# CHAPTER III

# EXPERIMENTAL WORK

## 3.1 The Design of a Low Cost Portable Solar Radiometer.

For utilization of solar energy as an alternative resource, solar radiometers are required to survey the availibility of solar energy. Commercially available solar radiometers cost many thousand bahts, and they are delicate instruments, requiring skilled personnel for their operation. In developing countries, a low cost radiometer is needed by research workers with limited funds for testing their equipments. The aim of this research was to develop a simple portable radiometer to measure total solar radiation and costing not more than a few hundred bahts. The conditions of design were simplicity of construction, minimum cost and no scientific training or knowledge required by an operator.

When an object is exposed to solar radiation its temperature rises until its heat losses become equal to its heat gains. The losses depend on the emission of radiation by the heated material, the movement of the surrounding air, and the thermal conductivity of the materials in contact with it. The gains depend on the intensity of solar radiation and the absorptivity of solar radiation by its surface. The basic idea of the radiometer design comes from a performance of flat-plate collector which uses black coated metal sheet for collecting total solar radiation. The black absorbing sheet is placed in a frame, usually wood, and tilted at the proper angle. The box holding the collector is made of thin wood, plastic, or very thin metal to minimize heat losses by thermal conduction, and covered with insulation material such as glass wool or plastic foam to reduce heat losses to the surrounding air. The glass or plastic transparent cover reduces the heat losses from convection and radiation[10].

In the radiometer design, the black coated metal disk which placed in a wooden circular case with glass cover was used as a solar radiation receiver. By making an energy balance on the metal disk the thickness of the disk was chosen to give a suitable response time of the radiometer. The range of thickness of the metal disk which might be accepted for the design was from 0.3 to 3 mm. For measuring the temperature rise of the disk when it was exposed to solar radiation, a liquid in glass type thermometer was chosen because it was cheap, easy to read the temperature and have sensitivity more or less equal to a thermocouple in some case. Moreover, it could be used to indicate temperature without any accessories, The thermometer was attached under the disk at center. In order to provide better contact between thermometer bulb and the disk, the bulb was wrapped by a metal strip before taping to the disk. Several test models were studied. In order to reduce the heat losses from the disk by thermal conduction, several insulation materials such as glass wool, asbestos powder, asbestos sheet and polyethylene foam, etc. were tried by placing under the disk in the radiometer case. But the final design was without any insulating materials.

The detailed design of the instrument is shown in Figure 3.1. The instrument consisted of three parts as follows.

1. Base
2. Radiometer Case
    2.1 Supporting Frame
    2.2 Frames for Glass Cover
        2.2.1 Upper Frame for Glass Cover
        2.2.2 Lower Frame for Glass Cover
    2.3 Glass Cover
3. Disk
    3.1 Wooden Ring for Metal Disk
    3.2 Metal Disk

The detail of each unit of the instrument is presented separately as follows.

1. Base

The base of the solar radiometer was made of wood. It was used for supporting the radiometer case in horizontal plane. Provision was made for holding a thermometer to indicate ambient temperature underneath the base. The details of the base are shown in Figure 3.2.

2. Radiometer Case

The radiometer case was employed for housing the disk. There are 3 parts of the case as follows:

2.1 Supporting Frame

The detail of this wooden frame are shown in Figure 3.3, it was mounted on the base. The disk was supported in this supporting frame by five supporting nails protuding radially from the frame.

2.2 Frame for Glass Cover

These wooden frames were used for holding the glass cover on the supporting frame. The detail of the lower and upper frames for glass cover are shown in Figure 3.3. Four screws were provided for tightening the frames upon the base.

2.3 Glass Cover

It was an ordinary glass plate available commercially with 0.32 cm thickness and 16.5 cm diameter.

3. Disk

The blackened metal disk which was used as a solar radiation receiver was fitted on a wooden ring inside the radiometer case on a horizontal plane. The disk consisted of two parts. Figure 3.4 shows their details.

3.1 Wooden Ring for Metal Disk

This ring was also made of 0.16 cm thick wood. Three small pieces of wood were taped on the ring for fitting the metal disk in central position.

