CHAPTER III.

# EXPERIMENTAL INVESTIGATION

## 3.1 General Description

In this experiment the tapioca chips were dried in the column through which hot air from the preheater flew. The schematic diagram of the experimental set-up is shown in Figure 3.1. The air was fed to an air-preheater from a compressor. Air flowrate was measured by a calibrated orifice meter and controlled with a globe valve. Gaseous fuel from a fuel storage tank was used as a heat source in the air-preheater. Fuel pressure and feed rate were controlled by a pressure regulator and a globe valve respectively. The combusted gases left the air preheater to the atmosphere directly. Hot air from the preheater was sent to a fixed bed column. Hot air temperature was measured by a thermocouple and recorded continuously on a chart-recorder.

## 3.2 Details of Apparatus and Instrumentation

### 3.2.1 Fixed bed column

The detailed design of the column is shown in Figure 3.2. The column consisted of two parts. The upper part was a plastic column (or basket) of 20 cm. I.D. with the sieve

welded to the bottom to hold the tapioca chips in the column. The height of the column was 35.7 cm. The lower part which was the steel cylinder with conical bottom connected to the air inlet, was filled with porcelain balls of 2 cm. in diameter serving to distribute hot air into the column. The plastic wall of the column has poor heat conduction which not only help to conserve heat but also to maintain the inside wall at temperature above the dew point of the air to prevent condensation of moisture upon the wall. Outside the bottom rim of the basket was wound by elastic tape to make it attach tightly with the upper rim of the lower part so that hot air could not leak out. Another smaller size of the column was also designed and used in few runs as shown in Figure 3.3. The design was similar to the one shown in Figure 3.2.

3.2.2 Air-preheater

The detailed design of the equipment is shown in Figure 3.4. Air-preheater resembled a shell and tube heat exchanger with an additional combustion chamber at the lower section. The shell was 50 cm. O.D. and 120 cm. high. Nineteen steel tubes 3.8 cm. I.D. were attached to the tube sheet by grooving the holes circumferentially. Combustion products flowed through the tube side and air through the shell side. Exhansted gas left the preheater at the upper exhaust pipe to the atmosphere. Outer surface of the preheater was insulated with asbestos. Inner surface of the combustion chamber was

insulated with fire clay. An observation window was provided at the combustion zone. A gas burner was installed at the bottom of the combustion section. The burner could be changed to any desired sizes as determined by the amount and temperature of the hot air required. The preheater was mounted on a steel frame 3 feet above the floor for convenience of operation.

### 3.2.3 Tapioca cutter

Special cutter was designed to cut the tapioca longitudinally to produce the uniform thickness chips. The blade of the cutter could be regulated to get the desired thickness of the chip. The blade was 13.5 cm. long and 2 cm. wide with its wooden base of 15 x 20 cm. size. The chips produced by this cutter was cut later by a rectangular die of 2 x 6 cm. to give the desired definite size.

A Malaysian cutter, type Jenis-B, designed by the National Institute for Scientific and Industrial Research (NISIR) consisted of the blade which produced tapioca slices (0.2 - 0.3 cm. thick) at one side was also used in this study. The Malaysian cutter is shown in Figure 3.5.

### 3.2.4 Temperature measurement

The measurement of the temperatures of the hot air inlet and outlet was made by the using of two thermocouples connected to the cojunction swith of the temperature recorder. The thermocouples used were the Chromel and Alumel type. Temperature recorder was the Servotrace type of Sefran Paris.

### 3.2.5 Air flowrate measurement

The instrument to measure the air flow rate was an orifice meter. A water-manometer was connected to orifice taps in a line joining the compressor and the preheater. The orifice was calibrated against a calibrated rotameter. The results of calibration are listed in Table C.1 and displayed on Figure C.1.

### 3.2.6 Weighing

The weighing of the bed of tapioca was done by using the balance type Berkel with total capacity 5 Kg, calibrated by 1 g., estimated to 0.5 g. and had probable accuracy $\pm$ 0.5 g.

