The gas aspiration and aspiration flow rate measurement of the dust sampling devices described in the old version are quoted in the latest revision.

6.1 Draft Tube Method

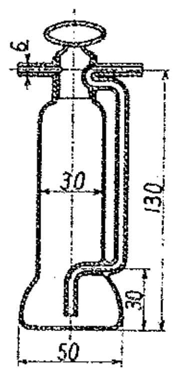
6.1.1 Measurement Points: Section 4.1 in the main body of this standard specifies that the measurement points shall be near the duct center. Since the moisture content in the exhaust flue gas varies very little within the same cross section of the duct and therefore seen to be distributing uniformly, the standard specifies that measurement may be taken only at one point near the central point.

6.1.2 Moisture Content Measuring Device

(1) Moisture Content Measuring Section

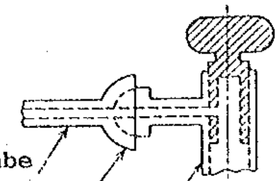
(a) Sheafield type humidifier shown in Explanatory Figure 7 are used often. Besides, U-tubes are also used.

Unit: mm



Explanatory Figure 7 Sheafield Type Humidifier

(b) Ball joints shown in Explanatory Figure 8 may be used to connect the draft tube to the gas aspiration tube for better handling.



Explanatory Figure 8 Example Usage of Ball Joint Use

(2) Gas Aspiration Section

(a) The gas aspiration section consists of an exhaust flue gas aspiration device with a aspiration flow rate regulator valve, a bottle for containing SO_2 gas to protect the aspiration device from SOx and a bottle for removing mist.

(b) The SOx bottle contains 3% hydrogen peroxide. The mist removal bottle contains glass fibers or absorbent cotton that removes mist from the SO_2 bottle.

(c) The SO_2 bottle becomes less effective after a long operation. It should be replaced as necessary.

(d) If a vacuum pump or similar device is used at the discharge of the aspiration device, oil mist will be generated. An oil mist remover should be installed to protect the flow meter.

(3) Aspiration Flow Rate Measurement Section

(a) A cumulative flow meter (gas meter) is used on the aspiration flow rate measurement section to measure aspiration flow rates. A throttling flow meter or an area flow meter is used as an instantaneous flow meter to check the aspiration flow rate. Some of the recent gas meters are automated so that cumulative and instantaneous flow rates can be measured simultaneously. Any of these automated gas meters may also be used.

When a dry gas meter is used as a cumulative flow meter, a moisture absorbent device should be installed in the first stage to thoroughly remove moisture.

(b) When measuring moisture content, the aspiration flow rate is low so that the instantaneous flow rate can be readily obtained by checking the gas meter readings with a timer. In this case, the instantaneous flow meter can be omitted.

6.1.3 Measurement Method

(a) The draft tube should be installed as near to the measurement hole as possible. The aspiration tube and draft tube should be connected directly.

(b) The moisture absorbent charged into the draft tube should be capable of absorbing only steam from the sample gas and do not absorb other substances. In this regard, for example, barium oxide, calcium oxide, aluminum oxide or silica gel must not be used for gases containing CO_2.

Grain calcium chloride anhydride is generally used for combustion exhaust flue gas. After absorbing moisture, this material dissolves through deliquescence and may hinder smooth gas flow. The material should therefore be closely monitored externally during aspiration.

(c) The rate of absorption depends mainly on the gas aspiration flow rate with respect to the amount of moisture absorbent. Explanatory Table 2 shows the relationships between the amount of absorbent and aspiration flow rate for each of the two U tubes that are arranged in series. The results indicate that one stage of moisture absorbent and 0.1 L/min or low of aspiration flow rate per one gram of moisture absorbent are enough. This means that if 10 grams of moisture absorbent is used, the aspiration flow rate will be below 1 L/min. Unless otherwise specified, the two draft tubes arranged in series shall be used for safety.

Explanatory Table 2 Experimental Resuls of Humidifier

(Case of Usage of Anhydrous Calcium Chloride as a Humidifier)

Dia-Meter of U Tube mm	Gas Aspiration Flow Rate			Humidity Absorbed, mg/L_n		Humidity Rate % 1st/1st+ 2nd stage	Humidity Rate % 2nd/1st+ 2nd stage	Time of Gas Aspi-ration min
	L/ min	cm/s	L/ min·g	1st stage	2nd stage			
10	2.0	43	0.122	9.95	0.11	98.9	1.1	30
10	1.5	32	0.092	13.6	0.17	98.8	1.2	35
10	1.0	22	0.062	13.1	0.31	97.7	2.3	30
10	0.5	11	0.031	11.6	0.25	97.9	2.1	45
20	2.0	11	0.125	7.55	0.16	97.9	2.1	30
20	1.5	8	0.094	9.67	0.22	97.7	2.3	30
20	1.0	5.3	0.063	7.35	0.21	97.1	2.9	30
20	0.5	2.7	0.032	7.12	0.23	96.7	3.3	30

(d) Since the absorption efficiency is high at low gas temperatures, a water tub is used to cool the draft tubes. A higher absorption efficiency can be expected if the water tub contains ice.

(e) When a dry gas meter is used to measure the aspiration gas quantity, the following equation is used to calculate the gas quantity. This equation is not listed in the main body of this standard since it is similar to the equation when a wet gas meter is used.

$$Xw = \frac{\frac{22.4}{18} M_a}{V'm \times \frac{273}{273 + \theta m} \times \frac{Pa + Pm}{101.3} + \frac{22.4}{18} M_a} \times 100$$

Where, Xw : Volume percent of steam in exhaust flue gas (%)

Ma : Mass of absorbed moisture (ma2 - ma1) (g)
V'm : Quantity of aspiration dry gas (dry gas meter reading) (L)
θm : Temperature of aspiration gas read on gas meter (°C)
Pa : Atmospheric pressure (kPa) (mmHg)
Pm : Gas gauge pressure read on gas meter (kPa) (mmHg)

Note: In this equation, "101.3" should be replaced with "760" if the pressures are expressed in "mmHg".

Also note that a dry gas meter can be used if the exhaust flue gas does not contain corrosive gases such as SO_2 or if the exhaust flue gas is dried after the SO_2 absorption bottle.

6.2 Theoretical Calculation: This method calculates the moisture content in the exhaust flue gas based on the amount and composition of fuel, amount of air for combustion, humidity and other particulars. This method can be used when the values of these particulars are known.

In the downstream duct of a scrubber that uses water or other solution to clean or cool the exhaust flue gas, water mist exists very often in the exhaust flue gas. Since the mist cannot be separated from the steam moisture, the draft tube method may result in larger moisture content than the actual value. To cope with this situation, note 2 specifies a calculation method. This calculation assumes that moisture content of the exhaust flue gas is saturated at that temperature so that the moisture content can be calculated from the saturated steam pressure. This method, therefore, can be applicable only when the exhaust flue gas temperature is no greater than 100°C.

7. Measuring Flow Speed and Flow Rate of Exhaust Flue Gas: The exhaust gas flow speed is necessary for calculating the equal speed aspiration flow rate, and dust concentration and exhaust flue gas flow rate. When a normal sampling device is used, the exhaust flue gas speed shall be measured after measuring the moisture content.

Generally, a Pitot tube is used widely to measure the exhaust flue gas speed. A note is added to the main body of this specification to allow the use of air speedometers such as a thermal anemometer specified in JIS T 8202 "Portable Type Thermal Anemometer" and Karman vortex flow speed meter. The reasons why these air speedometers are included in this standard are that (1) not only combustion exhaust flue gas but ambient air may be drawn, (2) While Pitot tubes cannot measure air speeds below 5 m/s (≑ dynamic pressure approximately 10 Pa {1 mm H_2O}), these air peedometer can measure significantly low air speeds, and (3) these air speedometers are service-proven in terms of missions regulations for sulfur oxides and nitrogen oxides.

As described later, some of these air speedometers are affected by the temperature, pressure, composition and other particulars of gas. If such devices are used, the measured values should be corrected by the values obtained by a Pitot tube.

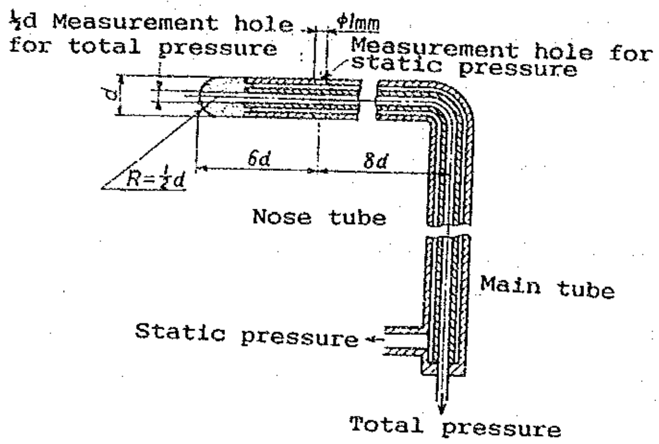
Dust stuck to the probe may affect the reading significantly, requiring special precautions on use.

7.1 Measurement Points: Measurement points shall be established in accordance with section 4.3 in the main body of this standard.

7.2 Measurement Devices

(1) As shown in Explanatory Figure 9, L-shaped Pitot tubes shall be used in accordance with JIS B 8330 "Testing Methods for Turbo-Fans and Blowers". In this case, Pitot tube factor c can be 1.0.

If dust concentration is as high as several tens g/m^3_N, it affects changes in the exhaust flue gas density. This makes the measurement by the Pitot tube inaccurate.

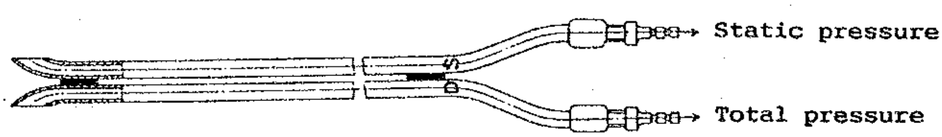


Explanatory Figure 9 Example of L-shaped Pitot Tube

The measurement hole of the L-shaped Pitot tube could be plugged with dust, making measurement impossible. A pitot tube with long sleeves may not be put into the duct. If it is the case, a special Pitot tube with known Pitot tube factor is used. Note that if the absolute value of the static pressure is high, the Pitot tube factor of this type of Pitot tube changes.

Explanatory Figure 10 shows one type of special Pitot tubes (western type) that have been used in dust measurement. Pitot tube factor c of this type is approximately 0.85. Pitot tube factor varies approximately ±2% depending on the manufacturing accuracy. When a special Pitot tube is used, the Pitot tube factor shall be measured through a wind tunnel test.

Stainless steel Pitot tubes shall be used to handle corrosive gases.



Explanatory Figure 10 Example of Special Pitot Tubes

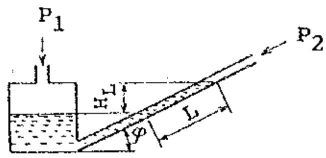
(2) In addition to Pitot tubes, the latest revision specifies in the note columns that the portable thermal air speedometers and Karman vortex speed meters calibrated by Pitot tubes may be used. Some of the advantages of these air speedometers are (1) measurement is easy and continuous measurement is possible because the speed is directly read on the meter, and (2) they can be available for measurement of combustion exhaust flue gas of 5 m/sec or lower. However, it should be noted that the readings of these air speedometers may be affected by the characteristics of the exhaust flue gas (such as temperature, pressure, composition, etc.) and the characteristics of dust (adherence among others). Generally, these air speedometers are designed for air and the scales are established for air measurement. If these air speedometers are used for combustion exhaust flue gases, the readings will depend on the characteristics of the exhaust flue gases. The readings shall be corrected by the measurement values obtained by a Pitot tube. To prevent dust from sticking to the probe, the probe shall be cleaned. If dust is stuck on the probe, the compensation is difficult.

If creating a compensation curve compared with values obtained by the Pitot tube, such compensation can be available below 5 m/sec. It is difficult to find measurement points within the same gas flow system at which gas flow speeds are different. Thus, the compensation curve may have to be devised using measurement results obtained from only one or two measurement points. In addition, it is questionable if the flow speed and output are in linear relationships with each other that run through the zero point. This raises question with reliability. Some of the air speedometers can be compensated by these precise testings. However, the same considerations should be taken if the characteristics of the test exhaust flue gas are different. Thus, these speedometers have limited use in actual situations.

These air speedometers should be used carefully with thorough considerations and necessary compensations. Air speedometers considered available for use presently are portable thermal anemometers in accordance with JIS T 8202 "Portable Type Thermal Anemometer", Karman vortex flow speedometers, blade wheel current meters and air speedometers utilizing pressurized jet air. Some of the commercially available portable thermal anemometers can measure up to 400 to 700°C. One of the advantages of Karman vortex air speedometers is that they are not affected by the characteristics (such as temperature, composition, pressure, etc.) of exhaust flue gas. Many of them are stationary types. Some of the blade wheel current meters are turbine type. These air speedometers are used often for the flow speed measurement of heavy oil combustion exhaust gas. Some of the air speedometers utilizing pressurized jet air detects air flowing through the by-pass section driven by the pressure difference between two points ahead of the jet or the pressure difference between two air jet nozzles. However, service records are few. These air speedometers directly indicate air flow speeds. Many of them can record data continuously.

(3) The slope manometer shown in Explanatory Figure 11 is used as a pressure gauge. The slope manometer can enlarge the reading of the dynamic pressure of exhaust flue gas. It is used widely because of this advantage. The rate of enlarging the reading depends on the angle of inclination. In many cases the rate is ten. The factor of enlargement of some of the slope manometers are fixed to ten. Because the slope manometer uses a single tube, the ratio of tube cross sectional area to the water tank cross sectional area should be no less than 100 to achieve practical measurement accuracy. Before using the slope manometer, the factor of enlargement should be checked with the standard water column.

The support table should be horizontal while using the slope manometer. Gettingen type and Ascania type manometers are also used.



$H_L = L \sin Y$

Explanatory Figure 11 Example of Slope Manometer

U-tube manometers are used when the pressure difference to be measured is large.

Liquids used in manometers are generally distilled water or ion exchange water. When the rate of dynamic pressure enlargement is higher or when anti-freezing is of concern in cold areas, alcohol or toluene having lower specific weight than water and not freezing at relatively low temperatures is used. When using liquids other than water, the accurate physical properties of the selected liquid must be known, especially the specific weight at the temperatures of use. These values are used to convert the measured pressure to water head.

Manometers converting pressure to electrical values utilize several electrical principles. Bellows, diaphragms, sunk weights, strain gauges and other devices are used to detect pressure. Some manometers use a magnetic scale or photo-electric tube to detect pressure. All these manometers have systems to convert pressure to electrical values and indicate and record the measured values. The automatic equilibrium sampling device, which will be described later in this paper, uses one of these manometers.

Some manometers measure pressure variations over a set period of time, average the values and indicate and record the results. These manometers are extremely convenient to measure varying pressure. Manometers that can automatically compute the flow speed from the dynamic pressure are also used. Such pressure gauges require the exhaust flue gas density data to be entered before measurement.

7.3.1 Measuring Exhaust Gas Dynamic Pressure: The Pitot tube shall be put into the duct to the point of measurement through the measurement hole. The total pressure measuring hole of the Pitot tube shall squarely face the line of exhaust flue gas flow. Dynamic pressure indicated on the manometer shall be read and recorded along with the location of the point of measurement.

Angular orientation of Pitot tube with reference to the line of exhaust flue gas flow shall be within 10°. Only when the axis of the total pressure measurement hole coincides with the line of gas flow, the maximum dynamic pressure can be read on the manometer. The manometer shall therefore be installed so that the maximum dynamic pressure can be measured.

If the gas drift is so high that the Pitot tube is to be at an angle larger than 10° with reference to the line of gas flow, the following measures shall be taken.

(a) Install a straightening vane,
(b) Increase the number of measurement points. Take measurement promptly, and
(c) Increase the number of measurement takes as much as possible and average the measured values.

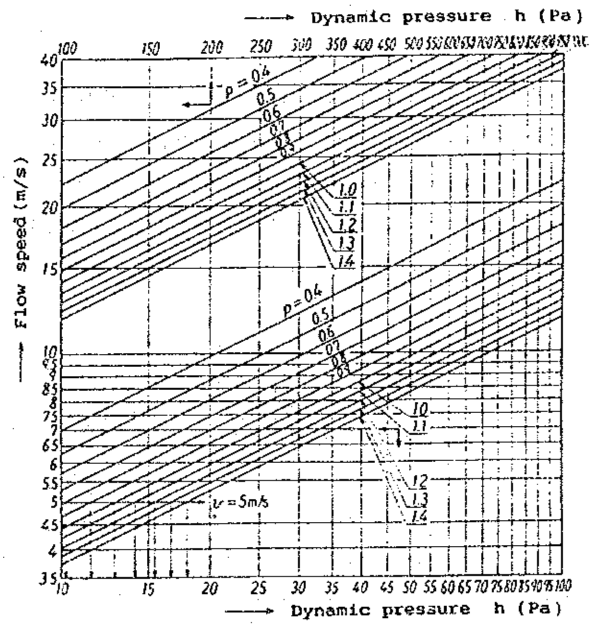
A method to correct the dynamic pressure based on the angle of inclination could be used. However, it is not practically available because the measurement is not easy due to varying dynamic pressure and the results may not be very accurate.
The static pressure measurement hole of the L-shaped Pitot tube is often plugged with dust in the exhaust flue gas. It should be taken out and cleaned after measuring several points.

