Feature Article

# Feature Article

## VA-3000 Series Multiple Gas Analyzer

Norikazu Iwata

VA-3000 Series Multiple Gas Analyzer is a gas analyzer that enables users to measure three components at the same time within a single instrument. As a measurement principle, it can consist of the non-dispersive infrared method, the chemiluminescence method and the oxygen analysis method (magnetopneumatic type, zirconia type, and galvanic cell type) of measurement modules. In the measurement module based on non-dispersive infrared absorption, high vibration resistance and compact size have been achieved by using a flow-sensor type detector. In this article, we describe the features of the VA-3000 series as well as applications to fuel cell systems that are attracting great attention as a next-generation energy source.

### Introduction

The history of HORIBA's gas analysis equipment originated from a scentometer (breath analyzer) intended for medical use. Today, the company is covering numerous application fields including automobile exhaust gas measurement systems, air pollution monitoring systems, stack gas analysis systems, etc. At present, the issues and needs that gas analyzer systems are facing are dynamically changing over various fields from environmental problems to assessment of new energy. Analyzing gas components has become very important in such fields as fuel cell development, catalytic agent research, bio-gas research, aeration tank[*1] monitoring, engine combustion efficiency research, etc. Looking at today's needs and seeking true versatility, we have developed the VA-3000 series multiple gas analyzer system.

*1 : An aeration tank is a tank for encouraging microorganism proliferation by blowing air into polluted sludge including microorganism-contaminated sludge.

### Product Overview

The external appearance and main specifications of the VA-3000 system are shown in Figure 1 and Table 1, respectively. This system, assembled into a 19-inch panel-mount case, can accommodate up to three gas component measurements simultaneously. The VA-3000 uses a chemiluminescence method for measuring nitrogen oxides ($NO_x$). It has three type measurement methods, magnetopneumatic, galvanic cell and zirconia types, are used for measuring oxygen, and a NDIR (Non Dispersive Infrared) method is used for measuring various components that absorb infrared light. Now realized is a versatile multiple gas analyzer system that can meet numerous needs for analyzing gas components. In the NDIR measurement module, a newly developed flow sensor type detector has been employed.

Figure 1 External Appearance of the VA-3000

### Measurement Principle of the Flow Sensor Type Detector

When a molecule consisting of more than two different atoms is illuminated by infrared light, transition between energy levels of vibration and rotation of the molecule occurs in general, and infrared light having a wavelength that is particular to the molecule is absorbed. NDIR measures the amount of absorption of infrared to obtain a quantitative analysis of a particular gas component.
The amount of infrared absorption changes depending on the concentration of molecules to be measured. This relationship is expressed by equation (1) given by the Lambert-Beer law.

Table 1 Specifications of VA-3000 System

| Measurement principle | NDIR (Non-Dispersive Infrared) | CLA (Chemi-luminescence) | MPA (Magneto-pneumatic) | Zirconia | Galvanic cell |
|---|---|---|---|---|---|
| Components to be measured | $CO$, $CO_2$, $CH_4$, $SO_2$, $N_2O$, etc. | NO | $O_2$ | | |
| Minimum range | 0 to 100ppm (depends on component) | 0 to 20ppm | 0 to 5% (vol) | 0 to 5% (vol) | 0 to 5% (vol) |
| Maximum range | 0 to 100% (vol) (depends on component) | 0 to 5000ppm | 0 to 100% (vol) | 0 to 25% (vol) | 0 to 25% (vol) |
| Range ratio | 1:10 | 1:100 | 1:10 | 1:5 | 1:5 |
| Linearity | ±1.0% of full scale | | | | |
| Drift | ±2.0% of full scale/week | | | | ±1.0% of full scale/day |
| Response time | 90% response: within 30 seconds | | | | |
| Warm-up time | Approx. 20 min. | Approx. 60 min. | Approx.60 min. | Approx. 20 min. | Approx. 40 min. |
| Gas flow quantity | Approx. 0.5 L/min | | | | |
| External Dimensions | 430 mm(W) x 132 mm(H) x 550 mm(D) | | | | |
| Mass | Approx.20 kg | | | | |

