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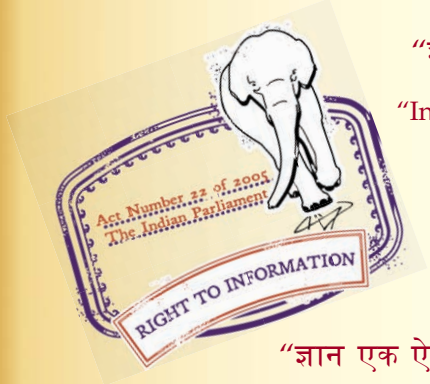

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IS : 11255 (Part 1) - 1985
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Indian Standard

METHODS FOR MEASUREMENT OF EMISSIONS FROM STATIONARY SOURCES

PART 1 PARTICULATE MATTER

(First Reprint APRIL 1998)

UDC 628.512 : 543.275.3

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 5 *March* 1986

Indian Standard

METHODS FOR MEASUREMENT OF EMISSIONS FROM STATIONARY SOURCES

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(*Continued on page* 19)

Indian Standard

METHODS FOR MEASUREMENT OF EMISSIONS FROM STATIONARY SOURCES

PART 1 PARTICULATE MATTER

0. FOREWORD

0.1 This Indian Standard (Part 1) was adopted by the Indian Standards Institution on 28 March 1985, after the draft finalized by the Air Quality Sectional Committee had been approved by the Chemical Division Council.

0.2 Particulate matter is one of the common pollutants discharged into air by industrial processes. As this pollutant is known to be potentially harmful both from health and economic point of view, it is necessary to regulate the emission of particulate matter.

0.3 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

---

1. SCOPE

1.1 This standard prescribes the method for determination of particulate matter in a moving gas stream in confined space such as ducts, chimneys and flues for qualitative and quantitative measurements.

1.1.1 The procedure described is a method of sampling in stacks and flues, which has been standardized with the limits of variety of conditions encountered in the normal course of sampling stacks. Since any procedure or set of apparatus, which will satisfy a number of commonly encountered conditions, may often leave many other problems unanswered, the objective has been to select apparatus that gives reliable data when applied to a variety of situations. The apparatus selected permits a change

*Rules for rounding off numerical values (*revised*).

in the collecting element under stated conditions. The collector recommended for use under specific field conditions and its use to obtain satisfactory results are described. These procedures utilize particulate filtering systems which are located within the stack. If properly used, those systems are satisfactory for determining the mass concentration of particulate matter in the gas stream at stack conditions. The use of collection systems located outside the stack for collecting samples at other than in-stack conditions is an alternative.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions of terms given in IS : 4167-1980* shall apply.

3. GENERAL

3.1 The determination of the particulate concentration consists essentially of sampling isokinetically a measured amount of gas from the flue and separating the particles from the gas and hence determining the particulate concentration. To obtain a representative particulate sample, the sampling should be carried out isokinetically, that is, the kinetic energy of the gas stream in the stack should be equal to kinetic energy of the gas stream through the sampling nozzle. To allow for non-uniformity of distribution, samples should be taken at pre-selected number of stated position (known as transverse points) in the duct stack cross-sections.

3.2 Since the composition of the two gas streams is the same, this energy balance simplifies if the velocity of the stack is equal to the velocity through the nozzle. Sampling at other than isokinetic velocities induces systematic error for two reasons as given below:

a) Firstly, sampling at greater or less than isokinetic ratio tends to cause a respectively larger or smaller volume to be withdrawn from the flue than accounted for by the cross-sectional area of the probe.

b) Secondly, particles greater than 3·5 μm in size have sufficient inertia so that particle motion may deviate significantly from the gas flow stream line pattern. In that case, particles are selectively drawn into the probe in a size distribution different from that existing in the duct or flue. It has been observed that if sampling velocity is greater than isokinetic rate, the sampling will have a lower mass concentration of particulate material than the main stream because of greater percentage of the fine particles.

