Technical Information

MG8G/MG8E
Paramagnetic Oxygen Analyzers

TI 11P03A05-01E

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1. Introduction

The MG8G/MG8E Paramagnetic Oxygen Analyzers can measure the oxygen concentration in a gas mixture with high precision. They do this based on the principle that oxygen is a paramagnetic material (magnetically susceptible). Unlike zirconia oxygen analyzers, the MG8G/MG8E analyzers can also measure the oxygen concentration in a flammable gas mixture.

The MG8G/MG8E Paramagnetic Oxygen Analyzers use a magnetic proportional flow rate sensor that was developed by Yokogawa to improve the performance of its magnetic wind sensors. This has the following features:

- Clean auxiliary gas (N_2) flows past the sensor in the detection unit without coming into contact with the sample gas, ensuring long-term measurement stability even when corrosive or contaminated gas is measured.
- Thermistors with high sensitivity and fast response times directly detect changes in the flow rate of the auxiliary gas, achieving a 90% response within 3 seconds.
- There are no moving parts, ensuring excellent resistance to vibration and shock.
- An interference-gas compensation function ensures accurate measurements even when flammable background gases with magnetic properties (having a much lower level of magnetic susceptibility compared to oxygen) are present.
- Excellent indicating stability in the vicinity of zero makes it suitable for low-concentration measurements (e.g. for safety control).

This technical information document (TI 11P03A05-01E) was prepared with the purpose of helping users understand and make the best use of these features of the MG8G/MG8E Paramagnetic Oxygen Analyzers. It describes the measurement methods used by various types of oxygen analyzers as well as their features and applications, the design and operation of the MG8G/MG8E Paramagnetic Oxygen Analyzers, and the effects and characteristics of interference gases.

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2. Types and Applications of Oxygen Analyzers

Oxygen, which makes up about 21% of the air, is an essential element in combustion and cellular respiration. Since oxygen is involved in various types of chemical processes, the measurement and control of the oxygen concentration are very important for controlling these processes.

There are various methods for measuring the oxygen concentration, and the majority of these fall into the two following rough categories: (1) methods that use the paramagnetic property of oxygen, (2) methods that use the electrochemical property of oxygen, and (3) methods that use the absorption spectroscopy of oxygen.

2.1 Paramagnetic Oxygen Analyzers

Figure 2.1 compares the paramagnetic properties of oxygen and other gases, and only oxygen exhibits very high magnetic susceptibility; most other gases have a relatively weak attraction to magnetic fields.

Nitrogen monoxide (NO) also exhibits a fairly strong magnetic susceptibility; however, even in exhaust gases its concentration is approximately only 100 ppm, which is so low that its paramagnetic property can be ignored.

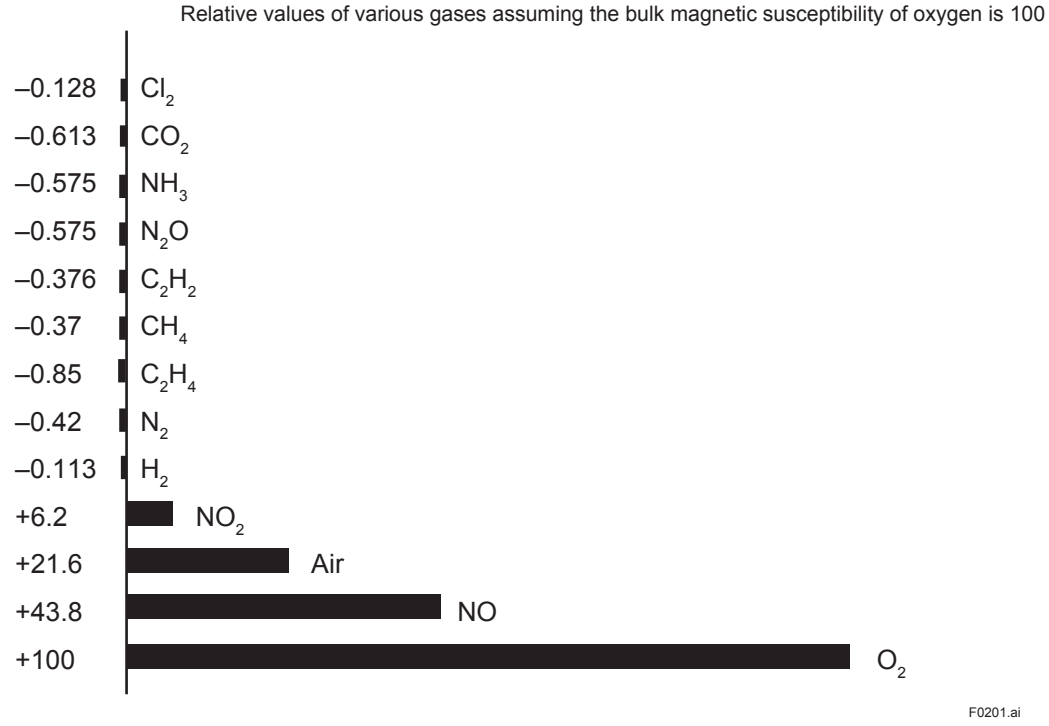


Figure 2.1 Relative Bulk Magnetic Susceptibilities of Gasses

Paramagnetic oxygen analyzers use the following methods

(1) Magnetic proportional flow rate method

(2) Magnetic wind method

(3) Magnetic force method (dumbbell type)

(4) Magnetic force method (pressure sensor type)

2.1.1 Magnetic Proportional Flow Rate Method

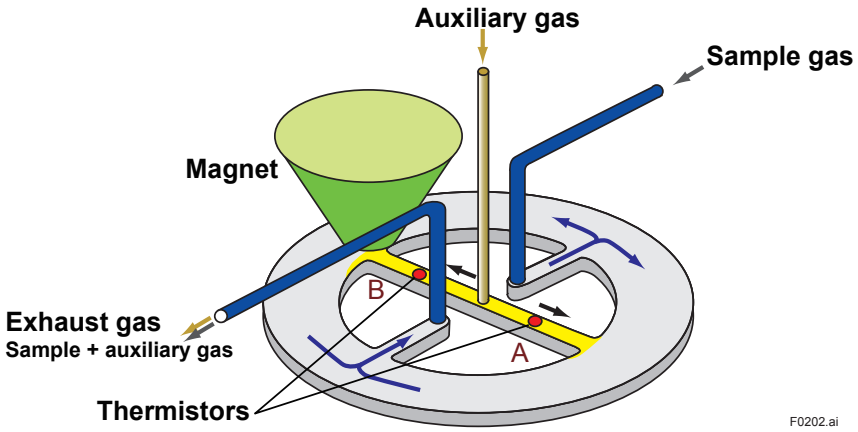


Figure 2.2 Magnetic Proportional Flow Rate Sensor

As shown in Figure 2.2, a sample gas is introduced from the sensor's sample gas inlet and divided into two streams in the ring-shaped gas flow path. An auxiliary gas is introduced from the auxiliary gas inlet and divided into two streams, A and B, which flow towards the ring-shaped gas flow path. A thermistor is installed in each of these streams to determine their flow rates, and a magnet generates a magnetic field in stream B.

When a sample gas contains oxygen, the oxygen is drawn into the magnetic field, thereby decreasing the flow rate of auxiliary gas in stream B. The difference in the flow rates for streams A and B is proportional to the oxygen concentration of the sample gas. This difference is determined and output by the thermistors. The MG8G/MG8E Paramagnetic Oxygen Analyzers use this method.

A magnetic proportional flow rate oxygen analyzer is characterized by fast response and strong resistance to vibration and shock. Furthermore, the thermistors do not come in contact with the sample gas, thereby ensuring long-term measurement stability even when corrosive or contaminated gas is measured.

2.1.2 Magnetic Wind Method

This method was developed a long time ago and uses many different types of measurement cells.

Figure 2.3 shows two cylindrical chambers with opposing conically shaped magnetic poles that have flat tops and are separated by a glass-coated ring-shaped heating wire element. The chamber on the left is the measurement chamber. When a sample gas is introduced into this chamber, oxygen is drawn toward the heating wire, where the magnetic field is strongest. Heated by the wire, the oxygen loses its magnetic susceptibility and is pushed upwards by cooler gas coming from the lower part of the chamber. In this way, a so-called magnetic wind is generated in the measurement chamber, and its intensity is proportional to the oxygen concentration in the sample gas.

