# Chapter IV

# EXPERIMENTAL APPARATUS AND PROCEDURE

## 4.1 Description of Dust Explosibility Tester

The Dust Explosibility Tester used in this investigation consists of an explosion chamber section and a compressed air supply compartment as shown in Figure 4.1.

### 4.1.1 Explosion chamber section

The explosion chamber section consists of a pyrex tube, a tube support plate, a dustcup for sample loading, a mushroom-like cup for dispersion of air (dispersion cup), a pair of discharge electrodes, a neon transformer, two timers and a supporting table.

1) Explosion chamber

The parts and the dimensions of the explosion tube are shown in Figure 4.2. The tube is fixed on the tube support plate by four rods. A piece of filter paper is placed tightly over the top of the tube. The two discharge electrodes for ignition are installed facing each other on the tube side wall. Pyrex glass tube is used as the explosion tube. A mark to measure the required flame propagation length is placed at 100 mm above the discharge electrodes.

2) Explosion tube supporting plate

The design and the dimensions of the explosion support plate are shown in Figure 4.3. The underside of this device is connected to the dustcup. It is designed to securely hold the entire explosion chamber section.

3) Dustcup and mushroom-like cup for dispersion of air

The design and the dimensions of the dustcup are shown in Figure 4.4, whole those of the mushroom-like cup for dispersion of air are shown in Figure 4.5 . The dustcup is use to hold the test powder sample. Its central hole is for inserting the dispersion-cup supporting rod. Compressed air enters the chamber through an annular gap between the central hole and the dispersion cup supporting rod. The dispersion cup is designed to inflect

the compressed air towards the dustcup so that the test powder on the dustcup is dispersed upward in the tube to form a uniform dust cloud.

4) Discharge electrodes

The electrodes are connected to the neon transformer and the ignition-delay timer is used to the delay in the discharge of electrical sparks to initiate the explosion of the dust cloud. The electrodes are made of two tungsten rods (having semi-circle types). The gap between the electrodes is 4-6 mm. It is designed so that the sparks will take place at the tube central axis. To initiate the explosion a neon transformer with a secondary voltage of 15 kV and a current of 20 mA, or a higher powered transformer, is to be used. The spark delay time can be controlled freely with the use of the timer, which is typically set to activate the electrical discharge 0.1-0.5 seconds after the opening of the electromagnetic valve to introduce compressed air to disperse the test powder. The spark discharge continues until a definite observation to decide the success or failure of a dust explosion can be made.

5) Supporting holder

The supporting holder is to support the entire explosion chamber section. The explosion tube support plate, dustcup, compressed air connecting tubes, and the support holder connector are shown in Figure 4.6 and 4.7.

### 4.1.2 Compressed air supply section

The compressed air supply section consists of an air compressor, an air tank, a pressure gauge, an electromagnetic valve, a check valve, and air pipes.

1) Compressor

The compressor supplies the required high pressure air typically working pressure 5 bars to disperse the test powder in the explosion chamber.

2) Air tank and pressure gauge

The air tank stores the standard amount of high pressure air supplied from the compressor. Its capacity is 1350 $cm^3$. The pressure gauge measures the air tank pressure. Its range is 0-300 kPa (0-3 bar).

3) Electromagnetic valve and check valve

The electromagnetic valve is used to instantaneously release the high pressure air stored in the air tank. The check valve is to prevent any possible backward flow of air due to the flame propagation or high pressure generated by an explosion.

4) Air pipes

The air pipes carry the air from the air tank to the explosion chamber. The inner diameter is 6.5 mm. (See Figure 4.8)

## 4.2 Test Procedure for Dust Explosibility

The test procedure for dust explosibility is as follows.

**4.2.1 Test conditions** - The test conditions are as follows.

1) Temperature 20±5 °C range is preferred.

2) Humidity Air relative humidity of 65±10% range is recommended.