3.2 Metal Disk

The solar radiation receiver was 12 cm. diameter metal disk coated with flat black color by spraying. On the other side of the disk, two pieces of strip metal were rolled and taped to the disk in order to provide better contact between thermometer bulb and the metal disk.

The thermometer which was used as a measuring element was a 0-100°C mercury thermometer with 1°C scale.

3.2 Experimental Test and Calibration

For studying the performance of the radiometer, 7 units of them were constructed. The unit no.1, 2, 3, 4 and 5 were of the same size but unit no.6 and 7 had different sizes of radiometer case. The dimensions of all seven units are shown in Table 3.1.

Following tests were made.

1. Test for the reproducibility of a radiometer by exposing it to a spot light lamp with constant radiant energy.

2. Test for the reproducibility of the various radiometers by exposing each of them to the spot light lamp.

3. Test for studying the effects of

- size of radiometer
- kind of metal disk
- thickness of metal disk
- diameter of metal disk
- kind of flat black paint

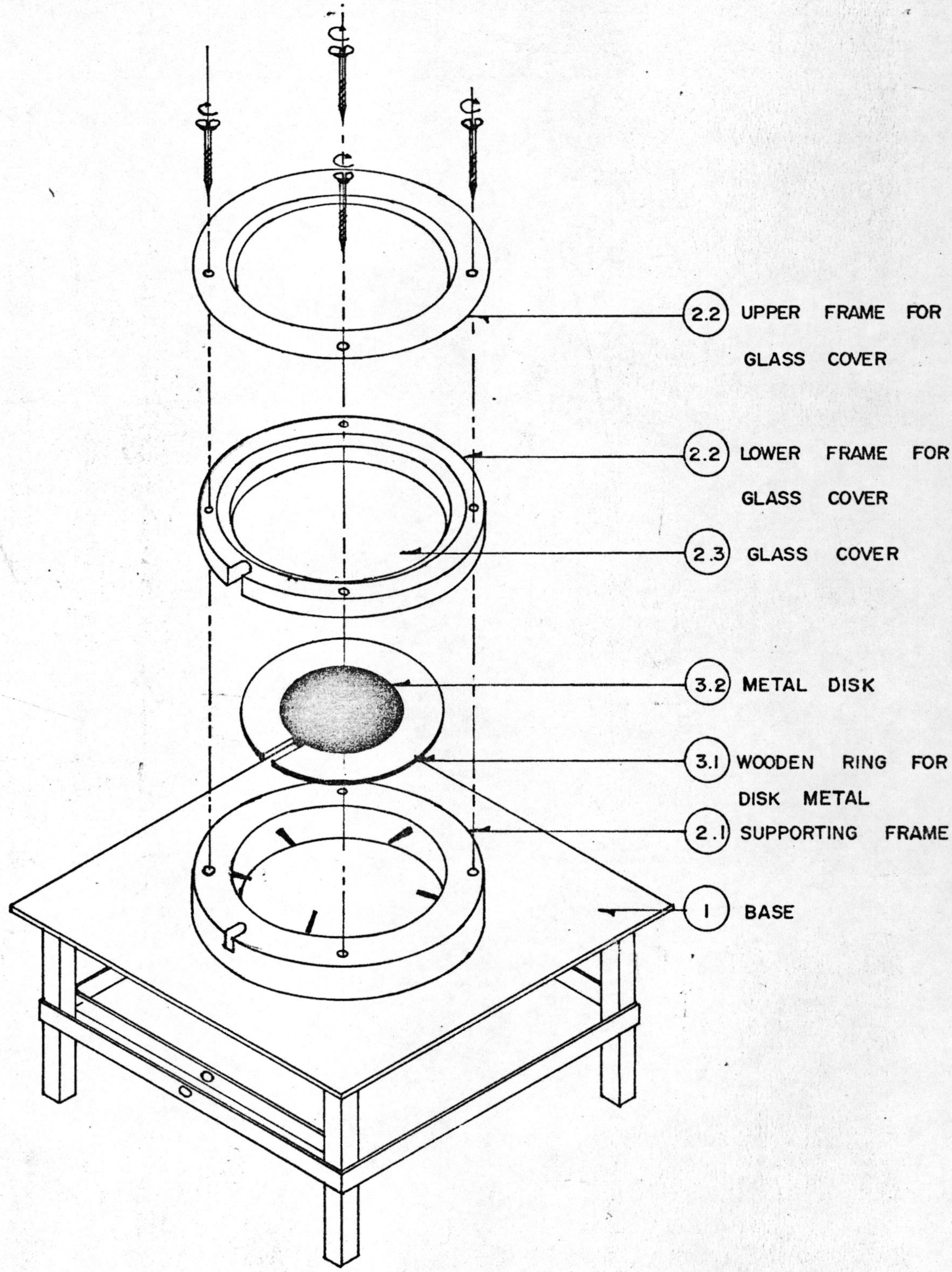



FIGURE 3.1 THE DETAILED OF LOW COST PORTABLE SOLAR RADIOMETER

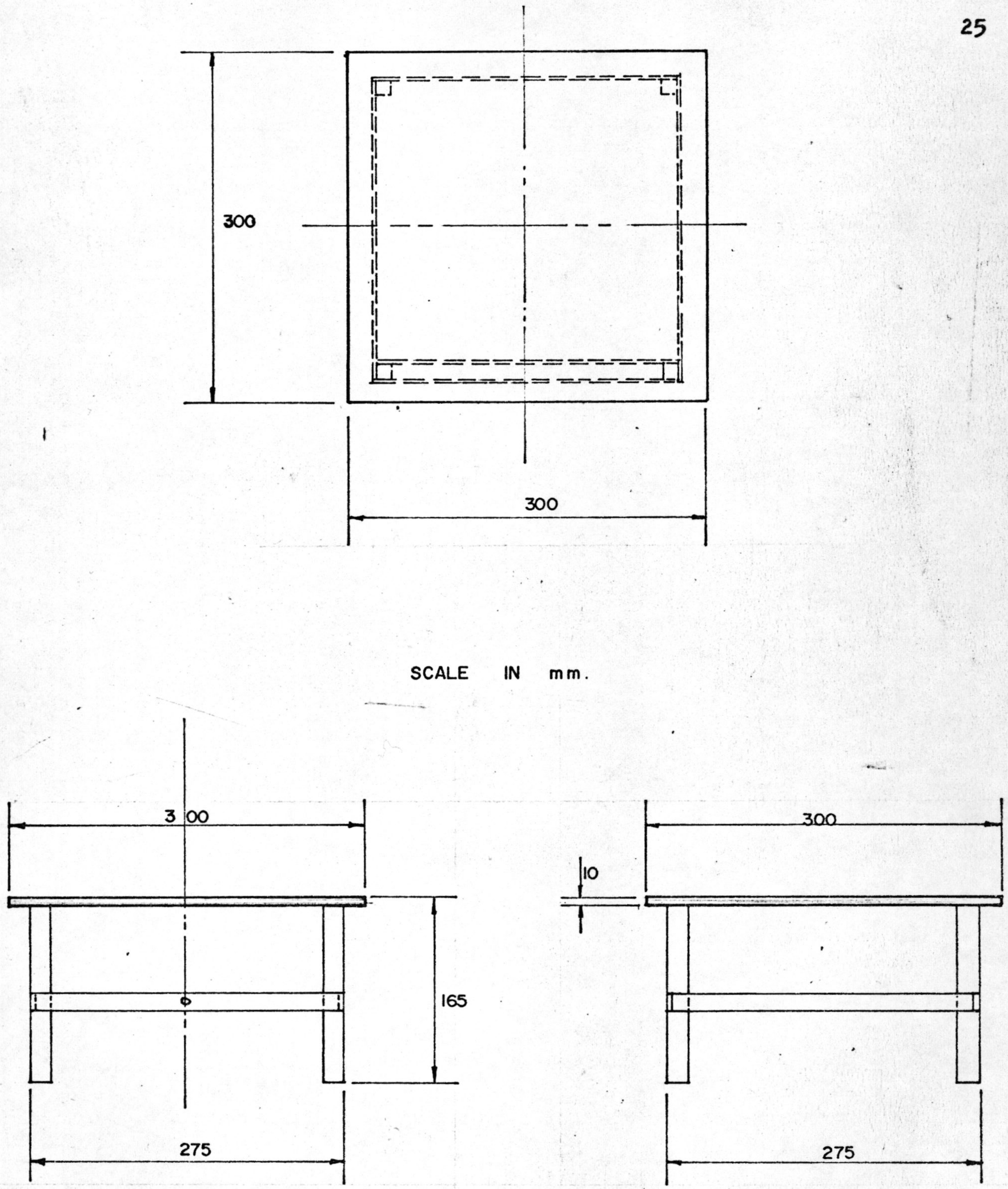
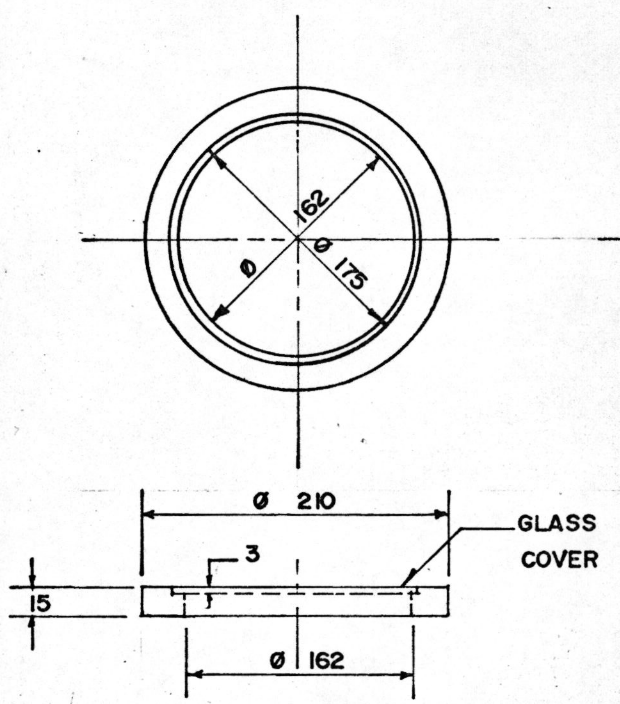
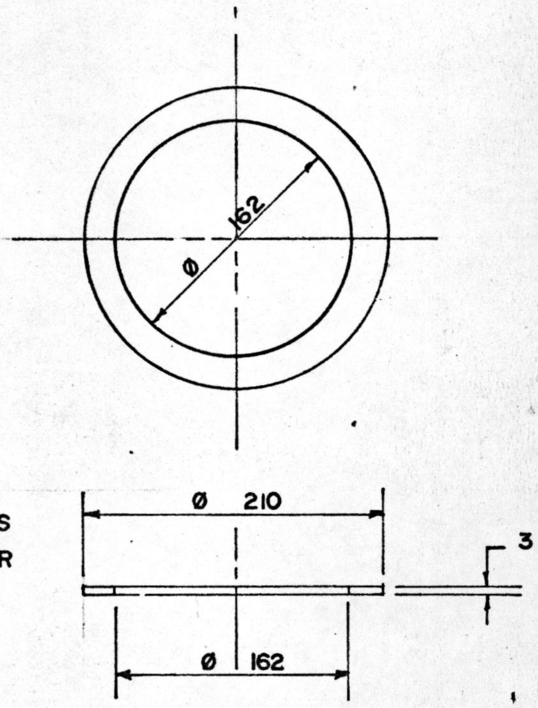



