Data Sheet
SS/6515_2

Measurement of CO_2 in Flue Gases

6515 Series

Fuel Economy and CO_2 Measurements

Cost of fuel is a major item in the budget of all concerned with the operation of industrial boiler plant. If combustion is inefficient, fuel is wasted and money spent needlessly. Many industrial concerns have proved that significant savings can be made by installing instruments to improve boiler plant performance, the end result not infrequently being an increased profit on the same basic turnover. The use of CO_2 measuring equipment can, for a limited capital outlay, soon lead to big savings in the use of fuel. It continuously monitors the CO_2 content of the flue gases, thus providing information that indicates, in conjunction with the temperature of the same gases, to what extent the draught in solid-fuel boilers, or the air/fuel ratio in liquid-fuel boilers, needs regulating in order to supply the right amount of excess air for efficient working. The equipment provides an accurate and reliable indication of CO_2 content under rigorous day-to-day conditions in the boilerhouse. Its proven success is due primarily to the design of the metering unit (a precision-built katharometer and bubbler/aspirator) which makes the most of the advantages of water aspiration.

The metering unit has no moving parts. It is compact, light in weight, strongly made and can be operated from any stable single-phase AC supply. Its output is in the form of an electrical signal that can operate most industrial indicators or recorders. ABB products are particularly recommended. Water is used not only to aspirate the gases, i.e. draw them from the flue, but to clean, cool and saturate them before they pass to the katharometer. This eliminates the need for special coolers, cleaning columns and bubblers, and as the katharometer is surrounded by a water-jacket, the metering unit does not need to be enclosed in a temperature-controlled cabinet.

These features not only favourably influence the performance and long-term reliability of the equipment, they also have an effect upon its price, which is well within the budget of even the smallest industrial boilerhouses. In well-installed systems the equipment measures continuously with an accuracy of 0.5% CO_2 and the half-time of the metering unit is 60s or better.

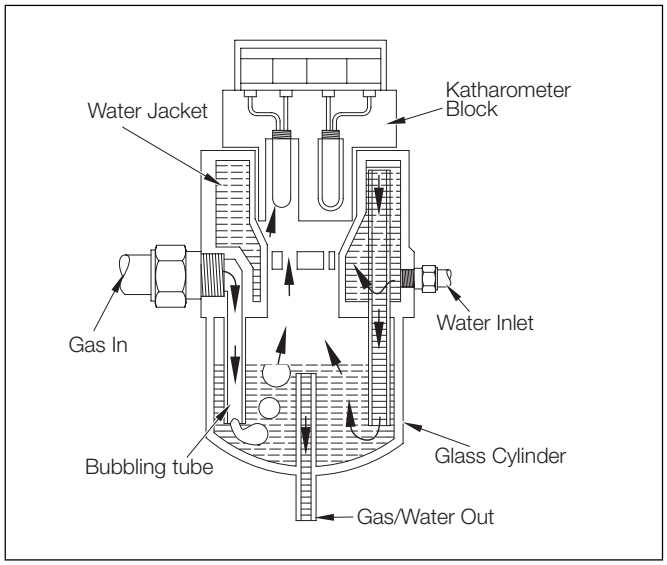
Instrumentation

Every complete installation must contain at least one item from each of the following four groups:

1. Sampling Group (intake-pipes and soot filters)
2. Primary Measuring Group (CO_2 metering unit)
3. Final Measuring Group (indicators and recorders)
4. Supply Group (power supply units)

The simplest possible system contains one item only from each group but the flexibility of the equipment is such that more complex systems containing two or more instruments from one or more of the groups can easily be installed to suit the requirements of any boilerhouse, large or small. In addition, as instruments from each group are connected only by a sampling-line or by electric cables, the separate items can be sited in positions best suited to their functions or to the layout of the boilerhouse. For example, although the CO_2 metering unit must be as near the sampling-point as possible, indicators or recorders might well be more conveniently sited in a separate control room.

A simple Katharometer-type measuring system for CO_2 in flue gases as a guide to combustion efficiency



Diagrammatic View of Katharometer

1. Sampling Group

A sampling probe is necessary for each point in the flue at which CO_2 is to be measured. For oil-fired boilers this may simply comprise an open-intake pipe in the flue attached to the sampling-line at its outer end, but for coal-fired boilers a soot filter is always necessary. The simplest form of soot filter is a porous, fused-alumina pot that fits on the end of the intake pipe inside the flue. This type has to be mounted in such a position that it points upwards in the flue to prevent condensing liquid running back into it. It has to be removed occasionally for cleaning. An alternative type is fixed to the intake pipe outside the flue and filters the gases through replaceable sleeves. This filter must be mounted pointing downwards in the flue and it includes an electric heating element to prevent condensation before the gases leave the filter, thus protecting the felt sleeve from choking.