**4.2..2 Test powder** The test powder is treated as follows.

1) Test powder storage

In order to avoid any change in the powder properties, the test powder is fully filled in a container and tightly capped, then stored in a cool place. If there is any doubt as to possible powder quality change during storage, the powder should be used up for the tests as soon as it is received.

2) Preparation of the test powder

The test powder is prepared as follows.

a) Since powder explosibility depends significantly on its particle size distribution, the test powder is first sieved using a standard sieve with mesh opening of 75 μm (250 mesh). The under sieve portion is used as the test sample.

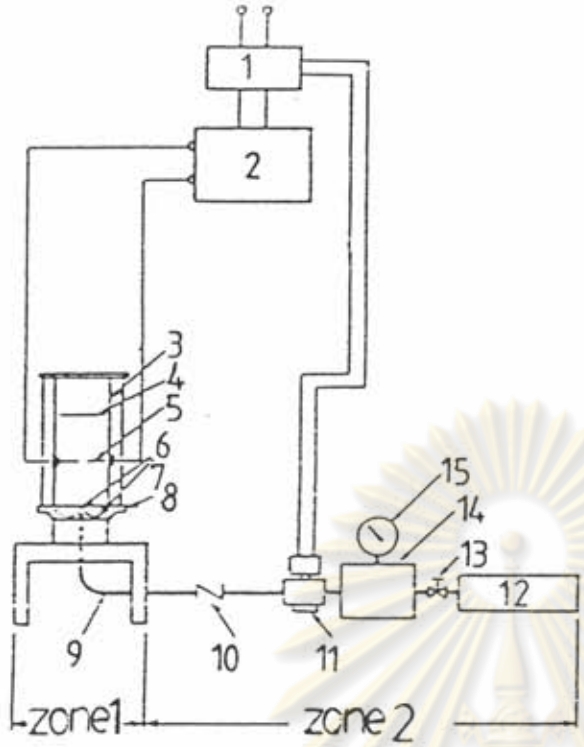


**FIGURE 4.1 DIAGRAM OF DUST EXPLOSIBILITY TESTER**

1. TIMER
2. NEON TRANSFORMER
3. EXPLOSION CHAMBER
4. CENTER SCALE
5. ELECTRODE
6. DUST CUP
7. EXPLOSION TUBE SUPPORT PLATE
8. EXPLOSION CHAMBER SUPPORT PLATE
9. AIR PIPE
10. CHECK VALVE
11. ELECTROMAGNETIC VALVE
12. AIR COMPRESSOR
13. BALL VALVE
14. AIR TANK
15. PRESSURE GAUGE