FIGURE 3.2 BASE OF RADIOMETER

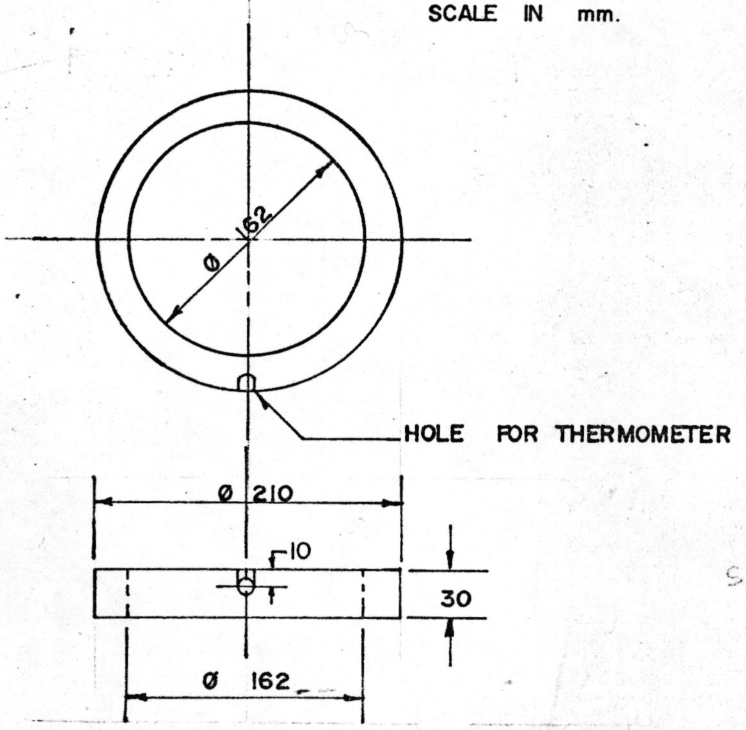



LOWER FRAME FOR GLASS COVER




UPPER FRAME FOR GLASS COVER

SCALE IN mm.




SUPPORTING FRAME

SCALE IN mm.