*Glossary of terms relating to air pollution (*first revision*).

However, if the sampling velocity is less than isokinetic rate, the particulate sample has a higher mass concentration than actually present, with lower concentration of fine particles.

4. SAMPLING TRAIN

4.1 The sampling train comprises the following five essential parts:

a) A probe along with sampling nozzle of proper dimension and design;

b) An efficient collector for removing the particulates from the gas sample;

c) Means for ensuring that the rate of sampling is approximately equal to the gas velocity at the point of sampling (isokinetic sampling);

d) Means for measuring the total volume of the gas filtered; and

e) A vacuum pump for drawing the gas through the sampling nozzle and filter.

4.1.1 There is a wide variety of sampling train configurations and individual element which may be used for stack sampling. Only two arrangements have been described. The particular arrangement and materials of construction for each element depend upon several factors which include, but are not limited to, the following:

a) Temperature and corrosiveness of flue gases;

b) Particle size and other physical characteristics of material to be collected;

c) Moisture content of flue gases; and

d) Type of particulate sample desired.

4.1.2 Regardless of the varying requirements and variety of sampling configurations available, the primary aim is to obtain a truely representative sample of particulate matter in the flue. Equally important is the careful measurement of gas volume sampled so that an accurate calculation of particulate concentration in the flue can be made.

5. THIMBLE SAMPLING TRAIN

5.1 One of the simplest and most commonly used stack sampling trains is shown in Fig. 1. Elements of the sampling train are, nozzle, sampling probe, particulate collector, condenser, volume flow meter and vacuum sources.

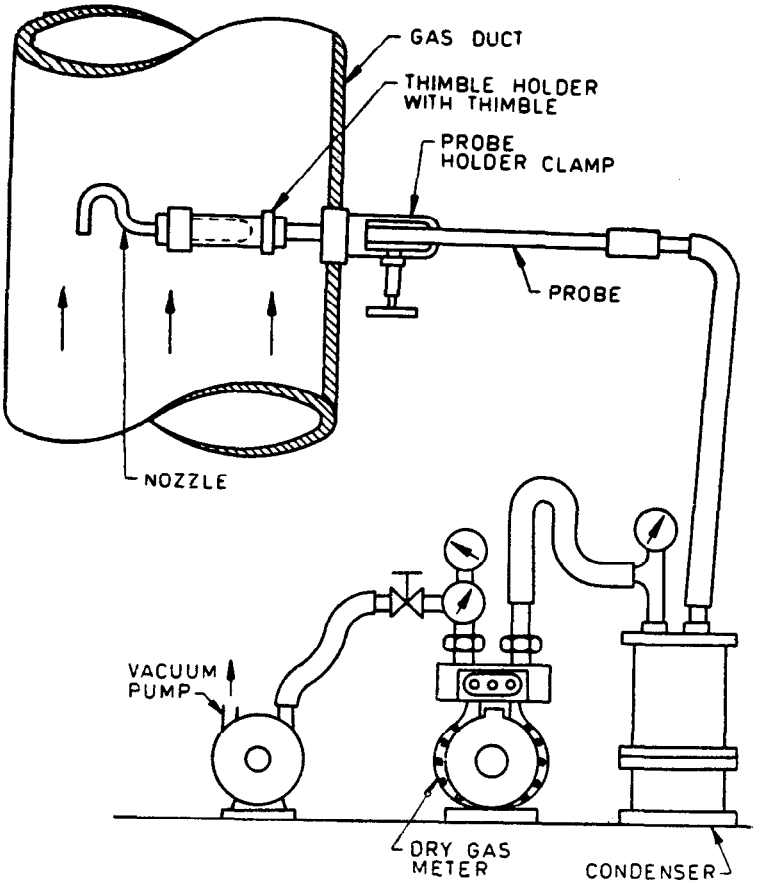

FIG. 1 THIMBLE SAMPLING TRAIN

5.2 Elements of the Sampling Train

5.2.1 *Nozzle* — In order to extract an uniform sample of gas and particulates, use a nozzle of predetermined and definite diameter. It should be made of stainless steel with sharp tapered leading edge. The minimum internal diameter recommended is 7 mm. Drawings of typical nozzles are shown in Fig. 2. The size may increase (diameter) depending upon the collection equipment, the velocity in the flue, and amount (mass) of sample required.

