CONTENTS

1.   Overview

Infrared gas analyzers are broadly classified into two types: non-dispersive and dispersive.

Non-dispersive infrared (NDIR) gas analyzers directly use broadband radiation emitted from a light source for measurement. Most of the process and automatic infrared instruments are of the non-dispersive type.

Dispersive infrared gas analyzers use infrared light of wavelength separated by a prism, grating or other optical device for measurement. This type is commercially available mainly for laboratory use.

Non-dispersive infrared gas analyzers became widely used at first as a process analyzer in chemical plants, and then has become popular for environmental analysis in automobile emissions and stack gas applications.

For these diversified applications, Yokogawa offers the lineup of infrared gas analyzers as follows.

- IR100 Infrared Gas Analyzer
- IR200 Infrared Gas Analyzer
- IR400 Infrared Gas Analyzer
- SG400 Stack Gas Analyzer
- SG700 Stack Gas Analyzer

These infrared gas analyzers have been developed based on long-term experience and field proven technology and provide higher measurement accuracy and improved maintainability as compared to previous models. Various options are available to meet various users' needs.

This Technical Information (TI 11G00A01-01E) is intended for those who wish to make good use of Yokogawa's infrared gas analyzers. It includes not only the information about the analyzers but also descriptions of system configurations including external sampling units and precautions for use.

2.   Yokogawa's Lineup of Infrared Gas Analyzer

Yokogawa offers the following lineup of infrared gas analyzers to accommodate diversified applications.

- IR100 Infrared Gas Analyzer

- IR200 Infrared Gas Analyzer

- IR400 Infrared Gas Analyzer

- SG400 Stack Gas Analyzer

- SG700 Stack Gas Analyzer

Gases measured by and measuring ranges of each model are listed in Table 2.1 and their features and typical applications are summarized in Table 2.2.

2.1   Gases Measured and Ranges

Table 2.1 Gases Measured and Ranges

Model	Method	Gas Measured	Measuring Range	
			Minimum Range	Maximum Range
IR100	Single beam	CO CO_2 CH_4	0 to 500 ppm 0 to 500 ppm 0 to 1000 ppm	0 to 100 vol% 0 to 100 vol% 0 to 100 vol%
IR200	Single beam	CO CO_2 CH_4 SO_2 NO O_2 (*1)	0 to 200 ppm 0 to 500 ppm 0 to 1000 ppm 0 to 500 ppm 0 to 500 ppm 0 to 5 vol%	0 to 100 vol% 0 to 100 vol% 0 to 100 vol% 0 to 5000 ppm 0 to 5000 ppm 0 to 100 vol%
IR400	Double beam	CO CO_2 CH_4 SO_2 NO O_2 (*1)	0 to 50 ppm 0 to 20 ppm 0 to 200 ppm 0 to 50 ppm 0 to 50 ppm 0 to 5 vol%	0 to 100 vol% 0 to 100 vol% 0 to 100 vol% 0 to 10 vol% 0 to 5000 ppm 0 to 25 vol%
SG400	Single beam	CO O_2 (*2)	0 to 200 ppm 0 to 25 vol%	0 to 2000 ppm 0 to 25 vol%
SG700	Double beam	CO CO_2 SO_2 NO_X O_2 (*1)	0 to 50 ppm 0 to 1 vol% 0 to 50 ppm 0 to 50 ppm 0 to 10 vol%	0 to 5000 ppm 0 to 20 vol% 0 to 1000 ppm 0 to 5000 ppm 0 to 25 vol%

(*1)   Oxygen (O_2) is measured by paramagnetic or zirconia method.
(*2)   Oxygen (O_2) is measured by zirconia method.

2.2   Features and Typical Applications

Table 2.2 Features and Typical Applications

Model	Feature	Application
IR100	• Excellent long-term stability: unique optical system reduces drift caused by cell fouling, etc. • Minimal interference from other gases (serial dual cell type of transmission detector) • Simple unit configuration allows for easy maintenance	• Various industrial furnaces • Boilers • Gas leak detection • Carbon dioxide assimilation in plants • Fruit storages
IR200	• Simultaneous measurement of up to four gas components including O_2 • Excellent long-term stability: unique optical system reduces drift caused by cell fouling, etc. • Minimal interference from other gases (serial dual cell type of transmission detector) • Single beam method and simple unit configuration allow for easy maintenance • Extensive functions, high precise measurement and interactive interface	• Combustion control at various industrial furnaces • Combustion control at boilers • Global environment protection • Botanical research facilities
IR400	• Simultaneous measurement of up to five gas components including O_2 • Unique optical system with high sensitivity and wide dynamic range: a maximum range ratio of 1:25 • Compensation for interference from other gases • Functions to meet various application requirements: O_2 correction, averaging, automatic calibration, one-touch calibration, high/low alarm, remote range switching, range identification contact output, etc. • Large LCD to display readings of all components and calculated values. Interactive interface allows for easy routine inspections and operations	• Gas measurement at various industrial furnaces • Combustion control at boilers • Global environment protection • Botanical research facilities
SG400	• Functions in line with dioxin emission standards • Space-saving compact design, easy access for maintenance • Automatic calibration function reduces maintenance	• CO measurement at incinerators (to comply with dioxin emission standards)
SG700	• Simultaneous measurement of up to five gas components including O_2 • Unique optical system with high sensitivity and wide dynamic range; a maximum range ratio of 1:25 • Compensation for interference from other gases • Convenient functions; O_2 correction, averaging, automatic calibration, one-touch calibration, high/low alarm, remote range switching, range identification contact output, etc.	• Stack gases of boilers and incinerators • Stack gases of various industrial furnaces

2.3   Model Selection Guide

Figure 2.1 shows a model selection flowchart. In practice, required measurement accuracy, presence of interfering components, application requirements and other conditions should be considered when selecting.

```
Infrared Gas Analyzer
        │
        ▼
  For dioxin          YES      Model
  regulations        ─────→    SG400
        │ NO
        ▼
  Stack gas           YES      Model
  measurement        ─────→    SG700
        │ NO
        ▼
  Five                YES      Model
  components incl.   ─────→    IR400
  O₂ (*1)
        │ NO
        ▼
  Low                 YES      Model
  concentration      ─────→    IR400
  measurement
  (*2)
        │ NO
        ▼
  Measuring    YES   One           YES     Model
  range ≥1%   ────→  component    ─────→   IR100
        │ NO         measurement
        ▼            (*3)
  Model IR400          │ NO
  Model IR200          ▼
                     Model
                     IR200
```
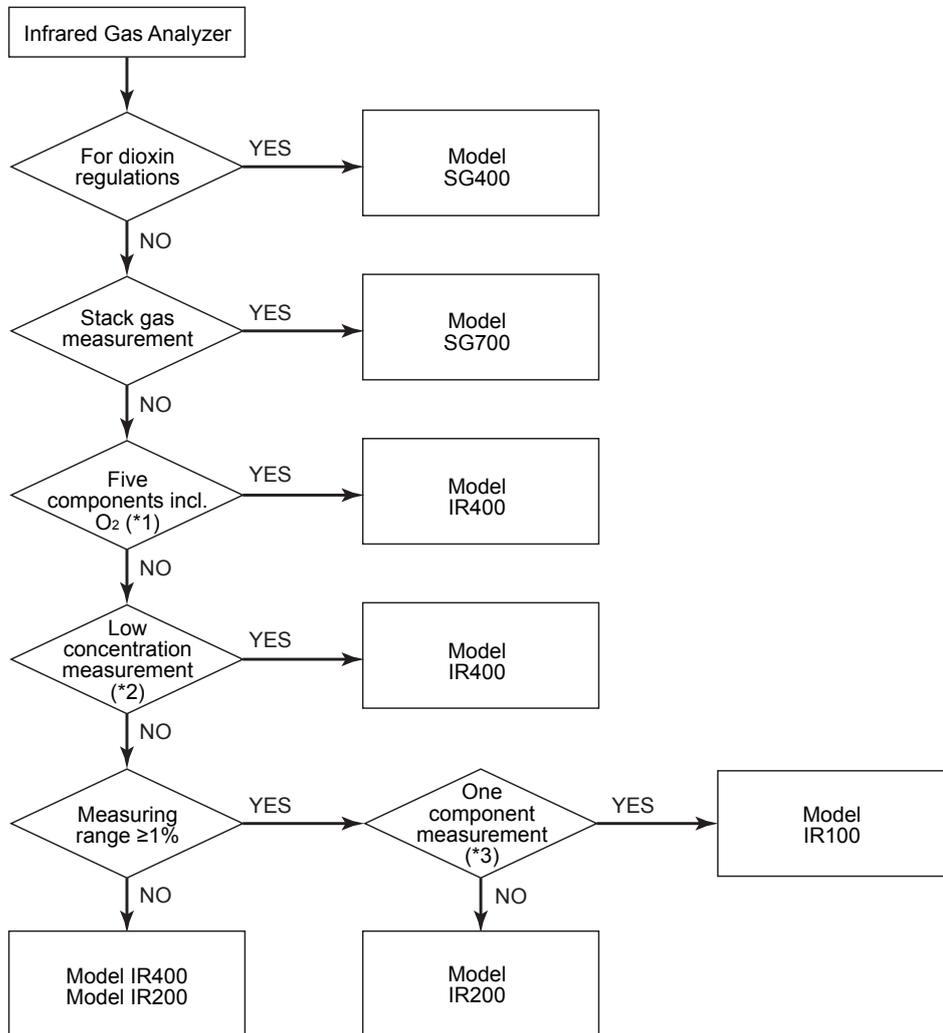
(*1) Up to 5 components including O_2 (CO/CO_2/CH_4/SO_2/NO/O_2)
(*2) CO   : <200 ppm
      CO_2 : <500 ppm
      CH_4 : <1000 ppm
      SO_2 : <500 ppm
      NO   : <500 ppm
(*3) CO, CO_2 or CH_4