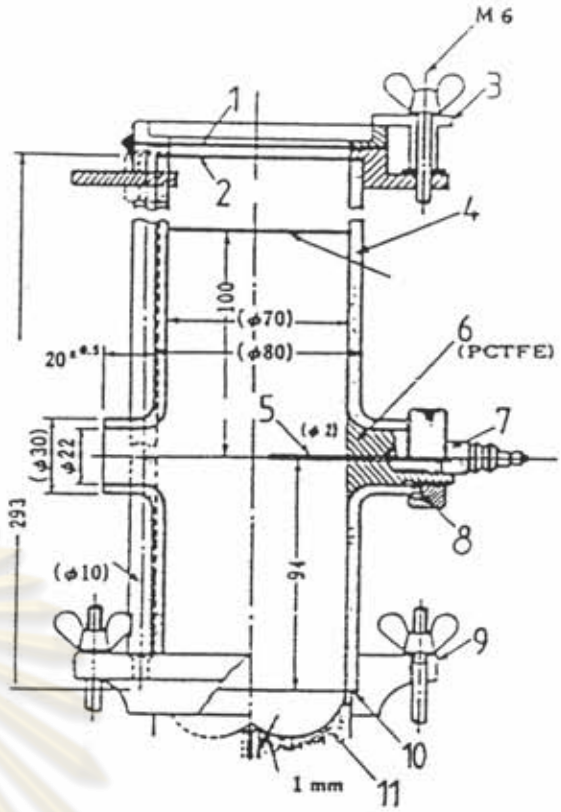


**FIGURE 4.2 EXPLOSION CHAMBER**

1. FILTER PAPER
2. TEFLON PACKING
3. STOPPER
4. PYREX GLASS CYLINDER
5. ELECTRODE
6. ELECTRODE HOLDER
7. ELECTRODE SUPPORTER
8. O-RING
9. EXPLOSION TUBE SUPPORT PLATE
10. TEFLON PACKING
11. DUST CUP



