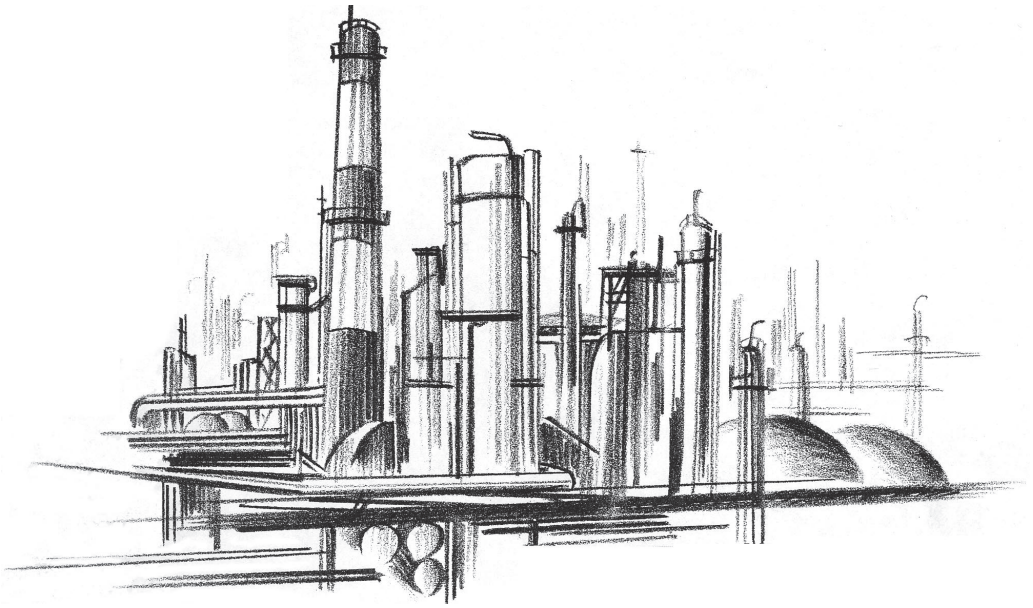
Technical Information

TI 11M12A01-01E

ZR22G, ZR402G
Direct In Situ
Zirconia Oxygen Analyzer
(Applications Volume)

EXAxt



YOKOGAWA

Yokogawa Electric Corporation
2-9-32, Nakacho, Musashino-shi, Tokyo, 180-8750 Japan
Tel.: 81-422-52-5617 Fax.: 81-422-56-5792

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ZR22G, ZR402G
Direct In Situ Zirconia Oxygen Analyzer
(Applications Volume)

TI 11M12A01-01E 4th Edition

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Revision Information i

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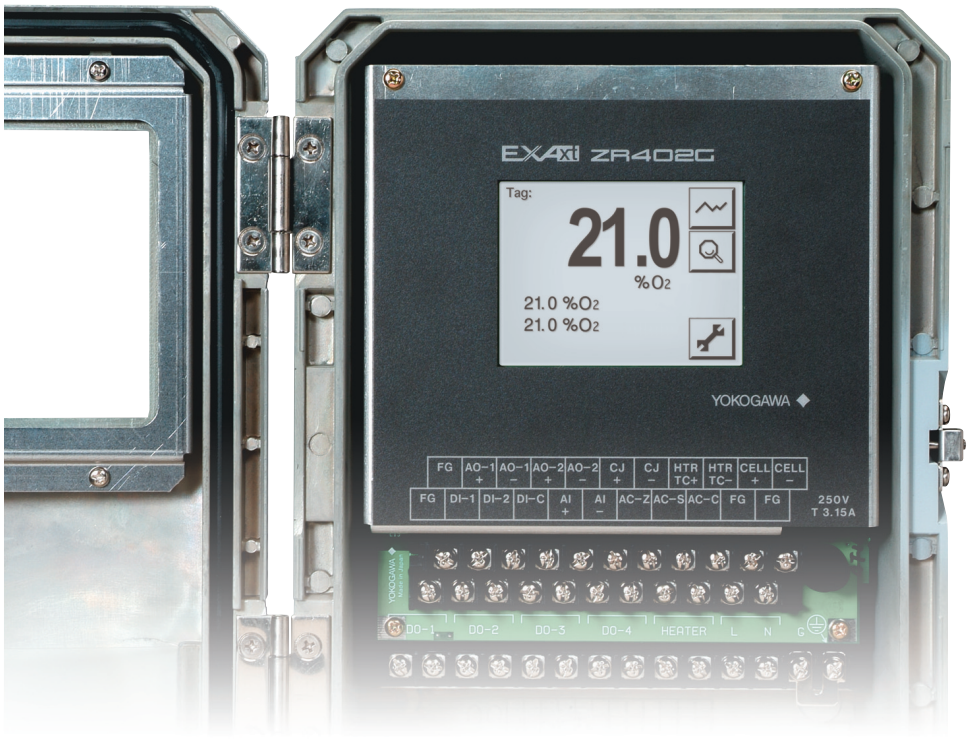
1. Overview

The EXAxt Zircon Oxygen Analyzer (Model ZR402G) is used to monitor and control the oxygen concentration in combustion gases, in boilers and industrial furnaces, for wide application in industries which consume considerable energy—such as steel, electric power, oil and petrochemical, ceramics, pulp and paper, food, or textiles, as well as incinerators and medium/small boilers. It can help conserve energy in these industries. The ZR402G also contributes to preservation of the earth's environment in preventing global warming and air pollution by controlling complete combustion to reduce CO_2 SOx and NOx.

The ZR22G Detector uses a high-reliability Zirconia sensor, and its heater assembly can be replaced on site. The detector is mounted, for example, on the wall of a flue and can measure the gases directly. For use in combustion gases at temperatures up to 1400°C, choose the general-use 0.15m long detector, which is combined with ZO21P-H, the high-temperature probe adapter.

The ZR402G converter is equipped with an LCD touch screen which has various setting displays, a calibration display, oxygen concentration trend display, with easier operation and improvement of display functions.
The ZR402G converter is equipped with various standard functions such as measurement and calculation as well as maintenance functions including self-test. Analyzer calibration can also be fully automated— and ZR40H, an automatic calibration unit, is available. Choose the detector version which best suits your needs so that an optimal combustion control system can be obtained.

Use this TI as a system selection guide and application note.



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2. Installation Guide

2.1 Selecting an Installation Site

Improper installation of the detector may cause inaccurate measurement or damage in short-term service.

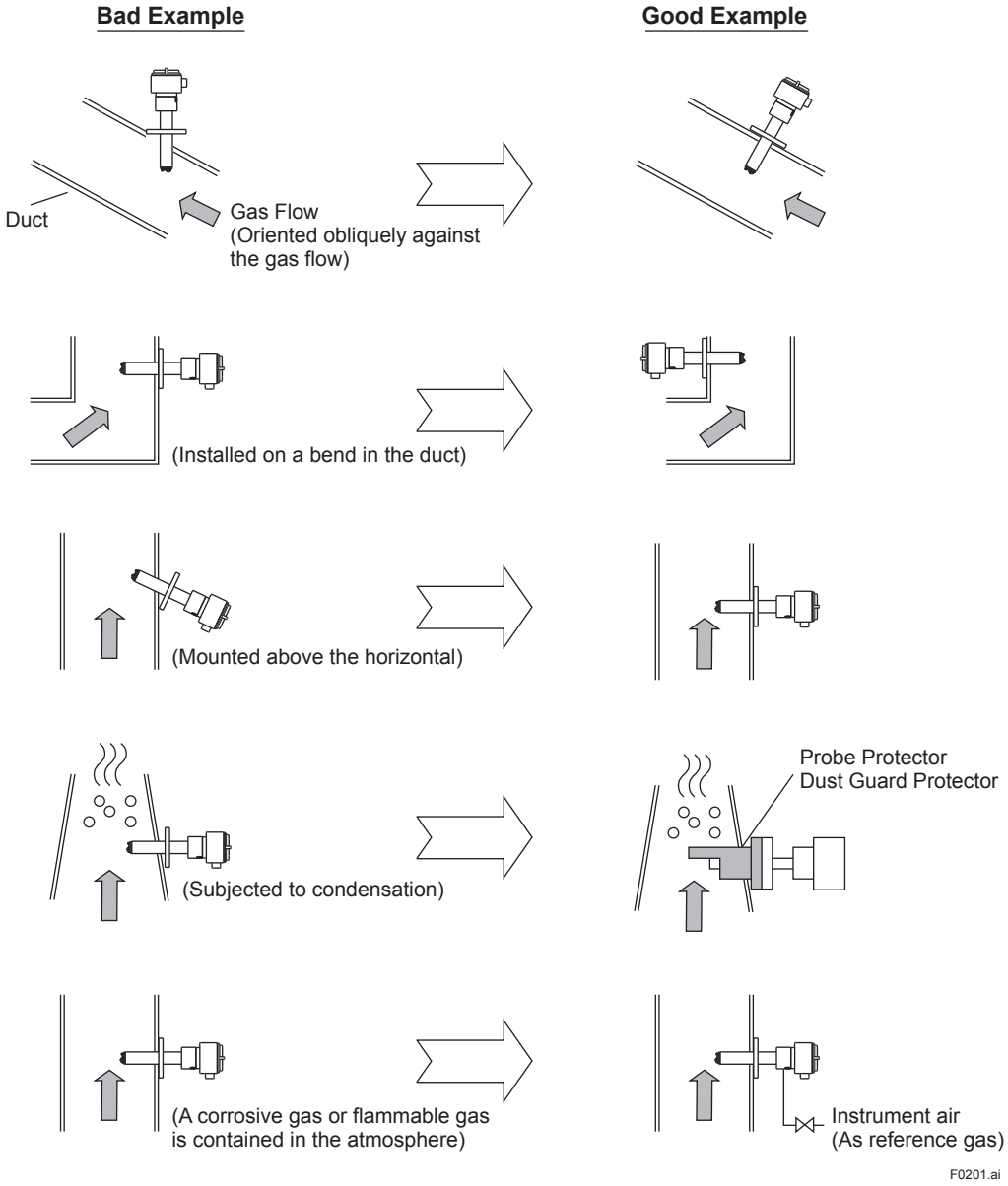
(1) Easy access for inspection and maintenance.

(2) Ambient temperature does not exceed 150°C, and the terminal box is not exposed to radiant heat.

(3) A clean environment free from corrosive gases.

(4) Minimum vibration.

Typical good/bad installation examples are shown below for your reference.



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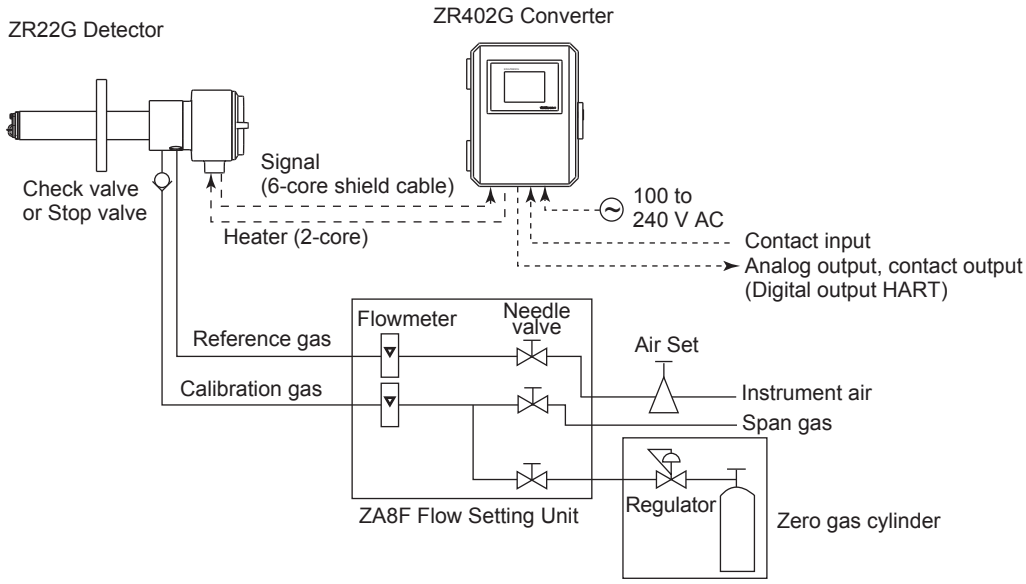
Installation Site of the Converter (in case of ZR402G)

1. Allows the operator to easily read the display and operate the keys.
2. Easy access for inspection and maintenance.
3. Ambient temperature does not exceed 55°C, and temperature variations are minimal.
4. Humidity is moderate (40 to 75% RH) and no corrosive gases are present.
5. Minimum vibration.
6. Near to the detector.
7. Not exposed to direct sun light.