In the study of diffusion coefficient, the balance used was the electric balance type Mettler H 33 capacity 160 g. and could be read to 4 positions after point.

## 3.3 Experimental Procedure

The experiment was started by lighting the burner. The amount of air and fuel gas were varied until the blue flame appeared. After that the air compressor was switched on by using low air flow rate first and later on it was gradually increased until the desired flowrate was reached. The temperature of the hot air inlet into the column was recorded by the temperature recorder. The fuel mixture flowrate was varied until the desired temperature was recorded. The time taken to reach steady state was about 2 to 3 hours. While waiting for

the temperature to reach the steady state, tapioca chips were prepared.

The empty basket was counterpoised on the balance and the desired amount of chips was weighed into it with random packing and placed in the dryer. The basket was removed, weighed and replaced in the dryer at regular intervals. The time required for weighing was about 10 to 13 seconds.

In the experiment to determine the equilibrium water content (We) for the study of diffusion mechanism the chips were dried until the rate of drying became zero; that is, the weight of tapioca chips was always constant.

In the determination of the diffusion coefficient (De), a definite size of tapioca chips was dried in the dryer and weighed at regular intervals by the electric balance. This was done by hanging the sample in the dryer with a very fine rope. It was dried until the equilibrium water content was reached and later on was placed in an oven to get the bone dry weight.

The tapioca roots used in this work were harvested in Chonburi province during the months of January to August, 1977.

All the experiments were conducted according to the operating conditions as shown in Table 3.1.

Table 3.1

Summary of Operating Conditions

Part A: Malaysian Size

| Run No. | Wt. of Sample Kg. | Drying Temp, °C | Air Flowrate | | Bed Depth cm. | Bed Loading Kg.B.D.S/$m^2$ |
|---|---|---|---|---|---|---|
| | | | liter/min | Kg/hr.$m^2$ | | |
| A - 1 | 1.608 | 80 | 400 | 762 | 10 | 20.9 |
| A - 2 | 1.608 | 80 | 600 | 1,144 | 10 | 20.9 |
| A - 3 | 1.608 | 80 | 800 | 1,524 | 10 | 20.9 |
| A - 4 | 1.608 | 80 | 1,100 | 2,096 | 10 | 20.9 |
| A - 5 | 2.608 | 80 | 1,100 | 2,096 | 15 | 34.9 |
| A - 6 | 3.208 | 80 | 1,100 | 2,096 | 20 | 42.9 |
| A - 7 | 1.608 | 40 | 800 | 1,524 | 10 | 20.9 |
| A - 8 | 1.608 | 60 | 800 | 1,524 | 10 | 20.9 |

Part B: Definite Size

a) Variable - Air flowrate

| Run No. | Wt. of Sample Kg. | Drying Temp. °C | Air Flowrate | | Bed Depth cm. | Bed Loading Kg.B.D.S/$m^2$ | Chip Size cm. |
|---|---|---|---|---|---|---|---|
| | | | liter/min | Kg/hr.$m^2$ | | | |
| B - 1 | 2.458 | 80 | 1,100 | 2,096 | 15 | 32.1 | 2x6x0.5 |
| B - 2 | 2.458 | 80 | 800 | 1,524 | 15 | 32.1 | 2x6x0.5 |
| B - 3 | 2.458 | 80 | 600 | 1,144 | 15 | 32.1 | 2x6x0.5 |
| B - 4 | 1.705 | 80 | 1,100 | 2,096 | 10 | 22.3 | 2x6x0.5 |
| B - 5 | 1.705 | 80 | 800 | 1,524 | 10 | 22.3 | 2x6x0.5 |
| B - 6 | 1.705 | 80 | 600 | 1,144 | 10 | 22.3 | 2x6x0.5 |