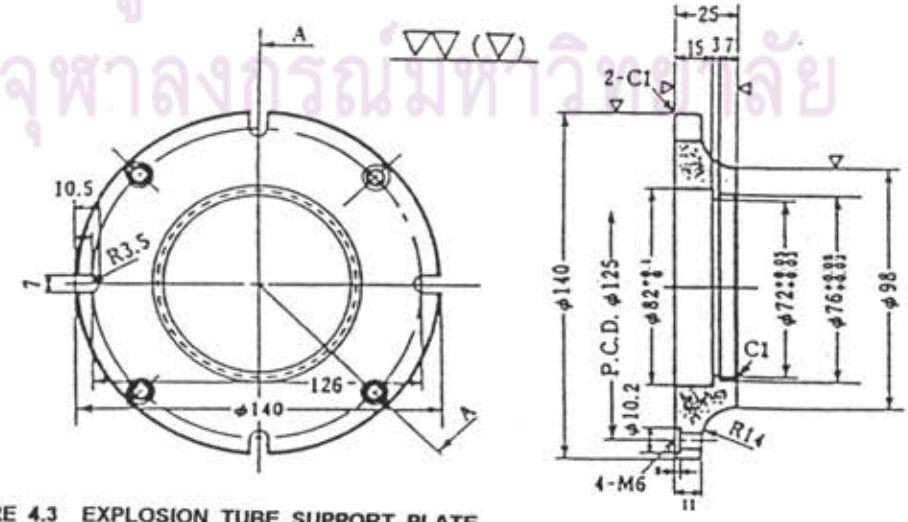


**FIGURE 4.3 EXPLOSION TUBE SUPPORT PLATE**

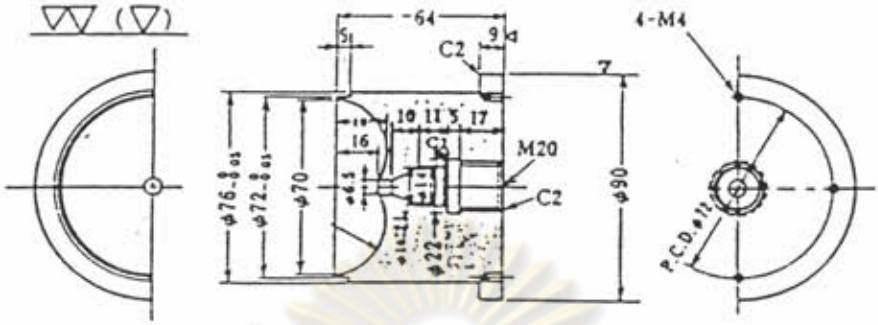


FIGURE 4.4 DUST CUP

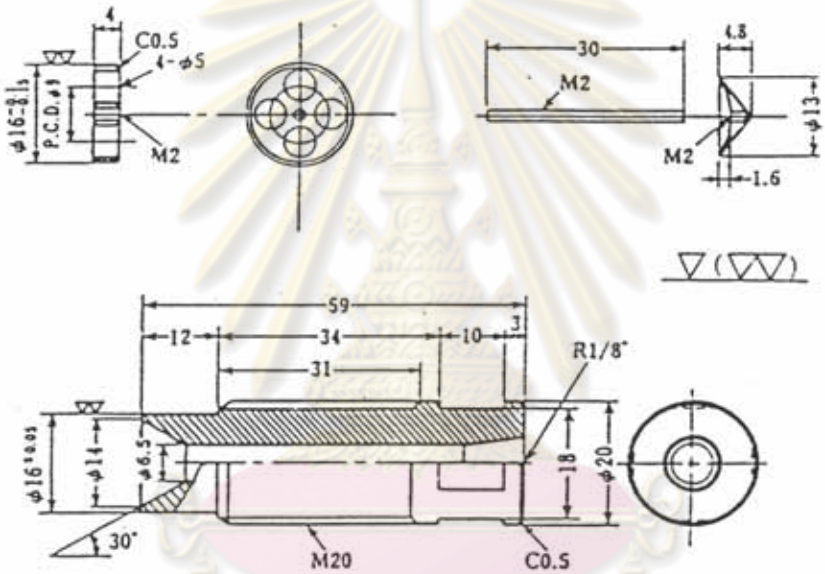


FIGURE 4.5 SCREW ROD SUPPORTING, MUSHROOMLIKE CUP, CYLINDER FOR AIR FLOW TO DISPERSION



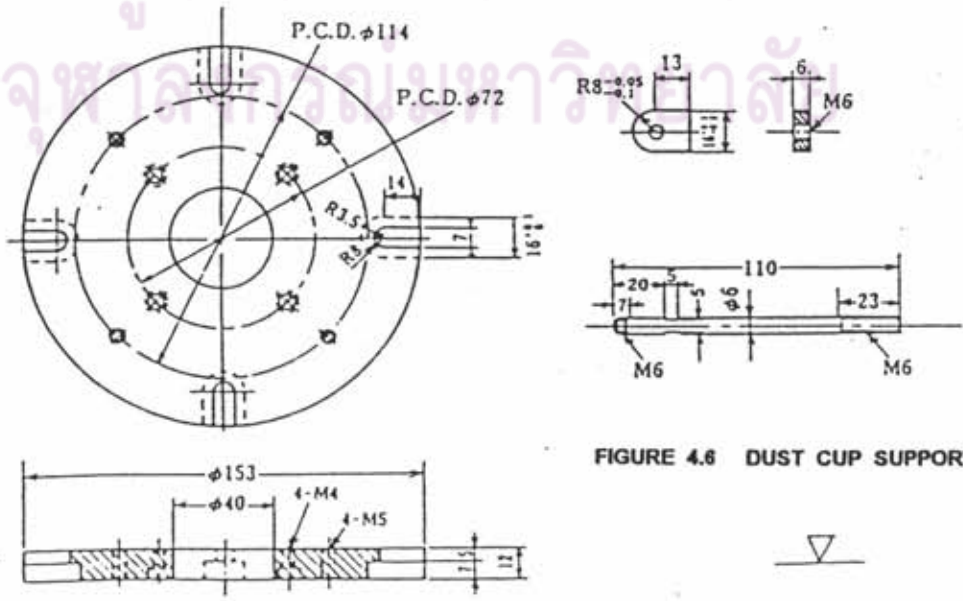


FIGURE 4.6 DUST CUP SUPPORT PLATE

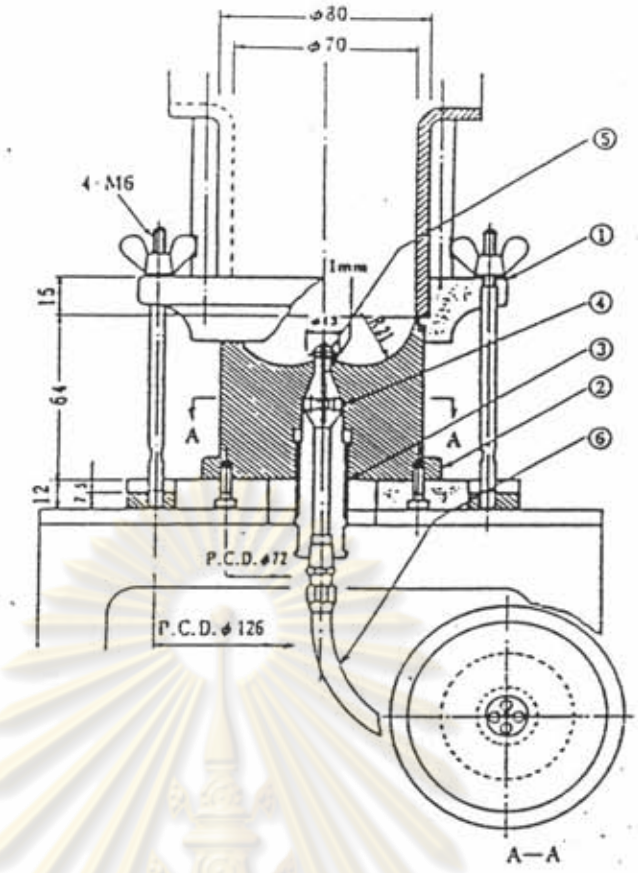


**FIGURE 4.7 SCREW ROD SUPPORTING, MUSHROOMLIKE CUP, AIR PIPE, DUST CUP SUPPORT PLATE**

1. EXPLOSION TUBE SUPPORT PLATE
2. DUST CUP
3. AIR FLOW CYLINDER
