CHAPTER III

THIN-LAYER DRYING APPARATUS AND EXPERIMENTAL PROCEDURE

A photograph of laboratory grain drying apparatus used in this research is shown in Figure 3.1. The apparatus consists of two major parts : 1) An air conditioning system to supply air at predetermined temperatures and relative humidities to the grain sample, and 2) The drying unit.

3-1 Air conditioning system

The purpose of the air conditioning system is to deliver a specified quantity of air to the grain sample at constant conditions of temperature and relative humidity. The main apparatus consists of a centrifugal blower,(Figure 3.3) a boiler and a steam valve, (Figure 3.5) electrical resistance heaters, duct work, insulator etc. Figure 3.2 is a schematic drawing of the apparatus. The centrifugal blower was manufactured by the National Company (Model FY-23CG). It has a 21 cm diameter forward-curved blade wheel and is capable of delivering 20 m^3 of air/min against a pressure of 2.16×10^2 N/m^2. The speed of blower is controlled by autotransformer (Yokohama Electric Work Co.,Ltd,Type SB-2) which was adjusted to give a required air velocity. The inside cross-sectional dimensions of the air duct were 0.30 m. x 0.30 m. The entire duct was well insulated to minimize the effect of heat loss to the surrounding. The outlet of the air duct was connected to the drying unit (Figure 3.8). The air temperature was raised to the desired level by turning on as many of the electrical fin-strip heaters as required. The heaters controlled by variable voltage transformer provided adjustment of air temperature. The

