

# Cross Stack Laser Gas Analyzer Contributing to Energy Conservation, “ZSS”

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## ABSTRACT

Fuji Electric has been developing gas analyzers that contribute to overall energy conservation of processes. Cross stack laser gas analyzers are capable of high-speed response because they are directly installed in flues for measurement and are suited for control aimed at energy conservation. Fuji Electric has developed a technology that allows a device to measure two components, though this was conventionally limited to one component, and commercialized the world's first cross stack laser gas analyzer for two-components ( $O_2+CO$ ): “ZSS”. Instrumentation air is available as the purge gas for  $O_2$  measurement, and the analyzer features improved environmental resistance, or resistance to inhibitory substances in the measured gas. Application to the converter and combustion control processes of steel plants is expected.

## 1. Introduction

With the aim of restricting global warming and creating a sustainable society, renewable energy is becoming prevalent, but we are facing many challenges in achieving stable supply and cost. On the other hand, the development of shale gas and shale oil are progressing, and the production amount of these fossil fuels is predicted to increase. Against such background, it is estimated that fossil fuels will remain the dominant source of primary energy for a while.

In order to reduce  $CO_2$  emissions in the whole of society, our task is to make efforts for the effective utilization of fossil fuels. That is required also from the viewpoint of energy conservation. As regards “utilization,” not only the reduction of fuel consumption but also the “reuse” of it should be considered. In addition, a comprehensive reduction of fossil fuels, including toxic materials generated in the processes of fossil fuel incineration and their treatment energy, have to be taken into consideration.

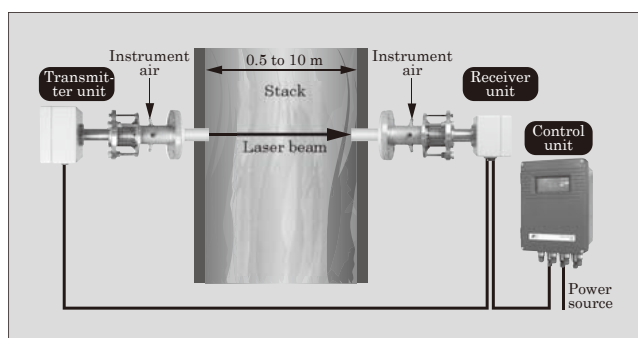


Fig.1 “ZSS”

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Fuji Electric has been developing gas analyzers that contribute to the comprehensive conservation of energy in processes from such a point of view.

This time, we have developed cross stack laser gas analyzers “ZSS,” one unit of which can measure two components, oxygen ( $O_2$ ) and carbon monoxide ( $CO$ ), at the same time (see Fig. 1).

## 2. Market of Gas Analyzers for Processes

Almost 60 years ago, Fuji Electric started manufacturing infrared gas analyzers for the first time in Japan. They have been applied in many fields, particularly for the monitoring of the atmosphere in incinerators used in steelmaking processes and thermal treatment processes, helping to enhance the quality of the process products.

With air pollution becoming a focus of attention as a social problem, we have been providing analyzers for the monitoring of toxic gases emitted from factories and business establishments, making a contribution to the improvement of environmental issues in Japan. The demand for environmental measurement is estimated to increase further in China, where air pollution is a serious problem, and in India and other countries in the Middle East, where there is concern about similar environmental issues.

On the other hand, in Japan, Europe and the U.S.A., where systems to monitor toxic gas emissions have already established, because the generated toxic gases are removed through after treatment, their demand is shifting to restricting generation of the toxic gas itself and reducing resources and energy necessary for the after treatment, that is, comprehensive energy conservation. The cross stack laser gas analyzer, released by Fuji Electric in 2007, the first time as a Japanese corporation, is installed directly in flues for

measurement and is characterized by its high-speed response. That is why it is optimally suited for control applications aimed at conserving energy, and its market is expected to expand in the future.