4. SCREW ROD SUPPORT
5. MUSHROOMLIKE CUP
6. AIR PIPE

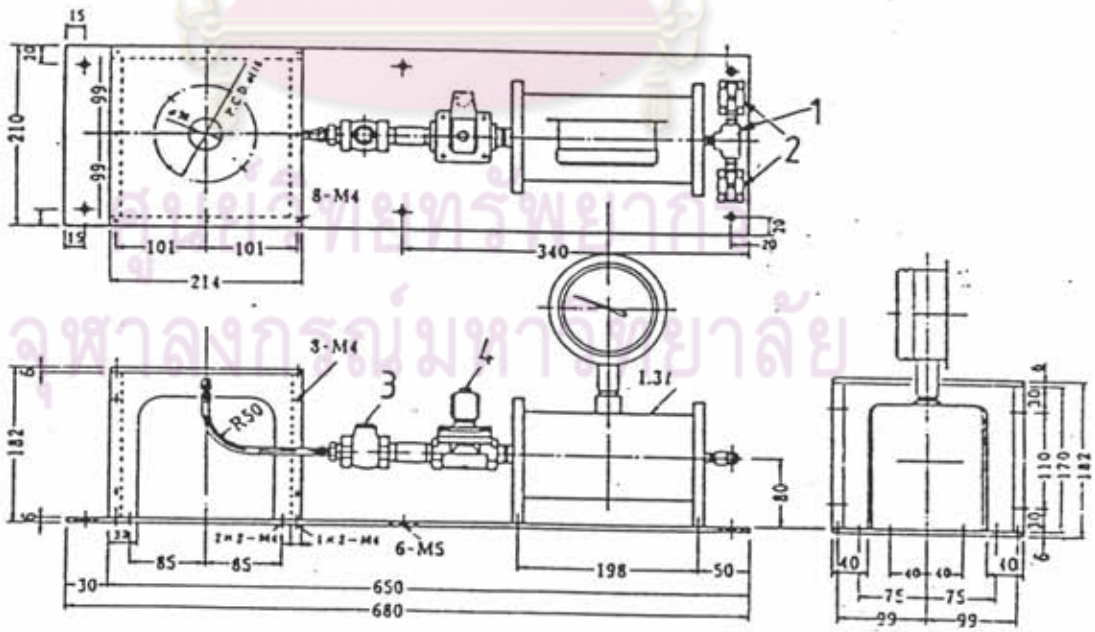


**FIGURE 4.8 COMPRESSED AIR SUPPLY SECTION**

1. COMPRESSOR
2. BALL VALVE
3. CHECK VALVE
4. ELECTROMAGNETIC VALVE

b) Any powder containing a large amount of moisture or powder that easily absorbs moisture is dried while taking special care not to alter the powder properties. The preferred moisture content is below 1-2 %.

c) A test sample which is difficult to disperse can be treated by adding dispersion aid additive(s) (see note below) and thoroughly mixing.