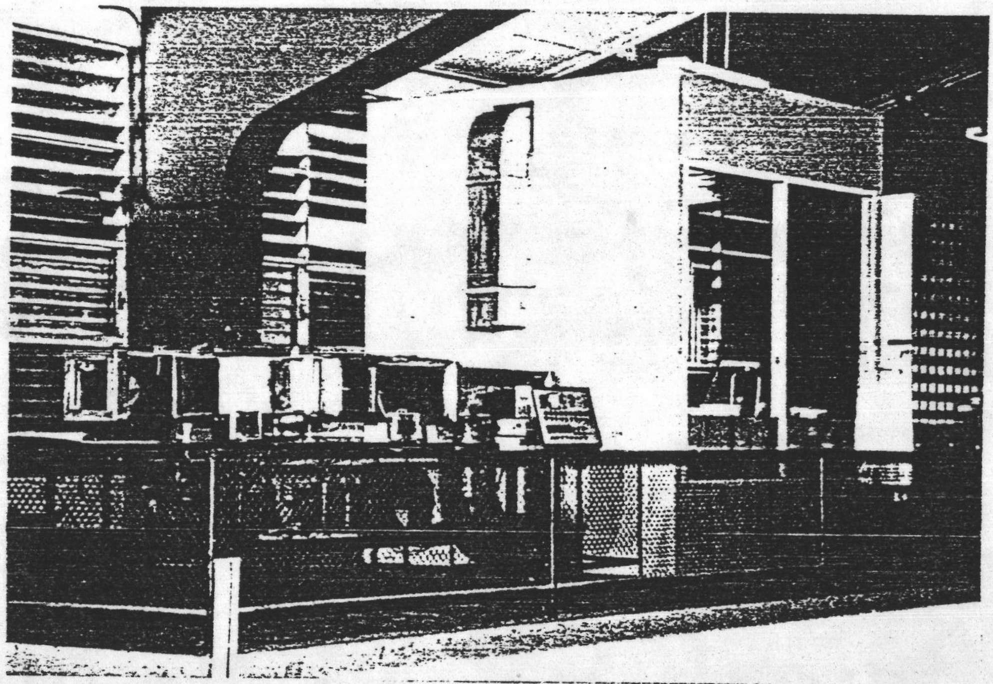

Figure 3.1 Photograph of overall view of the laboratory experimental apparatus

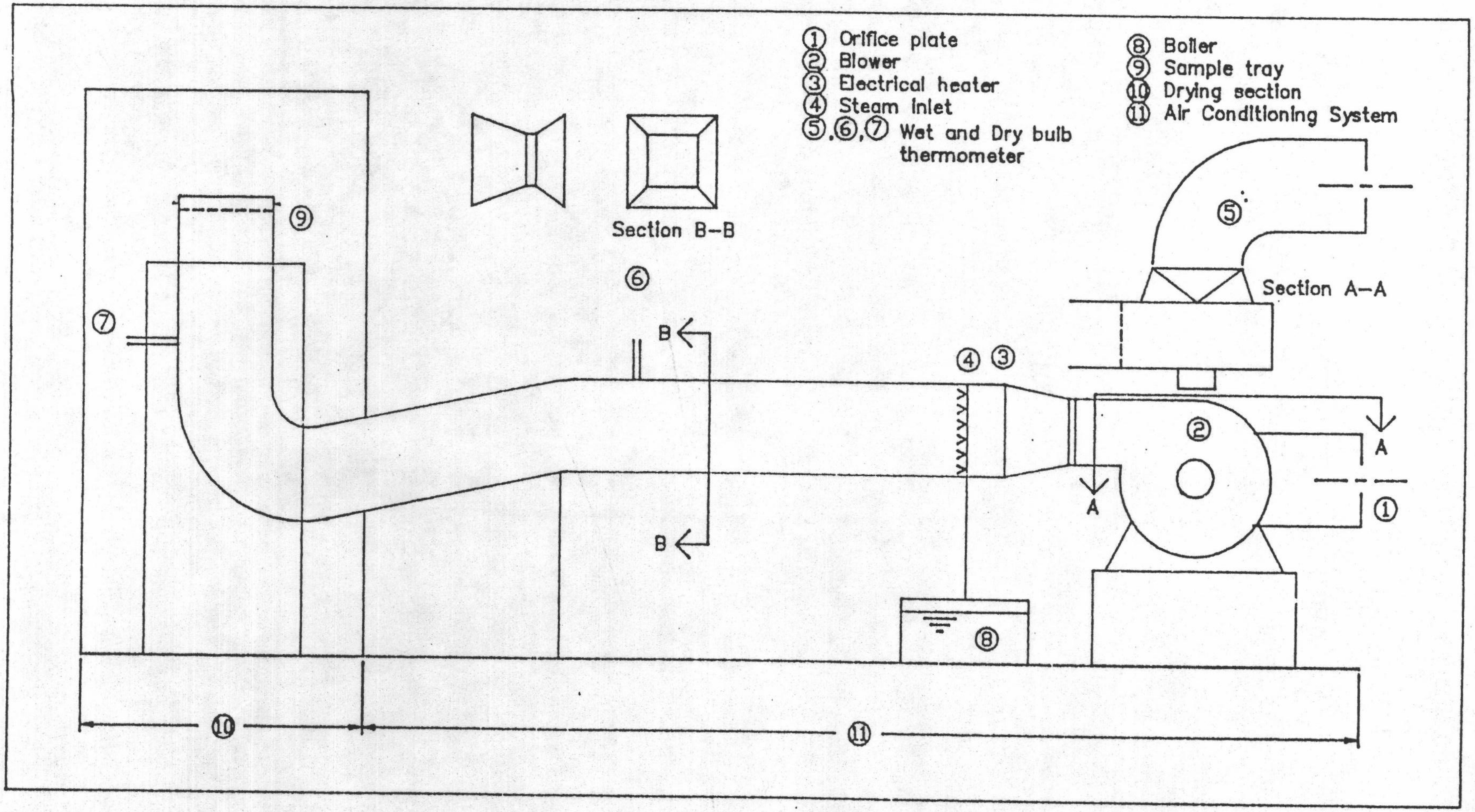

Figure 3.2 Schematic of laboratory grain drying apparatus

humidity of drying air was adjusted by injecting steam into the humidifying section (Figure 3.6). Electrical heaters in the boiler are also controlled by variable voltage transformer. A sharp-edged orifice (Figure 3.4) with Cd = 0.561 is used as an air flow rate measuring instrument. The pressure drop across the orifice plate was measured by a manometer (Figure 3.4). The drying air will be forced through a heating, humidifying area and then through the rough rice samples. Figure 3.7 is also shown a photograph of panel containing steam, drying air temperature and air flow rate controllers.

3-1.1 Measurement of temperature

The chromel-alumel thermocouples and data logger (Takeda Riken Co.,Ltd,Model TR2721),(Figure 3.9) were calibrated with a mercury-in-glass thermometer in oil bath. Wet and dry bulb thermocouples were placed at three points in the duct. The locations of the thermocouples are shown in Figure 3.2. The wet wicks were fed from a constant level distilled water glass tube. The data logger was used to record and monitor various temperature at each location. The drying air temperature was checked by a digital temperature meter (Chino Co.,Ltd, the probe of meter, Model HN-L18 and indicator, Model HN-K), (Figure 3.12). The platinum resistance thermometer is used to be the sensor of the meter.

