New Infrared Gas Analyzer

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1. Introduction

Fuji Electric's NDIR (Non-Dispersive Infrared) gas analyzers have been widely used in many applications including polution monitoring.

The newly developed dual beam infrared gas analyzer (models: ZRF, ZRG) has a zirconia oxygen sensor for measuring oxygen. An internal microprocessor increases functionality, improves operation ease, and simplifies maintenance. A variety of functions required for analyzing systems can be installed internally, resulting in a very simple and cost effective system structure.

The compact 19 inch model ZRF and ZRG (for measuring low concentrations) shown in **Figs. 1** and **2** respectively have both passed Japanese measurement standard tests.

A single beam infrared gas analyzer (model: ZRH) is shown in **Fig. 3**. This 19inch model is even more compact and also has an internal microprocessor to increase functionality and simplify maintenance.

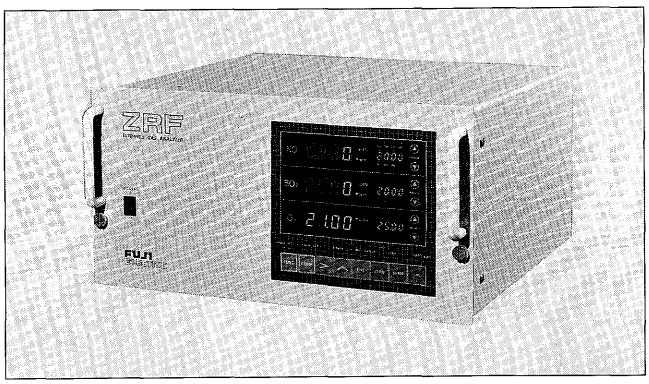
2. Features

2.1 ZRF/ZRG

2.1.1 A maximum of 3 components measurement

One or two components such as NO_x, SO_2, CO, CO_2, etc. can be measured. With the addition of a special zirconia sensor (model: ZFK3), O_2 is also measured. With this special sensor, three components are measured simultaneously.

Fig. 1 Infrared gas analyzer (ZRF)



2.1.2 Multi-functionality and ease of use

Since a wide variety of options can be installed inside the analyzer, there is no need for separate automatic calibration or processing equipment as in the past. This makes system structure much simpler. Also in contrast to past systems, operation is controlled entirely from the analyzer's control panel, resulting in increased operation ease and simplified maintenance.

(1) Automatic calibration function (option)

An automatic calibration function can be installed to calibrate a maximum of three components. Remote start from an external signal is possible.

(2) O_2 correction function (option)

O_2 correction for NO_x or CO is processed from data received by a specialized zirconia O_2 sensor (ZFK3) or other O_2 meter. A corrected value of NO_x or CO concentration is output.

(3) Value averaging computation function (option)

In addition to the instantaneous measured concentration value, a moving average value over a time period of

Fig. 2 Infrared gas analyzer (ZRG)

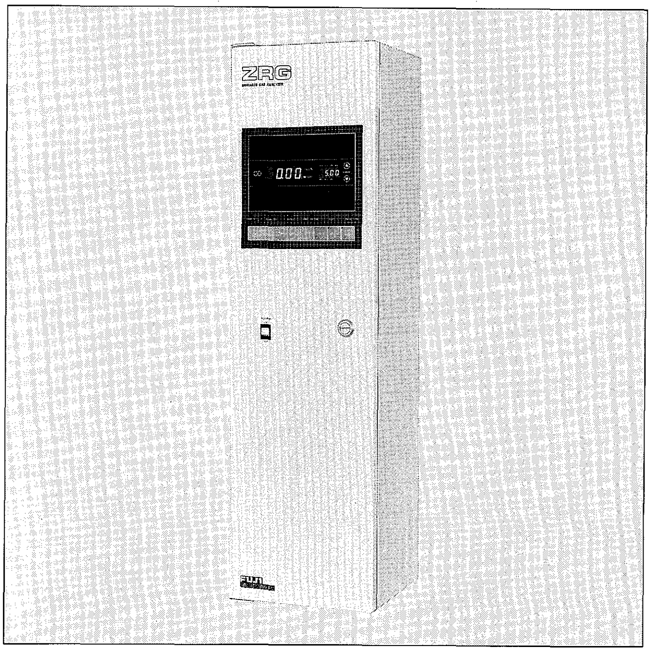


Fig. 3 Infrared gas analyzer (ZRH)