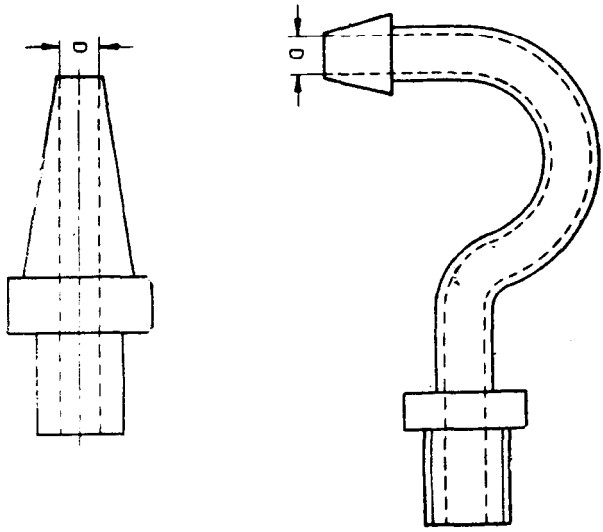

FIG. 2 TYPICAL NOZZLES

5.2.2 *Sampling Probe* — This should be made of stainless steel.

5.2.3 *Particulate Collector*

5.2.3.1 *Thimble holder* — A holder for paper or alundum thimble is shown in Fig. 3. The overall diameter is kept to a minimum to facilitate insertion of the entire holder through a relatively small sampling port (75 mm). The holder provides a method for clamping the thimble firmly in position with its lip, pressed firmly against soft asbestos gasket. The gasket sealing together with the component of the holder is made of relatively hard asbestos materials.

5.2.3.2 *Filter media*

a) *Paper thimbles* — These are widely used, being accurate, inexpensive and covenient to use. Paper thimbles may be used at temperatures up to 150°C and suction pressure of 100 mm of mercury column if kept dry. Temperatures and pressures higher than this may puncture the thimble and spoil the test. If temperature is higher than 150°C, either use an alundum thimble. In case of high moisture content, either use an alundum thimble or keep the temperature of paper thimble above the dewpoint by heating the thimble holder by an electric heater.

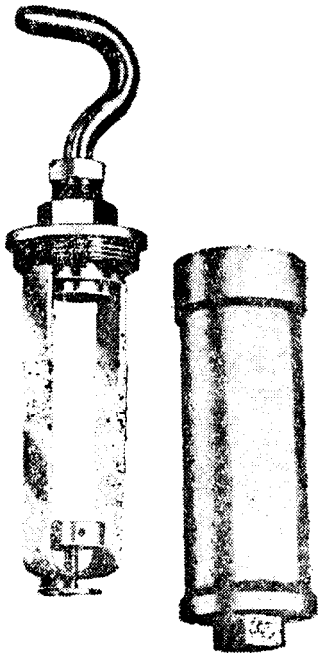

FIG. 3 THIMBLE HOLDER

b) *Alundum thimbles* — Alundum thimbles may be used where it is important to have high wet strength, chemical resistance and high temperature resistance. Also, where the moisture content of a gas is high and condensation occurs, alundum may be over dried to its original water content more accurately than paper. Being able to withstand high temperatures (up to 550°C), this thimble may be inserted in the flue, just behind the sample nozzle. When this is done, cleaning of sample probe is eliminated and sample is collected dry.

c) *Glass cloth filters* — These filters are made of finely woven glass fibre so that it can be used well on coarse dust and where samples are to be taken under heavy dust loading conditions. These can be used very satisfactorily ahead of a paper thimble, the latter catching the fine particulates that pass the glass filter.