2. Primary Measuring Group

The upper part of the CO_2 metering unit comprises a katharometer surrounded by a water jacket; the lower part of the unit is a bubbler/aspirator that draws a sample continuously from the flue, cleans, cools and saturates it before passing it to the katharometer.

The katharometer, or thermal conductivity meter, comprises four platinum windings; two surrounded by saturated air and two exposed to the flue gas sample. The differing temperatures achieved by the windings, due to differences in the thermal conductivity between CO_2 and air, results in an electrical output which is measured by an indicator or recorder. Clean water at a rate of 18 to 22 l/hr (4 to 5 galls/hr) and a maximum temperature of 40°C (104°F), continuously flows into the aspirator from a constant-head tank with a head pressure of from 0.6 to 3m (2 to 10 ft.). In the aspirator the water first passes through a water-jacket, then through the bubbler and finally out through the 1m (3 ft.) long aspirator tail-pipe to some form of open drainage.

3. Final Measuring Group

A comprehensive range of indicators and recorders, normally calibrated 0 to 20% CO_2, is available for use with CO_2 equipment and details of approved and recommended ABB units are available on request.

4. Supply Group

Power supply units convert AC-mains supplies into suitable stabilized DC currents for the katharometer bridge circuits of the CO_2 metering units.

Installation and Sampling

The figure opposite illustrates diagrammatically the installation of a simple system and shows the main requirements. The instruments are easy to install and connect.

The most critical aspect of installation is the selection of a sampling-point. Briefly, this should be as near the flue outlet as possible in a region of strong flow fully representative in composition of the flue gases as a whole. The sampling-line should be as short as possible and should slope downwards to the metering unit along its entire length to prevent pockets of condensate forming and choking it. If this is not practical, T-type water seals are necessary in all troughs. The factors involved in selecting sampling-points and installing sampling-lines are discussed comprehensively in BS1756 Code for the sampling and analysis of flue gases.

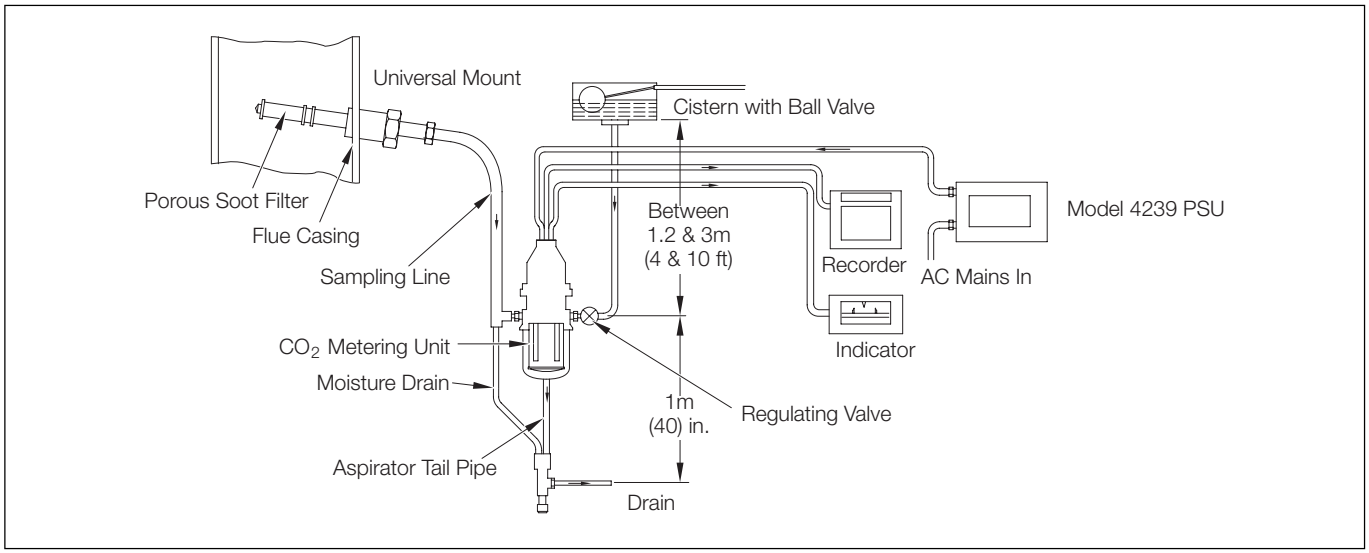
Performance

The accuracy of the equipment, for continuous measuring over a long period, is ±0.5% CO_2 and this is not significantly affected by changes in flow, pressure or ambient temperature; a great advantage as it is not necessary to install flow regulators or to enclose the metering unit in a thermostatically controlled cabinet. The half-time of the metering unit is 40s, but the overall response time of any installation also depends to a great extent upon the bore and length of the sampling-line, a further 60s being added for every 6m (30 ft.) of 9mm ($^3/_8$ in). bore pipe.