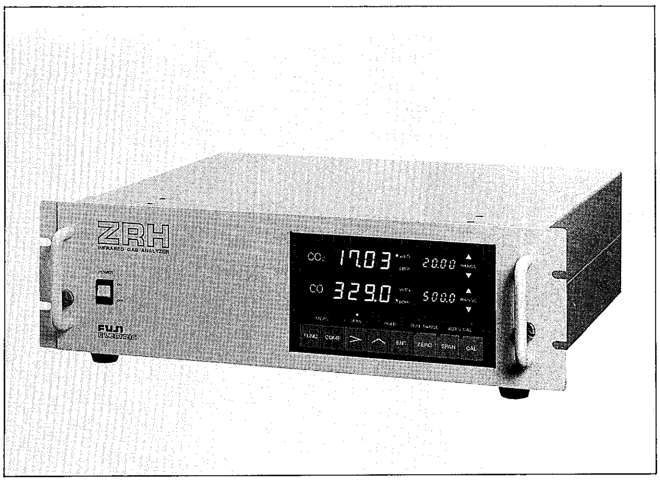
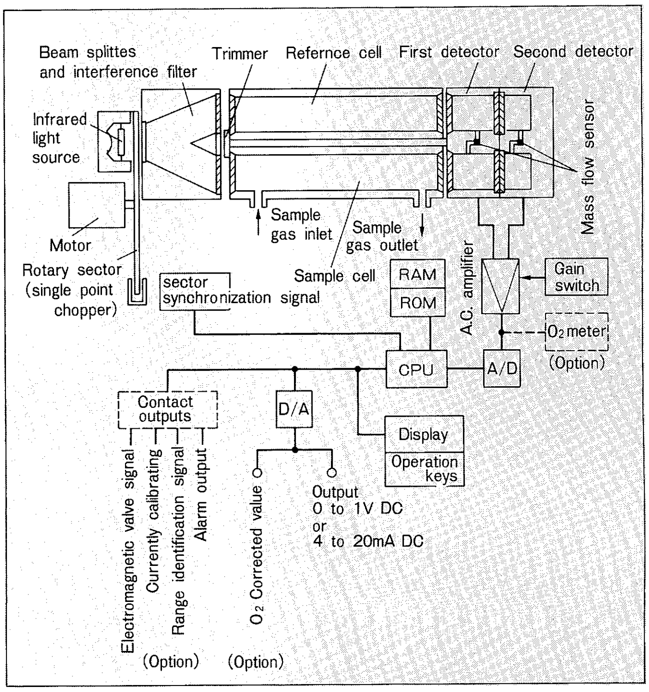


Fig. 4 Block diagram of ZRF/ZRG Infrared gas analyzer



one or four hours is also output.

(4) Upper or lower limit alarm (option)

An alarm function announces when each component reaches its upper or lower limit. A signal is sent to the alarm contact output.

(5) Remote range changeover/range identification signal (option)

The measurement range is changed by an external signal. Also a signal is sent to the range identification contact output.

(6) Easy to operate calibration

Accurate zero or span calibration is performed by simply pressing the corresponding calibration key.

(7) Self diagnostic function (option)

In the event of a malfunction, the self diagnostic function can be used to determine the type of malfunction. Maintenance can be easily performed.

2.1.3 Wide dynamic range

Using a highly sensitive and reliable mass flow type detector, a maximum range ratio of 1:20 is possible.

2.1.4 Minimal interference

By using an interference compensating detector, the effect of interference from coexisting gases in the sample gas is minimized.

2.1.5 Three types of measurement methods possible

In addition to the standard method, measurement is also possible with a differential flow method, or a sample switching method used for low concentration measurements.

2.2 ZRH

2.2.1 Multi-functionality and ease of use

A maximum of two components can be measured. Remote range changeover/range identification functions can be installed.

2.2.2 Minimal interference

Use of a serial dual-layer type detector greatly reduces the interference caused by coexisting gases.