5.2.4 *Condenser* — The condenser equipped with a dial thermometer should have sufficient storage capacity to hold the total liquid accumulation for complete test and permit its removal at the conclusion of test.

5.2.5 *Volume Flow Meters* — Use a dry gas meter attached with temperature and vacuum gauge for measuring the sampled gas. The vacuum and temperature gauge gives the metering conditions of sampled gas. A calibrated rotameter may be used in conjunction with dry gas meter to provide essentially instantaneous flow data for relating to isokinetic flow at the nozzle.

5.2.6 *Vacuum Source* — Use blowers, pumps or ejectors to induce gas flow through the sampling train. It is necessary to overcome the resistance in train itself, and also the negative pressure, when present in the flue, whatever type vacuum source is selected, it should be adequate to provide the desired sample volume rate against total resistance. Use a valve or other suitable means of control to adjust to the proper flow rate. Usually a pump having a capacity of 100 l/min is used. Use an ejector or an explosion proof motor for the pump in plant areas where explosion hazards exist.

5.3 Procedure

5.3.1 *Gas Velocity and Temperature Measurement* — Record the results of gas velocity and temperature measurements as prescribed in IS : 11255 (Part 3) - 1985 for flow rate. These readings shall be used to determine. The appropriate nozzle size and the sampling rate for each sampling point.

5.3.2 *Selection of Location of Sampling* — Sample for particulate concentration at same traverse points where velocity measurements were carried out.

5.3.3 *Calculation of Proper Sampling Rate* — The meter for measuring the gas sample measures the gas at conditions of temperature, pressure and moisture content which are different than those in flue. Therefore, calculate the sampling rate at the meter for each sampling point before starting the test and record the required rate on the log sheet. Calculate the sampling rate at the meter as follows:

$$R_m = U_s \times A_n \times \frac{T_m}{T_s}\left[\frac{P_u}{B_a - P_m - V_p}\right]\left(1 - \frac{M}{100}\right)$$

where

R_m = flow rate at meter (m^3/s);

U_s = velocity of flue gas at sampling point (m/s);

A_n = area of sampling nozzle (m^2);

T_m = absolute meter temperature (°K);

*Methods for measurement of emissions from stationary sources : Part 3 Flow rate.

T_s = absolute stack gas temperatures (°K);
P_u = absolute stack gas pressure (kPa);
B_a = barometric pressure (kPa);
P_m = suction at meter (kPa);
V_p = water vapour pressure at condenser exit temperature, kPa; and
M = moisture content of the gas, percent by mass.

5.3.3.1 Select the nozzle size, which will provide a meter sampling rate between 10 to 60 min. Charts relating sampling rate with stack and meter conditions may be prepared for the range of conditions expected.

5.3.4 *Duration of Sampling* — Deam the run to be of sufficient length if one of the following criteria have been obtained:

a) Sampling has continued for at least one hour;

b) A minimum of 1·6 m^3 of dry gas has been withdrawn for sampling; and

c) The mass of particulate matter amounts to at least 20 percent of the mass of the filtering medium in the sampler.

5.3.4.1 Experience and intelligent judgement should be applied in determining the sampling time. Too short a time may give unreliable results and too long a time may cause the resistance of the sampling train to exceed the capabilities of vacuum source. In case of heavy dust concentration sampling period should be of much less duration than in case of very low dust concentration.

5.3.5 *Preparation of the Sampling Train*

5.3.5.1 After proper nozzle and filtering medium have been selected assemble the sample train as shown in Fig. 1. The assembly comprises the nozzle, filter holder, sampling probe, condenser, dry gas meter, rotameter and a suction source. Mark the sampling probe (including nozzle and filter holder) with the same traverse points used for conducting the velocity traverse. Sample only at traverse points.

5.3.5.2 Place a clean, preweighed thimble in the filter holder and tighten securely. Mark the end of sampling probe to indicate the nozzle tip direction.