Instrument air is used as the reference gas



1) Install the stop valve or check valve securely so that the gas does not leak.
2) Use the ZA8F flow setting unit and zero gas cylinder.
3) Use a shielded cable for the signal line.

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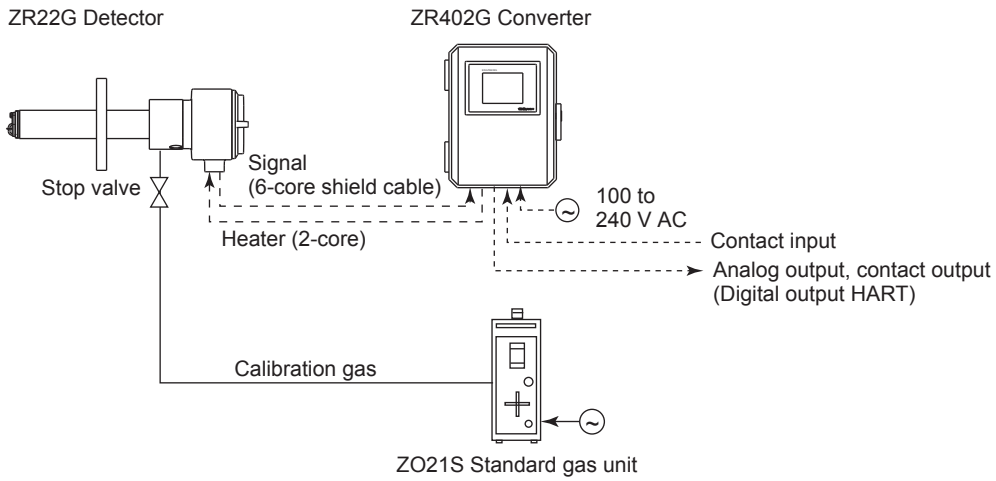
Ambient air is used as the reference gas



1) Install the stop valve securely so that the gas does not leak.
2) Use the ZO21S standard gas unit.
3) Use a shielded cable for the signal line.

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3. System Configurations

This section includes two types of system selection guides for direct in situ zirconia oxygen analyzers. The reader should refer first the examples of system selection by application, and then examine the system block diagram and component device overviews.

3.1 ZR402G Direct In Situ Zirconia Oxygen Analyzer System Block Diagrams

(1) System Selection Examples, by Application

Application		General-purpose detector (0 to 700°C)		High-temperature detector (700 to 1400°C)	
		System types	Detector	System types	Detector
Common	Boiler (fuel oil, gas)	L1, L2, L3	D1, (D2)	H2, H3	
	Boiler (pulverized coal, fluidized bed)	L2, L3	D4	H2, H3	
	Boiler (bark, wood scrap)	L2, L3	D3, (D1)	H2, H3	
Iron & steel	Heating furnaces & soaking pits	L2, L3		H2, H3	D5
	Hot blast stove	L2, L3	D1	H2, H3	
	Coke ovens & annealing furnaces	L2, L3	D1, (D2)	H2, H3	D6, (D7)
	Sintering furnace	L2, L3	D1, (D4)	H2, H3	
Non-ferrous metals	Heating, sintering & melting furnaces	L2, L3	D1, (D4)	H2, H3	D5, (D6)
Ceramic, brick, glass & cement manufacture	Coal kilns (rotary & vertical)	L2, L3	D4, (D3)	H2, H3	(D5, D6)
	Cement kilns (cyclone outlet)	L2, L3	D4, (D3)	H2, H3	
	Ceramic firing furnaces	L2, L3		H2, H3	D5, (D6)
Petroleum/ Petrochemical	Fired heaters & cracking furnaces	L2, L3	D1, (D2)	H2, H3	D5, (D6)
Pulp & paper	Black liquor recovery boilers	L2, L3	D3, (D4)	H2, H3	
Other	Electrical generating boilers (window box)	L2, L3	D1	H2, H3	
	Garbage & sludge incinerators	L2, L3	D1, D3	H2, H3	D5
	Oxygen enrichment equipment	L2, L3		H2, H3	D7*1

The meanings of these codes are explained on the pages that follow.

Note 1: Sampling system is required due to the high pressure.

The symbols such as L1 and D1, representing system types or detectors in the table above and others in this manual, are only applicable in this Technical Information document for quick reference. They do not appear in other literatures including the bulletin, general specifications, or user's manual.

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(2) System Block Diagram Types

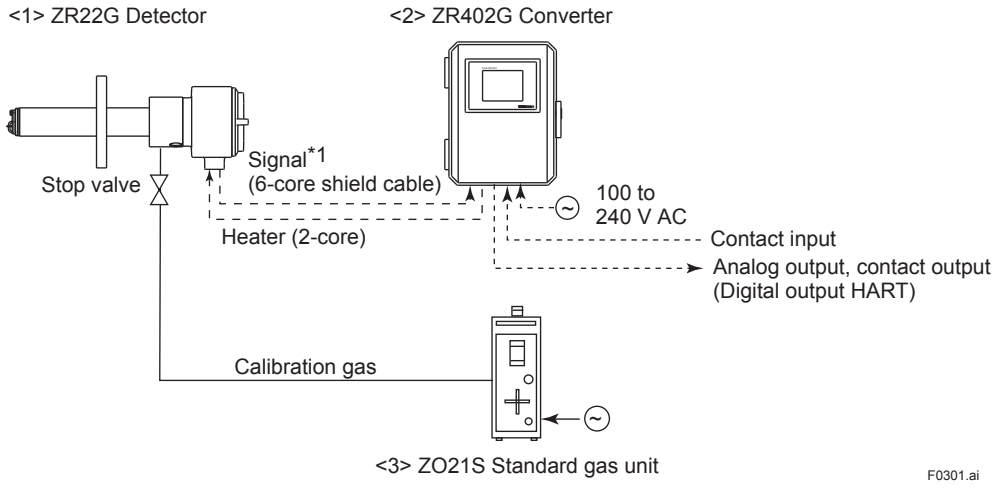
O : Yes , × : None

System type No.	Detector	System type			Remarks
		Simple type	General type		
		—	Manual Calibration	Automatic Calibration	
L1	General-purpose	O	×	×	using ZO21S standard gas unit
L2	General-purpose	×	O	×	using instrument air & zero gas cylinder
L3	General-purpose	×	×	O	using instrument air & zero gas cylinder
H1	High-temperature	O	×	×	using standard gas unit
H2	High-temperature	×	O	×	using instrument air & zero gas cylinder
H3	High-temperature	×	×	O	using instrument air & zero gas cylinder

3.2 Selection According to Use

Examples of selection according to use	System type No.
For monitoring (package boilers, etc.)	L1 / H1
For high precision measurement for control purposes, etc.	L2 / H2
For automatic calibration options	L3 / H3

(1) Type: L1 (simple measurement system)



*1: Shield cable; Use shielded signal cables, and connect the shield to the FG terminal of the converter.

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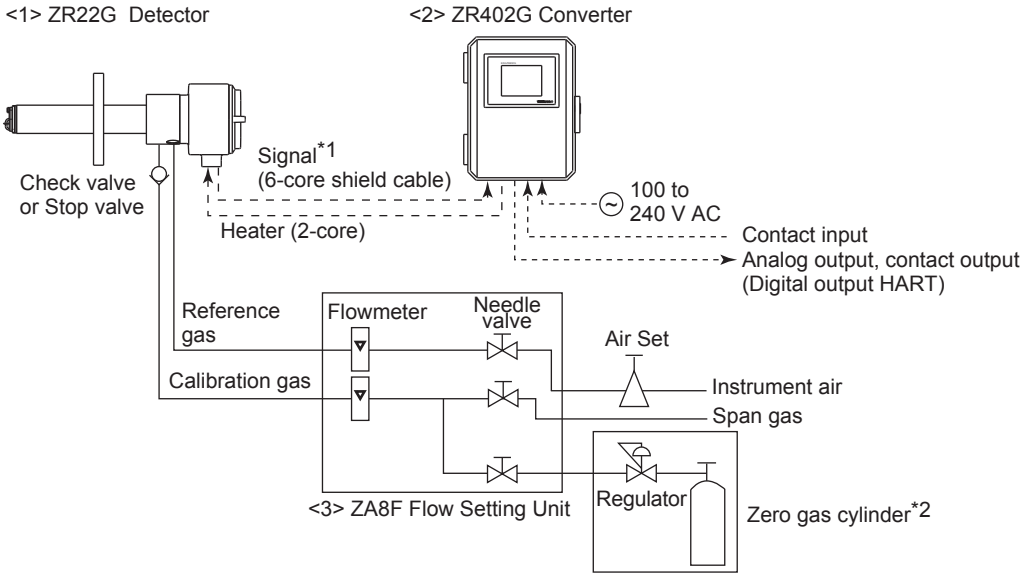
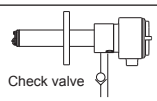
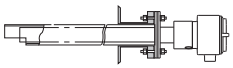
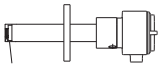
(2) Type: L2 (manual calibration)



Note : Detector can be selected from among the following

No.	Check	Name	Sketch of shade
1		General-purpose detector (with check valve or stop valve)	
2		Detector with probe protector (same as above)	
3		Detector with filter (same as above)	

See Section 3.3 for details concerning detectors.

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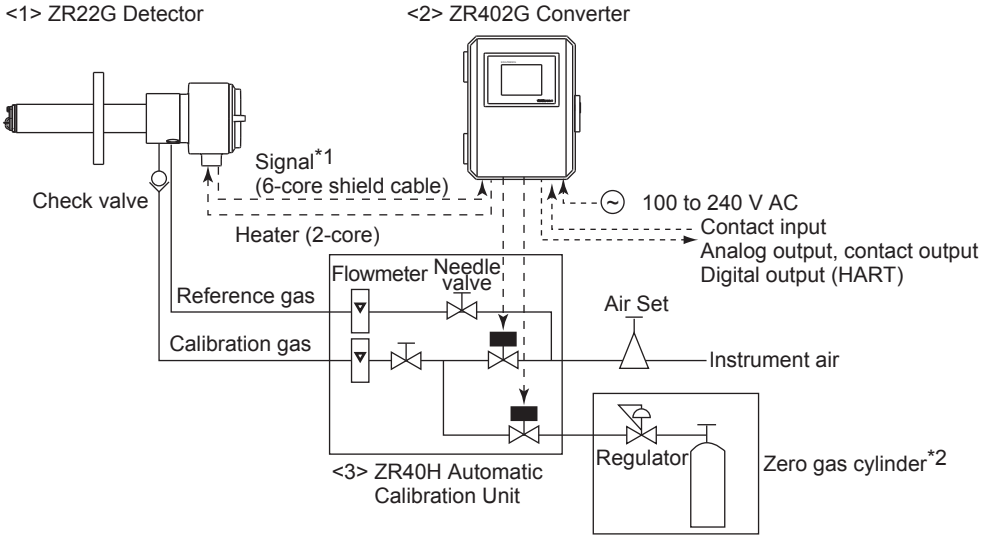
(3) Type: L3 (automatic calibration)



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*1: Shield cable; Use shielded signal cables, and connect the shield to the FG terminal of the converter.
*2: When a zirconia oxygen analyzer is used, 100% N_2 gas cannot be used as the zero gas. Use approximately 1% of O_2 gas (N_2-based).