2.2.3 Long term stability

The optical system has been improved to reduce drift caused by dirt in the measurement cell. Excellent long term stability has been achieved.

2.2.4 Simple maintenance

The straightforward construction of a single beam system simplifies maintenance and handling.

3. Operating Principles

In general, molecules consisting of different atoms have different specific absorption spectra in the infrared region. The relation between strength of infrared absorption and gas concentration is described by Lambert Bear's law.

$$I = I_0 e^{-kcl} \quad \text{.......................... (1)}$$

I_0: intensity of incident infrared light

I: intensity of the infrared light that passes through (not absorbed)

k: absorption coefficient

c: concentration of the gas component to be measured

l: length of infrared ray penetration

Infrared gas analyzers use infrared light having a wavelength corresponding to the specific absorption band for the gas under measurement. By detecting the amount of infrared light absorbed by the gas, concentration can be determined. The good selectivity and high sensitivity of this method results in one of the best gas analyzers. These anlyzers have been used in a wide variety of applications including industrial applications.

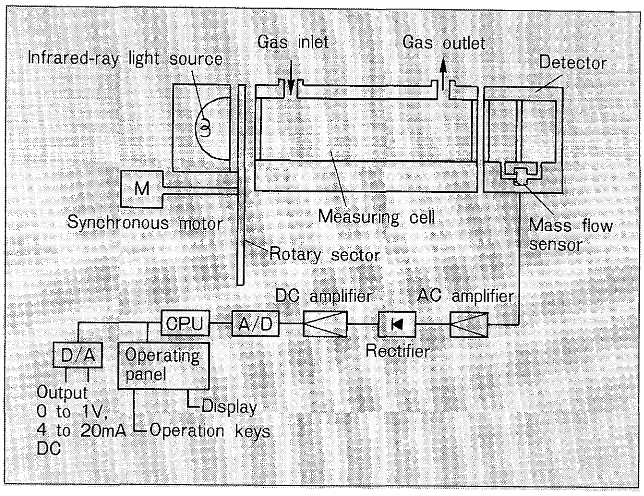
Figure 4 shows a block diagram of the ZRF/ZRG structure. Infrared ray emmitted from the infrared light source are chopped by a rotating sector with constant frequency. This intermittent light is then split into two beams by a interference filter cell. A gas to eliminate interference is filled inside the cell. This eliminates in advance the effect of absorption by the interference components. Split into two beams, the infrared light passes through both the sample cell and reference cell. Inside the sample cell, a specific wavelength of the infrared light is absorbed in an amount proportional to the concentration of the components in the sample gas. The infrared light intensity is detected when it arrives at the detector. On the other hand, since an inert gas such as N_2 is sealed in the reference cell, the incident light is not abosrbed and passes directly through to the detector.

The detectors are known as interference compensating detectors. The first detector allows infrared light to pass through to the second detector. Narrow gas passageway connects the sample cell side detection chamber and reference cell side chamber for the first and the second detectors respectively. A mass flow sensor is located in the middle of the gas passageways. The detection chamber for the first detector usually contains the same type of gas as that under measurement. This gives the detector wavelength selectivity. The second chamber contains gas which is sensitive to the interfering components. The gas contained in each detection chamber absorbs a specific wavelength of infrared light. Absorbed energy will cause the gas to expand which in turn will create a rise in pressure. If the gas to be measured is currently in the sample cell, then the amount of infrared light absorbed in the reference cell's detection chamber will be greater than that in the sample cell. Pressure in the detection chamber will become greater for the reference cell side than for the sample cell side. This pressure difference will cause a small amount of gas to flow through the gas passageway. This flow is detected by a hot wire anemometer type mass flow sensor which is constructed from two adjacent micron sized metal latices. Change in resistance is used to convert the signal. The relation of pressure difference ΔP between detection chambers to change in resistance ΔR of the sensor element is as follows. From this relation concentration of measured component can be known.

$$\Delta R \propto \Delta P \propto I_0 - I = I_0(1-e^{-kcl}) \quad \ldots\ldots\ldots\ldots (2)$$

With this relation, an electrical calculation is performed to eliminate the effect of the interference components. The calculation uses concentration values of the measured component and interference components detected at the first detector and the interference component concentration detected at the second detector. Because the infrared light which irradiates the detectors is chopped intermittantly by a rotating sector, the detector's a.c. output signal is in synchronization with the sector rotation. This signal is amplified by an alternating current amplifier and then digitized by an A-D converter. The CPU calculates values for interference and temperature compensation, as well as zero and span calibration. The signal is then linearized and displayed digitally. At the same time, the digital signal is fed back through a D-A converter where it is transformed to an analog signal of 0 to 1VDC or 4 to 20mADC.