3-1.2 Measurement of relative humidity

The relative humidity of air was calculated from wet bulb and dry bulb temperature and checked by digital humidity meter (Chino Co.,Ltd, the probe of meter, Model HN-L18 and indicator, Model

HN-K),(Figure 3.12). A polymer film humidity sensor (electrostatic capacitance type) is used to be the sensor.

3-1.3 Measurement of air flow rate and velocity

Air flow was measured by recording the pressure drop across a sharp-edge orifice, C_d = 0.561 (Figure 3.4). The pressure drop across the orifice plate was measured by Dwyer manometer (Model No.25 molded plastic manometer).

3-2 Thin-layer drying Unit

The drying unit is shown in Figure 3.8. The entire unit was well sealed and insulated with 3 cm thick glass wool. The drying sample tray was .30 x .30 m. inside dimension,(Figure 3.8). The sides of the tray were made of sheet metal and the bottom was made of 1.6 mm (1/16 inch) brass mesh. This tray was designed to accommodate a 180 gram sample of one grain thickness and could be easily removed and placed on a Oertling digital balance (Model TP41),(Figure 3.10) where it could be weighed with an accuracy of 0.005 g. The edges of the tray were contacted perfectly with the outlet of air duct. Thus all the air was forced through the tray.

Wet and dry bulb chromel-alumel thermocouples junctions were located 25 cm. below the sample tray, they were used to sense the air conditions just prior to entering the sample tray. The wet bulb wicks were fed from a constant level distilled water reservoir. Dry bulb and wet bulb temperatures were also monitored and recorded continuously with a data logger (Takeda Riken Co.,Ltd, Model TR 2721)