If the Pitot tube hole is plugged with dust in a short period, a special Pitot tube described before should be used.

Generally, an inclined manometer with the scale enlargement factor of ten as shown in Explanatory Figure 11 is used to measure dynamic pressure. Based on this general practice, this revision specifies that the minimum dynamic pressure reading shall be to 1 Pa or 0.1 mm H_2O. Dynamic pressure reading needs to be in two digits, accordingly. However, if the dynamic pressure is as high as 200 Pa (approximately 20 mm H_2O), the angle of manometer inclination should be larger or a U-tube manometer may have to be used instead. In such cases, the minimum reading may not be to 1 Pa or 0.1 mm H_2O.

Besides manometers for measuring dynamic pressure with a Pitot tube, the dynamic pressure can be indicated and recorded electrically by means of a pressure difference transducer as described in this paper. Recently, manometers that automatically take dynamic pressure for a set period, average the values and indicate and record the result are available on market. These devices are useful when dynamic pressure pulsates or varies greatly with time, making conventional measurement methods impractical and inaccurate. Before using these devices, the characteristics, accuracy, repeatability and other particulars of the pressure difference transducer shall be checked thoroughly.

Explanatory Figure 12 shows the relationship between the dynamic pressure and flow speed with p = 0.4 to 1.4 kg/m^3.



Explanatory Figure 12 Relationship between the Dynamic Pressure and Flow Speed (in the case, p = 0.4 to 1.4 kg/m^3)

7.3.2 Measuring Exhaust Gas Static Pressure: By connecting the static capillary tube of the L-shaped Pitot tube or static tube to the U-tube manometer, static pressure and dynamic pressure can be measured simultaneously. The number of points of static pressure measurement may be reduced because the static pressure is almost constant within the same cross section of the duct. The nozzle of the Pitot tube for static pressure measurement shall be in the same direction as that of the dynamic pressure measurement.

When using the static pressure measurement nozzle of a special Pitot tube (western type), the following equation gives the static pressure.

$$Ps = Pt - c^2P'4$$

Where, Ps : Static pressure of exhaust flue gas (kPa) {mmHg}
Pt : Total pressure reading measured on special Pitot tube (kPa) {mmHg}
c : Pitot tube factor, and
P'd : Dynamic pressure reading measured on special Pitot tube (kPa) {mmHg}.

The manometer contains water or mercury. When static pressure or total pressure is to be measured separately, one end of the manometer is open to the atmosphere and the other end is connected to either the static capillary or total pressure capillary depending on the type of measurement.

Generally, the static pressure hole is provided in the side walls of the duct near the inlet and outlet of the dust collector to monitor the pressure loss characteristics of the equipment.

This revision specifies in a note column that the static pressure value may be used. The static pressure hole should be checked to prevent the hole from being plugged with dust.

7.3.3 Calculating Exhaust Flue Gas Density: To obtain density p of the exhaust flue gas, density p of that gas under the standard condition (temperature at 0°C, barometric pressure at 101.3 kPa {or 760 mmHg}) shall be calculated first. The equation (6) in section 7.3.3 in the main body of this standard shall be used to convert the calculated value to the density under the wet exhaust gas condition in the duct.

Three methods are available as follows including the specification for reference purpose to obtain p_0.

(1) Method of calculating p_0 based on results of chemical composition analysis of exhaust flue gas As methods of composition analysis of combustion gases, Hempel's and Orsat analysis methods are specified in JIS K 2301 "Methods for Chemical Analysis and Testing of Fuel Gases and Natural Gas". Although these methods count all acid gases such as SO_2 as CO_2, they are still practical because normal combustion gases contain little acid gases other than CO_2.

Assuming that moisture content Xu in an exhaust flue gas measured in accordance with section 6.1 in the main body of this standard is 10.6% and that the chemical composition analysis of this dry exhaust flue gas in accordance with JIS K 2301 results in CO_2 = 12.1%, O_2 = 8%, CO = 0.1% and N_3 = 79.8%, p_0 will be calculated by the following equation.

$$p_0 = \frac{1}{22.4\times100}\left[\frac{100-10.6}{100}(121\times44+8.0\times3.2+0.1\times28+79.8\times28)+10.6\times18\right]$$

$$= 1.29\ (kg/m^3{}_N)$$

This calculation also assumes that the molecular weight of each composite gas is CO_2 = 44, O_2 = 32, CO = 28 and N_3 = 28.

(2) Method of calculating p_0 based on measurement by gas density meter

Gas balance method, gas column method, outflow method, wind pressure method and sonic method are used to measure gas density. JIS K 2301 defines the Bunsen-Shilling method (outflow method) and specific weight bottle method for analyzing fuel gases.

These methods require the sample gas to be sealed in a container. The measurement takes place manually.

Besides, a practical meter called Lauter gas density meter that employs the wind pressure method is also used. It can indicate and record continuously the specific weight of the exhaust flue gas or density under the standard condition (temperature at 0°C and barometric pressure at 101.3 kPa {or 760 mmHg}).

For example, assuming that moisture content xw in the exhaust flue gas is 12.0% and p_d measured by the gas density meter is 1.42 kg/$m^3{}_N$, p_0 is calculated by the following equation.

$$p_0 = 1.42 \times \frac{100 - 12.0}{100} + 0.805 \times \frac{12.0}{100} = 1.35 \text{ kg/m}^3{}_N$$

(3) An example of calculation assuming that τ_0 = 1.30 kgf/$m^3{}_N$ when a solid or a liquid fuel is burned in air:

The reason why the note in section 7.3.3 in the main body of this standard allows to assume that τ_0 is 1.30 kgf/$m^3{}_N$ is as follows. The τ_0 values of the theoretical combustion gases of various solid or liquid fuels are approximately 1.30 and the τ_0 value of air is 1.29. Thus, changes in air-fuel ratio affect very little. However, even when solid or liquid fuels are burned in air, this fixed value cannot be applicable if the process is used for heating reaction and gases with different τ_0 values are generated or if the exhaust flue gas contains moisture generated by drying or similar process.

The p_0 value obtained from any of these methods is used together with the temperature and pressure of the exhaust flue gas and barometric pressure to calculate the p_0 value of the actual exhaust flue gas in the duct. For combustion exhaust flue gases specified in the note column, τ_0 = 1.30 kgf/$m^3{}_N$ is conveniently used.

Since the p value is necessary for the calculation of flow speed using a Pitot tube, it shall be obtained before measuring the flow speed.

7.3.4 Calculating Exhaust Flue Gas Flow Speed: When using conventional units, the flow speed of the exhaust flue gas can be calculated by the following equation with known exhaust gas dynamic pressure and exhaust gas weight per unit volume.

$$v = c\sqrt{\frac{2gh}{\tau}}$$

In this equation, the unit of dynamic pressure h is kgf/m^2. Since this value coincides with the value read in mm H_2O on the manometer, the value on the manometer can be used directly. Do not convert the value from "mm" to "m" in such a case. Or else, the result will incorrect.

A typical calculation example is shown in attached Table 3 of this explanation paper that deals with an example of measurement and recording of flow speed.

7.4 Calculating Exhaust Flue Gas Flow Rate: The flow rate of the exhaust flue gas is expressed as the flow rate of wet gas converted to the standard condition (temperature at 0°C and barometric pressure at 101.3 kPa {or 760 mmHg}). In addition to the calculation method multiplying the exhaust gas flow speed by the cross sectional area of the duct, combustion calculation can be used to obtain the exhaust flue gas flow rate. This method uses wet exhaust gas quantity G per unit fuel quantity specified in section 6.2 in the main body of this standard and fuel consumption W per one hour specified in section 7 in the main body of this standard. This method, however, cannot be applicable if external air enters the duct or exhaust flue gas leaks out because such events will make the results inaccurate. The consumption of liquid or gas fuels for calculating W is measured in accordance with JIS Z 8762 "Measurement of Fluid Flow by Means of Orifice Plates, Nozzles and Venturi tubes" or a comparable method.

The dry exhaust flue gas flow rate is calculated by subtracting the moisture content form the wet exhaust flue gas flow rate.

8. Dust Sampling Device

8.1 Types of Dust Sampling Devices: Only one type of this device was available before dust sampling devices that used equilibrium aspiration nozzles and automatic operating functions became widely available.

The latest revision of this standard specifies the two dust sampling devices; (1) conventional dust sampling device that uses conventional aspiration nozzles and (2) equilibrium dust sampling device that uses equilibrium aspiration nozzles. The construction of the devices and structure and functions of each component are also defined.

(1) **Conventional Dust Sampling Device:** Preparatory measurement for exhaust flue gas temperature, moisture content, flow speed and other particulars shall be taken to obtain the equal speed aspiration flow rate. This operation is complex. The device can be applicable when the exhaust flue gas condition is stable.

(2) **Equilibrium Dust Sampling Device:** It is not necessary to obtain the equal speed aspiration flow rate. Because of the automated operating features, the operation is easy. The device can be applicable even when the exhaust flue gas condition varies. The construction of the device is complex even though some portions are similar to the conventional dust sampling device.

8.2 Conventional Dust Sampling Devices

Same as the dust sampling device specified in the previous version of this standard.

8.2.1 Construction of Conventional Dust Sampling Device: The conventional dust sampling device consists of the components shown in Figure 8 in the main body of this standard. The term "by-pass cock" in the previous version is revised to "aspiration flow rate regulator.

Type 1 in Figure 8 (1) in the main body of this standard is widely used. Since the dust sampling unit of this type is installed in the duct, heat insulator or heating means to prevent condensation due to temperature drop is not necessary.

The dust sampling unit of type 2 shown in Figure 8 (2) in the main body of this standard is installed outside the duct. If the exhaust flue gas temperature is below 100°C, the exhaust flue gas temperature could go below the due point by cooling. To prevent such occurrence, aspiration tubes and dust sampling unit shall be thermally insulated or heated.

After sampling the dust, residual dust in the aspiration tube from the aspiration nozzle to the dust sampling unit should be either shaken off or washed and dried so that the residual dust can be added into the sampling bottle. The operation is complex. It should be noted that residual dust may not be completely recollected.

In the following cases, type 2 is preferable:

(1) when the exhaust flue gas is explosive or toxic, requiring special safety attachments, or

(2) when the exhaust flue gas is at high temperature and may cause the sampled dust to re-burn or reduce in quantity due to heating if type 1 dust sampling device is used.

When scrubber exhaust flue gas that contains significant quantity of mist is to be handled, the drain installed on the dust sampling device may not be able to sufficiently collect mist. In such a case, a drain (condensation) bottle or dust sampling unit equipped with an impactor (which will be described later) shall be installed before the SO_2 aspiration bottle.

When the conventional dust sampling device is used, gas leakage or external air entry into the duct shall not be allowed over the entire area. The construction and materials of joints, clamps, connectors and piping are designed to be leak-tight. To conduct a precise leak test, the aspiration nozzle is completely closed, a mercury manometer capable of measuring pressure difference up to 33.3 kPa or 250 mmHg is installed between the vacuum pump and the mist removal bottle. The vacuum pump operates to obtain negative pressure with pressure difference between 4.0 and 6.7 kPa (or 30 to 50 mmHg). The test is successful if the change in pressure is no greater than 0.13 Kpa (or 1 mmHg) for one minute. Since the precise leak test is very complex, a simplified leak test is also available though it is considered incomplete. The simplified leak test requires the aspiration nozzle to be closed and the vacuum pump to operate. The test is successful if the gas meter hand does not move. Usually, it is suggested that the simplified method be used for leak test.

8.2.2 Dust Sampling Unit: The dust collecting unit is shown in Figure 9 in the main body of this standard. Of these components, the drain catcher may be omitted if the moisture content in the exhaust flue gas is minimal.

(1) **Aspiration Nozzle:** The previous version specified two types of aspiration nozzles; conventional type and equilibrium type. The latest revision eliminates these names and defines the end portion that is common to the two types as "aspiration nozzle".

The construction and dimensions of the aspiration nozzle are approximately the same as those in the previous version. The latest revision defines the material and that the inner diameter of the aspiration nozzle shall be measured precisely to a minimum of 0.1 mm. The inner diameter of the aspiration nozzle shall be measured precisely by a vernier caliper or a dial indicator because the diameter (or cross sectional area in other words) is closely related to the equal aspiration flow rate. Aspiration nozzles made of hard glass or silica are widely used as they are required to be heat and corrosion resistant. Stainless steel aspiration nozzles are used very rarely. If other materials are to be used, such materials shall be as heat and corrosion resistant as the materials described above.

If the exhaust flue gas contains fluorine, materials listed above will be damaged. Aspiration nozzles made of fluorine resin shall be used.

If the tip of the aspiration nozzle is finished to 30° or less as shown in Figure 10 in the main body of this standard, the tip shall be slightly rounded to prevent tip breakage.

The length of the aspiration nozzle is not specifically defined. Too short a nozzle may be affected by the disturbance of exhaust flue gas flow due to dust sampling unit and may result in inaccurate measurement.

The bend of the aspiration nozzle shall be gradual as shown in Figure 11 in the main body of this standard so that dust collection can be avoided.

(2) Dust Collecting Unit: Similar to the previous standard except the following.

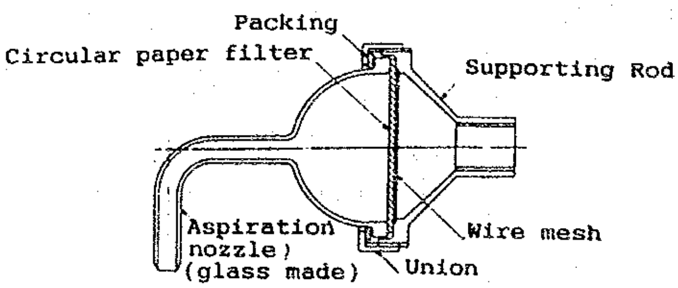
(2.1) **Functions and Types of Dust Collecting Units:** The dust collecting rate shall be 99%. This means that 99% of particles of 0.3 fm shall be collected. This collecting rate corresponds to symbol A1 in JIS K 0901, the test method of which is also defined.

The dust collecting unit shall not be chemically reactive during use. For example, the material shall not be affected by sulfur oxides or similar substances in the exhaust flue gas.

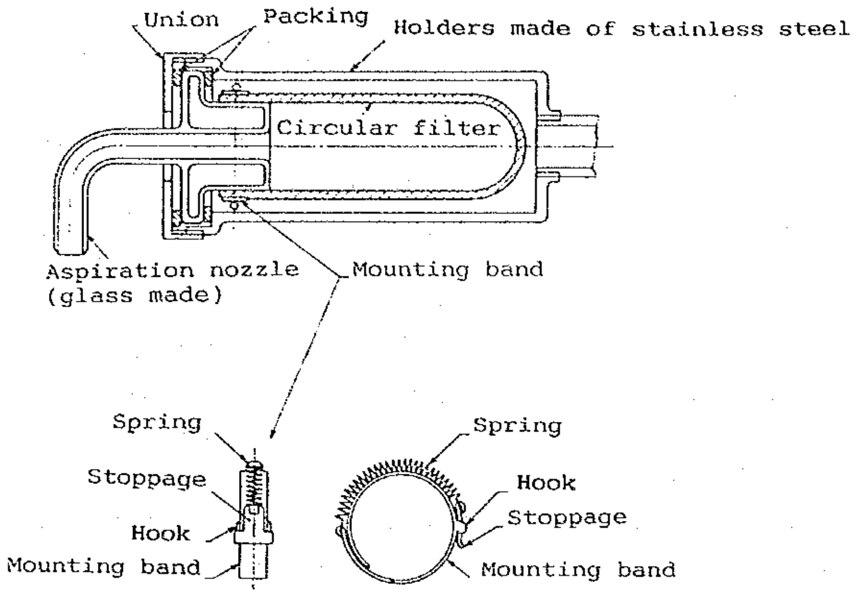
(2.2) **Dust Collecting Unit Using Paper Filters:** JIS K 0901 established in 1981 defines the shapes, dimensions, materials, performance, performance test methods and other particulars which are quoted in this standard. While the previous version of this standard did not define the dimensions of round paper filters, the latest division defines the effective diameter (which is responsible for actual filtering) as 30 mm or more. This definition is to make the filter capable of collecting several milligrams of dust and is to be consistent with the latest revision of dust collecting amount from 1 mg per 1 cm^2 to 0.5 mg per 1 cm^2. A paper filter with the effective diameter of 30 mm is expected to collect approximately 3.5 mg of dust.