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

$I_0$ : Incident light intensity

$I$ : Transmitted light intensity

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

$\mu$: Absorption coefficient (determined by molecule type and wavelength)

$d$ : Thickness of absorbing molecule layer (gas layer)

Since $I_0$, $\mu$ and $d$ are constants determined by the type of gas to be measured and equipment, it is possible to obtain the concentration ($c$) of gas component by measuring the transmitted light intensity ($I$). In this method, the wavelength selectivity of the infrared detector is an important factor for measuring absorption without being affected by other gas components. In the VA-3000 system, excellent wavelength selectivity has been realized by using a pneumatic type detector into which in principle, the same kind of gas component as the target gas component is charged[1].

Figure 2 shows the structure of the NDIR measurement module used in the VA-3000 system. Light-source infrared light goes through the measurement cell or comparison cell and enters into the detector after being condensed by the light-condensing block. These two infrared beams are split using a rotating chopper as light enters alternately into the detector.

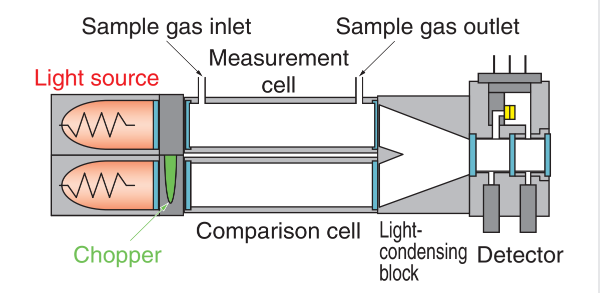



Figure 2 Structure of NDIR Measurement Module Used in VA-3000 System

Figure 3 shows a structure of flow sensor type detector used in the NDIR measurement module of the VA-3000 system. This detector has two light input chambers; a front chamber and a back chamber, and a flow sensor using a hot wire resistance located between the two chambers. Inside the light input chambers, the same kind of gas as the gas component to be measured is enclosed. If the target gas component to be measured exists inside the measurement cell, infrared light is absorbed in proportion to gas concentration and, as a result, the intensity of transmitted infrared light through the measurement cell decreases. On the other hand, if a gas that does not absorb infrared light is enclosed, the infrared light is not attenuated, that is, the intensity of transmitted light will be unchanged. Since the transmitted light coming via the measurement cell and the light coming via the comparison cell enter alternately into the detector due to the operation of the chopper, differing intensities of infrared light alternately enter into the detector. Gas enclosed in the front and back-chambers of the detector repeatedly contracts and expands depending on the exposure time and intensity of the incident infrared light. Since the amount of infrared light incident to the back chamber is less than that incident to the front chamber (because of absorption in the front chamber), expansion and contraction of gas in the front chamber, corresponding to the exposure and intensity of light, is greater than in the back chamber. As the result, there is

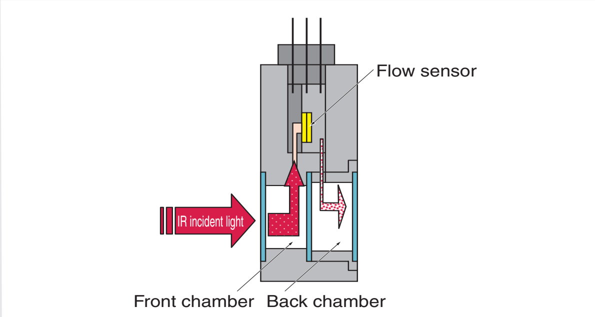



Figure 3 Structure of Flow Sensor Type Detector

movement of gas between the front- and the back-chambers. The flow sensor comprised of two hot-wire resistors is placed perpendicular to the direction of gas flow from the front chamber to the back chamber. The hot-wire resistors are biased to keep their temperature higher than the ambient temperature. When gas flows from the front chamber to the back chamber, the temperature of hot-wire resistor of the front chamber side decreases and the temperature of hot-wire resistor of the back chamber side increases, and vice versa. Since the resistance value depends on the temperature, by detecting the change of resistance value using a bridge circuit as shown in Figure 4 as a change of voltage, it is possible to obtain the changing infrared absorption as an alternating electrical signal.