The temperature of the heating wire is related to the cooling effect of the magnetic wind, and to the thermal conductivity, density, specific heat, and viscosity of the gas surrounding the heating wire.

Compensation is performed with the reference chamber, which is identical in construction to the measurement chamber, with the exception that no magnetic field is created. The two heating wires form a Wheatstone bridge, and the resistance change is detected as a change in the voltage.

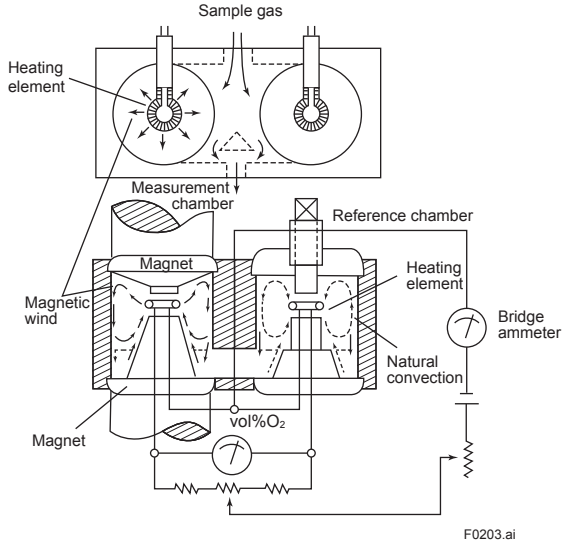


Figure 2.3 Example of Construction of Magnetic Wind Oxygen Analyzer (with Cylindrical Measurement Chamber)

Figure 2.4 shows a measurement cell with a ring-shaped gas path. A thin glass tube with a heating wire wound around it provides a direct path through the center of the circular path. The magnetic pole of a permanent magnet is placed to the left of the center of this tube. A sample gas containing oxygen is attracted to the strongest part of the magnetic field generated by this magnet. When the oxygen is heated by the tube's heating wire, it loses its magnetization and is pushed out by cooler gas entering from the left side of the tube; thus, a magnetic wind passing from left to right is generated in the tube.

A magnetic wind oxygen analyzer is characterized by strong resistance to vibration and shock; on the other hand, since its detection method relies on the thermal conductivity of gas, it is susceptible to rapid changes in the ambient temperature and changes in the gas composition. Furthermore, measurements can be affected by the contamination of the sample gas through contact with the sensor unit.

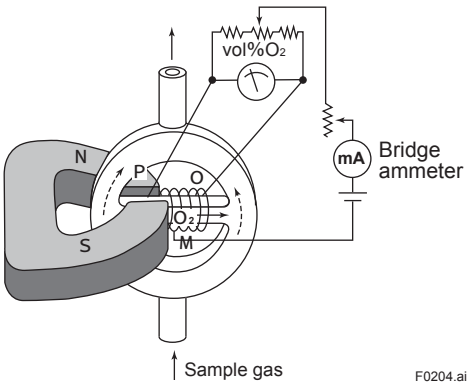


Figure 2.4 Example of Construction of Magnetic Wind Oxygen Analyzer (with Ring-shaped Measurement Chamber)

2.1.3 Magnetic Force Method (Dumbbell Type)

Figure 2.5 shows a dumbbell-shaped object with low magnetic susceptibility that is suspended from a platinum or quartz wire within a magnetic field. When a sample gas containing oxygen is guided to the vicinity of the dumbbell, the oxygen is attracted to the point of maximum magnetic field strength, causing the balls on the dumbbell to deflect slightly in an opposite direction. The twisting of the suspension wire is detected using a light source and a reflector that is attached to the center of the wire. The signal causes a current to flow through an excitation coil to correct the deflection. The current is proportional to the oxygen concentration.

This method is characterized by a wide dynamic range and is not influenced much by the presence of background gases. The downside is that it has less resistance to vibration and mechanical shock and is susceptible to contamination and corrosion.

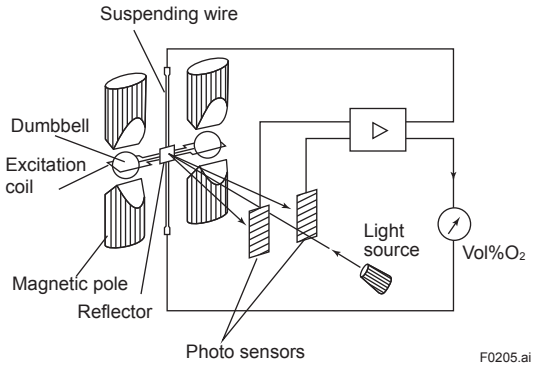


Figure 2.5 Magnetic Force Method (dumbbell type)

2.1.4 Magnetic Force Method (Pressure Sensor Type)

When two gases come into contact in a magnetic field, a differential pressure is generated that is proportional to the difference in the magnetic susceptibilities of the gases. Providing that the oxygen content of the auxiliary gas (reference gas) remains at a constant level, the oxygen concentration of the sample gas can be determined by means of the differential pressure. Since alternating current allows for easier detection and amplification of signals, a magnetic field is created using an electromagnet that is intermittently excited. A condenser microphone sensor or micro flow sensor that is used in infrared gas analyzers is used to detect small voltages. Figure 2.6 illustrates this method.

Although this method requires an auxiliary gas, it is affected relatively little by background gases and has a fast response time.

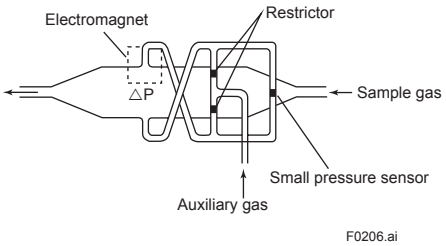


Figure 2.6 Magnetic Force Method (pressure sensor type)

2.2 Electrochemical Oxygen Analyzers

2.2.1 Zirconia System

(1) Oxygen Concentration Cell

A zirconia ceramic that has been stabilized, for example, by calcium oxide (CaO) or yttrium oxide (Y_2O_3), is a solid electrolyte that is conductive only to oxygen ions when it is heated to a high temperature.

Figure 2.7 shows a zirconia element with a porous platinum electrode attached on each side. When the electrodes are exposed to a gas that contains oxygen, the following reactions occur between the electrodes, with the zirconia element serving as a separator:

P_1 side (cathode): $O_2 + 4e \rightarrow 2O^{2-}$

P_2 side (anode): $2O^{2-} \rightarrow O_2 + 4e$

This means that oxygen molecules gain electrons and become oxygen ions at electrode P_1, giving it a higher partial oxygen concentration. These ions travel through the zirconia element to electrode P_2, creating an oxygen concentration cell. Here, electrons are released to form oxygen molecules, giving it a lower partial oxygen concentration. These reactions between the electrodes generate an electromotive force (E), which is represented by the following Nernst equation:

$$E = -\frac{RT}{4F} \ln \frac{P_2}{P_1}$$

R: gas constant

T: absolute temperature

F: Faraday constant

When the P_1 side is exposed to a reference gas (e.g. air) and the P_2 side is exposed to a sample gas, the oxygen concentration in the sample gas can be determined by measuring the electromotive force that is generated.

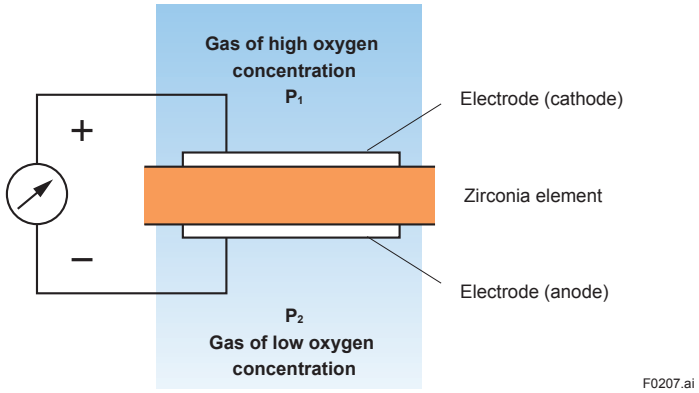


Figure 2.7 Oxygen Concentration Cell

The ZR402/ZR202 Zirconia Oxygen Analyzers, the AV550G Averaging Converter, the ZS8 Explosion-proof Oxygen Analyzer and the OX400 Low Concentration Oxygen Analyzer use this method.