b) Variable - Bed depth

| Run No. | Wt. of Sample Kg. | Drying Temp, °C | Air Flowrate | | Bed Depth cm. | Bed Loading Kg. B.D.S/m$^2$ | Chip Size cm. |
|---|---|---|---|---|---|---|---|
| | | | liter/min | Kg/hr.m$^2$ | | | |
| B - 7 | 0.707 | 80 | 800 | 1,524 | 5 | 9.1 | 2x6x0.3 |
| B - 8 | 1.492 | 80 | 800 | 1,524 | 10 | 18.4 | 2x6x0.3 |
| B - 9 | 2.236 | 80 | 800 | 1,524 | 15 | 24.5 | 2x6x0.3 |
| B -10 | 2.989 | 80 | 800 | 1,524 | 20 | 38.7 | 2x6x0.3 |
| B -11 | 1.492 | 80 | 1,100 | 2,096 | 10 | 18.4 | 2x6x0.3 |
| B -12 | 2.236 | 80 | 1,100 | 2,096 | 15 | 24.5 | 2x6x0.3 |
| B -13 | 2.989 | 80 | 1,100 | 2,096 | 20 | 38.7 | 2x6x0.3 |

c) Variable - Hot air temperature

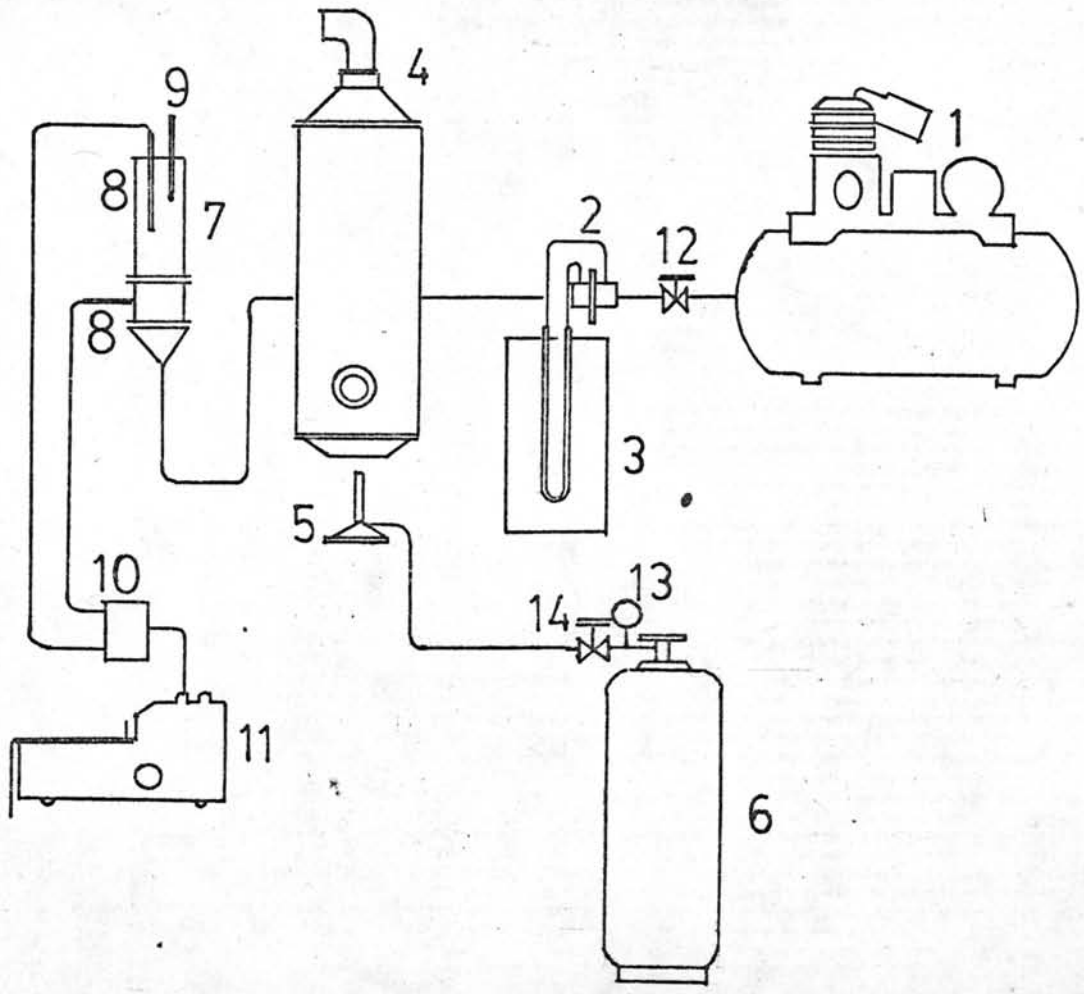
| Run No. | Wt. of Sample Kg. | Drying Temp, °C | Air Flowrate | | Bed Depth cm. | Bed Loading Kg. B.D.S/$m^2$ | Chip Size cm. |
|---|---|---|---|---|---|---|---|
| | | | liter/min | Kg/hr.$m^2$ | | | |
| B - 14 | 2.458 | 90 | 1,100 | 2,096 | 15 | 32.1 | 2x6x0.5 |
| B - 15 | 2.458 | 80 | 1,100 | 2,096 | 15 | 32.1 | 2x6x0.5 |
| B - 16 | 2.458 | 70 | 1,100 | 2,096 | 15 | 32.1 | 2x6x0.5 |
| B - 17 | 2.458 | 60 | 1,100 | 2,096 | 15 | 32.1 | 2x6x0.5 |
| B - 18 | 1.492 | 90 | 800 | 1,524 | 10 | 18.4 | 2x6x0.3 |
| B - 19 | 1.492 | 80 | 800 | 1,524 | 10 | 18.4 | 2x6x0.3 |
| B - 20 | 1.492 | 70 | 800 | 1,524 | 10 | 18.4 | 2x6x0.3 |