Figures 12 and 13 in the main body of this standard show examples of dust collecting units using round and cylindrical paper filters. Among the dimensional examples of the cylindrical paper filters and their holders, the largest two types defined in the previous version are eliminated since they are not commercially available presently.

Explanatory Figures 13 and 14 in this paper show compact filter holders and holders made of stainless steel to avoid mechanical damage.



Explanation Figure 13 Example of Dust Collector Using Circular Papar Filter



Explanation Figure 14 Example of Cylindrical Paper Filter Holders

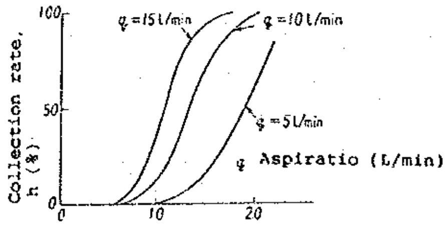
The latest revision defines the filter holder materials so that they are of the same materials as the aspiration nozzles.

In the note column of the main body of this standard defines a dust collecting unit with an impactor as shown in Explanatory Figure 14. This specification is intended to handle dust containing greater quantity of mist.

The dust collecting unit with an impactor utilizes the principle of inertial collision of dust to separate and collect dust particles of 2 µm or larger. With the impactor installed, the coarse mist and dust are eliminated at the collision plate. Exhaust gas drawn through the aspiration nozzle jets out of the jet nozzle of the inner diameter of 2 mm made by choking the rear portion of the aspiration nozzle to that dimension. The exhaust gas jetting out from the nozzle collide the collision plate 8 mm away from the nozzle. Here, dust and mist particles of 2 µm or larger are separately collected and flow into the dust container (4 ml capacity) and held there. Escaping mist and dust particles smaller than 2 µm run through the air hole to be collected on the round paper filter installed after the air hole. Thus, damage, clogging, blown-out mist can be avoided which otherwise would occur with the previous, direct collecting method using a cylindrical paper filter.

Theoretically, as shown in Explanatory Figure 15, this dust collecting unit can collect 100% of dust particles of 2 μm if equal speed aspiration flow rate q is 10 L/min or greater. It can collect 50% of dust particles if q is 5 L/min. This means that, by selecting an aspiration nozzle having a diameter that will result in 10 L/min of equal speed aspiration flow rate, normal mist containing a great deal of coarse particles can be separately collected. The connection between the aspiration nozzle and the filter holder is sealed air-tight with material such as vulca tape.

Since the capacity of the dust container is 4 ml, collected mist or dust should not exceed this capacity. Or else, particles will overflow into the cylindrical paper filter. Generally, 1 to 2 ml of dust is enough for measurement purpose.



Explanatory Figure 15 Example of Dust Collector with Impactor

(2.3) **Dust Collecting Unit Using Dust Tube:** Installation of filter material is difficult with this type of collecting unit. Because of increased quantity of collected dust, sampling takes time and therefore is not suitable for composite analysis of the collected dust.

With these disadvantages, this system is not used presently.

The fiber diameter is defined to be 7 to 10 fm. However, small diameter can be used because smaller diameter fibers improve collection rate.

Explanatory Figure 15 in the main body of this standard shows an example dimensions of a dust tube. Tubes smaller than this example can also be used. It should be noted that collecting rate of 99% or higher and charge rate of 0.25 mg/ml are difficult to achieve.

Hold-down plates and retainer springs made of heat and corrosion resistant materials such as asbestos plates or stainless springs are recommended.

(2.4) **Selecting Dust Collecting Unit:** Table 3 in the main body of this standard indicates specific values in defining the performance of the filter materials by quoting symbols that are specified in JIS K 0901.

The filter material shall be suitable for the condition (such as temperature, humidity, SOx and NOx) of exhaust flue gas. Other than the materials listed in Table 3 in the main body of this standard, filters made of fluorine resin or silica fibers shall be selected if the exhaust gas contains SOx or NOx because these substances trapped on the filter make the measurement inaccurate. Filters made of glass fibers must not be selected for exhaust flue gases containing these corrosive substances.

(3) **Supporting Hardware, Drain Collector and Connecting Tubes:** The latest revision defines that these devices shall be made of stainless steel used widely while considering the heat and corrosion resistant properties. JIS G 4303 "Stainless Steel Bars" is quoted for definition of stainless steel material.

Materials having equal to or better heat and corrosion resistance and strength are also employed.

(a) **Supporting Hardware:** Supporting hardware shall be made of stainless steel in general. Heat and corrosion resistant asbestos is recommended as the packing material. However, rubber packings may be used if the exhaust flue gas temperature is 100~C or below.

(b) **Drain Collector:** A drain collector should be used if the exhaust flue gas contains much mist and moisture. If not, the drain collector may be omitted. If the mist and moisture content is extremely high, the drain collector only may not be sufficient. A drain collecting bottle may be added after the connecting tube. If the dust collector with an impactor described above is used, the drain collector and drain collecting bottle may not be necessary.

(c) **Connecting Tube:** The connecting tube is generally 1 to 1.5 m long stainless steel pipe. The connecting tube may be extended by joining additional stainless steel pipes. Since hard glass tube is used occasionally, such description is included in the note column.

8.2.3 Gas Aspiration Section: This is the same as the gas aspiration section for the moisture sampling device. With the recent reduction in dust concentration, large aspiration pumps (approximately 100 L/min) are used. In this case, the flow meter capacity should be consistent with the pump capacity.

Note that the flow rate stabilizers that stabilize the equal speed flow rate are practically available.

8.2.4 Aspiration Flow Rate Measurement Section: An instantaneous flow meter and cumulative flow meter (gas meter) are used to measure the equal speed flow rate and aspiration gas quantity. Gas meters with automated flow rate measuring capability are available recently. These meters can measure the instantaneous and cumulative flow rates simultaneously.

8.2.5 Automatization of Conventional Sampling Device:
Recently, conventional sampling devices that are called as "automatic equal speed aspiration devices" are commercially available. These meters automatically calculate the equal speed aspiration flow rate and control the aspiration flow rate. These meters automatically measure some of the particulars such as dynamic pressure and temperature of the exhaust flue gas and, given other particulars obtained by the preparatory measurement, automatically calculate the equal speed aspiration flow rate. The calculated results are used to automatically control the aspiration flow rate.

This means that the meter measures some particulars to calculate the equal aspiration flow rate while assuming that other particulars have not been changed. These meters can therefore be useful when the exhaust gas condition is stable so that the assumed particulars have not changed since the preparatory measurement.

The conventional sampling devices are entirely different theoretically from the equilibrium sampling devices. Only the operation of the conventional sampling device is automated. Unlike the equilibrium sampling device, the conventional sampling device does not carry out equal aspiration depending on the changes in the exhaust flue gas condition.

Like the equilibrium sampling devices, the conventional sampling devices are seen as "black boxes". When these devices are widely used in future, the applicable conditions, mechanisms, performance and performance test methods will have to be defined. Before employing any of these devices, it shall be checked whether the device complies with the relative tolerance requirements defined in section 9.4 (2)(b) in the main body of this specification at the measurement site.

8.3 Equilibrium Sampling Devices: The equilibrium sampling devices are the dust sampling devices that incorporate the equilibrium aspiration nozzle defined in the previous version of this standard as part of the device. The equilibrium sampling device utilizes the principle in that equal speed aspiration can result if the aspiration flow rate is controlled so that the dynamic or static pressure of the exhaust gas at the point of measurement is equal to the dynamic or static pressure of the aspiration gas.

Since the above operations of this device are completely automated, the equal aspiration flow rate need not be obtained separately. This makes sampling dust extremely quick and easy. Besides changes in the exhaust flue gas flow speed, this device automatically follows the changes in other particulars while achieving equal speed aspiration. This makes the dust concentration measurement accurate.

8.3.1 Construction of Equilibrium Sampling Device: As shown in Figures 16 (1) and (2) in the main body of this standard, two types of equilibrium sampling devices are available;dynamic pressure system and static pressure system. Like the conventional sampling device, the equilibrium sampling device is made up of three sections.

Other than the equal speed aspiration mechanism and flow rate control device, the rest of the components are similar to the conventional one.

No leakage of gas or air shall be allowed through any joint of the device. Leak test shall be carried out in the same manner as for the conventional sampling device. However, because of many joints and pressure used, leak test on the aspiration system after the aspiration nozzle and on the pressure measuring system may have to be carried out separately.

8.3.2 Dust Collecting Section

(1) **Suction Nozzle and Dust Collector:** The dust collector is as aforementioned. If it is a static pressure type, the

suction nozzle has an internal static pressure measuring hole which measures the static pressure of the sucked gas, as shown in Figure 17 (2) in the main body.

(2) **Equal-speed suction mechanism:** Though it is equivalent to the balance type suction of the old standard, it is totally renamed the equal-speed suction mechanism since it is equipped with the nozzle and other accessories such as the Pitot tube which measures the dynamic pressure (differential pressure) and static pressure between the exhaust gas and suction gas.

The equal-speed suction mechanism is divided into the the dynamic pressure type and the static pressure type. The dynamic pressure type measures the dynamic pressure of the exhaust gas with the Pitot tube, and the static pressure type measures the dynamic pressure of the suction gas with the venturi tube instead of the Pitot tube. The venturi tube whose port size is the same as that of the suction nozzle measures the differential pressure between before and after the choke. The static pressure type measures the static pressure of the exhaust gas with the Pitot tube (static pressure tube), and the static pressure of the suction gas is measured at the internal static-pressure hole in the suction nozzle.

Here, the stainless steel tube is used as the pressure type conduit which connects the measurement hole of each pressure to the pressure gauge, but the pressure-resistant rubber tube is also applicable.

Moreover, the ordinary rubber tube, vinyl tube or equal is used since the temperature is low at the other parts except the duct. Next, the principle of the equal-speed suction of a dynamic pressure type and a static pressure type is described as follows:

(a) **Dynamic Pressure Type:** If the dynamic pressure of the exhaust gas is equal to the dynamic pressure (differential pressure) of the suction gas, the dynamic pressure type executes the equal-speed suction on the basis of the principle that the flow speeds of both are equal. As shown in the outline view in Figure 17 (1) in the main body, the Pitot tube which is adjacent to the suction nozzle measures the dynamic pressure of the exhaust gas, and the venturi tube whose inner diameter is equal to that of the suction nozzle connected to the dust collector measures the differential pressure of the suction gas. If both pressures are equal, both flow rates will become equal as shown by the following equation, and the equal-speed suction state will be achieved.

Here, Pd : Dynamic pressure (Pa) of exhaust gas at the measurement point

p : Density (kg/m^3) of exhaust gas at the measurement point

v : Flow speed (m/s) of exhaust gas at the measurement point

Pn : Differential pressure (Pa) between before and after the choke in the Venturi tube

pn : Density (kg/m^3) of suction gas in the Venturi tube

v_n : Flow speed (m/s) of suction gas in the Venturi tube

c : Coefficient (-) of Pitot tube

α : Flow rate coefficient (-) of Venturi tube

e : Compensation coefficient (-) of compression

The flow speeds of the exhaust gas and suction gas are expressed.

$$v = c\sqrt{\frac{sPd}{p}}, \quad vn = \alpha \cdot e\sqrt{\frac{2Pn}{p}}$$

Here, $\sqrt{2/p} = \sqrt{2/pn} = K$ is substituted since $p \approx pn$ and $e =: 1$ are considered. The following are gained.

If $c = \alpha = 1$ is considered here, the following are gained.

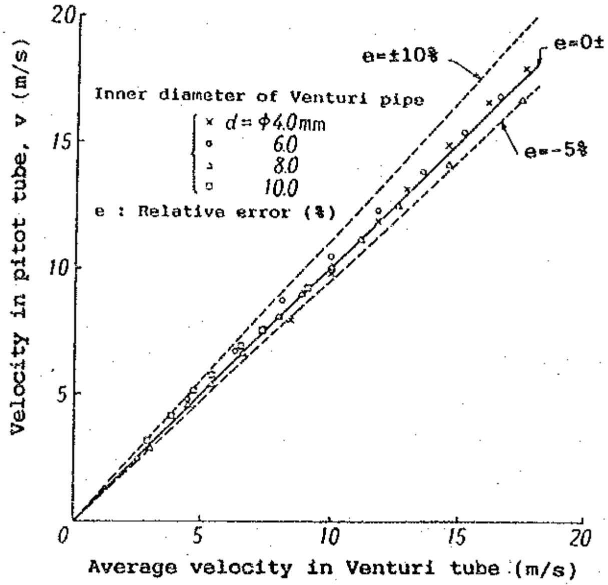
$v = K\sqrt{Pd}$, $v_n = K\sqrt{Pn}$

Since $v = v_n$ is gained in case of $Pd = Pn$, the equal-speed suction is gained.

Though a condition of $c = 1$ is here necessary, it is proper if the venturi tube of $\alpha = 1$ is used. Because $c = 1$ is gained by the standard Pitot tube. The venturi tube of $\alpha = 1$ is so special as to generate a small differential pressure, differing from the ordinary one which generates a large differential pressure. Todays, the Venturi tubes of 4 to 12 mm in the inner diameter and α = approx. 1±0.05 are produced, and are suffciently precise as practical.

Explanatory Figure 16 shows the measurement result of both flow speeds gained when the differential pressure of the venturi tube of 4 to 10 mm in the inner diameter is made to be equal to the dynamic pressure of the Pitot tube. Its relative error compared with the flow speed of the Pitot tube is always within ±5%.

Here, the error becomes within ±2% in the flow speed range where suction is possible for each inner diameter. Accordingly, it is applicable since the relative error of the equal-speed suction sufficiently settles within -5 to 10%.



Explanatory Figure 16 Example Performance of Dynamic Balancing Type Sampling Apparatus

(Case be equalized dynamic pressure of pitot tube and average differential pressure in ventri tube)

The dynamic pressure equation is sufficiently applicable for the flow speed of the exhaust gas in the range where the flow speed can be measured by the Pitot tube. Keep in mind that the coefficient of the Pitot tube largely varies to possibly make the measurement error large if the dynamic pressure of the low flow speed is less than Pa (0.5 mm H_2O). This is the common performance which the Pitot tube shows for measurement of the flow speed.

As practical, the special Pitot tube (western type) is often used instead of the standard type Pitot tube. It is equipment which electrically compensates the coefficient according to the coefficient of the Pitot tube.

Moreover, the venturi tube is also the common type which need not be replaced according to the inner diameter of the suction nozzle, and is equipped with the mechanism which can electrically compensate the differential pressure. It is so convenient as to allow the suction nozzle alone to be replaced.

(b) **Static pressure type:** The static pressure type executes the equal-speed suction according to the Verneuil's theorem that both flow speeds are equal if the static pressure of the exhaust gas is equal to the static pressure of the suction gas. As shown in the outline in JIS Z8808, the static pressure of the exhaust gas at the measurement point is measured with the Pitot tube which is equipped adjacent to the suction nozzle. Thus, the static pressure of the suction gas is measured with the inner static-pressure hole which is positioned near the inlet of the suction nozzle. If both pressures are equal, both flow speeds will become equal as shown by the following equation.

Here, Ps : Static pressure (kPa) of exhaust gas at the measurement point

p : Density (kg/m^3) of exhaust gas at the measurement point

v : Flow speed (m/s) of exhaust gas at the measurement point

Pn : Static pressure (kPa) of suction gas in the suction nozzle

p_n : Density (kg/m^3) of suction gas in the suction nozzle

v_n : Flow speed (m/s) of suction gas in the suction nozzle

K : Coefficient (-) of pressure loss at the suction nozzle inlet

h_n : Pressure loss (kPa) from the suction nozzle tip to the inner static-pressure hole

Therefore, it is expressed by the following equation according to the Bernoull's theorem.