In some circumstances the accuracy of the equipment can be improved to 0.25% CO_2 and the metering unit modified to give a still faster response, but the possible scope for these improvements can only be assessed on site by our own engineers.

Complete Systems

The inherent flexibility of the system makes it possible to design systems suitable for most types of boiler plant. By choosing different combinations of units from the four instrument groups, widely different requirements can be met. Every system supplied, if it is to operate efficiently, must be specified for the particular plant and this can only be done if all relevant information is supplied by the boiler operator. A questionnaire for this is available on request.



Schematic Diagram of Complete CO_2 Installation

Maintenance

The equipment needs very little routine maintenance. The sampling probe, sampling-line and bubbler/aspirator chamber of the metering unit need occasional cleaning, the frequency of which depends mainly upon the type of fuel used and the cleanliness of the water supply.

CO_2 Content, Excess Air and Temperature

The percentage of CO_2 in flue gases for maximum efficiency depends upon the composition of the fuel and the amount of excess air necessary for complete combustion. This amount in turn depends upon the efficiency with which the air and fuel are mixed in the combustion zone, the efficiency being generally higher for liquid and pulverized fuels than for solid fuels.

It is generally accepted however, that 11 to 15% for coal, 14 to 15% for coal-tar fuels, 17 to 19% for coke, 10 to 12% for oil (in converted Lancashire boilers) and 12 to 13% for oil (in Economic boilers) very approximately represent the permissible CO_2 limit.

For calculations of approximate heat losses caused by too much or too little excess air, it is necessary to know the temperature of the flue gases at the sampling-point as well as the CO_2 content. The following formula can then be used to calculate the heat loss (expressed as a percentage of the net calorific value of the original fuel).

This formula only applies to heat losses caused by too much excess air.

$$\% \text{ heat loss} = \frac{K(T - t)}{Y}$$

where: T = temperature of the flue gases in °C
t = temperature of the ambient air in °C
Y = percentage of CO_2 in the flue gases
K = constant for the particular fuel

Values of K for certain fuels are as follows: bituminous coal 0.63; dry steam coal 0.65; anthracite 0.67; coke 0.70; fuel oil 0.54; coal gas 0.45; natural gas 0.40.

The relationship between percentage CO_2, amount of excess air and temperature, is fully discussed in 'Efficient User of Fuel' 2nd edition (HMSO) Chapters 6, 7 and 8 and also in BS3048 – Code for the Continuous Sampling and Automatic Analysis of Flue Gases.

Measuring Flue Gas Temperature

Instrumentation for temperature measurement usually comprises a thermocouple (primary measuring element) fixed into the flue near the CO_2 sampling-point and a recorder or indicator (final measuring group). Mercury-in-steel type thermometers (dial indicators and circular chart recorders with incorporated bulb systems) can also be used in some cases. For reasons of cost and convenience it is often useful to record both temperature and CO_2 content with the same instrument.

We welcome enquiries which involve a combination of CO_2 and associated measurements, including temperature, oxygen and other flue gas constituents.

Portable CO_2 Monitor

A fully portable CO_2 monitor is available for routine or spot checks on boiler flue gases and is also suitable for use on board ships or in locations where a mains supply or water supply is not readily available.

This portable monitor comprises a katharometer working in association with a galvanometer calibrated directly in terms of percentage CO_2, these being mounted in a compact case which also includes the necessary batteries, katharometer zeroing and standardizing facilities and electric pump.

Dimensions and Weights

Heated Soot Filter

Length	330mm (13 in.)
Width	83mm (3.27 in.)
Height	152mm (25 in.)
Weight	9.8kg (21.6 lb)

Porous Soot Filter

Length	450mm or 900mm (17.7 or 35.4 in.)
Weight	2.9kg (6.4 lb) or 4.4kg (9.7 lb)

Model 4239 PSU

Length	238mm (9.37 in.)
Width (Depth)	55.5mm (2.18 in.)
Height	162mm (6.38 in.)
Weight	1.85mm (0.073 in.)

Model 6515 Katharometer and Aspirator

Length	1200mm (47.24 in.) including tail pipe	
Max. projection from wall		146mm (5.75 in.)
Weights	Katharometer	1.5kg (3.3 lb)
	Aspirator	4.3kg (9.5 lb)

Why ABB?

The metering unit, the vital element of all ABB CO_2 measuring systems, is of well-proven and practically foolproof design, efficient and reliable, the result of continual development and improvement over many years of operational experience. It is easy to install, needs only simple electrical and water supplies, virtually runs itself and requires very little maintenance. Associated instruments (soot filters, indicators, recorders, etc.) are also made to designs based on long experience in the manufacture of measuring instruments for varied applications in industry. The equipment as a system is inherently flexible, all variants, however simple or complex, being made up from standard units.

These features are responsible for the low cost of installing and running this type of CO_2 system and for a standard of reliability so high that the instrument can almost be forgotten once installed.

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