Chapter 8 Measuring method of air pollutants (emission sources)

8.1 Measuring and analytical method of air pollutants in exhaust gas

8.1.1 Overview

Measurement of the air pollutants concentration in the exhaust gas from air pollutants sources, contained fine particles such as soot, fume and dust and toxic gasses such as sulfur oxides and nitrogen oxides is extremely important, to obey the air pollution regulation low and ordinance, for the establishment of the air pollution control measures and for the testing on the performance of air pollution control equipments. Moreover, the calculation of air pollutant emission amounts from the air pollutants concentration and exhaust gas flow rate is necessary. The measurement technique of the air pollutants concentration in exhaust gas consist of suction (sampling) of exhaust gas, collection of air pollutants in suction gas, determination of collected air pollutant and measurement of suction gas volume. So, this technique is called " stack sampling" frequently.

The exhaust gasses suction method differs basically between particles floating with inertia in exhaust gas and gaseous air pollutant with no inertia. The reason being that if the flow of suction gas at the tip of suction nozzle of sampling tube have turbulence and appreciable change of flow direction, the particles concentration in suction gas is led to different concentration from actual in exhaust gas. In this regard, JIS-Z8808 on this measuring method prescribe that the measuring position shall be located at a place where the flue gas is under a comparatively uniform flow, avoiding the place where a duct bends or its sectional shape is sharply changed in flue, stack or duct. Because this is also important to measure the exhaust gas flow rate based on measuring results of exhaust gas velocity, JIS-B9905 on measuring method of gasses air pollutant concentration in exhaust gas prescribe in the same way. The particle concentration in exhaust gas is different even within the same cross-section of flue, stack or duct, so it is essential to select multiple sampling points within the same cross-section selected as the measuring position, as shown in Fig.8.1.1, for example. Further, collected particles sample by stack sampling are also used to analyze the heavy metal and polycyclic aromatic hydrocarbons. Measuring methods for the temperature and the static pressure of exhaust gas are prescribed in JIS-Z8808.

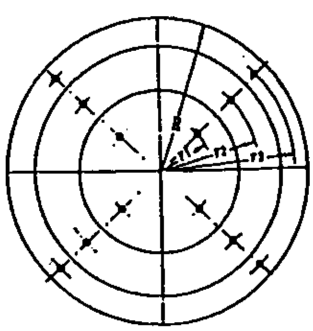


Fig.8.1.1 Measurement points in a circular cross-section of a smoke funnel (in the case of 12 points)

8.1.2 Particle concentration measuring method

(1) Sampling method of particles

In order to archive the quantitative particles sampling in exhaust gas, a sampling tube with suction nozzle whose tip has been completed to an acute angle of maximum 30° shall be prepared, and this is inserted into the flue through the sampling holes at selected sampling position in flue. Furthermore, stack sampling has to be prompted, holding equally the suction gas velocity at tip of suction nozzle of sampling tube and the exhaust gas velocity in sampling point, in order to avoid the inertia effect of the particles in exhaust gas. This operation is called isokinetic sampling, and in not considered necessary when sampling gaseous air pollutants.

There are two methods for isokinetic sampling. One uses an ordinary-type sampling tube that measure the exhaust gas velocity at sampling points by Pitot tube, calculate the suction gas flow rate realized the isokinetic sampling previously, and suck the exhaust gas with this gas flow rate. And another method uses a balanced-type sampling tube that has function to realize the isokinetic sampling, holding equally the static gas pressures of suction gas in suction nozzle and in exhaust gas at sampling point, or the dynamic gas pressure of suction gas in suction nozzle and the static gas pressures in the gas meter of particle sampling apparatus. Furthermore, the particle sampling apparatus consists of the sampling tube with suction nozzle, the particle collector with dust filter, suction gas flow rate measuring apparatus (gas meter) and gas suction pump.

In addition the dust (particle) collector is classified as either type 1 which is inserted into flue, and type 2 which is placed outside of the flue connecting behind suction nozzle.

The type 1 dust collector as shown in Fig.8.1.2 which has cylindrical heat-resistant silica fiber filter inside a glass filter holder to protect the filter inside a glass filter holder to protect the filter is used generally.

The exhaust gas velocity at sampling points is essential to realize the isokinetic sampling, and as a rule, an L-type Pitot tube as shown in Fig.8.1.3 is used frequently.

