8.2 Methods for measuring and analyzing the main components of combustion exhaust gas (flue gas)

8.2.1 Overview

The main components of combination exhaust gas (flue gas) emitted by fuel firing are by carbon dioxide and water vapor, and carbon monoxide, which is formed from the inefficient burning of fuels and the nitrogen and excess oxygen in the air for combination. Of these, the measurement and analysis of carbon dioxide, oxygen, and carbon monoxide have long been considered important for thermal energy management. Further, they are also necessary for calculating the flow rate of flue gas. In addition, in case that the air pollutant emission standards such as dust and soot and nitrogen oxides are prescribed in these concentration base, these are regulated under constant oxygen concentration condition in order to avoid dilution by air. So measurement of oxygen concentration in conduction combination exhaust gas is also indispensable for the judgment of the absence on the air pollutants emission standards according to law and ordinances. The most important items are explained in Table 8.2.1.

Table 8.2.1 Types and principles of gas analyzers

	Measuring method	Name of analyzer	Composition measured
Chemical gas analyzer	Solution absorption reaction	Hempel gas analyzer	CO_2, O_2, CO, CmHn
		Orsat gas analyzer	CO_2, O_2, CO
Physical gas analyzer	Gas thermal conductivity rate	Electrical CO_2 analyzer	CO_2, H_2
	Gas specific gravity	Specific gravity type CO_2 meter	CO_2
	Infra-red absorption	Infra-red gas analyzer	CO_2, CO, CH_4, SO_2
	Solution conductivity rate	Automatic SO_2 recorder	SO_2
	Power generated	Zirconium O_2 meter	O_2
	Current generated	Galvanic cell O_2 meter	O_2
	Thermal fuel heat	Thermal fuel O_2 meter	O_2
		Inflammable gas meter	$CO+H_2$
	Magnetic type	Magnetic type O_2 meter	O_2
	Separation by column	Gas chromatograph	CO_2, O_2, H_2, CH_4, SO_2, NO_2

8.2.2 Sampling methods of sample gas

There are many cases where flue gas is negative pressure, and it is deemed necessary to use a suction pump in sampling test gasses and, moreover, to ensure that no air becomes mixed into sampling tube. Further, because there are times when the water vapor in the flue gas condense within the sampling tube, sampling tube has to slant and attach the drain eliminator to prevent clogging. Moreover, in order to prevent the contamination of sampling gas with soot or ash contained in flue gas, a filter is attached to the sampling tube.

8.2.3 Orsat analyzer

The Orsat analyzer is used widely in the analysis of carbon dioxide, oxygen, and carbon monoxide in flue gas. In the operation of this apparatus, flue gas sample is filled in 100 mℓ (some analyzer use 50 mℓ) gas burette containing sodium chloride solution, and transferred to an absorption bottle containing potassium hydroxide solution to absorb CO_2. And then sample gas is returned to gas bullet once again and its volume reduction due to CO_2 absorption is read to determine the CO_2 volume concentration in flue gas. Next, sample gas in gas bullet is transferred to an absorption bottle containing pysogallol/potassium hydroxide solution which absorb Carbon monoxide, in order, and some operations are repeated in order to determine the O_2 and CO volume concentration in flue gas. An outline of which is shown in Fig.8.2.1. Moreover, results obtained from the Orsat analyzer are the volume concentration (%) of the gas components in the dry flue gas.
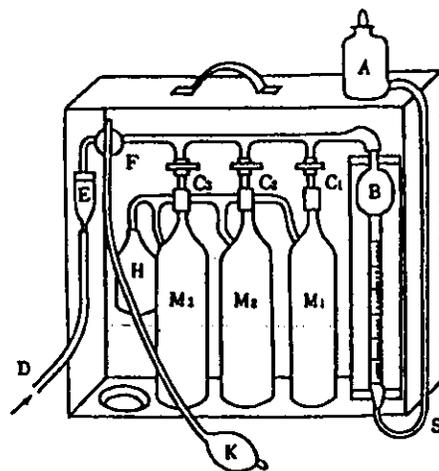

Fig.8.2.1 Orsat analyzer

8.2.4 Methods using measuring equipment

Besides the manual methods such as using the Orsat analyzer, continuous analyzers for determining the main component gasses in flue gas are also employed.