Fig. 5 Block diagram of ZRH infrared gas analyzer



Finally, optional functions such as O_2 correction, value averaging, automatic calibration, or upper/lower limit alarm are processed if installed. Results are output as an analog signal or contact output.

The ZRH block diagram is shown in **Fig. 5**. The ZRH uses a single beam method, there is a sample cell but no reference cell. The detector consists of two chambers arranged in series. The difference in amount of infrared light absorbed by the two chambers is detected. Absorption by interference gas components can be cancelled so as to have almost no effect. By carefully setting parameters which influence detection sensitivity, drift caused by dirt in the cell is reduced, and long term stability improved.

Data from the detector is processed by a microprocessor to calculate the concentration. This value is displayed and output externally.

4. Specifications

ZRF/ZRG specifications are listed in **Tables 1, 2** and **3**. ZRH specifications are listed in **Table 4.**

5. Characteristics

ZRF/ZRG typical characteristics (for NO: 0 to 100ppm) of repeatability, influence of interference gas, temperature characteristics and drift are shown in **Tables 5** and **6**, and **Figs. 6** and **7** respectively. The influence of interference gas for ZRH (CO: 0 to 500ppm) is shown in **Table 7.**

Table 1 Standard type specifications (ZRF/ZRG)

Item \ Model		ZRF	ZRG
Power supply		100V AC, 115V AC or 220V AC, 50Hz/60Hz	
Power consumption		125 VA	
Ambient temperature		–5 to +45°C	
Ambient humidity		90%RH or less	
External dimensions		443(Width)x463(Depth)x220(Height) (mm)	220(Width)x232(Depth)x835(Height) (mm)
Weight		Approx. 20 kg	Approx. 24 kg
Installation method		19 inch rack (panel mount or table top type)	Back side mounting
Display		Concentration display - 4 digit LED, supplementary display - 4 digit LED	
Gas inlet/outlet		Rc1/4 (PT1/4 internal thread) or NPT1/4 internal thread	
One component measurement	Measured component	Minimum measurement range	Minimum measurement range
	CO	0 to 100 ppm	0 to 50 ppm
	CO_2	0 to 50 ppm	0 to 50 ppm
	NO	0 to 100 ppm	0 to 50 ppm
	SO_2	0 to 100 ppm	0 to 50 ppm
	CH_4	0 to 500 ppm	0 to 200 ppm
Two component measurement	Measured component	Minimum measurement range	Minimum measurement range
	$NO + SO_2$	0 to 250/0 to 250 ppm	0 to 100/0 to 100 ppm
	$CO + CO_2$	0 to 200/0 to 200 ppm	0 to 100/0 to 100 ppm
Output signal		0 to 1V DC or 4 to 20mA DC linear	
Repeatability		Within ±0.5% of fullscale	
Linearity		Within ±2% of fullscale	
Zero drift / Span drift		Within ±2% of fullscale/week	Within ±2% of fullscale/ week (within ±3%/week)
Response time		Within 25 seconds (90% of responses)	Within 50 seconds (90% of responses)
Optional functions	O_2 correction	0 to 1V DC or 4 to 20mA DC linear Formula for computation $C=\frac{21-O_n}{21-O_s}\cdot C_s$ C: Concentration after O_2 correction, C_s: NO_x concentration, O_s: O_2 concentration, O_n: standard value for correction	
	Remote range changeover	External input 0 to 5V DC	
	Range identification signal output	Contact output 1a contact, contact capacity 250V AC/2A (resistive load)	
	Automatic calibration	Zero, span calibration (max. 3 components calibration)	
	Average value output	Moving average over 1 hour or 4 hours, 0 to 1V DC or 4 to 20mA DC linear	
	Alarm output	Upper limit/lower limit alarm Contact output 1c contact Contact capacity 250V AC/2A (resistive load)	

* values inside parenthesis are for the 0 to 50ppm range.