d) Variable - Chip thickness

| Run No. | Wt. of Sample Kg. | Drying Temp. C | Air Flowrate | | Bed Depth cm. | Bed Laoding Kg. B.D.S/$m^2$ | Chip Size cm. |
|---|---|---|---|---|---|---|---|
| | | | liter/min | Kg/hr.$m^2$ | | | |
| B - 21 | 1.492 | 80 | 800 | 1,524 | 10 | 18.4 | 2x6x0.3 |
| B - 22 | 1.705 | 80 | 800 | 1,524 | 10 | 22.3 | 2x6x0.5 |
| B - 23 | 1.662 | 80 | 800 | 1,524 | 10 | 21.1 | 2x6x0.7 |
| B - 24 | 2.236 | 80 | 800 | 1,524 | 15 | 24.5 | 2x6x0.3 |
| B - 25 | 2.458 | 80 | 800 | 1,524 | 15 | 32.1 | 2x6x0.5 |
| B - 26 | 2.474 | 80 | 800 | 1,524 | 15 | 31.4 | 2x6x0.7 |

Part C: Diffusion Mechanism Study

| Run No. | Wt. of Sample Kg. | Drying Temp. °C | Air Flowrate | | Bed Depth cm. | Bed Loading Kg.B.D.S/$m^2$ | Chip Size cm. |
|---|---|---|---|---|---|---|---|
| | | | liter/min | Kg/hr.$m^2$ | | | |
| C - 1 | 0.670 | 70 | 2,133 | 4,038 | 10 | 18.4 | 2x6x0.3 |
| C - 2 | 0.670 | 85 | 2,133 | 4,038 | 10 | 18.4 | 2x6x0.3 |
| C - 3 | 0.670 | 100 | 2,133 | 4,038 | 10 | 18.4 | 2x6x0.3 |
| C - 4 | 4.0227gm. | 85 | 2,133 | 4,038 | Single | - | 2x6x0.3 |
| C - 5 | 4.3432gm. | 70 | 2,133 | 4,038 | Single | - | 2x7x0.3 |
| C - 6 | 3.9805gm. | 55 | 2,133 | 4,038 | Single | - | 2x6x0.3 |




1 Air compressor
2 Orifice meter
3 Manometer
4 Air-preheater
5 Burner
6 Fuel storage tank
7 Column
8 Thermocouples
9 Thermometer
10 Co-junction switch
11 Temp. recorder
12 Globe valve
13 Pressure gauge
14 Control valve