5.3.5.3 Check the train for leaks by sealing the nozzle tip and turn on the pump or ejector with the control valve shut. Open the control valve until the vacuum gauge reaches a maximum reading and remains steady. The vacuum should hold steady if there are no leaks.

DUST CONCENTRATION MEASUREMENTS

LOG SHEET

(*Clause* 5.3.3)

Job: Date: Time:

Testing:

Barometric pressure (kPa), (B_a)

Point	Gas Meter Reading				
	Temperature (°C) (t_m)	Vacuum (kPa), (P_m)	Meter Flow Rate, (m^3/s), (R_m)	Sampling Period, min (t)	Gas Sampled (m^3), ($V_m = R_m \times t$)

Total gas sampled (m^3) = (V_m)

Volume of gas sampled, (dry, 298 °K, 101 kPa), $V_{mn} = V_m \times \frac{298}{t_m + 273} \times \frac{B_a}{101{\cdot}3}$

Volume of gas sampled, (wet, 298 °K, 101 kPa), $V_{mw} = V_{mn} \left(1 + \frac{M}{100 - M}\right)$ where M is moisture content of gas.

5.3.6 *Sampling* — Start the test after sampling rates have been calculated and train assembled and checked.

5.3.6.1 When equipment is ready in all respect, record the initial dry gas meter reading and push the sampling probe carefully into the duct to point nearest to the back wall. This will allow the probe to cool in hot stacks as it comes out, shortening the time required for cooling after the sample is taken. It is advisable to allow the nozzle and filter holder to preheat so that moisture present in the gases does not condense in the filter during initial part of the sampling.

5.3.6.2 When starting the test the nozzle should face the stream direction, start operating the suction source, open the control valve and start the stop watch. Note the time and record it in the log sheet. Adjust the flow rate with the help of the rotameter and control valve until the desired flow rate for isokinetic conditions is obtained. As the test proceeds, dust packing in the thimble will increase the amount of suction required to maintain the proper meter rate and the valves should be adjusted accordingly. This suction should not exceed 100 mm of mercury for paper thimbles. In case it exceeds this value before the completion of sampling, replace same with the new thimble and restart sampling. During the test if the mercury suction pressure at the meter drops suddenly it indicates that a leak has developed in the equipment or that thimble has cracked or burst. In this event, discard the test and repeat. Record the meter volume, pressure and temperature as well as condenser temperature at 5 minutes intervals during the test.

5.3.6.3 When sampling at one point has been completed, move the sampler to the next point as quickly as possible. Close the control valve only when transferring the sampler from one sample part to the other. Exclude the time required to transfer the sample from one part to another from the total sampling time. If possible, carry out sampling for at least 5 minutes at each traverse point.

5.3.6.4 At the completion of test, close the control valve, turn the sampler so that the sampling nozzle is facing downstream and record the final gas volume and time. Remove the sample carefully from the flue, plug the nozzle to prevent the loss of sample. Do not disconnect the sample recovery rubber tube until the sample has been withdrawn from the flue, because if it is under considerable suction, a reverse flow would be set up through the thimble which might cause some of the collected material to be drawn out through the sampling nozzle and lost.

5.3.7 *Sample Recovery*

5.3.7.1 After the sampler has cooled, brush down dust on the inside of the nozzle carefully into the thimble using a small brush. Remove the

thimble and place it in a dust tight container for transporting to the weighing room. In case the filter holder is kept outside during the sampling the dust from the sampling probe before the filter holder should be brushed down into the thimble.

5.3.7.2 Drain off the condensate from the sampling train by turning on the pump or ejector for a few minutes to draw the moisture in the probe and sampling lines into the condenser. Measure the condensate from the condenser in a graduated cylinder and record the amount.