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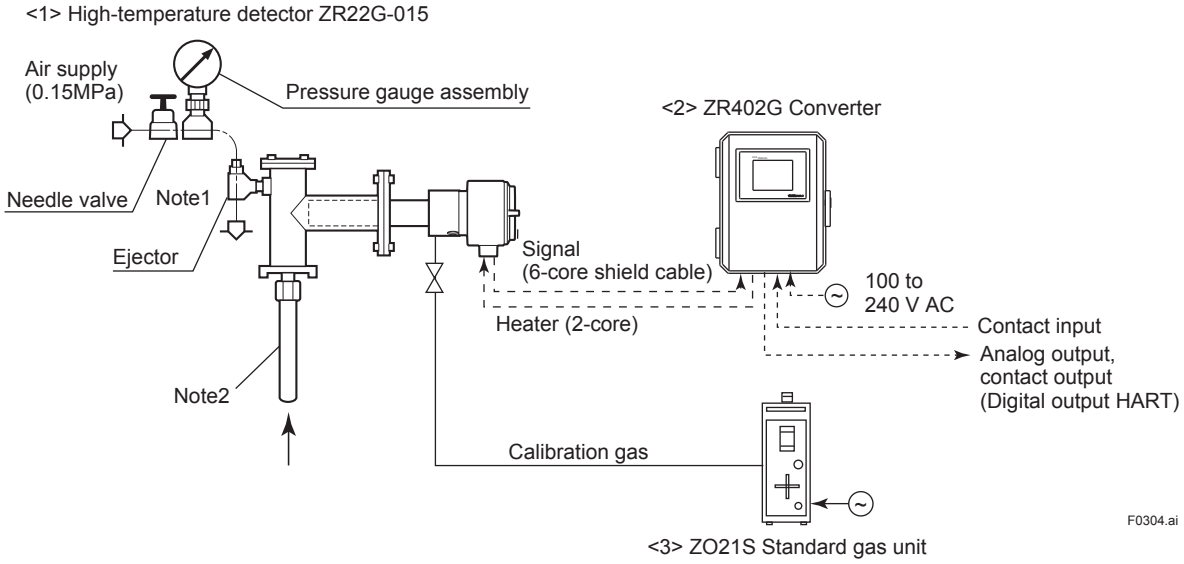
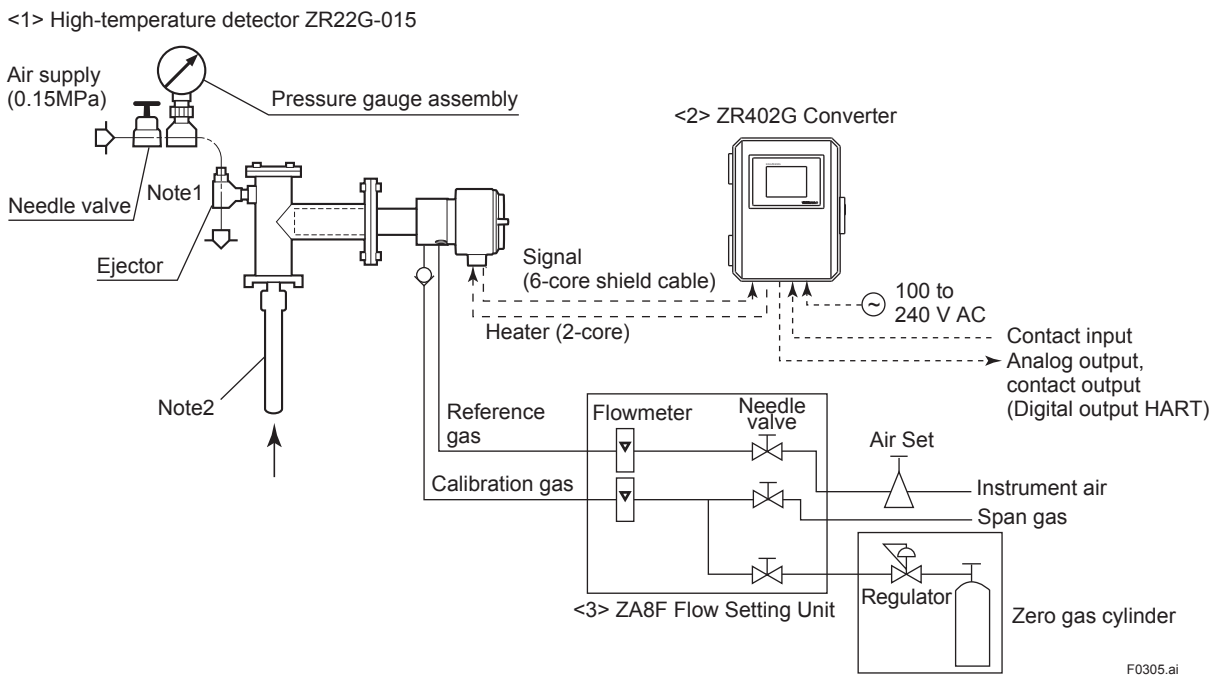
(4) Type: H1 (simple measurement system)



(5) Type: H2 (manual calibration)



Note 1: Selection of Needle valve or Ejector assembly ●: Necessary

Check	Pressure kPa	Needle valve*1	Ejector ASSY*2
	–0.5 or less*3		
	–0.5 to 0.05		●
	0.05 to 0.5		
	0.5 to 5	●	

Note 2: Selection of high temperature probe material

Check	Mounting orientation / Maximum temperature (ºC)	Horizontal mounting	Vertical downward mounting
	800	SUS310S	SUS310S
	1400	—	SiC

*1: G7011XH/G7013XH
*2: E7046EC/E7046EN
*3: consult with YOKOGAWA
Note: Ejector assembly consists of Needle valve, Pressure gauge assembly and Ejector.

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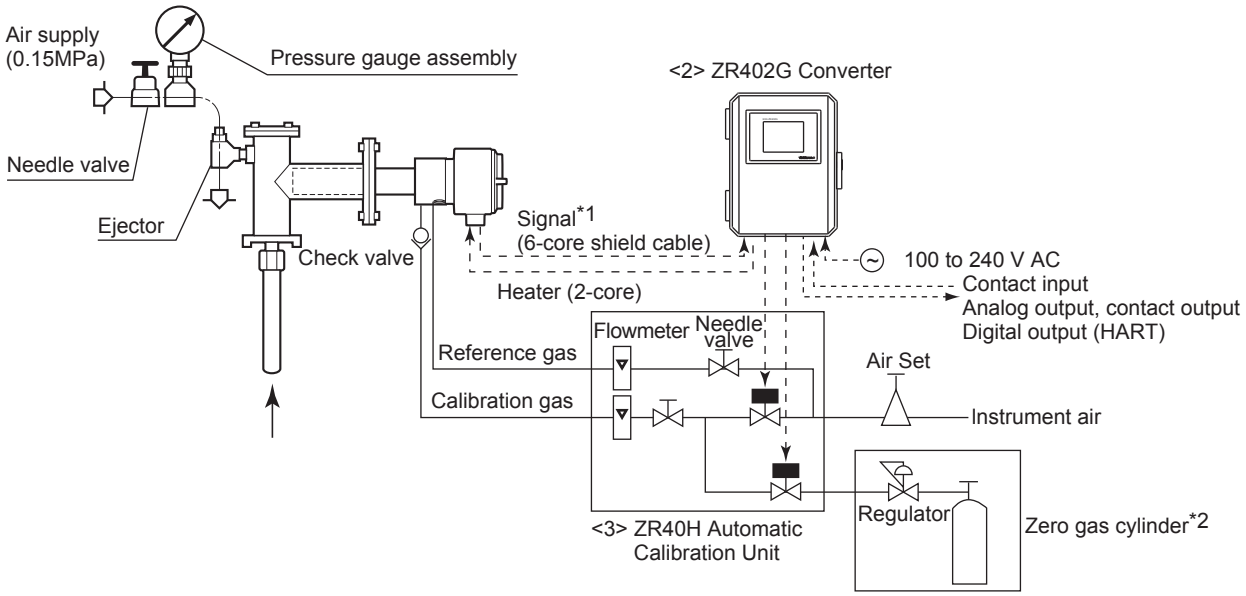
(6) Type: H3 (automatic calibration)

<1> High-temperature detector ZR22G-015



*1: Shield cable; Use shielded signal cables, and connect the shield to the FG terminal of the converter.
*2: When a zirconia oxygen analyzer is used, 100% N_2 gas cannot be used as the zero gas. Use

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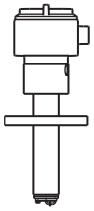
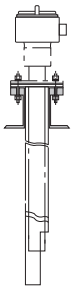
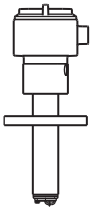
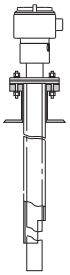
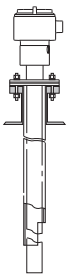
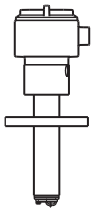
3.3 Examples of System Component Selection Based on Sample Gas Conditions

(1) Detector and accessories

Temperature (°C) \ Dust level / Pressure		Low (0.5 g/Nm³ or less)	High (10 g/Nm³ or less)	Remarks
		−5 to +250 kPa (Note 1)		
0 to 700	Insertion length: 0.4 to 2 m	[D1] General-purpose detector ZR22G 	[D4] General-purpose detector ZR22G with probe protector ZO21R-L Dust guard protector or Dust filter (Note 2) 	(Note 1) When the pressure in the furnace exceeds 3 kPa, it is recommended that you compensate the pressure. When the pressure in the furnace exceeds 5 kPa, you must perform pressure compensation. For 0.15 m probe, 0.5 to 5 kPa. No pressure fluctuation in the furnace should be allowed.
	Insertion length: 2 to 3 m	[D2] General-purpose detector (Vertical downward mounting)  When the detector is mounted horizontally, the ZO21R probe protector is used for enhance forth. 	[D3]  (Note) When the probe length is 2 m or more and sample gas contains high level dust, consult us.	(Note 2) When dust guard protector (K9471UA) or dust filter (K9471UC) is mounted to the ZR22G of 2 m probe length, consult us.
	General-purpose detector ZR22G 			

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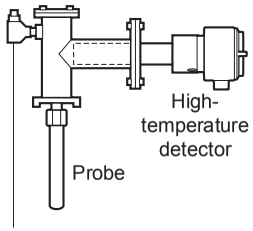
Conditions & specifications: Temperature (°C)	Mounting orientation	Dust level / Pressure kPa: Maximum temperature (°C)	Probe material	Low (1 g/Nm² or less. Consult us if higher): –0.5 to +0.05 (Note 1) Ejector for probe adapter: Required	–0.5 to +0.05 (Note 1) Valve: Not required	+0.05 to +0.5 Ejector for probe adapter: Not required	+0.05 to +0.5 Valve: Not required	+0.5 to +5 Ejector for probe adapter: Not required	+0.5 to +5 Valve: required	Remarks
Over 700 Up to 1400	Vertical downward	800	SUS310S	[D5]		[D6]		[D7]		(Note 1) Consult us if pressure is less than –0.5 kPa
		1400	SiC							
	Horizontal	800	SUS310S							
		1000	Inconel 600							
		over 1000	Not possible							

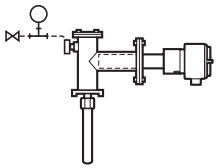
High-temperature probe adapter



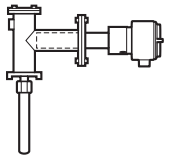
Ejector for probe adapter (or needle valve)

ZR22G-015
ZO21P-H-
(E7046EC or E7046EN)

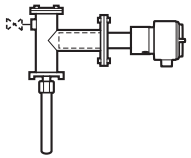
The high-temperature probe adapter includes a standard material probe.



ZR22G-015
ZO21P-H-
E7046EC
or
E7046EN

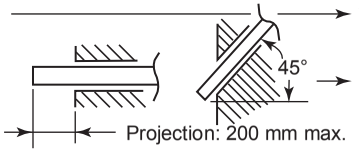


ZR22G-015
ZO21P-H-



ZR22G-015
ZO21P-H-

Needle valve not supplied



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(2) Converter and accessories (flow setting unit, calibration gas, etc.)

Use	Device	Converter	Flow setting unit/ Automatic calibration unit	Calibration gas	Remarks
General	For monitoring	ZR402G	None	ZO21S-□-□*A (standard gas unit)	Minimum configuration for small boiler monitoring, etc.
	Control/alarming	ZR402G	ZA8F-□*C (air set not included)	Cylinder: G7001ZC Regulator: G7014XF G7013XF Case: E7044KF	Most common configuration. Solenoid valve unit for handling unburnt gas in available as an accessory system for petroleum or petrochemical fired heaters.
		ZR402G	ZR40H (air set not included)	Same as above	This configuration automates the calibration operation.
Explosion-proof	Control/alarming	ZS8C	ZA8F-□*C (air set not included)	Cylinder: G7001ZC Regulator: G7014XF G7013XF Case: E7044KF	Sometimes required for petroleum and petrochemical, etc. Be sure to use with explosion-proof terminal box type detector.

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4. Applications

This section takes up typical application examples for the zirconia oxygen analyzer. These individual applications are structured as follows.

Application examples: Overview of individual devices, and sample points.