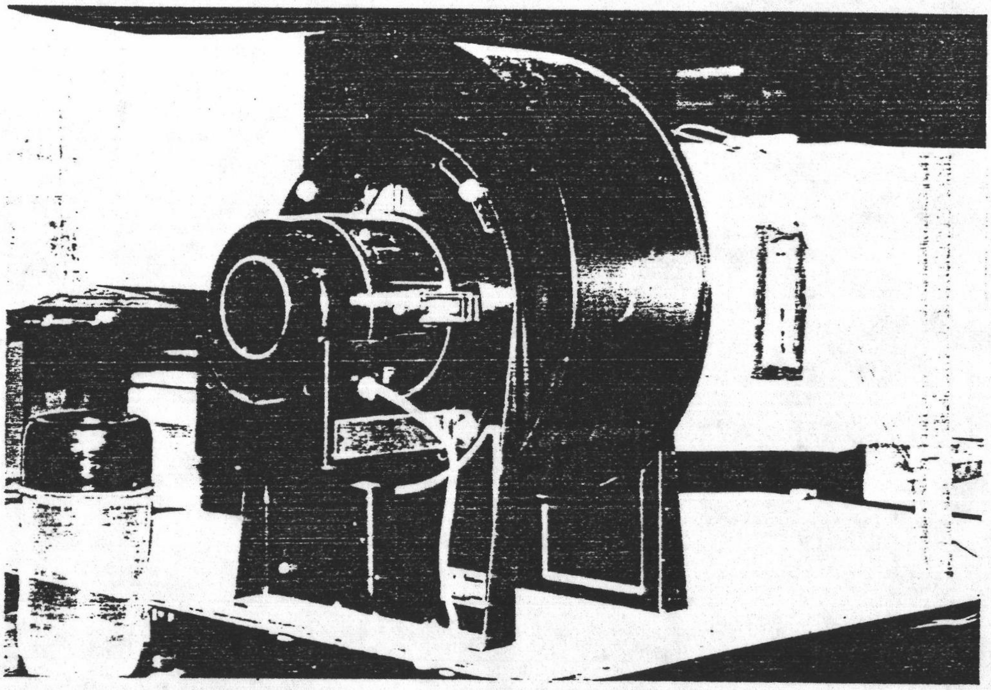

Figure 3.3 Photograph of centrifugal blower

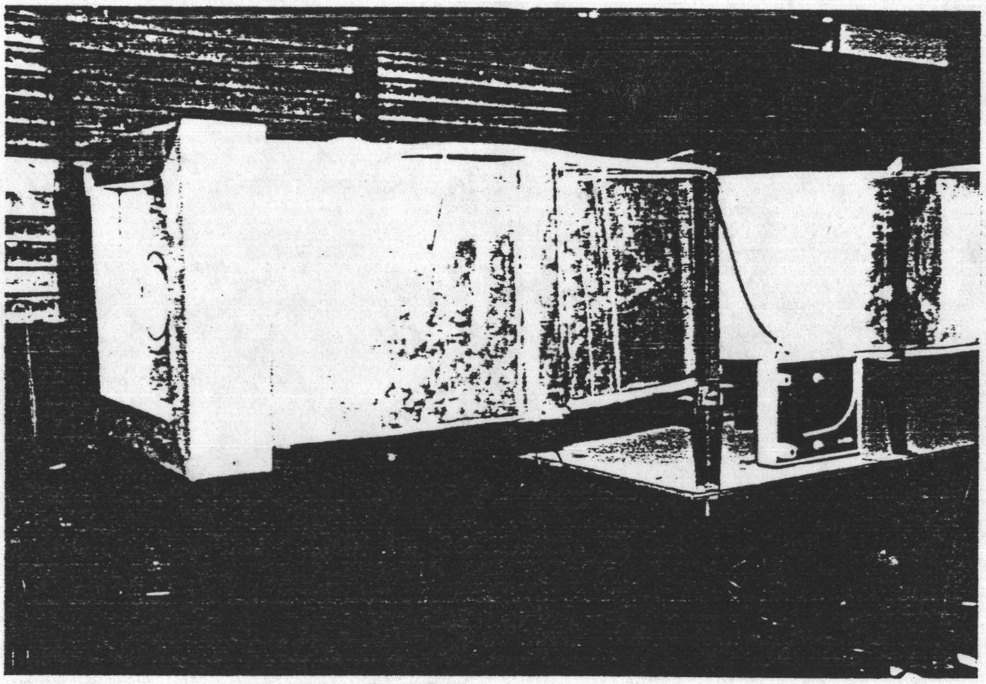

Figure 3.4 Photograph of orifice plate and manometer

that displayed at 1 minute intervals. The accuracy of these measurements was checked using a digital humidity and temperature meter. The probe of meter, Model HN-L18 and indicator, Model HN-K were supplied by Chino Co.,Ltd.

3-2.1 Measurement of grain moisture content

Initial moisture content determinations were made using the 16 h whole grain, 130 °C standard oven method and checked by moisture content obtained from an electronic tester (Proti-meter Co.,Ltd, Model G178 M/C).

3-3 Experimental procedure

3-3.1 Sample preparation

The long grain rough rice of RD7 variety, obtained from Pathum Thani Rice Research Center, was used in this study. The initial moisture content of rough rice was around 22 % dry basis. Kernels were selected carefully in an attempt to minimize the effect of kernel size. Average length, width and thickness of kernel were 7.3 mm, 2.3 mm and 1.8 mm respectively. Since freshly harvested rough rice at high moisture content could not be obtained for the experiment, the moisture content of dry grain was rewetted. To do this the grain was hand cleaned to remove dockage and dust before conditioning. The grain was spread on a brass tray and sprayed with calculated amounts of distilled water to bring the moisture content up approximately to the desired value. After throughly mixing the grain, it was stored in closed plastic containers at 5 °C for at least 14 days and shaken periodically to establish uniform moisture distribution within the

