Development of Gas Analyzer for Metal Hardening Process and Iron Manufacturing Process

FA-5000/5200 series, MPA-5000, VA-5000WM series

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We developed FA-5000/5200 series as the gas analyzer used in a metal hardening process, MPA-5000 as the gas analyzer used in an iron manufacturing process and VA-5000WM series as the gas analyzer used for a measurement of combustion exhaust gas and gas in various process application. FA-5000/5200 series were designed as a panel mount case and can measure up to three gases at the same time, such as Carbon monoxide, Carbon dioxide and Methane. Non-dispersive infrared method is used as measurement principle. MPA-5000 was designed as a 19-inches panel mount case and can measure Oxygen gas. Magnetic force method is used as measurement principle. VA-5000WM series was designed as a wall mount case and can measure up to four gases at the same time, such as Carbon monoxide, Carbon dioxide and Oxygen. Non-dispersive infrared method, Chemiluminescence method and Oxygen analysis method (magnetic force method, zirconia method and electrode method (galvanic cell type)) are used as measurement principle. This article describes the specification and characteristic of these analyzers, measurement principle used in these analyzers and improvements from conventional model.

Equipment overview

Figure 1 shows the external appearance of FA-5000/5200 series, and Table 1 shows the specification of FA-5000/5200 series. FA-5000/5200 series are the series of gas analyzers used in the metal hardening process which is carburizing or carbonitriding process. FA-5000/5200 series were designed as panel mount case and can measure up to three component gases at the same time. The NDIR (Non-Dispersive Infrared) method is used as the measurement principle for several gas components that absorbs infrared.

Figure 2 shows the external appearance of MPA-5000, and Table 2 shows the specification of MPA-5000. MPA-5000 is the versatile oxygen gas analyzer used mainly in the iron manufacturing process. MPA-5000 was designed as 19-inches panel mount case. The magnetic force method is used as the measurement principle.

Figure 3 shows the external appearance of VA-5000WM series, and Table 3 shows the specification of VA-5000WM series. VA-5000WM series is the series of analyzers used for the measurement of combustion exhaust gas and gas in the various process including iron manufacturing process. VA-5000WM series were designed as the wall mount case and can measure up to four component gases at the same tame. The NDIR method, chemiluminescence method for NO_X measurement, oxygen analysis method (magnetic force method, zirconia method and electrode method (galvanic cell type)) are used as the measurement principle in order to satisfy customer's needs.

Basics and principles

The flow sensor detector is used for the NDIR method of FA-5000/5200 series, VA-5000WM series. In general, when a molecule composed of two or more different atoms is irradiated with infrared, it absorbs infrared of a wavelength specific to the molecule based on the energy levels of vibration and rotational motion of the molecule. NDIR performs quantitative analysis by measuring this amount of absorption. The amount of infrared absorption changes depending on the concentration of the absorbing molecule (the gas component to be measured). This relationship is expressed by Lambert-Beer law of Equation 1.

$$I = I_0 \exp(-\mu c d) \quad \cdots\cdots (1)$$

I_0: Incident light intensity

I: Transmitted light intensity

Figure 1 External appearance of FA-5000 series (left), and FA-5200 series (right)

Figure 2 External appearance of MPA-5000

Figure 3 External appearance of VA-5000WM series

Table 1 Specification of FA-5000/5200 series

Model	FA-5000 series	FA-5200 series
Measurement principle	NDIR (Non-Dispersive Infrared)	
Components to be measured	CO, CO_2, CH_4, NH_3	
The number of modules	3	1
Minimum range	0~0.2 vol% (depends on component)	0~0.1 vol% (depends on component)
Maximum range	0~100 vol% (depends on component)	
Range ratio	1 : 10 (depends on component)	
Linearity	±1.0% of full scale	
Zero, span drift	±2.0% of full scale/week	
Gas flow rate	Approx. 0.5 L/min	
Response time	90% response : within 30 seconds	
Warm-up time	60 min	
External dimensions (W×H×D)	424 mm×424 mm×149 mm (depth dimension at the time of installation)	164 mm×424 mm×149 mm (depth dimension at the time of installation)
Mass	Approx. 23 kg	Approx. 11 kg