(2) Limiting Current System

As shown in the figure 2.8, if the flow of oxygen into the cathode of a zirconia element heated to high temperature is limited, there appears a region where the current becomes constant even when the applied voltage is increased. This limited current is proportional to the oxygen concentration.

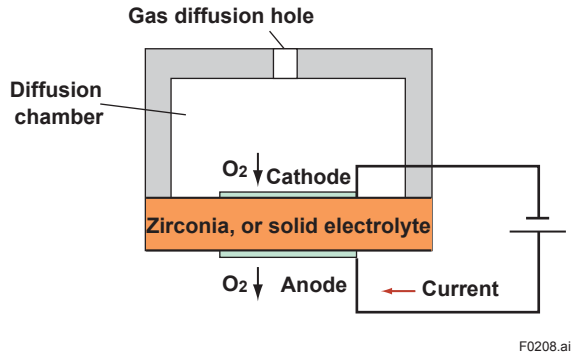


Figure 2.8 Limiting Current System

The OX100/OX102 Oxygen Analyzers use this method.

2.2.2 Electrode System

Figure 2.9 shows the interior of an electrode oxygen analyzer. A jelly-like electrolyte is applied to the gold cathode and silver anode, over which a thin Teflon membrane is stretched that is only permeable to oxygen. When a voltage of 0.5 V to 0.8 V is applied between the electrodes, a polarographic limiting current that is proportional to the oxygen concentration can be detected.

A galvanic cell oxygen analyzer uses an electrode system with this kind of separating membrane. With this method, an electrode (cathode) made of a noble metal such as gold or silver and an electrode (anode) made of a base metal such as lead are located in the electrolyte, which is in contact with the air through the separating membrane. This separating membrane is only permeable to oxygen. The permeated oxygen causes an oxidation reaction at the cathode and generates a potential when an additional resistor is connected to both electrodes. The oxygen concentration can be determined by monitoring the generated current.

The downside of this method is that the life of the sensor cell is limited by being in contact with the air even when measurement is not being performed, so periodic replacement is required. Another problem is that a negative drift occurs when the analyzer is operated continuously. Therefore, this analyzer is not suitable for continuous measurements over a long period of time. However, it is compact and costs relatively little, so it is used as a portable analyzer.

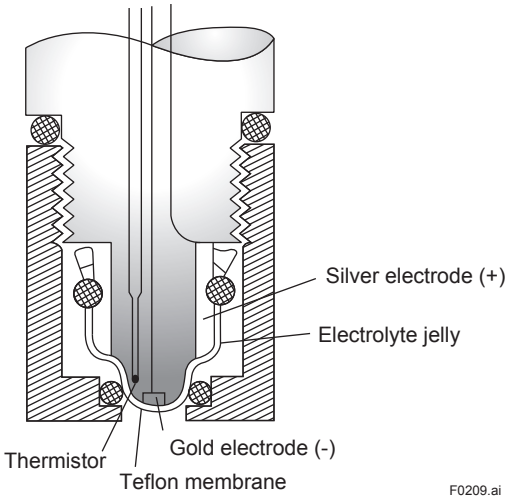


Figure 2.9 Separating Membrane Electrode for Measuring Oxygen Concentration

2.3 Absorption Spectroscopy Oxygen Analyzer

2.3.1 Tunable Diode Laser Spectroscopy (TDLS) Method

Operational Principle

TDLS measurements are based on absorption spectroscopy. TDLS Analyzer operates by measuring the amount of laser light that is absorbed (lost) as it travels through the gas being measured. In the simplest form a TDLS analyzer consists of a laser that emits infrared light, optical lenses to focus the laser light through the gas to be measured and then on to a detector, the detector, and electronics that control the laser and translate the detector signal into a signal representing the gas concentration.
Gas molecules absorb light at specific wavelengths, called absorption lines. This absorption follows the Beer-Lambert Law.

$I = I_0 \bullet e^{-E \cdot G \cdot L}$

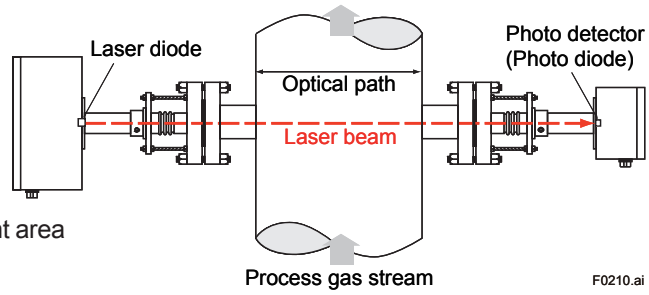
where I is the radiation intensity after absorption

I_0 is the initial radiation intensity

E is the extinction coefficient

G is the gas concentration

and L is the path length of the measurement area



Using a Tunable Diode Laser as a light source for spectroscopy has the following benefits:

- **Sensitivity.** Application Dependant. Sub-PPM in some applications.
- **Selectivity.** The narrow line width of the laser is able to resolve single absorption lines. This provides more choices of a particular peak to use for measurement, usually allowing one isolated peak to be used.
- **Power.** Diode lasers have power ranging from 0.5mW to 20mW. Also, being highly coherent this allows measurement in optically thick environments (high particulate loading).
- **Monochromatic.** No dispersive element (filter, etc.) required. Light source itself is selective.
- **Tunable.** Wavelength can be swept across the entire absorption feature, this allows resonant (peak) and non resonant (baseline) measurement during every scan. By measuring the baseline and peak, power at the detector can fluctuate rapidly by large amounts without affecting the measurement. This is useful for high particulate applications.

  The TDLS200 and the TDLS220 (Extractive Type) TDLS Analyzers use this method.

2.4 Applications of Oxygen Analyzers by Measurement Principle

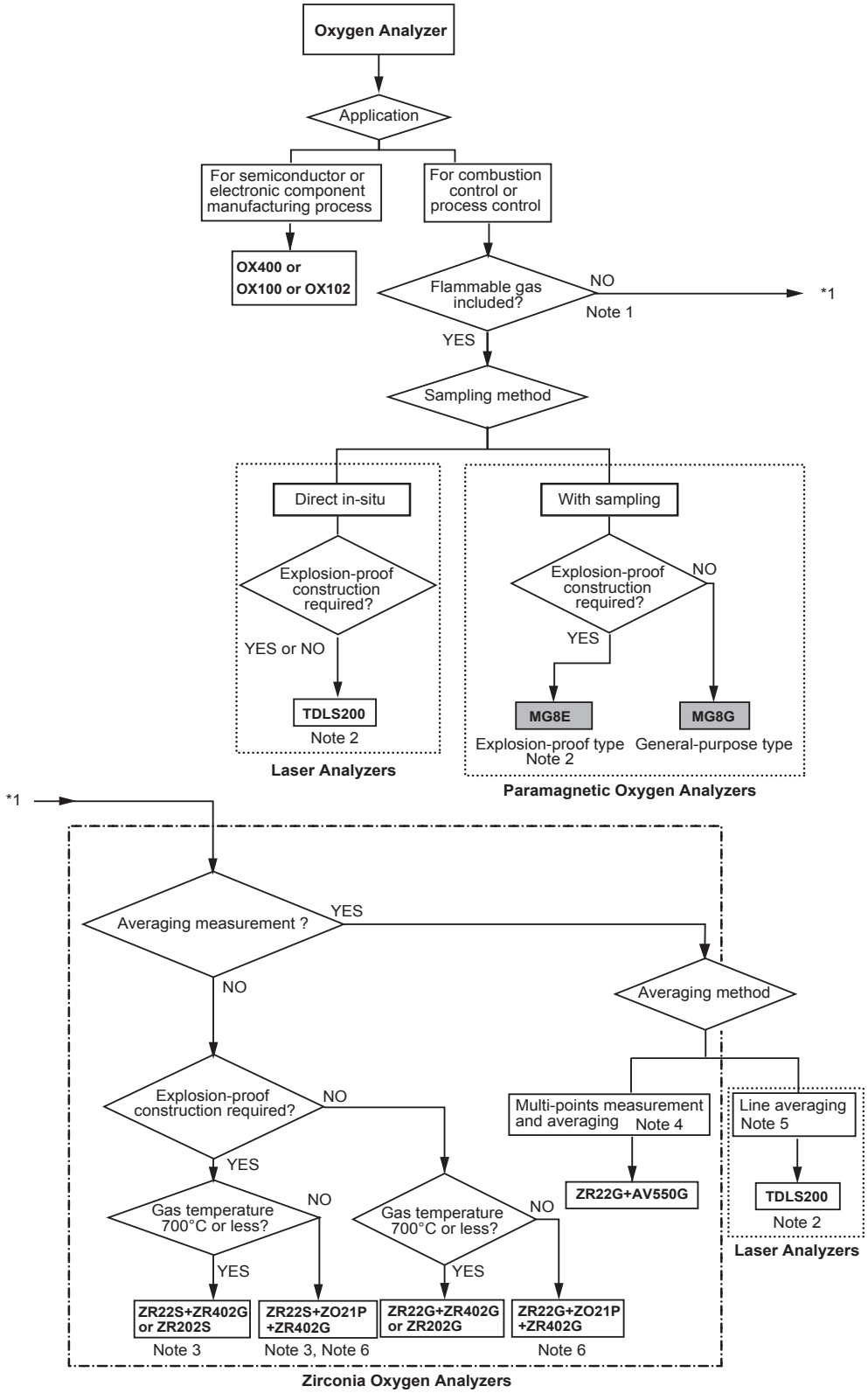
Table 2.1 shows which oxygen analyzer types are suitable for specific applications and industries.