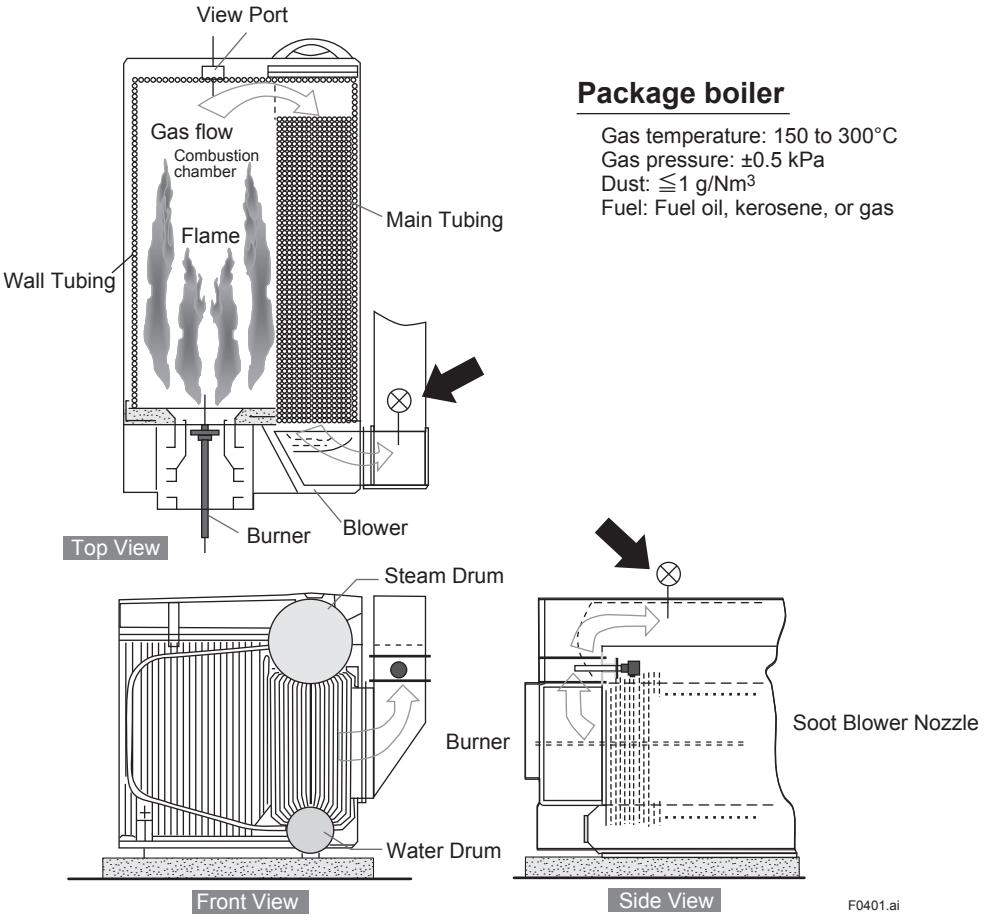
Sample gas condition examples: Examples of sample gas conditions, and block diagrams and type numbers for zirconia oxygen analyzer systems to be used under those conditions.

4.1 Boiler

(1) Package boiler

This is the most common application. Although the system is generally used for combustion monitoring, there are also cases in which it will be used for VVVF or other such combustion control schemes.

Sample point	System type	Detector	Objective
Boiler furnace outlet or economizer outlet	L1, (L2)	D1, (D2)	Combustion monitoring



Package boiler

Gas temperature: 150 to 300°C
Gas pressure: ±0.5 kPa
Dust: ≦1 g/Nm^3
Fuel: Fuel oil, kerosene, or gas

(2) Power generation boiler (Heavy oil, Gas)

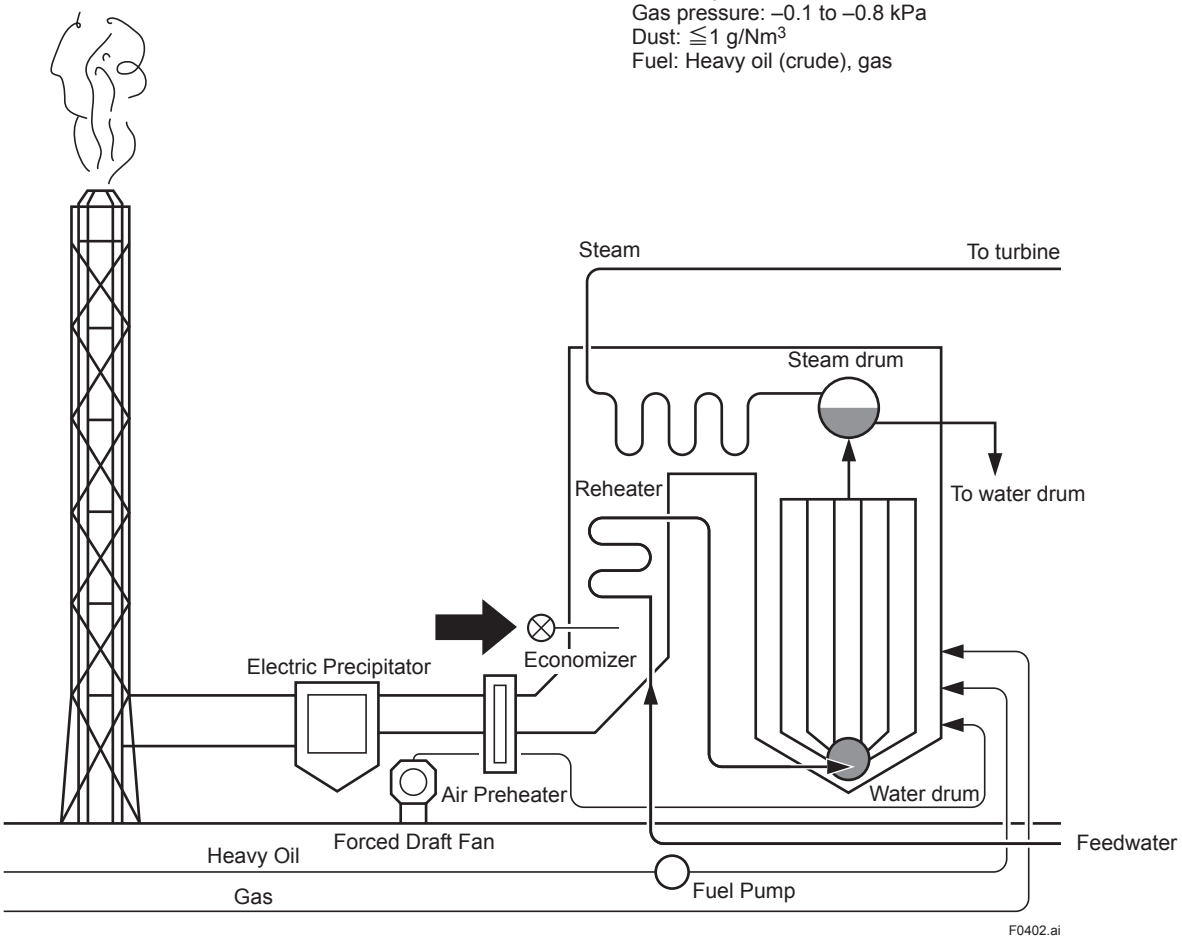
This is a large-scale facility in which use for combustion control is more common than for combustion monitoring.

In cogeneration, the majority of cases involve measurement at a single point. In electric power companies, measurements are performed at multiple points in a single flue.

Sample point	System type	Detector	Objective
Boiler furnace outlet or economizer outlet	L2, L3	D1, (D2)	Combustion monitoring O_2 control

Power generation boiler

Gas temperature: 250 to 350°C
Gas pressure: –0.1 to –0.8 kPa
Dust: ≦1 g/Nm^3
Fuel: Heavy oil (crude), gas



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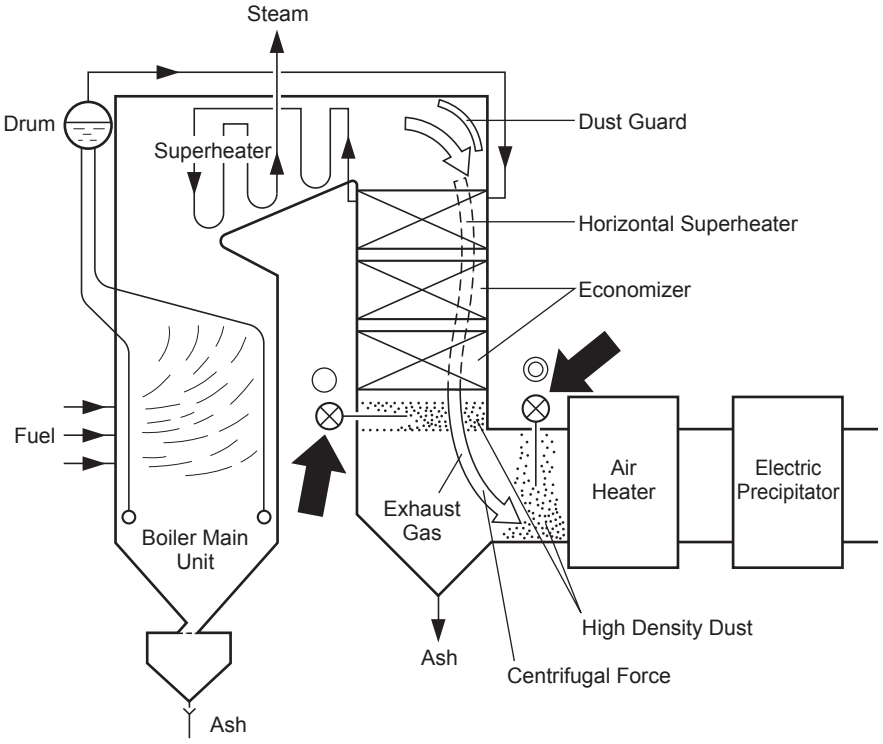
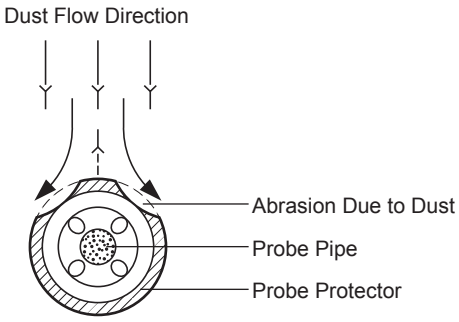
(3) Pulverized coal boiler

These are almost always large facilities such as power generation boilers; the zirconia oxygen analyzer is used for combustion monitoring and combustion control. Since the exhaust gas entrains a rather large amount of ash dust, a detector with dust protector will be used.

Sample point	System type	Detector	Objective
Economizer outlet (economizer, feedwater afterheater)	L2, L3 (detector with probe protector)	D4	Combustion monitoring O_2 control





◎: Optimum mounting position
◯: Second best mounting position

Pulverized coal boiler

Gas temperature: 300 to 400°C
Gas pressure: –1.5 to +1.5 kPa
Dust: Approximately 15 g/Nm^3
Fuel: Pulverized coal