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Figure 2.1 Infrared Gas Analyzer Model Selection Flowchart

3.   Measurement Principle

3.1   Principle of Infrared Gas Analysis

When a heteronuclear diatomic or polyatomic molecule, e.g., carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxide (NO) or methane (CH_4), is exposed to infrared light, it absorbs some of the light and thus gains energy to vibrate and rotate. As a result, the infrared absorbing gas expands. As shown in Figure 3.1, the wavelength region in which a gas absorbs is unique to each gas. The absorption intensity is governed by the Lambert-Beer's law shown below.

$$I = I_0 e^{-ckl}$$

Where:

I : the intensity of the transmitted light

I_0 : the intensity of the incident light

c : the concentration of the gas of interest

k : the absorption coefficient of the gas of interest

l : the light path length (the sample cell length)

From the above law, the concentration of a gas can be determined by measuring the intensity of infrared light that travels through the gas.

Homonuclear diatomic molecules, e.g., oxygen (O_2), nitrogen (N_2) or hydrogen (H_2), do not absorb infrared light. Concentrations of CO, CO_2, SO_2, NO, CH_4, etc. in air or exhaust gases can be measured by infrared analysis.

Transmission Range of
IR Transparent Window

Sapphire Approx. 6 μm

CaF2 Approx. 10 μm
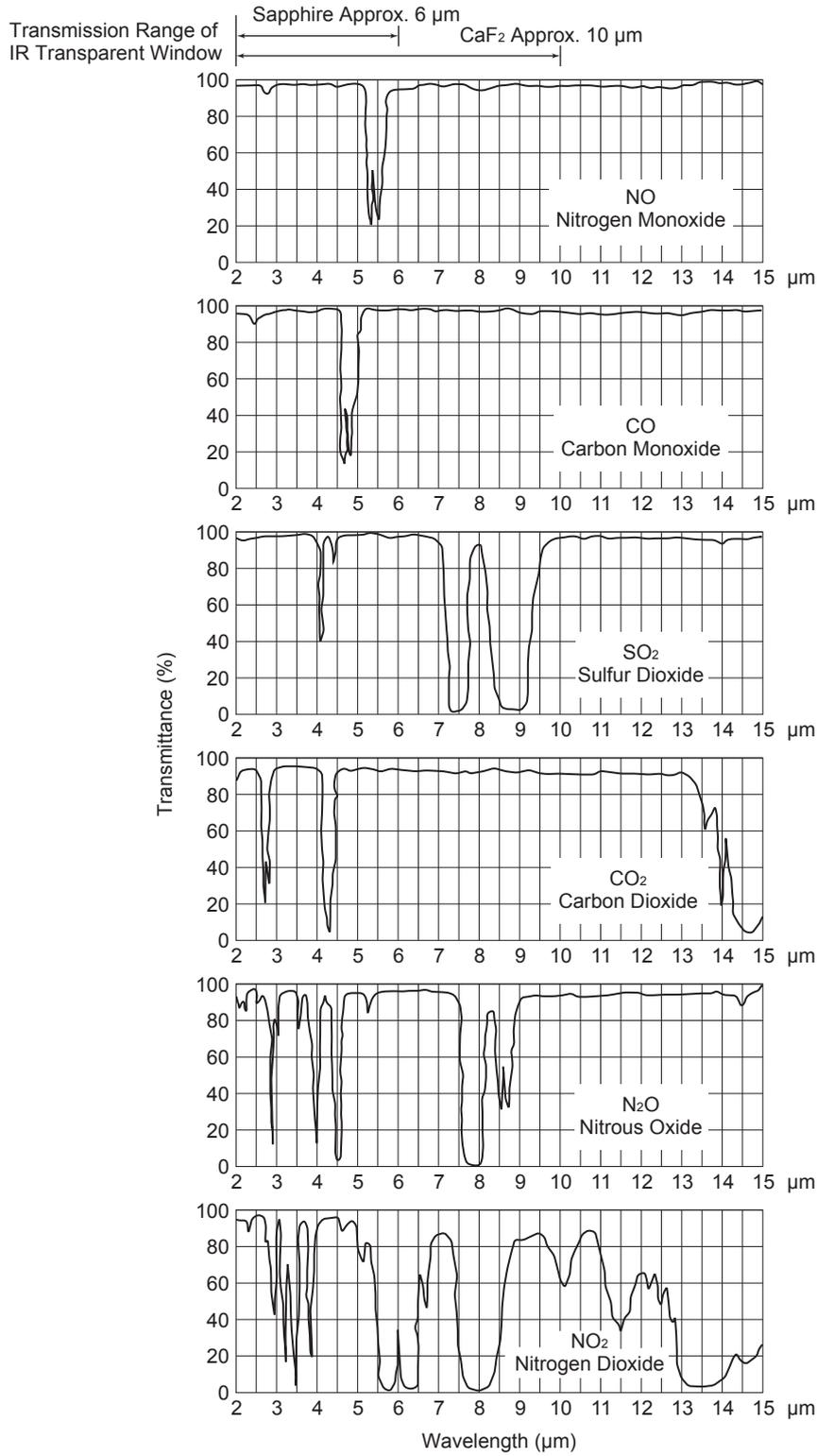
Figure 3.1 Infrared Absorption Spectra

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3.2   Typical Configurations of Infrared Gas Analyzers

With recent advances in mechanical technology, configurations of infrared gas analyzers have become diversified. The following typical systems are described in this section.

- Double beam system

- Single beam system

- Cross modulation system

3.2.1   Double Beam System

Figure 3.2 is the configuration of a typical double beam analyzer.

The analyzer uses one or two sources to generate two beams. The single-source/double-beam type uses one source to generate infrared radiation and divides it into two beams: one passes through a sample cell and the other through a reference cell. The double-source/double-beam type has two infrared sources for the two cells.

The advantage of the double-source/double-beam type is that each cell can receive high intensity of infrared radiation, while the disadvantage is that a zero drift tends to occur when the intensity of each light source changes differently with time.

Such a zero drift is less likely to occur with the single-source/double-beam type analyzer since it has a single source and so changes in its intensity over time, if any, will affect two cells equally. On the other hand, one of the disadvantages of this type is its complicated structure. It is designed so that it can divide the light source into two beams that give low light intensity per cell.

Infrared light from a source is interrupted by a rotating chopper (or rotating sector wheel) and is passed through an optical filter and sample and reference cells to a detector.
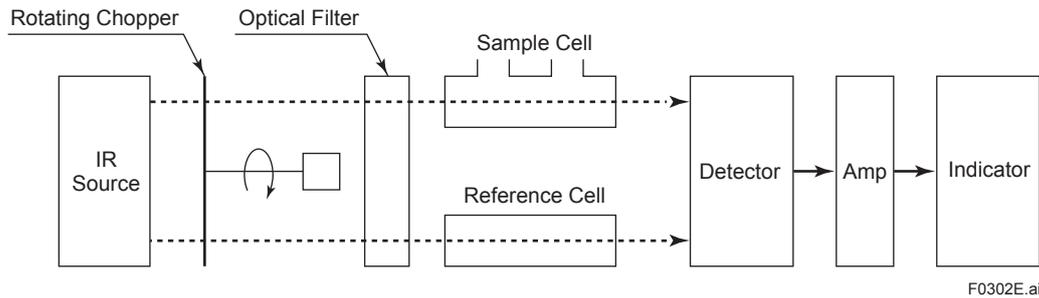
F0302E.ai

Figure 3.2 Typical Double Beam System

There are two types of detectors: selective and nonselective. A selective detector, also called a gas-filled detector, consists of two detector chambers that receive infrared radiation passed through a sample cell and a reference cell, respectively, a gas flow path between the two chambers, and a condenser microphone or a thermal flowmeter installed in the path (Figure 3.3).