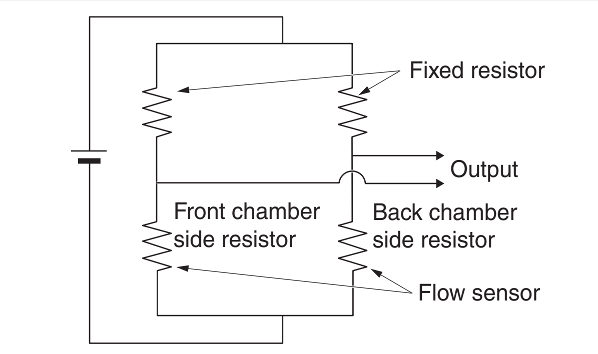



Figure 4 Bridge Circuit

## Improved Versatility

The VA-3000 can simultaneously measure three gas components due to the compactness of its measurement module, has improved anti-vibration capabilities using flow-sensor detectors and can provide analysis measurement for a wide range of needs. In the following sections, we will describe the features and benefits of the VA-3000.

### Simultaneous measurement of up to three gas components

This ability to measure up to three gas components has been realized through the compact light-weight design of the infrared detector by adopting a flow sensor type detector as well as by reviewing the whole analysis system to spur efforts to miniaturize all components. Since the VA-3000 is comprised of three independent measurement modules, it is possible to freely select the gas component to be measured and the range of concentration measurement without being limited by other gas components. Through this feature, in cases when evaluating a system by continuously monitoring multiple gas components (or measuring the same components with multiple measurement ranges) such as in a fuel cell system, it is possible to greatly save the number of analyzer installations required. Also, since one can simultaneously measure three different gas, when continuously monitoring a certain component gas concentration and executing process control for a parallel installation of multiple process lines, it is possible to reduce the number of analyzer installations.

### Improved Anti-Vibration Capability

In the VA-3000 system, the detector has been changed from the previous condenser microphone type to a flow sensor type. As an advantage of adopting this type of detector, there is an improved anti-vibration capability. In the conventional condenser microphone type detector, electrical signals converted from vibration of the microphone's diaphragm caused by changes of pressure between the two light accepting chambers. While in the flow sensor type detector, the difference of gas expansion between the two light input chambers is detected as a difference of gas flow amount, and, since there are no mechanical moving parts within the detector, it is possible to suppress the effect of vibration. Figure 5 shows a comparison of the effects of vibration between the condenser microphone type detector and the flow sensor type detector. The direction of applied vibration is perpendicular to condenser film. While changing the vibration frequency, the output signals from both detectors was observed. In this experiment, strong vibration was applied that is not realistic in normal usage conditions in order to make it easy to compare the effects of vibration on the detector. From Figure 5, we can see that the anti-vibration capability has been greatly improved by adopting the flow sensor type detector.

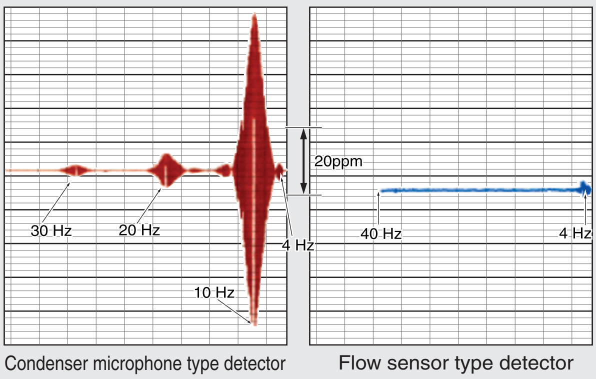



Figure 5 Comparison of Effect of Vibration

## Reduction of Interference Effects

In the NDIR measurement module, gas components are identified and measured by using the infrared absorption characteristics of each component. But, in cases when the absorption wavelength range of the target gas is overlapping with one of the other gas components in the sample, the result may be influenced. As typical examples of such cases, we can cite the influence of $CO_2$ on CO measurement, and the influence of $H_2O$ on $SO_2$ measurement. If there exists only one component, the influence of this gas component can be eliminated by a conventional method that arranges two detectors in series with different gas concentrations enclosed. However, with this method, it is impossible to eliminate interference when there exists two types of interference component in the sample gas. For example, influence of $CO_2$ and $N_2O$ on CO measurement, and the influence of $H_2O$ and $CH_4$ on $SO_2$ measurement. Since the VA-3000 can simultaneously measure up to three gas components, even if there exists two types of interference component, the system can measure the target gas component with a high accuracy by measuring one of the interference components added to the target gas component to be measured simultaneously and by internally processing these results.