Figure 3.1 Arrangement of Apparatus

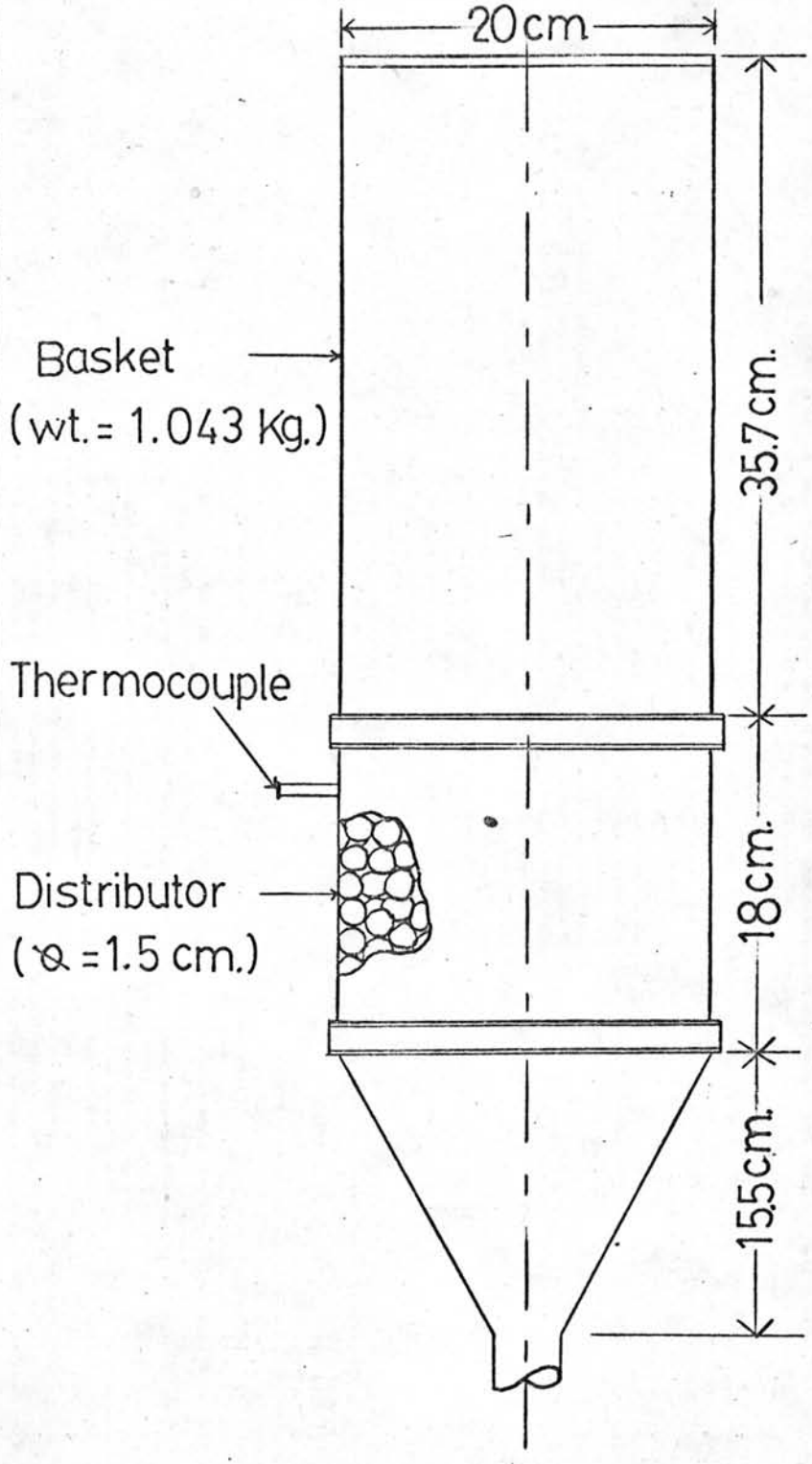



Figure 3.2 Design of Column (large)