5.3.8 *Weighing Filters and Dust* — For accurate work, determine the mass of dust collected in the thimble by difference, that is, by weighing thimble before and after the run. Dry the thimble in an oven for about 2 hours at approximately the same temperature as in duct to be tested prior to sampling. After sampling, cool, dry and again weigh the thimble along with dust maintaining the same conditions as prior to sampling. Record all masses on a suitable test sheet.

5.4 Calculations

5.4.1 Calculate the moisture content of the gas as given in IS : 11255 (Part 3) - 1985*. Then calculate the volume of gas sampled using the following equations:

Volume in m^3 of dry gas through the meter (298 °K, 101 kPa), V_{mn}

$$= V_m \frac{B_a}{101{\cdot}3} \times \frac{298}{t_m + 273}$$

Volume in m^3 of wet gas through the meter (298 °K, 101 kPa), V_{mw}

$$= V_{mn} \left(1 + \frac{M}{100 - M} \right)$$

where

V_m = volume of gas sampled at meter conditions (m^3);

B_a = barometric pressure (kPa);

t_m = temperature of the meter (°C); and

M = moisture content of the gas.

5.4.2 *Dust Concentration* — Calculate the dust concentration using the following equations:

Dust concentration in g/m^3 (298°K, 101 kPa, dry basis), $S_{OD} = \frac{G}{V_{mn}}$

*Methods for measurement of emissions from stationary sources: Part 3 Flow rate.

Dust concentration in g/m³ (298°K, 101 kPa, wet basis), $S_{ow} = \frac{G}{V_{mw}}$

where

G = mass of the dust in the thimble (g);

V_{mn} = volume of dry gas through the meter (298°K, 101 kPa) (m³); and

V_{mw} = volume of wet gas through the meter (298°K, 101 kPa) (m³).

5.4.3 *Emission Rate* — Calculate the dust emission rate as follows:

$$\text{Dust emission rate (0°C, 101 kPa) (g/h)} = S_{ow} \times Q_n$$

where

S_{ow} = dust concentration in g/m³ (298°K, 101 kPa, wet basis); and

Q_n = flue gas flow rate in m³/h (298°K, 101 kPa).

5.5 Report — Report the results including additional information as given in Appendix A.

6. ALTERNATIVE SAMPLING TRAIN (CYCLONE ANALYZER)

6.0 Cyclone analyser sampling train is an alternative method for thimble sampling train (TST). Few advantages are that its sampling capacity is much higher than thimble sampling, train, that is, it can collect a larger amount of sample in lesser time, which can be utilized for other tests such as particle size distribution, for chemical and physical properties and for electrical resistivity tests. It may also be used for finding out particle size distribution at site directly. It is possible to use this for high dust concentration in the range of 400 to 500 g/m³ (298°K, 101 kPa).

6.1 Elements of Sampling Train

6.1.1 *Nozzle* — The first part of sampling equipment to encounter the dust, or moisture laden stream, is the nozzle. In order to extract a uniform sample of gas and particulates, use a nozzle of predetermined and definite diameter. The minimum internal diameter recommended is 15·5 mm, the size may increase depending on the velocity in the flue, and the amount of sample required. Use a nozzle of such size that it is possible to maintain isokinetic flow. The leading edge of the nozzle should be sharp and tapered.

6.1.2 *Sampling Probe* — The probe is used to extend the nozzle into the stack to the proper position. It is made of stainless steel with adequate stiffness for support at the greatest distance within the stack.