Table 2.1 Oxygen Analyzer Applications, by Analyzer Type

Analyzer type	Zirconia			Magnetic		Laser
Yokogawa's model	ZR202G ZR22G +ZR402G	ZR202S ZR22S +ZR402G	OX400 OX100 OX102	MG8G	MG8E	TDLS200
Application: Boiler / combustion furnace						
All industry types	A					B
Electric power	A					B
Oil / petrochemical	A	A				B
Pulp / paper	A					B
Application: Heating furnace						
Oil / petrochemical	A	A				B
Iron and steel, non ferrous metal	A			B		B
Ceramic	A			B		B
Application: Process quality and safety control						
Oil / petrochemical					A	A
Pulp / paper	C			B		
Other (Iron and steel etc.)	B		B	A		B
Remarks	Combustion control, (C: humidity measurement)	Explosion-proof type	Built into device	Quality control, combustion control	Explosion-proof type, safety and quality control	Combustion, safety control

A: Most suitable B / C: Suitable

2.5 Oxygen Analyzer Selection Flowchart



Note 1: If a flammable gas makes up 0.5 % or less of the gas mixture, select “NO.”
Note 2: All of these instruments must be ordered with the custom order process.
Note 3: The ZR402G converter must not be installed in a hazardous area.
Note 4: Max. of 8 points for measurement and averaging.
Note 5: Optical path averaging
Note 6: The ZO21P is a high temperature probe adapter.

3. MG8G/MG8E Features

◆ Highly Reliable and Easy to Maintain

- The sensor is designed so that it does not come into contact with the sample gas (see section 4.3). Long-term measurement stability is ensured even when corrosive or contaminated gas is measured.
- The lack of any moving parts ensures excellent resistance to vibration and shock.
- The MG8E is explosion-proof (Ex d IIB T4X).

◆ High Stability and Fast Response

- The main part of the sensor unit including the measurement cell is in a housing where a constant temperature is maintained. This minimizes any effect on the sample gas by the ambient temperature and also prevents draining, thereby assuring stable measurement.
- Highly sensitive thermistors with fast response times directly detect the flow rate of auxiliary gases, ensuring a 90% response within three seconds.
- Excellent indicating stability in the vicinity of zero makes the sensor suitable for low concentration measurement (e.g. for safety control).
- An interference-gas compensation function ensures accurate measurement even when paramagnetic background gases (including flammable gases) are present.

◆ Converter with a Wealth of Convenient Functions

- Easy calibration

  All you need to do to calibrate the unit is introduce a calibration gas with a zero oxygen concentration and press the calibration button, then repeat the procedure with the gas containing a pre-determined oxygen. To save time, automatic calibration mode can be selected. Furthermore, an output function that drives a solenoid valve to switch between zero and span is provided as a standard feature.

- Rich self-diagnostic functions

  Cell, measurement unit temperature, analog unit, digital unit, and memory failures can be detected. If a failure is detected, the FAIL lamp lights and a message is displayed. Furthermore, if the auxiliary gas pressure falls below the setpoint, contact output is activated.

4. MG8G/MG8E System Configuration and Sensor Construction

4.1 System Configuration

Figure 4.1 shows the basic system configuration of the MG8G/MG8E Paramagnetic Oxygen Analyzers.

The pre-treatment unit varies depending on the device and application, so all pre-treatment units have to be custom-ordered.

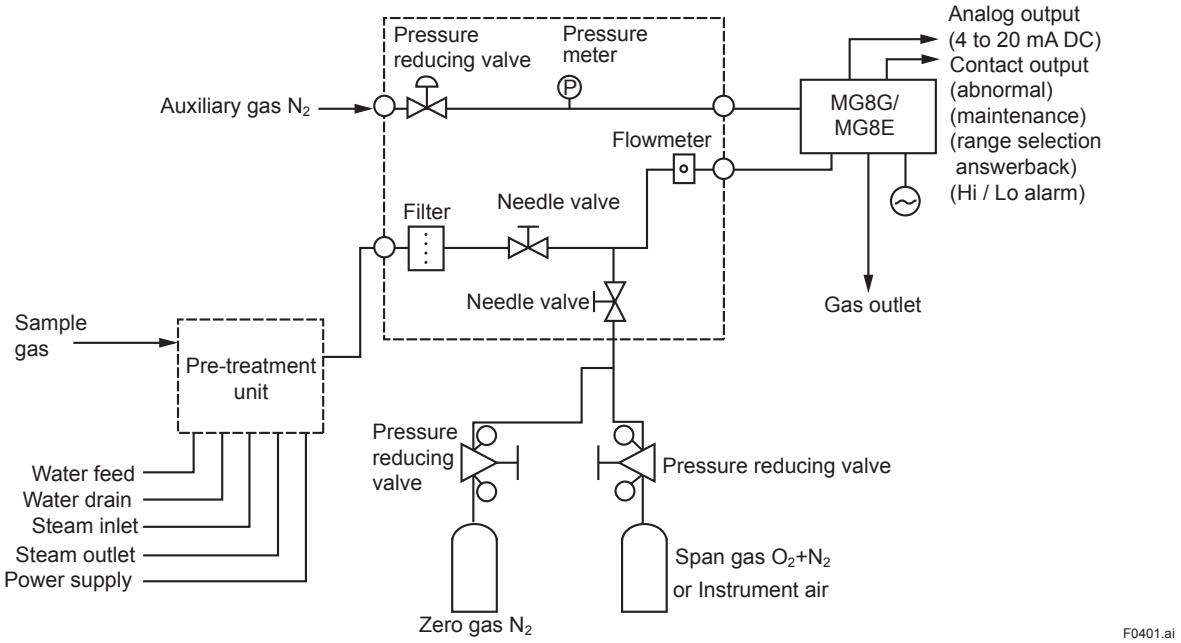


Figure 4.1 MG8G/MG8E Oxygen Analyzer System Configuration

4.2 Suitable Applications for MG8G/MG8E Paramagnetic Oxygen Analyzers

The MG8G Paramagnetic Oxygen Analyzer is for general use and the MG8E Paramagnetic Oxygen Analyzer is for explosion-proof applications. The MG8E has been certified by the TIIS* to meet the Ex d IIB T4X standard.

* Technology Institution of Industry Safety, Japan

The following table shows the applicable criteria of the MG8G and MG8E.