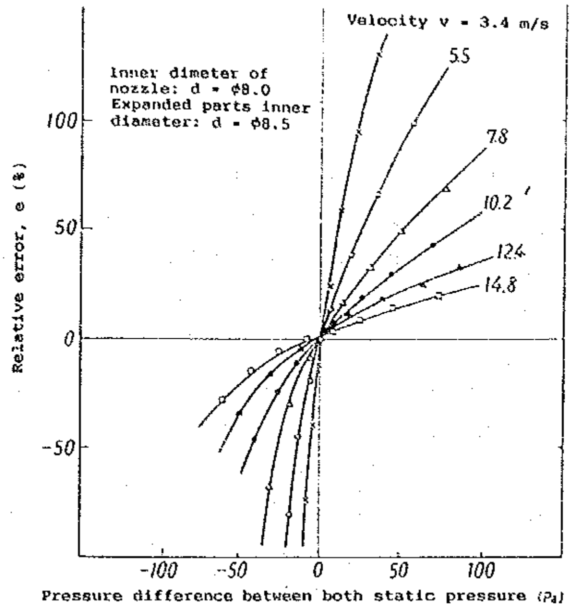
$$\frac{v^2}{2} + \frac{Ps}{p} = \frac{v_n{}^2}{2} + \frac{Pn}{p_n} + K\frac{v_n{}^2}{2} + hn$$

Since p = pn may be considered here, Ps = Pn is established to gain $v = v_n$ if $K \cdot v_n{}^2/2$ and hn are negligible.

However, compensation is necessary since $K \cdot v_n{}^2/2$ and hn are practically not negligible. Therefore, the suction nozzle which does not require this compensation is developed and is put into operation. The outline JIS Z 8808 shows an example. The pressure loss is recovered by slightly increasing the inner diameter which is positioned soon after the suction nozzle tip. Thus, it is devised to make the above compensation unnecessary.

Moreover, there are several other types such as the special reference static-pressure tube is used for measurement by reversely compensating the static pressure of the exhaust gas instead of the pressure loss of the suction nozzle, and the outer static pressure hole which measures the static pressure of the exhaust gas is provided on the outer side of the suction nozzle (the inner static-pressure hole is the same as above).

Explanatory Figure 17 shows a type whose inner diameter is slightly increased to 8 mm soon after the tip of the suction nozzle. The flow speed is set at 3.4 to 14.8 m/s by the test wind tunnel. It is sucked to make both static pressures equal (dP = 0 Pa), and it is sucked to generate a pressure difference of dP = -50 to 100 Pa between both static pressures. The measurement result is shown. In case of dP = 0 Pa, the relative error e between both flow speeds is 0%. Since an error of 10% or more generates if the flow speed is low even though the different is as small as dP = 10 Pa or less, care must be taken to make both static pressures sufficiently equal.



Explanatory Figure 17 Example of Performance of Static Balance Type Sampling Apparatus

(3) **Conduit for pressure:** The conduit is used to transfer the pressure measured by the equal-speed suction mechanism to the pressure gauge, and must be heat-resistant and corrosion-resistant. The stainless steel pipe is generally used. However, the heat-resistant rubber tube may be used if the exhaust gas temperature is not so high. On the other parts except the duct, the rubber, vinyl or similar tube may be used since the temperature is low.

Since the dust collecting section is often combined with the temperature detecting section in order to measure the exhaust gas temperature, it is specified in the remarks.

8.3.3 Gas Sucking Section

Like the ordinary type specimen sampling equipment, the gas sucking section is composed of the pressure gauge and flow rate controller (on the automatic type) in addition to the SO_2 absorbing bin, mist removal bin, sucking unit, suction flow rate control valve.

(1) **Pressure Gauge:** Though the specified pressure gauge is used on the main body 7.2 (2), the automatic type converts all the pressure into the electrical signals, and executes the

indication and comparison.

Here, the equipment must be able to precisely measure the pressure to a minimum of 1pa (0.1 mmH_2O) according to its principle. Care is taken to maintain and control the measurement precision.

(2) **Suction Flow Rate Control Valve:** The valve is used to control the suction flow rate in order to make both pressures of the exhaust gas and suction gas equal. In order to automatically control the flow rate, the automatic type opens and closes the valve by driving the motor coupled with the valve. It is installed in front of the suction pump or on the by-pass area of the suction pipe.

(3) **Flow Rate Controller:** Since the signal to control the suction flow rate is output by the automatic type, both pressures are calculated and compared. If any difference is found, the signal to open, close and stop the suction flow rate control valve is output. Since the controller can be equipped with the accessories such as the pressure gauge to indicate both pressures, the pressure balance indicator which indicates the balance state of both pressures, the exhaust gas thermometer and so on, they are so convenient as to check the operational state of the equipment. Among them, it is desirable to install the pressure indicator or pressure balance indicator. The terminals to record the pressure and temperature are provided to output the alarms if the suction flow rate is additionally insufficient.

8.3.4 Suction Flow Rate Measuring Section: One which is the same to that of the ordinary type specimen sampling equipment is used.

8.3.5 Cautionary Items for Use of the Balance Type Specimen Sampling Equipment

(1) After being inserted into the duct, the dust collecting section is made to wait for several minutes in order to be accustomed to the exhaust gas temperature by directing the

suction nozzle opposite to the flow of the exhaust gas. Then, the dust specimen is sampled. If the duct is small and a part of the dust collecting section is outside the duct, the thermal insulation and heating are executed according to the type 2 specified in the main body 8.2.1.

(2) For the exhaust gas which includes the high-density dust and mist, care is taken since the pressure measuring hole of the equal-speed suction mechanism is liable to be clogged.

(3) After use, the dust collection section and suction flow rate control valve is cleaned well. Particularly if any corrosive exhaust gas is sucked, it is rinsed and is sufficiently dried.

(4) In order to check the performance of the equipment, it is desirable to previously check the operational state and the performance of the applied suction nozzle according to the appendix sheet 3.2(2).

(5) The maintenance and control of the other parts are the same as those of the ordinary type specimen sampling

8.4 **Performance and Performance Test Method of Balance Type Specimen Sampling Equipment:** Though the equipment has the function to immediately sample the dust specimen with the constant-speed suction on the site, the performance of the constant-speed suction must be within -5 to +10% as specified in the main body 9.4(2)(b). Accordingly, it is necessary to test the performance in order to check this. The performance test method is specified in the appendix sheet since the main body and content are described in the separate items.

9. **Dust Specimen Sampling Method:** The description sequence of the old standard is changed, and is described for easier understanding according to the the sequence in which the dust specimen is practically sampled. In other words, the measurement point and sampling method are first selected, the necessary preparation is taken for sampling, and the sampling is next

executed.

Since there are many common sampling points between filter paper and dust tube, they are collectively described separation.

9.1 Measurement Point: Specified in the main body 4.3.

9.2 Kinds of Sampling Methods of Dust Specimen:

(1) **Respective-Point Sampling Method:** This is suitable if the number of the measurement points is small. Since the dust density at each measurement point is gained, the density distribution is known, and the representative point can be gained.

(2) **Movement Sampling Method:** If there are many measurement points or the dust density is low, this method is suitable. It has an advantageous point to shorten the sampling time.

(3) **Representative-Point Sampling Method:** The measurement point which shows the average dust density gained by the respective-point sampling method is selected as the representative-point. It has an advantageous point that it is the easiest and fast. However, it is necessary to newly check whether it is the representative point or not if any working condition or exhaust gas condition is changed. Among the above sampling methods, the most suitable one is selected after the number of the measurement points and the conditions of the exhaust gas are taken into consideration.

9.3 Preparation for Sampling the Dust Specimen: If the ordinary type specimen sampling equipment is used, the necessary constant-speed suction flow rate must be first gained, and the dust collector which is common for both ordinary type and balance type specimen sampling equipment must be prepared before sampling. This has been already described.

9.3.1 Calculation of Suction Flow Rate for Constant-Speed Absorption: If the ordinary type specimen sampling is used, the suction flow rate (L/min) required for constant-speed must be previously calculated. The calculation equation is as shown by the equation (11) of the main body 9.3.1.

In the equation (11), the inner diameter d of the suction nozzle must be selected after the flow speed of the exhaust gas, the suction flow rate (L/min) of the suction pump and the filtering speed (0.5 m/s or less as a rule) are taken into consideration. If the flow speed of the exhaust gas is large, the suction nozzle whose inner diameter is small must be selected. On the contrary, one whose inner diameter is large must be selected if it is small.

As the suction nozzle with the larger inner diameter is used, the suction flow rate is also the larger and the dust specimen can be sampled for the shorter time. The rated capacity of the suction pump which is now widely used is approx. 50 l/min, and care is necessary that the suction flow rate of approx. 20 to 30 l/min. alone is practically gained because of the resistance of the filtering material and flow path.

Here, the filtering speed of 0.5 m/s or less is selected after the strength of the filtering paper is taken into consideration. However, unless the filtering paper is broken, that of 0.5 m/s or more may be selected as described later. If the flow rate is applicable for suction as the result of the calculation based on the inner diameter of the selected suction nozzle, it is sufficient. If it is insufficient, whether it is applicable or not is judged by calculating one of the smaller inner diameter again.

Among the calculation equations, the other items except d are calculated by using the temperature, moisture content, and flow speed of the exhaust gas and the temperature, pressure and so on of the exhaust gas, which are preparatorily measured. In other words, the premise is necessary that the conditions of the exhaust gas are not different between when the dust specimen is sampled and when the above measurement values are gained. Accordingly, it is necessary that the conditions of the exhaust gas are stable when the specimen is sampled. Care is necessary that the measurement error may result if any exhaust gas condition varies.

The Explanatory Table 3 shows the calculation example of the constant-speed absorption flow rate when the cylindrical filtering paper (ϕ25 x 90) is used under the conditions of X_w = 10%, P_s = 0 kPa {mmHg} and θm = 20°C. They must be used for reference.

Explanatory Table 3 Example of Calculation of Flow Rate of Equal Velocity Aspiration by Inner Diameter of Aspiration Nozzle and Flue Gas Velocity in Cartridge Type Filter For Dust Collector

Flow Rate of Equal Velocity Aspiration (Gas Meter), Qm

(Unit: L/min.)

v m/s		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
$d=\phi4$ $a=12.57$ mm²	θ_s ℃ 150	0.48	0.95	1.44	1.92	2.40	2.88	3.36	3.84	4.32	4.80	5.28	5.76	6.24	6.72	7.20	7.68	8.16	8.64	9.12	9.60	10.1	10.6	11.1	11.6	12.1	12.6	13.1	13.6	14.1	14.6
	250	0.39	0.78	1.17	1.56	1.95	2.34	2.73	3.12	3.51	3.90	4.29	4.68	5.07	5.46	5.85	6.24	6.63	7.02	7.41	7.80	8.19	8.58	8.97	9.36	9.73	10.1	10.5	10.9	11.3	11.7
	350	0.33	0.66	0.99	1.32	1.65	1.98	2.31	2.64	2.97	3.30	3.63	3.96	4.29	4.62	4.95	5.28	5.61	5.94	6.27	6.60	6.93	7.26	7.59	7.92	8.25	8.58	8.91	9.34	9.67	9.90
$d=\phi6$ $a=28.27$ mm²	θ_s ℃ 150	1.08	2.16	3.24	4.32	5.40	6.48	7.56	8.64	9.72	10.8	11.9	13.0	14.1	15.2	16.2	17.3	18.4	19.5	20.6	21.7	22.7	23.8	24.9	26.0	27.1	28.2	29.3	30.3	31.4	32.5
	250	0.88	1.76	2.64	3.52	4.40	5.28	6.16	7.04	7.92	8.80	9.68	10.6	11.5	12.4	13.1	14.0	14.9	15.8	16.7	17.6	18.5	19.3	20.1	21.0	21.9	22.8	23.6	24.5	25.4	26.3
	350	0.73	1.46	2.19	2.92	3.65	4.38	5.11	5.84	6.57	7.30	8.03	8.76	9.49	10.2	11.0	11.8	12.5	13.2	14.0	14.7	15.4	16.2	16.9	17.6	18.4	19.1	19.8	20.6	21.3	22.0
$d=\phi8$ $a=50.27$ mm²	θ_s ℃ 150	1.92	3.84	5.76	7.68	9.60	11.5	13.4	15.3	17.3	19.3	21.2	23.1	25.0	27.0	28.9	30.8	32.8	34.7	36.6	38.5	40.4	42.4	44.3							
	250	1.56	3.12	4.68	6.24	7.80	9.36	10.9	12.5	14.0	15.6	17.1	18.7	20.2	21.8	23.4	24.9	26.5	28.0	29.6	31.1	32.7	34.3	35.8							
	350	1.31	2.62	3.93	5.24	6.55	7.86	9.17	10.5	11.8	13.1	14.4	15.7	17.0	18.3	19.6	20.9	22.2	23.5	24.8	26.1	27.4	28.7	30.1							
$d=\phi10$ $a=78.54$ mm²	θ_s ℃ 150	3.01	6.02	9.03	12.0	15.1	18.0	21.1	24.1	27.1	30.1	33.1	36.1	39.1	42.1	45.1															
	250	2.43	4.86	7.29	9.72	12.2	14.6	17.0	19.5	21.9	24.3	26.8	29.2	31.6	34.1	36.5															
	350	2.04	4.08	6.12	8.16	10.2	12.3	14.3	16.3	18.4	20.4	22.5	24.5	26.5	28.6	30.6															
$d=\phi12$ $a=113.1$ mm²	θ_s ℃ 150	4.33	8.66	13.0	17.3	21.7	26.0	30.3	34.5	39.0	43.3	47.7																			
	250	3.50	7.00	10.5	14.0	17.5	21.0	24.5	28.0	31.5	35.0	38.5																			
	350	2.94	5.88	8.82	11.8	14.7	17.6	20.6	23.5	26.5	29.4	32.3																			
$d=\phi14$ $a=153.8$ mm²	θ_s ℃ 150	5.89	11.8	17.7	23.6	29.5	35.4	41.3	47.2																						
	250	4.76	9.52	14.3	19.1	23.8	28.6	33.3	38.1																						
	350	4.00	8.00	12.0	16.0	20.0	24.0	28.0	32.0																						
$d=\phi16$ $a=201.0$ mm²	θ_s ℃ 150	7.70	15.4	23.1	30.8	38.5	46.2																								
	250	6.23	12.5	18.7	24.9	31.1	37.3																								
	350	5.23	10.5	15.7	20.9	26.1	31.3																								

Formula of Flow Rate of Equal Vlocity Aspiration

$$q_m=\frac{\pi}{4}d^2v\left(1-\frac{x_w}{100}\right)\frac{273+\theta_m}{273+\theta_s}\times\frac{p_a+p_s}{p_a+p_m-p_v}\times60\times10^{-3}$$

Here, $x_w=10$ %

$\theta_m=20$ ℃

$p_a=101.3$ kPa {760 mmHg}

$p_s=0$ kPa {0 mmHg}

$p_v=2.33$ kPa {17.5 mmHg}

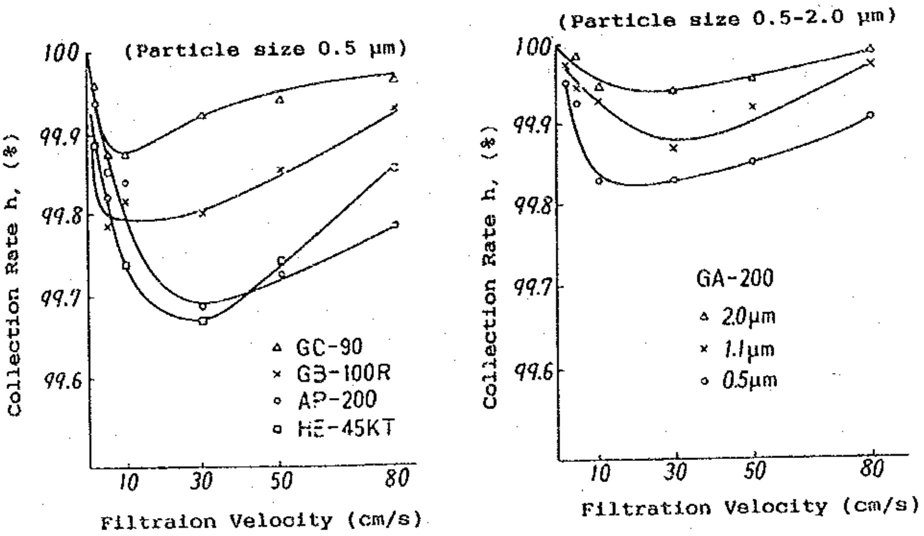
$\theta_s=150\sim350$ ℃

$d=4\sim16$ mm

Qm was calculated.

9.3.2 Preparation of Dust Collector

(1) The apparent flow speed (filtering speed) of the gas which passes through the filtering is 0.5 m/s or less. However, the collecting efficiency is 99% or more even at 0.5 m/s or more as shown in the Explanatory Figure 18.



Explanatory Figure 18 Example of Collection Rate for Miscellaneous Filters

Accordingly, unless the suction flow rate drops according to breakage of the filtering paper and clogging of dust as aforementioned, there is no problem even if it is made to be 0.5 m/s or more.

The filtering speed is necessary to determine the inlet diameter of the suction nozzle and the dimensions of the filtering paper and dust tube. The constant-speed suction flow rate is calculated and estimated to select the dust collector.