The chambers are sealed with a target gas or substitute gas. The target gas filled in the detector chamber selectively absorbs the infrared light at the wavelength which is characteristic of the gas. The light energy absorbed is converted into thermal energy, which increases the temperature in the detector chamber and thus thermal expansion occurs. This causes the pressure to increase in the detector chamber. The pressure difference between the two chambers is measured by a condenser microphone and converted into an electrical signal. Alternatively, a gas flow created by the pressure difference is detected by a thermal flowmeter and converted into an electrical signal. The infrared radiation from the source is pulsed at a specific frequency, as described above, and so the electrical signal is an AC signal with the pulsing frequency of the light.
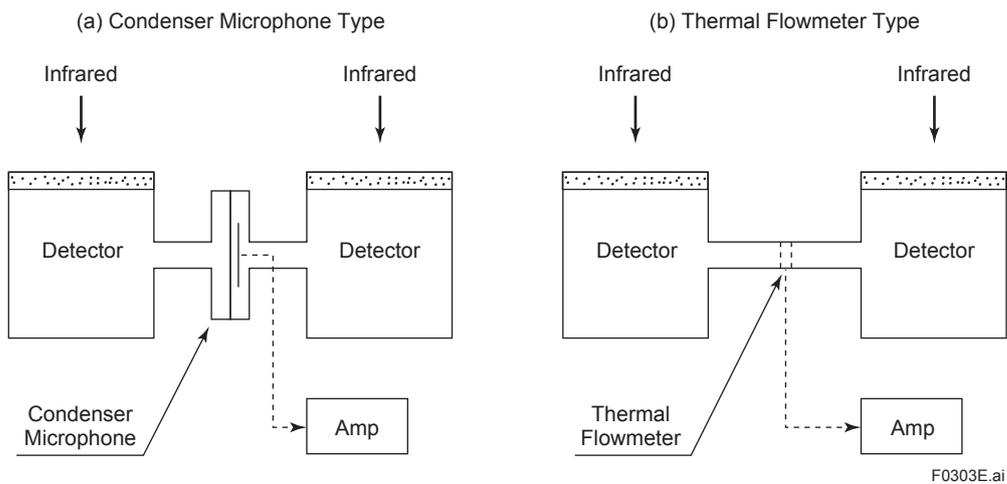
Figure 3.3 Typical Selective Detectors

Nonselective types are a thermal detector and a solid-state detector. A thermal detector once converts infrared radiation energy into thermal energy, and then converts it into an electrical signal, while a solid-state detector converts radiation energy into an electrical signal directly. A nonselective detector itself is not capable of selectively detecting infrared radiation at a specific wavelength. Therefore, it needs to be used in conjunction with an optical filter that passes only the specific wavelengths of interest in order that it is not affected by the absorption of radiation by other gases contained in a sample cell.

3.2.2   Single Beam System

Single beam analyzers are similar to double beam analyzers with the exception of a reference cell (see Figure 3.4). The single beam system configuration, in principle, makes it difficult to keep the stability of the analyzer because there is no reference cell. On the other hand, a simple design and no need for optical adjustment which is required for double beam analyzers, allow for easy maintenance and inspection.
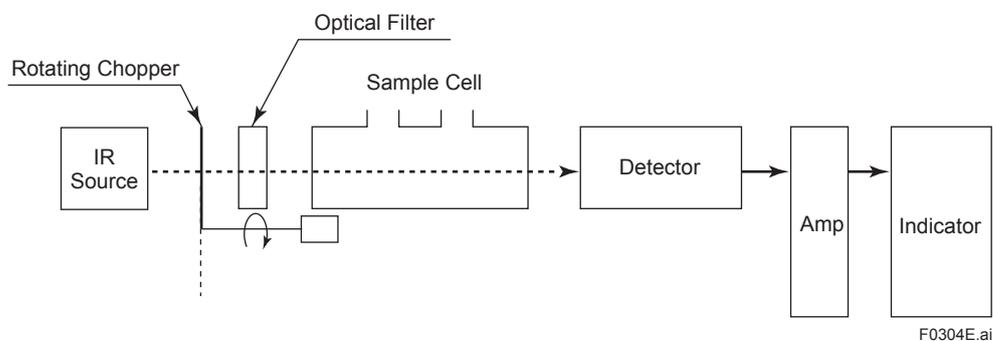
Figure 3.4 Typical Single Beam System

3.2.3   Cross Modulation System

A cross modulation system does not use a rotating chopper. As shown in Figure 3.5, it uses a switching valve or appropriate device to introduce a sample gas and a reference gas alternately at a specific frequency. A modulated signal obtained by switching a sample gas and a reference gas is used and the difference in quantity is measured.

The advantage of this system is that there is no zero drift because an AC output is not generated if a sample gas and a reference gas are identical. Another advantage is that the system requires no optical adjustment. On the other hand, the system requires a switching valve that is capable of switching a sample gas and a reference gas at a short frequency (approximately 0.5 seconds). The disadvantages include short life of this switching valve and complicated sampling equipment.

Figure 3.6 shows another configuration of this system: two gas cells are used alternately as a sample cell and a reference cell.

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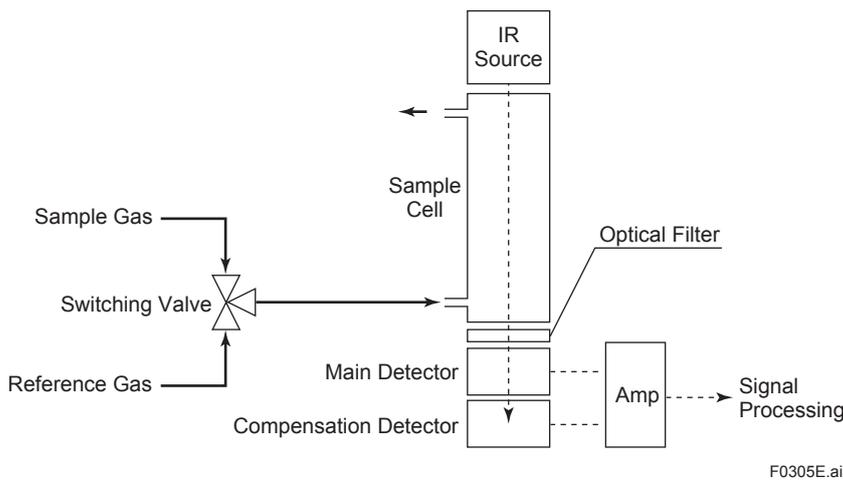
Figure 3.5 Cross Modulation System: Example (1)

F0306E.ai
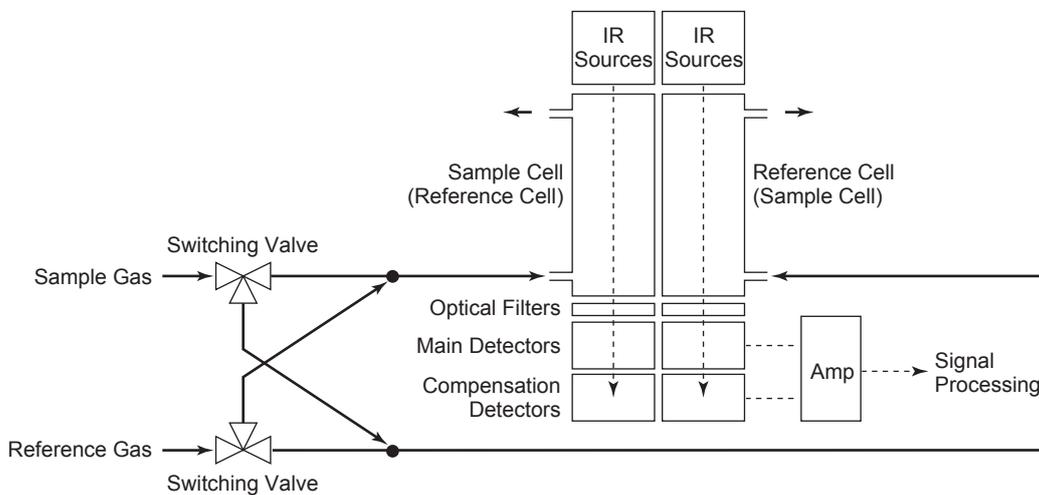
Figure 3.6 Cross Modulation System: Example (2)

3.3   IR100 and IR200 Infrared Gas Analyzer Configurations

The IR100 and IR200 infrared gas analyzers use a single beam system. Figure 3.7 shows the basic configuration of the two analyzers.