Table 4.1 Applicability Criteria of MG8 Paramagnetic Oxygen Analyzers (Installation Environment and Measured Gas)

MG8 Oxygen Analyzer	Applicable Range	Installation Site		Sample Gas					
		Hazardous Area	Non-hazardous Area*2	Class A and B hazardous gases*1 or Mixed gases of less than 4% hydrogen		Mixed gases of 4 to 100% hydrogen		Class C hazardous gas*1, excluding hydrogen*3	
				Atmosphere	Sample Gas	Atmosphere	Sample Gas	Atmosphere	Sample Gas
MG8E used as explosion-proof (Ex d IIB T4X*4)	0-1 to 25% O_2 (Not applicable for 21-25% O_2)	OK	OK	OK	OK	NA	NA	NA	NA
MG8E used as non-explosion-proof	0-1 to 25% O_2	NA	OK	NA	OK	NA	OK	NA	NA
MG8G used as non-explosion-proof	0-5 to 25% O_2	NA	OK	NA	OK	NA	NA	NA	NA

NA:Not applicable

*1: Refer to the Users Guide to Installing Explosion-proof Electrical Apparatus at Plants, issued by the Technology Institution of Industrial Safety, Japan.
*2: The definition of the non-hazardous area is followed by the description in the Users Guide to Installing Explosion-proof Electrical Apparatus at Plants, issued by the Technology Institution of Industrial Safety, Japan: As a non-hazardous area is considered a place where no occurrence of explosive gas atmospheres is guaranteed by the foreperson and confirmed by a written document.
*3: Acetylene, carbon disulfide, hydrogen, and ethyl nitrate.
*4: Ex d IIB T4X
(a) Structure: Explosion-proof
(b) Scope of area: Industrial sites and hazardous areas in office buildings. May not be used in hazardous locations in mines.
(c) Scope of sample gas or vapor:
(c-1) Class A and B hazardous gases or vapor
(c-2) Gas or vapor with ignition temperature of 135°C or greater
(c-3) Hydrogen concentration must be below 4%. Not applicable for gases containing acetylene, carbon disulfide and ethyl nitrate.
(d) Operating conditions
(d-1) Before opening the cover, remove power and make sure of non-hazardous atmospheres.
(d-2) Do not use for measuring oxygen concentration of gases other than those containing air or oxygen equivalent to or less than air, or those mixed with flammable gas or vapor.

4.3 Sensor Construction

The MG8G/MG8E Paramagnetic Oxygen Analyzers use a magnetic proportional flow rate sensor that was developed by Yokogawa. This sensor has high sensitivity and the same fast response time of a zirconia sensor, and its construction provides high resistance to vibration and shock.

In addition, the sensor's thermistors do not come into direct contact with the sample gas, thereby ensuring long-term measurement stability even when corrosive or contaminated gas is measured.

(1) Construction and Operating Principle

Figure 4.2 shows the construction of the ring-shaped sensor.

- A sample gas enters from the sample gas inlet and is divided into streams A and A' in the ring-shaped gas path.
- An auxiliary gas enters from the auxiliary gas inlet and is divided into streams B and B', which then pass through a thermistor that is positioned in each of the gas paths. These thermistors detect the flow rates of the auxiliary gasses.
- The auxiliary gas streams then enter the ring-shaped path at points D and E, where they meet with the sample gasses and flow in direction C toward an outlet.
- A strong magnetic field is created at point D, where stream B of the auxiliary gas enters the ring-shaped path. If the sample gas contains oxygen, the oxygen is attracted to and concentrated in the magnetic field at point D. The oxygen thus restricts the flow of auxiliary gas at point D, which alters the ratio of flow rate B to flow rate B'. This change in the ratio is proportional to the oxygen concentration, and it is detected with the thermistors and output.

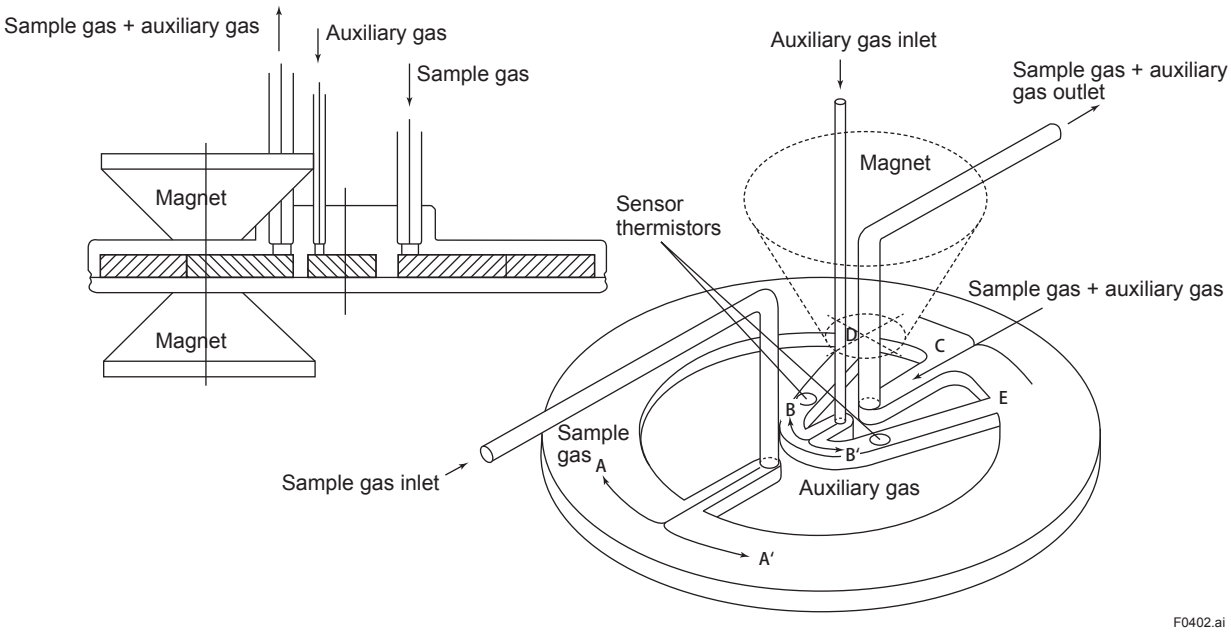


Figure 4.2 Magnetic Proportional Flow Rate Sensor

(2) Sensor Unit Gas Path

The MG8G/MG8E Paramagnetic Oxygen Analyzers achieve stable measurement by a variety of means. (See Figure 4.3.)

- The main part of the sensor unit, including the cell, is contained within a housing. Inside this housing a constant temperature is maintained to ensure that the gas temperature is not affected by changes in the ambient temperature.
- In order to stabilize the temperature within this housing, an integral computation function has been added.
- Measures have also been taken to prevent fluctuating indications caused by changes in the sample and auxiliary gas flow rates.

(a) Bypass Unit (only available with the MG8E)

The horizontal axis represents the flow rate of the sample gas entering the paramagnetic oxygen analyzer, and the vertical axis represents the flow rate of the sample gas entering the cell. If the sample gas enters the paramagnetic oxygen analyzer at a slow rate, all the gas flows into the cell. If the rate exceeds 235 ml/min, the excess portion flows into the bypass unit.

(b) Sample Gas Pre-heating Unit (only available with the MG8E)

The sensor unit housing is kept at a constant 55°C. The temperature of the sample gas entering the housing is usually less than 55°C. Any change in the sample gas temperature can change the measurement cell temperature and affect its output.

Before the sample gas enters the measurement cell, the MG8E Paramagnetic Oxygen Analyzer passes it through a pre-heating unit in order to bring it close to the temperature maintained inside the sensor unit housing.

(c) Stabilizing Flow Rate of Auxiliary Gas

The auxiliary gas is nitrogen (N_2). The MG8G/MG8E Paramagnetic Oxygen Analyzers determine the oxygen concentration using the ratio of the flow rates for this nitrogen gas; therefore, it is essential to keep the flow rate constant. This is done by means of capillary restriction resistance.

(d) Pressure Switch (only available with the MG8E)

If the auxiliary gas flow is disrupted while the paramagnetic oxygen analyzer is operating, the output signal overshoots the scale. To prevent this from occurring, a pressure switch on the primary side of the auxiliary gas line regulator activates an alarm to notify the operator that preventive action should be taken.