Table 2 Specification of MPA-5000

Specification of carrier gas	Nitrogen	Ambient
Measurement principle	Magnetic force method	
Component to be measured	O_2	
Minimum range	0~1 vol%	0~10 vol%
Maximum range	0~100 vol%	
Range ratio	1 : 10	
Linearity	±1.0% of full scale	
Zero, span drift	±2.0% of full scale/week	±2.0% of full scale/day
Gas flow rate	Approx. 0.5 L/min	
Response time	90% response : within 30 seconds	
Warm-up time	60 min	
External dimensions (W×H×D)	430 mm×132 mm×380 mm	
Mass	Approx. 13 kg	

Table 3 Specification of VA-5000WM series

Measurement principle	NDIR (Non-Dispersive Infrared)	CLA (Chemiluminescence)	Magnetic force method	Zirconia method	Electrode method (galvanic cell type)
Components to be measured	CO, CO_2, CH_4, SO_2, N_2O etc.	NO	O_2		
Minimum range	0~50 ppm (depends on component)	0~20 ppm	0~5 vol%		
Maximum range	0~100 vol% (depends on component)	0~5000 ppm	0~100 vol%	0~25 vol%	
Range ratio	1 : 10	1 : 100	1 : 10	1 : 5	
Linearity	±1.0% of full scele				
Zero, span drift	±2.0% of full scale/week				±1.0% of full scale/day
Gas flow rate	Approx. 0.5 L/min	Approx. 0.3 L/min	Approx. 0.5 L/min		
Response time	90% response : within 30 seconds				
Warm-up time	60 min			20 min	40 min
External dimensions (W×H×D)	424 mm×484 mm×206 mm				
Mass	14~24 kg (depens on the combination of mounted components)				

c: Concentration of infrared absorbing molecule (gas component to be measured)

μ: Absorption coefficient (constant determined by molecule type and wavelength)

d: Thickness of infrared absorbing molecular layer (gas layer)

Because I_0, μ and d are constants determined by the gas component species to be measured and the device, if the transmitted light intensity "I" is measured by analyzer, the concentration of the gas component to be measured "c" can be determined. At that time, the selection of the infrared wavelength, which detector responds on is for great importance, in order not to be affected by the absorption of the coexisting components. The pneumatic detector used in the FA-5000/5200 series and the VA-5000WM series basically has excellent wavelength selectivity due to the same kind of gas enclosed in the detector as the measurement component.[1] Figure 4 shows the structure of NDIR measurement module. The infrared emitted from the light source passes through the measurement cell or reference cell, is collected by the light collection block and proceeded to the detector. The two infrareds are interrupted by the chopper, and the transmitted light of the measurement cell and the transmitted light of the reference cell are alternately proceeded in the detector.