(2) When it is heated by the exhaust gas, the filtering material varies and decreases in the mass since the adsorbed

moisture, impurities or other materials volatilize. Accordingly, when the exhaust gas temperature drops to 100°C or less, it is sufficiently dried to the constant amount at 105 to 110°C before the dust specimen is sampled. It is cooled down to the room temperature in the desiccator in which descicant is put. It is weighed with the balance.

If the exhaust gas temperature is 100°C or more, it is heated to the same or higher temperature. As described above, it is weighed with the balance.

Since the decreased amount due to filtering material heat causes a measurement error, the heating and drying process is necessary before sampling. Though the cylindrical filtering paper made of silica fiber heat-processed to 800°C is now commercially available, the heating process aforementioned need be applied before use.

If it is compensated for sulfuric acid mist as said later, the heating process must be taken at approx. 250°C. Particularly if the dust density is low and the exhaust gas temperature is high, the heating process must be surely executed since the heated and decreased amount of the filtering paper largely influences the measurement.

Since the other filtering materials except that made of fluoric resin is hydroscopic and the collected dust is generally hydroscopic, it is desirable to prevent the influence of the humidity by using the weighing bin during weighing.

As described later, this correction largely decreases the dust collecting amount of the filtering paper. In order to extremely reduce the weighing error, it is desirable to weigh it in the environments of the relative humidity of approx. 50% in order to prevent it from being influenced by the humidity.

Here, the sensitivity of the applicable weighing bin is 0.1 mg or less. For example, the balance of 0.01 mg is used.

This is the same as the weighing method of JIS Z 8814 (in-air suspension dust measuring method with low volume air sample and low volume air sampler) which specifies the dust density measuring method with the low volume air sampler.

9.4 Sampling of Dust Specimen: Though the old standard separately describes the measuring method which uses the filtering paper and dust tube, there are many overlapped areas. Since the specimen is sampled in the same procedure on both specimen sampling equipment of the ordinary type and balance type, this revision standardizes both for description.

(1) When the preparation for sampling the dust specimen, the dust collector is installed on the dust specimen sampling equipment, and the air-tightness of the whole equipment is tested for leakage. Care is necessary that this check is often skipped on the site.

(2) To sample the dust specimen, the exhaust gas is sucked at the constant speed to filter and collect dust. The sampling procedure is described as shown in the main body 9.4(2).

When the dust collecting unit is inserted or pulled out through the measurement hole, the suction nozzle is directed oppositely to the flow direction of the exhaust gas. This prevents dust from flying into the suction nozzle.

When the suction nozzle reaches the measurement point, the suction nozzle is properly faced to the flow of the exhaust gas, and the suction pump is run for constant-speed suction. Though this procedure is shown in the main body 9.4(2)(a) and (b), the flow rate is read by the instantaneous flow rate type, or the suction flow rate is calculated with the second clock by using the integral flow-rate type if the ordinary type specimen sampling equipment is used. Thus, the constant-speed suction flow rate is quickly matched.

Here, the suction rate measurement is started with the gas meter at the same time when the suction is started. If the filtering resistance is increased by the collected dust during specimen sampling to lower the suction flow rate, the flow rate is adjusted to precisely maintain the constant-speed suction flow rate. If the balance type specimen sampling equipment is used, the automatic equipment automatically will come into the constant-speed suction state at the same time when the suction is started, and it will follow up even if any exhaust gas condition varies. On the manual equipment, the suction flow rate is controlled to quickly make both pressures equal. Also during sampling, both pressures are made to be equal in the same manner.

(3) Though the suction gas rate is determined according to the collected amount of the dust to be sampled, the density of the dust must be previously known. However, it is often practically unknown, and there is not any other method except it is estimated from the past measurement example, or the data of similar generation source.

If any approximate dust density is known, the suction gas amount can be roughly calculated by the following equation.

$$I = (m \times 1{,}000)/C$$

Here, V: Suction gas rate (L)
m: Mass (mg) of dust to be collected
C: Dust density (mg/m^3_N)

However, it is necessary to strictly compensate the temperature and pressure of the exhaust gas since the V must be in the standard state (0°C, 101.3 kPa{760 mmHg}). The point largely changed by this revision is that the amount of dust by the filtering paper is largely reduced. Since the exhaust standard of the dust content was revised in 1972, the recent dust density considerably drops as exampled in the Explanatory Table 4. If the old standard is continuously applied, it will cause a problem point that the sampling time is considerably long. These circumferences are taken into consideration, and the collected amount of the dust is largely reduced to 1/2 to 1/4. However, if the dust tube is used, reduction of the collected amount increases the measurement error since the container itself is heavy. Therefore, the existing one is continuously used.

Explanatory Table 4 Measurement Example of Dust Concentration in Flue Gas of Thermal Power Plant

(Unit: mg/m^3N)

Fuel	Average Value	Maximum Value
Gas	0.1-0.2	1
Naphtha	1	2.5
Crude Oil	1.5	6
Heavy Oil	2	6

As the reason why the amount of dust collected by the filtering paper can be reduced, it is listed that the stability is improved as the filtering material is improved later. As aforementioned, it is also judged that the proper measurement of the amount of the collected amount is totally possible. Accordingly, sufficient care is necessary to handle, maintain and control the filtering paper.

(4) When the specimen sampling is ended, the dust collector is taken out of the duct. However, the suction rate is measured when the suction nozzle is directed oppositely to the flow of the exhaust gas as aforementioned. The suction pump is not soon stopped, and is stopped after the dust collector is taken out of the duct. Because the collected dust flies out from the suction nozzle when the pump is stopped if the pressure is negative in the duct. This is prevented.

(5) The dust collector is removed from the equipment. In order to remove sticking moisture, it is dried at 105 to 110°C for one hour. It is weighed again like before sampling. If the dust which sticks to the suction nozzle is not negligible in

this case, it is dried as it is in the same manner, and is weighed. Next, dust is cleaned off, the suction nozzle is weighed. From the difference, the mass of the sticking dust is gained, and the collected dust is added.

(6) If any sulfuric oxide is included in the exhaust gas, sulfuric acid mist will be generated when the exhaust gas temperature drops below the acid dewing point, and will be collected together with dust. When the dust density becomes high, an error will be generated. As known from the definition of the dust, sulfuric acid mist must be removed. It can be compensated with the remarks in the old standard. However, the compensating method is described in the explanation but is not specified in the main body. Then, the compensating method is researched, and the practical method is established. Therefore, this revision mainly covers the compensation which uses the heating volatilization, and also specifies the compensation which uses the chemical analysis.

The compensation with heating volatilization collects dust with the filtering paper which does not chemically react with sulfuric acid mist. After collection, it is heated at approx. 250°C for approx. 2 hours to volatilize the sulfuric acid mist, and is weighed. Therefore, it is necessary to heat the filtering paper at approx. 250°C before sampling and weigh it.

The filtering paper is made of fluoric resin, silica fiber (composite filtering paper) which uses fluoric resin as the binder, silica fiber which includes the alumina binder processed with sulfuric acid, silica fiber which does not include any binder, or other materials. The method to process with sulfuric acid (4)(5) is devised to prevent reaction between alumina binder and sulfuric acid. For example, it is washed for 30 minutes in the 2N-H_2SO_4 solution with the supersonic method. After it is lightly rinsed, the filtering paper is gradually heated. It is heated to 250°C until white smoke is not generated, and free sulfuric acid is voltatilized. Then, it is heated at 300°C for 3 hours. After the dust collection, the heating process and weighing method are the same as above but must be within 24 hours.

The compensation with heating volatilization is relatively simple and is suitable for daily measurement. Since it is heated at 250°C after collection, it is not suitable for the dust which decreases in weight due to heating. However, the dust which passes through the ordinary burning process includes a considerably small amount of unburnt content. It is known that weight reduction due to heating hardly occur at approx. 250°C. The applicable range is estimated to be wide.

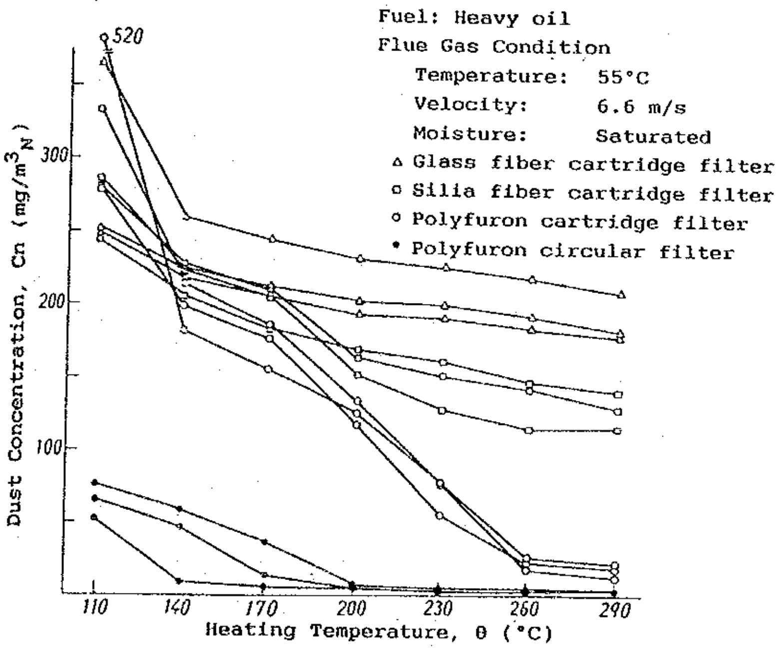
On the other hand, the compensation with chemical analysis in the remarks uses water to extract the sulfuric acid content in the filtering paper which collects dust. After calculating it as SO_4^{-2}, it is subtracted from the mass of the collected dust in this method. Calculation of $SO_4^{-2}$is executed with the neutralizing method or nephelometry method which is specified in JIS K 0103 (in-exhaust-gas sulfuric oxide analysis method). The ion chromato method is also applicable. It is necessary to heat the collected dust at 250°C. However, the compensation with chemical analysis may subtract the sulfate including dust, and the neutralization method may subtract the acid material. If these materials are included, it is not applicable.

Because of the above, two compensating methods are employed, but the heating volatilization method is easier than the chemical analysis method. It is estimated to be high in the versatility.

In addition, there is a method to collect the dust by heating the whole dust collector to approx. 200°C. Since the heater is necessary, it becomes complicate. Since sulfuric acid mist may not be sufficiently volatilized during sampling, it is not called the general method, and is not employed.

When the compensation method of sulfuric acid mist is applied, it is applied with care for the conditions of the exhaust gas and the properties of the dust. Even if any method is used, it is necessary to clarify the compensation method during record of the measurement value.

The Explanatory Figure 19 shows an example that dust in the exhaust gas to which the wet type flue desulfuration is applied is collected by various filtering paper, and the heating temperature for volatilization is varied to 110 to 290°C for measurement. The cylindrical filtering paper made of glass fiber, or silica fiber including alumina binder is reacted with sulfuric acid, and the sulfuric acid content is not voltatilized even if it is heated to approx. 250°C. On the other hand, the cylindrical polyflon filtering paper made of fluoric resin will show the nearly constant value at 200°C. Since drips are present in the same cylindrical filtering paper, it shows the constant value at approx. 250°C. Since neither reaction between the filtering material and sulfuric acid nor adsorption is present, the compensation due to the heat-volatilization is possible.



Explanatory Figure 19 Relationship between Dust Temperature of Dust Collected and Dust Concentration for Miscellaneous Filters

The Explanatory Table 5 shows an example that dust density in the exhaust gas (140°C) to which the flue desulfuration is applied is processed with the cylindrical filtering paper made of fluoric resin (No. 89R) and the silica fiber made cylindrical paper (No. 88RH) including alumina binder which is processed and deactivated with sulfuric acid. The density which is heated and dried to 250°C shows the nearly same value for both filtering paper. The process with sulfuric acid is effective.

Explantory Table 5 Measurement Results for Vaporization Heating Method

No.	Aspiration (m^3_N)	Dust Concenration(g/m^3_N)		Filter Used
		110°C	250°C	
1	0.357	0.198	0.012	No.89R (Fluoric Resin)
2	0.547	0.158	0.011	No.89R (Fluoric Resin)
3	0.497	0.034	0.006	No.89R (Fluoric Resin)
4	0.568	0.098	0.009	No.89R (Fluoric Resin)
5	0.597	0.204	0.011	Nonactivated Filter (H_2SO_4 treated)
6	0.586	0.238	0.007	Nonactivated Filter (H_2SO_4 treated)
7	0.572	0.221	0.009	Nonactivated Filter (H_2SO_4 treated)
8	0.582	0.199	0.010	Nonactivated Filter (H_2SO_4 treated)
9	0.538	0.246	0.008	Nonactivated Filter (H_2SO_4 treated)
10	0.538	0.212	0.006	Nonactivated Filter (H_2SO_4 treated)

(7) If any dust is collected by the type 2 of the dust specimen sampling equipment, the dust which sticks in the suction tube from the suction nozzle to the dust collector is

negligible. Therefore, it is brushed off with the suitable method (example; nylon brush), or is washed off with water. It is solidified with evaporation, and need be added to the collected dust.

(8) If any exhaust gas includes much dust, the aforementioned dust collector with the impacter may be used for collection.

If this collector is not used, the drain collection bin is connected to the rear of the connection tube, and the collected drain is solidified with evaporation and is added to the collected dust. However, care is necessary that the filtering paper may be broken since mist flows out through the filtering material.

9.5 Measuring Method of Suction Gas Amount: The gas meter is used to measure the suction gas amount, and the instantaneous flow meter is used to check the constant-speed suction flow rate. Though the wet type gas meter of 5 L or 10 L per turn is often used, care is necessary that the measurable range is limited.

Here, the gas meter is leveled with the level gauge, water is filled to the marked line. In the cold district, it is thermally insulated to prevent water from freezing.

Since the measuring procedure is as specified in the main body 9.5, the instantaneous flow meter is compensated with the gas meter. There are tow types of the gas meters: wet type and dry type. As usual, the wet type is used. When the dry type is used, it is necessary to connect the container filled with water absorbing descicant in front of the gas meter. The absorbed gas amount must be the value in the standard state by the equation (12) in the main body 9.5(4).

Since the dry type gas meter is not standardized, it is unnecessary to calibrate the wet type gas meter.

10. Calculation of Dust Density: The dust density is expressed by converting the mass (g) of the dust in the dry exhaust gas of $1m^3{}_N$ into the value in the standard state, and there are various expression of the dust density according to the states of the exhaust gases.

10.1 Dust Density in the Dry Exhaust Gas at Each Measurement Point: This is the method to calculate the dust density at each measurement point with the respective-point sampling method. In case of the movement sampling method and representative-point sampling method for which one dust collector is sufficient, the calculated value is regarded as the average density on the whole cross-section.

In case of the plural representative point sampling method, the average value is regarded as the average dust density.

10.2 Average Dust Density in the Dry Exhaust Gas on the Whole Cross Section: When the dust density is measured with the respective point sampling method, it is calculated with the specifications of the main body 10.2 in order to gain the average value.

In case of the plural representative dust collector, it is calculated as described above. In this case, the area totaled from the cross sections sampled with one dust collector is used, and the gas flow speed is an average of the flow speeds on the respective cross-section for calculation.

10.3 Conclusion of Dust-Density Measurement Value: In this revision, the dust mass and sucked gas amount required for dust density calculation are gained to three effective digits, and the dust density is rounded to two effective digits. This is required from the relationship to the exhaust standard of the air pollution preventive law, and the third digit is discarded according to the notice of Environmental Bureau.

Next, the method to express the dust density in the exhaust gas state in the actual duct is shown. These dust densities are often used to measure the dust collecting ratio of the dust collecting equipment.

10.4 Method to Compensate the Dust Density According to the

Oxygen Density in the Exhaust Gas: The flue exhaust standard revised in 1972 prescribes the exhausting flue gas apparatus which compensates the dust density according to the residual-oxygen density (density of oxygen in the exhaust gas), and it is calculated with the following equation.

$$C = \frac{21-O_n}{21-O_s} \cdot C_s$$

Here, C : Dust density ($g/m^3{}_N$)

On: Standard oxygen density (%) of each apparatus

O_s: Residual oxygen density (%)

C_2: Dust density ($g/m^3{}_N$) measured by JIS Z 8808

O_n is specified in Article 4 and its Appendix Table 2, Regulation of Air Pollution Preventive Law, being the standard oxygen density specified according to the kind and scale of the flue generating apparatus. The notice Kandaiki No. 191 (May 13, 1972) of Environmental Bureau specifies that O_s must be measured with the Orsat gas analyzer or oxygen density analyzer which gains the equivalent measurement value. The oxygen density analyzer complies with JIS B 7983 (automatic in-exhaust-gas meter). Refer to the JIS standard.