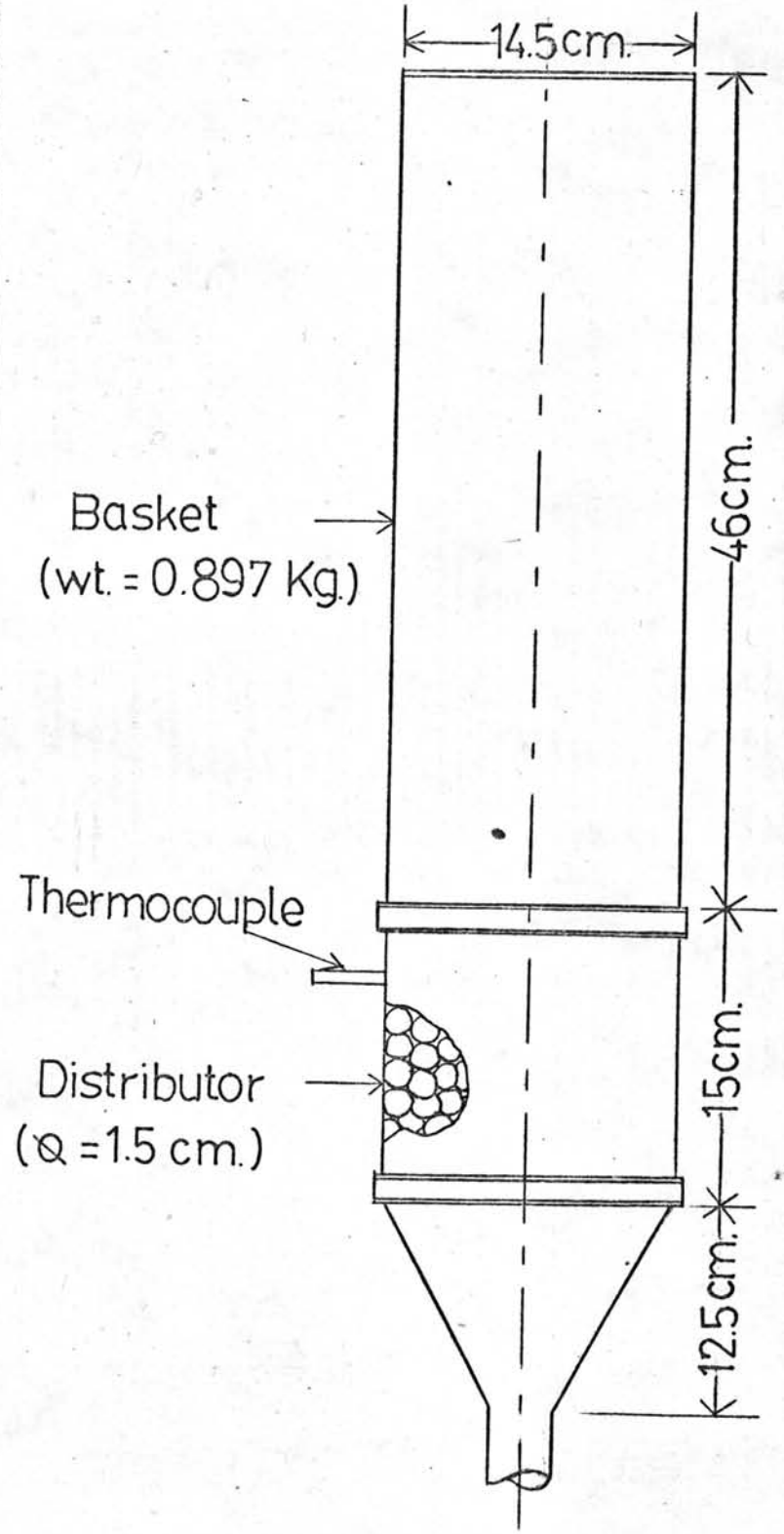



Figure 3.3 Design of Column(small)