**Note :** As a dispersion aid additive, fullers earth, lycopodium, light magnesium oxide, or silicon dioxide may be used. When any dispersion aid additive is used, its characteristics and the mixing ratio must be clearly stated. The recommended concentration of the additive(s) is less than 2 %.

d) The dried test powder is stored in a desiccator.

## 4.3 Measurement of Lower Explosion Limit (LEL)

### 4.3.1 Preparation before testing

After checking each component of the test apparatus to ensure that they are in good working conditions, LEL measurements are conducted as follows.

1) Loading of test sample

Loading of a test sample on to the dustcup is accomplished as follows.

a) The amount of the test sample to be loaded is pre-determined based on the actual explosion chamber volume (preferably 1,200 $cm^3$) and the test powder concentration of interest. The calculated amount is weighed using a microbalance. For example, when the apparent test powder concentration is to be 100 $g/m^3$ or 200 $g/m^3$, the calculated test powder mass is 0.1200 g and 0.2400 g, respectively.

b) The test sample is evenly spread on the dustcup which is centrally located above the compressed air exhaust nozzle. The explosion tube is then installed, and a piece of paper filter (see note below) is placed over the top of the explosion tube.

**Note :** In the present investigation the paper filter is Whatman No. 93 of 11 cm diameter.

2) Adjustment of compressed air pressure

Compressed air is introduced to the air tank up to the specified air pressure as indicated by a pressure gauge (see note below). The suitable air pressure for good dust cloud formation is determined in the following preliminary test.

**Note :** Typical air pressure is about 50 kPa (approx. 0.5 bar) gauge.

3) Preliminary test

The preliminary test aims to determine the suitable air pressure by visually checking the conditions of dust cloud formation. The test is conducted in the following manner after completing items (1) and (2) described above.

a) By activating the electromagnetic valve the test powder is blown upward. Visually observe the resulting cloud formation.

b) The powder concentration should be nearly uniformly distributed throughout the bottom, the middle, and the top of the explosion chamber.

The preliminary test is repeated with these above two steps until the suitable air pressure is found. After each LEL measurement is carried out according to the procedure described in Section 4.3.2, the explosion tube must be thoroughly cleaned. Again follow the preliminary steps (1) and (2) before proceeding to the next measurement.

A repeated determination of the lower explosion limit concentration may also use the same preliminary test procedure as described above.



**4.3.2 Explosibility test**

The dust cloud formed at a given concentration is to be ignited with electrical sparks. Observe carefully whether the cloud has exploded or not. The lower explosion limit concentration is determined by repeating this procedure at different dust concentrations. The test procedure is as follows.

1) After the preliminary test described in 4.3.1 has been completed, set the timer and press the "Start" button to open the electromagnetic valve and initiate the dust cloud formation.

2) After a specified time lapse (see note below) the electrical discharge commences. Whether the cloud has ignited and exploded or not is determined by visual observation.

**Note :** The recommended spark delay time is either 0.100, 0.300 or 0.500 second after the valve opening. Choose the delay time that is best suited to the formation of the dust cloud.

**Note :** The ignition and explosion process may be recorded on a video tape for later slow-motion observation.

3) The criterion for the onset of explosion is the propagation of the flame length more than 100 mm above the discharge electrodes during the ignition. The propagation length is determined by visually observing the flame length relative to the mark placed 100 mm above the electrodes.