### 3. Measurement Principle and Product Features

#### 3.1 Measurement principle

The measurement principle of ZSS is shown in Fig. 2. Each gas component has its own wavelength range where it absorbs light. ZSS uses only one absorption line out of several tens to several hundreds of lines for concentration measurement, and the tunable laser element that can be adjusted to produce a wavelength around the selected absorption line is to be used. For instance, a laser element producing a wavelength of around 0.760 to 0.765  $\mu\text{m}$  is used for  $\text{O}_2$  concentration meters, while for  $\text{CO}$  concentration meters a laser element producing a wavelength of 1.580 to 1.583  $\mu\text{m}$  or 2.330 to 2.335  $\mu\text{m}$  is used depending on the measurement range.

The electrical current range of a laser element is adjusted so that it can sweep a range of wavelengths around the absorption line used for measurement, and the laser element is driven with a modulated (e.g., 10 kHz) signal (1f). This modulated laser beam is projected toward a target gas to be measured and the transmitted beam is received with a photodiode. When the target gas exists in the flue, a signal (2f) having twice the frequency (20 kHz) of the modulated signal (1f) will be contained in the received signal. The intensity of the amplitude of 2f is proportional to the concentration of the target gas, and this property is utilized for measurement.

#### 3.2 Product features

ZSS has features that are the most suitable for

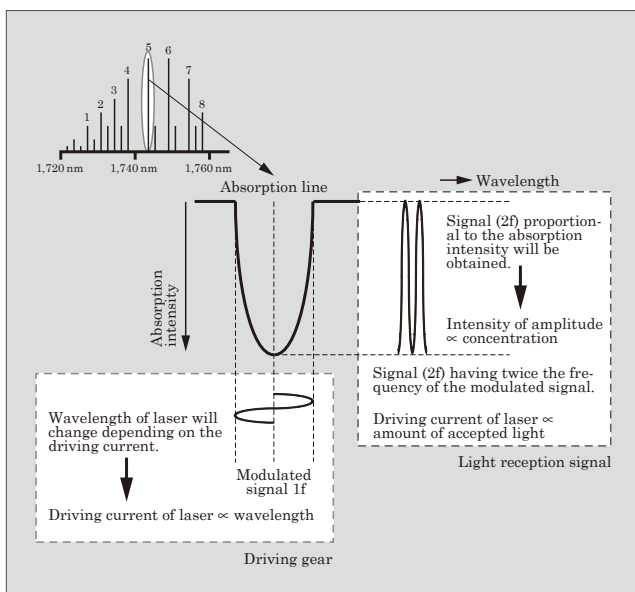


Fig.2 Measurement principle of "ZSS"

steelmaking processes and incineration processes.

#### (1) Measurement of two components with a single unit

The external appearance of ZSS is almost the same as conventional devices, but two types of laser element, for  $\text{O}_2$  and  $\text{CO}$ , are integrated in it. The ZSS has its original optical system where laser beams projected from each laser element are combined on the same axis.

Furthermore, the photo acceptance unit which is sensitive to wavelengths of both  $\text{O}_2$  and  $\text{CO}$  is installed on the receiving unit to streamline the structure of the device, and this makes it easy to adjust the optical axis (see Fig. 3).

Conventionally, it has been necessary to install two units for measuring  $\text{O}_2$  and  $\text{CO}$ . Mounting flanges had to be installed on two points in a flue and the optical axes had to be adjusted individually. In contrast, since the ZSS has a structure with two laser components in one unit, one set of procedures such as the installation of a mounting flange and the adjustment of an optical axis is enough. Consequently, it will reduce not only the manufacturing cost but also the installation cost and easies maintenance afterwards, producing significant merits for users.

#### (2) Use of instrument air

The installation environment for ZSS in incineration processes is shown in Fig. 4. When installing laser

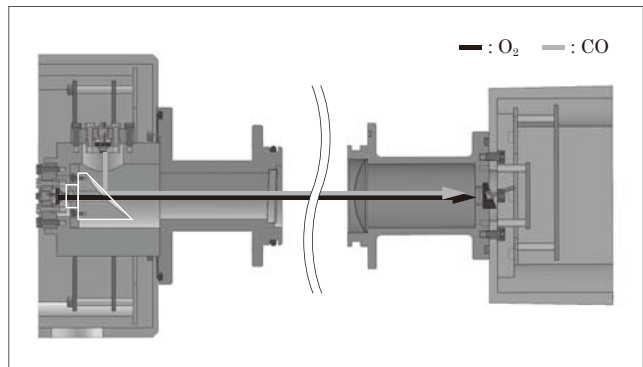


Fig.3 Structural drawing of two-component analyzer ( $\text{O}_2$  concentration meter+ $\text{CO}$  concentration meter)