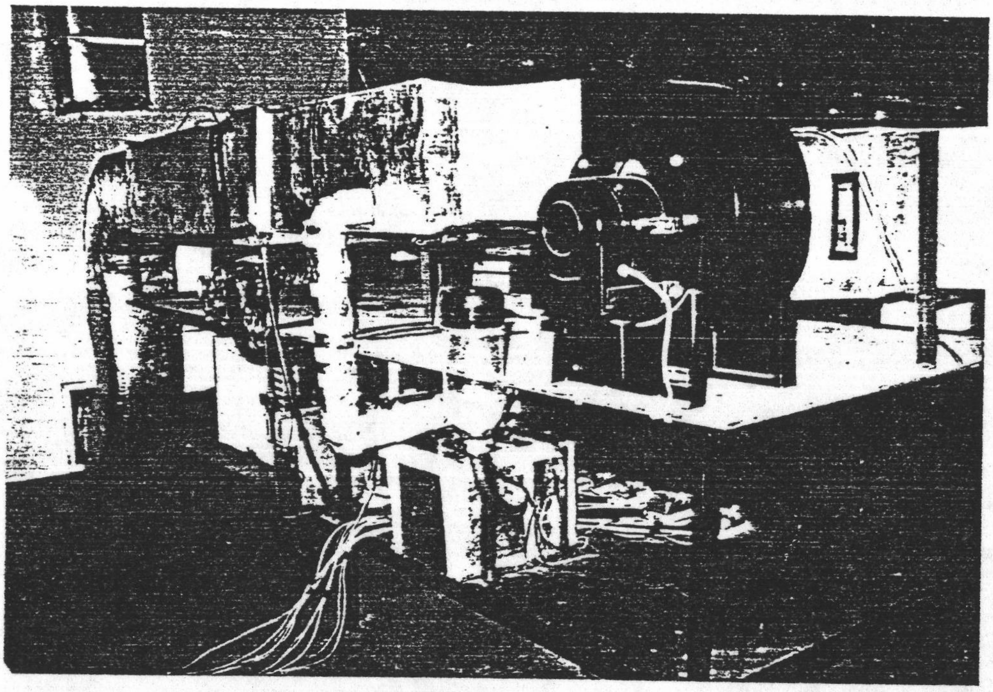

Figure 3.5 Photograph of boiler and steam valve

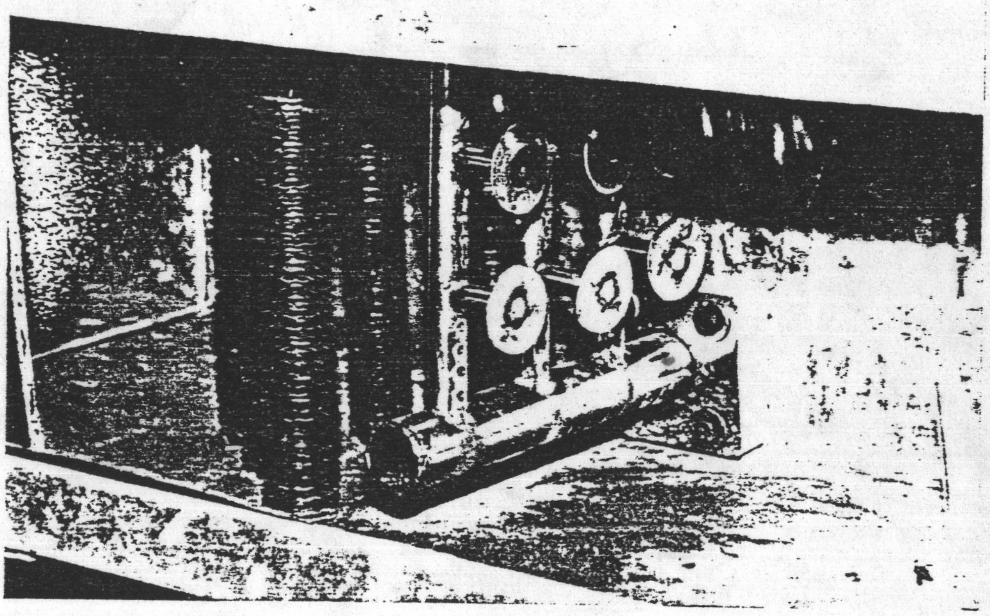

Figure 3.6 Photograph of air heater and steam inlet

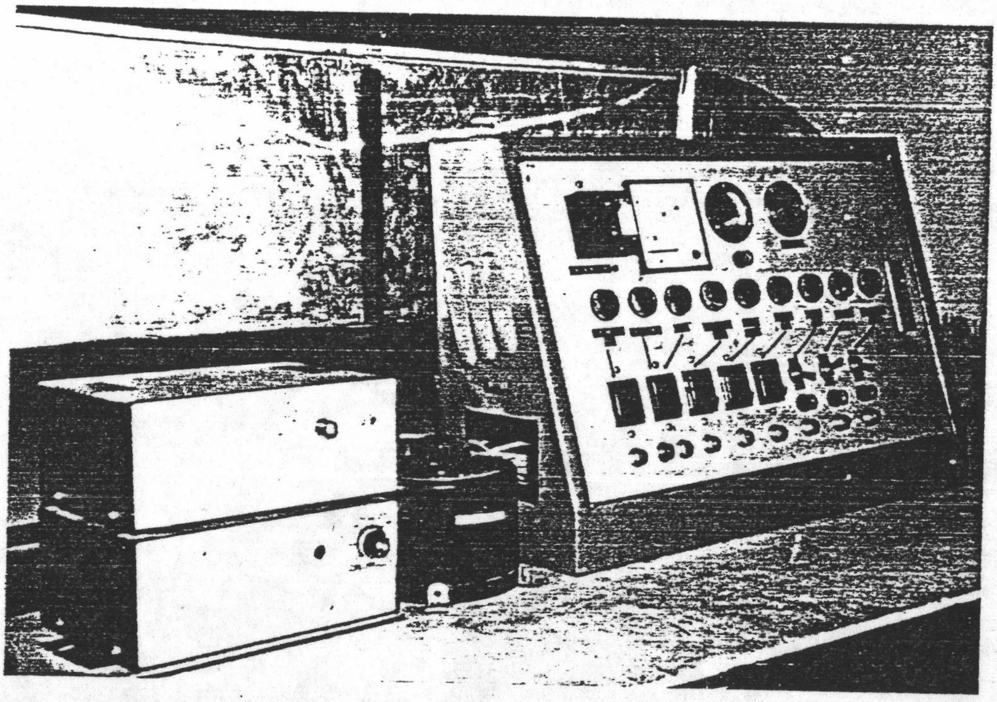

Figure 3.7 Photograph of panel containing