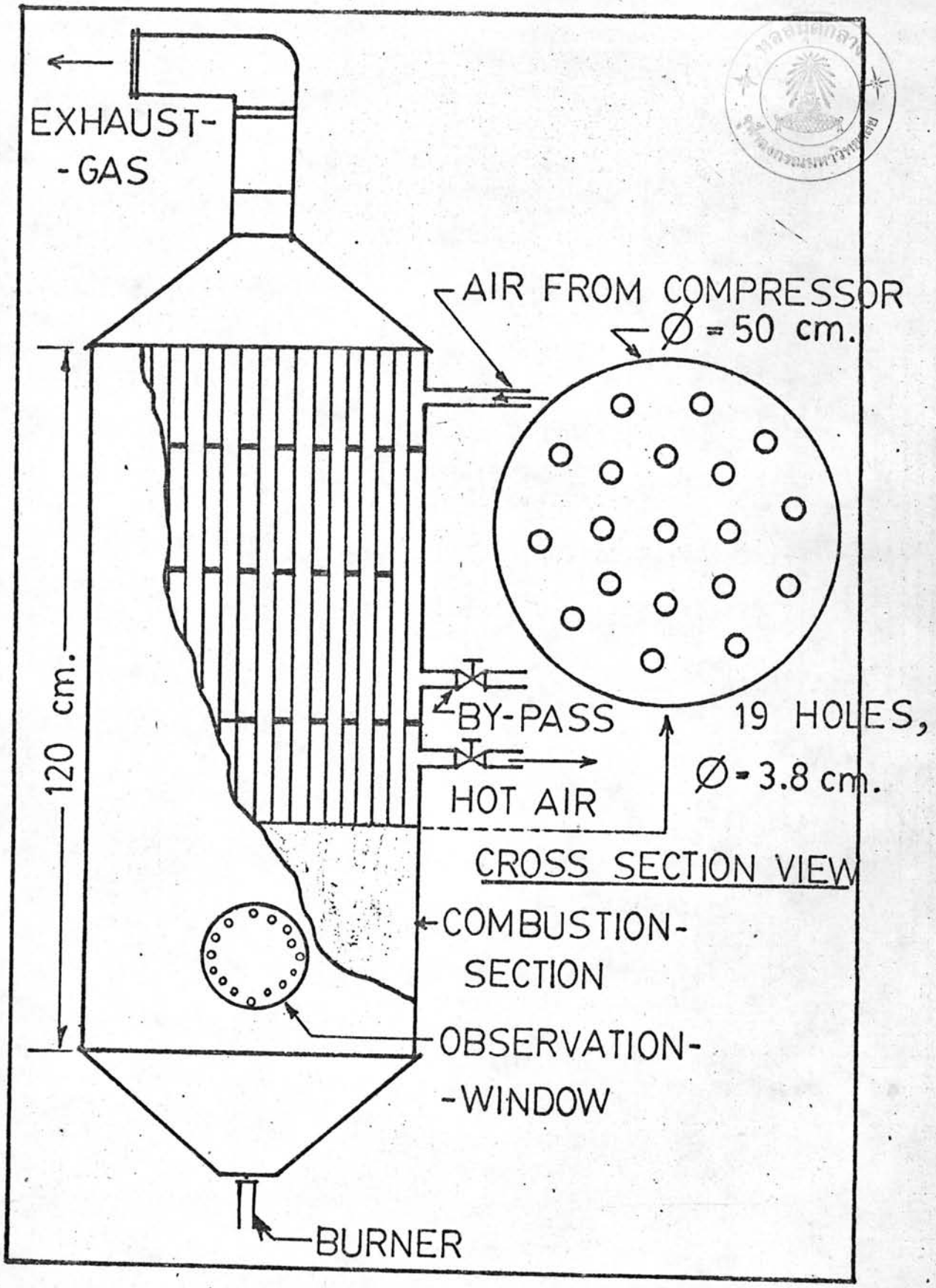



Figure 3.4 Assembly of Air-preheater

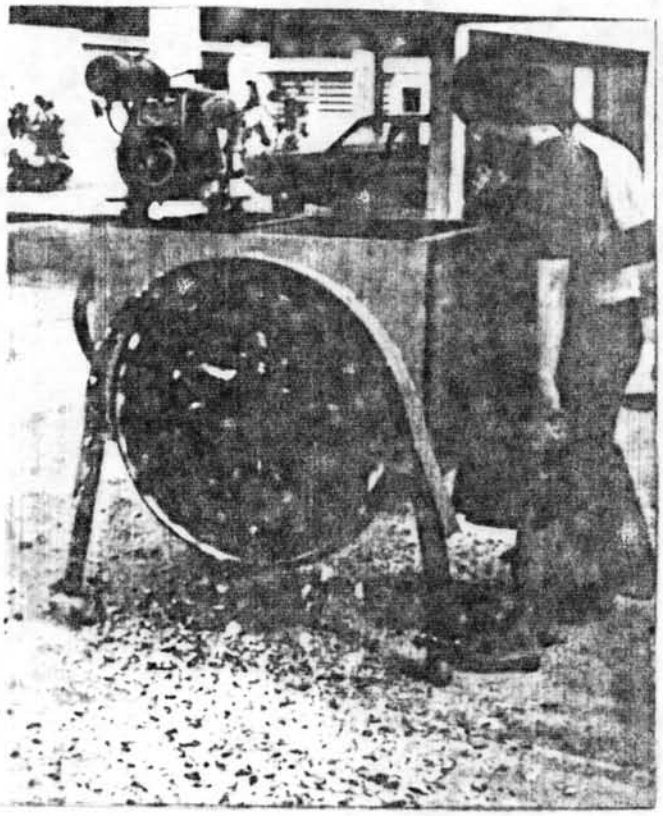