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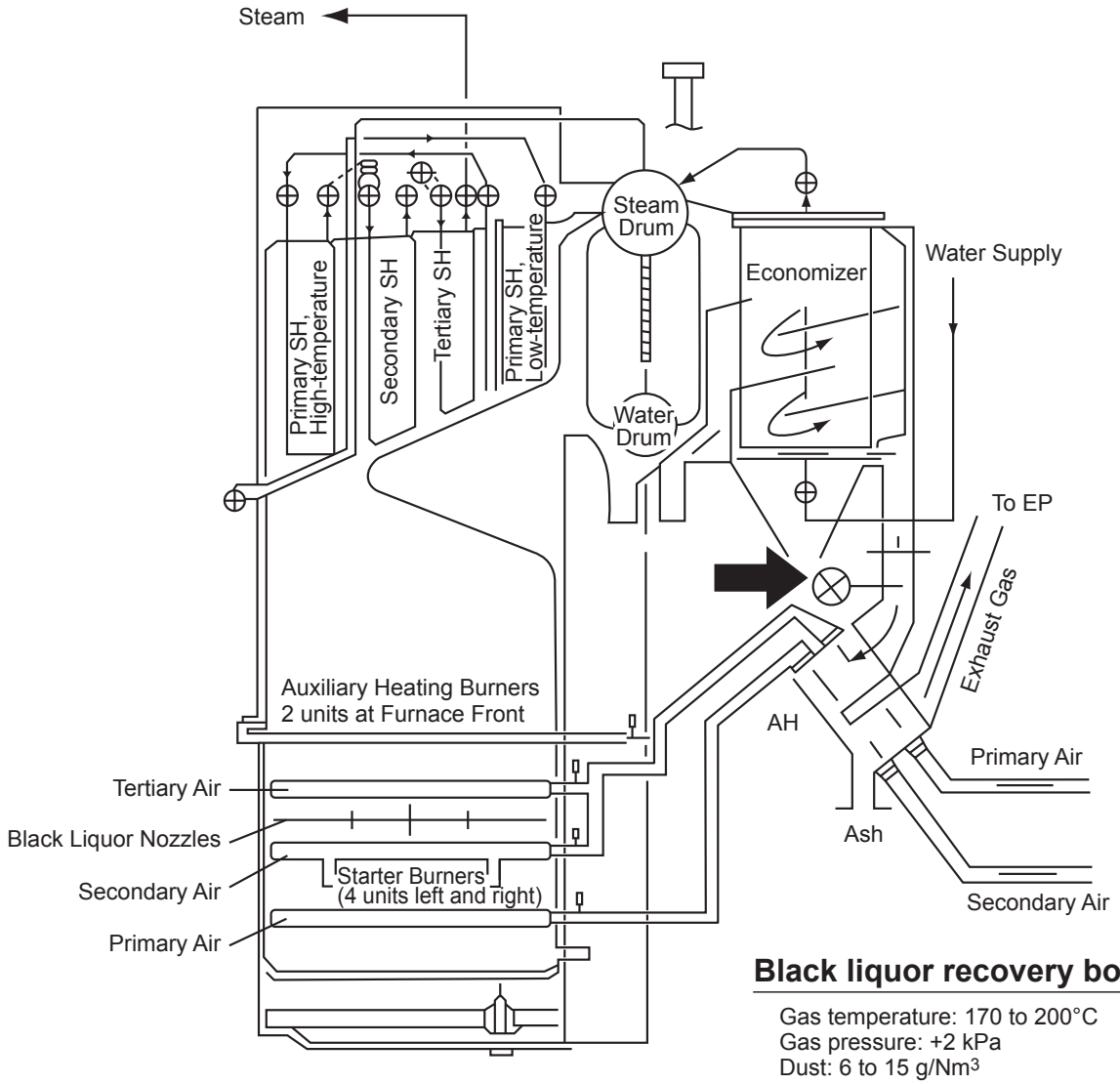
(4) Black liquor recovery boiler

The spent liquor in a pulp production process is commonly referred to as “black liquor”. The sodium carbonate and sulfate components in this black liquor are recovered by burning it and using the heat to generate steam. The oxygen analyzer is used to monitor or control the combustion in the combustion facility (boiler). Since the exhaust gas includes large amounts of dust (hydrated sodium sulfate) and water vapor, a detector with filter is selected.

Sample point	System type	Detector	Objective
Economizer outlet (economizer, feedwater preheater)	L2, L3 (detector with filter)	D3, (D4)	Combustion monitoring



Black liquor recovery boiler

Gas temperature: 170 to 200°C
Gas pressure: +2 kPa
Dust: 6 to 15 g/Nm^3
Main dust components: $Na_2SO_4 \leqq 90\%$
$Na_2CO_3 \geqq 10\%$

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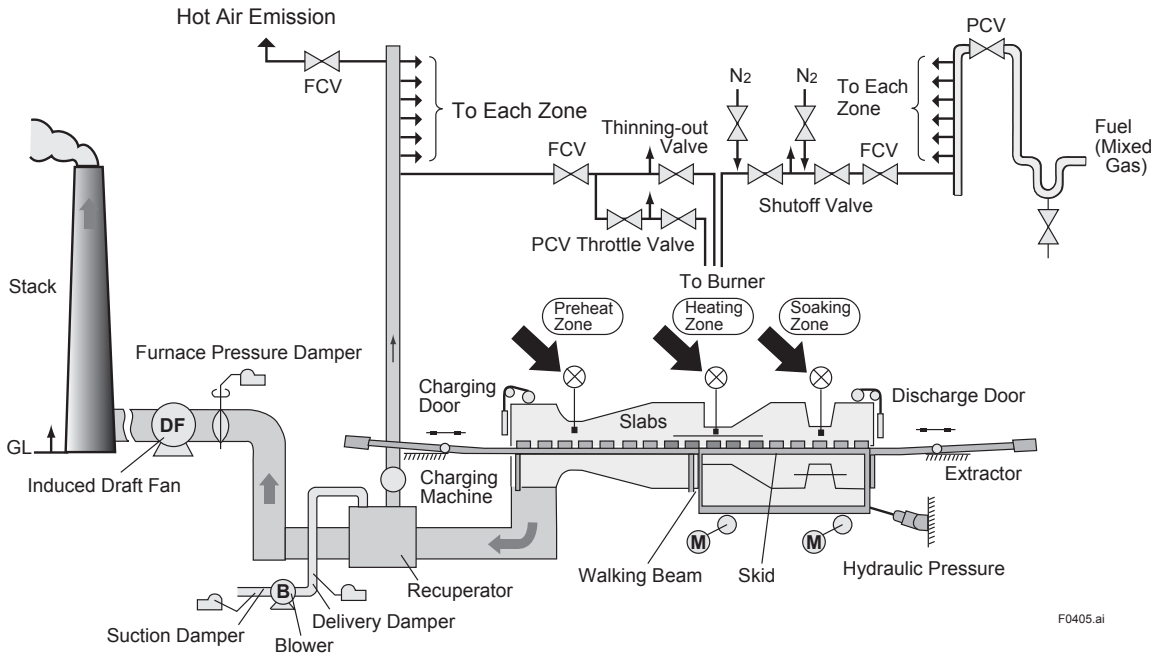
4.2 Iron and Steel Furnaces

(1) Iron & steel heating furnace

These furnaces are for the heating of steel slabs, and generally the measured gas is at a high temperature of 1000°C or above. The oxygen concentration is controlled to a low level to prevent oxidation of the slabs. These are also some cases in which there is some amount of CO in the gas, and in which magnetic oxygen analyzers or infrared type CO analyzers are used.

Sample point	System type	Detector	Objective
Preheat zone, heating zone, soaking zone	H2, H3	D5	Combustion monitoring



Iron & steel heating furnace

Gas temperature: 900 to 1400°C
Gas pressure: 0.03 to 0.05 kPa
Dust: Minute
Fuel: Gas

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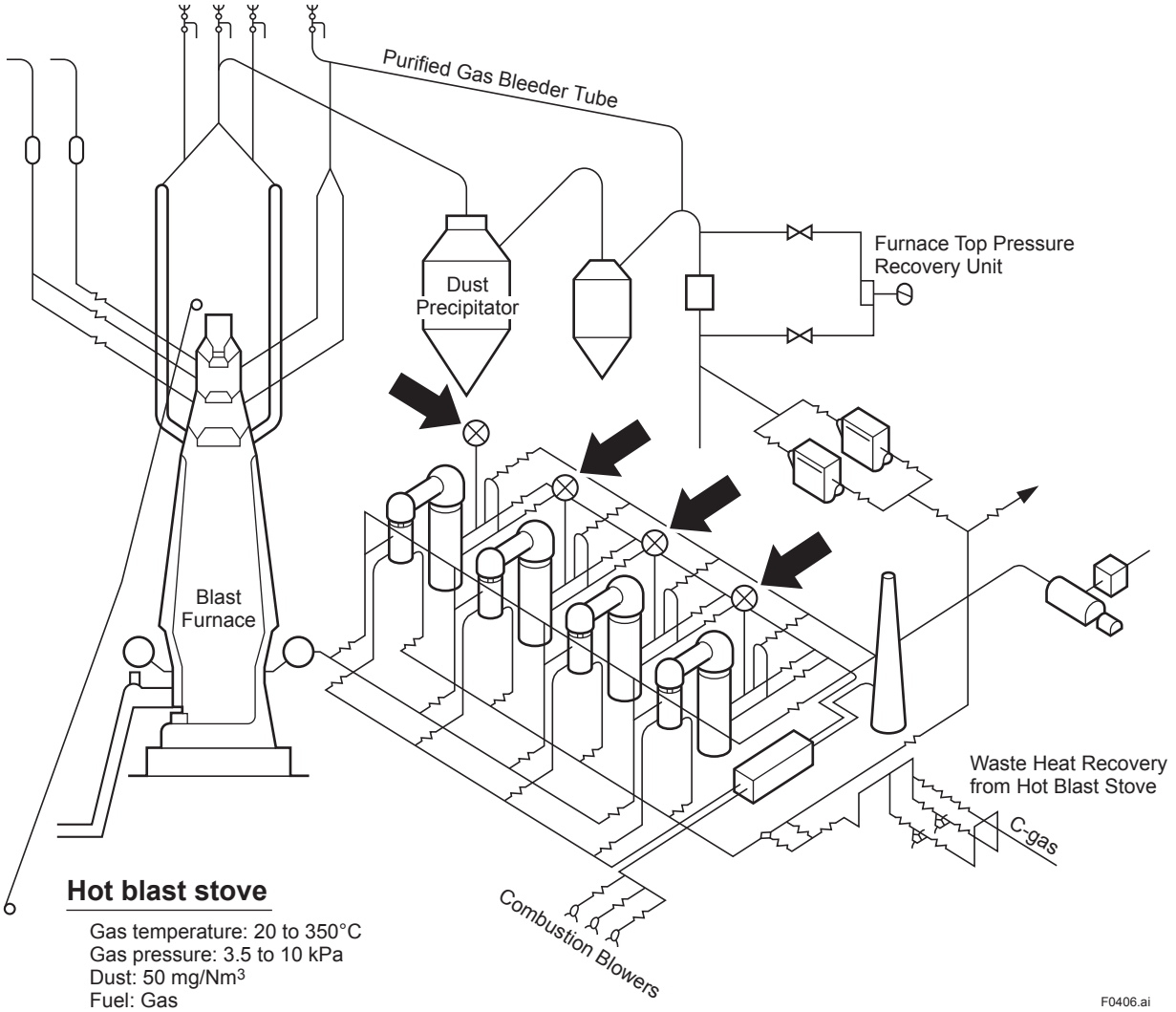
(2) Hot blast stove (blast furnace facility)

The hot blast stove is a facility used to heat the air used in a blast furnace to provide the high temperature hot air blast.

The air is heated by combustion of the gas generated from the coke ovens. The zirconia oxygen analyzer is used to control or monitor this combustion.

Sample point	System type	Detector	Objective
Duct	L2, L3 (If pressure is high, a pressure compensated detector is selected.)	D1	Combustion monitoring O_2 control



Hot blast stove

Gas temperature: 20 to 350°C
Gas pressure: 3.5 to 10 kPa
Dust: 50 mg/Nm^3
Fuel: Gas

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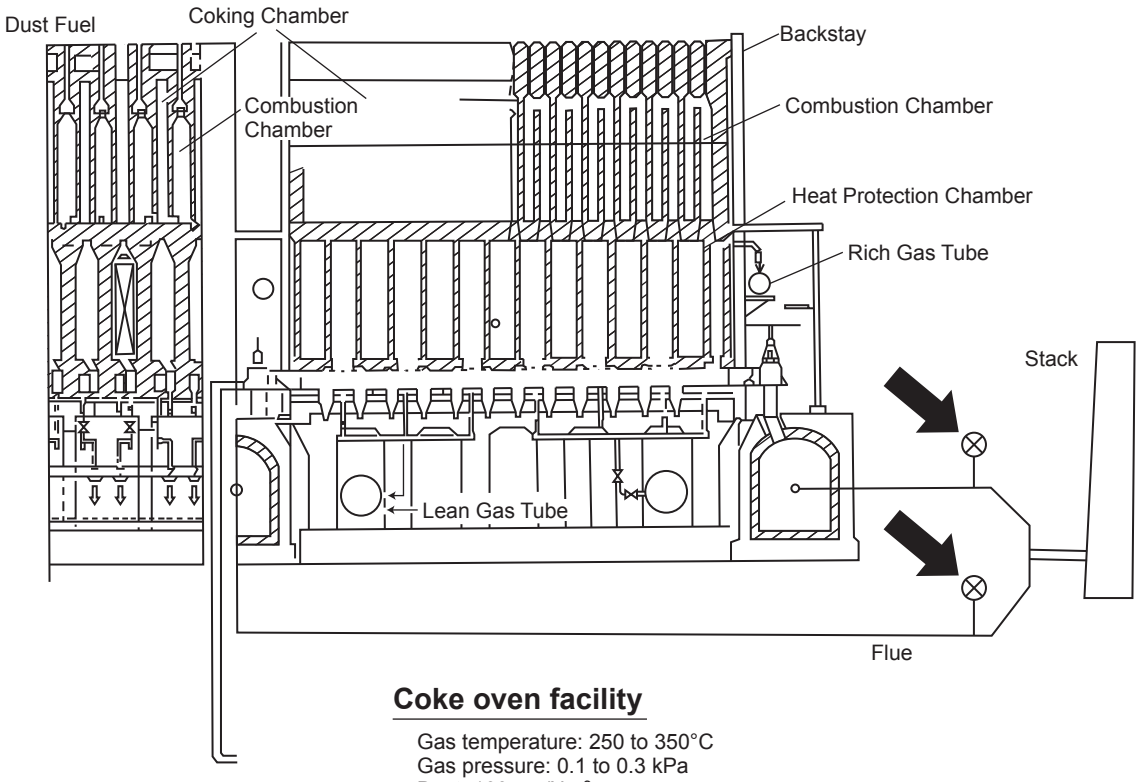
(3) Coke oven facility

This facility is used to produce the coke used in the blast furnace.