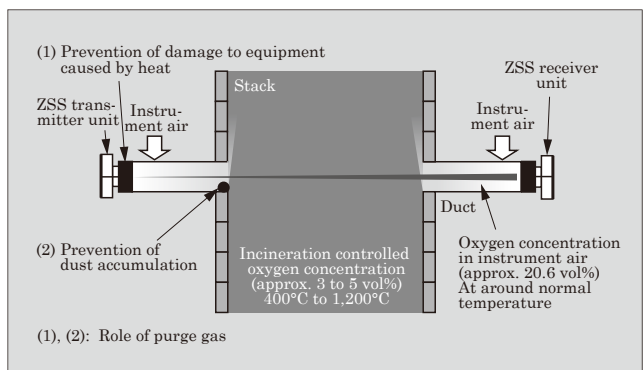


Fig.4 Installation environment for "ZSS" in incineration processes

gas analyzers in incineration processes such as in garbage incineration plants, in order to prevent measurement failures due to the accumulation of dust in ducts and the damage of equipment caused by heat (700°C to 1,200°C) in furnaces, purge gas flow in the ducts should be maintained continuously. If instrument air is adopted as purge gas, the O<sub>2</sub> concentration in the purge gas will interfere with the O<sub>2</sub> concentration in the flue, becoming an impediment to precise measurement. The O<sub>2</sub> concentration in instrument air is 20.6 vol%, while the O<sub>2</sub> concentration in the furnace subject to the control is 3 to 5 vol%. Therefore, a sufficient SN ratio will not be achieved.

For those reasons, for O<sub>2</sub> concentration meters of laser gas analyzers, nitrogen is commonly used as the purge gas. However, with the exception of the steel industry, there are few installations which have a nitrogen supply system. Moreover, introducing a laser gas analyzer using nitrogen gas requires several millions of yen annually for the nitrogen gas supply system in general.

In order to solve this problem, taking note of the temperature difference between the gas in a flue and purge gas, Fuji Electric considered that if a wavelength (absorption line) which is hardly absorbed by O<sub>2</sub> at around normal temperature but well absorbed by O<sub>2</sub> at high temperature is used, the interference of O<sub>2</sub> contained in the purge gas will become negligible. However, at high temperature the kinetic energy of molecules will increase and, consequently, the absorption intensity will become lower in general. Actually in many absorption lines, the higher the temperature became, the smaller their absorption intensity became. After investigating numerous absorption lines, we have discovered an absorption line which has the intended gas temperature response at around 760 nm and confirmed that it had an absorption intensity which allows O<sub>2</sub> gas to be measured. In this way, even with the use of instrument air as purge gas, it became possible to precisely measure the O<sub>2</sub> in a furnace, without suffering interference from the O<sub>2</sub> in the air.

(3) Enhanced environmental resistance (measures for resistance against inhibitory substances)

When adopting laser gas analyzers as O<sub>2</sub> and CO concentration meters in incineration processes or combustible gas recovery processes at outlets of converters at garbage incineration plants, the effects of inhibitory substances such as a high amount of dust and water droplets become a problem.

If there are many inhibitors, they will interfere with the device's laser beam and its intensity will be deteriorated, resulting in a measurement failure due to the decrease in the SN ratio. Moreover, inhibitory substances fluctuate greatly in these facilities. In some cases, the amount of accepted light becomes insufficient or, to the contrary, output power becomes saturated, and these will hinder continuous measurement.

By incorporating a function to automatically op-

imize reception gain depending on the amount of accepted light, Fuji Electric has developed an analyzer which can surely perform measurements even in the event of a great fluctuation in the amount of inhibitors. Furthermore, the time required to sample data once is reduced to one-tenth compared to the conventional devices. In this way, this analyzer can diminish the strain in accepted waveform caused by fluctuations in the light amount during data sampling, and, at the same time, significantly reduce the effects of inhibitory substances by increasing the number of times data is sampled.