**Note :** In carrying out the first determination of LEL concentration, if an approximate value of the LEL concentration can be estimated or has been reported, use that value as a reference. If the value is completely unknown, the starting concentration may be about 100 $g/m^3$. Either increase or decrease the concentration stepwise by 20-50 $g/m^3$ depending on the ignition condition. In this way an approximate value of lower explosion limit concentration may be found as a first step.

**4.4 Calibration of the dust explosibility test apparatus**

The test apparatus for dust explosibility must exhibit the same characteristics in each test. For this purpose the device is calibrated as needed, using a some standard calibration powder.

(1) As a calibration powder, the standard lycoodium powder supplied by the Association of Powder Process Industry and Engineering, Japan, is used in the present investigation.

(2) The lycopodium powder is kept in a desicator for more than a day before use.

(3) The ignition test described in 4.2.2 is conducted by use of the calibration powder, and an apparent lower explosion limit concentration is determined. In this case a spark delay time of 0.100 second should be used.

(4) If the test in (3) above gives a lower explosion limit concentration of 45±5 $g/m^3$, the appratus can be judged to be in satisfactory calibration.

## 4.5 Measurement of Particle Size Distribution

### 4.5.1 Sieve measurement

4.5.1.1 Introduction

The particle size distribution of various dust samples can be measured using a standard vibrating sifter. The method uses mechanical vibration to classify dust particles on sieve screens. Dust particles smaller than the aperture of each sieve screen will fall through it on to a lower sieve screen of decreasing aperture until the final screen is penetrated by the finest particles.

4.5.1.2 Procedure

The standard vibrating sifter consists of several standard sieve screens and a mechanical vibrating mechanism.

- Standard sieve screens

The set of standard sieve screens contains screens with apertures of 180, 150, 106, 75, 53 and 45 microns, respectively.

- Mechanical vibrating mechanism

The mechanism consists of a timer and spring vibrator. The timer is used to set the duration of vibration. The vibrating frequency of the spring vibrator is adjustable.

Particle size distribution measurements are carried out at ambient temperature (approximately 29-35 $^{0}C$) and atmospheric pressure.

First every standard sieve screen is weighed and its weight is recorded. Then the screens are packed up in the sequence of increasing apertures from the bottom to the top. Approximately 100 grams of the dust sample is needed for measuring the particle size distribution.

The weighed sample is placed on the top most screen (sieve aperture 180 microns), before covering it with a lid. Then the timer is set at 5 minutes and the frequency of vibration is set at 5 Hz. After the vibration is finished, each standard screen together with residual dust particles is

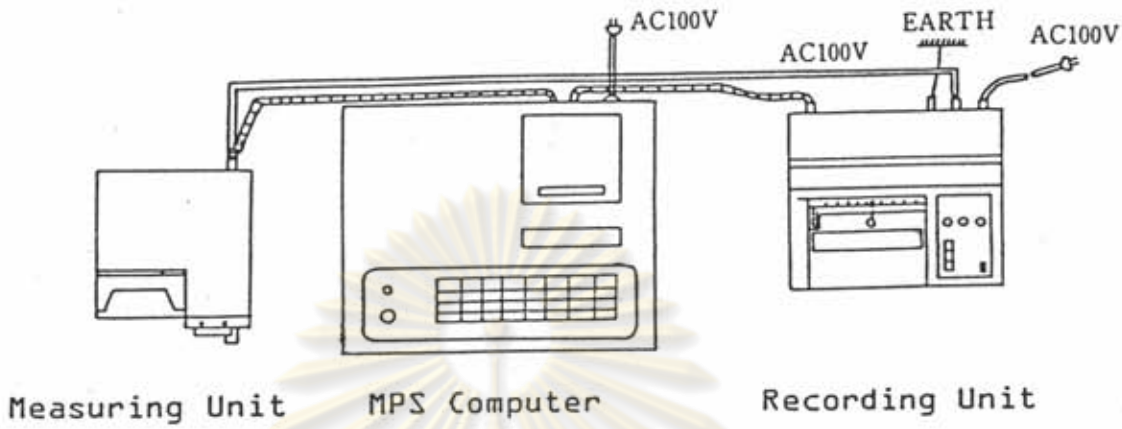


Figure 4.9 Micron Photo Sizer (Model SKC-2000, Seishin Enterprise Co. Ltd.)