Here, it is specified as follows. The O_s measuring position is the same as the sampling port of the dust specimen, or extremely near the port. The average value in the sampling time of the dust specimen is employed. However, if it is difficult, it is measured before and after the dust specimen sampling of each time. The measurement is averaged.

11. Calculation of Dust Flow Rate: The dust flow rate in the exhaust gas is used to measure the dust collecting ratio, and is additionally used as the exhaust coefficient of the dust. The dust flow rate is quotated into JIS B 9910 (performance measuring method of duct collector).

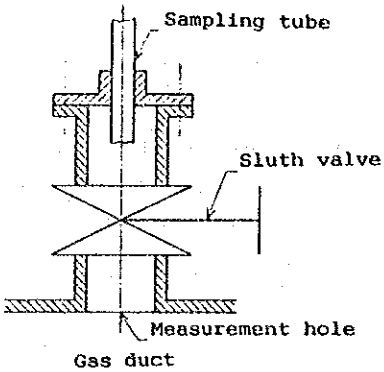
12. Record of Dust Flow Rate: The measurement conditions of the dust density, the measurement result of each item, and so on are recorded. This record respectively is meaningful for each measurement result. Since they are mutually related, the measurement error, the calculation mistake and so on can be checked.

Moreover, it can be also compared with the past measurement example, and is used to improve the generating source facility. Accordingly, it is not suitable to merely record the dust density alone.

If the balance type specimen sampler is used for measurement, all the items need not always be recorded since the preparatory measurement can be omitted.

13. Other Cautionary Items

(1) If any exhaust gas is poisonous at the positive pressure in the duct, if it is explosive at the negative pressure, or if the static pressure of the duct including explosive (poisonous) gas such as carbon monoxide is negative, it is desirable to use the attachment which is used for the gas seal as shown in the Explanatory Figure 20. When such dangerous exhaust gas is measured, care is necessary for the following point.



Explanatory Figure 20 Example of Attachment for Gas Sealer

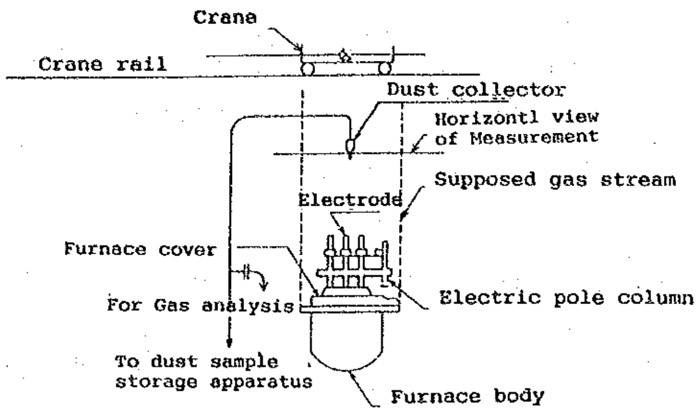
(a) The footing for measurement is wide and sturdy.
(b) Two or more measuring persons are necessary. It is desirable to use the safety rope.
(c) The wind direction is checked, and the work is done on the upstream side.
(d) When the attachment is used, it will be safer if it is purged with N_2 gas.

(e) If any explosive gas is at the negative pressure when the type 2 is used, N_2 gas is prepared for purging in order to clean dust clog since the suction nozzle is fixed.

(2) **No Duct Like Open Type Electric Furnace:** If any duct is provided, the dust density can not be strictly measured by the main body. However, as practical, the measurement is often necessary in this case.

As the measurement method in this case, the temporary duct is often provided. If it is difficult, the virtual duct is imagined as the duct of the main body by assuming that the duct generated from the furnace is sucked into the virtual duct and is raised as the Explanatory Figure 21. This virtual duct is regarded as the duct of the main body, and the gas flow speed and dust density are measured. In this case, the specimen is sampled by taking the speeds and disturbance of the in-room current and ascending current into consideration, selecting the large-size suction nozzle and executing the constant-speed suction according to the flow speed of the ascending current at the suction nozzle port. The amount of gas generated at the furnace top is calculated from the analysis value of CO in the cross-section for measurement, the consumed amount of the carbon electrode, and the decrease amount of carbon included in the molten steel.

Moreover, the open type bag filter can measure the dust density by using the high-volume air sampler, but it is difficult to gain the accurate measurement value.



Explanatory Fiture 21 Example of Measurement Position in Electric Furnace

(3) **Variation of dust density:** If the dust density varies as the time elapses depending on the operational state of the generation source facility, the dust density is measured at the constant time intervals for the constant period with the representative point sampling method, and the average value is gained. If the dust density periodically varies in this case, the above measurement is repeated several times every frequency and is averaged in order to gain the stricter dust density. For details, refer to the explanation of JIS B 9910.

If the dust density periodically varies, the dust density is gained every unit time according to the above method, and is averaged.

The notice of Air Maintenance Bureau Manager, Environment Bureau as of August 25, 1971 informs the following: "The sampling time of flue specimen is limited at the period of one process, and the measurement value is the average of this period. If the melting time is determined like the open hearth furnace and electric furnace, the time is regarded as the period of one process. If any periodic variation occurs according to the hammering of the dust collector, the average value is determined after the variation is taken into consideration. However, when one process is very long, the measurement is practically difficult. Therefore, the period which suitably represents one process is selected for the period. If the period of one process is obscure, the sampling is mostly executed at the following times and intervals in the period when the average density is grasped.

Sampling Time	Frequency of Sampling
- 20 minutes	approx. 5 times
20 - 40 minutes	4 times
40 - 60 minutes	3 times
60 minutes	2 times

If the dust density or exhaust gas condition varies in time in any case, the preparatory measurement requires the time regardless of the periodic time or non-periodic time when the ordinary type specimen sampler is used. As practical, it is considerably difficult or impossible to sample the dust specimen with the constant-speed suction.

Therefore, if the automatic balance type specimen sampler is used in such a case, the variation of the exhaust gas conditions can be followed up and the constant speed suction becomes possible. Therefore, this sampler is desirable for measurement.

14. Saturated Vapor Pressure Table of Water, and Dust Density Measurement Record Example: The saturated vapor pressure P_V of water required for calculation and so on of the suction gas amount is shown in the Explanatory Table 1 [expressed in the SI unit (kPa)] and Explanatory Table 2 [expressed in the existing unit (mmHg)], and the measurement record example of the dust density with the ordinary type specimen sampler is shown in the Explanatory Tables 3, 4 and 5.

Appendix Note Performance and Performance Measuring Method of Balance Type Specimen Sampler: The balance type specimen sampler (hereafter, referred to as the equipment) is one which is completed by integrating the balance type suction nozzle of the old standard as a part of the equipment, and the equipment which is automatically operated is widely used. However, the structure and performance of the equipment are not specially specified, and various claims are raised by the users as the equipment becomes popularized. Therefore, it is desired to strictly specify the performance. Therefore, this revision newly specifies the structure and function of the equipment in the main body 8.3, and the performance and performance test method are specified in the appendix note as shown in the main body 8.4.

1. **Applicable Range:** This appendix note specifies the performance and test method of the equipment.

2. **Performance of Equipment:** The equipment must be able to sample the specimen of dust with the constant-speed suction. Accordingly, the performance must match within a relative error of constant-speed suction of -5 to +10% specified in the main body 9.4(2)(b). If this performance can not be satisfied, it is not applicable for practical use.

3. **Performance Testing Method**

3.1.1 **Test Conditions:** The general meters and similar testing conditions are specified.

3.1.2 **Testing Equipment:** In the testing equipment, the test wind tunnel is special. If this is not provided on the static type equipment, the performance can not be precisely tested. Though the performance test is also similarly possible on the dynamic type equipment, the test can be theoretically taken even if the test wind tunnel is not provided.

3.2 **Relative-Error Testing Method of Constant-Speed Suction:** As a rule, the test wind tunnel is used for the test on both dynamic pressure type and static pressure type equipment, but the test wind tunnel is not used particularly for the dynamic pressure type. It is generally not easy for the user to have the test wind tunnel. Accordingly, the method which does not use the test wind tunnel is also applicable. For daily performance check, the latter method is desirable for the test.

(1) **Testing Method With the Test Wind Funnel:** This testing method is mainly applicable for the manufacturer. This method must be used particularly for the static pressure

type.

In this test, the constant-speed suction is executed by the equipment when the constant flow speed (A) is set (the flow speed is measured with the Pitot tube). The flow speed (B) in the suction nozzle is gained by dividing the suction flow rate of the accessory gas meter by the cross-sectional area of the nozzle, and the relative error is calculated. In this case, the filtering paper is installed on the dust collector (hereafter, the same conditions are applied for all).

In addition, the test wind tunnel can inspect the follow-up property of the equipment for variation of the flow speed. In other words, when the flow speed is rapidly varied approx. ±50% from the constant-speed suction at the constant flow speed, the equipment automatically controls to execute the constant-speed suction for the varied flow speed. In this case, the shorter response time is the better. It is desirable that the 90% response is within 10 seconds.

(2) **Testing Method Without the Test Wind Funnel**

(a) **Dynamic Pressure Type Equipment:** In the testing method of an automatic type, the difference from the atmospheric pressure works as the dynamic pressure when the constant pressure is given to the full-pressure hole (or the conduit for pressure) of the Pitot tube of the equipment by the rubber ball. The dynamic pressure is measured with the accessory pressure gauge. If the dynamic pressure is given, the equipment automatically controls the suction flow rate to immediately make the differential pressure of the venturi tube equal to the dynamic pressure. Thus, the constant-speed suction state is produced. Then, the flow speed (B) in the suction nozzle is gained in the same manner as (1). On the other hand, the flow speed (A) is gained from the given dynamic pressure as specified in the main body 7.3.4, and the relative error (C) is calculated. However, the weight of the air is gained by the equation (2) in the remarks.

In this test, the flow speed (A) is not the flow speed of air which actually flows. Since it is theoretically calculated from the dynamic pressure, it does not matter even if it is regarded as the flow speed of the air. (Hereafter, this is also applicable.)

(b) **Dynamic Type Equipment (Manual Type):** Open air is sucked at the constant flow rate, and the differential pressure h of the venturi tube is measured with the accessory pressure gauge. The flow speed (B) in the suction nozzle is gained in the same manner as (1). On the other hand, the differential pressure h is regarded as the dynamic pressure measured by the Pitot tube, and the flow speed (A) is gained in the same manner as in (a). The relative error (C) is calculated.

(c) **Static Pressure Type:** The equipment is fully automatic. This testing method is easy instead of the test wind tunnel, and care is necessary for operation. Because a measurement error is liable to occur since stable flow is not easily produced as the fan, blower or similar is used as the method to generate flow of air.

In the test, the dynamic pressure of the air flow generated by the accessory Pitot tube is measured with another pressure gauge, and the flow speed (A) is gained from this dynamic pressure. Since the equipment automatically controls the suction flow rate in order to make the static pressure in the suction nozzle equal to the static pressure of the flow, the constant-speed suction state is produced. Therefore, the flow speed (B) in the suction nozzle is gained in the same manner as (1), and the relative error (C) is calculated.

4. Other Tests: Though the appendix sheet of the main body specifies the relative error of the constant-speed suction as the total performance of the equipment. Moreover, the performance of the pressure gauge which influences the precision of the constant-speed suction as the respective performance is an important item. Accordingly, it is desired that the performance of the accessory pressure gauge is checked in comparison with the standard pressure gauges of Gettingen type, Ascanian type or similar. Since the equipment is a so-called black box type, it is necessary to sometimes check the performance of the equipment like general other meters.

III. AUTOMATIC MONITORS FOR SUSPENDED PARTICULATE MATTER IN AMBIENT AIR

4. Description of Terms

(1) **Suspended Particulate Matter:** There are two types of suspended particulate matter in ambient air: that generated naturally or artificially, and that generated by secondary reactions in the ambient air. Suspended particulate matter consists of solid or liquid particles. As the particle diameters of suspended particulate matter range from the molecular class to several thousand µm, there is no strict constant for the particle diameters. The particle diameter of suspended particulate matter specified by the environmental standards must be less than 10 µm diameter, but since there is no constant, the particle diameter is not prescribed here.

(2) **Relative Concentration:** There are JIS monitors which make it possible to measure mass concentration directly, but the monitors of the light scattering method and of the light absorption method measure the light scattering strength and the light absorbancy as a physical quantity in fixed correlation with mass concentration. The value obtained by multiplying the measured value by a certain coefficient, is mass concentration. The concentration indicated by these monitors is called relative concentration, and is distinct from mass concentration.

(3) **Mass Concentration:** This is the unit which indicates the concentration of suspended particulate matter in ambient air. The concentration is expressed as the mass of suspended particulate matter contained in the unit volume. Usually mass concentration is expressed as $\mu g/m^3$, and sometimes as mg/m^3. The standard measuring method of mass concentration is JIS Z 8814 the filter collection method. As it is not possible to carry out continuous measurement with this method, however, automatic monitors which come under this standard are used when continuous measurement is

required.

(4) **Calibration Particles:** These are the particles used for the calibration of monitors. Usually artificial particles are used. For calibration, any particles can be used as long as they have repeatability, stability, a fixed particle diameter distribution, and are appropriate for the calibration of monitors. As calibration particles are used suspended in the air (called calibration aerosol), they must be generated by a generator selected according to the type of calibration particles required.

(5) **Calibration Aerosol:** This is the air containing calibration particles. The calibration particles are generated using a generator, diluted to a fixed concentration with purified air, and used for the calibration of the value indicated by a monitor.

(6) **Relative Sensitivity:** Monitors using the light scattering method and the light absorption method which do not directly measure mass concentration require the relation of the concentration of suspended particulate matter with the light quantity of the monitors' light detectors. JIS calls the concentration of calibration particles against the minimum response unit of the monitors is called "relative sensitivity".

(7) **Particle Diameter:** This is the diameter of a particle with hydrodynamic behavior equivalent to a spheroidal particle of 1 gravity. As actual particles are diverse in a gravity and form, they are often expressed with equivalent diameters.

(8) **Monodisperse Particles of the Homogeneous System:** These particles specify the particle diameter distribution of calibration particles. They must be made of a homogeneous substance, and they must have a narrow range of particle diameter. For example, the particles with a diameter range of 0.1 - 3 μm, have an average diameter (or the medium diameter) of 0.3 μm, and geometric standard deviation σg within 1.5, and are considered monodisperse particles of the

homogeneous system.

(9) **Equivalent Input:** Basically, the value indicated by a monitor is calibrated using calibration aerosol, but the aerosol cannot be used easily for daily calibration. If there is a method to check zero or fixed sensitivity (span and the midpoint) instead of using calibration aerosol, it is very useful and effective for the maintenance and management of the monitors.

This method is called equivalent input. There are three types of equivalent input: zero equivalent input (equivalent to a concentration of 0 $\mu g/m^3$), midpoint equivalent input (equivalent to a concentration around 500 $\mu g/m^3$), and span equivalent input (equivalent to a concentration around 1,000 $\mu g/m^3$). Refer to 9.2.5. of this document.

5. **Types of Monitors:** There are four types of JIS automatic monitors for suspended particulate matter in ambient air. The monitors using the piezoelectric balance method and the beta-ray absorption method indicate the mass concentration of suspended particulate matter in ambient air directly. The monitors using the light scattering method and the light absorption method indicate the physical quantity in a fixed correlation with mass concentration, and mass concentration is obtained by multiplying the indicated value by a coefficient, so-called F value correction.

(1) **Piezoelectric Balance Method:** Suspended particulate matter in ambient air is collected electrostatically on a quartz oscillator which constitutes an oscillator circuit oscillating at a fixed frequency. When particles are attached, the oscillation frequency of the quartz oscillator decreases. In this method, the oscillation frequency of the oscillator circuit is measured before and after the attachment of particles, and the mass concentration of suspended particulate matter is obtained from the variation in the oscillation frequencies.

(2) **Beta-Ray Absorption Method:** Suspended particulate matter is collected on tape-type filter paper in spots, and a low level beta-ray is irradiated from a radiation source. The beta-rays absorbed by the filter paper are measured before and after suspended particulate matter is collected, and the mass concentration of suspended particulate matter is determined from the increase in the absorption quantity of the beta-ray.

(3) **Light Scattering Method:** Sample air is introduced into a measuring room which is kept dark, and then light is irradiated. The strength of the light quantity scattered by the suspended particulate matter is measured, and the relative concentration of the suspended particulate matter is determined from the strength.

(4) **Light Absorption Method:** Suspended particulate matter is collected on tape-type filter paper in spots, and the relative concentration of the suspended particulate matter is determined by measuring the light absorption quantity in the wave-length band of visible radiation.