Figure 3.5 Malaysian Blade Cutter

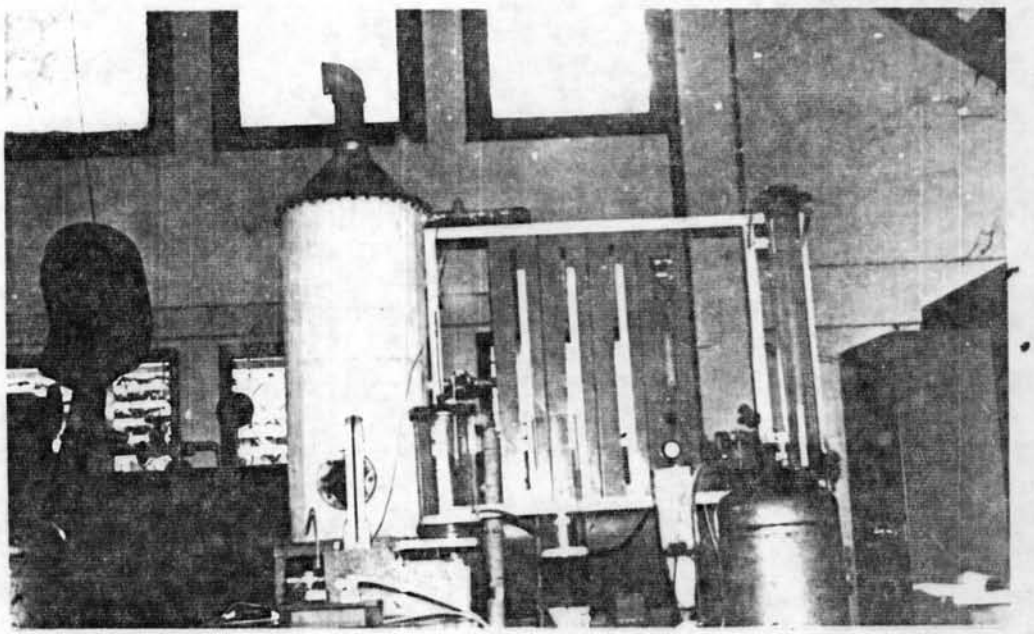


Figure 3.6 A photographic showing the arrangement of experimental equipment.