ZSS Cross Stack Laser Gas Analyzer

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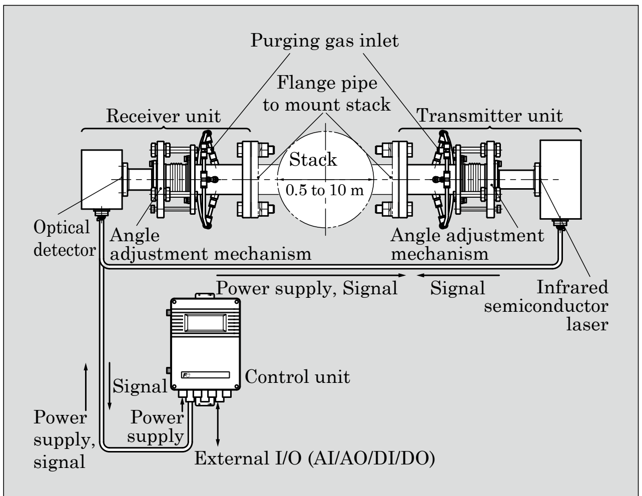
1. Introduction

To protect society from air pollution and to preserve living conditions and the environment, Japan enacted an Air Pollution Control Law in 1968. The Air Pollution Control Law prescribes emissions standards for each type of emission matter according to the type and size of a facility, and also regulates the total pollutant load control criteria by region.

At incinerators and industrial waste incineration facilities, the emission of hydrogen chloride, a harmful chemical substance, must be controlled. For this purpose, a continuous analyzer for hydrogen chloride is often used to measure sampling gas, which is automatically and continuously extracted from the vicinity of a smokestack outlet at a facility, by passing the sampling gas through an absorption tank and then using the ion selective electrode method to take measurements. Also, at large boilers used for power generation and the like, denitrification equipment that uses ammonia is often installed and ammonia analyzers are provided to monitor the residual ammonia and to monitor the denitrification. As in the measurement of hydrogen chloride, ammonia is measured by continuously extracting a gas sample and measuring it with infrared analysis, chemiluminescence or the like.

Fig.1 Configuration of the cross stack laser gas analyzer



Fuji Electric's ZSS, which uses a laser and does not require sampling, is the first cross stack laser gas analyzer to be released in Japan, and the structure, operating principles, features and uses of the ZSS cross stack laser gas analyzer are described herein.

2. Device Configuration

Figure 1 shows the configuration and Fig. 2 shows the external appearance of the ZSS cross stack laser gas analyzer. The device is configured from three units: a transmitter unit, a receiver unit and a control unit.

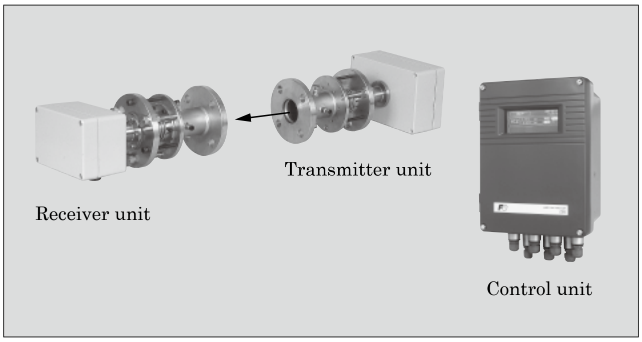
(1) Transmitter unit

The transmitter unit is configured from an infrared semiconductor laser, a laser temperature control circuit, a Peltier and the like, and emits light having a stable wavelength suitable for the absorption spectrum of the component to be measured.

(2) Receiver unit

The receiver unit is configured from a photodiode, an amplification circuit, a concentration detector circuit and the like, and converts light that has passed through the stack into electrical signals to detect the concentration. The transmitter unit and the receiver unit are also provided with angle adjustment mechanisms, attached so as to sandwich the stack and enabling the optical axis displacement to be adjusted according a shift in the flange attachment location or warping of the stack. Additionally, a purging mecha-

Fig.2 External appearance of the cross stack laser gas analyzer



nism is also provided to prevent dust from causing clogging or dirty windows.

(3) Control unit

The control unit supplies electric power to the transmitter unit and the receiver unit, corrects the concentrations in consideration of gas temperature, gas pressure and the like, displays the concentration levels and alarms, and controls the inputting and outputting of signals.

3. Measuring Principles[1]

Gas molecules of hydrogen chloride, ammonia and the like each have their own unique infrared absorption spectrum. Figure 3 shows the absorption wavelength ranges of various gases and the absorption spectrum for hydrogen chloride. Infrared absorption exists as a line spectrum.