Infrared radiation from a source is interrupted by a rotating chopper at a specific frequency and passed through a measurement cell. A target gas in a sample in the measurement cell absorbs some of infrared energy and so reduced energy reaches a detector. The detector consists of front and rear expansion chambers, both are filled with the target gas. Two chambers are linked by a narrow path, in the middle of which a thermal flow sensor is installed. First, some amount of energy is absorbed in the front expansion chamber, and then the rest of energy is absorbed in the rear expansion chamber. This causes the pressure to rise in both chambers. The chambers are designed so that the pressure rises differently in the two chambers. The pressure difference between the two chambers causes a subtle flow in the path, which is detected by the thermal flow sensor and converted into an AC signal. The signal is differentially amplified, and is then converted to digital by an analog-to-digital (A/D) converter. The digital signal is processed, together with a synchronous signal by the rotating chopper, to provide an output signal which is proportional to the concentration of the target gas.

A single beam system is suited for detecting relatively high concentrations of gases. It provides excellent maintainability because of its simpler configuration as compared to a double beam system or cross modulation system.
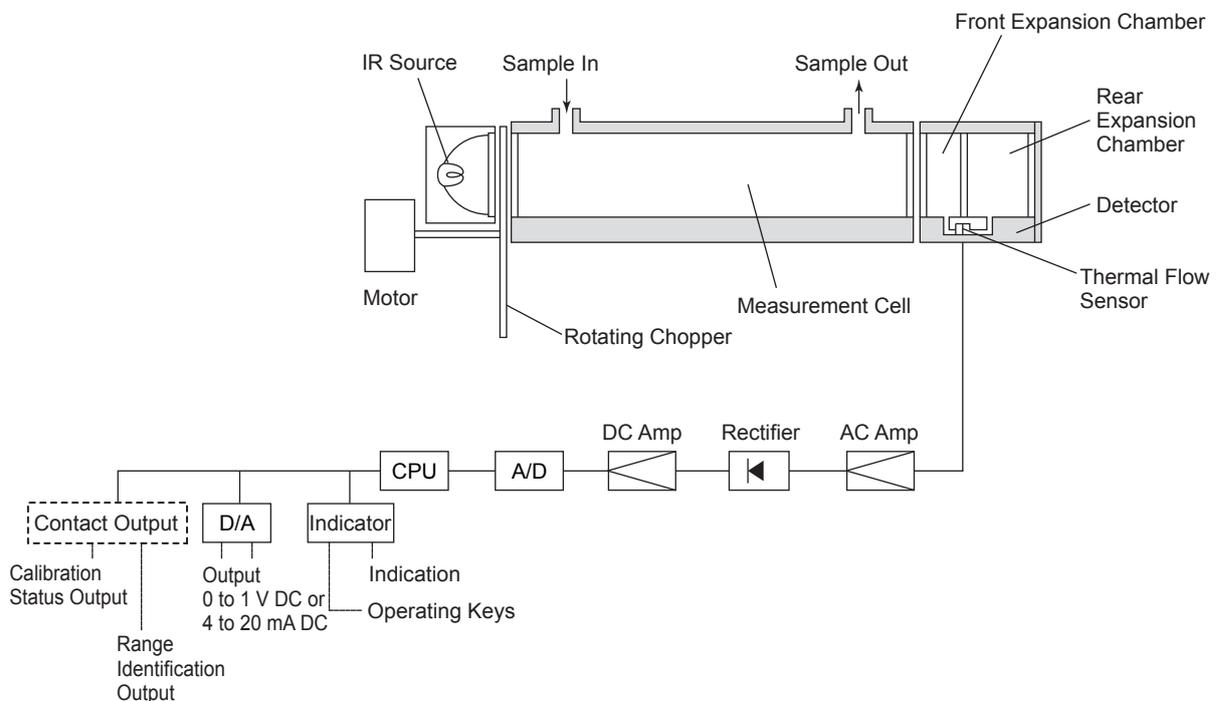
F0307E.ai

Figure 3.7 Basic Configuration of the IR100 and IR200 Infrared Gas Analyzers

3.4   IR400 Infrared Gas Analyzer Configuration

The IR400 Infrared Gas Analyzer uses a double beam system to provide high sensitivity in measurement and a wide dynamic range. Figure 3.8 shows the basic configuration of the analyzer.

Infrared radiation from a single source is interrupted by a rotating chopper and divided into two beams in a distribution cell. Then, the two beams are passed through a sample cell and a reference cell, respectively. The distribution cell is filled with interfering species, which prevents the effect of interference from other components.

In the sample cell a target gas contained in a sample absorbs infrared radiation, and thus the intensity of transmitted infrared light is reduced by the amount of radiation absorbed. In contrast, the reference cell is sealed with nitrogen or inert gas, and so infrared radiation is not absorbed in the cell. Therefore, the radiation energy received by the sample detector chamber is less than the one by the reference detector chamber.

The difference between the two chambers is detected by a thermal flow sensor and converted into an AC signal. The signal is differentially amplified, and is then converted to digital by an analog-to-digital (A/D) converter. The digital signal is processed, together with a synchronous signal from the rotating chopper, to provide an output signal which is proportional to the concentration of the gas of interest.
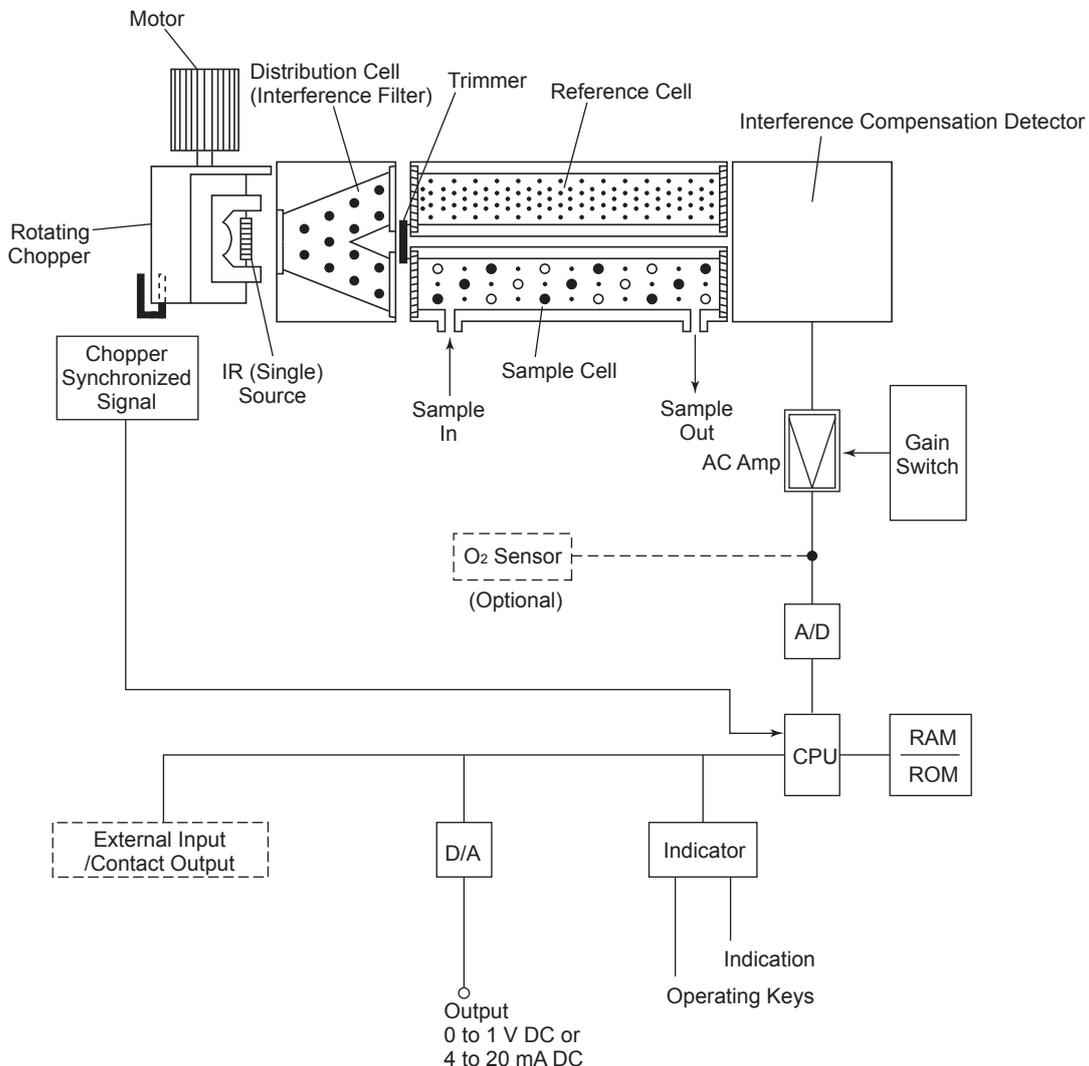
F0308.ai

Figure 3.8 Basic Configuration of the IR400 Infrared Gas Analyzer

3.5   Detector

3.5.1   Detector Structure and Principle of Operation

Figure 3.9 shows the structure of a detector.