6. **Measuring Range:** In most cases, 2 or 3 of the ranges specified by JIS are selected as the measuring ranges of the monitors: 0 - 1,000, 0 - 2,000, 0 - 5,000, 0 - 10,000 $\mu g/m^3$.

The value indicated by a monitor is the concentration of the suspended particulate matter collected in a one-hour period; that is, the average concentration of one hour. The measuring ranges of monitors are, therefore, determined so that they cover average concentrations of one hour. The measured results of most monitors include printed out concentration records, the output of the analog dc voltage corresponding to the concentration, and the output of pulses, the number of which corresponds to the concentration. In this way, most monitors have more than one outputs.

When concentration of suspended particulate matter is high, the one-hour measuring period is automatically divided into several spans, and the average concentration is calculated from the values obtained in the spans in most monitors, even if the concentration is within the measuring ranges of the monitors. As the factors and functions of monitors differ according to their type, monitors using the piezoelectric balance method and the beta-ray absorption method are described below.

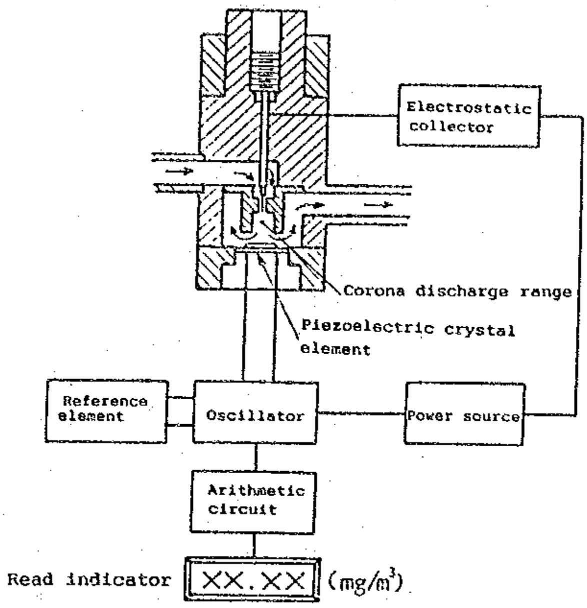
(1) **Piezoelectric Balance Method:** In principle, the sensitivity of this method is high. When many particles are collected electrostatically on the quartz oscillator, the linearity of the change in the oscillation frequency of the quartz oscillator is lost. Every time the quantity of the particles collected on the quartz oscillator exceeds 10 μg, the wet scrubber is actuated, and the quartz oscillator is cleansed with detergent and water. After removing the collected particles in this way, measurement is restarted. The average concentration of suspended particulate matter in one hour is calculated from the values measured and the collection spans in the measuring period of one hour. The value obtained in this way is indicated on the monitor.

(2) **Beta-Ray Absorption Method:** With the collection of suspended particulate matter on the filter paper, the aeration resistance of the filter paper becomes larger and the differential pressure increases. When the concentration of suspended particulate matter is high, or when particles are of the type which causes blinding of the filter paper, the flow rate sometimes decreases below the air flow rate stabilizer's adjustment range. Every time the differential pressure of the filter paper reaches 200 - 300 mmHg, measurement is automatically reset, the used part of the filter paper is rolled up, and measurement is restarted on a new section of the filter paper. The average concentration of suspended particulate matter in one hour is calculated from the values measured and the collection spans in the one-hour measuring period. The value obtained in this way is indicated on the monitor. There must be more than 2 spots of particles collected on the filter paper in a one-hour measuring period, and the concentration is output as the movement of the paper set on the printer.

7. **The Structures of Monitors:** Automatic monitors for the continuous measurement of suspended particulate matter in ambient air record the concentration of suspended particulate matter in the sample air collected every hour as average concentration of one hour. This type of monitor is composed of a sample air intake port, a detecting element, a sample air suction element, and an indicator-recorder. As the structure and the function of the detecting element differ with the type and model of monitors, details of the various monitors are described below.

As most monitors employed for continuous measurement of environmental air are used to assess the levels of suspended particulate matter specified by the air pollution-related environmental standards based on the Basic Law for Environmental Pollution Control, separators based on JIS Z 8814 are installed at the sample air intake port, and the suspended particulate matter in ambient air with particle diameter of less than 10 μm is measured. Separators are not, however, installed on monitor using light scattering method, because in principle these monitors do not detect particles with diameters exceeding 10 μm.

(1) **Piezoelectric Balance Method:** To prevent particles from depositing on the sample air intake pipe, sample air is introduced at a flow rate of 22 l/min, 1 l/min of which is branched and directed to the detecting element with an equal velocity suction mechanism. Expranatory Figure 1 indicates a detecting element in which particles are collected in spots on the surface of the quartz oscillator with a corona discharge from the discharge electrode set on the passage of sample air. The combination of the quartz oscillator and the oscillator circuit forms a quartz oscillator circuit, and oscillates at the characteristic frequency (about 5 MHz) of the quartz oscillator. When the quantity of particles collected on the quartz oscillator exceeds 10 μg, detergent and water are introduced on the oscillator, and measurement is restarted after the particles are removed by cleansing. The discharge electrode is replaced very 20 - 30 days to keep the discharge current constant. The replacement interval changes depending on the concentration and the type of suspended particulate matter.



Expranatory Figure 1 A Detecting Element of the Piezoelectric Balance Method

(2) **Beta-Ray Absorption Method:** Monitors using the beta-ray absorption method are diversified by differences in the beta-ray source, the structure of the detecting element and the filter paper feeding mechanism, and in their configuration.

(2.1) **Filter Paper:** The filter paper which collects the suspended particulate matter is tape-type and made of either glass fiber, quartz fiber, or tetrafluoroethylene resin. Usually the filter paper is used in a roll to make it possible to use the paper for 1 to 3 months continuously. To select the particle collecting filter paper, it is necessary to consider the particle collection efficiency, the hygroscopicity, the strength, and the gas adsorptivity. The collection efficiency for particles of 0.3 µm must be hnigher than 99%.

The filter paper used have the A1 collection efficiency specified by JIS K 0901 (the filter medium for the collection of sample dust in gas).

(2.2) **Beta-Ray Source:** The beta-ray sources used are sealed sources of low energy such as ^{14}C and ^{147}Pm. As the radioactivity of these sources is very weak, less than 3.7 x 10^6 Bq (100 μ Ci), and because they do not fall under the definition of "radioisotope" prescribed by the Radiation Hazard Prevention Law, a qualified person is not required to handle the monitor. Care must be taken, however, in handling the monitor. Beta-ray sources which are no longer used due to replacement of the sources or the renewal of monitors should be delivered to and recovered by the manufacturers of the sources.

(2.3) **Structure of the Detecting Elements:** Detecting elements are for the measurement of the strength of the beta-ray absorbed by the filter paper before and after the collection of suspended particulate matter in ambient air, and the structures of the elements are varied. Representative positional relation of the ray source and the detector against the filter paper, and actuating machinery are described below.

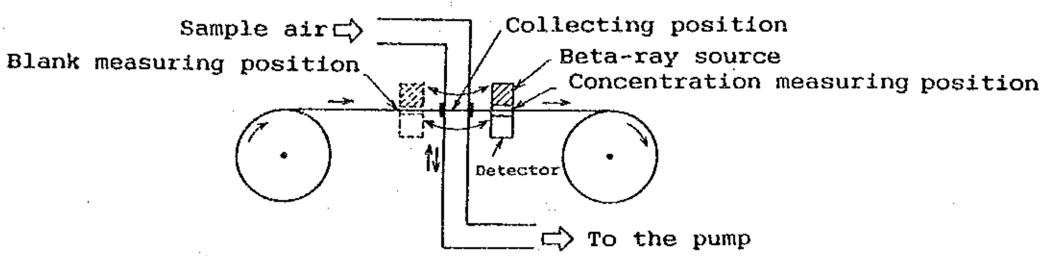
To prevent fluctuation in the flow rate of sample air caused by rises in differential pressure when particles are collected by the filter paper, a flow rate stabilizer is integrated into the detecting element.

(a) **Detecting Element which Moves Both the Filter and the Detector:** An example of this type of structure is indicated in Explanatory Figure 2. The strength of the beta-ray is first measured at the blank measuring position, and then the filter paper is moved to the collecting position and collects suspended particulate matter. Next, the filter paper is moved to the concentration measuring position at the same time that the detector is moved from the blank measuring position to measure the strength of the beta-ray, and finally the concentration is obtained.

(b) **Detecting Element Which Moves Only the Filter Paper:** An example of this type of structure is indicated in

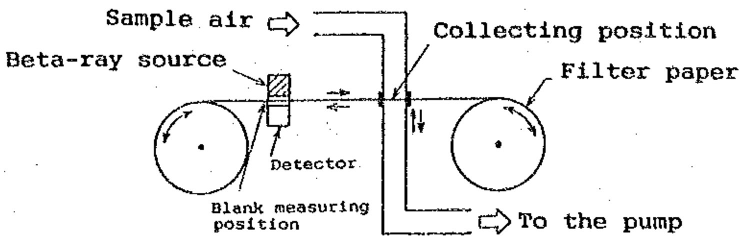
Explanatory Figure 3. In this structure, the strength of the blank beta-ray is measured by the detector fixed at the measuring position. The filter paper is moved to the collecting position and collects suspended particulate matter. Next, the filter paper is returned to the measuring position and the strength of the beta-ray is measured to obtain the concentration.

(c) **Detecting Element Which Moves Neither the Filter Paper Nor the Detector:** An example of this type of structure is indicated in Explanatory Figure 4. In this structure, the measurement of the strength of the beta-ray before and after the collection of suspended particulate matter on the filter paper and the collection of suspended particulate matter are carried out at the same position, without moving the filter paper or the detector. It is, therefore, possible to carry out the measurement of the concentration while collecting particles.



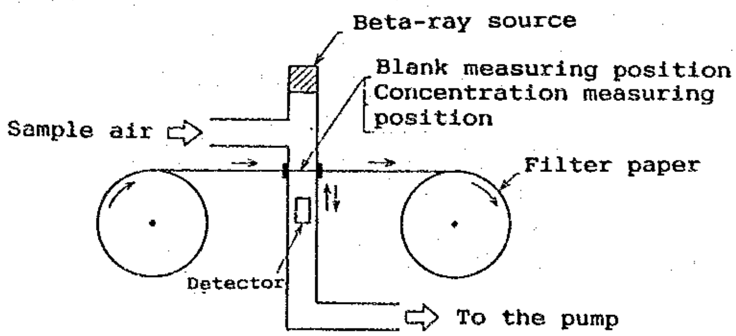
Blank measurement-->Filter paper goes forward-->Suction -->Filter paper goes forward-->Ray source and detector move -->Concentration measurement-->Ray source and detector reset -->Filter paper moves

Explanatory Figure 2 An Example of a Detecting Element using the Beta-Ray Absorption Method with Structure that Moves Both the Filter Paper and the Detector

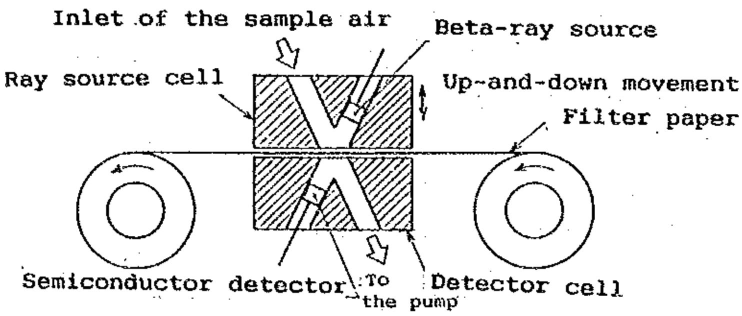


Blank measurement-->Filter paper goes forward-->Suction -->Filter paper reset->Concentration measurement-> Filter paper moves

Explanatory Figure 3 An Example of a Detecting Element using the Beta-Ray Absorption Method with a Structure that Moves Only the Filter Paper

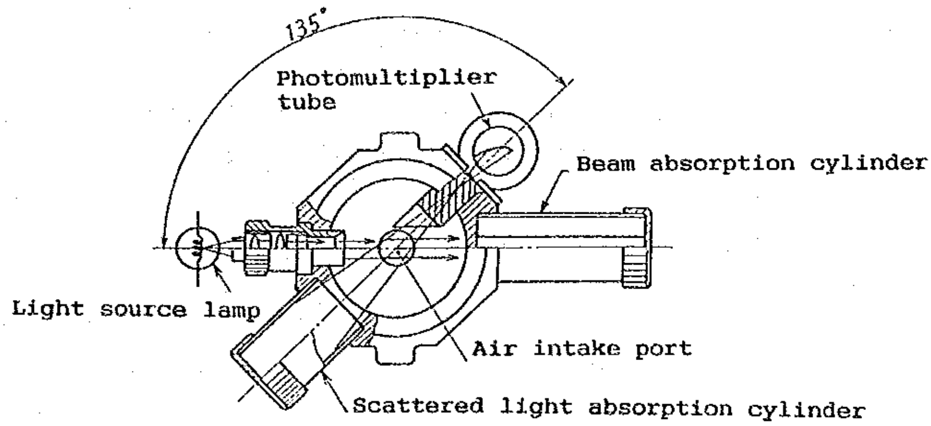


Blank measurement-->Suction-->Concentration measurement -->Filter paper moves



Explanatory Figure 4 An Example of a Detecting Element using Beta-Ray Absorption Method with a Structure that Moves Neither the Filter Paper Nor the Detector

(3) **Light Scattering Method:** An example of a detecting element which measures the strength of the light quantity scattered by suspended particulate matter in ambient air is indicated in Explanatory Figure 5. The beam from the tungsten lamp irradiates the sample air introduced from the air intake port. The inside of the detecting element is kept dark by installing a beam absorption cylinder on the side facing the light source. The light scattered by particles is detected by a photomultiplier tube installed at a 135°C angle to the optical axis.



Explanatory Figure 5 An Example of the Detecting Element using the Light Scattering Method

(4) **Light Absorption Method:** The same filter paper used for the beta-ray absorption method is used in this method for the collection of suspended particulate matter in ambient air. The particles collected are determined by the light absorption quantity or by the light reflectance. Monitors using this method are not currently used.

8. Calibration Aerosol and Equivalent Input

Calibration Aerosol and Its Generating Method: The generating methods of artificial aerosol are varied, and use different particles according to the purpose. The particles used for calibration in the JIS monitors are, however, limited to 2 or 3 kinds. Particles of stearic acid and smoke particles from incense coils are the most widely used.

Of these two types, smoke particles from incense coils are very easy to generate. The diameter range of these smoke particles is narrow; the medium diameter is around 0.3 µm, and the geometric standard deviation σg is less than 1.5. These particles are, therefore, monodisperse particles of the homogeneous system appropriate for use as calibration aerosol. The generator of smoke particles and the characteristics of the generated aerosol are described below.

(1) **Calibration Aerosol Generator:** A representative calibration aerosol generator is indicated below.

(a) **Composition of the Calibration Aerosol Generator:** The generator is composed of the following parts. The block diagram of the generator is indicated in Explanatory Figure 6.

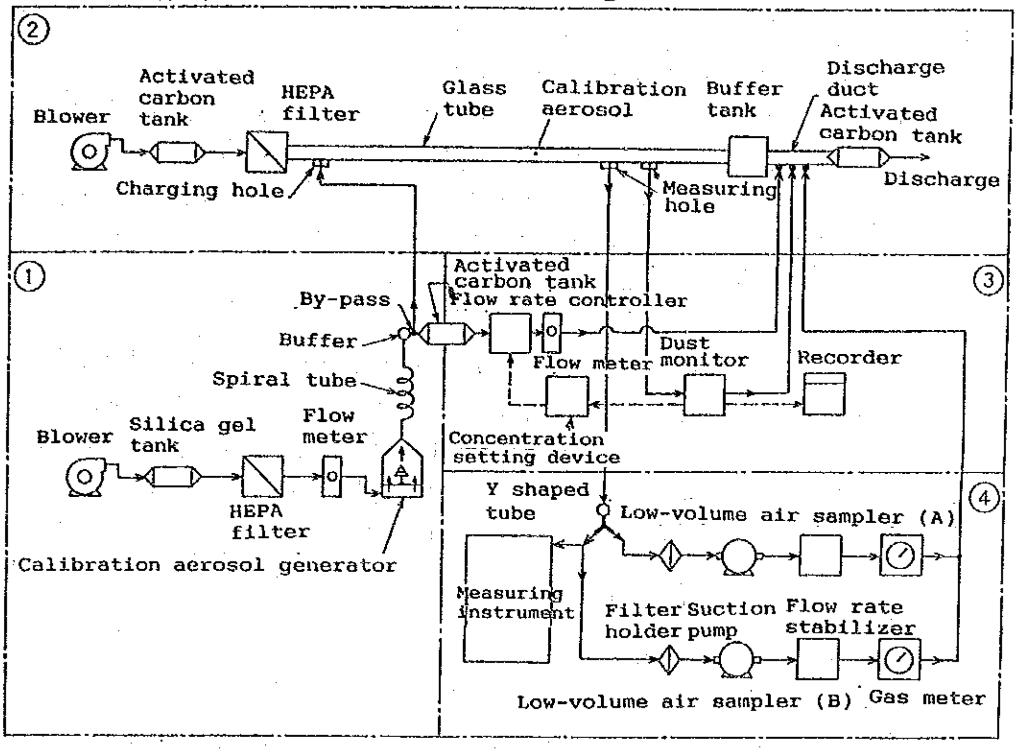
1) Calibration particles generating section
2) Calibration aerosol generating section
3) Concentration-setting monitoring section
4) Concentration measuring section

(b) **Calibration Particles Generating Section:** This is the part which generates smoke particles as calibration particles. The incense coils (usable for 8 hours) placed in the acrylic chamber (dia. 400 x 850 mm) are ignited and combusted by sending the combustion air into the chamber, and smoke particles are generated. The combustion air intake process is as follows: The air sucked by the blower (20 l/min) is dried and made dust-free, passing through the silica gel tank (dia. 100 x 300 mm) and the HEPA filter (high efficiency particulate air filter) (250 x 250 x 200 mm). After adjusting the flow rate of the air to a fixed rate (20 l/min) in the flow meter (float type), the air is sent into the chamber.