Laser light emitted from the transmission unit is absorbed according to the concentration of measuring gas in the stack, in accordance with the Lambert-Beer law, and then reaches the receiver unit. The intensity of the received light is sensed to measure the concentration of gas inside the stack.

$$I(L) = I_o \exp(-knL) \quad \cdots\cdots (1)$$

$I(L)$: Received light intensity

I_o : Emitted light intensity

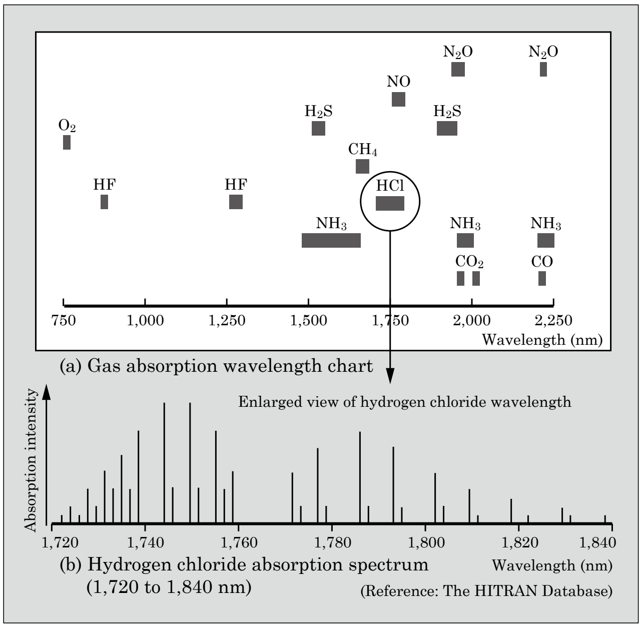
k : Proportionality coefficient

n : Concentration (density) of measurement gas

L : Optical path length

Figure 4 shows the principles of the measurement method. The laser light is approximately a single wavelength of about 10 pm (pm = 10^{-12} m) at half-bandwidth, but may be frequency modulated by changing the drive current and temperature. By modulating the wavelength around the line spectrum of the measurement gas component at a fixed cycle, a signal having a frequency characteristic is obtained, and that signal, having been attenuated and weakened due to absorption, is received as frequency components which are extracted to achieve measurement with good accuracy.

Fig.3 Infrared absorption line spectrum



4. Features

(1) Low running cost

The ion selective electrode method requires periodic maintenance, such as the preparation of an absorption solution, to be performed approximately twice a month. With the laser method, however, due to the use of automatic zero point correction based on detection of the absorption line position, zero point stability is excellent and maintenance free operation for six months to a year can be realized. Owing to the low maintenance cost and non-necessity of reagents, running cost has been reduced to approximately 1/5th that of prior methods. Another feature of the laser method is that dead time is eliminated since there is no need to perform periodic automated calibrations.

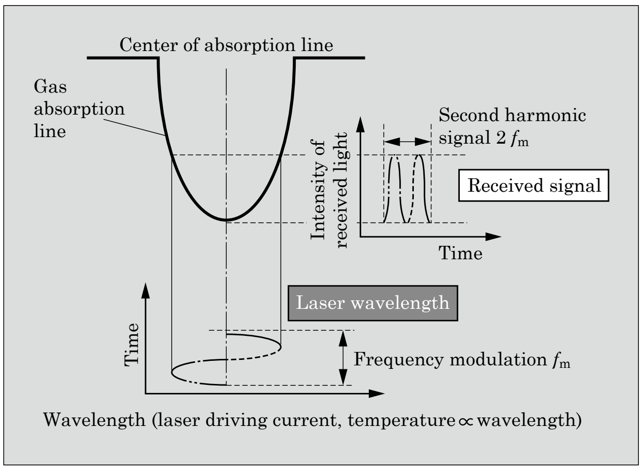
(2) Low power consumption

With the sampling method, in order to suck in and feed the gas to an analyzer, a dust removal filter, suction equipment, a gas cooling system and the like are required, and to prevent condensation, the sampling pipe must be heated, which requires approximately 50 W/m. On the other hand, with the laser method, the analyzer is mounted directly on the stack, and therefore these components are unnecessary. Moreover, with a small power consumption of 70 VA, the laser analyzer places a low burden on the environment.

(3) Can be used with exhaust gas containing high dust levels

When gas containing high levels of dust is used with the sampling method, a dust filter or the like is closed for short intervals, during which time a condition occurs in which measurement is not possible. However, with the cross stack laser method, sampling

Fig.4 Measurement principles



is not required and the window surfaces on the transmitting and receiving sides may be constantly being purged with clean air so that exhaust gas containing high levels of dust can be analyzed.

(4) Can be used with control processes

The sampling method has a response time of several minutes in duration (depending upon the length of the sampling pipe). On the other hand, the laser method has a high-speed response of 2 seconds or less, and by linking the dechlorinization equipment and denitration equipment with more precise control, the amounts of slaked lime used for dechlorinization and ammonia used for denitrification can be reduced.