## 4. Application Examples

Examples of ZSS application will be described here. In every case, the effectiveness of this device has been verified through field tests.

### 4.1 Enhancement of combustible gas recovery rate in converter processes

In converter processes at steel plants, as shown in Fig. 5, in order to oxidize and remove impurities from molten iron produced in blast furnaces, a huge amount of O<sub>2</sub> is blown into the molten iron. As a result of a reaction with O<sub>2</sub>, a great amount of CO<sub>2</sub> and CO will be generated. Since CO is a combustible gas, recovering it as a fuel material in gas holders and reusing it as a fuel for incineration at other processes will contribute to energy conservation and help reduce CO<sub>2</sub> emissions in overall processes in steelmaking. In addition, if O<sub>2</sub> remains in the gas to be stored in gas holders, it may cause an explosion. That is why monitoring is required. Therefore, by measuring the O<sub>2</sub> concentration and controlling valves, gases with high O<sub>2</sub> concentration are exhausted, while combustible gases whose concentration becomes sufficiently low are recovered.

The magnetic O<sub>2</sub> concentration meters, which have been used conventionally for this process, require gas sampling devices. Since the response speed of an entire device will differ depending on the distance from the sampling point and the structure of gas sampling devices, it takes 30 seconds to 3 minutes, in general. Longer response time means loss of opportunities to recover combustible gases. Applying the high-speed

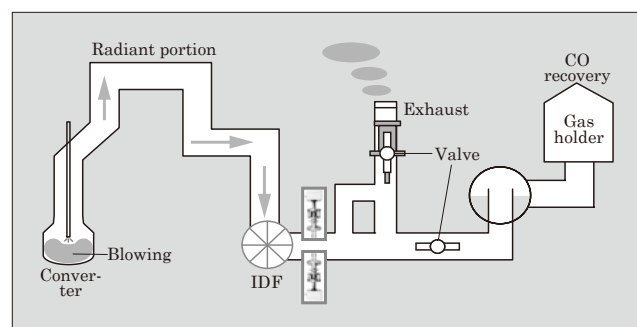


Fig.5 Schematic diagram of converter process

Table 1 “ZSS” effects on combustible gas recovery

Response speed of conventional model	30 sec.	1 min.	1 min. 30 sec.	2 min.	3 min.
Combustible gas recovery increased rate	2.7%	6.1%	9.4%	12.7%	19.4%
Annual economic effects	13.68 million yen	30.91 million yen	47.46 million yen	64.36 million yen	98.32 million yen

Size of converter:

- Converter capacity: 250 t/charge (15 min./charge)
- Annual gross output of steel: 1.4 million tons (per converter)
- Amount of heat recovered: 200,000 kcal/t (C heavy oil cost: calculated at 1.81 yen/1,000 kcal)

response ZSS will effectively help to improve the recovery rate of combustible gases.

The results of a trial calculation of the economic benefits related to recovering combustible gas by implementing ZSS is shown in Table 1. If the response speed of a magnetic O<sub>2</sub> concentration meter used for combustible gas recovery in a converter is 30 seconds to 3 minutes, the economic benefits gained from the improved combustible gas recovery by switching from a magnetic O<sub>2</sub> concentration meter to ZSS becomes 13 million yen or more annually. Installation cost can be recovered in half a year as a moderate estimate.

Moreover, if the concentration of CO in recovered gas is not sufficiently high, even when its O<sub>2</sub> concentration is low, the recovered gas cannot be reused. By directly measuring the CO concentration, it becomes possible to upgrade the quality of combustible gas to be recovered.

In this way, in addition to securing safety by monitoring the O<sub>2</sub> concentration, which has been performed for some time, introducing the ZSS has made it possible to conserve energy by improving the recovery rate of reusable combustible gases.

#### 4.2 Optimization of incineration efficiency in incineration processes

An incineration control system is required in various processes such as in boilers for industrial use, garbage incineration plants and industrial furnaces.