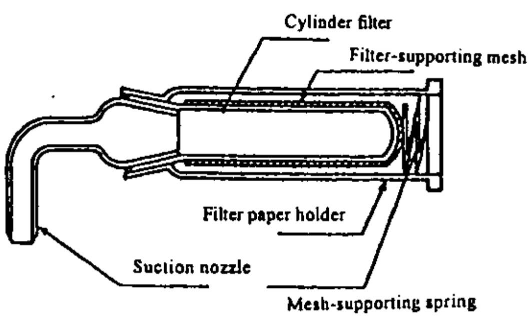


Fig. 8.1.2 Example of dust collector using type I cylinder filter paper

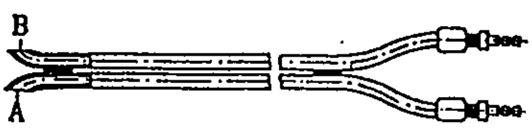


Fig. 8.1.3 Special Pitot tube

In this case, the Pitot tube coefficient has to be calculated previously. The gas velocity can calculate using Eq. (1) to measure the pressure difference between 2 pressure measuring holes center (A), (B) and direction of exhaust gas flow at sampling point as shown in Fig.8.1.4.

$$v = c \times [\frac{2gh}{\gamma}]^{0.5} \quad \cdots\cdots (1)$$

Where, V: gas velocity (m/s)

c: Pitot tube coefficient (-)

g: acceleration of gravity = 9.8 (m/s^2)

h: value of pressure difference measured by inclined-tube manometer (mmaq)

r: density of exhaust gas (kg/m^3)

For stack sampling to measure the particle concentration in exhaust gas, the particle sampling apparatus is assembled at sampling position, the sampling tube is inserted into flue, the tip of suction nozzle is turned towards direction of exhaust gas flow and is matched to the location of sampling point, suction nozzle is held parallel to direction of exhaust gas flow, and the stack sampling is started holding the isokinetic sampling operating the particle sampling apparatus. In this case, the filter of dust collector is set for a constant weight and has to be weighed by balance.

During the sampling, the isokinetic sampling operation has to be maintained, and the temperature and pressure in suction gas flow rate measuring apparatus has be measured.

Moreover, for dust sampling, in the "each point sampling method", the dust filter for particle collection is replaced at every sampling point that has been selected multiple ones, the particle concentrations at each point are determined, and the mean concentration in cross-section of flue is calculated, and in "traverse sampling method", particle sample is collected during equal time at each sampling point by same dust filter for particle collection, and mean concentration only is obtained.

With later method, it is not possible to obtain a particle concentration distribution for a cross-section of the sampling position of flue, and therefore has no link to the simple sampling method that use the sampling point of representative particle concentration for a cross-section of flue.

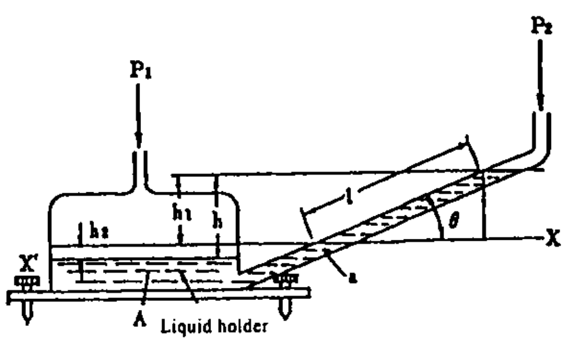


Fig.8.1.4 Inclined-tube monometer

(2) Particle concentration measurement and calculation method

Following the dust stack sampling operation, dust filter used for particle collection is set for a constant weight again and is determined, and weight of collected particle is determined.

The particle concentration in exhaust (flue) gas shall be expressed by the mass of particle contained in 1 m_N^3 of dried flue gas (g/m_N^3) which has been converted into standard condition (0℃ in temperature, 101.3 Kpa {760 mmHg} in atmospheric pressure), and it can be obtained from the mass of collected particle, the suction gas volume measured by suction gas flow rate measuring apparatus (gas meter), and the temperature and the pressure at gas meter in stack sampling operation. See JIS-Z8808 for details.

In addition, the particle size distribution in flue gas and the concentration of each particle size ranges can measure using the classifying dust collector as shown in Fig.8.1.5.