4.5.2.2 Procedure

- Blank measurement

Take a clean measurment cell and fill in the pure medium up to the 25 ml mark. Set it in the cell holder and turn it to the measuring position. Adjust the cell height.

With the measuring lamp off, the recording pen should be set at 0 by manipulating the zero adjustment knob and the L.E.D. dark value should be set at 0-2.0 by manipulating the dark adjustment knob.

With the lamp on, the recorder pen should be set at 2.000 by turning the span adjustment knob while the L.E.D. gain value should be around 120-180.

Push B ESC. The MPS computer the memorizes the maximum amount of the collimated light that passes through the cell and the pure medium.

If the adjustments are all right, the word 'OK' is displayed. Otherwise, a buzzer sounds and 'BASE LINE ERROR' is displayed. Stop the buzzer by pressing Z ESC and repeat the above steps. Press B ESC to confirm that the blank measurement is proper.

- Initial concentration measurement

1. Put the sample powder into a beaker, add the medium and put the beaker into the SK-Disperser for about three to five minutes.

2. Take out the beaker and pour the suspension into a clean cell.

3. Mix the suspension well in the cell and wipe clean both faces of the cell with gauze. Set it in the cell holder. Be sure that the cell height is properly set.

4. Push C ESC. If the concentration of the suspension is suitable [the recorder pen indicates between 1.300 and 1.400], 'OK' is displayed.

- Measurement

1. Take out the cell from the unit place the cell lid over the cell mouth and mix gently by inverting the cell several times. During this procedure, push S. Bring the cell to the upright position and push ESC. Promptly turn on the measuring switch Natural sedimentation measurement then begins. The time chart is displayed and the cursor is alway placed at the T column in accordance with the time of natural sedimentation.

2. When the buzzer sounds and 'COMMENCE CENT' is displayed, the cell needs to be taken out and centrifuged. Stop the buzzer by pressing Z ESC. Note that

a) If there exist particles larger than the selected maximum size on the time chart, the buzzer sounds and 'TOP SIZE?' is displayed. Stop the buzzer and make out the time chart again.

b) If convection in the suspension is observed during the measurement, the buzzer sounds and 'CONVECTION' is displayed. Stop the buzzer and repeat the procedure from 1. This problem often happens when the suspension is not at the same temperature as room temperature.

3. When 'COMMENCE CENT' is displayed, switch off the measuring switch of the measuring unit and take out the cell.

4. Set the cell in the no.1 cell holder in the centrifuge. Another cell filled only with the same medium should be set in the no. 2 holder as counter-balance.

5. Set the NT time on the timer of the centrifuge.

6. Turn on the timer switch while turning the r.p.m. adjusting dial. Check the r.p.m. indicated on the Tachometer.

7. The buzzer sounds to indicate the completion of the centrifuging.

8. Turn off the timer switch and reset the r.p.m. adjusting dial.

9. After the rotation has completely stopped, take out the cell and set it in the measuring unit.

10. Turn on the measuring switch. The recording pen might move before stopping at a certain point. Usually it takes about 10 seconds for the pen to come to a complete stop. Next, unroll the chart paper about 10 mm to trace by using the chart knob. Push <> ESC and K ESC.

11. Repeat the above procedure till the last line has been printed.

12. The buzzer sounds and 'ANALYSIS COMP' is displayed after pushing <> ESC and K ESC at the end of the last line.

13. Push E ESC. This concludes the measurement.