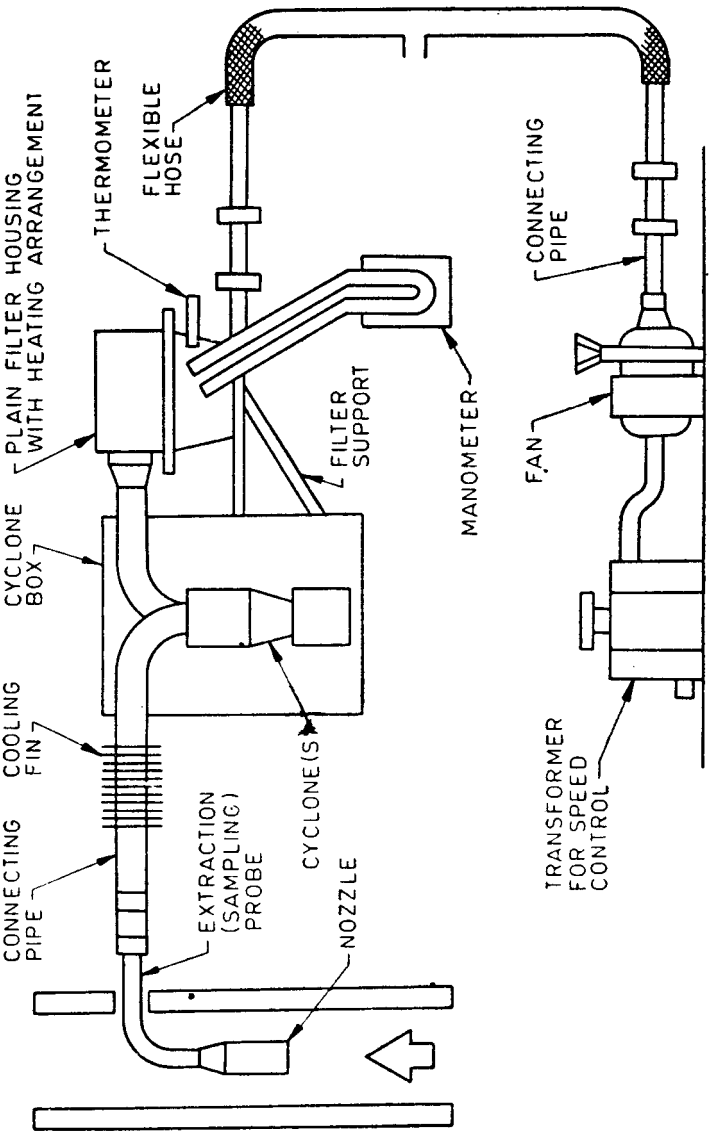

FIG. 4 TYPICAL CYCLONE ANALYZER FOR DUST CONCENTRATION MEASUREMENT

6.1.3 *Connecting and Cooling Pipes* — These are used to connect the cyclone collector to the sampling probe and cooling pipe is used in case of high stack temperatures for cooling sampled gases before entering the particulate collector.

6.1.4 *Particulate Collector* — In this type of sampling train, particulate matter is collected in two stages as follows:

a) The coarser range is collected in cyclone(s) made of aluminium bronze and polished inside. Each cyclone is provided with a dust container. Two cyclones if used are connected in series and placed in a cyclone box with thermostatically controlled heating; and

b) The finer particles escaping from the cyclone (s) are collected on a plain filter of glass fibre. This filter is placed in a stainless steel filter housing which follows the cyclone. The filter housing has a fixed orifice plate for measuring the gas sampled. It also has a heating arrangement and provision of thermometer for determining the temperature of the gas sampled.

6.1.5 *Filter Media* — Circular borosilicate glass or quartz filter paper of 293 mm diameter for collection of finer particulate matter after the cyclone in.a filter housing.

6.1.6 *Volume Flowmeter* — The filter casing has fixed orifice plate for gas flow measurement. The pressure drop across the orifice is measured by a manometer.

6.1.7 *Vacuum Source* — Blower or injector is used to induce gas flow through the sampling train. It is necessary to overcome the resistance in the train itself, as well as the negative pressure, when present in the flue. Whatever type of vacuum source is selected, it should be adequate to provide the desired sample volume rate against total resistance. A blower having a capacity of 20 to 30 m^3/h along with a variable transformer, which is used for obtaining the proper isokinetic rate, or an ejector along with a filter-cum-regulator is used with compressed air.