The detector chambers are filled with a gas that is the same as the one to be measured and sealed with infrared transparent windows. A sample detector chamber and a reference detector chamber are linked by a narrow path, in the middle of which a thermal flow sensor is installed. When infrared radiation passes into the detector, the gas filled in the detector absorbs the radiation at the wavelength which is characteristic of the gas and expands by an amount corresponding to the energy it absorbed.

When the sample containing target gas flows through the sample cell, the intensity of infrared radiation received by the sample detector chamber is lower than the one received by the reference detector chamber. This means that the amount of energy absorbed by the gas filled in the sample detector chamber is smaller than the amount of energy absorbed by the gas filled in the reference detector chamber. This causes the pressure difference between the two chambers, which creates a gas flow in the narrow path from the reference side to the sample side. This flow is detected by a thermal flow sensor, a kind of hot wire anemometers, and converted into a change in resistance.

IR Transparent   Infrared thru   Infrared thru   IR Transparent
Window   Sample Cell   Reference Cell   Window

Sample   Reference
Detector   Detector
Chamber   Chamber

Thermal Flow Sensor
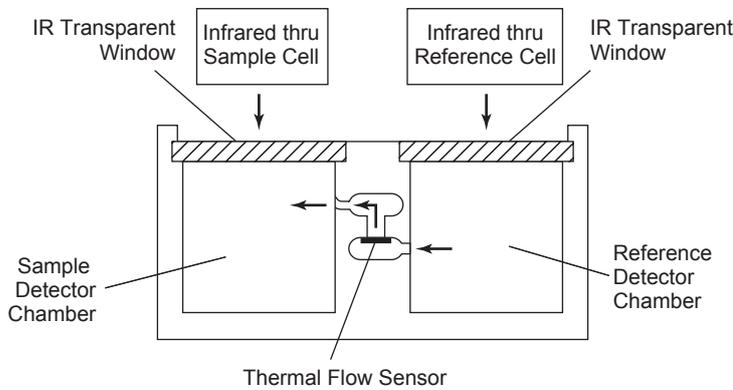
F0309E.ai

Figure 3.9 Detector Structure

3.5.2   Thermal Flow Sensor

A thermal flow sensor is used as an element to detect the difference in light intensity between a sample cell and a reference cell and convert it into an electrical signal. The thermal flow sensor is a nickel film manufactured using IC production technology and as shown in Figure 3.10, it is woven from nickel wire in 1 mm width and connected in series from end A to end B. Nickel gratings are mounted in a gas flow path so that they are faced each other with a very little space between and that they are oriented perpendicular to the direction of gas flow. The gratings are heated by applying the current. When there is no gas flow, temperatures of the two gratings are balanced and the temperature distribution is as shown in Figure 3.11 (a). When gas flows from left, the left nickel grating cools down and the gas heated by the left grating runs into the right nickel grating, causing its temperature to rise, and the temperature distribution is as shown in Figure 3.11 (b). Likewise, when gas flows from right, the temperature distribution is as shown in Figure 3.11 (c). As the temperature distribution changes, nickel resistance changes. The change in resistance is converted into a change in voltage.
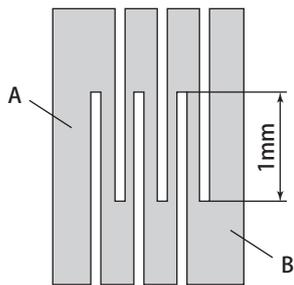
F0310.ai

Figure 3.10 Thermal Flow Sensor
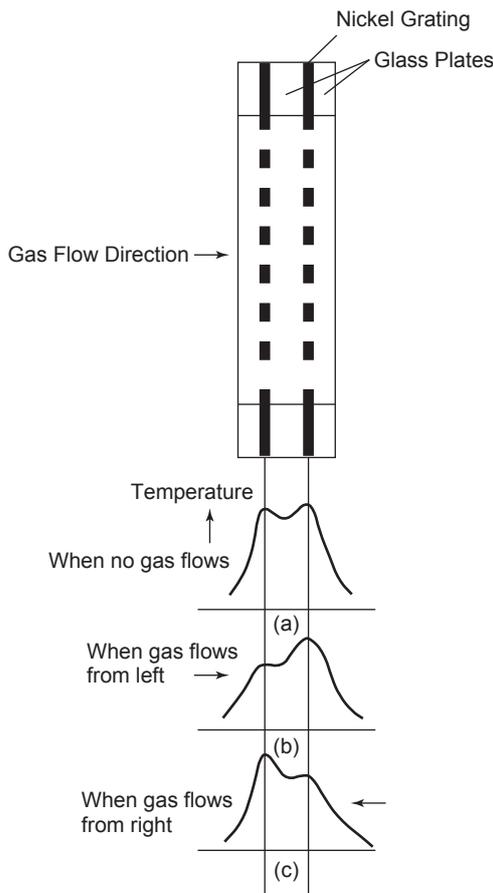
F0311E.ai

Figure 3.11 Grating Layout and Temperature Distribution

3.6   Effects of Interfering Gases and Removal of Interference

3.6.1   Effects of Interfering Gases

When a sample contains gases (interfering species) that have the absorption wavelengths similar to that of a target gas, an error will occur in response to changes in concentrations of the interfering species. To remove the effects of interfering species, an optical filter or other device is placed in front of the detector to filter out radiation with wavelengths of interfering specifies. However, when very low concentration of a target gas is measured, the above method is not sufficient and so interference is removed in the manner described in Section 3.6.2.

Table 3.1 shows the degree of the effects of interfering gases after the above method has been taken.

Table 3.1 Effects of Interfering Gases

Model	Interfering Gas and Concentration		Analyzer				
			CO Analyzer	CO_2 Analyzer	CH_4 Analyzer	SO_2 Analyzer	NO Analyzer
IR100	CO CO_2 H_2O CH_4 SO_2	1000 ppm 15% 20 °C sat. 5000 ppm 1000 ppm	≤1% FS (*1) ≤5 ppm ≤2 ppm	≤5 ppm ≤1% FS ≤5 ppm ≤2 ppm	≤5 ppm ≤1% FS ≤1% FS ≤0.5% FS		
IR200	CO CO_2 H_2O H_2O CH_4	1000 ppm 15% 20 °C sat. 2 °C sat. 1000 ppm	≤1% FS (*1) (*2) ≤1% FS	≤5 ppm ≤1% FS ≤1% FS	≤5 ppm ≤1% FS ≤1% FS	5 ppm ≤50 ppm ≤50 ppm	5 ppm ≤60 ppm
IR400	CO_2 NO_2 N_2O	15% 50 ppm 1000 ppm	≤10 ppm ≤80 ppm		≤3 ppm	≤–6 ppm	
SG400	CO_2 H_2O CH_4	15% 2 °C sat. 5000 ppm	≤2.5% FS ≤2.5% FS ≤1% FS				
SG700	CO_2 NO_2 N_2O	15% 50 ppm 1000 ppm	≤10 ppm ≤80 ppm			≤–6 ppm	

(*1)   ≤12 ppm or 1% FS, whichever is greater.
(*2)   When measuring range for 0 to 500 ppm or less is specified.