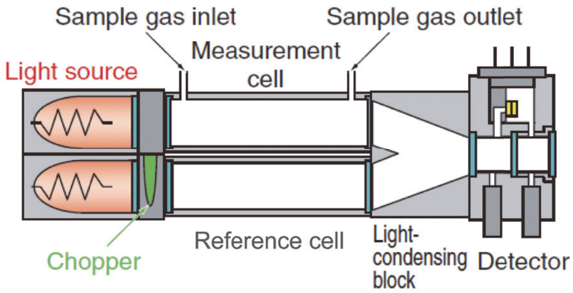

Figure 4 Structure of NDIR measurement module

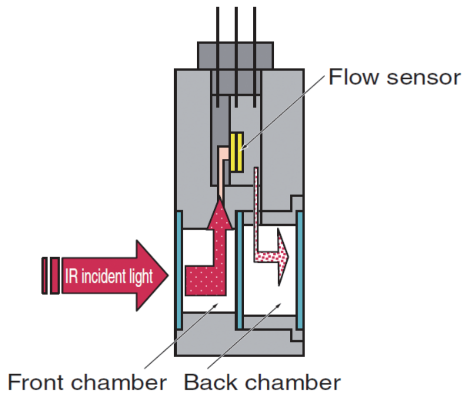

Figure 5 Structure of flow sensor type detector

Figure 5 shows the structure of flow sensor type detector. The detector has two light receiving chambers, a front chamber and a back chamber, and a flow sensor based on hot wire resistor is installed between them. In the light receiving chamber, the same kind of gas as the measurement component has infrared absorption is enclosed. When the gas component to be measured is present in the measurement cell, absorption of infrared according to the gas concentration occurs, and the amount of infrared transmitted through the measurement cell decreases. On the other hand, because the reference cell is filled with a gas that does not absorb infrared, the amount of infrared transmitted through the reference cell does not decrease and is constant. Since the transmitted light of the measurement cell and the transmitted light of the reference cell are alternately proceeded to the detector by the chopper, different amount of infrared alternately enters into the detector. The gas in the front and back chambers of the detector repeats expansion and contraction due to the temporal change in the amount of incident infrared, and the infrared absorption by the gas in the front chamber reduces the amount of infrared incident on the back chamber. The amount of expansion and contraction corresponds to the temporal change of the amount of infrared incident in the chamber is larger in the gas in the front chamber than the back chamber. As a result, gas movement occurs between the front and back chambers. The flow sensor consists of two hot wire resistors, and is installed perpendicularly to the direction of gas flow from the front chamber to the back chamber with a voltage applied to be higher than the ambient temperature. When the gas flows from the front chamber to the back chamber, the temperature of the front chamber side resistor decreases and the temperature of the back chamber side resistor increases. Conversely, when the gas flows from the back chamber to the front chamber, the temperature of the back chamber side resistor decreases and the temperature of the front chamber side resistor increases.

By detecting the change in resistance due to these temperature changes as a voltage change with the bridge circuit shown in Figure 6, the change in infrared absorption is taken out as an AC electrical signal.

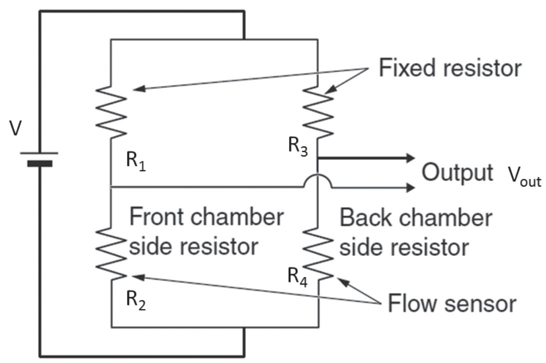

Figure 6 Bridge circuit

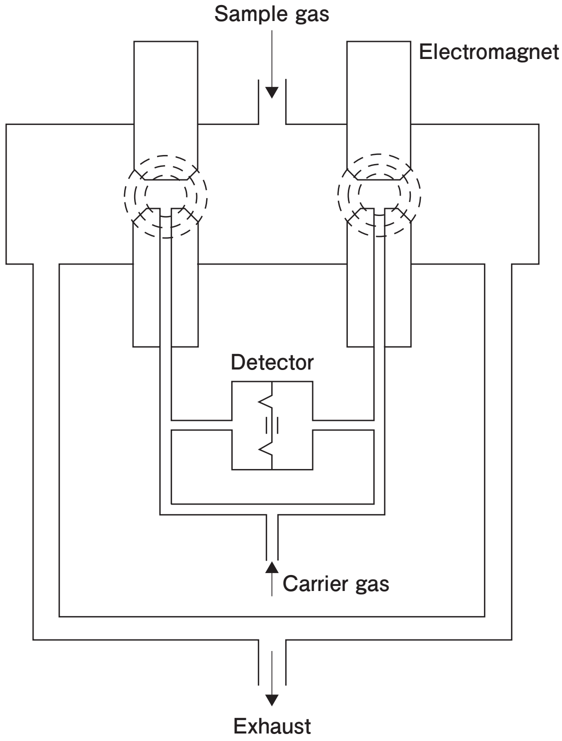

Figure 7 Pressure detector structure of magnetic force method

A pressure detector is used in the MPA-5000. Figure 7 shows the pressure detector structure of magnetic force method. In the presence of oxygen, which is a paramagnetic gas, in a nonuniform magnetic field, the oxygen is attracted to the stronger side of the magnetic field, and the pressure in that part rises. In general, the pressure rise at that time is represented by Equation 2.

$$\Delta P = \frac{1}{2} H^2 \cdot X \cdot C \quad \cdots\cdots (2)$$

H: Magnetic field strength
X: Magnetic susceptibility of the paramagnetic substance (Oxygen)
C: Oxygen concentration difference between sample gas and carrier gas

This pressure rise is extracted out of the magnetic field using carrier gas, detected by a condenser microphone, and converted into an electrical signal. Nitrogen or air is used for the carrier gas. The magnetic field is generated by an AC-driven electromagnet, and the signal is processed as an AC signal, so stable measured values can be obtained.