The zirconia oxygen analyzer is used to monitor the exhaust gas from the heater combustion used for destructive distillation of the coal.

Sample point	System type	Detector	Objective
Flue	L2, L3	D1, (D2)	Combustion monitoring



Coke oven facility

Gas temperature: 250 to 350°C
Gas pressure: 0.1 to 0.3 kPa
Dust: 100 mg/Nm^3
Fuel: Gas

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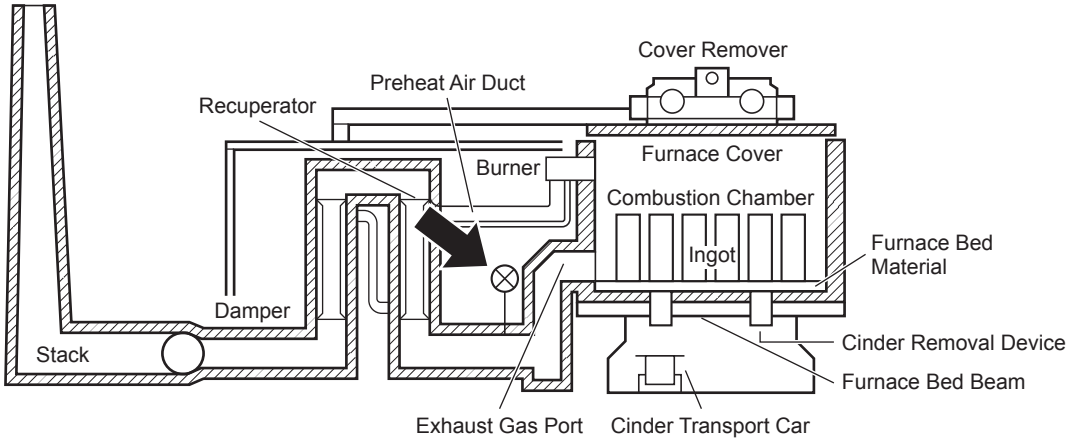
(4) Soaking pit

The soaking pit is a type of furnace used to maintain the ingots at a constant temperature. Oxygen concentration is controlled at a low level to suppress ingot surface oxidation.

Sample point	System type	Detector	Objective
Ahead of recuperator	H2, (H3)	D5	Combustion monitoring



Construction of unidirectional top section combustion soaking pit

Soaking pit

Gas temperature: 1000 to 1200°C
Gas pressure: 0.03 to 0.05 kPa
Dust: 0.5 g/Nm^3
Fuel: Gas

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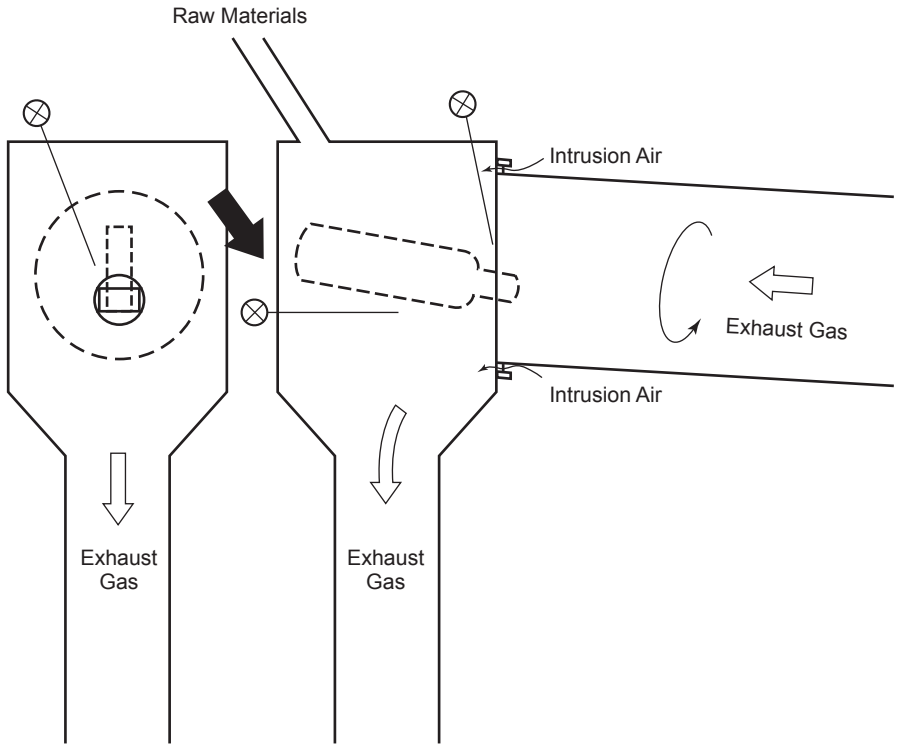
4.3 Ceramic, Brick & Cement (Furnaces / Kilns)

(1) Rotary type lime kiln

The zirconia oxygen analyzer is used for combustion monitoring to conserve energy.

Careful attention to detector mounting position and orientation is required due to the presence of large amounts of abrasive particulates and intrusion air.

Sample point	System type	Detector	Objective
Kiln end	L2, L3 (H2, H3)	D4 (D3, D5, D6)	Combustion monitoring



Rotary type lime kiln

Gas temperature: 250 to 500°C*1

Note 1: Depending on the kiln, there will be cases when the temperature at the measuring point will be 600°C or greater (600 to 750°C). Under these conditions, the high-temperature detector should be used.

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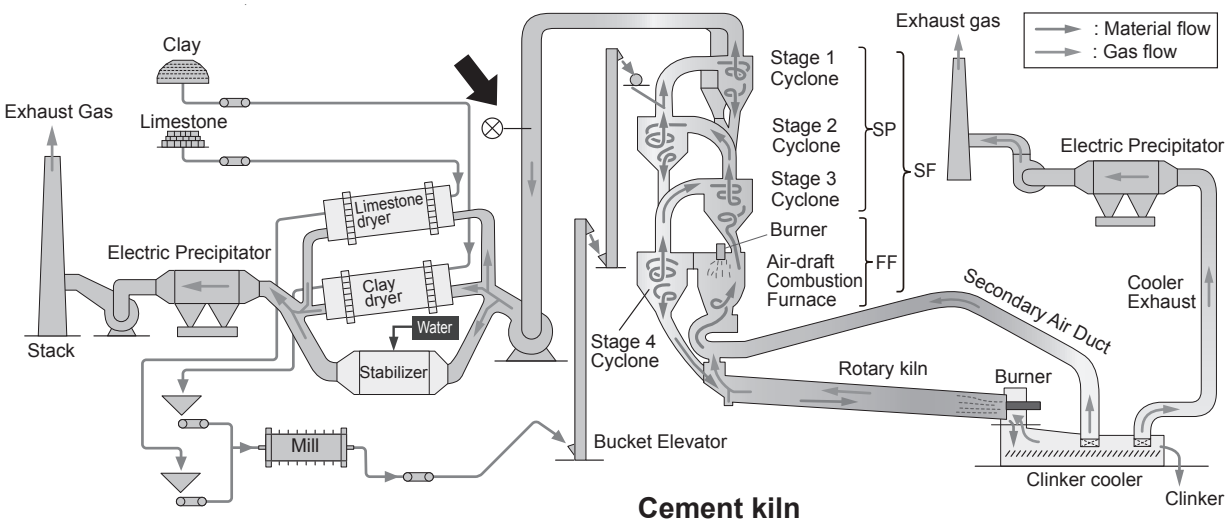
(2) Cement kiln (cyclone outlet gas)

Cement production consumes approximately 100 liters or more of fuel (heavy oil) per ton of cement. Thus, combustion management by means of zirconia oxygen analyzers has become a critical element.

There are cases in which O_2, CO, and CO_2 measurements are performed using a sampling system at the kiln outlet.

Sample point	System type	Detector	Objective
Cyclone outlet	L2, L3	D4, (D3)	Combustion monitoring

NSP Cement Kiln



Cement kiln

Gas temperature: 350 to 400°C
Gas pressure: –3 to 5 kPa
Dust: ≧200 g/Nm^3
CO: ≧0.2%

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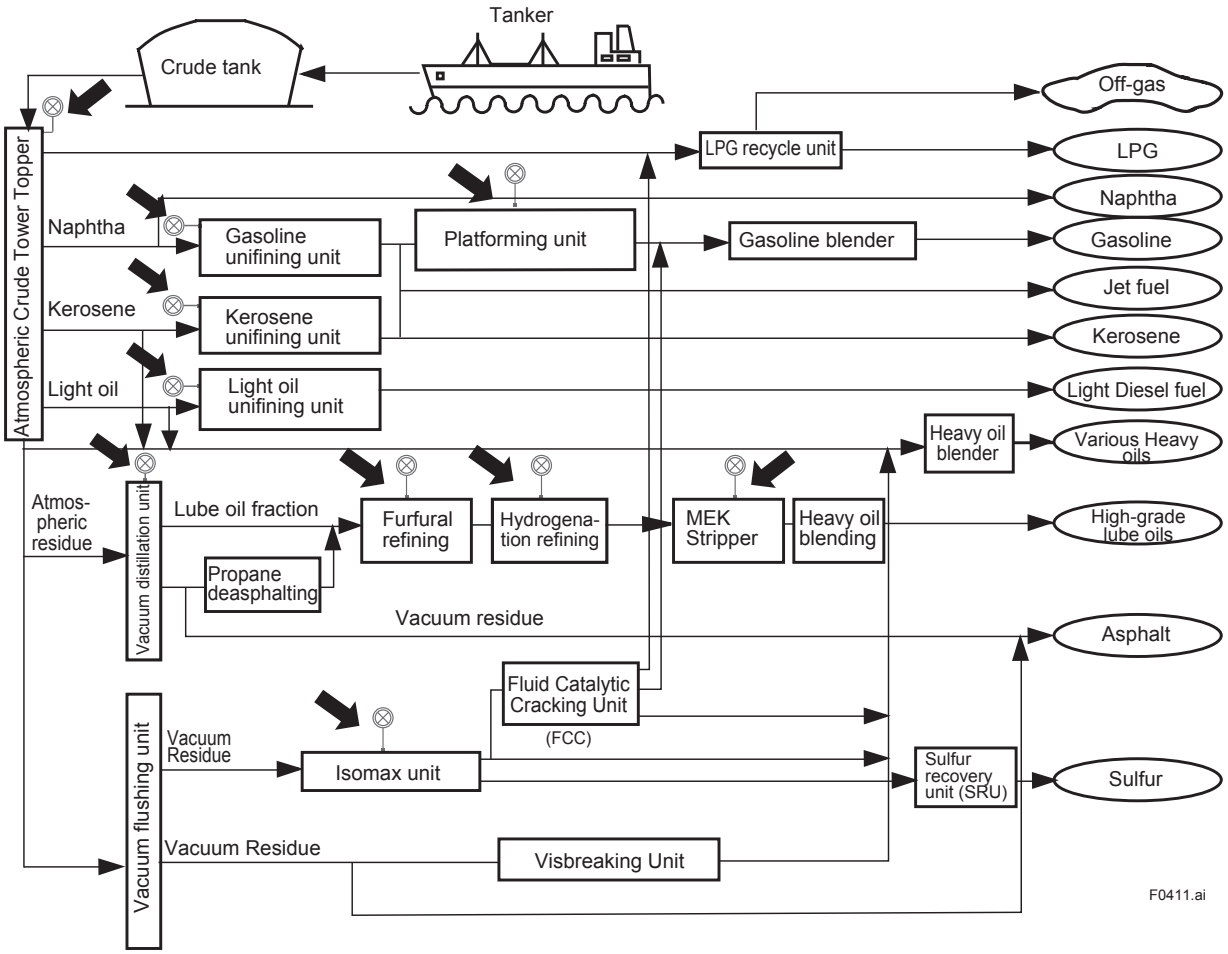
4.4 Petroleum Refining and Petrochemical Fired Heaters

In petroleum refining and petrochemical plants fired heaters are so numerous that you could almost say that there is one in almost every process. Also, since a site consists not of just a single petroleum refining process but rather of ten or more processes, this means that you have that many fired heaters, too (located at the arrows in the diagram above).