3.6.2   Removal of Interference

As shown in Figure 3.12, when a sample contains a gas (interfering gas) that has an infrared absorption spectrum overlapping with the one of a target gas, a significant measurement error may occur. To remove the error caused by interference, a detection system that comprises a first detector and a second detector is used (see Figure 3.13). Two detectors are placed in series and infrared radiation passes through the first detector that is filled with a target gas, and then the second detector that is filled with a gas that has an absorption band wider than that of the gas filled in the first detector.
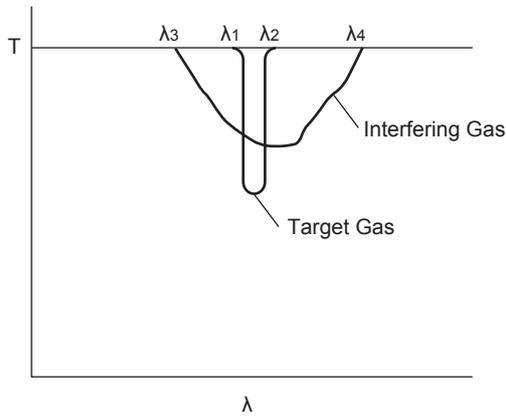
F0312E.ai

Figure 3.12 Absorption Spectra of Target and Interfering Gases.
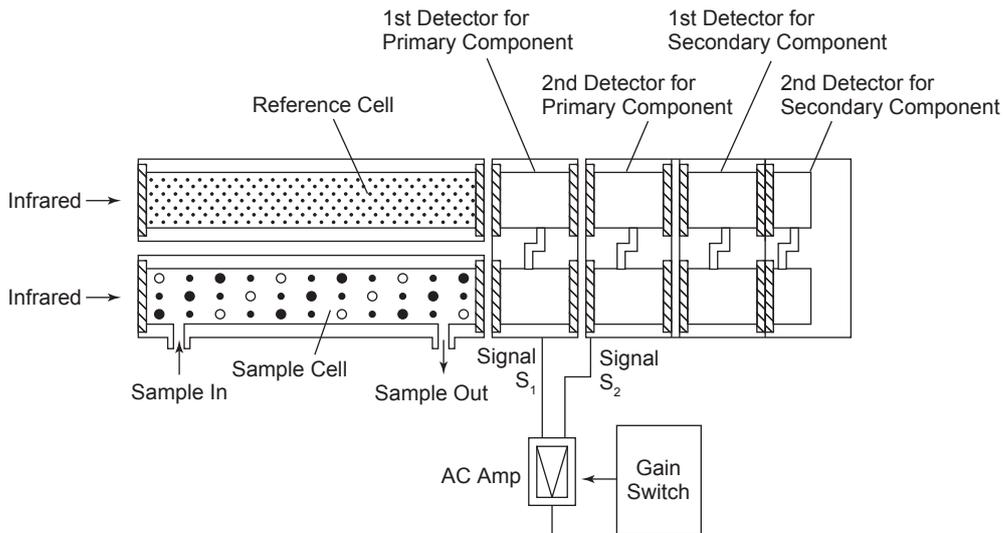
F0313E.ai

Figure 3.13 Compensation Detector

Figure 3.14 shows spectra of the incident light to the measurement cell, the incident light to the first detector (i.e., the light transmitted through the measurement cell), the incident light to the second detector (i.e., the light transmitted through the first detector), and the light transmitted through the second detector, respectively in the sample path and the reference path.

In Figure 3.14, (c) and (c'), the amount of radiation absorbed in the first detector on the sample path is E_{10}, while the amount of radiation absorbed in the first detector on the reference path is E_{20}. The output signal of the first detector, S_1, is expressed by the equation below.

$$S_1 \propto (E_{20} - E_{10}) = E_2 + E_3$$

where:

E_2: the amount of radiation absorbed by target gas in sample

E_3: the amount of radiation absorbed by interfering species in sample

Likewise, in Figure 3.14, (d) and (d'), the output signal of the second detector, S_2, is expressed by the equation below.

$$S_2 \propto (E_{21} + E_{22}) - (E_{11} + E_{12}) = E_4 + E_5$$

where:

E_4, E_5: the amount of radiation absorbed by interfering species in sample

It is assumed that E_2 is nearly proportional to the concentration of the target gas, C, and E_3, E_4, and E_5 are to the concentration of interfering gases, Cl. Therefore, the S_1 and S_2 are expressed as follows:

$$S_1 = k_1 C + k_2 Cl$$

$$S_2 = k_3 Cl$$

where:

k_1, k_2, k_3: proportionality constants

From electrical computation of S_1 and S_2, signal S that is proportional to the concentration of the target gas, C, is obtained. This theoretically corrects the error due to interference.

$$S = k_3 S_1 - k_2 S_1 \propto C$$
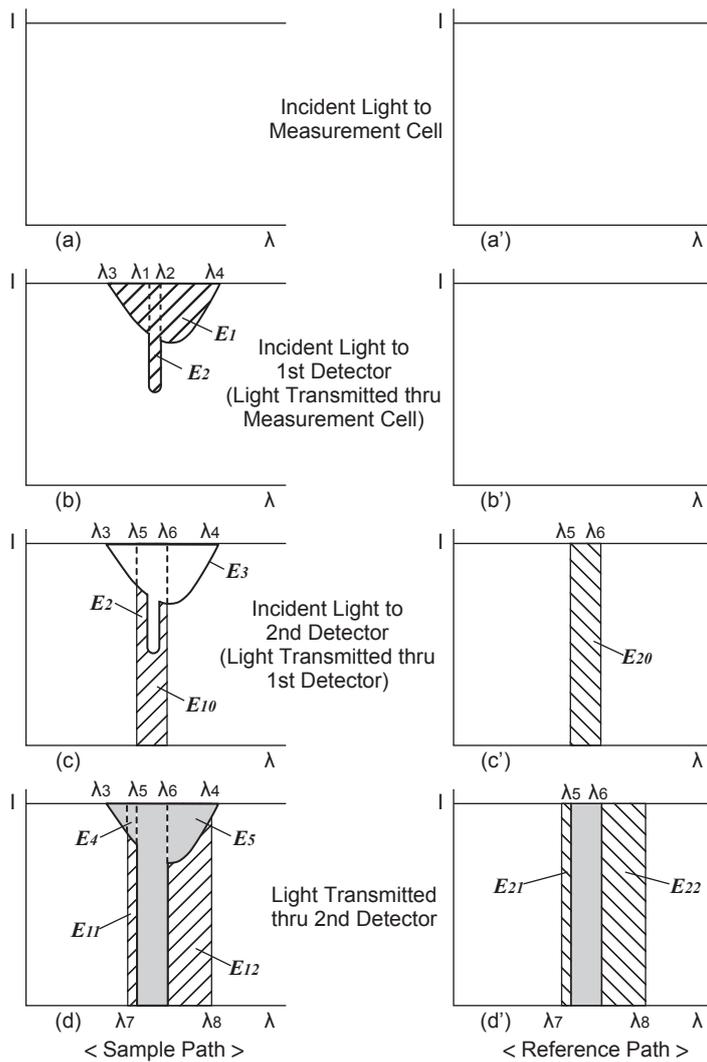
Figure 3.14 Infrared Absorption Spectrum

3.7   Correction to Reference Oxygen Concentration

Regulations of nitrogen oxides (NOx) emissions from stationary sources require that the NOx concentration measured should be corrected to a reference oxygen concentration using the following equation.

$$C = \frac{(21 - O_n)}{(21 - O_s)} \times C_s$$

where:

C : oxygen corrected NOx concentration (ppm)

O_n : reference oxygen concentration (%)

(Dependent on combustion facilities, combustion types, etc. Setting range: 0 to

19% O_2, user configurable. Default: 4%)

Oil fired boiler: 4%

Gas fired boiler: 5%

Solid fuel fired boiler/oil heating furnace: 6%

Coke oven: 7%

Incinerator: 12%

O_s : oxygen concentration (%) (limit setting: 1 to 20% O_2, Default: 17%)

C_s : NOx concentration measured (ppm)

SO_2 and CO concentrations are also corrected to a reference oxygen concentration using the above equation.

Infrared Gas Analyzer
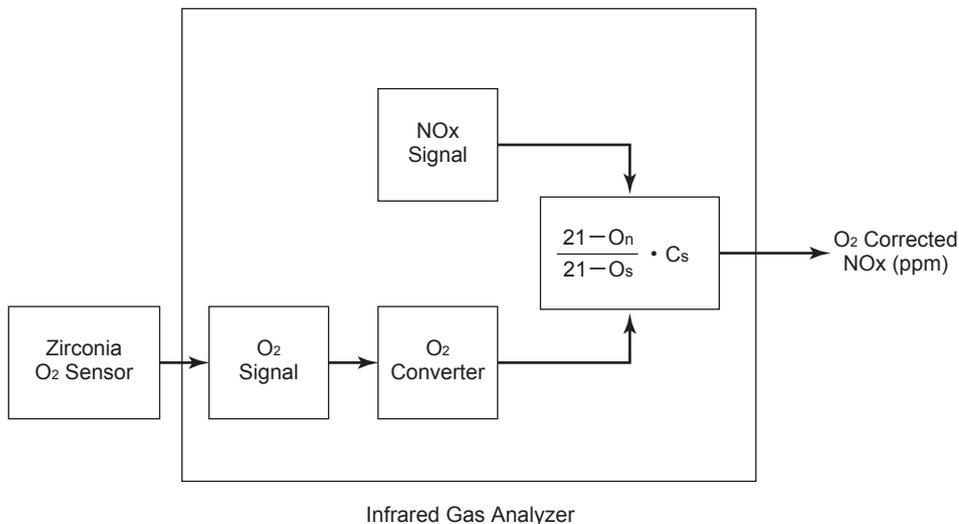
F0315E.ai

Figure 3.15 Block Diagram of Concentration Conversion

3.8 NO_2/NO Converter

In order to measure NOx (the sum of NO and NO_2) concentration in sample gas using an NO analyzer, NO_2 first needs to be converted into NO efficiently and selectively, which is performed by an NO_2/NO converter. The converter is categorized broadly in two types.