## Application to fuel Cell Systems

At present, the fuel cell is attracting great attentions from industry as a new energy source that has high compound efficiency including power generation efficiency and waste heat recovery and is also environmentally friendly. There are of course, numerous types of fuel cell. A typical example is the type that extracts hydrogen from gas fuels such as utility gas and LPG and obtains electrical energy from an electrochemical reaction between hydrogen and oxygen. When developing and evaluating such a fuel cell, it is important to establish the gas composition at each stage. Herein is described a fuel cell application of the VA-3000 citing as an example, Polymer Electrolyte fuels cell (PEFC) that are anticipated to become domestic units because of such features as low operating temperature, small size and light weight. Figure 6 shows the concept of a PEFC system and an application example of the VA-3000.

Fuel gas such as utility gas and LPG first has its sulfur components removed by desulfurization, then it is reformed so as to consist of $H_2$, CO, $CO_2$, $CH_4$, $H_2O$ through the chemical reaction as shown in equation (2) and (3).

$$CH_4 + H_2O \longleftrightarrow CO + 3\,H_2 \cdots\cdots\cdots\cdots (2)$$

$$CO + H_2O \longleftrightarrow CO_2 + H_2 \cdots\cdots\cdots\cdots (3)$$

This reformed gas is further processed to reduce its CO concentration to as low as 10ppm by CO eliminator while increasing its $H_2$ concentration using the reaction of equation (3) by CO transformer and introduction into the cell stack. Although heating is required for inducing reaction in the reformer, the temperature of the reformer is increased by burning a part of the fuel gas along with off-gas that has passed through cell stack. By installing a VA-3000 into each stage of this fuel cell system, it becomes possible to monitor the reaction rate of the CO transformer, CO removal rate of CO eliminator, and reaction efficiency in the cell stack. We believe that in ways like this, the VA-3000 will be able to greatly contribute to development and evaluation of fuel cell systems.

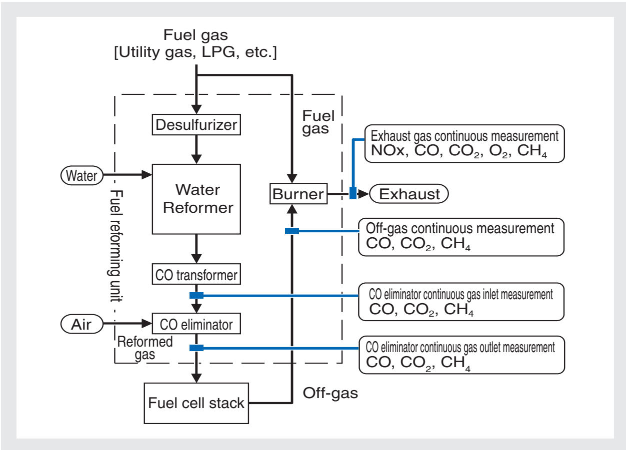


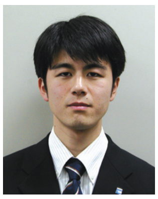

Figure 6 Concept of PEFC System and Application Example of VA-3000

## Conclusion

We have described improvements in versatility of the VA-3000 series multiple gas analyzer and introduced an application example to monitoring the power generating processes in fuel cell systems. The VA-3000 is a versatile analyzer that can address numerous wide-ranging needs from research and development to monitoring environmental gas concentrations. We believe that we will be able to contribute to industrial development and global environmental preservation through this excellent analyzer.

## Reference

[1] Junji Aoki, "Pneumatic infrared detector," *Readout*, 7, 64-71 (1993).



Norikazu Iwata
HORIBA, Ltd.
Gas Measurement R&D Dept.
Process Instruments