6.2 Procedure

6.2.1 Assemble the sampling train as shown in Fig. 4. Insert a sampling probe along with selected nozzle to provide a sampling rate around 25 m^3/h in the gas duct at the point of sampling. Connect the probe to the cyclone(s) by the help of stainless steel connecting pipes. Connect the cyclones in series if two are used, providing each with a dust container, and place in a cyclone box with thermostatically controlled heating.

6.2.1.1 Place in the filter housing, the selected and preweighed filterpaper intended for collection of dust in gas stream after cyclone(s)

with heating arrangement and fixed orifice plate and manometer filled with methylated spirit for gas flow measurement of sampled gas. Provide a thermometer also for determining the gas temperature. Use a suitable suction. Source with regulator for maintaining isokinetic rate.

6.2.1.2 Connect the filter casing to suction source by the help of flexible hose. The cyclones should be made of aluminium bronze and polished inside. Other parts which come in contact with gas should be made of stainless steel except flexible hose.

6.2.1.3 After the isokinetic sampling rates have been calculated and train assembled and checked for leakage, the test may be started. Turn on heating if required and push the sampling probe along with the selected nozzle carefully into the duct to the point nearest to the back wall.

6.2.2 When starting the test the nozzle should be facing in the upstream direction. Start the suction source and adjust the flow rate for isokinetic conditions with the help of either the control valve or adjustable transformer. As the test proceeds, dust packing in the filter will increase the amount of suction required to maintain the proper meter rate. The flow should be adjusted accordingly. The filter should be changed in case it is not possible to keep the required flow rate. When sampling at one point has been completed move the probe to the next point as quickly as possible. After completion of the test, switch off the regulator if duct is under pressure, or reduce the gas flow to nearly zero and loosen the sampling tube from cyclone before the fan has stopped completely as otherwise the gas may flow backwards and dust collected on filter may blow back to the cyclone. Record the final gas volume and time. Use cleaning brushes to remove the dust accumulation in the sampling probe and connecting pipes in the inlet cyclone.

6.2.3 Accumulation between the cyclone (s) and filter shall be brushed down to the filter. Other dust accumulation should be counted as collected in the respective cyclones. Weigh the dust collected in the cyclones (B_1), and on the filter paper (B_2). The total dust collected is sum of these.

6.3 Calculation

6.3.1 Calculate the dust concentration as follows:

$$S_{ow} = \frac{B_1 + B_2}{Q_n}$$

where

S_{ow} = dust concentration (g/m³) (298°K, 101 kPa);

B_1 = dust collected in the cyclone(s) (g);

B_2 = dust collected on the filter paper (g); and
Q_s = flue gas flow rate (298°K, 101 kPa).

6.3.2 Calculate the emission rate as given in **5.4.3.**

NOTE — This cyclone analyzer sampling train can also be used to find out particle size analysis at the site.

6.4 Report — Report the results including additional information as given in Appendix A.

APPENDIX A

(*Clauses* 5.5 *and* 6.4)

STACK SAMPLING DATA SHEET

A-1. DATA SHEET

A-1.1 The stack sampling data sheet for particulate matter should contain the following information:

a) Date, time and place of measurement;
b) Job;
c) Test number;
d) Barometric pressure (kPa);
e) Stack pressure (kPa);
f) Elapsed time of test (min);
g) Water vapour condensate (ml);
h) Water vapour volume meter conditions (m^3);
j) Volume of gas sampled meter conditions (m^3);
k) Volume of gas sampled (298 °K, 101 kPa) (m^3);
m) Moisture content, percent;
n) Mass of thimble after test (g);
p) Mass of thimble before test (g);
q) Mass of dust collected (g);
r) Dust concentration (wet/dry) (mg/m^3) (298°K, 101 kPa);
s) Total dust emitted per day (kg);
t) Average dust concentration (wet/dry) (g/m^3) (298°K, 101 kPa); and
u) Average dust emitted (kg/day).

(*Continued from page* 2)

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Printed at New India Printing Press, Khurja, India