● Equilibrium (high temperature) type

This method utilizes the fact that in the equation, $2NO_2 \leftrightarrow 2NO + O_2$, an increase in temperature will cause the equilibrium to shift in the direction of NO. Sample gas is introduced to a metal tube that is kept at a high temperature (>700 °C) to convert NO_2 into NO.

● Reduction (low temperature) type

A reaction tube that contains catalytic metal and is filled with carbon material, is used at relatively low temperature to convert NO_2 into NO.

In terms of operating and other conditions, it may be said that the reduction type has advantages over the equilibrium type. The reduction type, however, has the following drawbacks.

- If ammonia (NH_3) coexists, denitration proceeds in parallel. The selectivity can be limited.

- Carbon is oxidized by coexisting oxygen, which makes the life shorter.

Yokogawa has overcome the drawbacks of the conventional reduction type NO_2/NO converter by making the following improvements:

- The converter temperature is set to 250 °C or below.

- The converter uses carbon material that is inoxidizable, does not adsorb NO_2, and has high converting (reducing) activity.

- The converter uses catalytic metal that is inactive in the denitration reactions and selectively accelerates the NO_2/NO conversion reaction. The catalytic metal is effectively added to the carbon material.

Yokogawa's NO_2/NO converter provides excellent performance as follows:

Converter temperature:	<200 to 220 °C
Amount of catalyst used:	Approx. 2 mL (approx. 1.5 g)
Cycle of catalyst replacement:	Approx. 9 months (normal boiler flue gas at a flow rate of 0.5 L/min)
NH3 interference:	<0.1 × [concentration of coexisting NH_3]

Interference effects of other coexisting gas components (SO_2, CO, HC, etc.) are not observed.

Yokogawa's NO_2/NO converter allows low temperatures for catalytic action and requires only a small amount of catalyst. This allows easy heating and insulating, simple construction, and easy replacement of catalyst.

The catalyst of the reduction type NO_2/NO converter accelerates the reaction, $2NO_2 + C \rightarrow 2NO + CO_2$, where carbon is consumed. A life test of the converter using actual flue gas at an oil fired boiler was conducted and the results are shown in Figure 3.16. As it shows, the converter maintained high efficiency of over 95% even when the amount of catalyst decreased by half in about nine months.
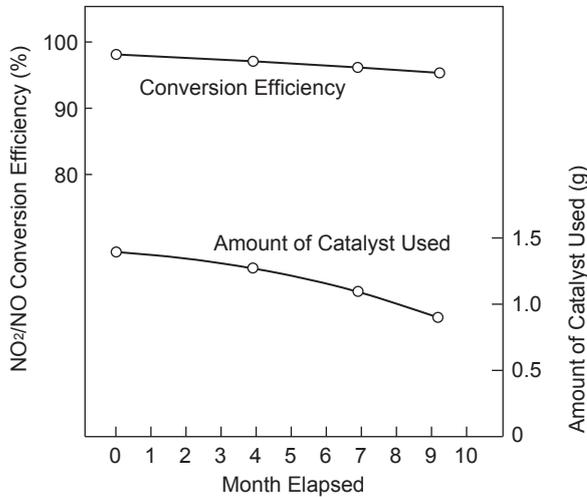
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Figure 3.16 Life Test of the Catalyst

Figure 3.17 shows the dependence of the conversion efficiency on the gas flow rate. The converter has the efficiency of over 90% at a flow rate of 1.5 L/min or less, which shows that the conversion efficiency is hardly affected by changes in sample gas flow rate.
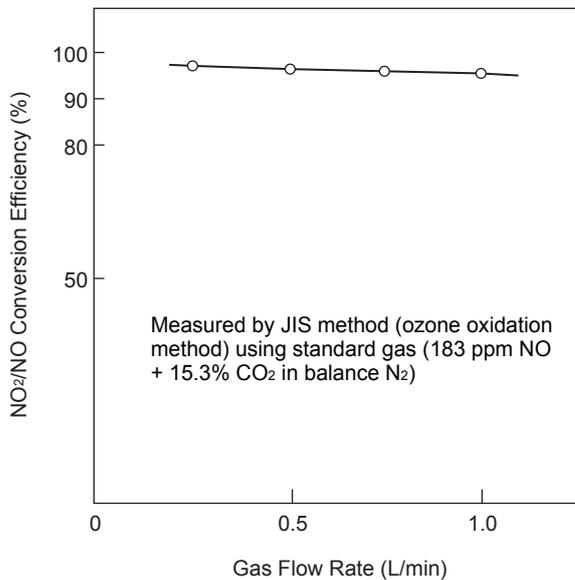
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Figure 3.17 NO_2/NO Conversion Efficiency vs. Sample Gas Flow Rate

4.   System Configurations for Stack Gas Measurement

Infrared analyzers are widely used in various industrial applications.

A typical system configuration consists of an analyzing system, which incorporates infrared analyzers, condensate collection pots, dehumidifiers, and other sampling devices, and external sampling equipment such as a sampling probe, dust filters, and condensate separators.

This chapter discusses system configurations for multiple gas measurement in stack gas emissions as typical examples of the applications.

Stack gases vary in the composition, temperature, dust content and others. Therefore, appropriate system configuration should be considered. In system construction it is important to note that a sample gas should be free of dust and cooled before being introduced to the analyzer system. The temperature difference between the sample and the analyzing system, may cause condensation to form and together with mist and dust, it may interfere with stable measurements. By using a sampling system suitable for the application, condensation and deposition should be prevented and condensate formed should be removed immediately.

Table 4.1 Examples of System Configurations for Stack Gas Measurement

	Standard System	**System with Heating Sample Tubes**	**System with External Primary Filters**
Application	• General boilers • Oil heating furnaces • Relatively low temperature at sampling point • Sample with a water content at saturation or less	• Where condensate may freeze due to cold temperature • SO_2 concentration is normally not greater than 100 ppm	• Sludge incinerators • Steel heating furnaces • High temperature at sampling point • Sample with a high water content
Temperature of sampling point	150 to 700 °C	150 to 700 °C	150 to 1400 °C
Probe	• Type F filtering probe • Type M1E filter probe • Type M2E filter probe	• Type M1E filter probe • Type M2E filter probe	• Type M2 probe • Type M3 probe
External primary filter	Not required	Not required	• Type M1E primary filter • Type MS primary filter
Sample tube	Ø10/Ø8 Teflon tube	Ø10/Ø8 heating type Teflon tube	Ø10/Ø8 Teflon tube
External condensate separator	Where necessary (*1)	Where necessary (*2)	Required

(*1)   External condensate separator is required when:
  • the distance between the probe and the analyzing system is too short to cool sample gas.
  • the distance between the probe and the analyzing system is long and in the sampling tube, condensate may form and some components of sample gas may dissolve in the condensate, causing errors.
  • the tilt of the sample tube is less than 15°.
  • the saggy sample tube may cause condensate to form.
(*2)   External condensate separator should be installed near the analyzing system when:
  • the distance between the probe and the analyzing system is long and in the sampling tube, condensate may form and some components of sample gas may dissolve in the condensate, causing errors.

4.1   Standard System

The standard system is used where the temperature at a sampling point is in the range from the acid dew point (150 °C) to 700 °C. When the temperature at a sampling point is below the acid dew point (150 °C), the sampling probe should be heated and insulated to prevent condensation in the probe. The sampling system consists of a filter probe, a standard sample tube, and an external condensate separator. The filter probe is available in Type F, Type M1E (electrically heated), and Type M2E (electrically heated). The external condensate separator may be required depending on the sample conditions.

Type F Filter Probe
150 to 400 °C at sampling point

10 to 15° above the horizontal

Tilt probe to prevent backflow of condensate into probe head

Sample Tube (Ø10/Ø8)

Hold tube as vertically as possible

Approx. 1 m minimum

Type M1E Filter Probe
150 to 700 °C at sampling point

Tubing for external condensate separator

Power supply to heater

15° minimum

Type M2E Filter Probe
150 to 700 °C at sampling point

0 to 90°

Vent

External Condensate Separator

Power supply to heater

Drain

Analyzing System

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Figure 4.1 Standard System Configuration for Stack Gas Measurement

4.2   System with Heated Sample Tube

Where the ambient temperature is at or below 0 °C and the condensate may freeze, a sample tube should be heated to prevent condensation or freezing. Also, where the SO_2 concentration is normally not greater than 100 ppm, a heated sample tube should be used to prevent condensation that can cause sample loss from dissolution. The sampling system consists of a heated filter probe and a heated sample tube. The filter probe is available in Type M1E and Type M2E. Where the temperature at a sampling point is below the acid dew point (150 °C), the probe should be heated and insulated. The system with a heated sample tube cannot be used in conjunction with an external primary filter.