FIGURE 3.3 RADIOMETER CASE

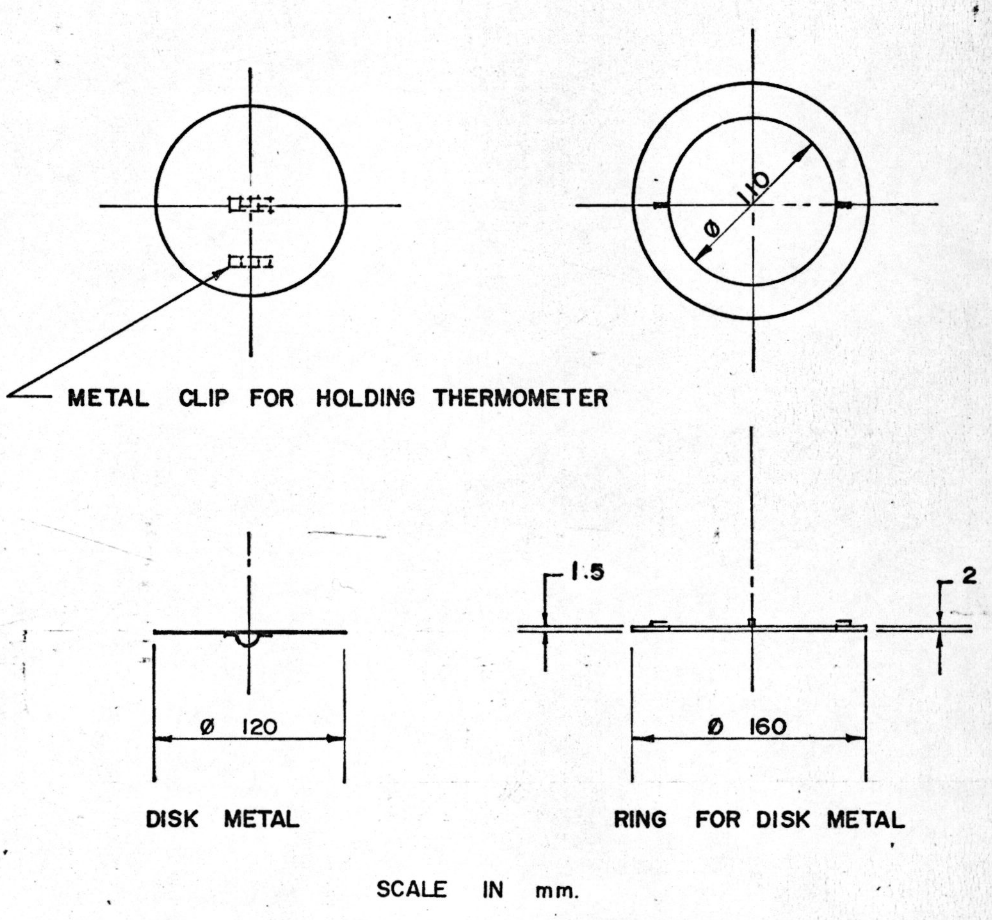



FIGURE 3.4 DISK

TABLE 3.1 Dimensions of Testing Units

| Unit no. | Base WxLxH (mm.) | Supporting Frame Dxt (mm.) | Frame for Glass Cover Dxt (mm.) | Glass Cover Dxt (mm.) | Ring for Metal Disk Dxh (mm.) | Type of Metal Disk |
|---|---|---|---|---|---|---|
| 1 | 300x300x165 | 210x30 | 210x15 | 175x3 | 160x2 | Can be varied |
| 2 | " | " | " | " | " | " |
| 3 | " | " | " | " | " | " |
| 4 | " | " | " | " | " | " |
| 5 | " | " | " | " | " | " |
| 6 | " | 210x40 | " | " | " | " |
| 7 | 350x350x165 | 250x30 | 250x15 | 210x3 | 200x2 | " |

Note. W = width of base

L = length of base

H = height of base

D = diameter

t = thickness

The list of testing schedule is shown in Table 3.2. The experiments were carried out from about 8.00 a.m. to 4.00 p.m. on clear days and sometimes on dull days but not on rainy days. The testing was conducted in the open air where there was no shading all day long. The radiometers were placed horizontally on the table a few feet above the ground. During the testing, the radiometer thermometers were read every 10 minutes.

The radiometer which had already been tested for its performance was later on calibrated against a standard instrument. The bi-metallic mechanical pyranograph (Model R-401, Serial no. 1024, By Weather Measure Corporation, U.S.A.) was chosen as the standard measuring solar radiation instrument in the calibration. The purpose of this part was to find conversion constants for converting the readings from radiometers into solar radiation quantity. The calibration was performed by exposing the radiometers and the standard instrument to the sun. The solar radiation reading from the standard and the temperature reading from the radiometer were recorded every 10 minutes.

TABLE 3.2 List of Testing Schedule

| Testing no. | Testing Variables | Unit | Kind of Metal | Thickness of Disk (mm.) | Dia.of disk (mm.) | Kind of colour |
|---|---|---|---|---|---|---|
| 1 | Radiometer Size | 5 | Brass | 0.3 | 12 | PYLOX |
| | | 6 | " | " | " | " |
| | | 7 | " | " | " | " |
| 2 | Disk Material | 1 | Alumimium | 0.3 | 12 | PYLOX |
| | | 2 | Zinc | " | " | " |
| | | 3 | Brass | " | " | " |
| | | 4 | Stainless | " | " | " |
| 3 | Disk Thickness | 1 | Stainless | 0.3 | 12 | NISSAN |
| | | 2 | " | 0.5 | " | " |
| | | 3 | " | 1.0 | " | " |
| | | 4 | " | 1.5 | " | " |
| | | 5 | " | 3.0 | " | " |
| 4 | Disk Diameter | 3 | Brass | 0.3 | 10 | PYLOX |
| | | 4 | " | " | 12 | " |
| 5 | Disk Coating | 2 | Zinc | 0.3 | 12 | PYLOX |
| | | 3 | " | " | " | PAGODA |
| | | 4 | " | " | " | TORA |
| | | 5 | " | " | " | NISSAN |

Note. Pylox, Nissan, Pagoda and Tora are trade name of spraying colour. For more details, refer to Table 3.3.

TABLE 3.3 Description of Spraying Colour

| Trade Name of Spraying Colour | Descriptions |
|---|---|
| Pylox | 109 A Black Flat<br>Aerosol Lacquer<br>Capacity 400 cc.<br>Nippon Paint Co. Ltd. |
| Tora | 22 Black Board<br>Aerosol Lacquer<br>Capacity 400 cc.<br>Thai Toa Paint L.P. |
| Pagoda | Black Board<br>Aerosol Lacquer<br>Capacity 400 cc.<br>Pagoda Chemical Co. Ltd. |
| Nissan | No. 35 Flat Black<br>Acrylic Aerosol Lacquer<br>Capacity 400 cc.<br>Aladin Trade Mark |