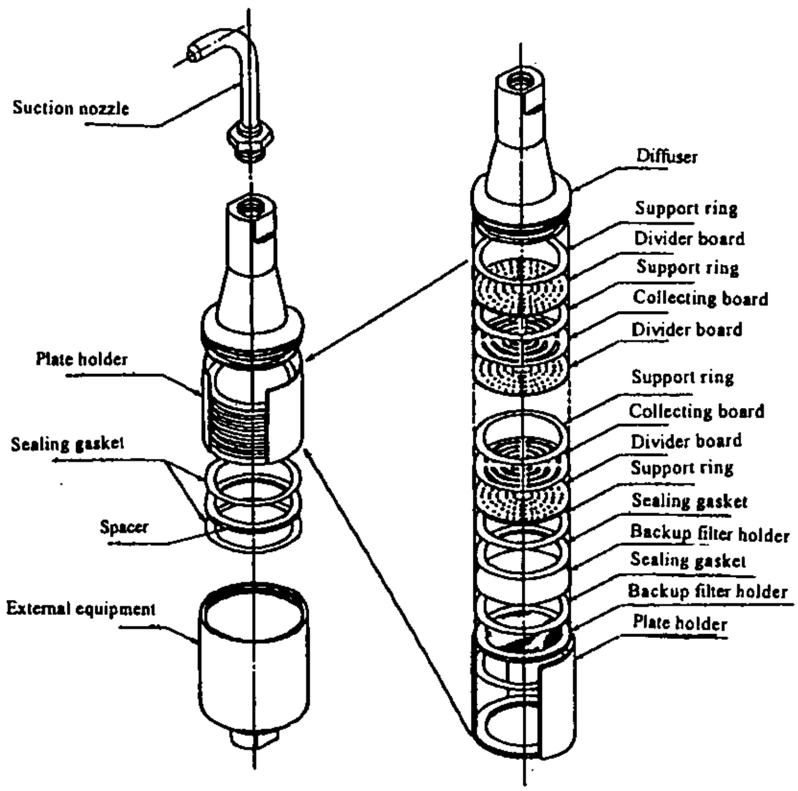
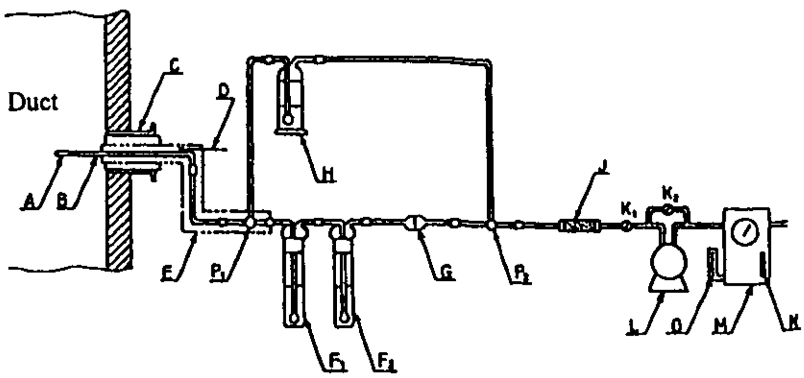


Fig.8.1.5 An example of classifying collector

8.1.3 Gaseous pollutants concentration measuring methods

The sampling apparatus used for measuring the concentrations of gaseous air pollutants consists of a test gasses collecting tube, the collecting part for sample gas such as gas absorption bottle, a collection bottle, the section gas flow meter (gas meter), and a suction pump, as shown in Fig.8.1.6. In addition, a filter is fitted into the test gasses collecting tube in order to prevent contamination by particle, into condenses water. Further, in order to prevent the component gas is absorbed, collecting tube is either heated or kept at a high temperature. Moreover, designated quantity absorbing liquid to use absorption of gaseous air pollutants that ought to be analyzed, is added to in the absorption bottle or collection bottle. For collecting the gaseous air pollutants, a test gasses collecting tube is inserted into the flue, a fixed quantity of sample gasses are sucked using a suction pump, and the target pollutant gas components are absorbing by the absorbing liquid. In this event, if an impinger or other gas absorption bottle is used, the total quantity of suction gas is measured by the gas meter, and both its temperature and pressure, are determined. Further, if a collection bottle for which the contents in a vacuum are known is used, its temperature and pressure are determined. Generally, the test gasses collection tube is inserted into the center of the flue and there is no need for isokinetic sampling. When the collection operation is completed, the gaseous air pollutants absorbed in absorbing liquid in gas absorption bottle or collection bottle are determined, according to prescribed analytical method. And the concentration of gaseous air pollutants can calculate because volume of determined air pollutants can be obtained. In this case, because the determined air pollutant volume under the standard condition can be calculated, it is necessary to convert the suction gas volume of sampling operation to standard condition using the measurement results of temperature and pressing of suction gas in gas meter. See JISKO1303, JISKO104, and JISKO095 for details.