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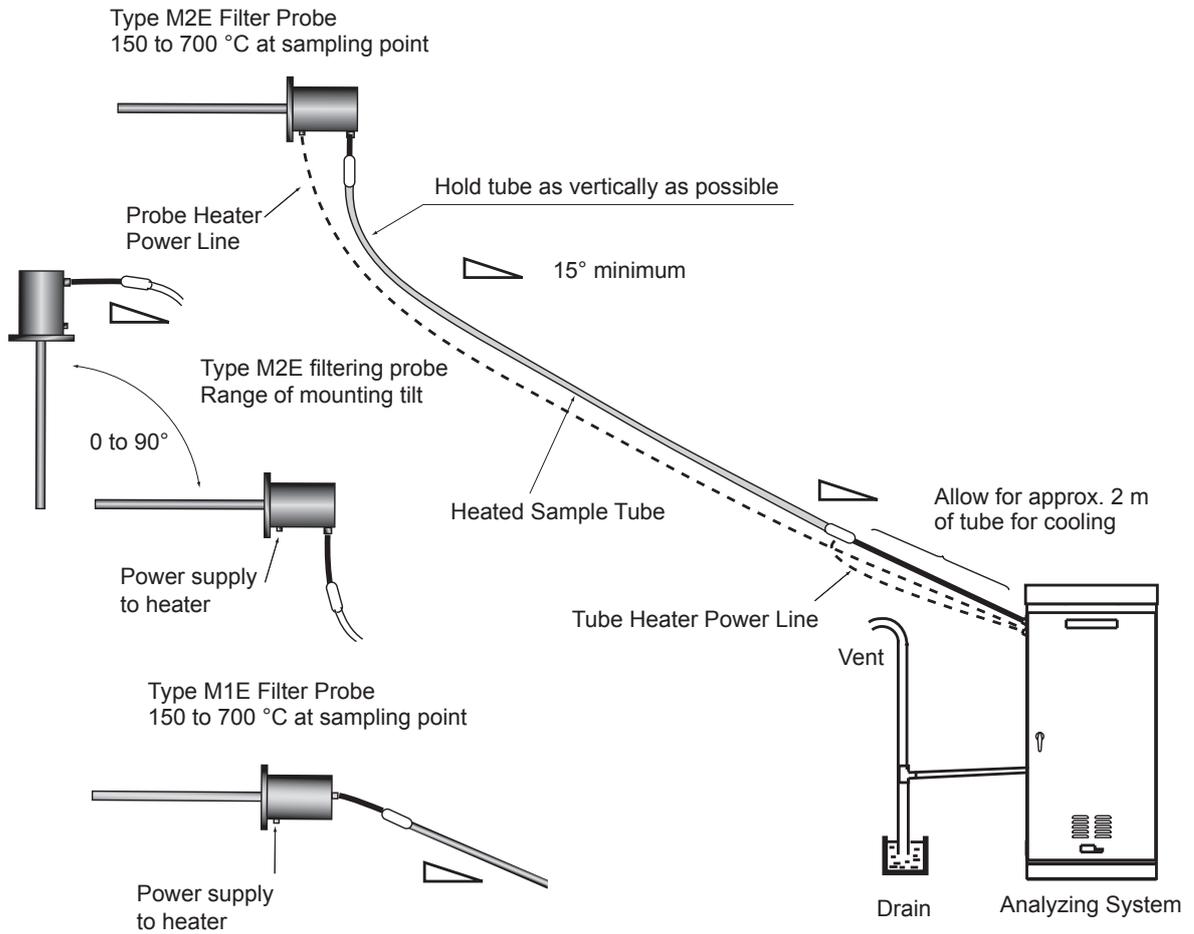
Figure 4.2 System Configuration When Using Heated Sample Tube

4.3   System with External Primary Filter

This system is applicable where a filter probe cannot be used due to locational restrictions or to high temperature of sample gas. The system consists of an open type probe, a standard sample tube, an external condensate separator, and an external primary filter. Condensate that forms in the sampling system should be removed by an external condensate separator. The external primary filter is required for eliminating dust in sample gas that is extracted from a stack via the open type probe. The open type probe is available in Type M2 (operating temperature range of 150 to 800 °C) and Type M3 (800 to 1400 °C). The external primary filter is available in Type M1E (electrically heated) and Type MS (steam heated).
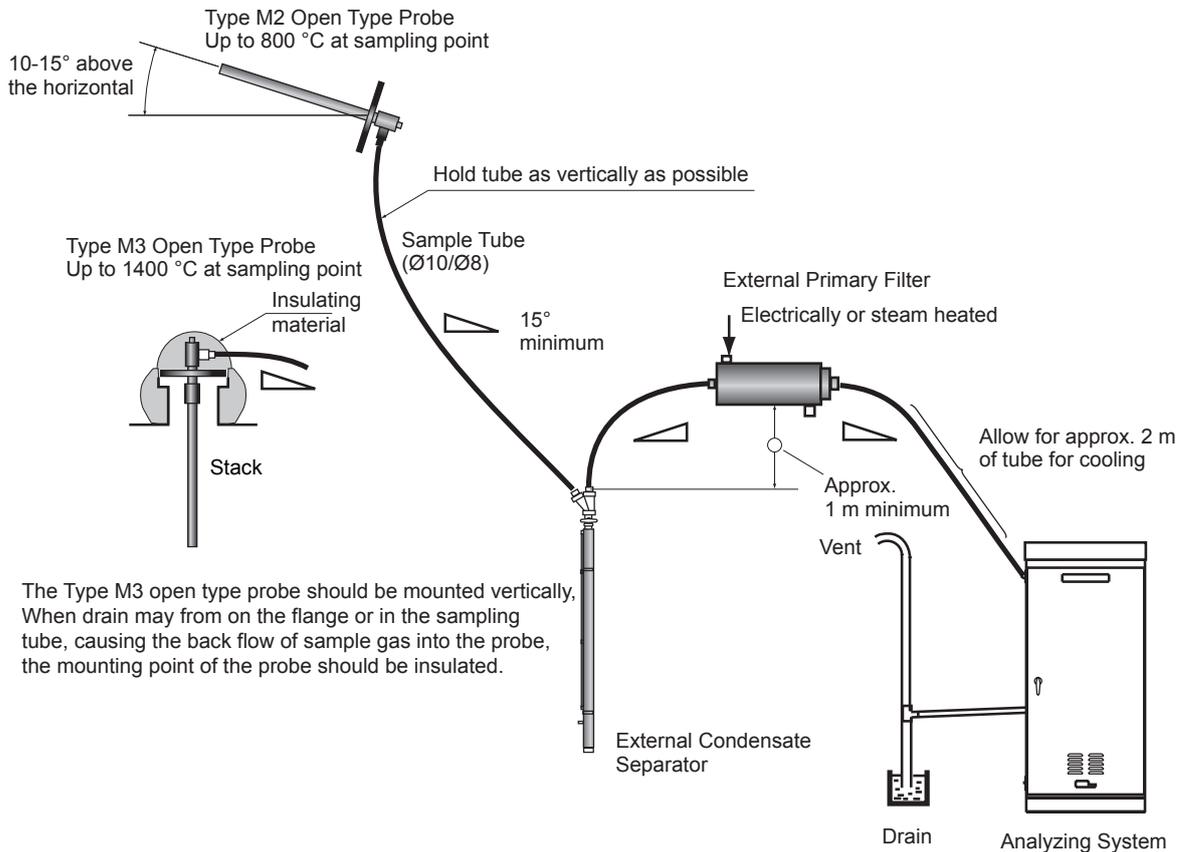
Figure 4.3 System Configuration When Using External Primary Filter

5.   Selection of External Sampling Components

Appropriately selecting sampling components and configuring a sampling system for the analyzing system, is important for accurate and stale measurements. A typical system configuration consists of an analyzing system, which incorporates infrared analyzers, condensation collection pots, dehumidifiers, and other sampling devices, and external sampling equipment such as a sampling probe, dust filters, and condensate separators.

For the selection of external sampling components for stack gas measurement, refer to our General Specifications (GS 11G04G06-E). For measurements for other applications, consult Yokogawa.

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