(e) Temperature Control for Sensor Unit Housing (only available with the MG8E)

To guard against disturbances such as voltage fluctuations, an integral computation function has been added that makes it possible to control the temperature to within 0.005°C. Furthermore, the measurement cell temperature is controlled during the warm-up phase by capturing the cell temperature (summing of the signals from the left and right thermistors) and increasing the heater temperature if the cell temperature is low, then gradually lowering the heater temperature as the cell temperature rises.

(f) Compensation for Atmospheric Pressure Error (only available with the MG8E)

Equipped with an atmospheric pressure-compensation sensor as standard, atmospheric pressure error can be compensated.

(3) Block Diagram of Oxygen Analyzer Gas Path in Sensor Unit

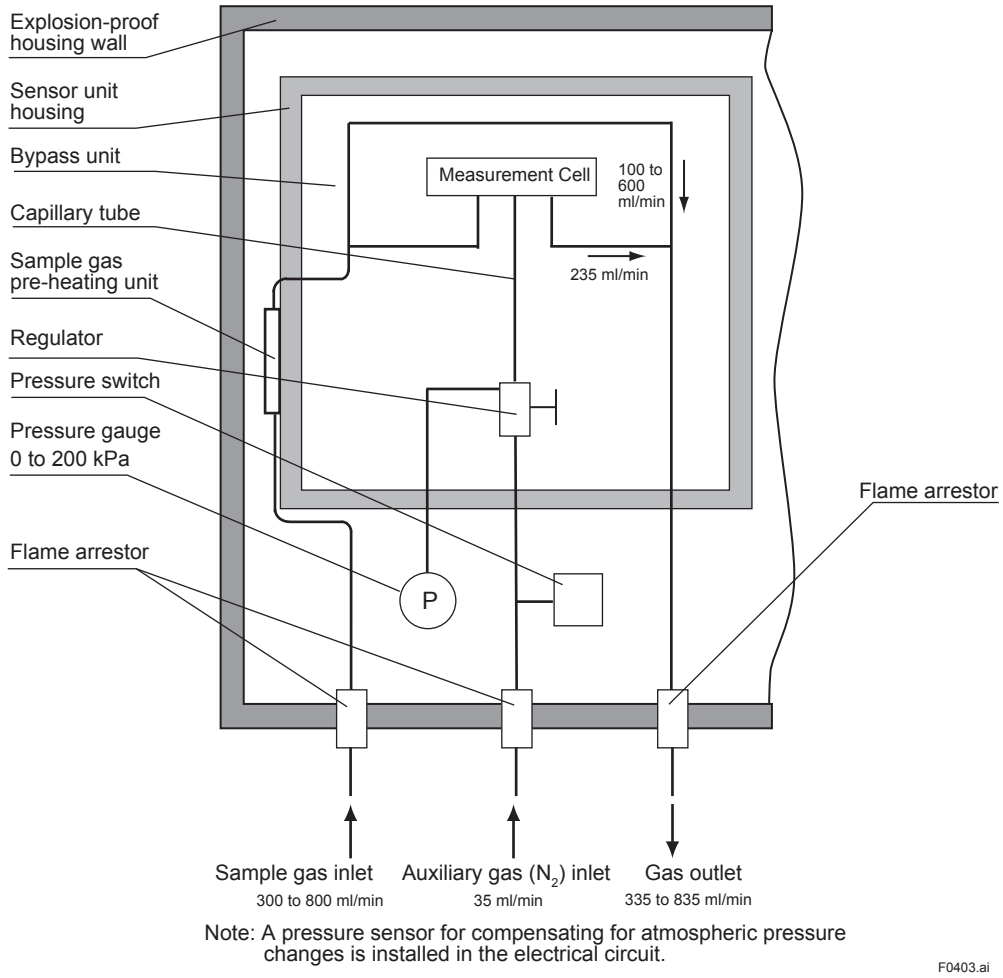


Figure 4.3 Block Diagram of MG8E Gas Path in Sensor Unit

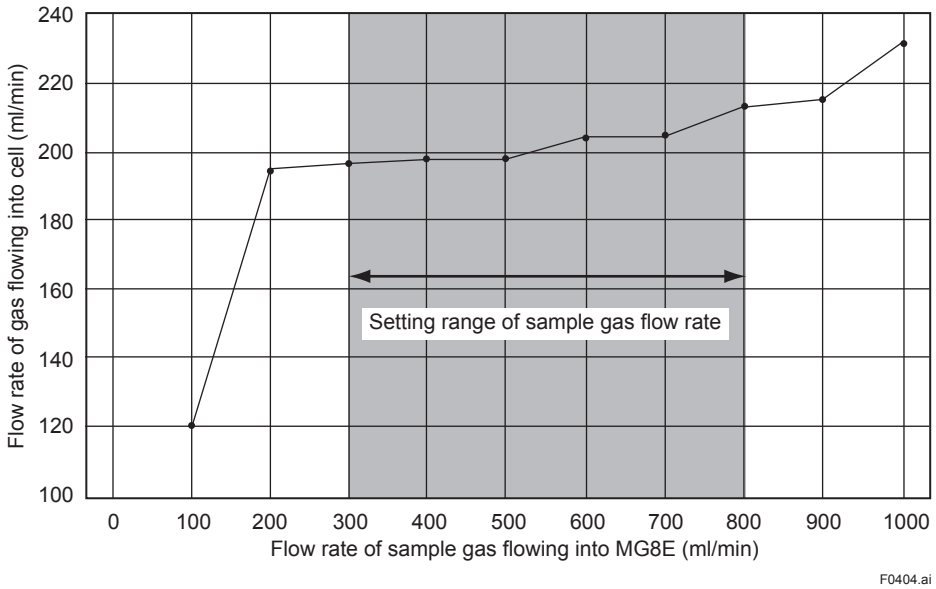


Figure 4.4 Flow Characteristics of MG8E Bypass Unit

5. Effects of Interference Gas

5.1 Measurement of Oxygen (O_2) in the Presence of Interference Gases

The following table indicates when the MG8E analyzer can be used to measure oxygen (O_2) in the presence of interference gases.

No.	Type of industry	Interference gas components	Measuring range (%)			Remarks
			0 – 1	0 – 2	0 – 5	
1	Petrochemical	H_2: 35%, CO_2: 7%, N_2: B	A	A	A	Note 1
2		C_3: 0 – 5%, C_4: 5 – 10%, N_2: B	—	A	A	Note 1, off gas
3	Oil	H_2: 10 – 40%, C1: 20 – 30%, C_2: 15 – 30%, N_2: B	A	A	A	Note 1, to flare stack
4	Chemical	VCM (C_2H_3C1) + Air	A	A	A	
5		C_4H_{10} + Air	—	A	A	Note 2
6		CH_4: 50%, C_2H_4: 25%, CO_2: 4%, Ar: 15%	A	A	A	
7		C_4H_{10}: 20%, O_2: 6%, N_2: B	A	A	A	
8		H_2 +O_2	A	A	A	Note 1, electrolytic plant
9	Iron and steel	H_2: 75%, N_2: 25% + Air	—	A	A	Note 1
10		(H_2: 45%, CH_4: 17%, CO: 16%, CO_2: 4%) + Air	—	A	A	Note 1
11	Electric power	(H_2: 30%, CO_2: 36%, CH_4: 4%) + Air	—	A	A	Note 1, fuel cell
12	Environmental sewage	CH_4: 55%, CO_2: 39% + Air	A	A	A	Digestion gas
13	Nuclear power	He + O_2	A	A	A	Note 2

A: Measurement is possible when the effect of the interference gas is within ±0.02%O_2 or ±1% of span, whichever is higher.
Note 1: Auxiliary gas flow rate: 55 ml/min
Note 2: Please contact us when C_4H_{10} is 50vol% or more, or when nuclear power (He + O_2) is to be measured.

Testing Method

(1) Adjust the zero balance with the interference gas and nitrogen (N_2) gas.

(2) Perform calibration with the O_2/N_2 gas and obtain the deviation from the O_2/interference gas.

CAUTION

The information in the above table applies only to class A and B hazardous gases or vapors and to gas mixtures that are less than 4% hydrogen gas, in which cases the analyzer must be used as specified in the explosion-proof specification.

The analyzer cannot be used to measure the oxygen concentration in gases or vapors containing acetylene, carbon disulfide, or ethylene nitrate. Furthermore, the explosion-proof certification does not apply to Nos. 1, 3, 8, 9, 10, and 11 in the above table.