(5) Measurement is not susceptible to interference from other gases

Measurements made using the ion selective electrode method are susceptible to influence from other halogen substances. On the other hand, since a wide wavelength range is used for measurement with an infrared analyzer, a band-pass filter (optical filter that allows the transmission of only a specific wavelength range) is used in combination to lessen the interference, but measurements made using this method are inherently susceptible to interference from other gases. The laser method uses an extremely narrow wavelength range of 1 nm or less ($nm = 10^{-9} m$). Furthermore, since a wavelength in which other gases are not absorbed is selected, this method is inherently insusceptible to interference from other gases.

(6) Highly accurate measurements in regions of low concentration

The hydrogen chloride concentration in the vicinity of a smokestack outlet at an incinerator has a low value of less than 5 ppm, and therefore the measuring device is desired to have low range specifications. This analyzer is capable of measuring in the low concentration region of 10 ppm (when the measuring optical path length is 1 m), and can measure with higher accuracy than the previous methods which had a minimum range of 50 to 100 ppm.

Table 1 Specifications of the cross stack laser gas analyzer

Item		Specification
Measurement principle		Non-dispersive infrared system (NDIR)
Measuring method		Cross-stack system (path system)
Light source		Near-infrared semiconductor laser
Laser class		Class 1
Measurable component and range	Hydrogen chloride Ammonia	Min. 10 ppm, Max. 1,000 ppm Min. 15 ppm, Max. 1,000 ppm (measurement range when optical path length is 1 m)
Detection limit	Hydrogen chloride Ammonia	0.05 ppm 0.15 ppm
Performance	Repeatability Linearity Zero drift Response time	±2.0 % FS ±3.0 % FS ±2.0 % FS/six months (±3.0 % FS/six months for ammonia range of 20 ppm or less) 2 seconds or less
Warm-up time		90 minutes
Allowable angle adjustment		5 degrees or more
Protection classification		IP65
Measurable range (optical path length)		0.5 to 10 m
Measuring gas condition	Temperature Pressure Moisture Velocity	450 °C max. ±10 kPa 50 vol% or less 10 m/s or less
Ambient temperature	Receiver unit Transmitter unit Control unit	−20 to + 55 °C −20 to + 45 °C
Power supply, power consumption		100 to 240 VAC, 50/60 Hz, approx. 70 VA
Analog output		4 to 20 mA DC (550 Ω) 2 points (measurement value, O_2 corresponding value) (optional 4 points max.)
External I/O	Analog input Contact input Contact output	4 to 20 mA DC, 2 points (optional 6 points max.) 12 to 24 V/ 5 to 20 mA DC, 4 points (optional 5 points max.) 24 VDC, 1A, 8 points (optional 17 points max.)
External dimensions, mass	Receiver unit Transmitter unit Control unit	180 (W) × 400 (D) × 200 (H) (mm), approx. 10 kg 240 (W) × 400 (D) × 200 (H) (mm), approx. 10 kg 240 (W) × 135 (D) × 320 (H) (mm), approx. 8 kg

5. Specifications

The main specifications are listed in Table 1.

6. Example applications to processes

Figure 5 shows an example on an application to an incinerator or industrial waste incineration facility.

(1) Slaked lime injection control based on hydrogen chloride concentration measurement

At the dust collector inlet of an incinerator or industrial waste incineration facility, slaked lime is

Fig.5 Example of installation at waste incineration facility

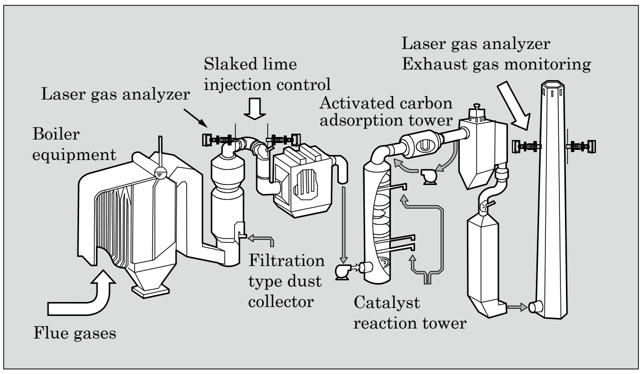


Fig.6 Measurement comparison 1: Cross stack laser analyzer compared to ion selective electrode method (response time)