A	: Filter substance	J	: Dry tube
B	: Test gasses collecting tube	K_1, K_2	: Flow adjustment cock
C	: Temperature-preserving substance	L	: Suction pump
D	: Thermometer	M	: Gas meter
E	: Heater	N	: Thermometer
F_1, F_2	: Absorption bottle (capacity 250 mℓ or 100 mℓ)	O	: Manometer
G	: Glass filter	P_1, P_2	: Three-way flow cock
H	: Cleaning bottle (Holds absorption liquid 50 mℓ)		

Fig.8.1.6 Example of test gasses sampling apparatus

8.1.4 Calculation of quantities of air pollutant emissions

The quantity of air pollutant emissions is calculated using Eq.(2) from the exhaust gas flow rate and the concentration of pollutants in the exhaust gas. In this case, the concentration of pollutants in the exhaust gas is expressed as the value in dry gas, excluding the water (moisture) content, and the exhaust gas flow rate is determined for wet gas conditions, which includes the water (moisture) content, so that it is necessary to know the flow rate of the dry exhaust gas. For this reason, the water (moisture) content of the wet exhaust gas is calculated using regulation JISZ8808. Moreover, value of moisture content in flue gas is necessary to determine the suction flow rate to realize isokinetic sampling of the particulate substance in an ordinary type sampling tube.

$$S = 0.06C \times \left(1 - \frac{Xw}{100}\right) \times Q \qquad \cdots\cdots\cdots \qquad (2)$$

Here, S = Quantity of air pollutant emissions (kg/h)

C = Concentration of air pollutants in the exhaust gas (g/m_N^3)

Xw = Water (moisture) content of the exhaust gas (volume %)

Q = Wet exhaust gas flow rate (m_N^3/min)

Moreover, Q is determined from fuel a cross-sectional area in sampling position, and the exhaust gas flow velocity at sampling point regulation of JISZ8808 and JISB8222, or calculated from the fuel composition and the main exhaust gas composition.

8.1.5 Easy measuring methods of black smoke emission using Ringeleman's smoke chart

Ringeleman's smoke chart is the oldest measuring method of smoke concentrations emitted from chimneys, and was widely used by heat management engineers. Further, it was also used in the Osaka Prefectural Pollution Control Ordinance, proclaimed in 1932, to prevent air pollution by ban of black smoke emissions exceeding a level 3 on Ringelmain's chart over 6 minutes per 1 hour.

As shown in Fig.8.1.7, Ringleman's smoke chart depicts black grids of 0 mm, 1.0mm, 2.3 mm, 3.7 mm, 5.5 mm and complete black on intervals that are complete white, 9.0 mm, 7.7 mm, 6.3 mm, 4.5 mm, and 0 mm on a sheet of white paper 21 cm × 14 cm, creating a Ringeleman's smoke chart in which the black sections occupy the white paper in proportions of 0, 20, 40, 60, 80, and 100%, and a visual comparison is then made between the smoke chart and the blackness of smoke emitted from a chimney, which smoke is then classified in six stages from 0 to 5.

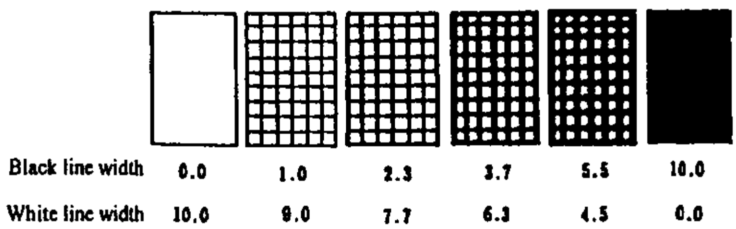


Fig.8.1.7 Ringeleman's smoke chart

When measuring, the observer must stand to keep a distance of approximately 40 m from the chimney, and the blackness of the smoke at a distance 30 to 45 cm above the chimney vent is compared with the naked eye, with the chart standing observer's eye level at a location 16 m away. In this case, the measuring position and the flow of the smoke are kept at right angles without ever facing into the sun, and care must be taken that there are no impediments such as mountains, buildings, or trees in the background. Moreover, this method use for grading the concentration of black smoke, although there are various problems in, anybody can make this type of measurement easily.