In addition to the fired heaters, there will also be a number of boilers. Thus combustion monitoring (or control) is a vital element.



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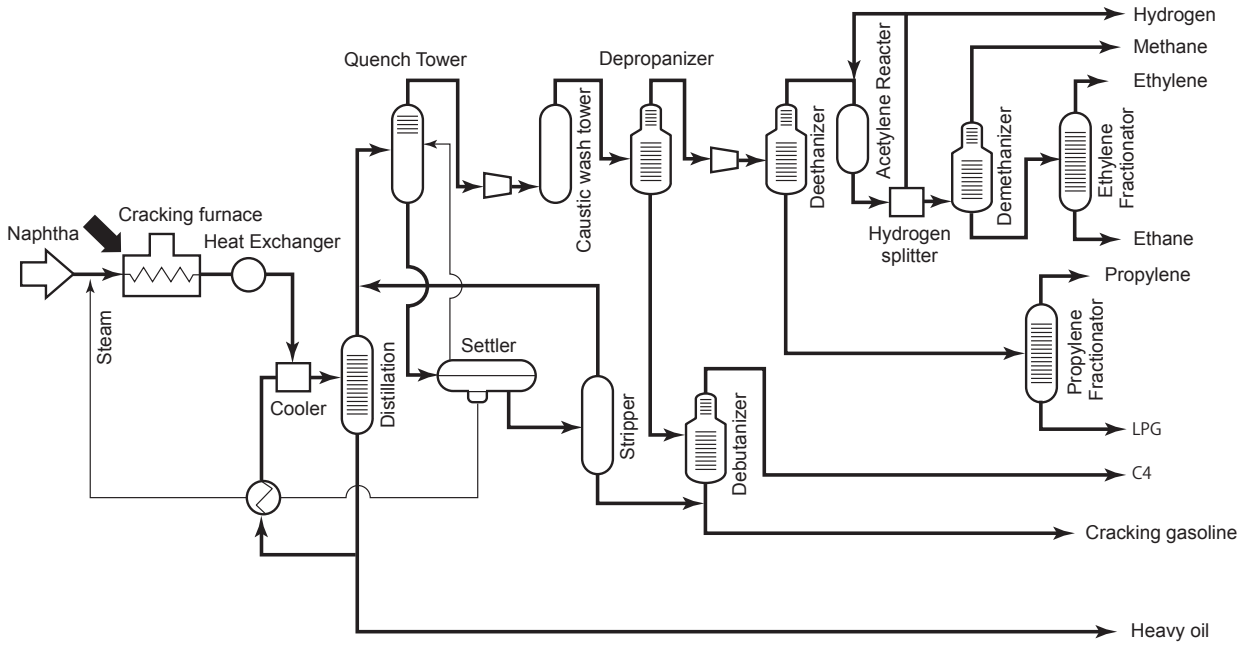
(1) Naphtha cracking furnace

This is the first process in a petrochemical facility, in which the Naphtha supplied from the petroleum refinery is heated and cracked to produce a variety of products. There will be not just one but rather anywhere from six to twelve fired heaters, each with its own stack.

Analyzer installation locations		Sample point	System type	Detector	Objective
➡	Fired heaters	Stack or convection	L2, L3 H2, H3 Explosion-proof type external terminal box may also be selected	D1, D2 D5, D6	Combustion monitoring



Naphtha cracking furnace

Temperature: Stack: 300 to 600°C
Convection: 600 to 1100°C
Pressure: −0.2 to 0 kPa
Dust: 1 g/Nm^3 max.

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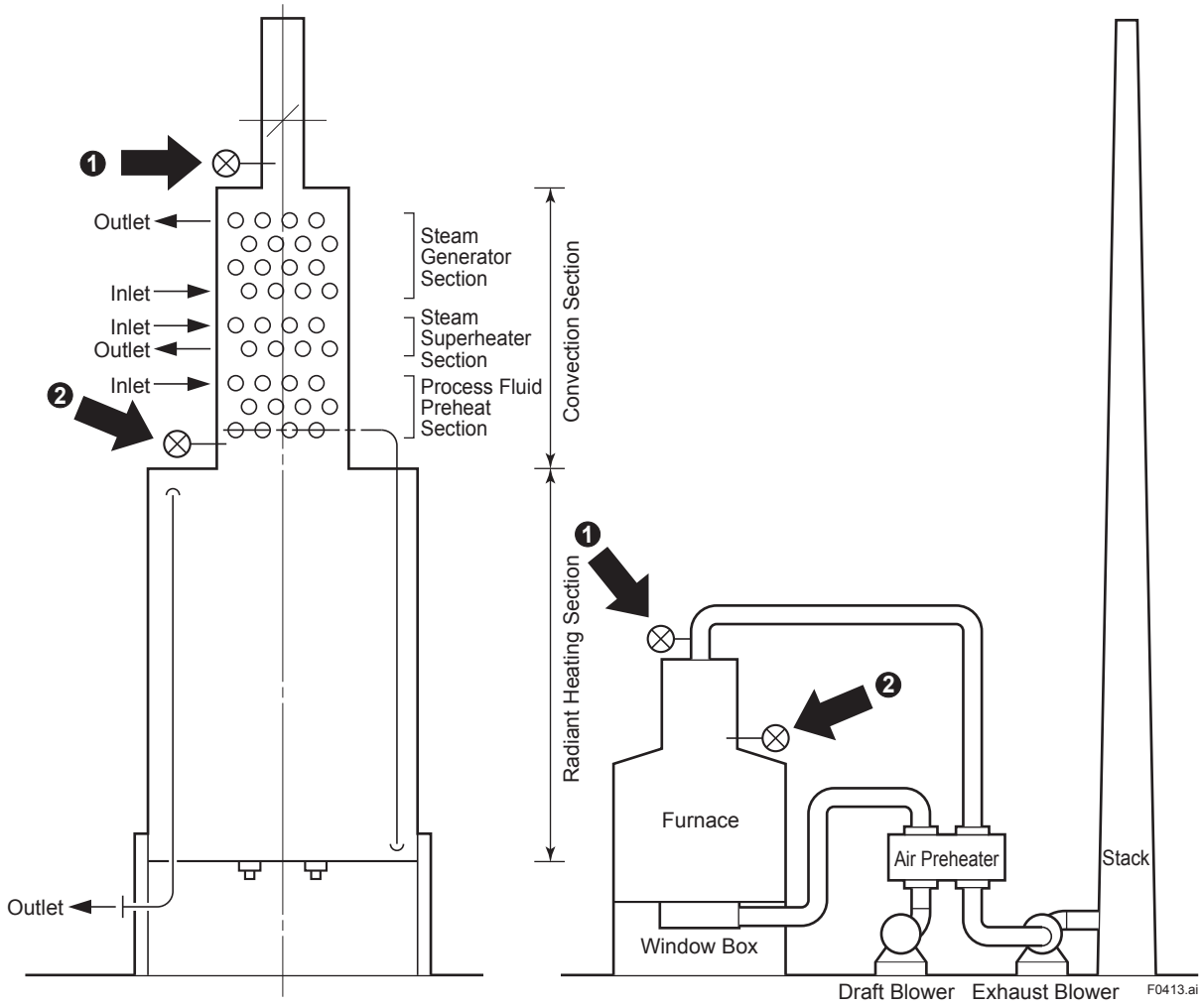
(2) Petroleum refinery process fired heater example

There are two possible locations for the sample point in fired heaters for petroleum refining and petrochemicals: in the stack, or in the vicinity of the furnace outlet (convection zone).

Sample point	System type	Detector	Remark
Stack	L2, L3	D1, D2	Explosion-proof type with terminal box may also be selected.
Furnace outlet (convection zone)	H2, H3	D5, D6	

Analyzer installation locations	Sample point	Temperature
❶ ➡ ❷ ➡	Stack Convection	Approx. 300 to 500°C Approx. 600 to 900°C



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4.5 Garbage Incinerator

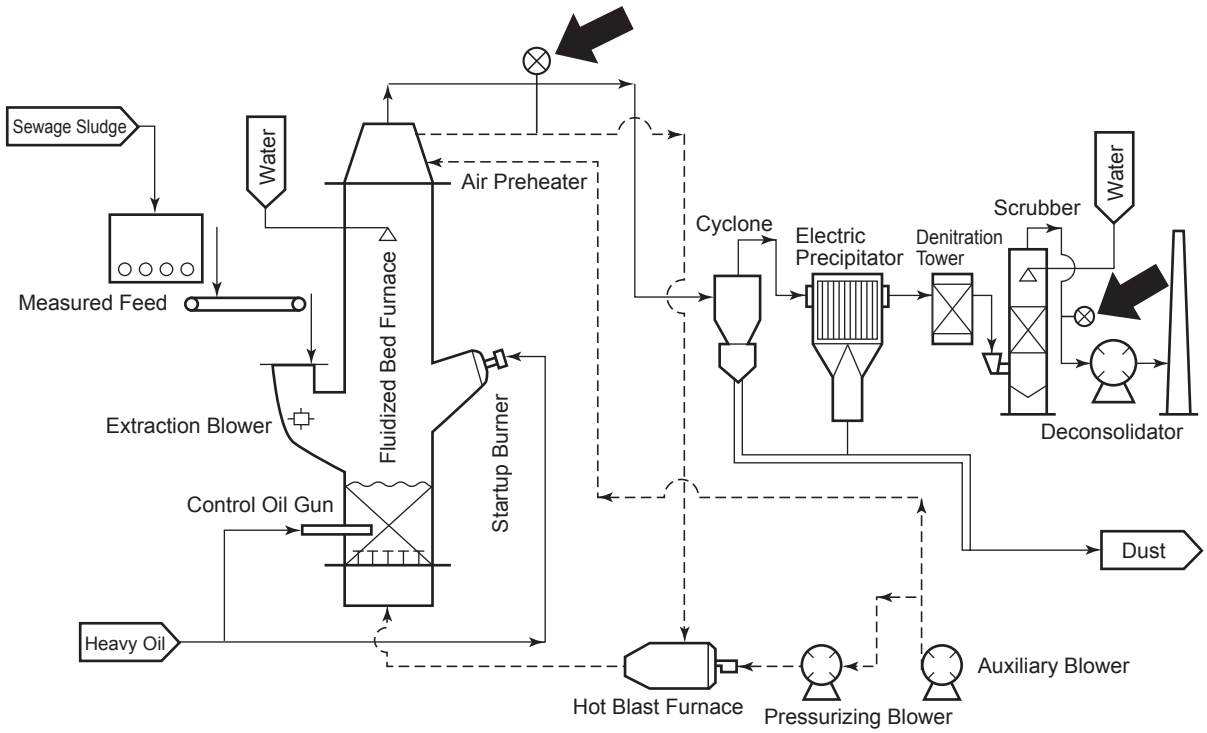
This is a facility to handle by incineration the combustible waste generally contained in municipal garbage.

The exhaust gas of the incinerator outlet contains large quantities of dust and corrosive gases, and a large water vapor component.

Yokogawa should be consulted concerning the installation of the unit.