steam, air temperature and air flow rate controllers

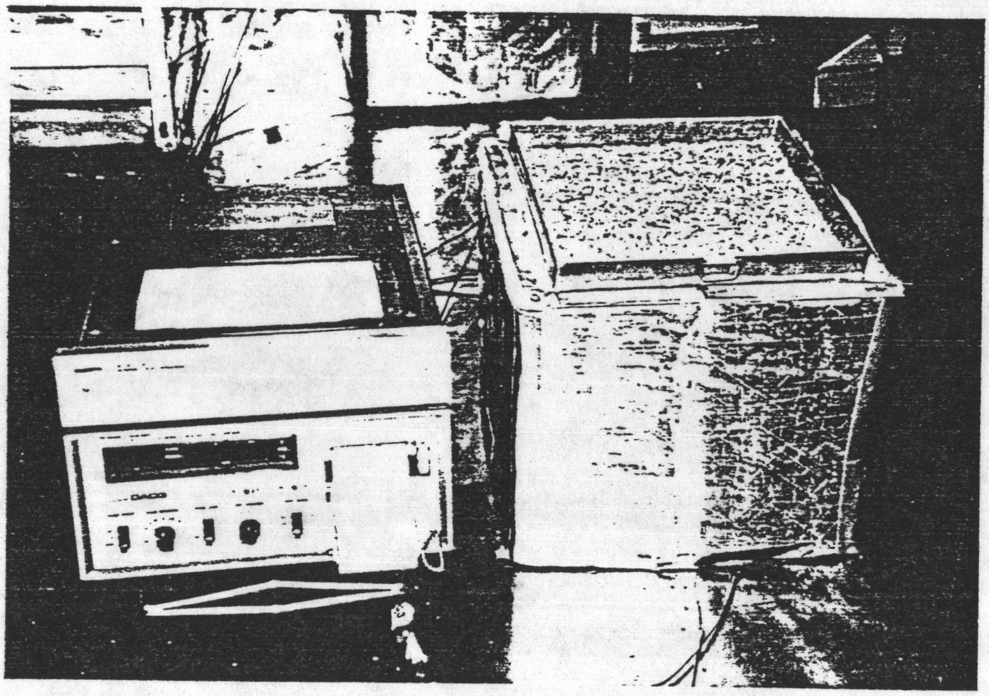

Figure 3.8 Photograph of drying section and sample pan

grain kernels and throughout the grain mass. The above rewetting process have been presented and used by Dung (1980).