(1) Electric analyzer for Carbon dioxide

Each gas has its own unique thermal conductivity. And if the assumption that the thermal conductivity of air is 100, can be concluded, or the thermal conductivity of flue gas main component, water vapor is 100, oxygen is 101, nitrogen is 100, and carbon dioxide is 59. Like this, the thermal conductivity of the main component gasses excluding CO_2 is approximately 100, so CO_2 concentration in flue gas can analyze by the measurement of flue gas thermal conductivity. Fig.8.2.2 is principle of CO_2 analyzer used this principle. The air that is standard gas is filled up in cell S_1, S_2 and flue gas is flown in cell G_1, G_2. And platinum filament heated by constant electric current is set in each cells and bridge is wired as shown Fig.8.2.2. Because the electrical conductivity of the filament changes depending on the thermal conductivity of the gas in each cells, in this instance the conductivity of the gas

indicator, that is to say, the electrical current, which is related to the concentration of carbon dioxide, is shown, so that the CO_2 in the fuel can be continually analyzed by this circuit.

(2) Mechanical carbon dioxide analyzer

This analyzer shows the density of gas mechanically. In other word, this CO_2 analyzer is instrument sown in Fig.8.2.3, adopting the measuring principle that the density of CO_2 is longer than air. As the figure shows, this device houses two identical winged wheels, one is the air chamber, and another is the chamber passed into flue gas, and wheel turn at the same speed, and the wind pressure due to this is encountered by the winged wheels, which can rotate freely against the pressure. Because a torque proportional to the density of the gas in each chamber is generated against the opposite side winged wheels that encounter the wind pressure, a device that displays the torque proportion makes a record, thereby analyzing the gas density or, in other words, the CO_2.
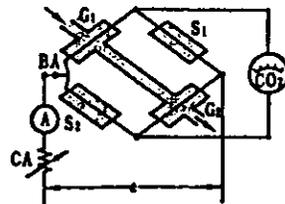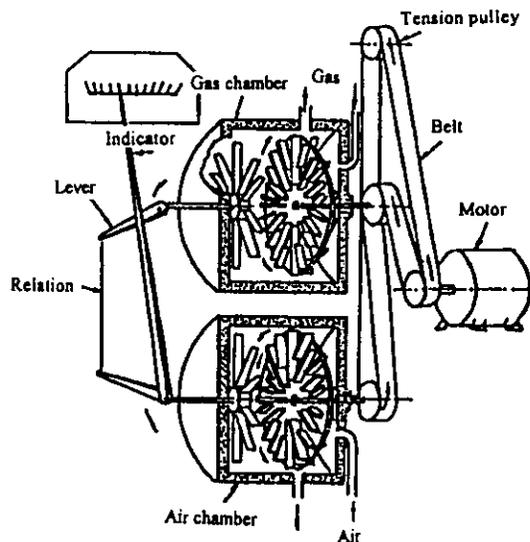

Fig.8.2.2   Principles of CO_2 analyzer

Fig.8.2.3   Principles of mechanical CO_2 analyzer

(3) Magnetic oxygen analyzer

The magnetic oxygen analyzer uses the attraction force generated when oxygen molecules, which are paramagnetic, are magnetized in a magnetic field to measure the oxygen concentration, which can be classified by both the magnetic wind method and the magnetic strength method. The former heats part of the O_2 molecules that have been attracted by the magnetic field and detects the strength of the magnetic winds generated by the loss of

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magnetism, and the latter classifies the pressure detected as changes in the background pressure of the supporting gasses that continually pour suction in fixed amounts into the magnetic field to work continuously on the oxygen molecules that cycle the dumbbell, to detect the level of deviation in the dumbbell generated by differences in the strength of the magnetization of the oxygen in the test gas.

(4) Electrochemical oxygen analyzer

The electrochemical oxygen analyzer uses an electrochemical oxidation-reduction to continuously measure the oxygen concentration. A pole is fixed at each tip of a zirconium element that has been heated to a high temperature, the test gasses are passed along one end, and air along the other, and by means of a gas permeable membrane and the zirconium, which can detect electrical impulses at both ends, the electrical current of the oxygen, which has been absorbed and diffused in the electrolytic cell is reaction (redox) by the surfaces of the solid electrode.

(5) Infra-red absorption carbon monoxide analyzer

Using an infra-red gas analyzer, the concentration of carbon monoxide in the flue gasses is measured continuously.