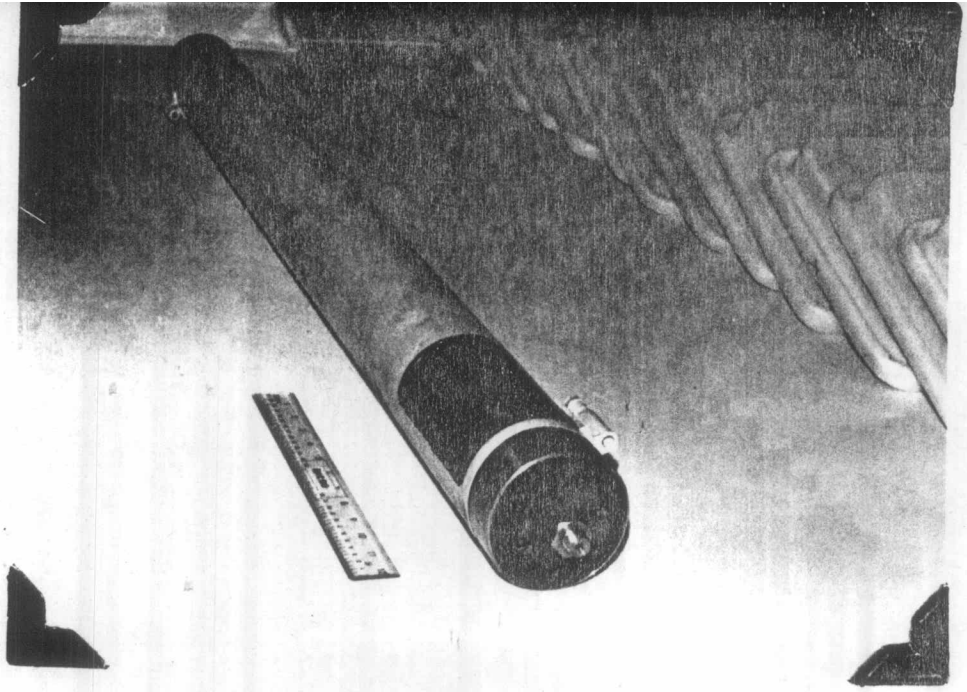


Figure 4.11 UF & RO tubular module

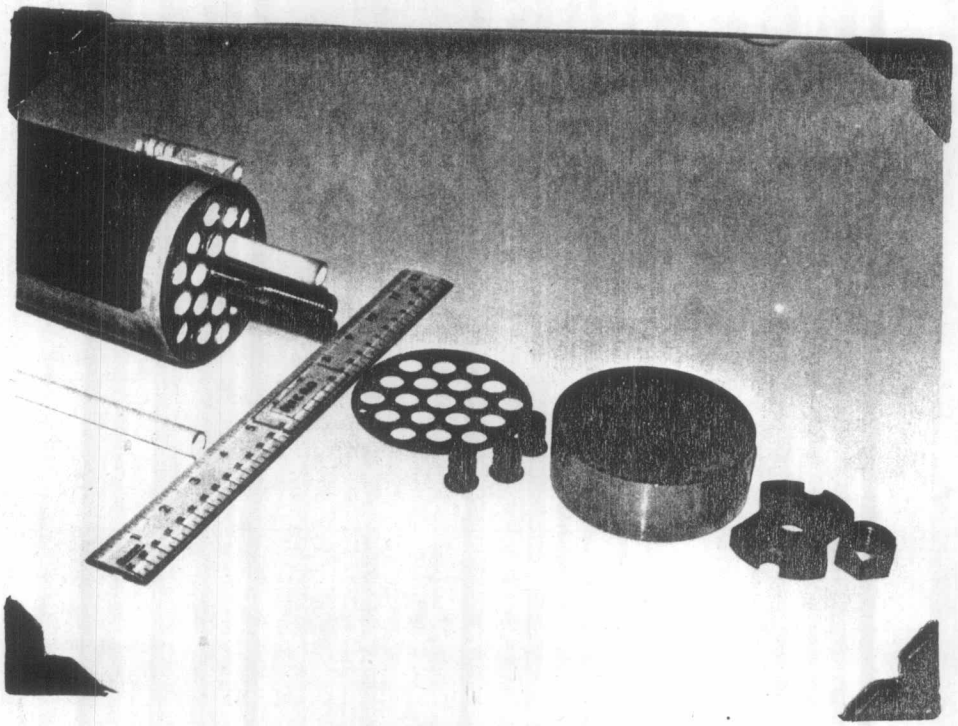


Figure 4.12 Tubular module in parts

4.4 Reverse Osmosis membranes

Two types of Reverse Osmosis membranes were used in this experiments. They are T1/12W and T2/15W which the characteristics are described below :

4.4.1 Membrane type T1/12W

General characteristics:

This membrane is a high rejection cellulose acetate membrane.

Typical uses :

- Stage 1 of 2 stage sea water desalting.
- Concentration of mineral and high BOD effluents.
- Concentration of fruit juices - grape, apple, orange, peach, cherry, strawberry.
- Concentration of low molecular weight such as organics in aqueous systems.

Membrane performance standard test conditions :

Feed Solution :	1500 mg/l sodium chloride in water
Feed pressure :	40 Bar
Minimum feed flow :	6 l/min.
Temperature :	15^{o}C
Salt passage :	2 to 4.9 %
Water Flux :	20 to 26 l/m^{2}hr.

Maximum operating temperature :

30°C at pH 3 to 6

15°C at pH 2 to 8

Maximum operating pressure :

Normal : 40 Bar

Maximum : 80 Bar

Tolerance to free chlorine :

Continuous exposure : 1 mg/l max.

Short exposure : 50 mg/l max.

Tolerance to solvents :

Low concentration of many solvents (eg. acetone) in water can be tolerated but some organic substances with molecular weights 80 to 105 (eg. methyl isobutyl ketone) severely reduce flux.

4.4.2 Membrane type T2/15W

General characteristics :

This membrane is a very versatile cellulose acetate reverse osmosis membrane. In commercial use on dewatering applications.