The relation between the air ratio and incineration efficiency in incineration processes is shown in Fig. 6. The air ratio refers to the ratio of actual amount of air to the theoretical amount of air. With an adequate air ratio, fuel is combusted completely, and this enables the highest incineration efficiency and sufficiently reduces the generation of nitrogen oxide (NO<sub>x</sub>) and sulfur oxide (SO<sub>x</sub>) as a result. Accordingly, as shown in Fig. 7, optimized incineration can be secured by measuring the O<sub>2</sub> concentration and feeding back the results to the system.

However, the air ratio in an actual incinerator is not consistent, being affected by the structure and temperature of the furnace. Even when the O<sub>2</sub> concentration at the measurement portion is controlled

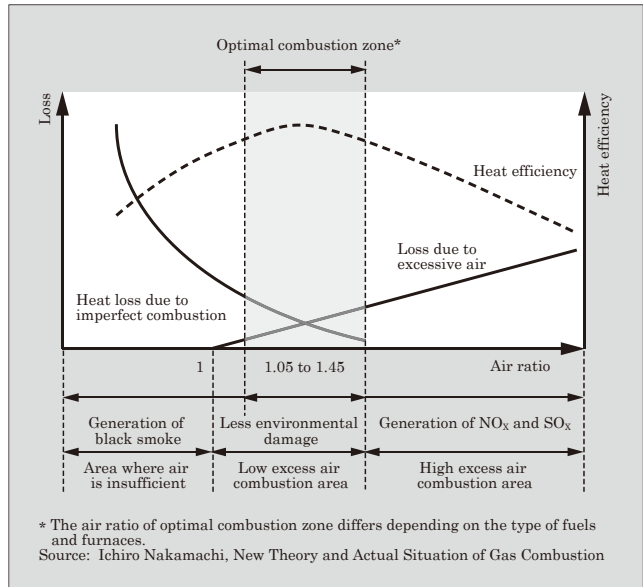


Fig.6 Relation between air ratio and incineration efficiency

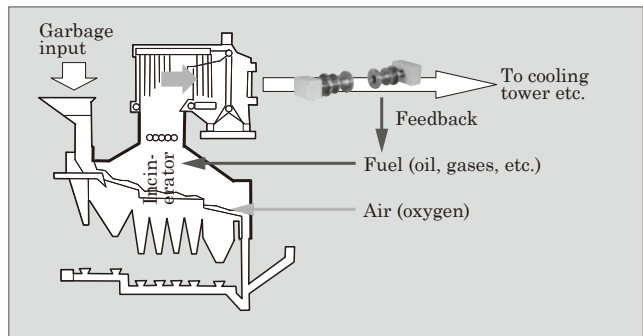


Fig.7 Schematic diagram of incineration process (example of incinerator)

adequately, some degree of imperfect combustion is inevitable. Figure 6 shows how the amount of heat loss increases rapidly when combustion is imperfect. In addition, CO and black smoke are also generated. That is why the occurrence of imperfect combustion should be restricted also from the viewpoint of environmental conservation. For these reasons, incinerators are generally operated at an excess O<sub>2</sub> ratio compared to the optimal air ratio. On the other hand, although the increased amount is not as much as in the case of imperfect combustion, excess air also becomes a cause of heat loss. Therefore, the O<sub>2</sub> concentration should be minimized as much as possible to enhance the incineration efficiency.

By measuring not only O<sub>2</sub> but also CO at the same time and performing incineration control, the optimal air ratio will be achieved. If ZSS is used soon after incinerator to measure the exhaust, CO can be detected immediately. In this way, this system will simultaneously reduce the ratio of excess air and CO emissions as much as possible.

Introducing ZSS makes it possible to optimize the incineration efficiency and contribute to further energy

conservation as a result.

## 5. Postscript

In this paper we have outlined the cross stack laser gas analyzer “ZSS” that contributes to energy conservation. By achieving the measurement of two components ( $O_2+CO$ ), it becomes possible to apply this sys-

tem to process control. We intend to acquire explosion-proof certification to expand its application area. This structure with meters for two components is applicable also for other component combinations. We will develop this system further while considering market needs.

We are determined to work on the development of gas analyzers that contribute to comprehensive energy conservation in processes.





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