3-3.2 Equipment operation procedure

Thin-layer drying tests were conducted for each combination of the following parameters :

1. Temperature of drying air (35-60°C)
2. Relative humidity of drying air (30-70 percent)
3. Initial moisture content of rough rice (20-40 percent, dry basis)

The air conditioning unit was run at specified conditions of drying air at least 1 hour before each experiment begun, so that the temperature, relative humidity and air velocity could become stabilized. During the experiment they were accurately maintained in the apparatus. The samples were removed from the container and allowed to warm up to the room temperature to avoid condensation during drying. A sample of 20 g in triplicate were initially used to determine the grain moisture content by using the standard oven method (16 hours at 130°C). The approximate initial moisture content of the sample were also determined by electronic tester. After stabilizing the temperature and relative humidity of the drying air, a 180 g sample was placed in the brass-mesh tray which was placed in the air stream. The air at a controlled temperature and relative humidity and at a known flow rate passed through a sample tray. Samples were weighed periodically on an electronic balance which had a capacity of 400 g and a sensitivity of 0.005 g. This operation could be carried out rapidly and it was

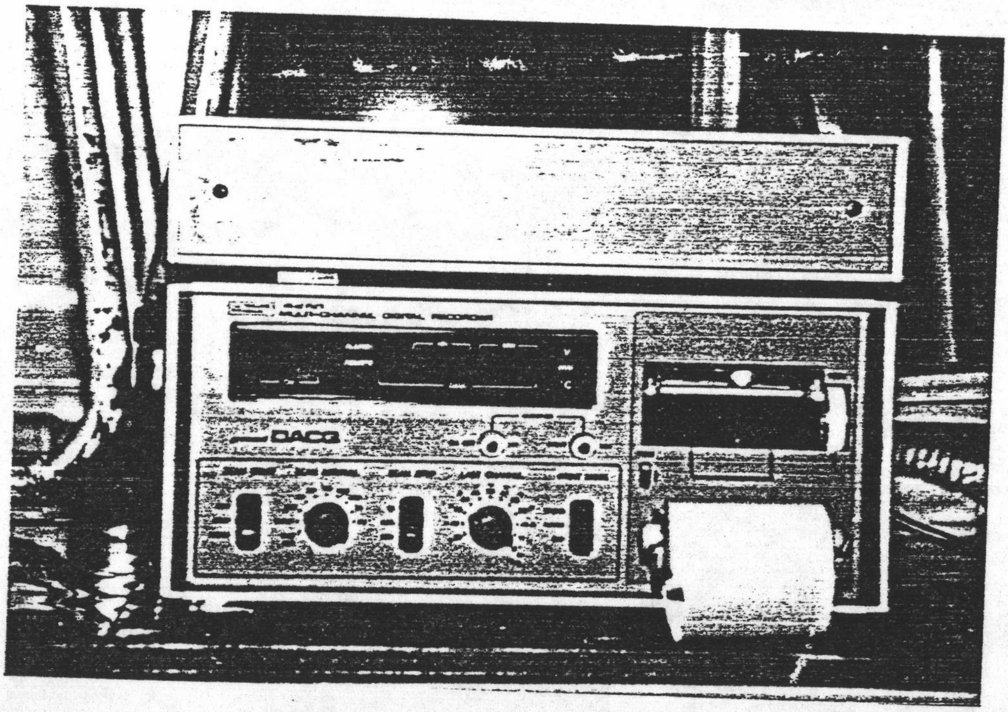

Figure 3.9 Photograph of data logger

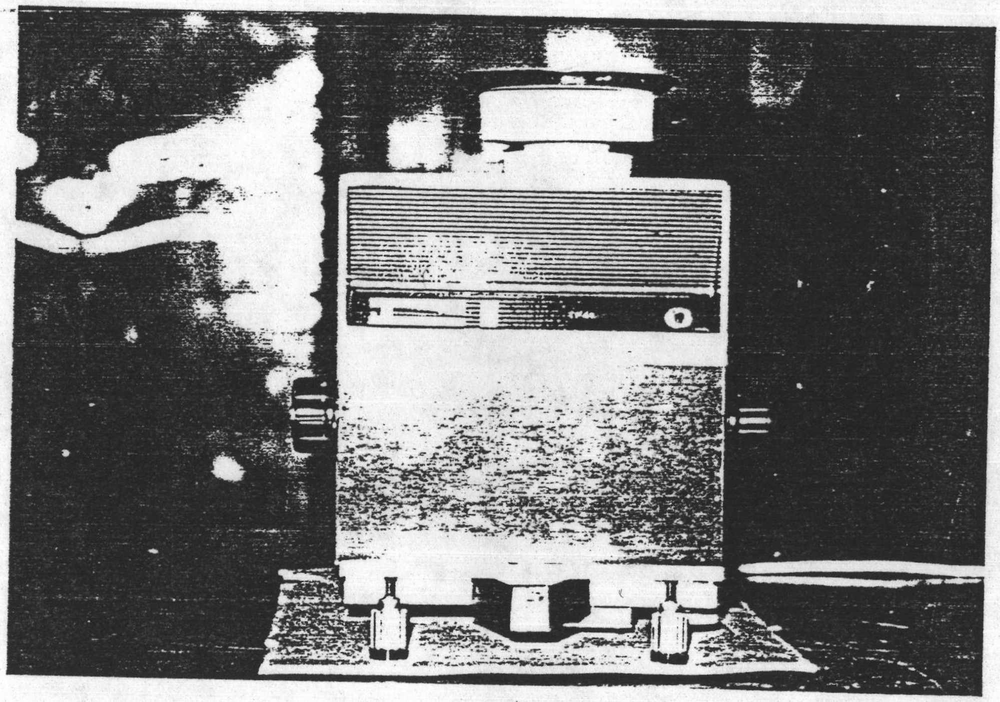

Figure 3.10 Photograph of precision balance

considered that such brief interruptions did not interfere with the drying process. During the initial stages of drying, a measurement was made every 5 minute. This time interval was increased as the drying rate decreased. All the drying time,dry bulb and wet bulb temperatures of drying air were monitored by a data logger and controlled continuously by manual. The airflow was also controlled by an autotransformer. The temperature was measured for checking at various points in the system. At the end of each drying run the final moisture content of rough rice was checked by the standard oven method (16 hours at 130°C).

The weight of the samples which was periodically measured by the electronic balance was transformed to moisture content. Then the moisture content, drying time and drying air conditions used to find the thin layer drying model. A complete summary of the conditions for all of the samples and the data collected from the experiment are contained in Appendix A.

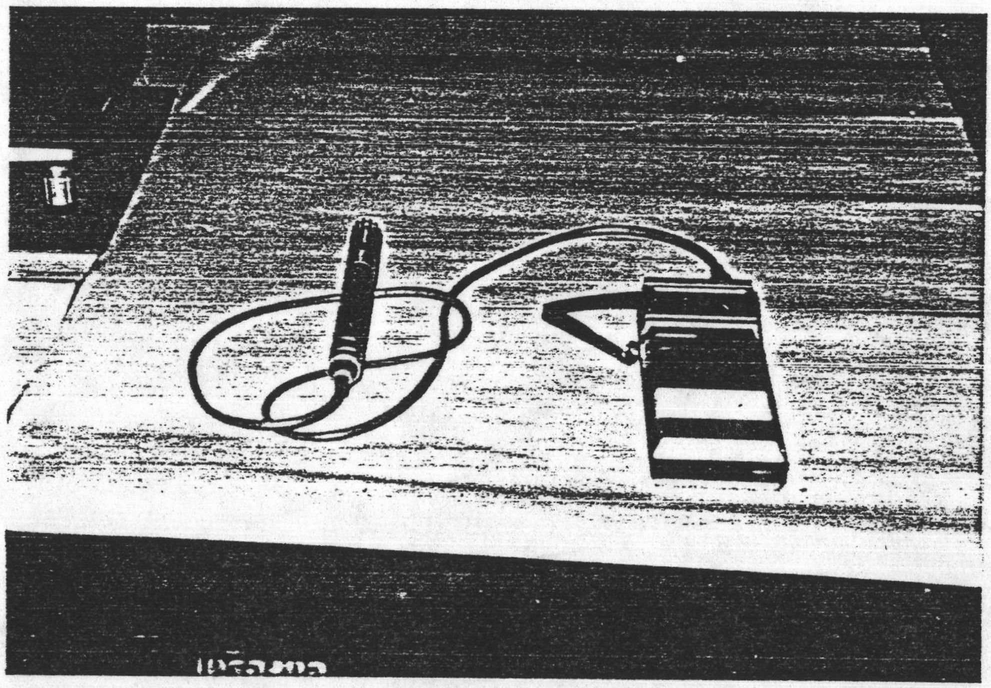

Figure 3.11 Photograph of digital thermometer and its probe