5.2 Data on Effects of Interference Gases

The following data on a mixture of interference components and O_2 is from an analyzer that has been calibrated with N_2 and O_2+N_2.

The oxygen concentration can be measured within ±2% of span.

O_2+CO_2 (92%)+N_2 (8%)

Range: 0 to 1 vol%O_2

Auxiliary gas flow rate: 35 ml/min

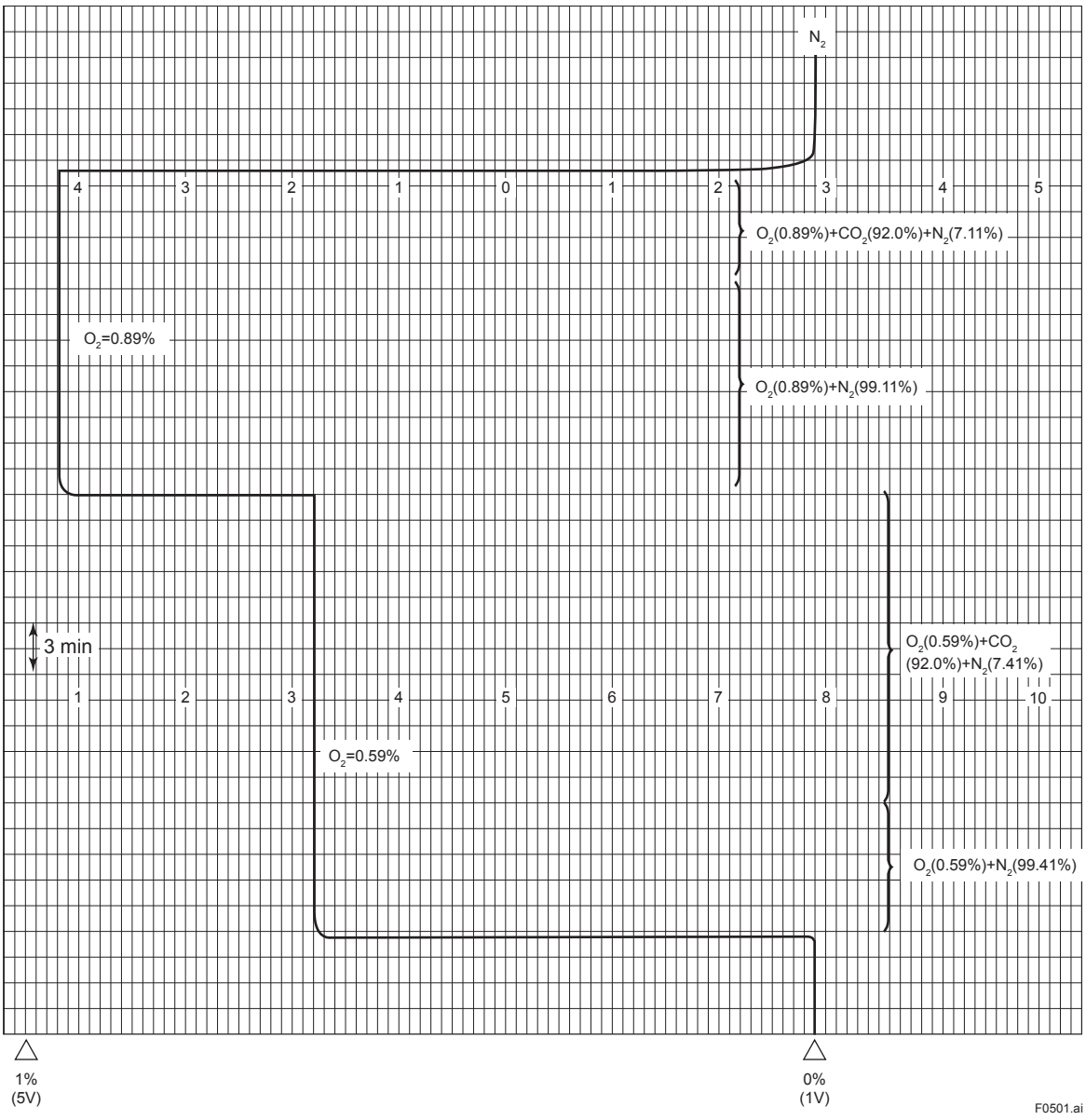


Figure 5.1 Data Example of Effects of Interference Gases

5.3 Interference Gas Compensation

MG8G/MG8E Paramagnetic Oxygen Analyzers make use of the paramagnetic property of oxygen (magnetic susceptibility, i.e. the ability to become magnetized in the presence of an externally applied magnetic field) to measure the oxygen concentration. Gases other than oxygen may also exhibit this characteristic, although they will not be nearly as magnetically susceptible as oxygen. Accordingly, process gases with varying levels of magnetic susceptibility can interfere with and cause errors in the measurement of the oxygen concentration.

Errors such as these that are caused by the paramagnetic property of process gases may be significant with low oxygen concentrations in the range of 0% to 1%; however, the MG8G/MG8E Paramagnetic Oxygen Analyzers are able to cancel out this interference error based on the difference in density of a sample gas and a reference gas. As shown in Figure 5.2, a sample gas is divided into streams A and A' in the ring-shaped gas path. An auxiliary gas (N_2) enters at the center of the sensor unit and flows left and right in streams B and B'. A magnetic field is applied at point D where the auxiliary gas enters the ring-shaped path. Even if the auxiliary gas does not contain oxygen, the present of paramagnetic gases such as N_2 will affect the ratio of the auxiliary gas flow rates in streams B and B', resulting in an error. This error can be compensated by changing the cell angle (cell attitude).

For example, if carbon dioxide (CO_2), which has a lower magnetic susceptibility than nitrogen (N_2), passes through the measurement cell, the analyzer will read a negative value. If the cell is tilted as shown in Figure 5.3, the flow rate of the auxiliary gas toward stream B' will increase due to the higher density of the CO_2. This will change the flow rate, thereby canceling out the negative deviation. The change in the auxiliary gas flow rate due to the magnetic susceptibility of the gas is cancelled out by changing the measurement cell angle, which alters the density and causes a change in the auxiliary gas flow rate. In this way, the interference error can be compensated for.

Prior to shipment from the factory, each MG8G/MG8E Paramagnetic Oxygen Analyzer receives a final tuning in which the measurement cell angle (attitude) is adjusted based on the magnetic characteristics and density of the customer's sample gas. This cell angle is stored in the analyzer's memory.

When installing the analyzer, rotate the adjustment knob until the bubble in the built-in bubble level is at the center position. This brings the measurement cell to the correct angle.