Legend: ---> Flow direction of air and calibration aerosol

Calibration Aerosol Generator

1) Calibration particles generating section
2) Calibration aerosol generating section
3) Concentration-setting monitoring section
4) Concentration measuring section



Explanatory Figure 6 Block Diagram of the Calibration Aerosol Generator

The smoke particles generated are mixed with the combustion air, and become aerosol. The aerosol thus generated is homogenized as it passes through the spiral tube at the upper part of the chamber, and is introduced into the glass tube (dia. 100 x 1,300 mm) of the calibration aerosol generating section via the buffer (dia. 100 m) and the introducing nozzle.

On occasion, a portion of the aerosol is discharged into the discharge duct connected at the end of the above-mentioned glass tube, via the by-pass installed on the buffer, the activated carbon tank, and the flow rate controller. By controlling the amount of discharged aerosol with the flow rate controller, the amount of the aerosol introduced into the glass tube can be adjusted to set the concentration at a required value.

(c) **Calibration Aerosol Generating Unit:** This is the part which adjusts the concentration of the aerosol smoke particles introduced into the glass tube to a fixed value by diluting the aerosol with purified air at a certain flow rate, and then feeding the adjusted aerosol to the low-volume air sampler and the measuring instrument as calibration aerosol.

The air sucked by the blower (500 l/min) is purified and made dust-free, passing through the activated carbon tank (dia. 100 x 300 mm) and the HEPA filter (250 x 250 x 300 mm). After being rectified by the rectifier grating, the air is sent into the glass tube, and discharged into ambient air via the buffer tank (250 x 250 x 200 mm), the discharge duct and the activated carbon tank.

There is a charging hole (dia. 40 mm) on the upstream part of the glass tube, through which the above-mentioned aerosol is introduced from the intake nozzle. There are two measuring holes (dia. 40 mm) on the glass tube about 1,300 mm downstream from the charging hole, used for measuring of the concentration and monitoring the concentration setting.

(d) **Concentration-Setting Monitoring Unit:** This part is equipped with a device to automatically adjust the amount of aerosol discharged from the above-mentioned by-pass. This feature enables the machines to measure the concentration of the aerosol in the glass tube continuously, and at the same time, to set the concentration at a fixed value.

Aerosol is sucked from the measuring hole and its concentration is measured continuously with a dust monitor using the light scattering method. After measurement, the aerosol is discharged into the discharge duct. The concentration value obtained is indicated on the dust monitor and the concentration setting device, and is recorded on the recorder.

The concentration setting device compares the concentration value obtained and the value set beforehand. When there is a difference, the valve of the flow rate controller equipped on the by-pass is opened or closed to adjust the flow rate of the by-pass, thus adjusting the concentration to the set value.

It is possible to measure the flow rate of the by-pass with a flow meter (float type). The flow rate of the by-pass is normally adjusted automatically, but it can also be adjusted manually.

As the concentration of aerosol is automatically recorded on the recorder, it is possible to monitor fluctuation in the concentration. This concentration is relative concentration, but it is convertible to mass concentration with a low-volume air sampler. It is possible, therefore, to set the required mass concentration according to the relation of relative concentration and mass concentration.

(e) **Concentration Measuring Unit:** This is the part which measures the concentration of calibration aerosol. The aerosol in the glass tube is sucked with the suction nozzle equipped on the measuring hole, branched into two systems by the Y-shaped tube (dia. 10 x 200 mm) attached to the buffer (dia. 100 mm), and introduced to the low-volume air samplers (A) and (B), or to the measuring instrument to be calibrated.

It is an important prerequisite that the concentrations of the two systems of aerosol branched by the Y-shaped tube are the same. Low-volume air samplers (A) and (B) are, therefore, connected with the Y-shaped tube, making it possible to compare the concentrations of the two systems. The difference in the concentrations of (A) and (B) must be within 5%.

The low-volume air sampler sucks aerosol with the suction pump (0 - 30 l/min) via the filter (dia. 37 mm). To keep the suction flow rate fixed, aerosol is passed through the flow rate stabilizer (with the flow rate controller) and discharged into the discharge duct via the gas meter (5l per revolution).

For a real calibration of the measuring instrument, the low-volume air sampler (A) is connected with one of the branches of the Y-shaped tube, and the measuring instrument to be calibrated is connected with the other branch of the Y shaped tube. The concentration is measured adjusting the suction flow rate of the low-volume air sampler to match that of the measuring instrument. The value indicated on the measuring instrument is calibrated based on the concentration thus measured.

(f) **Performance Test Result of the Generator:** The performance of the calibration aerosol generator using the smoke particles from incense coils was confirmed by performing the required tests. The results are as follows.

1) **Concentration of Suspended Particulate Matter in Dilution Air:** Dilution air is air that contains no particulate matter, and the mass concentration of suspended particulate matter in dilution air must be sufficiently low to be negligible.

Without generating smoke particles, air was sent to the glass tube after being purified through the activated carbon tank and the HEPA filter. The concentration of the suspended particulate matter in the air branched through the Y-shaped tube was measured with the low-volume air samplers (A) and (B). The measured results are indicated in Table 1.

Explanatory Table 1 Concentration of Suspended Particulate Matter in Dilution Air

Measuring Point	Collection Value	Suction Value	Masss Concentration	Concentration Measured by the Light Scattering Method	Remarks
(A)	0.01 mg	21 m^3	0.5 $\mu g/m^3$	0 c.p.m.	(A) and (B) are measured simultaneously.
(B)	0.01 mg	21 m^3	0.5 $\mu g/m^3$		

As is clear from Explanatory Table 1, the mass concentrations of (A) and (B) are the same at 0.5 $\mu g/m^3$. When the concentration is of this level, it is possible to use the air for the zero drift test of a monitor.

2) **Diameter Distribution of Smoke Particles:** Smoke particles were generated and the concentration was adjusted to the required value of about 200 - 1,700 $\mu g/m^3$. The diameter distribution of these particles was measured with the particle diameter distribution measuring instrument using the light scattering method. The measured results are indicated in Explanatory Table 2.

Explanatory Table 2 Generating Conditions and the Diameter Distribution of the Smoke Particles from Incense Coils

Measurement No.	Number of Measuring Times	Particle Dimeter Distribution			Mass Concentration	Concentration Measured by the Light Scattering Method	Quantity of Combustion Air
		n	Dp_{50} (μm)	σ_g	μg/m^3	c.p.m.	l/min.
2	1	270 108	0.35	1.31	(A)1 057	650	20
		296 079	0.35	1.34	(B)1 049		
	2	267 828	0.36	1.31	(A)1 066	650	20
		268 273	0.35	1.31	(B)1 054		
	3	267 481	0.35	1.34	(A)1 067	650	20
		267 735	0.34	1.32	(B)1 066		
4	1	245 237	0.31	1.32	(A) 467	280	20
		243 350	0.32	1.28	(B) 464		
	2	242 814	0.32	1.28	(A) 472	280	20
		243 802	0.31	1.26	(B) 475		
	3	240 966	0.31	1.29	(A) 455	280	20
		238 345	0.31	1.26	(B) 463		
5	1	213 237	0.28	1.29	(A) 207	140	20
		208 848	0.28	1.29	(B) 208		
	2	210 544	0.28	1.28	(A) 202	140	20
		211 261	0.28	1.29	(B) 204		
	3	209 670	0.29	1.31	(A) 227	140	20
		212 627	0.29	1.31	(B) 229		

Judging from the characteristics of the measuring instrument, it is permissible for the diameter distribution of calibration aerosol to have some width. With the particulate matter specified by the environmental standards, particles with diameters less than 10 μm will suffice. Especially for measuring instruments using the light scattering method, the medium diameter must be less than 0.3 µm and the geometric standard deviation σg to be less than 1.5. For filter collection (with a low-volume air sampler) using the standard measuring method, however, it is not proper to contain fine particles (less than 0.01 µm) which will reduce the collection efficiency (more than 99% collection of 0.3 µm particles).

As is clear from Explanatory Table 2, the medium diameter Dp_{50} is around 0.3 µm, and σg is less than 1.33. According to the particle diameter distribution, therefore, it is judged that the calibration aerosol has the performance of the prescribed monodisperse particles of the homogeneous system.

3) Set Concentration and Stability of Smoke Particles

It is possible to set the concentration of smoke particles in a range of 0 - 2 mg/m^3. JIS tests are, however, made in a concentration range of 0 - 1,000 µm/m^3. Therefore, it is necessary to generate particles with a midpoint concentration stable between 1/4 - 1/2 (250 - 500 σg/m^3) of the above-mentioned concentration.

Using the concentration setting device of this generator, and automatically maintaining the concentration in a range of 200 - 1,700 µg/m^3, the concentration stability was measured and the repeatability was tested. The results are indicated in Explanatory Table 3.

Explanatory Table 3 Generated Concentration Stability and Repeatability of Smoke Particles

Measurement No.	Number of Measuring Times	Mass Concentration μg/m^3	Concentration Measured by the Light Scattering Method c.p.m.	Concentration's Fluctuation Range %	Concentration Stability	Generated Concentration's Repeatability %
2	1	1 053	650	±3	Almost constant	1.3
	2	1 060		±3	Almost constant	
	3	1 067		±3	Almost constant	
4	1	466	280	±5	Almost constant	3.3
	2	474		±5	Almost constant	
	3	459		±5	Almost constant	
5	1	208	140	±9	Almost constant	12.3
	2	203		±9	Almost constant	
	3	228		±9	Almost constant	

Remarks:

1. $$\text{Generated concentration's repeatability} = \frac{\text{Mass concentration's maximum value} - \text{Minimum value}}{\text{Mass concentration's average value}} \times 100(\%)$$

2. Concentration's fluctuation width is the fluctuation width against the set concentration.

As is clear from Explanatory Table 3, it is possible to set the concentration in a range of 200 - 2,000 μg/m^3.

As to the stability of the set concentration, it was confirmed from the values recorded by the measuring instrument using the light scattering method that the concentration is maintained at a fixed level for more than 3 hours within a fluctuation width of ± 10%. These data were obtained using an automatic controller which actuates the flow rate controller of the by-pass with the concentration setting device. When automatic control is not applied, there is a fluctuation of around ± 50% in the concentration.

4) Concentration Difference of Smoke Particles Branched by the Y-Shaped Branch Tube

The concentration of the calibration aerosol made from the generated smoke particles must be measured simultaneously with both the low-volume air sampler (A) and the measuring instrument to be calibrated. For that purpose, calibration aerosol is sucked from the measuring hole with the Y-shaped tube with a buffer, branched, and fed to both the low-volume air sampler (A) and the measuring instrument. The concentration was measured with the low-volume air samplers (A) and (B), and concentration was set in a range of 200 - 1,800 $\mu g/m^3$. The measured results are indicated in Explanatory Table 4.

The difference in the concentrations of the branched aerosol in (A) and (B) is within 2%, and sufficiently satisfies the value of 3% specified by JIS.

(2) **Performance of Calibration Aerosol Generator:** The performance of the calibration aerosol generator was tested and the test results are summarized in Explanatory Table 5.

Explanatory Table 4 Concentration of Aerosol Branched by the Y-Shaped Tube with a Buffer

Measurement No.	Number of Measuring Times	Measuring Point	Collection Quantity mg	Suction Flow Rate l/min.	Suction Quantity m^3	Mass Concentration $\mu g/m^3$	Difference in the Concentration of (A) and (B) %
2	1	(A)	1.26	19.9	1 192	1 057	-0.76
		(B)	1.25	19.9	1 192	1 049	
	2	(A)	1.27	19.9	1 191	1 066	-1.13
		(B)	1.26	19.9	1 195	1 054	
	3	(A)	1.27	19.8	1 190	1 067	-0.09
		(B)	1.28	20.0	1 201	1 066	
4	1	(A)	1.14	20.3	2 439	467	-0.64
		(B)	1.13	20.3	2 433	464	
	2	(A)	1.14	20.1	2 415	472	0.64
		(B)	1.15	20.2	1 192	475	
	3	(A)	1.12	20.5	1 192	455	1.76
		(B)	1.14	20.5	1 192	463	
5	1	(A)	0.78	20.9	1 192	207	0.48
		(B)	0.78	20.9	1 192	208	
	2	(A)	0.75	20.7	3 717	202	0.99
		(B)	0.76	20.7	3 719	204	
	3	(A)	0.83	20.3	3 662	227	0.88
		(B)	0.84	20.4	3 663	229	

Remarks: The difference in the concentrations of (A) and (B) is based on the concentration of (A).

$$\text{Concentration difference (\%)} = \left(\frac{A - B}{A \times 100}\right)$$

Explanatory Table 5 Summary of the Performance of Calibration Aerosol Generator

Particle Type	Concentration of Suspended Particulate Matter in Dilution Air	Particle Diameter Distribution of Caliburation Aerosol	Concentration's Stability	Difference in the Concentration of Aerosol Branched by the Y-Shaped Tube
Smoke Particles	less than 0.5 μg/m^3	Medium diameter (DP_{50}) 0.28-0.39μm Geometric standard deviation (σg) 1.28-1.33	within ±10% of set concentration	within 2%

The above-mentioned calibration aerosol generator was developed by the Machinery and Electronics Test and Inspection Foundation under the direction of the Measurement Administration Department of the Ministry of International Trade and Industry. The description of the generator was given as a reference.

Aerosol generators using the smoke particles from incense coils are developed by various measuring instrument manufacturers and the same principle is applied to all these generators.

On the other hand, there are calibration aerosol generators that use stearic acid particles. For these generators, stearic acid particle generators are used instead of the generators of the smoke particles from incense coils, but the other parts are quite the same as the above-mentioned generator.

9. **Attached Devices:** The devices mentioned below are attached to monitors in case they are needed. These devices are selected and used depending on the monitor type and the intended function.

(1) **Separator:** A monitor for the continuous measurement of environmental air is equipped with a separator at the sample intake port. The separator is based on JIS Z 8814, and

measures suspended particulate matter with particle diameter of less than 10 µm in ambient air. Most monitors using piezoelectric balance method and the beta-ray absorption method employ so-called cyclone type centrifugal separators.

Monitors using the light scattering method are not equipped with separators because as a rule they do not detect particles of more than 10 µm diameter, and because the structure of the detector is similar to the inertial collision type.

(2) **Average Computing Element:** Monitors of suspended particulate matter in ambient air are structured to record the average concentration of every hour. A monitor whose signals do not indicate the average of the concentration values measured in one hour, is used in combination with an element that computes the average, and this element causes the signals indicate the average concentration of one hour. For example, when signals are output as a pulse train to indicate the measured results, a computing element counts the signals over the course of one hour, calculates based on the sensitivity per pulse, and outputs the average concentration of that hour.

(3) **Flow Rate Stabilizer:** The fluctuation in the flow rate of sample air affects the measured results of the monitors using the piezoelectric balance method, the beta-ray absorption method and the light absorption method. It is, therefore, important to stabilize the flow rate of sample air. In monitors using beta-ray absorption method, the aeration resistance of the filter paper becomes larger and the differential pressure increases during the collection of suspended particulate matter on the filter paper, and there is a possibility of the flow rate of the sample air reducing. A flow rate stabilizer is used to prevent fluctuation in the sample air flow rate over both long periods and one-hour periods because the filter paper in use advances forward every one-hour measuring period.