Typical uses :

In commercial use on dewatering applications such as : Cheese whey, sugar solutions, antibiotics, fermentation effluents. Other potential applications include :

- Pulp and paper industries effluents
- Potato fruit water concentration.

- Concentration of sodium sulphate, aluminium sulphate, or sodium chloride.
- Treatment of effluents such as dyehouse wastes, coffee, tobacco.

Membrane performance standard test conditions :

Feed Solution :	1500 mg./l sodium chloride in water
Feed Pressure :	40 Bar
Minimum feed flow :	6 l/min.
Temperature :	15°C
Salt passage :	6.2 to 10.7 %
Water flux :	35 to 45 $l/m^2hr.$

Maximum operating temperature :

30°C at pH 3 to 6

15°C at pH 2 to 8

Maximum operating pressure :

Normal : 40 Bar

Maximum : 80 Bar

Tolerance to free chlorine :

Continuous exposure	:	1 mg/l max.
Short exposure :		50 mg/l max.

Tolerance to solvents :

Low concentration of many solvents (eg. acetone) in water can be tolerated but some organic substances with MW. 80 to 105 (eg. methyl isobutyl ketone) severely reduce flux.

4.5 Module details :

Module length (mm.)	1200
Membrane area (m^2)	0.86
Diameter OD (mm.)	100
Weight Empth (kg.)	8.8
Weight full (tube side) (kg.)	11.6
Hold-up (tube side) (litre)	2.8
Membrane tube ID.(mm.)	12.5

The ultrafiltration and Reverse osmosis modules were used in combination for concentrating the pineapple cannery liquid waste. The procedures and the variables studied are described in the following chapter.