Improvements from conventional model

FA-5000/5200 series: Accuracy improvement of measurement value to ambient temperature change

If the temperature of the gas component to be measured in the measurement cell and detector temperature of the NDIR measurement module changes with the ambient temperature change, the measurement value is significantly influenced by these temperature change. In the conventional model FA-700 and FA-3000, the change of measurement value with temperature change of the NDIR measurement module itself is obtained experimentally, the correction formula is calculated from the average value of the results, and the correction calculation is performed with the correction formula. However, this change of measurement value is large, and the variation of the change of measurement value for each NDIR measurement module is also large, so there was a problem in the accuracy of correction calculation. Therefore, in this model FA-5000/5200 series, we introduced a mechanism to keep the temperature of the cell and detector of NDIR measurement module constant. As a result, the change of measurement value due to ambient temperature change and variations in change of measurement values of each NDIR measurement module were reduced, and the accuracy of the correction calculation has been improved.

MPA-5000: Lineup addition of ambient air carrier gas specification

In principle, MPA-5000 requires a carrier gas for sample gas measurement. The conventional model MPA-3000 used Nitrogen as a carrier gas, and the customer had to prepare a Nitrogen gas cylinder. In this model, the ambient air can be used as the carrier gas according to the customer's request, and the running cost can be reduced.

VA-5000WM series: Space saving at measurement site

The VA-5000WM series was developed as a lineup addition to the VA-5000 series.[2] The VA-5000 series uses a 19-inches panel mount case and requires a cabinet for installation. On the other hand, the VA-5000WM series uses a wall mount case, so it can be installed directly on the wall without the need for a cabinet during installation. As a result, the VA-5000WM series can be installed even in a site with limited space, enabling space saving at the customer's site.

Improved operability

The FA-5000/5200 series, MPA-5000, and VA-5000WM series emphasize the visibility and have adopted 5.7-inches color LCD screen and touch panel. Conventionally, if there was no peripheral device such as a data logger outside the analyzer, it was not possible to store gas concentration data or check the trend. But it takes tremendous efforts and time to prepare the peripheral device, and also requires its installation space. As an improvement, by displaying the trend graph shown in Figure 8 on the LCD screen, it became possible to visualize the trend of the measurement value and to grasp the measurement state

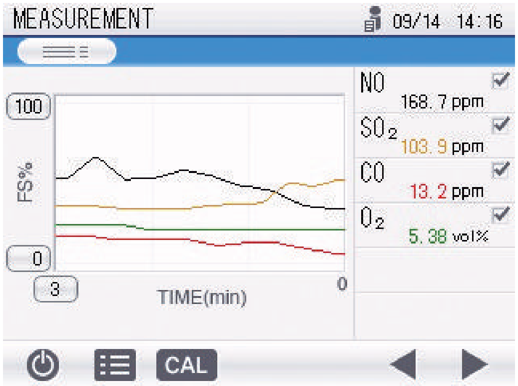

Figure 8 Trend graph of VA-5000WM series

instantly. In addition, the data logging function is built into the device, and measurement values, measurement time and event information at the time of measurement can be recorded in real time, and the data can be extracted using a USB memory. Therefore, it is not necessary to install the data logger outside the analyzer, and gas measurement can be performed more simply.

Conclusion

Iron is mainly used in the automobile industry and construction industry, and is an essential material for human being to live. Currently, iron is manufactured mainly in Asia, and continuous manufacture is expected in the future. Although CO_2 is emitted with iron manufacture, the amount of CO_2 emission of steelmaking industry is the largest in the Japanese manufacturing industry, accounting for around 30% of the total.[3] Therefore, Japan is working on reduce of CO_2 emission associated with iron manufacture. MPA-5000 is mainly used in ironworks to efficiently manufacture high quality iron, and FA-5000/5200 series are used in metal hardening process to increase the strength of iron. Furthermore, since VA-5000WM series can measure CO_2 concentration in exhaust combustion gas, it is possible to monitor CO_2 emissions associated with iron manufacture. Although the above is an example, we believe that these analyzers can support the development of industry around the world and contribute greatly to the preservation of the global environment.

References

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[2] Kazunori MIZUMOTO, Development of the Multi-Component Gas Analyzer VA-5000 Series, Readout, **50**, pp.51-55(2018).
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