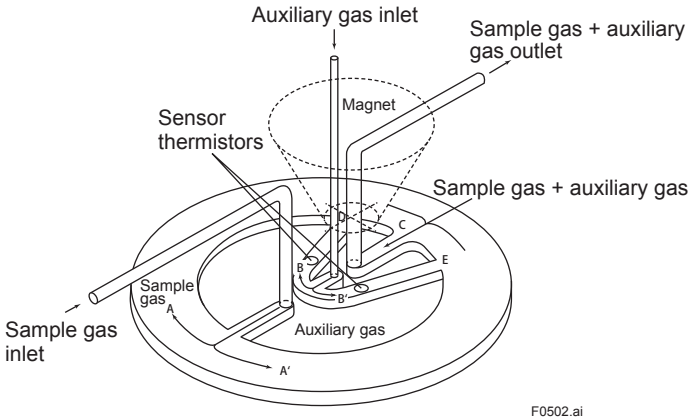


Figure 5.2 Diagram of Measurement Cell

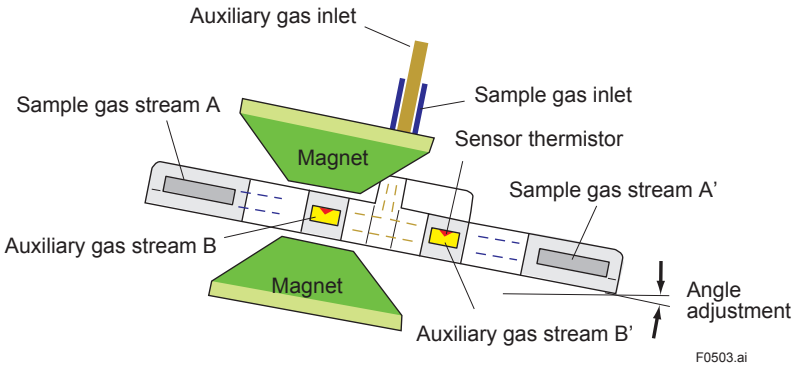


Figure 5.3 View of Measurement Cell Cross-section

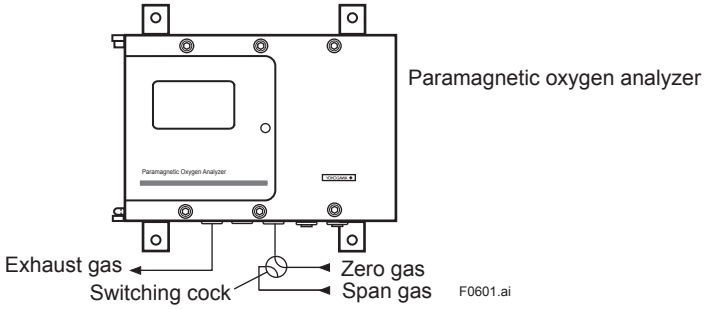
6. Characteristics (MG8E Test Data)

6.1 Response Characteristic

Response time: 90% response within 6 seconds (from the gas inlet of the oxygen analyzer)

Response check data: Range: 0% to 1 vol% O_2

Zero gas: N_2 (99.999%), Span gas: N_2+O_2 (0.978%)



Sample gas flow rate (ml/min)	Zero → Span		Span → Zero	
	Dead time(sec)	90% response(sec)	Dead time(sec)	90% response(sec)
300	3.2	1.6	3.3	1.5
600	2.9	1.5	2.6	1.5
900	2.2	1.6	2.2	1.4

Note: The analyzer reading will reach a 100% response in 10 seconds (Yokogawa's previous model: 30 to 50 seconds)

6.2 Flow Characteristics

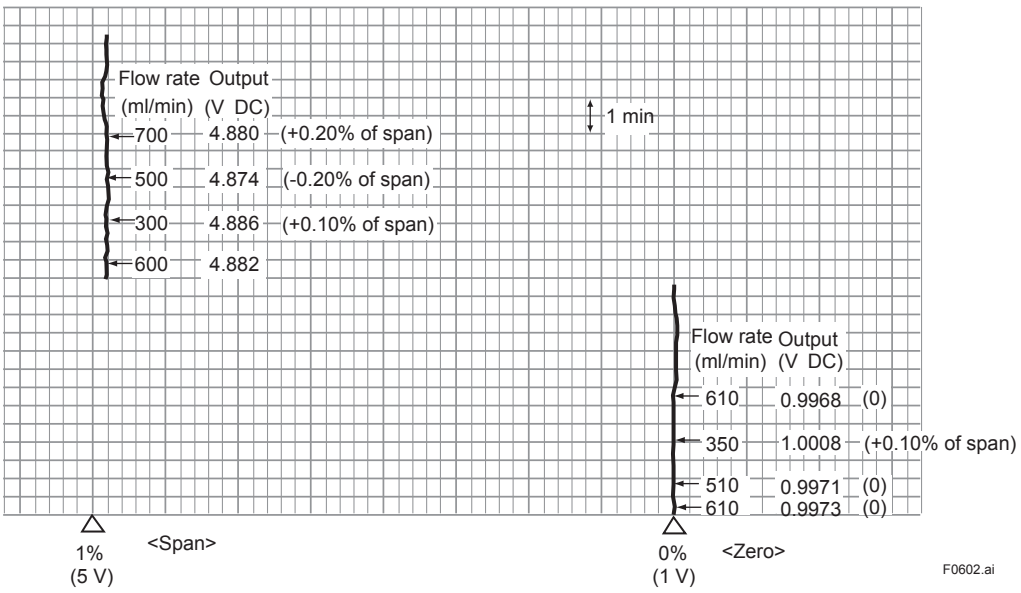
Specifications of flow characteristic testing

Range: 0 to 1 vol% O_2

Auxiliary gas flow rate: 35 ml/min

Zero gas: N_2, Span gas: O_2 (0.975%) +N_2

<Test result: ±0.2% of span>



6.3 Attitude Error

Testing that shows how changes in the attitude of the oxygen analyzer affect the indicated value

Range: 0 to 2 vol% O_2

Zero balance: CO (65%) +H_2 (4.5%) +CO_2 and N_2

Sample gas: Zero gas: N_2, Span gas: O_2 (1.61%) +N_2

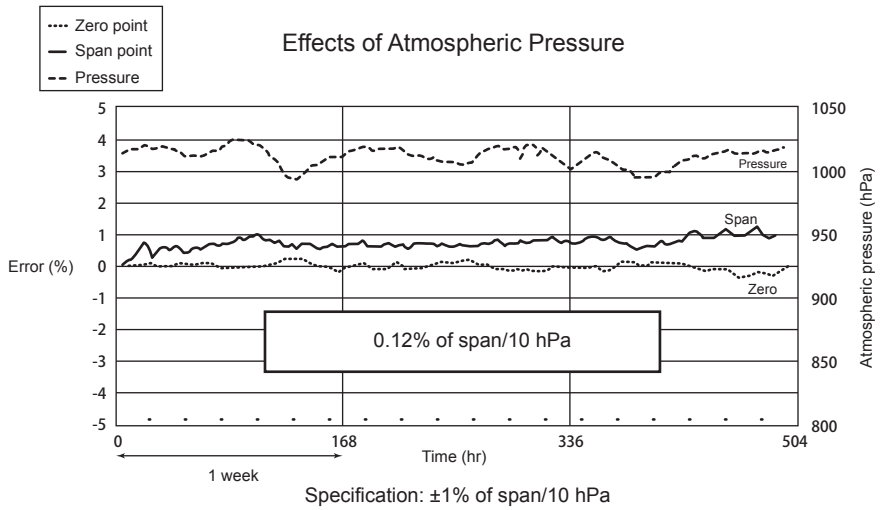
Sample gas flow rate: 600 ml/min

Auxiliary gas flow rate: 35 ml/min

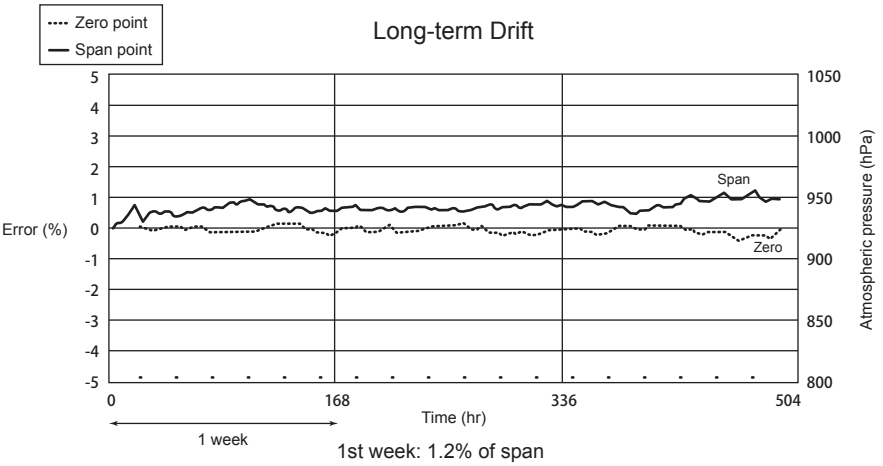
	Attitude change (1° increase in angle)			
	Front	**Back**	**Left**	**Right**
Zero gas	-0.02% of span	-0.001% of span	-0.137% of span	-0.095% of span
Span gas	-0.04% of span		-0.25% of span	-0.216% of span

*In the case of 0 to 1% O_2 range:
Vicinity of zero: 0.2%/1° of span (Yokogawa's previous model: about 10%/1° of span)
Vicinity of span: 0.4%/1° of span

6.4 Effects of Atmospheric Pressure and Long-term Drift



Specification: ±1% of span/10 hPa



1st week: 1.2% of span
2nd week: 0.5% of span
3rd week: 0.3% of span

Specification: ±2% of span

F0603.ai

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