Table 2 Sample switching type specifications (ZRF/ZRG)

Item \ Model	ZRF	ZRG
Measured component CO	Minimum measurement range 0 to 10 ppm	Minimum measurement range 0 to 2 ppm
Repeatability	Within ±0.5% of fullscale (within ±2%)*	
Zero drift	Within ±0.5% of fullscale/week	Within ±0.5% of fullscale/seek (Within ±1% of fullscale/week)*
Span drift	Within ±1.5% of fullscale/week	Within ±1.5% of fullscale/week (Within ±2.5% of fullscale/week)*
Response time	Within 120 seconds (90% of responses)	Within 120 seconds (90% of responses) (150 seconds)*

< Notes >
(1) * Values inside parenthesis are for the 0 to 2ppm range.
(2) Other specifications are the same as for the standard type.

Table 3 Differential flow type specifications (ZRF/ZRG)

Item \ Model		ZRF	ZRG
Measured components		Minimum measurement range	Minimum measurement range
	CO_2	350 ppm ± 50 ppm	350 ppm ± 50 ppm
	CO	0 to 100 ppm	0 to 50 ppm
Output signal	CO_2	–1 to +1V DC	
	CO	0 to 1V DC or 4 to 20mA DC linear	

< Note > Other specifications are the same as for the standard type.

6. Areas of Application

These infrared gas analyzers are used in a variety of areas. Representative examples are listed below.

(1) Emission monitoring (stationary emission source)

Table 4 ZRH specifications

Power supply		100V AC, 115V AC or 220V AC, 50Hz/60Hz
Power consumption		37VA
Ambient temperature		–5 to +45°C
Ambient humidity		90% RH or less
External dimensions		width 443 x depth 448 x height 133 (mm)
Weight		approx. 12kg
Installation method		19 inch rack mounting, panel or table top type
Display		Concentration display – 4 digit LED, Supplementary display – 4 digit LED
Gas inlet/outlet		Rc1/4 (PT1/4 internal thread) or NPT1/4 internal thread
One component measurement	Measured component	Minimum measurement range
	CO CO_2 CH_4	0 to 500ppm 0 to 500ppm 0 to 1000ppm
Two component measurement	Measured component	Standard measurement range
	CO_2 + CO	0 to 20%/0 to 500ppm
Output signal		0 to 1V DC/4 to 20mA DC
Repeatability		within ±0.5% of fullscale
Linearity		within ±2% of fullscale
Zero drift		within ±2% of sullscale/week
Span drift		
Response time		within 15 seconds (90% of responses)
Optional functions	Automatic calibration	Zero, span calibration (max. 2 components may be calibrated)
	Remote range changeover	External signal 0 to 5V
	Range identification signal output	Contact output la contact, contact capacity 250V AC/2A (resistive load)

Table 5 Repeatability (ZRF/ZRG)

Measure-ment number / Gas	First	Second	Third	Average value	Maximum deviation
Zero point	0.0ppm	–0.1ppm	–0.1ppm	–0.07ppm	–0.07%F.S.
Span point (94.3ppm)	94.5ppm	94.4ppm	94.3ppm	94.4ppm	0.1%F.S.

Analyzer range 0 to 100 ppm NO

Table 6 Influence of interference gas (ZRF/ZRG)

Interference gas / Item	Saturated H_2O at 0°C	15.6% CO_2	489ppm NH_3	1,490ppm CH_4
Interference error (ppm of NO)	–0.4ppm	0.4ppm	0.8ppm	0.8ppm

Analyzer range 0 to 100 ppm NO

These infrared gas analyzers are used for air pollution protection by monitoring the concentration of NO_x, SO_2, CO, CO_2, O_2, etc. in the exhaust gas produced by electric power plants, incinerators, etc. Required functions can be internally installed for calculating the O_2 correction for NO_x or CO in order to lower dioxins, value averaging, automatic calibration, etc. These functions can be processed at the same time as a maximum of three components (including O_2) are measured, which enable to build up a simple, reliable and easy-to-operate analyzing system.