Sample point	System type	Detector	Objective
Incinerator outlet (gas cooler outlet)	H2, H3 Note: depending on the conditions at the sample point, a sampling type system may be required.	D5	Combustion monitoring
Scrubber outlet (or stack)	L2, L3	D1, (D3)	Combustion monitoring

Fluidized Bed Incinerator Plant



Garbage incinerator

Incinerator outlet
Exhaust gas temperature: 700 to 750°C
Dust: 20 to 30 g/Nm^3
Exhaust gas components: SOx;Several hundred ppm
HCl;100ppm

Scrubber outlet
Exhaust gas temperature: 80 to 120°C
Dust: 0.1 g/Nm^3 maximum

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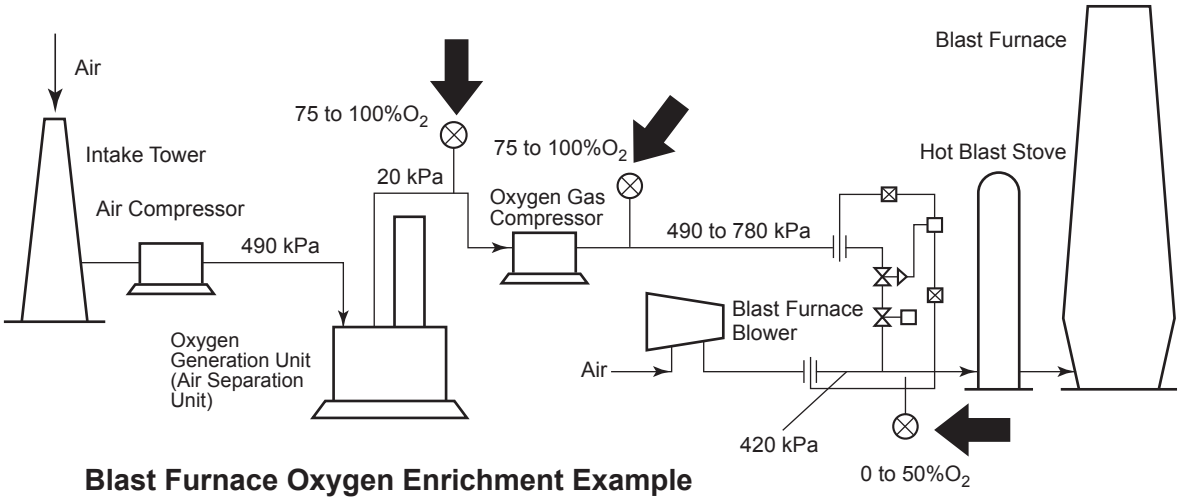
4.6 Non-Combustion Applications

(1) Oxygen enrichment facility

Although in most combustion systems air is used as-is, there are cases such as in blast furnaces in steel plants where the air will be enriched with oxygen gas to raise efficiency. When this is done, oxygen analyzers are used to monitor the oxygen generation unit (air separator, etc.), and/ or to check the condition of the mixing with the air in later process stages. In these cases, the oxygen analyzer will be measuring values higher than the concentration of oxygen in the air (approximately 21%).

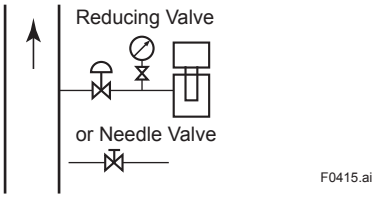
Sample point	System type	Detector	Objective
Oxygen supply line Oxygen compressor outlet	H3 (Note 1)	Note 2	Operational monitoring
Air-oxygen mixing line	H3 (Note 1)	Note 2	Operational monitoring

Note 1: Measurement will be done using a sampling system, since all the points are at high pressure.
Note 2: The high-temperature detector should be used.



Blast Furnace Oxygen Enrichment Example

Note 1: Due to the high pressure, measurement will be done with a sampling type system.



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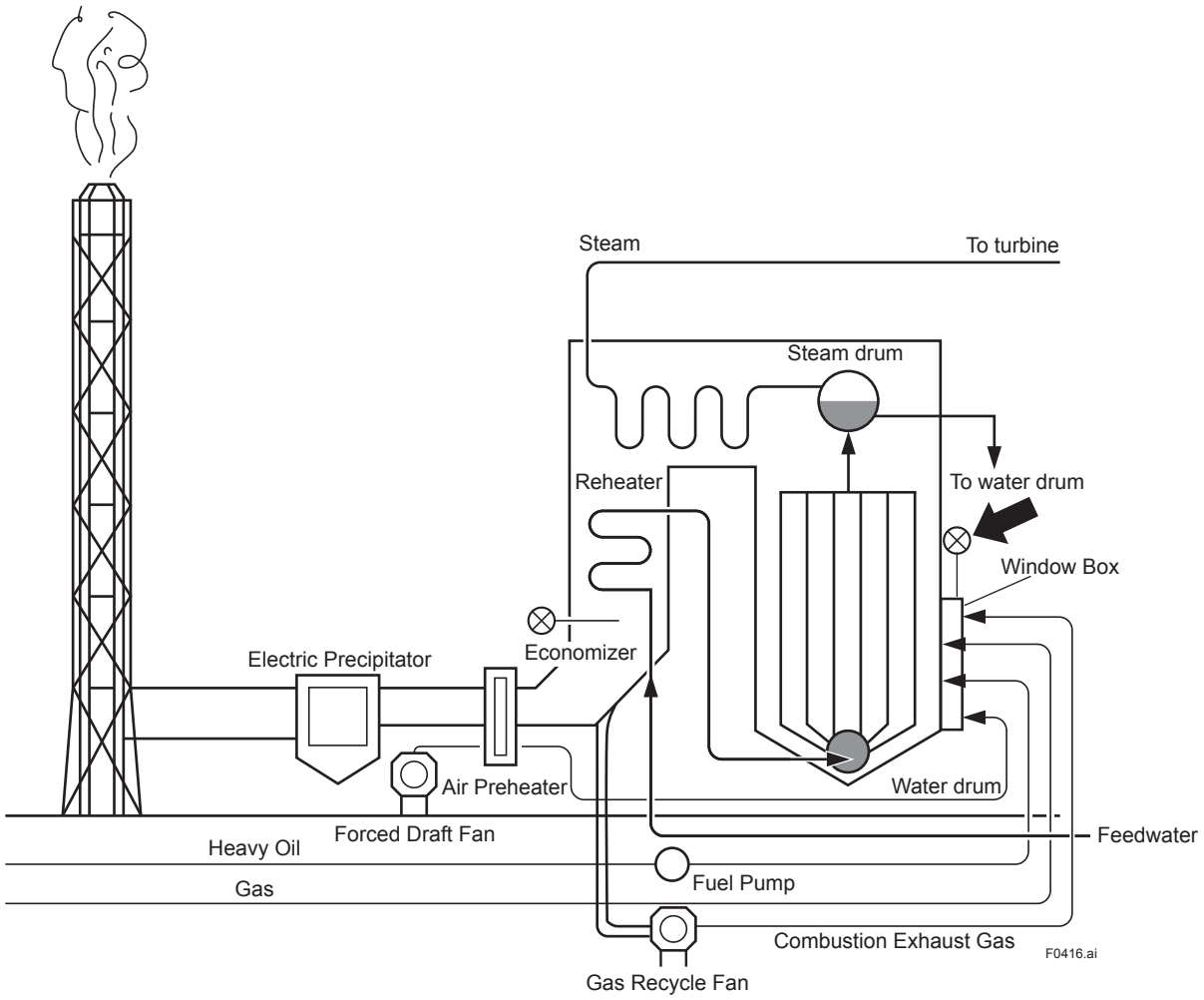
(2) Power generation boiler window box

In large boilers such as those for power generation, part of the combustion exhaust gas is recycled to the combustion intake, and the oxygen concentration in the recycled gas is monitored so that it does not drop too low.

The analyzer range will be a partial range that includes the atmospheric oxygen concentration, such as 15 to 22%O_2.

Sample point	System type	Detector	Objective
Window box	L2, L3	D1 (Note)	O_2, control alarm

Note: The ZO21DW (terminal box explosion-proof type detector; pressure compensated type) or the ZR22G (pressure compensated type) will be used. These are many cases in which the AV550G averaging converter will be used.



Power generation boiler window box

Gas temperature: Max. 550°C
Gas pressure: −5 to 20 kPa

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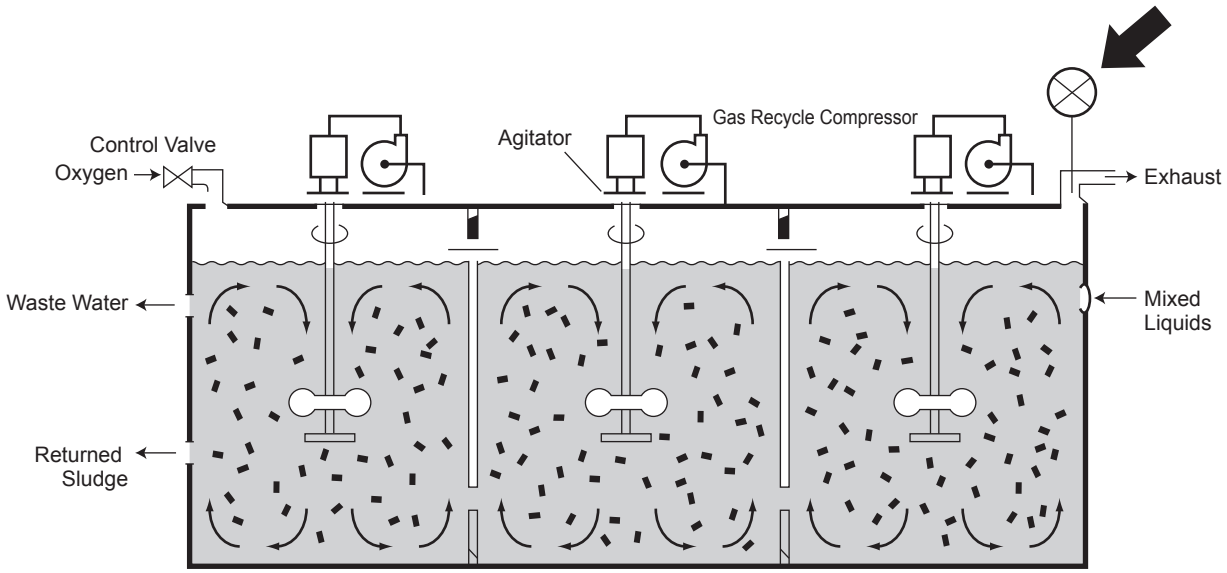
(3) Aeration tank

In one type of sludge processing, oxygen gas is introduced into the processing tanks to maintain the dissolved oxygen concentration in the sludge liquid at a proper level. Efficiency is checked by measuring the oxygen concentration in the exhaust gas from the processing tank.

Sample point	System type	Detector	Objective
Exhaust line	L2, L3	D1	Efficiency monitoring and alarm

Activated Sludge Processing Facility
(Surface Aeration System Aeration Tank)



Aeration tank

Gas temperature: Normal temperature
Gas pressure: 0 to 1 kPa
Concentration: Approximately 50%O_2 (0 to 100% range)

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4.7 Difficult Measurement Applications

(1) Calcination furnace

Exhaust gas oxygen concentration measurement for fluidized-bed calcination roasting furnaces, sulfur combustion furnaces and other such furnaces which burn sulfur-containing materials or elemental sulfur presents sample conditions such as the following, so direct in situ type zirconia oxygen analyzers cannot be used for measurement.

Corrosive gas in exhaust gas: SO_2 7 to 18%

Note: However, the Yokogawa direct in situ type zirconia oxygen analyzers are fully capable of measurement in exhaust gases containing SO_2 concentrations up to 5000 ppm.

(2) Facilities with reducing gas atmospheres

The term “reducing gases” refers to those gases which react with metal oxides to reduce them either to metal or to oxides of a lower degree of oxidation. These gases are composed of a reducing component, of which H_2 is the primary example, and an inert gas component such as N_2.

These reducing gases are used for purposes such as protecting metal surfaces from oxidation or decarbonization during heat treatment, or to improve certain properties. If an attempt is made to use a direct in situ type zirconia oxygen analyzer in such a metal treatment furnace, the combustible gas (reducing gas) and oxygen in the sample gas will incite a combustion reaction like that shown below in the high-temperature cell section (generally above 600°C), causing a negative measurement error, so that measurement is generally impossible under these conditions.

$$2CO+O_2 \rightarrow 2CO_2$$
$$2H_2+O_2 \rightarrow 2H_2O$$
$$CH_4+2O_2 \rightarrow CO_2+2H_2O$$

Reference document are as follows:

Bulletin 11M12A01-01E

GS 11M12A01-01E

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Revision Information

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Direct In Situ Zirconia Oxygen Analyzer (Applications Volume)

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Deleted an applicaation of “Glass melting furnace (in-furnace gas)” described in 4.7 Difficult Measurement Applications. Made other revision along with the deletion.

Feb. 2013/3rd Edition
Change the Table in page 3-6
Change the Flow sheet in page 4-2, 4-12, 4-13, and 4-16

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