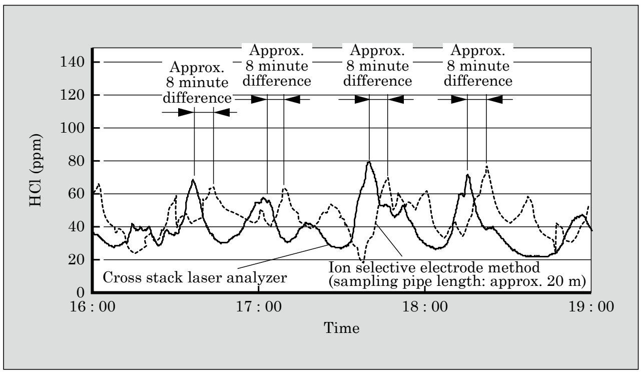
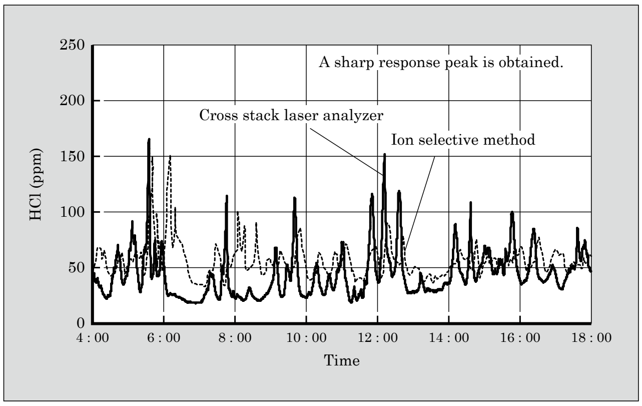


Fig.7 Measurement comparison 2: Cross stack laser analyzer compared to ion selective electrode method



sprayed in order to reduce the concentration of hydrogen chloride in the exhaust gas. Although dependent upon the type of material incinerated, the automated and continuous measurement of the exhaust gas had been difficult to implement previously due to the adverse conditions of 500 to 2,000 ppm of hydrogen chloride, a temperature between 200 and 400 °C, dust content of 2 to 10 g/m^3 (normal) and moisture of 10 to 20 vol%. The laser method is taking measurements under these types of conditions because purging with clean dry air is performed at 50 to 100 L/min, according to the flow rate of the exhaust gas, to prevent the accumulation of dust and to lower the temperature.

(2) Hydrogen chloride concentration monitoring in vicinity of smokestack outlet

The exhaust gas from an incinerator or an industrial waste incineration facility must be monitored to ensure that concentration levels do not exceed the prescribed emission levels. The exhaust gas has a hydrogen chloride concentration of 0 to 50 ppm, temperature between 100 and 250 °C, dust content of 200 mg/m^3 (normal) or less, and moisture of 10 to 40 vol%. With a laser analyzer, the exhaust gas is measured as a wet gas concentration (concentration including moisture). It is also possible to set the forecasted moisture concentration and output a dry gas concentration (concentration after moisture has been removed).

(3) Ammonia injection control for denitrification equipment

Denitrification equipment employing selective catalytic reduction (SCR) that uses ammonia or urea has been installed at large boilers, incinerators and the like. The measuring gas typically has an ammonia concentration of 50 to 200 ppm, a temperature between 300 and 400 °C, dust content of 200 mg/m^3 (normal) or less, and moisture of 10 to 20 vol%. The installation of the laser gas analyzer at the rear of the denitrification equipment enables efficient control to be implemented without excessive injections of ammonia. As a result of this type of control, the exhausting of excess ammonia is reduced and pipe clogging due to the generation of ammonium sulfate ($(NH_4)_2SO_4$) is also diminished.

7. Field measurement examples

Figures 6 and 7 show examples of measurements in the field.

For Fig. 6, the location at which sampling gas is extracted and the location at which the laser gas analyzer is installed are the same. Both outputs exhibit good correlation, but the results show that the laser analyzer provides an output response approximately 8 minutes earlier than the ion selective electrode method using a 20 m sampling pipe.

In Fig. 7, the output response from the laser gas analyzer provides a steeper peak value than that of the ion selective electrode method. This steep peak is thought to be attributable to the fact that the detector unit is attached directly to the smokestack can reflect instantaneous conditions.

8. Postscript

The cross stack laser gas analyzer provides many features not available with conventional sampling methods, such as high speed response, low running cost and maintenance-free operation, and can be used for control and other new applications to meet user needs.

At present, the cross stack laser gas analyzer is adsorptive of hydrogen chloride and ammonia and is being applied to measure gases that are difficult to sample, but through developing such products as an oxygen analyzer for combustion control, a dual-component analyzer for measuring the measurement gas and moisture simultaneously, and so on in the future, Fuji Electric intends to increase its lineup of measurement products having specifications suited to user needs.

Reference

(1) Peter Werle, et al. Near- and mid-infrared laser-optical sensors for gas analysis. Optics and Lasers in Engineering. 37 2002, p. 101-114.