(2) Safeguarding the environment

Table 7 Influence of interference gas (ZRH)

Interference gas / Item	Sat. H_2O at 20°C	15.6% CO_2	1,490ppm CH_4
Interference error (ppm of CO)	–4 ppm	2.5 ppm	–0.5 ppm

Analyzer range 0 to 500 ppm CO

Another application is to monitor the concentration of CO gas produced by automobiles inside a tunnel or in a parking garage. A sample switching system with a catalytic converter for CO-CO_2 conversion is used for CO monitoring in ambient air. (Minimum measurement ranges are, ZRG: 0 to 2ppm, ZRF: 0 to 10ppm).

(3) Analysis of general combustion furnace emissions

By monitoring concentration levels of CO, CO_2, O_2, etc. emitted from combustion furnaces, it is possible to regulate the combustion in high efficiency to save energy.

(4) Heat treatment

A furnace environment can be controlled by monitoring levels of CO, CO_2, CH_4, etc. inside carburization, sintering, and annealing furnaces, etc.

(5) Various types of experimental uses

Experimental uses have included testing combustion equipment and analyzing animal breath, etc. A CO_2 meter with a differential flow measurement system is used for photosynthesis experiements.

(6) Gas analysis for steel or ceramic industries

(7) Gas analysis for a gas manufacturing plant

Fig. 6 Temperature characteristics (ZRF/ZRG)

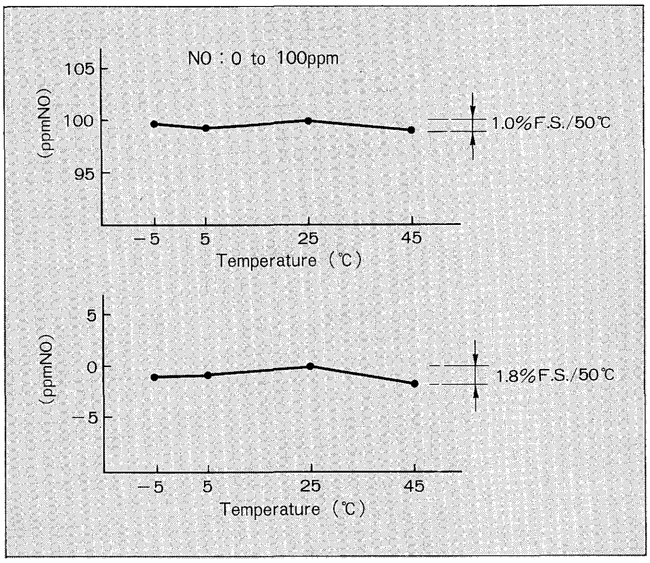
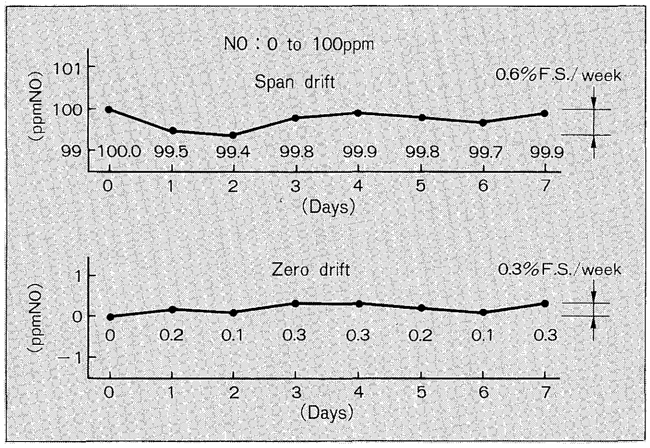


Fig. 7 Drift (ZRF/ZRG)



7. Conclusion

The newly developed infrared gas analyzer has many internal features that previously had to be purchased as separate additional equipment. This has improved system structure, operation ease and simplified maintenance. In the future there are plans to develop an entire series of gas analyzers based on this model. Fuji Electric will continue to make efforts to broaden areas of application and improve the performance and function of the analyzers.